UNEP – INDUSTRY & ENVIRONMENT GUIDELINES SERIES

GUIDELINES FOR ASSESSING INDUSTRIAL ENVIRONMENTAL IMPACT AND ENVIRONMENTAL CRITERIA FOR THE SITING OF INDUSTRY

Supplementary Volume

UNITED NATIONS ENVIRONMENT PROGRAMME

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FOREWORD

This Supplementary Volume to the "Guidelines for Assessing Industrial Environmental Impact and Environmental Criteria for the Siting of Industry" gives a compilation of scientific and technical data for reference and use in carrying out environmental impact assessment. Presentation of the data does not imply recommendation or approval.

TABLE OF CONTENTS

CHAPTER I - cont'd

CHAPTER I - cont'd

CHAPTER I - cont'd

I. DESCRIPTION AND FLOW DIAGRAMS OF SIX INDUSTRIES

I.(i). PETROLEUM REFINING INDUSTRY

I.(i).1. Introduction

Crude oil is predominately a complex mixture of hydrocarbons, but it may contain certain minor proportions of compounds containing sulphur, oxygen and nitrogen as well as trace metals such as vanadium and nickel. No two crude oils are alike, but usually the percentage by weight of the main elements are as follows: carbon 85 - 90, hydrogen 10 - 14, sulphur 0.1 - 7, oxygen 0.06 - 0.4, and nitrogen 0.01 - 0.9. The function of the refinery is to produce from the crude oil a very wide range of products which meet market needs for automotive and aviation fuels, fuels for power and heat generation, lubricants, bitumens, chemical feedstocks and other special products according to an overall company plan.

Four major operations take place within a refinery;

i) separation
ii) conversion
iii) treatment
iv) blending

Crude oil is first separated into selected fractions, according to boiling range and eventual products required. Some of the less valuable streams are converted or upgraded by splitting, rearranging or polymerizing component molecules. At some stage refinery streams may be treated to remove contaminants such as sulphur. In the final stages of product preparation, refinery streams may be blended together, often with additives, to meet specification requirements.

Some of the naturally occurring sulphur compounds in crude oils are malodorous and if they were not removed or converted to innocuous compounds during processing they would cause odour problems. By their very nature these compounds are mostly found in lighter fractions from crudes, such as gasoline. In heavier fractions, e.g. gas oils, the compounds are not malodorous, but sulphur is removed to minimise emission during subsequent use.

I.(i).2. Environmental Impact

The exact ways by which the four types of operation occur vary considerably and therefore it is not possible to describe a "typical" refinery. However, general similarities allow for a basic categorisation of impacts on the environment:

i) gaseous emissions, including odour;
ii) waste water effluent;
iii) solid wastes;
iv) noise;
v) visual or aesthetic effects

I.(i).2.1. Gaseous emissions These constitute the greatest potential impact, the major pollutants emitted being particulates, hydrocarbons, carbon monoxide, sulphur oxides and nitrogen oxides (Figure I.(i).1.). Of the few units discharging to the atmosphere, the major ones are the catalytic cracking unit, the sulphur recovery process, heaters and storage tanks. Fugitive emissions from pump seals, valves, etc., are another source of air pollutants which may occasionally be significant.

With regard to odours, compounds such as H_2S, mercaptans and hydrocarbons, can cause odour nuisance at very low concentrations. Generally, maintaining levels of pollutants within suggested environmental health and safety criteria will greatly reduce odour problems that could affect the general public (United Nations Environment Programme, 1978).

Possible sources of air emissions are given in Table I.(i).1. Suggestions for source control measures to reduce emissions are shown in Table I.(i).2.

TABLE I.(i).1. - Sources of Atmospheric Emissions in Refineries
(After Elkin and McArthur, 1974)

Emissions	Sources.
Hydrocarbons	Transfer and product loading operations, sampling valves, storage tanks, shut-downs and start-up operations, spills and leaks, oil separators, settling ponds. Relief valves, catalyst regeneration, pumps, compressors, cooling towers, vacuum towers, barometic condensers, asphalt oxidisers, chemical processing units.
Oxides of Sulphur	Catalyst regenerators, boilers, furnaces, flares, scrubbers, chemical processing units (burning of any sulphur containing fuel, subsequent burning of gases containing H_2S)., decoking operations.
Hydrogen Sulphide	May be emitted for oxides of sulphur
Oxides of Nitrogen	All combustion operations: Boilers, furnaces flares and also some catalyst regenerators.
Carbon Monoxide	Catalyst regeneration, scrubbers, furnaces, off-gas incinerators.
Aldehydes	Catalyst regenerators
Ammonia	Catalyst regenerators
Aromatics	Chemical processing units, asphalt oxidisers, barometric condensers, vacuum towers, oil separators, sewers
Particulate Matter, smoke.	Cracking units using fluidized catalyst, steam boilers, furnaces, scrubbers, off-gas incinerators. Inefficient combustion of heavy oils and tars, starting up and shutting down of heaters, flaring operations.

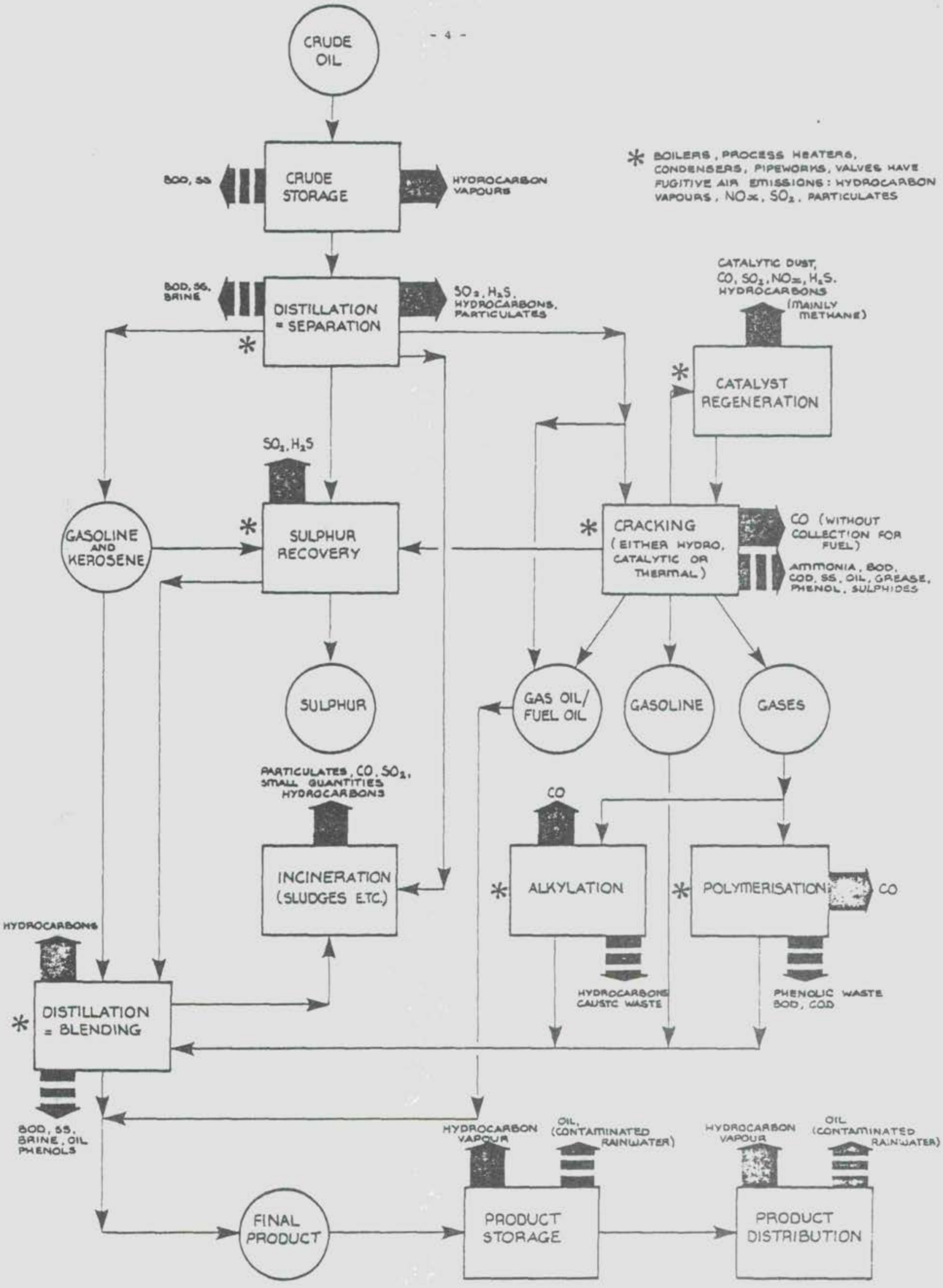

Fig. I(i)1 Flow Diagram for the Petroleum Refining Industry

Suggestions for source control measures to reduce air contaminants from petroleum refining are given in Table I.(i).2.

Source	Control Method
Storage vessels	Vapour recovery systems, floating-roof tanks, pressure tanks, vapour balance, painting tanks white
Refinery process gas	Ethanolamine absorption
Catalyst regenerators	Cyclones-precipitator in situ CO combustion CO boiler, cyclones-water scrubber, multiple cyclones
Accumulator vents	Vapour recovery, vapour incineration
Blowdown systems	Smokeless flares-gas recovery
Pumps and compressors	Mechanical seals, vapour recovery, sealing glands by oil pressure, maintenance
Vacuum jets	Vapour incineration
Equipment valves	Inspection and maintenance
Pressure relief valves	Vapour recovery, vapour incineration, rupture discs, inspection and maintenance
Effluent-waste-disposal	Enclosure of separators, covering of sewer boxes and use of liquid seal, liquid seals on drains
Bulk-loading facilities	Vapour collection with recovery or incineration, submerged or bottom loading
Acid treating	Continuous-type agitators with mechanical mixing, replacement with catalytic hydrogenation units, incineration on all vented cases, cessation of sludge burning
Acid sludge storage and shipping	Caustic scrubbing, incineration, return system
Spent-caustic handling	Incineration, scrubbing, neutralisation
Sweetening processes	Steam stripping of spent doctor solution to hydrocarbon recovery before air regeneration, replacement of

Cont/d ....

	treating unit with other less objectionable units
Sour-water treating	Use of sour-water oxidizers and gas incineration, conversion to ammonium sulphate
Mercaptan disposal	Conversion to disulphides, adding to catalytic cracking charge stock; incineration, use of material in organic synthesis
Asphalt blowing	Incineration, water scrubbing (non recirculating type)
Shutdowns, turn-arounds	Depressuring and purging to vapour recovery

Table I.(i).2. Control methods for air emissions (Mallat 1977)

It is difficult to suggest the 'average' refinery emission levels, not only because emission control methods and standards vary but also due to the variety of process methods available. It is even more difficult to specify emission levels from individual sources, e.g. storage tanks, catalyst regeneration unit. To accurately assess levels, in plant field testing is essential.

I.(i).2.2. Waste-water effluent The pollutants parameters usually present in waste water effluent are BOD_5, COD, TOC, oil, grease, ammonia, phenolic compounds, sulphides and chromium (Cadron and Klein, 1977; Figure I.(i).1.). Uncontaminated but heated waste water also constitutes a disposal problem.

Possible sources of effluent are given in Table I.(i).3. over.

Table I.(i).3. - Type and Source of Liquid Effluent

Waste	Source
Oil (accidental contamination)	rainwater from tank farms, pipetracks and product dispatch areas.
Oil (continuous contamination)	rainwater from processing area, tank drain water, deballasting water, cooling water blowdown, flushing and cleaning water, crude desalting.
Organic material e.g.: phenols, thiophenols, organic acids. Inorganic material e.g.: ammonium sulphide, inorganic salts, metals.	process water from steam stripping, crude oil washing, chemical oil treatment process, crude desalting, thermal cracking; catalytic cracking.
Elevated temperature water/uncontaminated water.	Boiler blowdown, boiler feed water, make up units, cooling water, rainwater from oil free areas.

Recycling of process water is a significant feature of modern refinery practice and extensive water treatment is therefore carried out. Primary treatment affords removal of suspended solids and undissolved oils by sedimentation and gravity separation; secondary treatment by filtration, flocculation or flotation remove additional oil, and dissolved organics are taken out by biological oxidation treatment techniques.

Tertiary treatment in holding ponds, allows for additional biodegradation to 'polish' effluent to a particularly high standard.

Examples of pollutant loadings from a range of refinery operations are given in Table I.(i).4.

Table I.(i).4. - Pollution Loads from Refineries of Various Technologies and Sizes (U.S. Department of the Interior, 1968)

Technology	Size	Throughput (bpsd)	Flow (mgd)	BOD (lbs/day)	Phenol (lbs/day)	Sulphide (lbs/day)
Older (15 years)						
	Small	30,000	7.5	12,000	900	300
	Medium	75,000	18.7	30,000	2,250	750
	Large	150,000	37.5	60,000	4,500	1,500
Typical						
	Small	30,000	3.0	3,000	300	90
	Medium	75,000	7.5	7,500	750	225
	Large	150,000	15.0	15,000	1,500	450
Newer						
	Small	30,000	1.5	1,500	300	90
	Medium	75,000	3.8	3,250	750	225
	Large	150,000	7.5	7,500	1,500	450

An example of typical effluent discharge standards is given in Table I.(i).5.

However, effluent standards should be related to volume throughput of a refinery water system, rather than specified as parts per million of pollutant in water, which may be achieved by dilution. Standards for refinery effluent should as far as possible be set on a local basis, taking into account the nature of the receiving waters, the uses to which they are put (amenity, recreation, fishing, wild life preservation, etc), the technology available for treating wastes and the benefits to be derived from the expenditure.

Table I.(i).5. - Typical Consent Conditions for Refinery Discharge (mgl^{-1})

Contaminant	Average Level	Maximum in any sample
Oil and Grease	3	5
Phenols	0.1	0.5
BOD_5	20	40
COD	50	100
Sulphides	0.3	1
Suspended Solids	20	50
All toxic metals	0.5	1
Free NH_3	0.5	1

I.(i).2.3. Solid wastes A variety of solid wastes is produced in a refinery and these include catalytic fines from cracking units, coke fines, iron sulphides, filtering media and sludges from tank cleaning operations, oil-water separators and biological oxidation processes.

Incineration and land-fill represent the two main methods of solid waste disposal, the cost of which may represent a major cost item in a refinery. Incinerators may ultimately result in limited air pollution for which suitable extraction equipment must be installed.

I.(i).2.4. Noise Sources which generate noise in a refinery are: high speed compressors, control valves, piping systems, gas turbines, flares, air cooled heat exchangers, cooling towers and vents. Typical noise levels in a refinery range from 100 - 110 dB (e.g. power plant, boilers near forced draft fan, hydrogen reformer) to 60 - 70 dB (e.g. control rooms) measured at 1 metre distance. (The problem of noise is discussed in more detail in Chapter VII).

I.(i).2.5. Visual or aesthetic effects Such aspects are beyond the scope of this section; they should be considered at the planning stage.

I.(i).3. References

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I.(ii). IRON AND STEEL INDUSTRY

I.(ii).1. Introduction

Iron and steel manufacturing may be grouped into six distinct sequential operations: 1) coke production and by-product recovery; 2) ore preparation, including sintering operations; 3) pig iron manufacture in blast furnaces; 4) steel-making processes using basic oxygen, electric arc and open hearth furnaces; 5) casting and rolling mill operations; and, 6) finishing operations. The first four of these operations encompass nearly all of the air pollution sources. With the exception of coke production and by-product recovery, water pollution sources originate principally from the washing of exit gases to control air emissions (Figure I.(ii).1.). Coke production is a net producer of waste water, most of which results from water in the coal charged to the ovens.

I.(ii).2. Coke Production and By-product Recovery

Large steel plants operate coke ovens, producing metallurgical coke from coal by heating coal in an atmosphere of low oxygen content, i.e. destructive distillation. Visible smoke, hydrocarbons, carbon monoxide, ammonia and other emissions originate from this process, which are then collected and subjected to various operations to separate and recover ammonia, coke-oven gas, tar, phenol, light oil (benzene, toluene, xylene) and pyridine. These unit operations are potential sources of hydrocarbon emissions (U.S. Environmental Protection Agency, 1976), most emissions, however, being removed by recovery and washing.

Liquid wastes originate from cooling and process water as ammonia still wastes, coke quenching effluents, light oil decant waters and acid washing effluents, and contain phenols, cyanides, thiocyanates, ammonia, sulphides and chlorides. These materials may appear alternatively in blast furnace gaswasher water when the coke plant effluent is used as quenchwater in the blast furnace. Coke plant effluents present particularly difficult waste control problems when reducing loadings, notably of phenols and cresols, to acceptable levels prior to discharge (U.S. Department of the Interior, 1968).

I.(ii).3 Ore Preparation

In order to increase the iron content, some of the mineral ores are screened, washed, crushed and blended. Some drying is necessary for high moisture content material before transport to concentrating plants, if these are employed. The aforementioned processes usually occur at the mine site where dust control measures are enforced to reduce air emissions.

The quality of iron ore is further improved by concentration employing one of five methods (McGannon, 1971): washing, jigging, heavy-media separation, magnetic separation (physical operations) and flotation (chemical process). These operations produce approximately 50 tons of tailings for each 100 tons of ore treated. Tailings can cause surface dust emissions when dry and drying of the ore fines also creates air pollution problems. Apart from the quantity of tailings produced, water pollution does not present a problem as only hardness is increased (Lewis, 1965); after suitable settling, clarified water can usually be discharged into public waters (U.S.Environmental Protection Agency, 1977).

The fine iron particles, whether natural or in concentrated ores, are agglomerated to a size suitable for blast furnace usage. Of the four processes available, i.e. sintering, pelletizing, nodulizing and briquetting, sintering and pelletizing are by far the most common agglomeration methods. The sintering process is particularly useful as it converts not only fine ore concentrates, but also blast furnace flue dust, mill casting, turnings, coke fines, limestone fines and miscellaneous fines into an agglomerated product suitable as a blast furnace feed material. The process emits significant quantities of sulphur oxides (sulphur content is as high as 200 ppm); hydrocarbon fumes may be evolved if only scrap is used in the sinter mix (Genton, 1972).

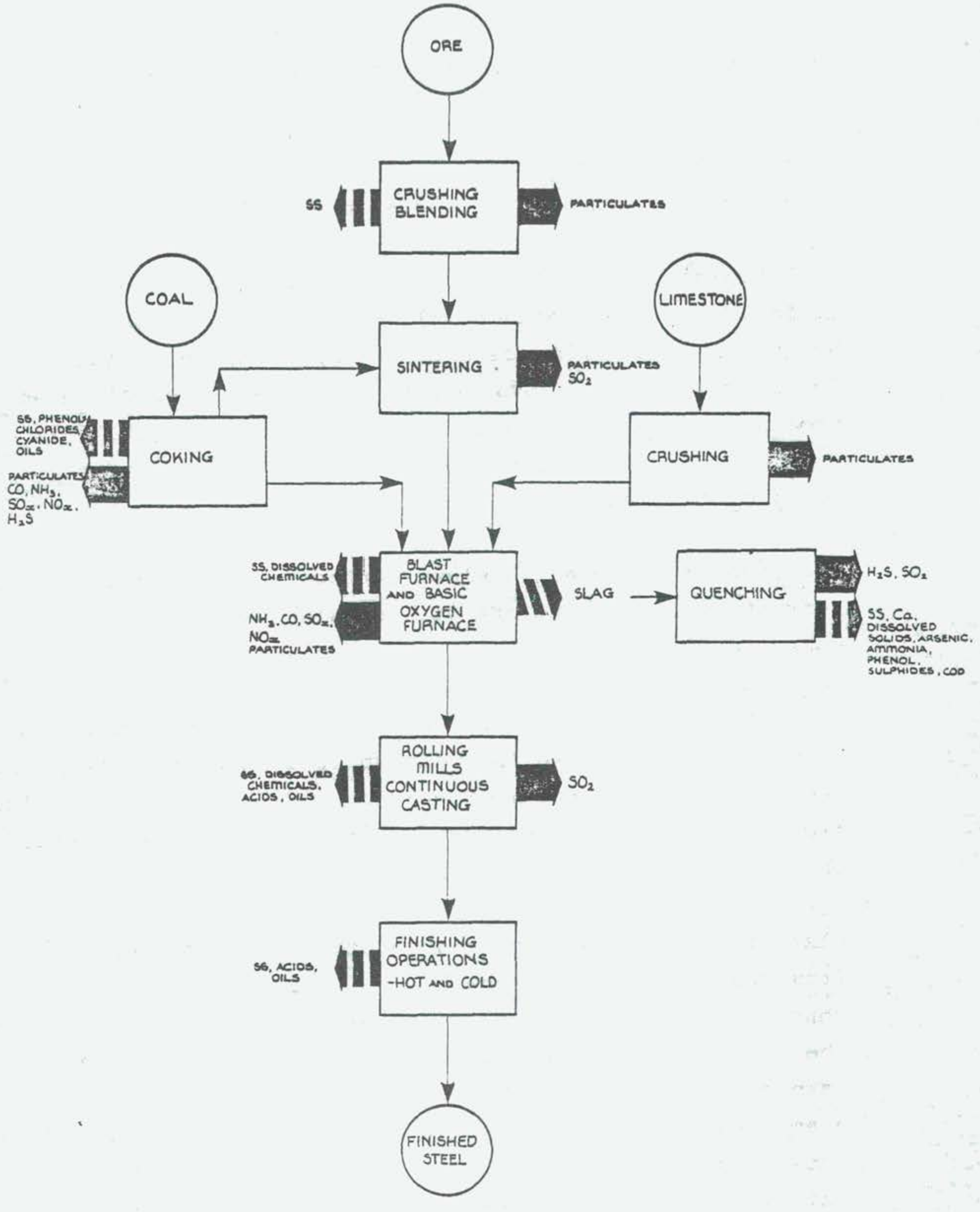

Fig. I(ii)1 Iron and Steel Industry

Dust control from sinter operations are effected by use of electrostatic precipitators, baghouses, scrubbers and dry cyclones. The latter control reduces emissions to 1 $kg.tonne^{-1}$; an electrostatic precipitator in series with a dry cyclone reduces emissions to 0.5 $kg.tonne^{-1}$.

Pelletizing usually occurs at the mine site and presents minimal problems (Goldberg, 1973). Nodulizing and briquetting both produce smaller emissions than sintering, due largely to the lower operating temperatures of these processes (U.S. Environmental Protection Agency, 1977).

I.(ii).4. Pig Iron Manufacture

Pig iron is produced in blast furnaces which are large refractory-lined chambers within which iron ore, sinter, coke and limestone are charged and allowed to react with large amounts of hot air to produce molten iron. Slag and blast furnace gases are by-products of this operation. Most of the coke used is produced in by-product coke ovens (see I.(ii).1.1. above); flue dust and other iron ore fines from the process are converted into useful blast furnace charge via sintering operations.

Blast furnace combustion gas and the gases that escape from the cast house at the base of the blast furnace constitute the major sources of particular emissions. The dust in the gas consists of 35 to 50% iron, 4 to 14% carbon, 8 to 13% silicon dioxide, and small amounts of aluminium oxide, manganese oxide, calcium oxide and other materials. The gas has a high carbon monoxide content, this gas being recovered, cleaned of particulates and used as a fuel within the plant.

Primary treatment of the gases usually utilises a settling chamber or dry cyclone where approximately 60% of particulates are removed. Wet scrubbers or electrostatic precipitators then effect final cleaning, removing up to 96% of particulates, the remainder of which are vented to the atmosphere. The cleansed gases are then used as a fuel in the stoves and for other heating purposes in the mill.

The principal liquid waste results from the washing of exit gases; effluent consists of suspended solids together with a range of hydrocarbons (phenols, cresols), ammonia, cyanides, arsenic, sulphides and COD material. When slag from the blast furnace is quenched with cooling water, carbon monoxide and hydrogen sulphide are evolved from these washings in the quenching pit. Coagulation and sedimentation are the principal methods of particulate removal; recirculation of the wastewater may be used. Physico-chemical methods are available for water purification but expense makes disposal via soakaways or deep wells an attractive alternative. This necessarily involves a risk of groundwater contamination - often an unacceptable penalty.

I.(ii).5. Steel Making

Open hearth furnaces, basic oxygen furnaces and electric arc furnaces constitute the most modern methods of steel production from blast furnace pig-iron. Outmoded bessemer converters are still in operation in old plants, but not included in new plant design. Large quantities of particulates are produced from all processes, principally iron oxide together with oxides of aluminium, manganese and silicon. Small amounts of fluorides are produced from open hearths when fluoride-bearing ore is used; basic oxygen furnaces produce large quantities of carbon monoxide (140 lbs ton^{-1} steel) which are removed by combustion in the hood, direct flaring, or other means of ignition, thereby reducing emissions of carbon monoxide to less than 3 lbs.ton^{-1}. Electric arc furnaces produce only moderate amounts of carbon monoxide, in the region of 15-20 lbs ton^{-1}. Note, however, that carbon monoxide, once collected and cleaned, is a valuable fuel which can be used in various mill processes.

High-energy Venturi scrubbers and electrostatic precipitators reduce particulate emissions by between 95 and 98%; the scrubbers in turn, however, produce a liquid effluent production of between 600 and 2000 gallons.minute^{-1}. Effluent is principally fine particulate ferric oxide (Fe_2O_3).

I.(ii).6. Casting and Rolling Mill Operations

Molten steel is either cast to a specific shape or made into ingots; these may then be heated for further shaping by hot working (rolling). Surface defects are removed prior to grinding, chipping, peeling or scarfing. Negligible quantities of particulates are produced during casting and rolling; scarfing causes release of extremely fine particulate iron oxide, together with steam from cooling processes. These emissions are retained within the buildings of operation, the most effective control device being electrostatic precipitators.

As liquid effluent, particles of scale and oil originating from hydraulic and lubricating procedures are removed at a rate of up to 100,000 gallons.minute^{-1} in the newest wide hot-strip mills.

I.(ii).7. Finishing Operations

Emissions and effluents from cleaning operations are included in this section on finishing. Pickling in acid or alkaline solutions removes rust and scale from metal surfaces as a preliminary exercise to cold rolling, tin-plating, galvanising, plating with other metals, coating and tempering.

Pickling usually employs hydrochloric, sulphuric, nitric, hydrofluoric or other acids; alkaline cleaning solutions utilise caustic soda, soda ash, silicates and phosphates. The acids and their respective iron salts appear in spent pickling solutions and in acid rinsewaters; various additive organic chemicals and trace metals other than iron are also found. Effluent volumes from pickling tanks range from 5,000 to 150,000 gallons.day^{-1} and exhibit high suspended solid content, considerable COD and ferric salt content. Alkaline washings contain saponified oils and dirt and considerable residual alkalinity, with total volumes ranging from 1,000 to 10,000 gallons per week.

Effluent from cold mills typically contains 200 mg l^{-1} oil, 25% of which is as a stable emulsion and relatively low concentrations of scale particles; effluent volumes range from 1,000-1,500 gallons.minute^{-1} per mill. Electrolytic tinplating solutions contain sodium stannate, sodium hydroxide and sodium acetate; wastewater effluents result from rinsing and quenching and typically amount to 2,800 gallons.minute^{-1}. Effluent from electroplating may contain cyanide from the plating bath; zinc from zinc-anodes is the major contaminant at up to 100 mg l^{-1}.

There is growing concern about the hydrocarbon emissions from both hot and cold rolling operations; these result from lubricants and other oils used in the processes or present in the recycled water system (Mackus and Joshi 1979).

Note

A comprehensive discussion of effluent sources from each process within steel manufacturing, is presented in a U.S. Environmental Protection Agency document (1977) entitled "Industrial Process Profile for Environmental Use: Chapter 24. The Iron and Steel Industry". For further details the reader is referred to this report.

I.(ii).8. Fugitive Emissions

Two main sources of fugitive emissions - process fugitive emissions and open dust source fugitive emissions - constitute a considerable source of air pollution problems within the steel industry. Emissions are primarily particulates though gaseous emissions associated with certain operations (such as sulphur dioxide, carbon monoxide, ammonia, hydrocarbons, and nitrogen oxides from coke manufacture and carbon monoxide from blast furnaces, sintering and steel-making furnaces) also constitute a problem.

Table I.(ii).1. Sources of Fugitive Emissions from Integrated Iron and Steel Plants

A. Process Sources
  1. Scrap cutting
  2. Sintering
     * Windbox leakage
     * Strand discharge
     * Cooling
     * Screening
  3. Hot metal transfer
  4. Hot metal desulphurization
  5. Electric are furnace
     * Charging
     * Electrode port leakage
     * Tapping
     * Slagging
  6. Basic oxygen furnace
     * Deskulling
     * Charging
     * Leakage (furnace mouth, hood sections, and oxygen lance port)
     * Tapping
     * Slagging
  7. Open hearth furnace
     * Charging
     * Leakage (doors and oxygen lance port)
     * Tapping
     * Slagging
  8. Slag quenching
  9. Teeming
  10. Scarfing (machine and hand)

B. Open Dust Sources

1. Unloading (rail and/or barge) - raw[a/] materials
2. Conveyor transfer stations - raw and intermediate[b/] materials
3. Storage pile activities - raw, intermediate, and waste[c/] materials
    - * Load-in
    - * Vehicular traffic around storage piles
    - * Wind erosion of storage piles
    - * Load-out
4. Vehicular traffic
    - * Unpaved roads
    - * Paved roads
5. Wind erosion of bare areas

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a/ Raw materials - iron ore, coal, and limestone/dolomite

b/ Intermediate materials - coke and sinter

c/ Waste materials - slag and flue dust.

I.(ii).9. References

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I.(iii). ALUMINIUM AND NON-FERROUS METAL PRODUCTION

I.(iii).1. Introduction

Most non-ferrous metals are recovered by the smelting of element bearing ores. Smelting proceeds at high temperatures, and large quantities of dusts and metal oxide fumes are generated. The mass of air handled daily in a smelter is far greater than the mass of solid materials, which itself may be several thousand tons per day.

In addition to the potential for substantial emissions of particulate matter, some of which could be toxic, there is a concomitant high production and emission of sulphur dioxide. Most of the copper, lead, and zinc in the earth's crust occurs as complex sulphide minerals. After mining, milling and concentration, the minerals shipped to smelters contain as much as 30% sulphur, all of which is oxidized during the various smelting steps, and nearly all of it appears as SO_2. It has been estimated that smelters contribute about 13% of the total SO_2 emitted annually in the United States.

The oxidation of sulphur provides valuable process heat and conserves energy that would have to be supplied from other sources. Also, sulphur dioxide can be a useful raw material for sulphuric acid production in areas where acid can be used and where smelter acid can compete in the market with acid derived from burning elemental sulphur. However, sulphur dioxide also causes a number of air pollution problems, including damage to human health, vegetation and building materials. Over the years SO_2 damage has been the basis of protracted and costly litigation. There have been numerous law suits against smelting companies. Damage from smelter particulate emissions has also been the subject of litigation. Farmers near lead smelters have claimed that lead fallout has accumulated in soil and pasture grasses in sufficient concentrations to poison farm animals, usually horses. In some cases there has been no doubt of the validity of the claims; others have been disputed. Fluoride fallout and gases from aluminium smelters have also been responsible for harm to grazing animals.

Large amounts of liquid effluent can also be produced. These tend to contain significant concentrations of dissolved and suspended solids, as well as pH fluctuations - both alkaline and acidic. Metal salts or oxides are often encountered in the waste streams, and cooling water requirements can add significantly to the quantity of the effluent. These pollutants are generated at most stages of the metal process.

In some cases the quantities of liquid effluent and suspended solids are vast. For example, the aluminium production industry can generate huge amounts of a sludge effluent, known as 'red mud' because of its colour and texture.

The aluminium, copper, lead and zinc processes have been considered, with greatest emphasis on the aluminium industry as an example of non-ferrous processing and emissions.

I.(iii).2. Aluminium Production Industry

Bauxite, a hydrated oxide of aluminium associated with silicon, titanium and iron, is the base ore for aluminium production. The ore is generally extracted by strip mining, blasting or utilising earth moving equipment. Some ores are crushed, washed to remove clay and other siliceous wastes, and dried prior to shipment. Such operations can therefore produce air particulate problems, in addition to sulphur oxide emissions from drying plants though this is dependent upon the sulphur content of the fuel used. Quantities of suspended solids must also be disposed of.

The production of aluminium is a two step operation and can take place in separate locations. Primary production consists of chemically purifying the bauxite ore by the Bayer process, to give alumina (aluminium oxide) or possibly aluminium chloride. Aluminium metal is then manufactured from alumina or aluminium chloride by the Hall-Heroult electrolytic reduction process in which alumina is continuously dissolved in molten cryolite. Tertiary aluminium operations involve making lightweight metal alloys from casting and ingots; scrap aluminium is also used. The principal wastes from aluminium production include:

i) solid wastes (bauxite residue and spent jot-linings)
ii) gaseous emissions (fluorides, sulphur oxides, carbon monoxide, hydrocarbons, particulates, chlorine)
iii) liquid effluents (spent solution containing sodium aluminate or calcium fluoride and sodium/calcium sulphate).

The major environmental problems are associated with the discharge of fluorides and particulates and the disposal of red mud.

I.(iii).2.1. Primary alumina production - the Bayer process

The chemical production of alumina from bauxite can be grouped into 5 stages: (i) milling and grinding; (ii) digestion; (iii) filtrations; (iv) precipitation; and, (v) calcination. See Figure I.(iii).1.

I.(iii).2.1.1. Milling and grinding

The raw bauxite ore is dried, ground in ball mills, and then mixed with sodium hydroxide. The grinding process is an important source of particulate emissions and usually protected by electrostatic precipitator, venturi scrubber or bag filter. In addition, transportation and storage of ground bauxite - especially during loading or unloading - leads to fugitive dust emissions. These can be quite significant and may necessitate surface stabilisation of abandoned impoundments.

I.(iii).2.1.2. Digestion

The ground bauxite is then digested at elevated temperatures by a sodium hydroxide liquor. Aluminium hydrates in the ore are converted to sodium aluminate.

$$Al_20_3.2H_20 + 2Na0H \longrightarrow 2Al0_2Na + 3H_20$$
$$Al(OH)_3 + NaOH \longrightarrow Al0_2Na + 2H_20$$

Steam injection releases the aluminium as the hydroxide and generates some particulates, and dissolved solids (TDS).

I.(iii).2.1.3. Filtration

Filtration separates the aluminium hydroxide leaving behind large amounts of "red mud" sludge: basically ferric oxide and other dissolved solids. For each tonne of alumina produced, between one third to one tonne (dry weight) of solids are discharged as this fine "red mud" (UNEP,1977). Dumping as landfill has given rise to some concern, e.g. ground water contamination and dumping at sea are increasingly facing prohibition. Amongst the small number of alternative disposal processes available, landfill of filtered mud is favoured, provided that recovery of alkaline leachate can be effected.

I.(iii).2.1.4. Precipitation

The aluminium hydroxide is precipitated from the cooled filtrate, producing some particulates.

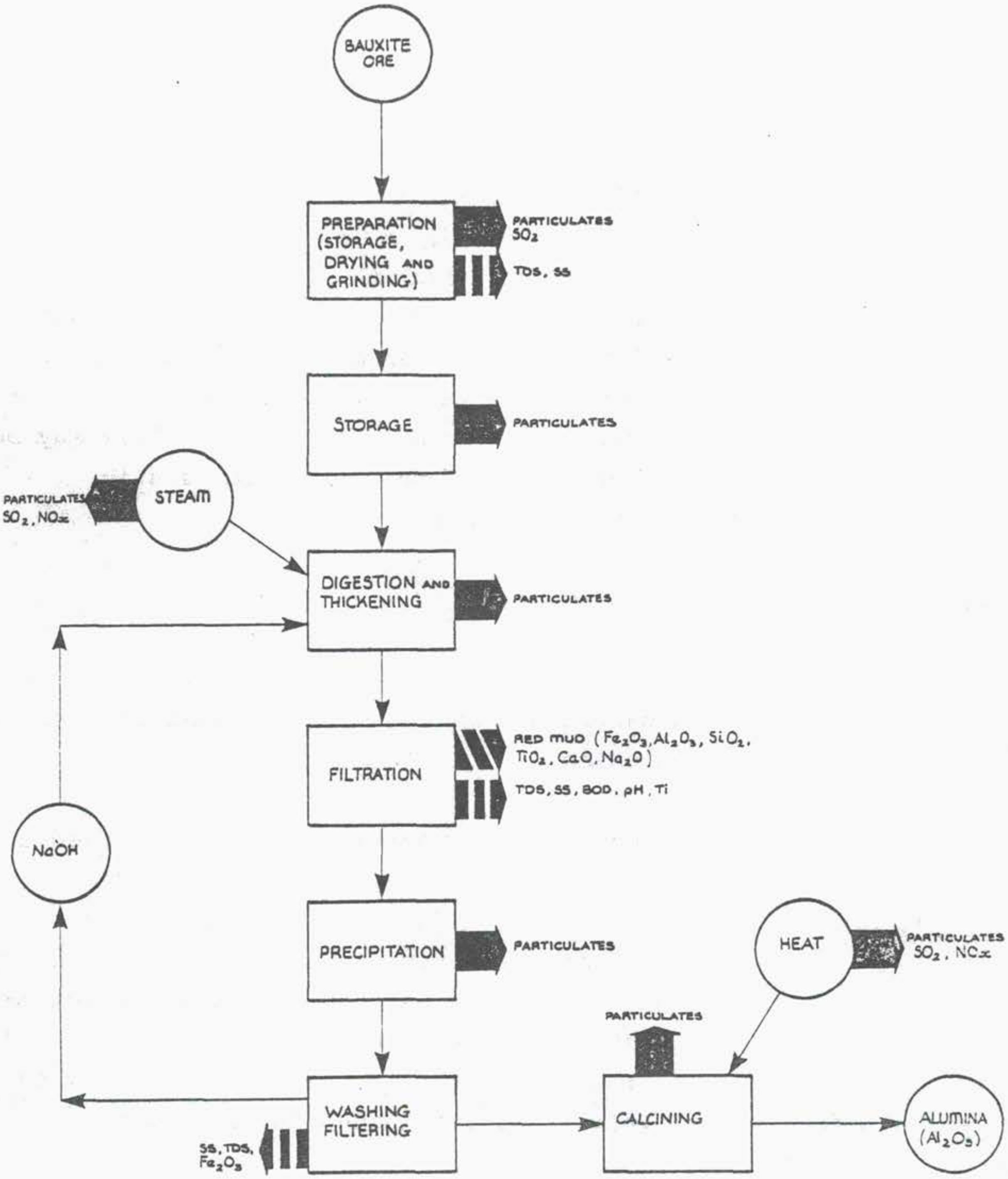

Fig. I(iii)1 Bauxite Processing to Alumina
Bayer Process

I.(iii).2.1.5. Calcination

The hydroxide is washed and filtered producing some dissolved solids and ferric oxide. These filters feed large kilns or calciners in which the aluminium hydroxide is calcined - heated to about 1200°C. This drives off much of the combined water producing alumina. The rotary kiln is one of the major sources of dust emissions - even with a particulate collection device further controls may be required. Such devices may be a combination of multicyclone and electrostatic precipitator or bag filter.

I.(iii).2.1.6. Further emissions

The burning of fuel for steam generation and alumina calcination can result in emissions of sulphur dioxide and nitrogen oxides.

Fly ash abatement may be necessary if coal is used as fuel.

Alumina plants use sulphuric or hydrochloric acids for periodic descaling of heat exchangers, filter beds or other equipment. The resulting waste is high in suspended solids (TSS), mainly sulphates, but low in free acid. It is sometimes added to the red mud effluent.

Other possible liquid effluents include boiler blowdown, evaporator salts, cooling tower blowdown, and barometric condenser cooling water.

I.(iii).2.1.7. Other processes

Highly siliceous bauxites rapidly scale the filtration plants. The red muds which are rich in sodium alumino-silicate, accordingly undergo calcining at 1200°C after addition of calcium carbonate and sodium carbonate.

The greater part of the silica thereupon changes to a dicalcium silicate and the alumina to sodium aluminate, which is washed in a lye and restored to the Bayer production circuit. The calcining process can produce large amounts of dust and particulate emissions.

I.(iii).2.2. Alumina reduction to aluminium - the Hall-Heroult process

Refined alumina is electrolytically reduced to produce aluminium. Alumina is continuously dissolved in molten cryolite (basically sodium aluminium fluoride), liberating aluminium at the cathode and oxygen at the anode. The carbon anode reacts with oxygen to produce carbon dioxide. See Fig. I.(iii).2.

The electrolytic cell is basically comprised of a rectangular steel tank, which is lined with refractory insulating brick lined with the carbon cathode, the only material able to withstand the corrosive fluorides. During reduction, molten aluminium collects at the bottom of the cell on the carbon cathode. This is drawn off at intervals into crucibles, the volume loss being made good by a steady feed of alumina into the electrolytic cell. There are two types of anode, the pre-baked, obtained from petroleum coke and pitch, and the Soderberg continuous self baking anodes. The anodes are suspended in the electrolyte classifying the cells as Soderberg (vertical or horizontal studs) or Prebake (open or closed) according to the design.

The older prebaked anodes require significantly less energy than the Soderberg system and because the anodes are baked in separate facilities it is easier to recover the volatiles released from the anode parts. However, small smelters benefit from the Soderberg system because there is lower capital cost - separate anode-making facilities are unnecessary.

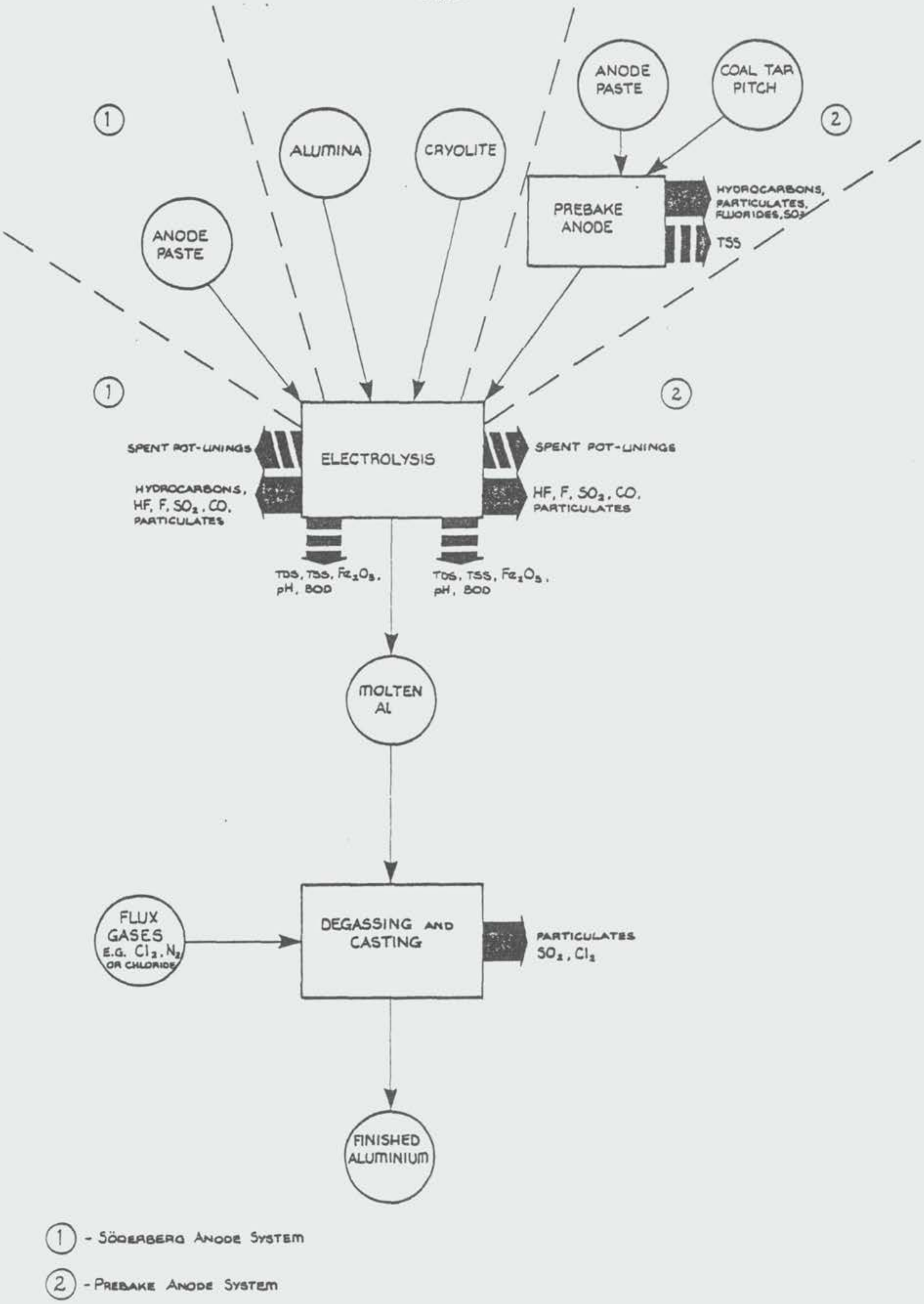

Fig. I(iii)2 Alumina Reduction to Aluminium
Hall-Heroult Process

The extraction process can lead to the production of gaseous and particulate fluorides (mainly hydrogen fluoride), dust, carbon monoxide, sulphur oxides, dissolved and suspended solids, ferric oxide, and unbalanced pH.

The process may be divided as follows: (i) prebaked anode fabrication; (ii) electrolysis - prebaked or Soderberg; and, (iii) degassing and casting. Hydrogen fluoride accounts for 50% to 90% of gaseous emissions. Sulphur dioxide present in the electrodes is also important.

I.(iii).2.2.1. Prebaked anode fabrication

The anodes, being fabricated from coal tar pitch and petroleum coke give rise to volatile or heavy hydrocarbons in significant amounts. Carbon dust, particulates and sulphur oxides are also produced during baking and typically removed by electrostatic precipitator, wet or dry scrubbing.

I.(iii).2.2.2. Electrolysis

(i) Prebaked anode

The anodes, having been previously made, give off few volatile hydrocarbons, in contrast with the Soderberg system. Particulate emissions include alumina and carbon from anode dusting, cryolite, particulate fluorides and ferric oxide. Large amounts of gaseous fluorides (hydrogen fluoride) and carbon monoxide are produced together with sulphur oxides and inorganic fumes. A tupical emission control method employs a castic scrubber. The prebake-cell is considered to have a higher hooding efficiency than the Soderberg system for trapping emissions

(ii) Soderberg cells

With Soderberg cells, "Soderberg paste" is continuously fed into the cell and baked by heat from the cell and current flow. Hydrocarbons (pitch volatiles) are emitted in addition to the emissions listed for prebake cells. Horizontal stud systems cannot burn off these hydrocarbons due to quenching by air, so tar fouling of ducts or control equipment can be a problem. Vertical study cells enable these anode gases to be collected and partly burnt off leaving only carbon dust and carbon dioxide.

Other emissions include inorganic fumes, alumina, carbon from anode dusting, cryolite, particulate fluorides and ferric oxides. Large amounts of gaseous fluorides (hydrogen fluoride) and sulphur oxides are also produced. The horizontal study method also produces a lot of carbon monoxide and tar, whereas the vertical study system converts this partly to carbon dust and carbon dioxide.

Control measures typically consist of a caustic scrubber for the vertical study and floating bed scrubber for the horizontal stud system. Emission abatement problems are primarily caused by the removal of particulates and gaseous hydrogen fluoride.

Total emissions from the two Soderberg systems are about the same - either generating more than an equivalent prebaked system. Emissions capture is not complete with either cell as access is necessary. Secondary emissions from these inefficient hoods are subsequently released through roof ventilators and constitute 5-40% of smelter emissions. Note, however, that some new Soderberg cells meet low emission levels.

I.(iii).2.2.3. Degassing and casting

After decanting off the molten aluminium, gases are removed and the metal is cast in bars or ingots. Degassing produces particulates and sulphur oxides, casting generates B.O.D., dissolved solids and acid wastes.

I.(iii).2.3. Sources of emissions

Tables I.(iii).1. and I.(iii).2. show the aerial and liquid emissions. Figures for uncontrolled and controlled emissions are given where possible. In many processes, aerial emissions are controlled by trapping pollutants in water or other solutions and removing as a liquid effluent. Thus controlled aerial emissions can lead to greater quantities of liquid effluent.

Water pollutants such as dissolved solids and ferric oxides are sometimes effectively treated by reverse osmosis, coagulation, electrodialysis and activated carbon. All these assure 95-100% efficiency of treatment. Dissolved solids and B.O.D. are effectively treated by lagooning.

Since waste water flow rates and quantities of pollutants present are dependent on the type of air pollution control equipment, it is not realistic to report raw wasteload values. Generally, however, plants with a once-through treatment system will have an effluent flow of 16 to 160m^3/tonne of aluminium. Fluoride concentration ranges from 20-50 ppm.

I.(iii).3. Copper Production

Copper ore is mined, milled and concentrated then smelted and refined. Most of the primary domestic copper is recovered from low grade sulphide ores and is open mined. Leaching can sometimes be used for these ores, although it is normally employed only for oxide and mixed ores. Leaching of waste dumps by weak acids can recover significant quantities of the metal.

Copper ores are handled in tremendous quantities - up to 500 tonnes/hour are not unusual. The ore is crushed and ground wet to a thin slurry. Flotation reagents are added and air beaten in to form a copper rich froth. The froth is skimmed off and the remaining solids dewatered, settled, filtered and sent off for smelting.

Table I.(iii).1. Aerial emissions - typical uncontrolled and controlled levels

Process	Particulates		Solid F		HF		SO_x		NO_x		CO		Hydrocarbon	
	u	c	u	c	u	c	u	c	u	c	u	c	u	c
Primary alumina production kg/tonne alumina														
Mining	*		*				*							
Grinding[a]	3.0	0.06												
storage	*		*											
Digestion	*		*		*									
steam generation	*						*		*					
Filtration					R E D M U D T O L I Q U I D E F F L U E N T									
Precipitation	*		*		*									
Calcining	100-1000	2-20												
heat generation							*		*					
Aluminium production kg/tonne Al														
Materials handling	5.0	0.1	-	-	-									
Anode furnace	1.5	0.03	-	-	0.47	0.02	*							
Prebake cell	30-100	0.8-6	8	0.2	8	0.5	15				200		NEGLIGIBLE	
Söderberg cell vertical	20-40	1	2	0.6	18	0.3	15				50		2-6	1
Söderberg cell horizontal	20-40	3	4	2.3	16	1.7	15				200		6	
Degassing and casting	*						*							

a Figure in kg/tonne of Bauxite

* Emissions significant, figures not available

Table I.(iii).2. Liquid effluent emissions

Process	Suspended solids	Dissolved solids	FeO	Ti	F	BOD	pH	SO_4
<u>Primary Alumina production</u> (kg/tonne Alumina)								
Mining	**	**						
Grinding								
Digestion)	***	***	***	***	**	**	*	
RED MUD)	← 500 - 1000 →							
Filtration)	***	***	***	***	**	**	*	
Precipitation								
Calcination	**	**	**					
Ancillary processes								
acid cleaning	*	**				*	*	**
evaporator	*	**					*	**
washing/filtering	**	**						
<u>Aluminium production</u> (kg/tonne Aluminium)								
Anode fabrication	*							
Electrolysis :								
prebaked	**	*	*		**	*	*	
Soderberg	**	*	*		**	*	*	
Degassing		*				*	*	
<u>Other liquid effluents</u>								
Cooling water		**					*	
Condenser blowdown		**						
Hose down	**	**						

*	emission
**	significant emissions
***	large emissions

Emissions at this stage include particulates from the running, transporting and grinding of the ores. In underground mines, silica may present a health risk; however, particulate emissions to the surface are relatively low. Open pit mines cause more of a local dust problem, so it is standard practice to use water while drilling, to wet down ore and waste piles and so forth. After blasting, concentrations of nitrogen oxides up to 30 ppm may remain in the pit for a few minutes.

The dust evolved during grinding is again usually controlled by wetting - however this can lead to a high suspended solids load in the effluent. The flotation process creates few air pollution problems, but waste material issued as tailings, or as sandy slurry from the concentrations may do so. These are usually channelled to a tailings dump. Surface drying of the dump can cause local dust problems, and leachate from the tailings pond may interfere with local groundwater quality.

.(iii).3.1.Copper smelting

Smelting is a three-stage process of sintering/roasting, smelting and converting. The ore is roasted and sintered in a multi-hearth or fluidized bed furnace. This removes moisture and oxidizes part of the sulphur. After the sulphur is removed by roasting, the ore is calcined as preparation for smelting by a reverberatory furnace. Here the copper as oxides, sulphides and sulphates are melted to form copper matte - a mixture of cuprous and ferrous sulphide. Some iron, calcium, magnesium and aluminium silicates are removed as a viscous slag.

In the convertors, air is blown through the molten matte to remove sulphur (as oxide). Various impurities form a surface slag which is recycled. Eventually free copper is left which is poured off for de-oxidizing and casting as slabs of 'blister copper'. Tables I.(iii).3. and I.(iii).4. summarise airborne emissions during copper production.

.(iii).3.1.1.Emissions and effluents

Sintering and roasting drives off any arsenic, antimony, lead and other metals as oxides - the amount depending on their concentration in the ore. Waste gases will also contain sulphur dioxide, and particulates. The water pollutants at this stage

Table I.(iii).3. Example Analysis of Collected Dust and Fume in Effluent Gases from Copper Roasters, Reverberatory Furnaces, and Converters

Element	From roasters	From reverberatory furnaces	From converters
Copper %	5.2	2.9	1.12
Iron %	6.6	1.6	1.2
Lead %	7.6	30.5	47.1
Zinc %	1.7	8.3	3.2
Arsenic %	43.0*	25.7*	9.6*
Antimony %	5.3	3.0	1.6
Bismuth %	0.4	1.11	1.64
Cadmium %	---	0.71	1.15
Silver oz/ton	7.6	18.6	10.9
Gold oz/ton	0.02	0.04	0.02

* Present to this extent only in smelting of concentrates high in arsenic.

Table I.(iii).4. SO_2 and Particulates Emission Rates from Copper Smelting

Process	Emission rate	
	gm SO_2/ kg of metal	Particulates gm/Kg of metal
Primary copper smelting		
If roasting is practiced		
Roasting	325-675	90
Reverberatory furnaces	150-475	40
Converters	975-1075	120
If roasting is not practiced		
Reverberatory furances	275-800	---
Converters	850-1800	---

are suspended solids, dissolved solids and alkalinity.

During calcining, air pollutants consist of particulates and sulphur oxides. Water pollutants are again suspended solids, dissolved solids and alkalinity. In the furnace, the list of pollutants for air and water wastes is again particulates and sulphur oxides; and dissolved and suspended solids with some change in alkalinity. During casting, only dissolved and suspended solids are generated.

.(iii).3.2.Copper refining

A small percentage of virgin copper is sufficiently refined by special furnace treatment at the smelter to be used directly in certain applications. However, the bulk of the copper is intended for electrical uses, and must be highly purified. Very small amounts of certain impurities greatly reduce copper's electrical conductivity, and adversely affect its annealability.

Anodes of blister copper are arranged alternately, face to face with thin sheets of pure copper in large tanks. The sheets are the cathodes of the multiple electrolytic cells to be formed in each tank. The tanks are nearly filled with a dilute solution of copper sulphate and sulphuric acid. A low voltage current passes between anodes and cathodes, causing dissolution of copper at the anodes and deposition at the cathodes. Trace metals present in the impure anode either dissolve in the circulating electrolyte or settle to the bottoms of the tanks as a black sludge called anode mud, or slimes. The slimes may contain selenium, tellurium, gold, silver, platinum and palladium. All these elements are frequently associated with copper in its ores.

.(iii).3.2.1.Emissions and effluents

Electrolytic copper refining does not create any significant pollution. Some traces of electrolyte mist are generated by liquid splashing. If the copper content of the electrolyte is low, and arsenic is present in the solution, hydrogen may evolve at the cathode to form poisonous arsine gas (AsH_3).

Treatment of slimes for recovery of gold, silver, selenium, tellurium and other metals may lead to additional pollution.

I.(iii).4.Lead and Zinc Processing

Lead and zinc frequently occur in the same ore and are, therefore, processed together. The first process steps, gravitation and flotation separation, concentrate the ore and remove impurities. Air pollutants generated are particulates due to crushing ore. The water pollutants generated are suspended solids, dissolved solids and iron. The concentrated ores are then sintered, crushed and roasted to purify them further. These steps generate particulate and SO_2 air pollutants, but no water pollutants. Three sequential steps are used to obtain zinc metal from the ore: distillation, conversion to zinc sulphate and electrolytic reduction. See Fig. I.(iii).3.

Lead is fired directly in the blast furnace and refining furnace. Air pollutants consist of particulates and SO_2. Water pollutants include heat and blowdown.

Mining of ores creates similar environmental problems as for copper. The ores are ground, crushed and concentrated before smelting.

I.(iii).4.1.Lead smelting

The sulphur content of lead concentrates is reduced by sintering them on Dwight-Lloyd sintering machines, most commonly on updraft machines. Moistened concentrate-flux-fuel mix is fed to an endless belt of cast iron grate sections. The charge is ignited, burned under forced draft, and finally discharged as a fused mass of material called sinter. It may be crushed, mixed with other materials, such as flue dusts, and sintered a second time, or it may be fed directly to the blast furnace.

In addition to eliminating most of the sulphur from PbS concentrates, the sintering procedure prevents dust losses which would occur if concentrates were smelted directly. Also, it creates a more porous raw material to facilitate smelting. Up to 85% of the sulphur in the smelter feed is released during the sintering process.

A mixture of sinter, iron and coke is charged into blast furnaces. Contact with carbon monoxide and possibly free carbon at high temperatures reduces lead compounds to metallic lead. A mixture of molten lead and siliceous slag accumulates in the hearth of the furnace and is tapped off, either continuously or intermittently. Gravity separation of the lead from the slag takes place in heavily insulated settlers. Slag is allowed to overflow from the top into slag pots for transport to the dump or to a fuming furnace for zinc recovery.

As it is tapped periodically from the settlers, the crude lead is at red heat and contains considerable amounts of dissolved impurities which become insoluble as the metal cools. Hence the hot lead is transferred to holding kettles for cooling and subsequent skimming of impurities from the surface. At this stage the metal is about 95 to 99% pure and is further refined on the premises or cast into blocks for shipment to a refinery.

I.(iii).4.1.1.Emissions and effluents

Hot gases from the lead concentrate sintering process carry dust, metal oxide fumes such as antimony, lead and zinc, and sulphur dioxide. The furnace itself produces similar pollutants including a range of lead oxides, quartz, limestone, iron pyrites, iron-lime-silicate slag, arsenic and other metals containing compounds associated with lead ores and additional carbon monoxide. However, the amount of sulphur dioxide produced is reduced.

Nearly 85% of the sulphur content is eliminated during sintering, and may be fed as the dioxide to a sulphuric acid manufacturing plant.

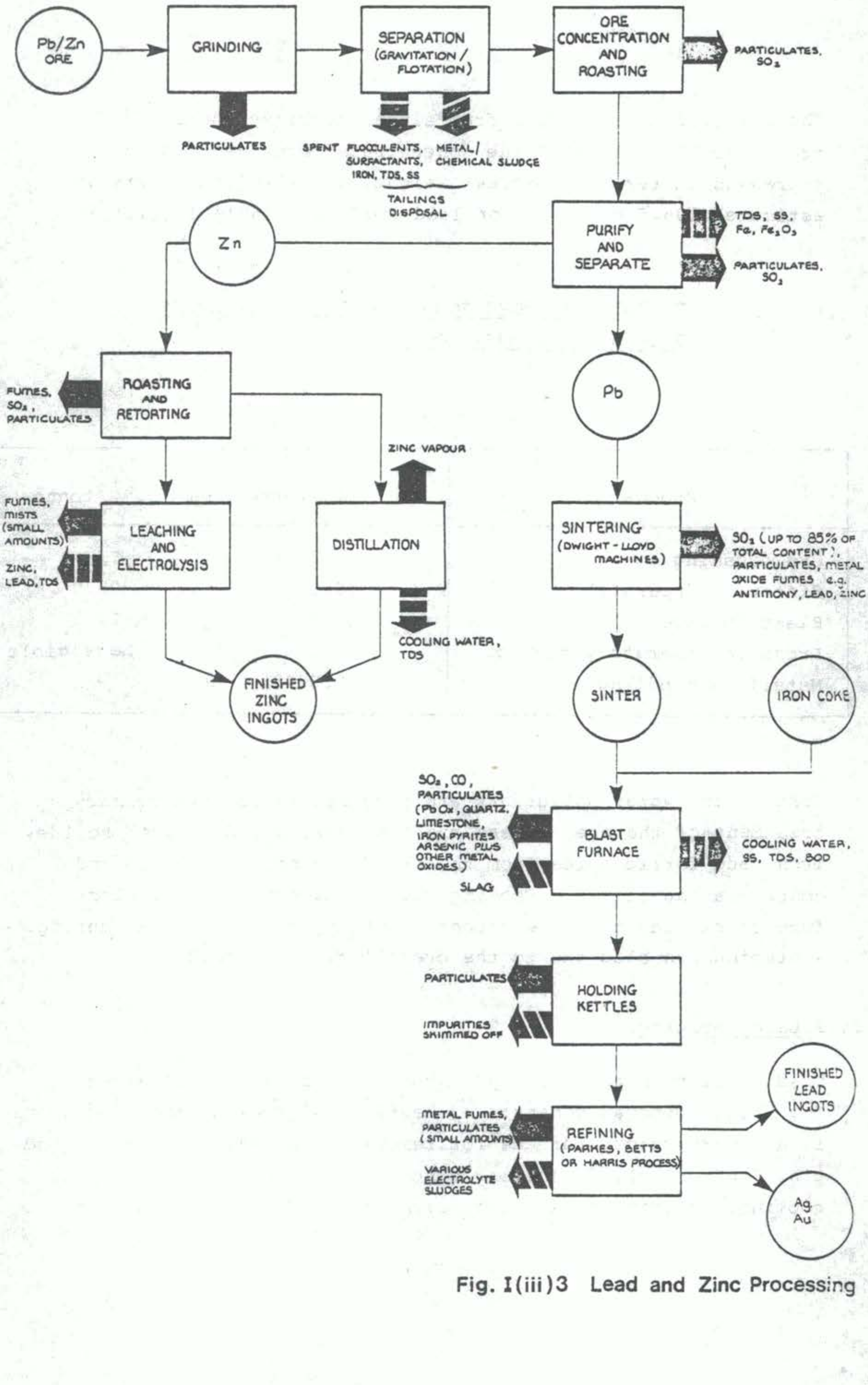

Fig. I(iii)3 Lead and Zinc Processing

The particulate emissions from sinter machines consist of from 5 to 20 percent of the concentrated ore feed. When expressed in terms of product weight, these emissions are an estimated 106.5 kg/ tonne of lead produced. (Table I.(iii).5.)

ble I.(iii).5. EMISSION FACTORS FOR PRIMARY LEAD SMELTING PROCESSES WITHOUT CONTROLS

Process	kg/tonne	kg/tonne
Ore crushing	1.0	-
Sintering (updraft)	106.5	275.0
Blast furnace	180.5	22.5
Dross reverberatory furnace	10.0	Negligible
Materials handling	2.5	-

Most of the water pollutants are produced in the preliminary treatment of the ore. These are suspended and dissolved solids, iron, and ferric oxide from the ore grinding, separating and concentrating stages. Cooling water blowdown from the blast furnace can add to the effluent quantity, and scrubbers, during sintering can also add to the overall effluent load.

(iii).4.2. Lead refining

Lead bullion is purified by a number of different processes. The Parkes process consists of heating under oxidizing conditions in a reverberatory furnace for removal of arsenic, antimony, and tin (softening), dissolving zinc in softened lead in kettles, cooling, skimming of a silver-rich crust (desilverizing), and removing dissolved zinc by vacuum distillation (dezincing). If bismuth is present, it is removed by treatment with calcium and magnesium (debismuthizing).

The Harris process employs treatment with molten sodium hydroxide and sodium nitrate as a substitute for furnace softening. Arsenic, antimony, and tin, if present, are separated as sodium salts.

The Betts process is electrolytic and produces pure lead cathodes plus a slime containing impurities derived from the crude lead bullion.

An important part of lead refining is the recovery of silver and gold. Zinc crust collects both metals. The crust, containing a considerable percentage of entrained lead, is heated in graphite or clay retorts to distill off the zinc. The residual bullion is transferred to cupel furnaces for separation of lead. This is done by means of an air blast directed on the molten bullion. The litharge (PbO) produced is molten and is carefully decanted as it accumulates on the surface. Dore metal, a mixture of gold and silver, is the final product of cupellation and is tapped off for further treatment.

I.(iii).4.2.1.Emissions and effluents :

Some fumes emanate from the softening furnaces and a small amount of particulates is generated by the dross reverberatory furnace (10 Kg/tonne of lead). Water pollutants are also to a minimum.

I.(iii).4.3. Zinc roasting and retorting

Zinc is obtained as sphalerite ore (ZnS) or as an impurity in lead smelting. Zinc as an impurity in lead smelting is recovered from lead blast furnace slag by heating the slag to high temperatures and blowing pulverized coal and air through it.

Zinc is reduced, volatilized, reoxidized and is collected as ZnO in bag filter units. The baghouse product is passed through a rotary kiln to reduce the lead and or cadmium content by volatilization and to increase the density of the material for easier handling and shipping.

For efficient recovery of zinc, sulphur must be removed from concentrates to less than 2%. This is done by roasting. Multiple hearth, flash or fluidbed roasting may be followed by sintering; or double-pass sintering may be used alone.

The liberation of zinc from roasted concentrates involves simple heating of a mixture of roast and coke breeze to about 1100°C. Simultaneous reduction of zinc from the oxide to the metal and distillation of the metal takes place. Zinc vapour passes from the heated vessel into a condenser where is condenses to a liquid which is drained off at intervals into moulds.

Reduction and distillation of zinc may be done as a batch process in banks of cylindrical retorts - the Belgian retort process - or in continuously operating vertical retorts. Gas is the preferred fuel, hence most smelters are located in natural gas fields. Electric distillation furnaces are used to a small extent.

A very pure grade of zinc is produced by a continuous fractional distillation process developed by the New Jersey Zinc Co.

A process for simultaneous smelting of roasted lead and zinc concentrates has been developed by the Imperial Smelting Corporation. The process makes use of carbon monoxide generated from coke to reduce lead and zinc oxides in a sealed shaft furnace. Lead bullion accumulates in the furnace bottom and acts as a collector for copper, silver and gold. Zinc passes as a vapour out the top of the furnace into condensers in which a shower of molten lead is continuously maintained. Zinc vapour is condensed quickly to a liquid which dissolves in the molten lead. Outside the condenser the lead-zinc solution is cooled and a 98% pure zinc floats to the surface and overflows into containers. The cooled lead is pumped back to the condensers.

I.(iii).4.3.1.Emissions and effluents

Dust, fume and SO_2 are evolved from zinc concentrate roasting or sintering (Table I.(iii).6. Sulphur dioxide attains concentrations of 6-7% in roaster gases which, after being freed of particulates, may be passed directly into a sulphuric acid plant or vented from tall stacks. In zinc distillation, appreciable quantities of zinc vapour may be burned off as the oxide and emitted to the atmosphere (up to 8% of the zinc throughput). A distinctive, highly visible, white plume is produced.

Table I.(iii).6. EMISSION FACTORS FOR PRIMARY ZINC SMELTING WITHOUT CONTROLS[a]

Type of Operation	Particulates kg/MT	Sulphur Oxides kg/MT	m^3 Waste Gas
Roasting (multiple-hearth)	60	550	-
Sintering	45	b	4000[c]
Horizontal retorts	4	-	12000 - 18000 d
Vertical retorts	50	-	-
Electrolytic process	1.5	-	-

a - Approximately 2 unit weights of concentrated ore are required to produce 1 unit weight of zinc metal. Emission factors expressed as units per unit weight of concentrated ore produced.

b - Included in SO_2 losses from roasting.

c - Per tonne of zinc sulphate.

d - Waste flue gas per ton of zinc.

Liquid effluents are minimal.

(iii).4.4.Leaching and electrolysis

Zinc of high purity may be produced from roasted concentrates, from densified zinc oxide from fuming furnaces, or from impure metallic zinc by solution in sulphuric acid, followed by the removal of impurities from the solution by appropriate chemical treatment, and, finally, electrolysis of the purified electrolyte.

Electrolysis is done in tanks containing alternating anodes of lead and cathodes of aluminium. Essentially, pure zinc is deposited on the cathodes and later stripped from them by hand. The zinc is then melted in a small reverberatory or electric furnace and cast into slabs or other forms for shipment.

(iii).4.4.1.Emissions and effluents

Leaching and electrolysis do not emit significant amounts of particulates or gases. Some fumes and mists may be produced if the working tanks are not covered, and mist may be produced by the electrolyte process.

Liquid effluents contain zinc, lead and dissolved solids for which information on quantities is not available.

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I.(iv). CHEMICAL INDUSTRIES

I.(iv).1. Introduction

Potential waste and emissions from chemical industries are high, but, because of the nature of the compounds, are usually recovered as an economic necessity. In other cases, the manufacturing operation is run in a closed system allowing little or no escape.

In general, emissions that reach the atmosphere are primarily gaseous, and are controlled by incineration, adsorption or absorbtion. In some cases particulates may also be a problem. They are generally very small and require elaborate treatment for control. Emission data are sparse, furthermore, methods used for sampling and analysis are seldom reported, the confidence limits of the results not computed, and the reporting format varied, thereby making comparison of different sources of data difficult, if not impossible.

Similarly, the waste in liquid effluents is difficult to evaluate in absolute terms. Wastes, which are primarily dissolved and suspended solids, high BOD and COD, can present large problems in terms of environmental hazard. The formation and release of pollutants vary according to the raw material used, the manufacturing process applied, range of end products produced, pollution control equipment installed, and to a certain extent, the meteorological and topographical conditions where the plant is sited. Due to these factors, published data on emissions and effluents must be interpreted with care.

The chemicals industry, according to the United Nations Standard International Trade Classification, SITC, Revision 2, Series M, No. 34/REV.2, 1975, includes organic and inorganic chemicals; dyein tanning and colouring materials; medicinal and pharmaceutical produ essential oils and perfume materials, toilet, polishing and cleansing preparations; fertilizers; explosives and pyrotechnic products; artificial resins and plastic materials, cellulose esters and ethers; chemical products and materials, not elsewhere specified.

Considered here are major industrial inorganic and organic chemicals, plastics and synthetic resins; pigments and dyes, and, some examples of chemical substances which have aroused concern due to their toxic and hazardous characteristics. Because of the immense numbers and variations in processes, it is not possible to go into them in detail. Therefore emissions and effluents are listed for individual processes only.

An assessment of typical pollutants discharged and environmental problems caused by a given process can be made. This, however, usually applies to the 'major' common pollutants discharged in large quantities. For other trace discharges there is very little information. This is partly due to the difficulties in their detection as well as the scarcity of knowledge on their effects. In addition, the problem is greatly compounded by the absence of any substantial understanding of ecotoxicological interactions among multiple contaminants that may be present in a given media or prescribed ecosystem.

.(iv).2. Emissions and Wastes from Manufacture of Major Inorganic Chemicals

.(iv).2.1. General considerations

Major inorganic chemicals such as acids, alkalis, soda and chlorine, phosphate fertilizers, ammonium nitrate and others are produced in large quantities. Though manufacturing process efficiencies have increased and pollution control technologies have advanced, resulting in lower specific rates of discharge, the sheer increasing tonnage that is being produced, will mean significant absolute quantities released. Furthermore, on a local scale, the potential of a concentrated point source discharge, can aggravate environmental problems that surround a chemical plant.

The production efficiency - calculated as a percentage of basic raw material effectively used to obtain the final product, is generally within the range of 97 to 99 per cent, being especially high for inorganic intermediates. The remaining 1 to 3 per cent are emitted into the biosphere in the form of gases, dispersed liquids and particles.

Of these processes, phosphate fertilizers and sulphuric acid have undergone the most significant changes, particularly in marketing during the past several years. Because of the increased world population and resulting demand for more agricultural products, fertilizer consumption in the United States and other noncommunist countries should double between 1965 and 1980.

The advent of many sulphur dioxide recovery plants for making Contact sulphuric acid has changed competition in the marketplace considerably. Recovery plants are expected to continue to operate at full capacity, regardless of the market price of acid, to conform to air pollution control regulations. They therefore dispose of acid at any obtainable price and may well sell acid at a zero dollar price as an alternative to other means of disposal. Conventional sulphuric acid plants can therefore compete with recovery plants only when they are outside of the shipping radius of the recovery plant.

I.(iv).2.2. Sodium carbonate (Soda ash)

Soda ash is manufactured by 3 processes: a) Solvay process, b) natural or brine process, c) electrolytic soda ash process. The Solvay process is the most common method employed. Purified salt brine is contacted with ammonia, and then pumped to carbon dioxide contact towers to form sodium bicarbonate. Ammonia and carbon dioxide are removed and the remaining bicarbonate slurry is heated to produce soda ash. Carbon dioxide and ammonia are returned to the beginning of the process.

Liquid Effluents: Suspended solids, silica; brine; magnesium and calcium, and other impurities, salts from brine purification.

Airborne Emissions: Particulates from handling and transfer, especially from dryers, conveyors, loading and packaging systems, lime processing; ammonia from fugitive losses during unloading, and from wash tower. 0.45 to 1.5 Kg/tonne of product.

Solid Waste: Sludge, from brine purification; magnesium and calcium salts; silica; overburnt limestone; boiler slag; about 0.1 to 0.2 m^3 of sludge is produced/tonne of soda.

I.(iv).2.3. Sodium hydroxide (Caustic soda) and chlorine

Produced by the electrolysis of sodium chloride. Mercury and chlorine require environmental control. In the diaphragm cell process, the diaphragm (made of asbestos) separates the evolved hydrogen and chlorine. With the mercury cell process liquid mercury, as the cathode, forms an amalgam with the alkali metal, transports it to a separate cell and allows it to contact water to form the hydroxide. Chlor-alkali plants account for 20-50% of mercury used in industry.

Liquid Effluent: Suspended and dissolved solids; NaOH; NaCl; H_2SO_4; $CaCO_3$; $Ca(OCl)_2$; filter acids; mercury; carbon; chlorinated hydrocarbons. The main sources are brine purification, caustic recovery, condensates from chlorine and hydrogen compressary, chlorine drying (H_2SO_4), spills and cleansing procedures.

Airborne Emissions: Chlorine; asbestos; particulates; mercury. Mercury emissions arise from the hydrogen gas stream, end box ventilation, mercury retort, and cell room gas ventilation.

Solid Wastes: Muds; sludges; mercury; and process compounds. The main sources are brine regeneration and filtration, and soda purification.

I.(iv).2.4.Hydrochloric acid: Most hydrochloric acid is produced as a by product of organic chlorination processes. The remainder are equally divided between the salt process and direct synthesis of hydrogen and chlorine. Greatest emissions are from tail gases, but hydrogen chloride can be lost to the atmosphere from leaks, spills and during transferring operations.

Liquid Effluent: Little information, significant input from tailgas scrubbers.

Airborne Emissions: Hydrogen chloride (0 to 4.3 Kg/tonne product)

Solid Waste: No information.

I.(iv).2.5.Sulphuric acid

Sulphuric acid is mainly produced by the Contact process. Major problems are with gaseous emissions - particularly sulphur dioxide and acid mists. Liquid effluents are minimal.

Liquid Effluents: Minimal discharge, mostly recycled cooling water. Some suspended and dissolved solids; and acidity. 1500m^3 process water per tonne of acid produced is required.

Airborne Emissions: Sulphur dioxide (dependent on sulphur conversion efficiency) up to 48 Kg/tonne of acid; exhaust gases; acid mists (as SO_3), more stable in oleum plants. The main sources are the elemental sulphur burning and Contact process.

Solid Wastes: Little residue unless sulphide ores are used to manufacture SO_2.

I.(iv).2.6.Nitric acid

Produced mainly by the ammonia oxidation method, and consumed largely by the fertilizer industry. Emissions are primarily airborne.

Airborne Emissions: Nitrogen; nitrous oxides, 500-3000 ppm, nitric oxide and nitrogen dioxide are the most significant and can cause local air pollution problems; and acid mists. The primary source is the tail gas discharge.

Liquid Effluent: Some suspended solids; dissolved solids; sulphuric acid from cooling tower; and chlorine from water treatment.

Solid Wastes: Sludges from boiler feed.

I.(iv).2.7. Phosphoric acid

The acid is manufactured by the wet and electric furnace processes. In the wet process raw phosphate is usually treated with sulphuric acid, the electrothermal method heats phosphorus and air and allows the products to hydrate to phosphoric acid. Significant wastes are calcium sulphate or phosphogypsum as solids/particulates, fluorine and its compounds, and 'phossy water'.

Liquid Effluent: Suspended solids, especially gypsum (4 to 5 tonnes/tonne acid product); phosphorus ; fluorides, from scrubbers; typical 'phossy water' composition, phosphorus 1000-2000 mg/l, phosphate 50-500 mg/l, fluoride 100-1000 mg/l, suspended solids 2000-4000 mg/l.

Airborne Emissions: Fluorides, mainly from the reaction system 0.1 to 0.5 Kg/tonne acid product; particulates, silicon tetrafluorides; phosphoric acid mist mainly from electrothermal processing; occasional hydrogen sulphide from electrothermal acid treater tank; some nitrogen oxides.

Solid Waste: Sludge, SiO_2 40 to 60%, CaO 5 to 15%, Fe_2O_3 2 to 4%, Al_2O_3 1 to 3%, P_2O_5 2 to 5%.

I.(iv).2.8. Ammonia

Ammonia is a fundamental inorganic intermediate with a very broad spectrum for application. About 80% of ammonia is used for fertilizer manufacture. The production of ammonia is primarily accomplished by the catalytic reaction of hydrogen and nitrogen at high temperatures and pressures.

Liquid Effluent: Ammonia (20 to 100 mg/l); Carbon dioxide (150 to 750 mg/l); Monoethanolamine (50 to 100 mg/l); BOD (50 to 100 mg/l); COD (60 to 200 mg/l); Oil (100 to 10,000 mg/l). The waste water quantity can vary from 0.4 to 4 m^3/tonne of ammonia produced. The main sources are process condensates; and wash solutions. Other effluents are produced from the boiler blow down and cooling water.

Airborne Emissions: Ammonia; nitrogen; hydrogen; methane; carbon monoxide. Scrubbing, incineration and recovery usually remove up to 99% of these emissions. The main sources of ammonia are the loading and storage operations.

I.(iv).2.9. Titanium dioxide

Titanium dioxide occupies a preeminent position amongst inorganic pigments. Its manufacture involves a complex and sophisticated technology. The sulphate process basically revolves around the reduction of ilmenite by sulphuric acid and iron shavings. The chloride process subjects natural or high grade stock to chlorination in the presence of reducing agents. The titanium tetrachloride is converted to dioxide in a fluidized bed or hot flame as a gaseous phase. The sulphate process gives rise to serious environmental problems - mainly as liquid waste or sludge (Red Mud).

Liquid Effluent: From the sulphate process, suspended solids, siliceous sludge; ferrous sulphate; strong and weak acids, (8 tonnes of strong acid and 1.5 tonnes weak acid/tonne titanium dioxide produced); magnesium and aluminium sulphate; titanium dioxide. The chloride process discharges a small quantity (about 20-40 Kg/tonne of product) of waste coke, metal salts, and hydrochloric acid. Most of the acid is recycled.

Airborne Emissions: From the sulphate process, sulphur dioxide; sulphur trioxide; and sulphuric acid mist; particulates, a major emission of crushed/dried process materials - especially from the calcining, grinding, digesting and handling operations; odour. From the chloride process, emissions can be carbon dioxide, carbon monoxide, hydrogen chloride; chlorine; sulphur compound; and possible nitrogen oxides, all emitted by the chlorinator off-gas; titanium tetrachloride, an intermittent pollutant from vents, valves, rupture discs etc. forms white hydrolysis products on contact with water vapour, presenting opacity problems.

Solid Waste: Siliceous sludge; slurry; iron salts. Most is released within the liquid effluents, or neutralised with crushed limestone and ammonia, and dumped at sea.

I.(iv).2.10. Sodium dichromate

Chromite ore and anhydrous sodium carbonate are roasted and the products dispersed in water. The sodium chromate solution is acidified, usually with sulphuric acid to produce sodium dichromate. This is concentrated and crystallized out of solution.

Liquid Effluents: Sodium chloride; sodium sulphate; suspended solids; chromate ions; ferric and magnesium salts. The main sources are spills, washings, cooling water and boiler blowdowns amounting to about 2 Kg/tonne product.

Airborne Emissions: No information.

Solid Waste: Slurry; metal oxides; calcium oxide; aluminium hydroxide; magnesium oxide; ferric oxide; chromates.

I.(iv).3. Emissions and Wastes from Manufacture of Major Organic Chemicals

I.(iv).3.1. General considerations

The industrial organic chemicals industry is closely related to other elements of the petrochemical industry in general. It does not lend itself to separation into various segments, but the proce descriptions can be grouped according to feedstock. This results in ten groups of processes or sections being defined: benzene, butylene, cresol, ethylene, methane, naphthalene, paraffin, propylene, toluene and xylene. The principal feedstock to the industrial organic chemicals industry is hydrocarbon products, such as olefins, paraffins and aromatics, from the basic petrochemical industry.

To synthesise organic chemicals, inorganic chemical raw materials such as nitric acid, sodium hydroxide, ammonia and chlorine are usually necessary. Thus there are close relationships between basic petrochemicals, industrial organic, industrial inorganic and downstream processing industries. Hence, information relating to physical size, production etc. of industrial organic chemical manufacturing facilities is not available, because these operations are generally completely integrated with facilities classified in other chemical sectors.

Trade statistics for chemicals are scarce, because the data generally do not deal with a single product but rather a group of products and their derivatives.

Liquid wastes present the greatest problems in the organic chemical industry. The sources of liquid waste streams can be divided into five general categories:

- waste containing a principal raw material or product resulting from the stripping of the product from solution,
- by-products produced during reactions,
- cooling tower and boiler blowdown, steam condensate, water treatment waste and general wash water,
- spills, washdowns, vessel cleanouts, sample overflows, etc.,
- rain, storm, water.

The principal contaminants in the effluents include organics from residual products and by-products, oils from the bottom of distillation and stripping columns, suspended solids, and catalysts.

With regard to air emissions, hydrocarbons are major constituents being emitted to the atmosphere in a number of ways. Vent gases from various process operations may contain hydrocarbons, and large quantities may sometimes be vented as a result of upset conditions or the passage of gases through safety valves or relief vents. Leaks in vessels, pump seals, and pipe walls are also a source of fugitive hydrocarbon emissions. Another source of significant hydrocarbon emissions can be reaction or process air required for a number of industrial organic chemical manufacturing processes.

The major solid waste from organic chemical processing is usually associated with bottoms from process tanks, from distillation and stripping columns and in wastes from the cleaning of storage tanks. This material is usually in the form of sludge which contains unreacted raw chemicals or products and spent catalyst.

I.(iv).3.2.Ethylene dichloride

There are two commercial processes for making ethylene dichloride from ethylene: the oxychlorination process and the direct addition process.

The direct chlorination of ethylene may be carried out in the liquid phase in the presence of ferric chloride catalyst. Approximately equimolar proportions of acetylene-free ethylene and chlorine are fed to a tower-type reactor through distributors. The reaction is fast, complete and exothermic. The gas stream from the reactor is passed through a caustic scrubber, where the unreacted gases and traces of HCl are removed. The uncondensed gases (primarily unreacted ethylene and chlorine) are then totally recycled to the reactor. The liquid stream from the reactor is sent to a distillation column to remove heavy ends and then to a wash tower, where a caustic solution is used to remove some impurities. The crude product is sent to a distillation column for purification and 99 per cent pure liquid ethylene dichloride is taken from the top of the fractionation column.

Liquid Effluents

Approximate quantities of water effluents from HCl absorber (scrubber) are:

Chlorine	0.9 kg/tonne	ethylene	dichloride
Ethylene dichloride	2.5 kg/tonne	"	"
HCl	3.8 kg/tonne	"	"
Vinyl chloride (VCM)	0.6 kg/tonne	"	"
Methyl chloride	0.05 kg/tonne	"	"
Ethyl chloride	0.05 kg/tonne	"	"

Purification section:

	caustic storage	filter effluen
Ethylene dichloride	0.15 kg/tonne	0.3 kg/tonne

	caustic storage	filter effluen
Sodium hydroxide	0.6 kg/tonne	trace
Sodium chloride	0.2 kg/tonne	

Airborne Emissions: Emission is primarily from the vent on the reflux condenser and the exit gas stream or the solvent scrubber. Ethane; ethylene; methane; chlorine; HCl;carbon monoxide; ethylene dichloride; ethyl dichloride; aromatic solvent; of the order of 3.0 kg, 7.5 kg, 3.0 kg, 0.5 kg, 0.5 kg, 0.5 kg, 7.0 kg, 6.0 kg, 1.0 kg, respectively per tonne of ethylene dichloride are produced.

Solid Waste: The distillation column bottoms of the purification section can also discharge: ethylene dichloride, 1,1,2-trichloroethane, tetrachloroethane and tar (traces) at the rate of 1.5 kg, 2.45 kg, 2.45 kg respectively per tonne of product.

I.(iv).3.3.Urea

There are basically three urea production processes which differ primarily in the way the unreacted ammonia and carbon dioxide are handled.

a) once-through process, in which no attempt is made to recycle these gases to the urea process. The off-gases containing ammonia and carbon dioxide are used in the production of fertilizer products.

b) partial recycle process, excess ammonia is recycled back to the process while any excess carbon dioxide is vented to the atmosphere or used in another process.

c) total recycle process, both the ammonia and carbon dioxide in the offgas are recycled back to the urea process.

The carbon dioxide-ammonia reaction to form urea, ammonium carbamate and water takes place in a reactor vessel at pressures ranging from 130 to 340 atmospheres and at temperatures from 120° C to 190°C. Unreacted ammonia and carbon dioxide are present in the reactor exit stream. The dehydration reaction proceeds to 40-70% completion. The ammonia, carbon dioxide and ammonium carbamate are removed and the resulting solution will be about 70 to 80 per cent urea. Depending upon product specification this solution can be used as it is or it can be further concentrated to a solid product. This solid product can be formed by prilling, crystallization or a combination of both.

Liquid Effluent: Ammonia; carbon dioxide; ammonium carbonate. These waste liquids arise from the process of urea solution concentration. In some processes leaking pump seals contribute 1 to 2 kg/m^3 and 50 kg/m^3 of urea and ammonia respectively to a 1000 ton/day plant vacuum system liquid condensate effluent.

Airborne Emissions: Ammonia from urea solidification, ammonium carbonate from the synthesis reactor; particulates, urea from the prilling tower.

Solid Wastes: No information.

I.(iv).3.4. Methanol

Methanol is synthesised from CO and H_2 at pressures of 200 to 300 atmospheres and temperatures of 350°C to 400°C. A catalyst of chromium oxide/zinc oxide is used and close control of operating parameters to suppress side reactions is of utmost importance. The mixture of gases from the converter pass through a condenser and then through a separator. The crude methanol condensate is subsequently purified in a two step distillation. By-products are mixed alcohols and dimethyl ether.

Methanol plant equipment must be resistant to carbon monoxide at high temperatures and pressures.

Copper based catalysts have been known to increase the rate of the reaction for the formation of methanol from synthesis gas, but are readily inactivated by sulphur impurities present in synthesis gas, and copper zinc catalyst has led to a new low-pressure process for the manufacture of methanol from synthesis gas. The new low pressure process developed by Imperial Chemical Industries of U.K. operates at pressures nearby half of those utilized in usual processes.

Liquid Effluents: Oils; methanols; high boiling point organics; these amount to 0.4 - 2.0 m^3/kg product and result from slab and vessel washdowns together with bottoms from the methanol purification process. Other pollutants are:

COD - 320 to 4930 mg/l
BOD - 120 to 2620 mg/l
TOC - 107 to 583 mg/l

Airborne Emissions: No information.

Solid Waste: No information.

I.(iv).3.5.Formaldehyde

Formaldehyde is produced from methanol by either vapour phase catalytic oxidation or by a combination oxidation-dehydrogenation process. The catalytic oxidation involves the reaction of methanol vapours and air over a stationary catalyst. Because methanol and air form explosive mixtures in the range of 6 to 37% at 60°C, the commercial processes operate either at methanol concentrations of nearly 50% or 5 to 10%. Using silver catalyst, dehydrogenation and oxidation of methanol may occur simultaneously.

Clean air is heated to 450 - 700°C and mixed with methanol vapours in a controlled ratio (1:1). Gases from reactors are quenched and the excess methanol in the resulting methanol-formaldehyde solution is removed by fractionation.

In the direct oxidation of methanol to formaldehyde in the presence of ironmolybdenum oxide catalyst, a low 5 to 10 per cent methanol concentration stream in air is used. The product is essentially free of methanol.

Liquid Effluents: The major effluent sources are the scrubber waters and the dimethyl ether by-product.

Airborne Emissions: Carbon monoxide, 63g/Kg of 37% formaldehyde, hydrogen, 7.6g/kg of 37% formaldehyde; methane, 1.3g/kg of 37% formaldehyde; and traces of methanol and formaldehyde. The source is mainly the scrubber exit gas stream.

Solid Waste: No information.

I.(iv).3.6. Styrene

The commercial process for styrene production involves the catalytic dehydrogenation of ethylbenzene at 600 to 700°C in the presence of catalysts e.g. SiO_2 - Al_20_3, solid phosphoric acid, zinc oxide promoted with alumina and chromates, and cobalt oxides.

The styrene recovery section consists of three columns. The small amount of benzene and toluene produced by cracking is removed in the first column and returned to the ethylbenzene system. Ethylbenzene is separated from styrene in the second column and recycled, polymerization inhibitors such as sulphur, paratertiary butylcatechol or 2-nitro-4,6-dichlorophenol are added. In the third column, styrene monomer is separated from small amounts of tar and polymer formed during the operation.

Liquid Effluents: COD, 2.34 to 5.13 g/kg of product; BOD, 0.38 to 1.62 g/kg: TOC, 0.12 to 0.53 g/kg of product. These emanate from the separater.

Airborne Emissions: No information.

Solid Waste: Tars, 5.9 kg/tonne from superheater, and 7.1 kg/tonne from the still bottoms. The tarry matters contain styrenetrimer, stilbene, biphenylnaphthalene, phenanthrene, ethylphenanthrene and other unidentifiable products.

I.(iv).3.7. Ethylbenzene

The majority of ethylbenzene is produced synthetically and only a minor quantity is recovered by careful fractionation of selected gasoline fractions or of the C_8 cut of aromatic naphtha.

The synthetic processes used are liquid phase, which is carried out in a lined reactor operating at the boiling point of the mixture (80 to 100°C). Aluminium chloride forms the complex in the reactor. Benzene, both feed and recycle, enters the process through a benzene drying column, and hydrogen chloride in the form of HCl or ethylene chloride is also added. The liquid products are cooled and the complex is returned to the alkylator. The alkylate is washed with water, removing any residual complex, and scrubbed with 20 per cent caustic soda for neutralisation, after which the components are separated in distillation columns.

The vapour phase process can operate on refinery gas streams containing 8 to 10 per cent ethylene. The temperature is typically 290 to 310°C. Fresh benzene is mixed with recycled benzene and ethylene, heated, and introduced into the fixed bed alkylator. The high pressure effluent is flashed and fed into the benzene recycle column where the benzene is recovered as an overhead product. The bottoms become the feed to the following column where the product ethylbenzene is separated from the (polyalkyl) benzenes. These are recycled to a separate dealkylator along with the necessary benzene for conversion back to ethylbenzene. The dealkylator effluent is then combined with the alkylator effluent for flashing. The improved catalyst for the alkylation is apparently a boron trifluoride-modified anhydrous γ -alumina, BF_3 being added also in the alkylator feed. The dealkylator uses the identical catalyst and operates under less severe conditions, 200°C and 35 atmospheres.

Liquid Effluent: With the liquid phase process the main wastes are benzene; hydrogen chloride; and tarry materials; of about 11 kg/mg, 3.2 kg/mg and 26.6 kg/mg respectively. The main source is scrubber effluent. Traces of aluminium salts may also be present. With the vapour process the main effluents consist of tars, benzene, ethylbenzene, and other polymers. COD 1.889 g/kg of product; BOD 0.149 g/kg of product; TOC 0.66 g/kg of product.

The major waste streams with the vapour process are the spent caustic and washing streams from the crude alkylate washing step.

I.(iv).3.8. Vinyl chloride

Vinyl chloride monomer (VCM) can be produced commercially as a liquid using one of two manufacturing processes:

a) pyrolysis of ethylene dichloride
b) vapour phase reaction of acetylene and hydrogen chloride.

The latter process is outdated and the majority of vinyl chloride is manufactured by the thermal dehydrochlorination of the ethylene dichloride.

If low pressure cracking is used, the VCM and ethylene dichloride are generally removed from the quench vapour stream by condensatio or absorption before the remaining HCl is compressed and fed to an oxychlorinating unit. If high pressure cracking is used, the quench vapour stream is fed directly to the distillation unit whic consists of two columns: the anhydrous HCl recovery column and the VCM recovery column. In the former, anhydrous HCl is recovered overhead by distillation with refrigerated reflux. The HCl is purified to remove acetylene and vinyl chloride which would yield higher chlorinated by-products in the oxychlorination unit. In the VCM recovery column, ethylene dichloride and other high boiling impurities are separated by fractionation to produce high purity VCM. The ethylene dichloride and higher boiling impurities, as well as the ethylene dichloride and heavy bottoms from the quench column are reprocessed in the ethylene dichloride purification unit. Purified ethylene dichloride is recycled to the cracking furnace and the heavy bottoms (higher chlorinated organics) are sent to waste disposal.

Liquid Effluents: Little information, but there are some higher chlorinated organics; suspended solids, vinylchloride/ polyvinylchloride.

Airborne Emission: VCM; particulates, PVC; PBC; waste gases.

A typical polyvinyl chloride plant has 12 sources of vinyl chloride monomer and particulate polyvinyl chloride emissions and these are:

i) Reactor safety relief valves: Atmospheric emissions from venting of the polymerizer consist of VCM, PBC or some combination thereof, depending upon the stage of VCM conversion. Emissions from this source range between 0.6 g/kg and 2.2 g/kg.

ii) Reactor Energy Purge: Emissions range from 0.8 to 5.0 g/kg.

iii) Stripper jets: Emissions are intermittent after polymerization, unreacted VCM is removed by venting the reactor to a recovery system. Stripping operations are important control of emissions from the slurry blend tank, the centrifuge, the dryer and the bulk storage silos is dependent upon effective removal of residual vinyl chloride trapped in the PVC granule. Atmospheric emissions consist of inerts and vinyl chloride. The emissions range between 0.5 g/kg and 12.3 g/kg.

iv) Monomer Recovery Condenser Vent: This is an intermittent emission source. Inert gas, water vapour, and VCM are discharged to the atmosphere. The emissions from this source range between 3.1 g/kg and 15.0 g/kg.

v) Slurry Blend Tank Vents: These are a continuous source of emissions resulting from the continuous purging of the vapour space in the atmospheric pressure slurry blend tanks with fresh air. In the slurry tank, vinyl chloride is released from the PVC granules where it was trapped. The emission rate for this source ranges from 2.5 g/kg to 5.7 g/kg.

vi) Centrifuge Vent: Emissions are continuous. The centrifuge separates the slurry into wet solids containing 75% to 77% PVC in water. Some of the vinyl chloride trapped within the PVC granules is released. The atmospheric emissions from the centrifuge vent consist of water vapour, air, VCM and PVC resin. The rate of emission varies between 0.04 g/kg and 1.3 g/kg.

vii) Dryer discharges are a continuous emission source. The wet polymer contains about 20% to 25% moisture and is dried using warm air. Atmospheric emissions from the dryer exhaust consist of air, water vapour, vinyl chloride and polyvinyl chloride. Emissions from this source range between 2.0 g/kg and 25.6 g/kg.

viii) Storage silos are a continuous source of emissions. The polymer stored in the silos is frequently mixed by passing dry air through the silos. This prevents moisture condensation and the build up of explosive concentrations of VCM. Atmospheric emissions consist of air, VCM and PVC. The rate of emission varies between 0.2 g/kg and 1.7 g/kg.

ix) Bulk Loading: A continuous discharge. Air and particulate PVC emitted during loading operations. The emission rate is estimated to be 0.4 g/kg.

x) The bagger vent is a continuous source of particulate emissions. This stream, containing PVC and air, is ducted to a baghouse for recovery of the solid product. The emission rate for this source is estimated to be 0.2 g/kg.

xi) Storage tank emissions have been estimated to be 0.6 g/kg.

xii) Fugitive emissions occur from pressure relief valves, pumps, compressors, agitator seals, loading and unloading of monomer, valve stems, flanges, unrepaired purging equipment and samples for laboratory analysis. There may be as many as 600 points of fugitive emissions at a typical PVC plant. The vinyl chloride emission rate from this source ranges from 6.2 g/kg to 17.5 g/kg.

Solid Waste: Little information, but some slurry containing VCM and PVC is produced.

Health_aspects: Epidemiological studies have revealed that vinyl chloride is a casual agent in the formation of angiosarcoma. Vinyl chloride has also been implicated regarding other diseases such as skin lesions, circulatory disorders, gastritis and acroosteolysis, a degenerative disease of the finger bones.

I.(iv).3.9.Ethylene oxide

Ethylene oxide is manufactured by direct vapour phase oxidation of ethylene over silver oxide catalyst. Most of the processes use air as the oxidant and some use oxygen.

A mixture of ethylene, air and recycle gas (3 to 5 percent volume ethylene) is pressured (9 to 22 atmospheres) and sent to a tubular reactor with a fixed bed of silver catalyst. The cooled gas is sent to a scrubbing tower in which the ethylene oxide is scrubbed with water. The gas that is not absorbed is primarily reacted ethylene and oxygen. The effluent is sent to a scrubbing tower where the ethylene oxide is absorbed. The noncondensable gases are purged. The dilute, aqueous ethylene oxide is sent to a stripper (desorber) where ethylene oxide is removed by heating. The crude ethylene oxide is then fractionated on distillation columns. The water from the stripper can be returned to the scrubbing towers, or in some cases it is sent to an ethylene glycol plant because this water contains about 2 percent ethylene glycol.

Liquid Effluents: COD, 4,800 mg/l to 52,000 mg/l; BOD 650 mg/l to 4,800 mg/l; TOC 3,000 mg/l to 19,600 mg/l. The main source is the ethylene oxide separation bottoms.

Airborne Emissions: Ethylene oxide (1 kg/tonne of product); ethylene (92 kg/tonne of product), small amounts: ethane (6 kg/tonne product). The main source is purge vent gases.

Solid Waste: No information.

I.(iv).3.10.Ethylene glycol

Ethylene glycols are primarily produced by the direct catalytic oxidation of ethylene to ethylene oxide followed by hydration. Ethylene oxide can be converted to glycol by catalytic or non catalytic hydration. The catalytic process uses a large excess of dilute aqueous acid, usually sulphuric acid and the non catalytic process uses a large excess of water. The reaction is carried out at 180° C and 21.5 atmospheres, and 95° C and 15 to 20 atmospheres for the catalytic and non catalytic processes respectively. Di- and triethylene glycols are reaction by-products which normally account for about 9 percent and 1 percent respectively of the total product. However, yields of these other glycols may be increased by higher temperature and slightly lower pressure in the reaction conditions. Small quantitiies of polyethylene glycols are also formed under normal reaction conditions, but their yields may be increased by using NaOH catalyst. Following reaction, the glycols are separated and purified by dehydration of the reaction effluent and vacuum distillation.

Liquid Effluents: Ethylene glycol; ethylene oxide; acetaldehyde; crotonaldehyde; sulphuric acid. The dehydration effluent stream has the following characteristics, COD 8.7 kg/tonne of product, BOD 0.38 kg/tonne of product, TOC 4.5 kg/tonne of product.

Airborne Emissions: No information

Solid Wastes: No information

I.(iv).3.11. Cumene

Cumene is produced by the alkylation of benzene in the vapour phase with propylene in the presence of a phosphoric acid catalyst. An excess of benzene is maintained to suppress dialkylation, oligomerization and other side reactions. The operating temperatures are of the order of 250° C and 7.0 atmospheres and catalyst consumption is in the range of one kilogram for 1.67 m^3 of cumene.

Liquid Effluent: The recovery of cumene from the process stream is the principal source of waste water effluents. The stream contains about 1 to 4 percent of the product stream and the quantity of water carrying the wastes depends largely upon the use of propane to control bed temperature.

Airborne Emissions: No information

I.(iv).3.12. Acetic acid

The most economical method for manufacture of acetic acid is the liquid phase oxidation of natural gas or light petroleum fraction. This contains 95 percent n-butane, and the process is carried out at 150 to 225° C and about 55 atmospheres, in the presence of a transition metal acetate, usually cobalt acetate. Compressed air and liquid butane are fed to a liquid phase reactor. The reaction product is sent for phase separation, the aqueous phase is recovered and purified and off-gases, primarily nitrogen, oxides of carbon and n-butane, are scrubbed for butane recovery and vented through an expander turbine to recover energy. Conventional distillation separates low boiling organics from the crude acetic acid. Recovered products are methanol, acetone, n-propyl alcohol and methyl ethyl ketone and also formic, propionic and butyric acids and their esters, (methyl and ethyl). Azeotropic distillation is used to purify the crude acetic acid to glacial acetic acid.

Acetic acid can also be produced when methanol is carbonylated with carbon monoxide in the presence of a catalyst.

Another process for producing acetic acid and acetic anhydride is the catalytic oxidation of acetaldehyde.

Liquid Effluent: Acetic acid; alcohols; aldehydes; ketones; esters; other organic acids; ethers and high boiling impurities. The main source is the purification section. With the methane carbonylation process about 40 kg of organics (50 percent propionic acid and 50 percent higher organics) are formed per tonne of acetic acid produced. With catalytic oxidation of aldehyde, the waste water stream contains organics of about 15000 mg/l and COD and BOD_5 which ranges widely between 186 to 305,000 mg/l and 84 and 64,000 mg/l respectively.

Airborne Emissions: Butane; propane; ethane; other hydrocarbons: With the carbonylation of methanol process, the offgas scrubber vent is the main source of air emissions. Hydrogen,carbon monoxide, methane, methanol and light ends are emitted in the order of 5.5 kg, 204 kg, 12.5 kg, 15 kg and 2.2 kg per tonne of acetic acid. The catalytic oxidation of acetaldehyde process emits offgas from the scrubber vent. This consists of methane and carbon monoxide of the order of 1.8 kg and 3.3 g per kilogram of acetic acid as well as some higher acids.

Solid Waste: No information

I.(iv).3.13. Xylene

Xylene is primarily produced by the catalytic reforming or hydroforming of certain petroleum fractions.

By superfractionation, ethyl benzene can be separated from the xylenes and o-xylene from the other xylenes by fractional distillation. The difference in melting points allows for practical separation of isomers. The dried feedstock, containing about 10 ppm H_2O is cooled to - 40° C and passed to a crystallizer at - 62° C to - 66° C. Crystals of xylene formed are centrifuged, partially melted and recrystallized at - 31° C. The mother liquor, rich in m-xylene, can be recycled or isomerized to yield more xylene. Catalyst such as platinum on a silica-alumina support is used in the isomerization process, which takes place in the vapour phase in the presence of hydrogen at temperatures around 450° C and pressures in the 10 to 25 atmospheres range. The product of isomerization is recycled to the crystallization unit.

Xylene can also be produced by the disproportionation of toluene.

Liquid effluent: Suspended solids, sludge containing 3,000-5,000 mg/l of organic material. The primary source is the crystallization stage.

Airborne Emissions: Organic vapours, mainly from the offgas vent.

Solid Waste: No information

I.(iv).3.14. Phenol

Synthetic phenol is primarily produced by the cumene peroxidation process, where cumene hydroperoxide decomposes under the influence of sulphuric acid to acetone and phenol.

After the reaction, the mixture is phase separated to yield an oil layer containing cumene, phenol, acetone, α-methylstyrene (1.5 percent), acetophenone (0.8 percent) and tars. These components are separated by distillation or by a combination of distillation and extraction.

Phenol can also be produced by reacting chlorobenzene with sodium hydroxide at elevated temperature (about 400° C) and pressure (250 to 350 atmospheres). Chlorobenzene and a 10 to 15 percent aqueous sodium hydroxide solution are introduced into a high pressure pump with approximately 10 percent by weight of diphenyl oxide. Small quantities of anti-corrosion agents, emulsifiers and a catalyst may also be added to the reactants. This process stream is fed to a continuous flow tubular reactor system. The reaction products, consisting of sodium phenate, sodium chloride, water and unexchanged reactants produce a two phase system. The first phase is an aqueous phase containing sodium phenate and the second phase is an oil phase consisting primarily of diphenyl oxidate and unreacted monochlorobenzene. The oil phase is distilled to produce diphenyl oxide or is recycled to the reactor. The aqueous phase is treated with hydrochloric acid to convert sodium phenate to phenol which is decanted and distilled under vacuum. The sodium chloride that is formed is electrolized to form sodium hydroxide and chlorine which is recycled.

The oxidation of benzoic acid will also produce phenol. The benzoic acid is melted in biphenyl, mixed with a small amount of manganese promoted cupric benzoate and fed to an oxidizer. A mixture of air and steam is sparged into the reactor where the benzoic acid is oxidized to phenol. Purification is accomplished by distillation. Phenol and water are removed overhead and benzoic acid taken from the column bottom and returned to the reactor. The phenol and water may be separated by azeotropic distillation and the bottoms may be extracted first, to recover organics for recycling.

Liquid Effluent: With the cumene peroxidation process - phenol (0.1 kg/tonne phenol); cumene; acetone (0.5 kg/tonne phenol) produced from the crude phenol surge vessel. Mesityl oxide (about 20 kg/tonne phenol); various contaminants from the mesityl oxide column. With the chlorobenzene process - chlorobenzene; dichlorobenzene; other chlorinated compounds; from the dichlorobenzene column, and phenol (≃ 0.75 Kg/tonne phenol) sodium chloride (≃ 1.6 kg/tonne phenol) and benzene (≃ 12 kg/tonne phenol) from the extractor brine. The oxidation of benzoic acid produces toluene; (≃ 0.001 kg/tonne phenol) from the separator; acetone (≃ 0.002 kg/tonne phenol) from the centrifuged separator.

Airborne Emissions: Cumene peroxidation process - hydrogen (≃ 15 g/tonne phenol); carbon monoxide (≃ 20 g/tonne phenol) both from the hydrogenation column vent; methylstyrene; carbon monoxide (≃ 0.2 kg/tonne phenol); phenol (1.5 kg/ tonne phenol) all from the catalytic column vents. The steam column vent also produces some contamination.

Solid Waste: With the chlorobenzene process the solid residues sources are the ortho-dichlorobenzene column, consisting of ortho-dichlorobenzene and other chlorinated compounds of the order of about 0.6 kg and 12 kg respectively per tonne of phenol; the diphenyl ether column, consisting of diphenyl ether (≃ 0.7 kg/tonne phenol) and phenyl diphenyl ether (≃ 19 kg/tonne phenol).

The oxidation of benzoic acid produces solid residues of tars (≃0.10 kg/tonne phenol); phenyl benzoate (≃ 0.002 kg/ tonne phenol); copper benzoate (≃0.002 kg/tonne phenol) and manganese benzoate (≃0.005 kg (tonne phenol).

I.(iv)3.15. Cyclohexane

Cyclohexane (35 percent) is produced from benzene by a liquid phase hydrogenation process. The reaction occurs at about 220° C and 35 atmospheres using a platinum or nickel catalyst. Generally, the recycled cyclohexane and hydrogen pass through the beds in series, while the benzene passes through in parallel. This reduces the quantity of recycled cylcohexane and excess hydrogen required.

The recycled cyclohexane absorbs the heat of hydrogenation, thus avoiding the high bed temperatures and possible isomerization.

Liquid Effluent: The major source of waste water are the spent caustic wash ($\simeq 2 \times 10^{-6}$ m^3/kg) and the cooling water which amounts to about (70 to 1700 g/m^3 of cyclohexane and which may contain 50 to 200 mg/l COD. In the aromatics extraction, there are two major sources of waste water: the extract water washing, containing aromatic hydrocarbons and wastes from solvent regeneration, containing the appropriate solvents.

Airborne Emissions: Benzene; hydrogen; sulphur; carbon monoxide. Purge gas from the hydrogenation reactor is the main source of air emissions.

Solid Waste: No information

I.(iv).3.16. Acetone

Acetone can be produced from the cumene peroxidation process. The oxidation of n-butane from acrolein, and from oxidation or catalytic dehydrogenation of isopropanol.

A significant amount of acetone is produced by the catalytic oxidation of the isopropanol. In this process, isopropanol is mixed with air and fed to a reactor maintained at about 500° C and 4 atmospheres over copper or silver catalysts.

Hydrogen peroxide is formed as a by-product if this process is run in the liquid phase.

In the dehydrogenation process, isopropanol is fed to a packed tubular reactor. The reaction taking place at about 350° C in the presence of a brass or zinc oxide catalyst. The hot reactor effluent contains acetone, unreacted isopropanol, hydrogen and minor amounts of by-products, such as propylene and diisopropyl ether. The mixture is cooled and the noncondensable gases are scrubbed with water. As the resultant gas stream is mainly hydrogen, a part of it can be recycled to control catalyst fouling. The liquids are fractionally distilled, removing the reconcentrated acetone overhead and the mixture of isopropanol and water as bottoms. In a second fractionating column, the aqueous isopropyl alcohol is concentrated for recycle to the reactor. The water removed may be rejected or reused in the gas scrubber.

Liquid Effluent: The catalytic oxidation process and hydrogenation process - acetone; isopropanol; heavy organics; COD (1.1 kg/tonne of product); BOD (3.3 kg/tonne of product) TOC (0.35 kg/tonne of product). The isopropanol stripping still and intermediate flush column and the main sources of effluent.

Airborne Emissions: The catalytic oxidation and the hydrogenation process - acetone; isopropanol waters. The main source being the absorber vent.

Solid Waste: No information

I.(iv).3.17. Acetic anhydride

Acetic anhydride (as well as acetic acid) can be produced by the catalytic oxidation of acetaldehyde and also from the reaction of ketene and acetic acid.

Ketene is first prepared by the catalytic cracking of acetic acid of 700° C to 750° C and 0.25 atmospheres. Triethyl phosphate is usually the catalyst.

Ammonia gas is injected into the gases leaving the converter to prevent reversion. The reaction product passes from the pyrolysis tube to a cooling-separation system where the water from unreacted acetic acid is removed. The ketene is then reacted with acetic acid in absorption towers at 30 to 40° C to produce acetic anhydride.

Liquid Effluent: Sodium hydroxide; sodium acetate; both from the gas scrubber system.

Airborne Emissions: Methane; ethylene; ketene; all from the gas scrubber system vent.

Solid Waste: Heavy organics, from the acetic anhydride and acetic acid columns, usually incinerated.

I.(iv).3.18. Adipic acid

This is produced from cyclohexane in a two stage process. The first stage involves the air oxidation of cyclohexane to an alcohol-ketone mixture, at 125 to 160° C and 4 atmospheres. Cobalt naphthenate or a cobalt stearate is used as the catalyst. The second stage oxidizes the alcohol-ketone mixture at 50 to 150° C and 3 to 17 atmospheres to adipic acid using 40 to 50 percent nitric acid. The catalyst is ammonium metavanadate and copper. The liquid product is air stripped to remove nitrous oxides and steam distilled to remove nitric acid and low boiling organics as overhead. The still bottoms are cooled to 40 to 50° C and the adipic acid crystallized and dried.

Liquid Effluents: Metallic catalyst residues; by product organics.

Airborne Emissions: Nitrous oxide; nitrogen dioxides; both from the oxidizer. Particulates, from the product drying vent.

Solid Waste: No information

I.(iv).3.19. Vinyl acetate

This product can be produced by the vapour phase reaction of ethylene or from acetylene. The former process involves a vapour phase oxyacetylation of ethylene, acetic acid and oxygen at 175 to 200° C and 5 to 10 atmospheres, over a palladium catalyst. The reaction mixture is separated into a liquid and gas phase. Vinyl acetate and CO_2 are removed in the scrubbers and recycled. The distillation train removes light ends, mainly acetaldehyde, water and polymers from the purified vinyl acetate. Acetic acid is recycled to the reactor.

In the acetylene process, the acetylene is specially purified to remove H_2S and phosphorus compounds. It is then mixed with gaseous acetic acid and fed into a fixed bed reactor with zinc acetate on carbon as a catalyst. Reactor temperature is maintained in the range of 175 to 2,000° C. The reactor effluent is condensed, light ends removed, and vinyl acetate distilled.

Liquid Waste: Ethylene vapour phase process - little information, possibly heavy organics; polymers; mixed aldehydes; acetic and vinyl acetate; acetaldehyde. The acetylene process - some acetic acid.

Airborne Emission: Ethylene vapour phase process - ethylene; vinyl acetate; acetaldehyde; other byproduct gases. The main source is waste gases from the scrubbers. The acetylene process - light ends; methyl acetylene; allene; acetylene.

Solid Waste: Little information, possibly heavy organics.

I.(iv).3.20. Acrylonitrile

This product is produced by the ammoxidation of propylene. In this vapour phase process, propylene, ammonia and air are combined in a fluidized bed reactor at about 450° C and 2 atmospheres. A catalyst such as 50 to 60 percent bismuth phosphonohydrate on Al_2O_3 can be used to increase the yield.

The reactor effluent is scrubbed and excess ammonia neutralized with sulphuric acid. The organic materials are recovered from the absorber water by distillation. Fractionation at atmospheric pressure removes hydrogen cyanide, water, light ends and high boiling impurities from the crude acrylonitrile. Acetonitrile and hydrogen cyanide which are produced in the quantities of approximately 15 kg and 75 kg respectively per tonne of acrylonitrile are collected as saleable by-products.

Liquid Effluent: Ammonia sulphate, from the reaction section neutralizer; acetonitrile, from the purification section stripper.

Airborne Emissions: Acrylonitrile (≃ 0.25-50 kg); carbon monoxide (≃ 200 kg); propane (≃ 50 kg); propylene (38-100 kg) per tonne of product; acetonitrile (≃ 5 kg); ammonia; these all occurring from the exit gas stream of the product absorber. Hydrogen cyanide (0.5-1 kg/tonne of product) from the purification section off gases. Nitrogen oxides, from the by product incinerator.

Solid Waste: No information

I.(iv).3.21. Carbon tetrachloride

Carbon tetrachloride can be produced by a number of processes. Some of these are: a) chlorination of methane, which involves the simultaneous breakdown of hydrocarbons and the chlorination of molecular fragments. As methane reacts in this manner, some carbon tetrachloride is produced, along with varying amounts of other chloromethanes. The gas flow must be rapid to keep the likelihood of an explosion to a minimum. This process requires corrosion resistant metals and exacting controls, since the reaction is exothermic. Crude carbon tetrachloride is generally purified by neutralization and drying, followed by distillation. Additional purification can be obtained at the distillation stage by maintaining the carbon tetrachloride for a prolonged period under total reflux before actually starting the distillation itself. Decomposition of carbon tetrachloride upon contact with water or on heating in air make it practical to add a small quantity of stabilizer to the commercial product.

b) chlorination of carbon disulphide, c) oxychlorination of ethylene dichloride, in which perchloroethylene, trichloroethylene and carbon tetrachloride are coproduced. The actual reaction is highly complex with substitutive chlorination, cracking, Deacon reaction, and carbon burning all occuring simultaneously. Ethylene dichloride, chlorine, oxygen and recycled chlorinated organics are fed to a fluid bed reactor. Catalysts such as PPG and copper chloride are used in the reactions, which occur at moderate pressure and around 425° C. After vent scrubbing, the condensed crude and weak acid are phase separated and the crude dried by azeotropic distillation. The crude is fed to a distillation train where it is split into perchloro rich and trichloro rich streams. The products are separated in stills, neutralized, washed and dried. Carbon tetrachloride is recovered as a by-product of this vigorous chlorination. d) hydrocarbon chlorinolysis process. Large quantities of perchloroethylene, carbon tetrachloride and other chlorohydrocarbons are coproduced by the simultaneous chlorination and pyrolysis of paraffinic hydrocarbons. This conversion is carried out by reacting ethane, propane, LPG or natural gas with an excess of chlorine at 500 to 700° C. Gaseous reaction products are quenched and most organics condensed. Any HCl remaining in the condensed crude is neutralized with dilute caustic, and the product is decanted from the aqueous phase, dried and distilled. Light end organics such as carbon tetrachloride and trichloroethylene are condensed and purified by further distillation. Perchloroethylene,hexachloroethane and higher boiling bottoms are separated and the saleable products are neutralized, dried and inhibited, if an organic linkage is present.

Liquid Effluents: Methane chlorination process - traces of spent liquid. Hydrocarbon chlorinolysis -sodium chloride; chlorinated by products; caustic products; traces of perchloroethylene and hexachloroethane. These are emitted mainly from the purification section. Other methods, no information.

Airborne Emissions: Methane chlorination process - various chloromethanes, from the chlorination stage. Oxychlorination of ethylene dichloride - chlorohydrocarbons; chlorine; hydrogen chloride. Hydrocarbon chlorinolysis process - mixed hydrocarbons; hydrogen chloride. Other methods; No information.

I.(iv).3.22. Carbon black

Most carbon black is manufactured by the furnace process. Natural gas and high carbon aromatic oil are preheated and introduced to a furnace with a limited amount of air. A combination of cracking and combustion occurs. The hot exit gas containing finely divided carbon particles is cooled and the particles removed by cyclones, precipitators, scrubbers, or bag filters. The exit gas is usually discharged to the atmosphere.

Liquid Effluent: Little information, but probably depends on use of scrubbers and on dampening of dust for handling purposes.

Airborne Emissions: Hydrogen (116 kg/tonne of product); carbon monoxide (1220 kg/tonne of product); hydrogen sulphide (27 kg/tonne of product); sulphur dioxide, traces; methane and acetylene (55 kg/tonne of product); particulates, carbon black (2 kg/tonne of product). The major emission source is the exit gas stream, but drier vents, conveyors, storage areas are also sources. Incineration of waste gases is usually practised.

Solid Waste: No information

I.(iv).4. Plastics and Synthetic Resins

I.(iv).4.1. General considerations

Plastics and resins are chain-like structures known chemically as polymers. All polymers are synthesized by one or more of the following processes: bulk, solution, emulsion, and suspension. A typical production reaction requires the addition of a free radical initiator and modifiers to the monomer, the building block of the polymer. This polymerization process creates relatively little water-borne waste, compared with that of other chemical manufacturing processes. In most cases, the preliminary step in polymerization, the synthesis of the monomer, creates considerably more waste than the production of the polymer from the monomer.

Because it is technically and economically advantageous, most firms manufacture several different related chemical products at one location and use a common waste disposal unit. It is not economically advantageous to identify and qualify the waste from each manufacturing process, so waste treatment is usually handled as a common cost centre. These costs are then entered into an overall burden rate. However, some firms do utilize a direct cost based upon loading, that is charged to each producing profit centre.

Plastics processing operations are performed on polymeric materials or systems to increase their utility. These operations involve chemical reactions, forming or shaping due to flow characteristics, and/or permanent changes in physical characteristics. The products of plastics processing are: adhesives, coatings, extruded goods, films and sheets, foams, laminates and moulded goods.

Raw materials consumed in plastics processing plants consist of plastic resins, chemicals and additives such as antioxidants, antistatic agents, catalysts, colourants, fillers, flame retardants, lubricants, organic peroxides, plasticizers,solvents, stabilizers and ultra-violet absorbers. These materials are blended together and converted into final products as a result of chemical reactions (e.g. cross-linking) application of heat and pressure (e.g. extrusion or moulding) or changes in physical characteristics. (e.g. foam generation).

Twenty operations are considered significant in characterizing the manufacture of plastics and resins. These operations and the products formed are:

Operation	Products
Mass Addition Polymerization	Polystyrene
	Acrylonitrile-butadienestyrene
	Styrene-acrylonitrile
	Methyl methacrylate
	Alkyl resins
Emulsion Addition Polymerization	Lattices
	Polystyrene
	Acrylonitrile-butadienestyrene
	Styrene-acrylonitrile
	Poly(vinyl chloride)
	Poly(vinyl acetate)
	Poly(vinylidene chloride)
	Polyalkyl acrylates and copolymers
	Polyalkyl methacrylates & copolymers
	Poly(vinyl esters) and copolymers
	Polyacrylonitrile
	Polybutadiene
	Polychloroprene
	Polyisoprene
	α-Methylstyrene copolymers
	Isobutylene copolymers

Operation	Products
	Solids Poly(vinyl chloride) plastisol resins Styrene-acrylonitrile graft polyblends with synthetic rubbers Teflon (polytetrafluoroethylene) Kel-F (polytrifluorochloroethylene)
Suspension Addition Polymerization Processes	Polymethacrylic esters & copolymers Polyacrylic esters and copolymers Polystyrene Rubber-modified polystyrene Poly(vinylidene chloride)-vinyl chloride copolymers Poly(vinyl chloride) and copolymers Poly(vinyl acetate) Styrene acrylonitrile Rubber-modified styreneacrylonitrile copolymers (i.e. ABS and others) Polydivinyl benzene and copolymers Polytrifluorochloroethylene)
High Pressure Mass Polymerization	Low density polyethylene
Solution Polymerization	Styrene polymers & copolymers α-Methylstyrene copolymers Polyacrylic acid Polymethacrylic acid Polyacrylamide Poly(vinyl pyrrolidone) & copolymers
Particle Form Polymerization (Polyethylene)	Polyethylene Ethylene-olefin copolymers

Operation	Products
Polyolefins Polymerization (Ziegler)	High density polyethylene Polypropylene Polybutene (Various copolymers)
Phenolic Resin Production	Resols Novolaks
Amino Resin Production	Amino Resins
Polycarbonate Production	Polycarbonates (linear thermoplastics polyesters)
Epoxy Resin Production	Epoxy resins
Unsaturated Polyester Resin Production	Polyester resins (Mixtures of unsaturated polyester resin & vinyl-type monomers)
Alkyd Resin Production	Alkyd Resins
Polyethylene Terephthalate Production	Polyethylene terephthalate
Nylon 6 Production	Nylon 6
Nylon 66 Production	Nylon 66
Polyurethane foam Production	Polyurethane foam
Polyamide Resin Production	Polyamide resins
Poly (phenylene sulfide) Production	Poly (phenylene sulfide)
Polyacetal Production	Polyacetal resins

I.(iv).4.2. Emissions from the plastics and resins industry

Gaseous emissions of hydrocarbon materials are encountered throughout. Some of these organic compounds are toxic materials, notably vinyl chloride, toluene diisocyanate, phosgene and pyridine and there is concern about the health of workers subjected to exposure to these substances.

The particulates are resin powders, solid additives and hydrocarbon aerosols. The hydrocarbons consist of blowing agents, monomers, dimers, solvents and additives introduced during processing.

Plastics and resins manufacturing uses very large quantities of olefins as well as aromatics and paraffins. Since olefins are the most reactive, followed by aromatics, paraffins and naphthenes, emission of these hydrocarbons contributes towards air pollution problems, especially photochemical smog. During these polymerization processes, excess monomers and solvents, by-product organic compounds, inorganic acids (HNO_3, HCl, H_2SO_4), and other oxides of sulphur and nitrogen may be emitted to the atmosphere.

Much of the waste water originates from processing in which the process streams are in direct contact with water. Waste water may also be formed during the course of a chemical reaction, it may arise from cleaning process vessels, area housekeeping, utility boiler and cooling water blowdown, and other sources such as laboratories. The contaminants encountered in the waste water include organic reactants, monomers, oligomers, polymers, salts, BOD_5, COD, and suspended solids.

Centrifugation, the process step following polymerization, is responsible for the largest wastewater discharge. Again BOD_5, COD, and suspended solids are the major pollutants. Some water pollutants are also discharged in small quantities during the drying and extrusion processes. Facility age, the design and type of production facilities, and the nature and source of the materials being processed all vary. This means that the range and nature of wasteloads vary also.

Solid wastes are principally screenings, solidified catalysts, and concentrates. These are bulk-gathered from the spills, leaks, and vessel drainage that are not normally diverted to liquid waste treatment, due to their concentration and the negative effects they would have on the usual biological treatment systems. For each kg of BOD, approximately 0.5 kg of solid waste is generated. Residues in the form of slurries from air pollution control equipment and sludges from water treatment facilities are also produced.

Solid wastes are landfilled or incinerated by the resin producers. The waste generating from off-spec and excess product as well as from captured particulates and fines is recycled when possible. There is significant potential for the regeneration and reutilization of non-industrial plastic wastes. Tables I.(iv).1. and I.(iv).2. summarise wasteloadings from some sections of the industry.

Emission sources to be found in a plastics processing plant are:

Processing
- Adhesive production
- Coating
- Extrusion
- Film and sheet production
- Foam generation
- Lamination
- Moulding

Storage
Conveying
Pretreatment
- Dry blending
- Hot roll mixing

Grinding

TABLE I.(iv).1. - PRINCIPAL AIR CONTAMINANTS AND EMISSION SOURCES: RESIN MANUFACTURING

Resin	Air Contaminant	Representative Toxicities	Possible Sources of Emission [a]
Phenolic	Aldehyde odor	13.8 mg/m^3	Storage, leaks, condenser outlet, vacuum pump discharge
Amino	Aldehyde odor	20 mg/m^3	Storage, leaks
Polyester and alkyds	Oil-cooking odors, phthalic anhydride fumes, solvents	500 mg/kg body weight	Uncontrolled resin kettle discharge Kettle or condenser discharge
Polyvinyl acetate	Vinyl acetate, solvents	4,000 mg/m^3	Storage, condenser outlet during reaction, condenser outlet during steam distillation to recover solvent and unreacted monomer
Polyvinyl chloride	Vinyl chloride	20 mg/m^3	Leaks in pressurized system
Petroleum and coal tar resins	Monomer fumes		Leaks in storage and reaction equipment
Polyurethane resins	Toluene diisocyanate (TDI)	0.5 mg/m^3	Emission from finished foam resulting from excess TDI in formulation
Polystyrene	Styrene	376 mg/m^3	Leaks in storage and reaction equipment

[a] Possible control options include combustion, afterburners, adsorption, and chemical oxidation.

TABLE I.(iv).2. - PETROCHEMICAL INDUSTRY WASTEWATER LOADING AND RAW WASTE LOADS

Product	Wastewater Loading (m^3/kkg)	Raw Waste Loads (kg/kkg of Production)		
		BOD_5	COD	SS
	Reported Range			
Polyvinyl chloride	2.5 - 41.72[a]	0.1	0.2 - 100	1 - 30
ABS/SAN	1.67 - 24.03	2 - 20.7	5 - 33.5	0 - 30
Polyvinyl acetate	0 - 25.03	0 - 2	0 - 3	0 - 2
Polystyrene	0 - 141.8[b]	0 2.2	0 - 6.0	0 - 8.4
Polypropylene	2.5 - 66.75	0 - 10	0 - 20	
Low-density polyethylene	0. - 41.72	0.2 - 4.4	0.2 - 54	0 - 4.1
Cellophane	100 -559	20 - 133	40 - 334	6 - 70
Rayon (Zinc: 12-50)	33.33 191.9	20 - 45	33 - 100	--
Polyester resin	0 - 167[c]	3 - 20	6 - 45	0 - 12
Nylon 6 & 66 resins	0 - 152.3	1 - 135	1 - 300	0 8
Nylon 6 & 66 fibers	--	0.1-60	0.2 - 90	0.1- 6
Cellulose acetate	16.69- 417[c]	6 - 70	11 - 100	2 - 20
Epoxy	2.5 - 5.1	57 - 82	30 - 127	5 - 24
Phenolic resin	0.5 - 20	15 - 51	90 64	0.5 - 7
Urea resin	--	--	--	--
Melamine	--	--	--	--
Acrylic resins	2.5 - 50.87	10 - 40	10 - 70	0.1- 1.7
High-density polyethylene	0 - 30.87	0 - 1	0	0 - 3.4

[a] Emulsion process.

[b] Suspension process.

[c] Resin (not including fiber).

TABLE I.(iv).3. – BEST PRACTICABLE CONTROL TECHNOLOGY CURRENTLY AVAILABLE EFFLUENT LIMITATIONS GUIDELINES

kg/kkg

Subcategory	BOD5		COD		SS	
	Maximum Average of daily values for any period of thirty consecutive days	Maximum for any one day	Maximum Average of daily values for any period of thirty consecutive days	Maximum for any one day	Maximum Average of daily values for any period of thirty consecutive days	Maximum for any one day
Polyvinyl chloride						
Suspension	0.36	.70	3.6	7.0	0.99	1.8
Emulsion	0.13	.26	1.3	2.6	0.36	.65
Bulk	0.06	.12	0.60	1.2	0.16	.29
Polyvinyl Acetate	0.20	.39	2.0	3.9	0.55	1.00
Polystyrene						
Suspension	0.22	.43	2.2	4.30	0.61	1.1
Bulk	0.04	.03	0.40	.80	0.11	.20
Polypropylene	0.42	.81	2.1	4.10	1.16	2.11
Polyethylene						
Low Density	0.20	.39	2.0	3.9	0.55	1.00
High Density Solvent	0.30	.58	3.0	5.8	0.83	1.31
High Density Polyform	0.052	.10	0.52	1.0	0.14	.29
Cellophane	8.7	17.8	87	178	16	29.10
Rayon	4.8	10	72	150	8.8	16.0
ABS/SAN	0.63	1.30	6.3	13.0	1.16	2.1
Polyester						
Resin	0.78	1.4	11.7	21.5	0.52	.95
Fiber	0.78	1.4	11.7	21.5	0.52	.95
Resin and Fiber Continuous	0.78	1.4	11.7	21.5	0.52	.95
Resin and Fiber Batch	1.56	2.8	23.4	43.00	1.04	1.90
Nylon 66						
Resin	0.66	1.20	3.3	6.0	0.44	.80
Fiber	0.58	1.1	3.0	5.3	0.39	.70
Resin and Fiber	1.24	2.3	6.2	11.3	0.83	1.53
Nylon 6						
Resin	3.71	6.8	37.1	68.1	2.48	4.51
Fiber	1.90	3.5	19	35.1	1.27	2.31
Resin and Fiber	5.61	10.3	56.1	103.1	3.75	6.81
Cellulose Acetate						
Resin	4.13	7.5	41.3	75.1	2.75	5.0
Fiber	4.13	7.5	41.3	75.1	2.75	5.0
Resin and Fiber	8.26	15.0	82.6	150.1	5.5	10.0
Acrylics	2.75	5.00	13.8	25.0	1.1	2.0

Table I.(iv).3. (Cont/d) - Best practicable control technology currently available
Effluent limitations guidelines
(kg/kkg (lb/1000 lb) of Production)

Subcategory	BOD_5		COD		SS	
	Max. av. of daily values for any period of thirty consecutive days	Maximum for any one day	Max. av. of daily values for any period of thirty consecutive days	Maximum for any one day	Max. av. of daily values for any period of thirty consecutive days	Maximum for any one day
Epoxy Resins Batch & Continuous (liquid, solid & solution)	2.1	3.9	32	58	1.4	2.6
Batch, Fusion (solid & solution)	0.25	0.45	3.9	6.7	0.17	0.30
Phenolic Resins	3.7	6.7	19	34	1.5	2.7
Urea & Melamine Resins (Batch (liquid)	0.20	0.38	3.2	5.5	0.13	0.25

The emission factors for the various operations in plastics processing, with no controls, are reported to be:

	Emission Factor (No control)	
	Hydrocarbons (g/kg)	Particulates (g/kg)
Storage		2.8
Conveying		0.9
Dry blending		15
Hot roll mixing		9
Grinding		34
Adhesive production	25	
Coating	55	
Extrusion	48	
Film sheet Production	20	
Foam generation	120	
Lamination	41	
Moulding	20	

The effluent limitation guide lines for best practicable control technology currently available are shown in Table I.(iv).3.

I.(iv).5. Organic Dyes and Pigments

Organic dyes and pigment manufacture involves the conversion of organic chemicals, usually cyclic benzenoids, into more complex intermediates and ultimately dyes and pigments. The distinction between these intermediate compounds and dyes or pigments is arbitrary since many of the intermediates may be dyes themselves.

A general description of the operations necessary for dyes and pigments manufacture includes the following five steps:

1. Introduction of substituents on aromatic ring (benzene, toluene, naphthalene, napththol, and anthraquinone). These are usually one-step processes such as sulphonation, nitration, halogenation, Friedel-Crafts alkylation or oxidation.

2. Replacement of substituents with more reactive groups which cannot be introduced directly, such as OH, NH_2, CH, OR, SR and MRR.

3. Further developments of functional groups in reactions specific to particular dyes.

4. Combination of intermediates to form products with a skeletal dye structure. This step includes such processes as condensation, coupling, and dimerization

5. Dye and pigment formation.

A large variety of raw materials, both organic and inorganic are used in the manufacture of dyes and pigments. The technical terms for pigments are toners and lakes. "Toners" are full strength organic or metallo-organic colours that do not contain inorganic pigment or carrier. "Lakes" are combinations of a dye with an inorganic base or carrier, usually aluminium hydrate.

Over sixty percent of the dye production is consumed by the textile industry and the remaining is used by the paper industry and for the production of pigments, dyeing of leather and colouring of plastics. About half of the organic pigments production is consumed by the printing industry; other uses include surface coatings, plastics, textiles, and paper.

TABLE I.(iv).4. - PIGMENTS AND DYES - APPLICATION AND TOXICITY

Class	Applications	Toxicity Information (2)
Nitroso (Quinone Oximes)	Wallpaper, rubber coloration, textile printing, interior aqueous paints	Pigment Green B(C.I. 10006) - acute oral LD_{50} > 10 g/kg$^{(2)}$
Nitro	Sulfonated nitro dyes and pigments - wool, silk, paper, printing ink, transparent lacquer, external drug and cosmetic colorant. Unsulfonated nitrodiarylamines - yellow and orange disperse dyes for synthetic fibers. Unsulfonated nitro dyes - pigments, fungicides, insecticides, explosives.	Acid yellow 1 (C.I. 10316) - consult latest Government regulations before using in food drugs, or cosmetics.(3)
Azo Monoazo Disazo Trisazo Polyazo Azoic (Mixtures of intermediates - Not finished dyes)	Very wide range of application. Natural and synthetic fiber dyes, pigments, solvent dyes and various non-textile applications.	Some azo dyes have produced cancer in rats and are considered carcinogenic. (4)
Stilbene	Direct dyes, fluorescent dyes, secondary uses as leather, lake-forming or solvent dyes.	Some azo dyes have produced cancer in rats and are considered carcinogenic. (4)
Carotenoid	Natural carotenoids (C.I. 75110-75135) Synthetic carotenoids - important food dyes	Food dyes - assumed non-toxic.
Diphenylmethane (Ketone Imines) (Auramines)	Dyeing wool, silk, leather, acrylic fibers, cotton, paper, and jute	Auramine ($C_{17}H_{22}N_3Cl$)-recognized as a carcinogen. (4)
Triarylmethane	Basic, acid, direct, mordant, cosmetic, and solvent dyes. Pigments of phosphomolybdotungstic acid lake type.	Peacock Blue Lake (from C.I. 42090) - low toxicity (4) malachite Green (C.I. 42000) - oral LD (rabbits) = 75 mg/kg (3) C.I. 42040: LD_{100} iv in mice 3 mg/kg (3) C.I. 42780: probably low human toxicity. (3)
Xanthene	In general, dyeing natural fibers. Hydroxy derivatives - mordant dyes	C.I. 45010: Carcinogenic (3) C.I. 45350: LD orally in rabbits 2.5 g/kg (3 C.I. 45380: LD orally in guinea pigs 5.0 g/kg (3)
Acridine	Broad applications in trade sales and industrial paints as tints, metallics, and blends with other pigments. Especially suitable for leather and plastic; also to some extent in textiles, silk, cellulose, and industrial antiseptic.	C.I. 46000: LD s.c. in mice 250 mg/kg.(3)

TABLE I.(iv).4. - CONTINUED

Class	Applications	Toxicity Information
Thiazole	May be used as direct cotton dyes; the original Ingrain colors. Used in printing to obtain colored discharges.	
Indamine	Intermediates in the preparation of sulfur dyes and in color photography.	
Indophenol		
Azine	Wool, silk, and mordanted cotton dyes. Nonsulfonated dyes used for cotton printing and as colors for fats, oils, and lacquers.	C.I. 50040: LD_{50} iv for rabbits 100 mg/kg (3) C.I. 50440: mild sensitizer (4)
Oxazine	Wool and mordanted cotton dyes. Also used for leather and solvent dyes.	
Thiazine	Medicinal usage, vat dyes, and microscopic stains.	C.I. 52015: Human toxicity - practically nontoxic (3)
Sulfur	Dyes for cellulosic fibers.	
Lactone	Dyes for chrome-mordanted wools.	
Aminoketone	Vat dyes for wool	
Hydroxyketone	Mordant dyes	
Quinoline	Drug and cosmetic color, food dye (Europe), paper. Sulfonated compounds valuable as acid wool dyes.	
Methine and polymethine	Important for use in photography as sensitizers.	
Anthraquinone	Wide variety of uses. Vat, acid, mordant, disperse, solvent dyes and pigments. Also used in cosmetics and in microbiological stains.	Some may cause local sensitivity as an allergen. (3.4)
Indigoid	Dyeing and printing of cellulosic and animal fibers.	Indigo carmine (C.I. 73015) consult latest government regulations before using in foods, drugs, cosmetics. (3)
Phthalocyanine	Pigments and vat dyes.	

Many of the intermediates used in making dyes and pigments are toxic in nature. Even more important is the fact that some of these intermediates are carcinogenic - for example benzidine and 2-naphthylamine. For most applications 2-naphthylamine is being replaced by 2-amino-1-naphthalenesulphonic acid.

Dyes and pigments are sold in the form of pastes, powders, pellets, concentrated solutions, and dispersants. Table I.(iv).4. summarises dye applications and toxicity data.

Liquid Effluent: These present the greatest problems. Liquid waste streams consist of brine solutions and dilute streams of acids and bases contaminated with toxic and/or explosive organic compounds which are often highly coloured dyes and intermediates. The waste solutions also contain metals or metal salts used as catalysts for various reactions. The specific compositions of waste streams vary widely with the dye or pigment manufactured and cannot be adequately represented by a typical composition.

Those liquid wastes originate from chemical reaction by-products; physical separations such as crystallization, filtration, and washing; and from equipment cleaning procedures. There is a scarcity of information and data on assessment and characterization of wastes produced in dyes and pigments manufacture in the open literature.

Airborne Emissions: Nitrogen oxides; sulphur oxides; hydrogen sulfide; hydrogen chloride; organic vapours including amines, phosgene and formaldehyde.

Solid Waste: Distillation residues; recovered particulates; sludges.

I.(iv).6. Environmentally Hazardous and Toxic Chemicals

Some chemicals have presented serious environmental and health hazards. There are several ways substances can be released to the biosphere and many chemicals may be easily and widely dispersed. They can persist and accumulate in the natural environment or in biological tissues and their effects intensified from link to link in the food chain - placing certain animal, plant and eventually human lives at magnified risk. Once lodged in the environment, some chemicals may be irremovable.

As examples, specific instances can be cited where significant adverse effects have occurred. Synthetic organics are of major concern because of the rapid growth of production and use, as well as the fact that many of these are not natural to the environment. Polychlorinated biphenyls (PCBs) and organo-halogen compounds, including DDT, for example, do not readily degrade, and exhibit harmful effects.

Heavy metals form another major category of chemicals that have produced serious unintended effects on man and his environment. Mercury has received world-wide attention as an environmental pollutant following outbreaks in Japan. Similarly cadmium is an important environmental pollutant as indicated by the occurance of "itai-itai" disease in Japan. Other metal compounds of concern include arsenic, chromium, lead and zinc.

For a number of organic chemicals already in use on a commercial scale, there is inadequate information as to their behaviour in the environment and subsequent effects on man. PCB, PBB, dioxin as a contaminant in trichlorophenol and certain organic solvents are some examples. Legislative trends in most countries is towards the control, phasing out, or even banning of some of these compounds. In addition there are stringent regulations for labeling, transport, disposal and monitoring in existance or being sought.

I.(iv).6.1.Polychlorinated biphenyls (PCBs)

These chlorinated hydrocarbons are manufactured by the progressive chlorination of biphenyl in the presence of a suitable catalyst. In appearance they range from clear oils to solid resins.

The chlorination of biphenyl can lead to the replacement of 1-10 hydrogen atoms by chlorine; it has been calculated that 210 different biphenyls of different chlorine content are theoretically possible. Their value depends on their resistance to heat, non-flammability, chemical inertness, low vapour pressure, and high dielectric constant. They are used as dielectrics in transformers, in heat tranfer and hydraulic systems, and in the formulation of lubricating and cutting oils, paint plasticizers, copy paper, adhesives, sealants, plastics and pesticides.

PCBs are stable compounds, and are concentrated by organisms in the food chain - gradually building up to toxic levels. The concentration in living organisms depends upon the extent of local pollution, the amount of fat in the tissues, and the organisms trophic level in the food chain.

Concentrations of PCBs measured in the air range from 50 ng/m^3 to less than 1 ng/m^3. Non polluted fresh waters should contain less than 0.5 ng/l compared with 50 ng/l in moderately polluted rivers and estuaries and 500 ng/l in highly polluted rivers. Surveys on human adipose tissue in several countries have shown that most samples contain levels of PCBs in the region of 1 mg/kg or less, although higher values have been reported. Much higher values, up to 700 mg/kg, have been found in fat from men occupationally exposed. Several national surveys give PCB concentrations in the blood in the range of 0.3 g/100 ml but levels approaching 200 g/ml have been measured in men occupationally exposed, and these may be associated with skin lesions. Most surveys on human milk have shown PCB concentrations in the region of 0.02 mg/l, although concentrations up to 0.1 mg/l have been recorded.

An estimate of the total daily intake of PCBs in air, water, and diet by individuals not occupationally exposed indicates that this falls within the range of 5 to 100 g, which may be supplemented by unknown amounts from non dietary sources. This estimate has some support from measurements of concentrations in human milk.

Little is known about the effluents and emissions during the manufacture of PCBs. However, the very nature of the compound, and possible emissions of the finished product, necessitate that great care is taken to control unnecessary waste losses. Other possible emissions include the chlorine and biphenyls used as the primary ingredients, catalyst material and any other primary, or intermediate chemicals.

I.(iv).6.2. Polybrominated biphenyls (PBBs)

PBBs are brominated hydrocarbons, similar to the PCBs in structure. They are manufactured by the substitution of bromine for hydrogen atoms on the biphenyl molecule.

PBBs have been found to meet most of the requirements for flame retardants to be used in synthetic polymers. Due to the growing recognition of the toll taken by fire and the need for improved fire restraint properties for plastics and synthetic fibres, flame proofing is particularly desirable in polyester-cotton blended fabrics used for children's wear and other apparel. Other synthetic polymers which require flame retardancy for use in electrical and high temperature applications are thermoplastic resins such as thermoplastic polyesters, polyphenylene oxides, and acrylonitrite - butadiene - styrene (ABS) terpolymers.

Considerable concern about PBBs has developed because of the structural similarity of PBBs and PCBs, and recent accidental contamination of foodstuffs. The acute toxicity is low for most animals, but chronic toxicity does appear to develop. The reproduction of many species is adversely affected, and bioaccumulation frequently observed. PBBs are stable compounds - especially in soil, and a recent review concluded that there is a need to control the manufacture, impotation, commercial use and disposal of PBBs in Canada.

Within most countries specific legislation to control PBBs is not fully developed.

Little is known about emissions and wastes produced during the manufacturing process. However, the possible loss of primary ingredients or finished product must be considered a possibility.

I.(iv).6.3. Mirex, Dechlorane, (Kepone)

The dimerization of hexachlorocyclopentadiene forms a fully chlorinated, cage-structured organic chemical, known as mirex. This can be formed by two pathways: (i) Involves the intermediate formation of kepone ($C_{10}Cl_{10}O$) which is converted to mirex by chlorination with phosphorus pentachloride. Sulphur trioxide is also used in the early stages of kepone manufacture. (ii) Proceeds in one step, however, the yield of mirex is lower than for the sequence (i) and involves separation of product from unreacted starting materials. In both cases the starting compound is hexachlorocyclopentadiene ($C_5 Cl_6$).

Mirex has been extensively used to control the spread of fire and, as a flame retardant in plastics and as a smoke generator in military pyrotechnics. It is a white crystalline odourless solid with a molecular weight of 545.59 and a melting point of 485°C. It is soluble in organic solvents but very insoluble in water. Chemically, mirex has a very low reactivity and does not undergo any reaction with common acids, bases and other reagents such as chlorine, ozone, or lithium aluminium hydride. In the environment and in the laboratory mirex has been found to be more persistent than even DDT, aldrin, dieldrin or heptachlor. The complete chlorination of the molecule makes it particularly resistent to attack.

Environmental degradation of mirex will form kepone in amounts relative to mirex. In heavily treated soils, 12 years after application of the mirex, from 27 to 35 percent of the total mirex related residues were degradation products. The major pathway for mirex breakdown in the environment is photolysis by sunlight. However, the conversion process is slow.

Mirex is accumulated by organisms that are exposed to it. Invertebrate and vertebrate aquatic organisms take up and accumulate mirex from the water by a factor of up to 10^5. Similarly, birds and mammals retain mirex ingested in the diet and exhibit extremely slow excretion of the material from their bodies. The chemical is toxic to many organisms and is characterised by delayed toxicity. The acute oral toxicity of mirex is moderate (LD_{50} rat 365 mg/kg) but since its metabolism is practically negligible and it accumulates in a dose dependent manner, the ratio of its single dose LD_{50} to the 90-dose LD_{50} is 60.8:1. The liver is a major target organ. Dietary levels of 5 and 25 ppm had a detrimental effect on reproduction in the mouse and rat, respectively.

Also, cataracts were present in approximately 33 percent of the weanling rats. Mirex crosses the placenta, and it is excreted in milk and eggs. Tests with mice and rats have shown mirex to be a heptacarcinogen. In rats, progeny from treated dams had an increased rate of abnormalities.

Little is known about the emissions and effluents from mirex or kepone manufacture. However, the ingredients and final products must be considered as potential waste losses.

I.(iv).7. Bibliography

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I.(v). FOOD AND AGROINDUSTRIAL INDUSTRIES

I.(v).1. Introduction

Before food products go before the consumer they undergo a number of processing steps such as:

refinement
preservation
product improvement
storage and handling
packaging or canning

At each step gaseous solid or liquid emissions can add to the pollution output. This section deals solely with the emissions from or during process at plant, not with aspects such as toxin run-off from crop spraying.

Each food processing plant has wastes of different quantity and quality. No two plants are the same and estimates of residues generated from each plant must be regarded as approximate. Few plants have adequate knowledge of the volumes, characteristics and fluctuations of their wastes. At each processing plant, material and water balances on the inputs and outputs to the plant can provide reasonable estimates of the total waste flow and residue generation.

Much of the available information on food processing waste characteristics is not comprehensive. Average waste loads reported in the literature should be regarded as guidelines rather than exact values that can be extrapolated to different plants. Associated emissions are typified by the liquid effluent having a very high Biochemical or Chemical Oxygen Demand (BOD or COD). Suspended or Dissolved Solids (TSS or TDS) form the major part of this effluent along with complex oils or other organic compounds.

In airborne emissions, particulates, sulphur oxides, nitrogen oxides, hydrocarbons or other organic compounds are often found in moderate amounts usually having a strong odour.

Solid wastes form a major problem with up to 50% of produce entering a cannary, being ultimately disposed of as solid waste. A limited amount is used in annual feeds; a major disposal method is landfill, though problems of odour, vermin and leachate production can arise.

Six main groups within the food industry are discussed. These are:

meat and meat products
fish processing
dairy products
grain milling, handling and feed manufacture
fruit and vegetable processing
canning

I.(v).2. Meat and Meat Products

Meat processing primarily involves the production of meat cuts, ham, bacon and sausages - sometimes for subsequent canning, pickling or smoking.

A high BOD effluent and odour problems typify emissions.

I.(v).2.1. Process emissions and removal (Figure I.(v).1.)

Meat packing plants or abbatoirs consist of several sections: (a) holding pens and yards; (b) killing floor; (c) hide room; (d) casing room; (e) paunch and intestinal removal area; (f) coolers; (g) trimming and boning room: (h) pickle room; and, (i) by-product processing area. If frozen meats are processed, then thawing or chipping into smaller pieces is required at some stage. The primary product is then cooked, or receives other treatment such as grinding or smoking.

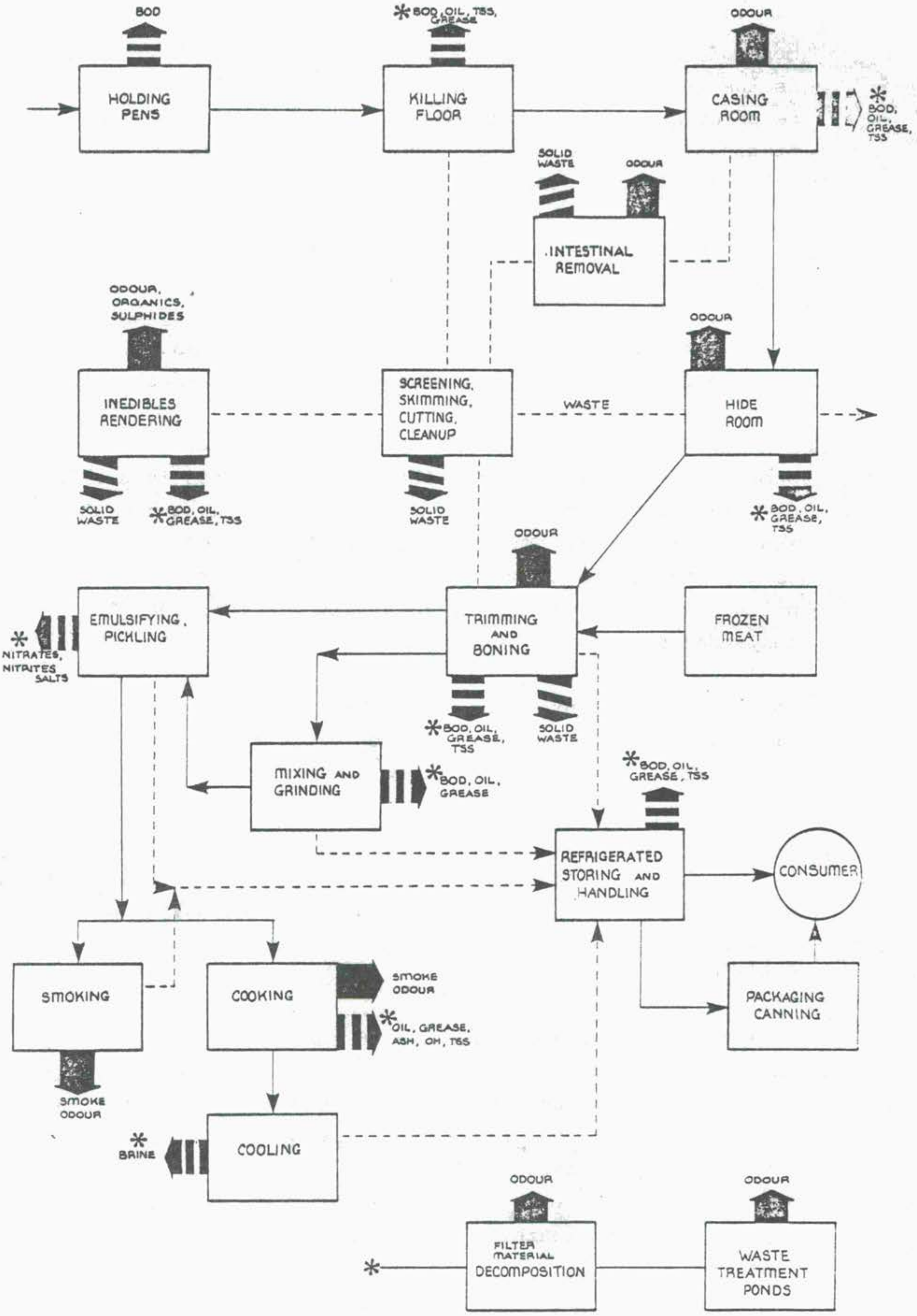

Fig. I(v) 1 Meat Processing

Most of the above steps are self-explanatory but trimming is the removal of excess or unwanted fat, etc. Boning may be performed at the same location as trimming. The large pieces of meat are cut or sawed for the directed marketing of the individual cuts.

Skin may be removed from a piece of meat by either machine or hand. The water pollution discharges from all these steps are BOD, oil, grease, thermal and suspended solids. Odour is an air pollution nuisance. Paunch, manure and sludge and other solid wastes are produced which are generally disposed to landfills.

Some meats may be pickled. The pickle solution is usually prepared by mixing sugar, sodium nitrite, sodium nitrate, and salt in water. The solution may be applied to the meat either by injection or by soaking. Important pollutants are nitrates, nitrites, sodium chloride, BOD, suspended solids, oil and grease.

Many of the meat products are either cooked or smoked. Smoke is generated from a hardwood sawdust or small-size wood chips.

Cooking is usually done in oven or wet cookers using steam. The meat product is then cooled with water. Oil and grease, ash, alkalinity, thermal, BOD, and suspended solids are the major water pollutants. Odour and particulates may contribute to air pollution.

Some processed meat products, such as hams or dry sausage, require holding or aging before they are shipped out of the meat processing plant. The holding areas are refrigerated and drippings are apt to accumulate daily on the floors. The water pollution discharges are BOD, oil, and grease. The processed meats are packaged in either paper or plastic wrappers or containers. Small quantities of solid waste are generated.

The significant air pollution problem is odours from the processing and decomposition of meats, as well as other combustion-related gases. Decomposition odours are mainly associated with meat processing, and waste treatment. Warm anaerobic treatment ponds create serious odour problems. Odours from the casing area are from manure and the sour, partly digested foodstuffs of the intestine. Further decomposition must be prevented by good sanitation practices. The air from the room may also be treated before it is exhausted to the atmosphere. Usually a water wash is adequate. Scrubbing the air with a potassium permanganate solution is effective but expensive.

Waste water treatment facilities may also produce obnoxious odours if good sanitation methods are not practiced. Common causes of odours are decomposition of screened solids (if not disposed of daily), low flow rates in trickling filters, and spring thawing of stabilisation ponds when the ice cover first disappears.

Old technology in the meat-packing industry would include blood recovery but only wet cleanup with washing of paunch manure to the sewer and no evaporation of rendering tank water.

Typical technology includes blood recovery, wet dumping of paunch manure with hauling of gross paunch material, dry rendering or evaporation of tank water, and wet cleanup. Advanced technology includes blood recovery, dry dumping of paunch manure, continuous dry rendering, and dry cleanup followed by wet cleanup. Table I.(v).1. shows the BOD load from these three stages of technical development.

Most waste treatment processes include catch basins with detention periods of 20 to 40 minutes, equipped with grease skimming as a pretreatment. BOD removal may average 25 per cent. Air flotation with coagulants has been used for the removal of greases, fat, and some proteins, resulting in 50 per cent BOD removal. Biological treatment has been most popular and effective. Anaerobic lagoons will yield 80 percent

BOD reduction, with the aerobic processes providing an excess of 90 percent removal. (An anaerobic lagoon followed by an aerobic lagoon will effect 95 percent reduction.)

(v).2.1.1.Poultry processing

Wastes from poultry processing originate primarily from blood, feathers, and cleanup. After arriving at the processing plant, the birds are slaughtered, followed by scalding and defeathering. The carcasses are then eviscerated and packed. The older plants will not recover blood and use water, feathers, and offal from the processing area. The newer plants will recover blood and other solid wastes. The waste loads are summarized in TableI.(v).2.

.(v).2.2. Inedible fat rendering

By-product processing presents the most difficult of all the odour problems of the meat industry, and the paramount process of all is inedible fat rendering. The fat rendering industry is for good reason widely noted for its odour problems. The process involves the application of heat to the raw material (meat scrap, intestines, bones, etc.) to remove water, disintegrate the bone tissue, and release fat or tallow.

In a typical rendering system meat scrap and other animal residues are ground to a hamburgerlike consistency and fed to horizontal, steel-jacketed kettles. During the cooking process, fat cells are broken down to water, grease, and proteinaceous solids. The solids are then separated from the grease, which may subsequently be purified to produce tallow. Odours are emitted through the entire process, beginning with the raw material storage bins.

The greatest odour sources in a conventional batch-cooker rendering plant are the cooker noncondensables and screw-press-vent gases. Percolation pan odours can also be quite high in the ambient air immediately above the pans. Even with efficient collection of cooker and screw-press-vent gases, odours from the percolation pan, spills, and minor vents go directly into in-plant air. Odour-masking agents have been widely used in the past but stricter odour regulations have resulted in all exhausted ventilation air being treated by scrubbing or adsorption on activated charcoal.

In modern practice, cooker exhaust is cooled by air condensers instead of barometric condensers (to reduce water pollution control costs). The air condensers are designed to reduce condensate temperatures to 100-120°F during the summer months. The noncondensables may then be destroyed by incineration or chemical scrubbing. Screw-press-vent gases are also incinerated or scrubbed. Although incineration is required by some local ordinances, it is being replaced by scrubbing because of the shortage and higher cost of natural gas and of sulphur-free fuel oil.

Incineration is most effective in handling relatively small volumes (up to 1000 or 2000 cfm) of concentrated odours, unless heat can be recovered and used advantageously. In a few plants, cooker noncondensables are incinerated in the plant steam boiler, if it satisfies the necessary combustion design criteria. Wet scrubbers with circulating chemical solutions have been shown to involve lower costs than incineration and to be equally effective. Recent studies have shown sodium hypochlorite to be the most effective solution overall (96 to 99% efficient in reducing odours). In some cases, potassium permanganate gives better results. At least one plant uses soda ash effectively.

Table I.(v).1. Wastewater Characteristics per Thousand Kilograms of Liveweight Killed[a]

Technology	kg of BOD/1000 kg
Old	20.2
Typical	14.4
Advanced	11.3

[a] Post catch basin

Table I.(v).2. Wastewater Characteristics per 1000 Birds

Plants	kg of BOD/1000 birds
Older	14.4
Newer	11.7

I.(v).3. Fish Processing (see also section I.(v).7.2.)

The canning, dehydration, and smoking of fish, and the manufacture of fish oil and fish meal are important segments of the fish industry. The biggest problem from fish processing is odours which emanate from the fishing boats and raw storage, and through all processing steps, e.g. cooking, pressing, screening, centrifuging, drying, and waste disposal. The principal malodorants are acrolein, oil decomposition products, hydrogen sulphide, ammonia, butyric and valeric acids, and trimethylamine. The only significant sources of dust emissions in fish processing are the driers and grinders used to handle dried fish meal. Emission factors for fish meal manufacturing are shown in Table I.(v).3.

Table I.(v).3. - Emission Factors for Fish Meal Processing

Emission source	Particulates kg/MT	Trimethylamine $(CH_3)_3N$ kg/MT	Hydrogen-sulphide (H_2S) kg/MT
Cookers, lb/ton (kg/MT) of fish meat produced			
Fresh fish	-	0.15	0.005
Stale fish	-	1.75	0.10
Driers, lb/ton (kg/MT) of fish scrap	0.05	-	-

There are two types of fish-canning operations: the "wet fish" method in which the trimmed fish are cooked directly in the can and the "pre-cooked' process in which the whole fish is cooked and then hand-sorted before canning. A large fraction of the fish received in a cannery is processed into by-products, the most important of which is fish meal. In the manufacture of fish meal, fish scrap from the canning lines is charged to continuous live-steam cookers. After the material leaves the cooker, it is pressed to remove oil and water. The pressed cake is then broken up usually in a hammer mill, and dried in a direct-fired rotary drier or in a steam-tube rotary drier.

Odour control entails passing gaseous processes effluents and exhaust air from processing areas through control equipment which will either destroy the odourous gas, absorb, or adsorb it. Some of the methods used are activated charcoal adsorbers, scrubbi with chlorinated water or some other oxidizing solution, catalytic combustion, incineration, and the use of masking and counteraction agents.

In many areas fish waste is still dumped into the harbour nearby. Often current flow is sufficient to carry the waste out to sea for dispersal, but wherever stagnant or estuarine conditions exist, solids settle to the bottom, break down anaerobically, and emit highly odorous gases.

I.(v).4. Dairy Wastes

Dairy products and processing can be broadly split into five categories:

creamery butter
cheese, natural and processed
condensed and evaporated milk
ice cream and frozen desserts
fluid milk

Wastewaters in the dairy industry originate primarily from tank and equipment washing, product spillage and losses. Water conservation, collection of drippings, and other practices can materially reduce the BOD discharged to the sewer.

Since many dairies are located in or near urban areas, treatment in municipal systems is common. Dairy wastes have also been treated by activated sludge and aerated lagoons and by spray irrigation.

Some 'wastes' may serve as the primary raw material for another process. In the butter industry, the remaining skim milk and butter milk are in large part utilised as a raw material in the condensed and evaporated milk manufacturing industries.

.(v).4.1. <u>Site location</u>

The actual processing facility often consists of two or more plants. Butter plants and condensers are usually combined so that both the cream and skimmed milk portions may be utilised in one location. Similarly, ice cream plants are often combined with fluid milk and cottage cheese plants for the most effective utilisation of milk. To the contrary, cheese plants usually manufacture cheese only since whole milk is completely utilised.

Fluid milk plants are generally located near the area of greatest consumption since transportation costs of the finished product are greatly increased by additional weight of bottles and cases.

I.(v).4.2. <u>Waste products</u>

Dairy wastes are similar in all the five processing groups. The most significant wastes include product loss in the process stream, water, soap and chemicals used in washing, cooling water, skim milk and butter milk from butter manufacture and cream and whey from cheese manufacture. These usually result in a high BOD effluent. Some wastes may be utilised by other processing groups. Table I.(v).4. shows overall BOD load for each process.

I.(v).4.2.1. Creamery butter

The significant wastes derived from the fundamental butter process are skim milk from the separation process and buttermilk from the churning operation. These waste products may be converted to valuable by-products through evaporating the moisture and drying the residue to a powder form for human consumption or animal feed. Direct feedings of wastes to animals reduce energy requirements for drying. Normally, these wastes are forwarded to condenseries; however, in the smaller plants a significant amount of skim milk and buttermilk is a "net" waste. If the skim milk and buttermilk are treated as wastes, they become a difficult waste problem because of the high BOD exerted by the significant protein fraction of the waste.

Less significant sources of wastes are (1) the spillage which occurs in normal processing and packaging operations and (2) the wastes incurred with cleaning equipment at the end of a day's operation. Some clear water waste occurs in those plants using water for once-through cooling in their refrigeration systems.

This technique is often used in rural plants with their own wells or in areas of abundant water supply.

No water that comes in contact with butter during the manufacturing process may be reused because of the danger of contamination.

I.(v).4.2.2. Cheese

The significant waste from the fundamental cheese process is whey. This waste product may be converted to valuable by-products through evaporating the moisture and drying the residue to a powder form for human consumption or animal feed. Again, direct feed of waste to animals reduces energy requirements.

If whey is sent to the plant disposal system, the material becomes a most difficult waste problem because of the high protein and acidic content. Approximately 54% of the solids in the raw material remains in the whey.

To date, whey processing remains a problem to the industry. Recent research has shown that mechanical screens are ineffective in separating whey waste; on a small scale, expensive centrifuging has been utilised effectively. Whey contains 0.9% to 1% albumin which, if heated and treated with acid, will result in removal of 60% to 70%. This processing, however, reduces the BOD load by only 20% to 25% and has proven to be too expensive for normal processing use. The most practical utilisation of whey has been through the facilities of drying plants; however, these operate either at the breakeven point or with only a slight profit, and may not be appropriate/necessary in the tropical and semi-tropical areas.

Less significant sources of wastes are (1) the spillage which occurs in normal processing and packaging operations and (2) the wastes incurred with cleaning equipment at the end of a day's operation. Some clear water waste occurs in those plants using water for once-through cooling in their refrigeration systems. This technique is often used in rural plants with their own wells or in areas of abundant water supply.

No water that comes in contact with cheese during manufacturing process may be reused because of the danger of contamination.

I.(v).4.2.3. Condensed and evaporated milk

The significant waste from the fundamental condensed and evaporated milk process is the miscellaneous spillage that occurs in normal processing and packaging operations, and loss that occurs from cleaning equipment at the end of the day's operation. Also, the soaps and chemical cleaning solutions used in daily sanitation procedures contribute to water waste, and are included in the computations. Shrinkage in the raw receipts and overfill of the finished product are not included in later waste quantity computation.

Significant clear water waste occurs in those plants using water for once-through cooling in their refrigeration systems and once-through condensing water in milk evaporators. The trend is toward the use of cooling towers which permit the reuse of cooling water.

I.(v).4.2.4. Ice cream and frozen desserts

The significant wastes derived from the fundamental ice cream and frozen desserts process are (1) the spillage which occurs in normal processing and packaging operations and (2) the wastes incurred with cleaning equipment at the end of a day's operation. Some clear water waste occurs in those plants using water for once-through cooling in their refrigeration systems. This technique is often used in rural plants with their own wells or in areas of abundant water supply.

No water that comes in contact with ice cream and frozen desserts during the manufacturing process may be reused because of the danger of contamination.

Table I.(v).4. Dairy Wastewater

Product	Volume l/100kg	B.O.D. mg/l
Creamery butter	3410 - 11300	3400 - 16800
Cheese	10780 - 19300	4500 - 30000
Condensed and evaporated milk	2590 - 3500	3700 - 6200
Ice cream[a]	5755 - 1110	1700 - 8100
Milk	1670 - 4140	500 - 2600

[a] Per 500 litres of product

I.(v).4.2.5.Other emissions

Some waste products are evaporated and dried to a powder form. Gaseous and particulate emissions may then be present.

I.(v).5.Grain Milling, Handling and Feed Manufacture

The cereal grains include barley, corn, grain sorghum, millet, oats, rice, rye, and wheat. At grain elevator locations the following operations can occur: receiving, transfer and storage, cleaning, drying, and milling or grinding. Many of the large terminal elevators also process grain at the same location. The grain processing may include wet and dry milling (cereals), flour milling, oil-seed crushing, and distilling. Feed manufacturing involves the receiving, conditioning (drying, sizing, cleaning), blending, and pelleting of the grains, and their subsequent bagging or bulk loading.

All grain-milling operations involve disintegration of the dried grain followed by a series of sizing, separating, and mixing processes. Inasmuch as all these processes involve handling fine dust particles in an air strea, potential problems always exist (e.g. explosion, air pollution, contamination of products). Even before the milling operation begins, the grain must be delivered, unloaded, cleaned, stored, and brought from storage to the processing site.

Of all these operations, the dustiest is the loading and unloading of boxcars, ships, trucks, and barges. Proper control involves loading and unloading in enclosed or semi-enclosed areas operated under negative pressure to prevent escape of dusty air. Baffles to contain dust and to direct airflow are useful in lessening dust losses during unloading. Finally, any exhausted airstream must be sent through cyclone collectors or baghouses. The use of special bulk feed and grain cars is highly recommended. These cars have discharge hopper bottoms, sectional compartments, and top spout openings, all of which reduce dust emissions.

Prior to processing, the grain is always cleaned by passing it over a series of scalpers (to remove tramp iron and other large objects), screens (to separate weed seeds, small stones, soil, etc.), and aspirators (where an airstream blows out chaff, grain hairs, pollen, mold spores, parts of insects, and other lightweight contaminants). Uncleaned grains usually contain 3% dockage, of which 90% is removed during the cleaning operation.

Cleaning leads to another major problem, disposal of the collected dust. Regardless of final disposition by the salvager, it must be loaded into dust cars, a difficult and extremely dusty operation. Again, cyclones and baghouses are required if dust is to be controlled. Baghouse air-cloth ratios for this application range from 0.08 to $0.13 m^3$/minute/m^2 of cloth.

Emissions from grain elevator operations are dependent on the type of grain, the moisture content of the grain (usually 10 to 30 percent), the amount of foreign material in the grain (usually 5 percent or less), the degree of enclosure at loading and unloading areas, the type of cleaning and conveying, and the type of control used.

Dust emissions from uncontrolled grain elevators have been estimated to be 12.5kg per tonne of grain. Emissions from controlled terminal elevators have been estimated as: shipping and receiving - 0.5 kg per tonne; transferring and conveying - 1 kg per tonne; screening and cleaning - 2.5 kg per tonne; drying - 2.75 kg per tonne. Shipping and receiving losses at country elevators may be five times greater; emissions from other operations at country elevators are 15 to 60% greater than at terminal elevators.

Usually grain-processing operations must meet general process-weight regulations for stationary sources. In a few instances, grain-processing plants are subject to specific regulations. Particulate emissions are shown in Table I.(v).5.

I.(v).5.1.Milling

Flour milling of grain (usually wheat) entails the following steps:

(a) blending of various grades of wheat in a mixer;
(b) scalping, screening, and aspirating the grain for a final cleaning;
(c) washing grain to toughen the outside bran layer so it will separate easily;
(d) rolling, screening, and sifting grain in a series of operations to yield flour;
(e) additional processing as desired, e.g. bleaching and enrichment; and,
(f) packaging.

The only air pollution problem of any consequence is the movement of the raw grain, as previously discussed. All emissions from the milling operation are usually well contained within the building itself by use of a closed cleaning system and the recycle of air from cloth-type filters (air-cloth ratios 3:1 to 4:1). The chief dust problem specific to the flour-milling operation is the loading of chaff and middlings into rail cars.

Other grains, e.g. corn, rice oats, barley, buckwheat and rye are secondary to wheat milling. As in the case with wheat, the major dusty operations are loading and unloading cars and cleaning the grain.

Buckwheat and rye are milled in a manner quite similar to wheat, other grains are processed by modified methods directed to separating the hulls, germ and bran from the endosperm. In the case of rice, an endosperm of maximum grain size is desired. Processing of all these grains involves grinding and separation of fine or lightweight material - cyclone separators are attached to nearly every piece of separation equipment. If the dust loss becomes a nuisance, the cyclones are backed up with cloth collectors.

Barley malting is a specialized process in which cleaned barley grain is germinated to increase its content of the enzyme, diastase. The germination is later stopped by drying the malt in a rotary kiln. The dried malt is separated from sprouts and other waste material and shipped to breweries or food manufacturers.

Table I.(v).5. Particulate Emission Factors for Grain Handling and Processing

Type of source	Emissions kg/tonne
Terminal elevators	
Shipping or receiving	0.5
Transferring, conveying, etc.	1
Screening and cleaning	2.5
Drying	3
Country elevators	
Shipping or receiving	2.5
Transferring, conveying, etc.	1.5
Screening and cleaning	4
Drying	3.5
Grain processing	
Corn meal	2.5
Soybean processing	3.5
Barley or wheat cleaner	0.1[a]
Milo cleaner	0.2[a]
Barley flour milling	1.5[a]
Feed manufacturing	
Barley	1.5[a]

[a] at cyclone exist (non ether soluble particulates)

Although the grain is cleaned prior to malting, continual handling of the malting grain releases dust all through the process It is captured in cyclone collectors and sold as animal feed.

The wet milling of corn yields cornstarch and its derivatives as end products. It is called wet milling because the corn is soaked (steeped) in a water solution of sulphur dioxide prior to the subsequent separations, and because water is used in large quantities in nearly every step of the process. Grain handling and finished product drying and blending are the only dust problems of note. At one time, sulpher dioxide emissions were a problem, but modern separation processes have reduced losses to almost nil.

In some of the older corn wet-milling plants, odours from the gluten settlers were a problem. Gluten was concentrated by settling in open tanks prior to filtration and drying. When the gluten was allowed to stand too long in the wet state or if spillage was not controlled, putrid odours developed. Rapid handling of gluten liquors and good sanitation practice has solved the problem in modern plants.

Factors affecting emissions from grain processing operations include the type of processing (wet or dry), the amount of grain processed, the amount of cleaning, the degree of drying or heating, the amount of grinding, the temperature of the process and the degree of control applied to the particulates generated.

Particulate emission factors for selected grain-processing operations are shown in Table I.(v).5.

I.(v).5.2. Drying and mixing

Whenever a powdered or dry product is desired, the final operation is drying. In the corn wet-milling process, for instance, the final wet products are a starch cake and a gluten cake. Similar cakes result from the wet processing of grain sorghum or various roots, e.g. potatoes, cassava (tapioca) and sago.

In any event, washed starch (or gluten) is fed to a rotary or belt dryer where it meets warm air usually in a countercurrent fashion. Some fine dried particles are picked up by the airstream and blown from the dryer. Usually the product is sufficiently valuable to warrant capture in a cyclone or bag collector. Similar equipment is used in the drying of sucrose (cane sugar) and dextrose (corn sugar).

In the past 15 years, spray drying operations have become widespread in the food industry. They dryer is so designed and operated that the resulting dried powder is uniform in size, denatured only slightly if at all, and readily soluble. Among the more common products are milk powder, coffee, tea, corn syrup solids, starches, potatoes, eggs, cheese, fruit and vegetable powders.

All dryers use cyclone collectors to collect the fine particles. Dust losses are normally less than 0.1% of product. In some areas regulations require even greater efficiency, in which case the cyclone must be backed up with a cloth collector, unless the material is hygroscopic. If this is the case a wet scrubber may be required.

Highly restrictive emission requirements have created difficult economic problems in those operations where large excesses of drying air are required to prevent deposition of moisture in fabric filters, or to prevent dust explosions. In either case, the size of the required fabric filter or scrubber may well be greatly out of proportion to the size of the basic dryer. After a product is dried, it is often blended with other dry products to form a dry food mix. The manufacture of dry food mixes which require a minimum of preparation before serving is a rapidly expanding business.

Among these convenience foods are cake and biscuit mixes, puddings, gelatin desserts, pie crusts, hot and cold cereals, soft drink powder, soups, dehydrated vegetables, etc. Processing entails drying, grinding, and pulverization, mixing, conveying and packaging, all operations that produce dust (usually 10-100m particle size). For economic reasons, dust recovery is almost universal. Both cyclones and cloth collectors are used.

I.(v).5.3. Feed manufacture

Feed manufacture can be divided into a) mixed feeds and b) by-product feedstuffs.

I.(v).5.3.1.Mixed feeds

Nearly all grain-handling and grain-processing operations involve by-product material which ends up in animal feed, e.g. cracked grain from elevators and cleaning operations: bran middlings and shorts from flour milling: bran and fibre from the milling of minor grains: gluten and steepwater solids from corn wet milling: spent grain and distillers' solubles from the fermentation industry: beet pulp from the beet-sugar industry. In addition, by-products of the meat packing and milk industries also end up in animal feeds. Alfalfa, molasses, calcium salts, and phosphates are further constituents.

Unloading the bulk grains and grain products from box cars and transporting them to bins are the chief dust-producing operations of the industry. Alfalfa is particularly dusty and must be handled carefully. After the raw materials are unloaded, the grains and other granular materials are ground in a hammer mill, then mixed - usually in continuous operations. When molasses is added, a batch mixing process is normally used. In either case, the mixtures are later moistened with steam and forced through dies to produce pellets. Both the grinding and mixing operations are dusty, but the dust may be adequately controlled with cyclones or cloth collectors.

The principal problem during pelleting is emission of odours. The odours are particularly strong and unpleasant when feeds contain large quantities of tankage and bone meal. The only solution is treating the exhausted air in scrubbers or incinerators, or passing it through a bed of activated charcoal.

I.(v).5.3.2.By-product feedstuffs

Air pollution problems accompanying the recovery of by-product feedstuffs are those inherent in the manufacture of the main food product. Whenever the by-product is high in protein value, it is dried, ground and sold as a high-protein feed, or mixed with low-protein by-products (chaff, hulls, bran, etc.) to increase the food value of the latter. Among the more important high-protein feeds are corn gluten meal, oil-seed meals, dried distillers' solubles, fish meal and various animal residues (blood, tankage, etc.)

Corn gluten meal is a by-product of the wet milling of corn, a process in which whole grain corn is steeped in a dilute sulphurous acid solution and subsequently separated into starch, fibre, gluten and corn germ. The separated gluten is concentrated and dried to produce a corn gluten meal. Some of the gluten meal is mixed with coarse and fine fibre (hulls and bran) and other low protein by-products to make a lower grade feed than the meal itself. Drying and handling of the final feed produces dust which may be controlled by cyclone collectors, or cloth collectors when necessary.

Oil-seed meals, eg. cottonseed meal, flaxseed meal, safflower-seed meal, are by-products of the recovery of vegetable oils by pressing or solvent extraction. Excessive loss of solvent vapours during extraction or subsequent steaming of the meal may produce a localized odour problem. Usually the solvent is valuable enough to warrant recovery by condensation or adsorption on activated charcoal. Subsequent processing of the oil may release odourous compounds.

Brewers' grains, distillers' dried grains, and distillers' solubles are all by-products of the brewing and distilling industry. Air pollution may arise from (1) raw material preparation, (2) the fermentation process, and (3) solid and liquid waste disposal. Fermentation odours are usually not strong enough to be objectionable. If they are, vent gases or air from the vicinity of the source may be passed through scrubbers or activated carbon adsorbers. Dust and odours from feed dryers may be controlled by means previously described.

I.(v).6. <u>Fruit and Vegetable Processing</u> (See also section I.(v).7.1.)

Each food processing plant has wastes of different quantity and quality. No two plants are the same and estimates of residues generated from each plant must be regarded as approximate. Few plants have adequate knowledge of the volumes, characteristics, and fluctuations of their wastes. At each processing plant, material and water balances on the inputs and outputs to the plant can provide reasonable estimates of the total waste flow and residue generation.

Much of the available information on food processing waste characteristics is not comprehensive. Average waste loads reported in the literature should be regarded as guidelines rather than exact values that can be extrapolated to different plants.

Food processing wastes result from the washing, trimming, blanching, pasteurizing, juicing of raw materials, the cleaning of processing equipment, and the cooling of the finished product. The characteristics of food processing wastes are such that they generally are low in nitrogenous compounds, have a high oxygen demand, and undergo rapid decomposition.

The effluent consists mainly of carbohydrates such as starches and sugars, pectins, vitamins, and other components of the product cell walls which have been leached during processing. Of the total organic matter, 70 - 85% can be present in the dissolved form. These dissolved solids are not removed by mechanical or physical separation methods, although they can be stablised and/or removed by biological or chemical oxidation and adsorption.

Some wastes, such as those from beet processing, are highly coloured. Fresh wastes generally have a pH close to neutral. During storage the pH decreases. In addition to the organic content, fruit and vegetable processing wastes can contain other pollutants such as soil, lye, heat and insecticides.

The pH values of some fruit and vegetable processing wastes result from the use of caustics such as lye in peeling. These caustic solutions can have a pH about 12 - 13 and are discharged intermittently as they lose their strength resulting in slug loads to the waste treatment facilities. Pickle and sauerkraut wastes are acidic and contain large chloride concentrations as well as organic matter.

The only important air pollution problem is related to the disposal of hulls, leaves, rinds, pods, cuttings, etc. If held too long these materials decay and produce revolting odours.

Water pollution regulations prohibit sending waste to streams unless it has been processed to reduce biological oxygen demand (BOD). One method commonly used to reduce BOD is digestion of the waste in anaerobic or aerobic lagoons. Even the best-operated lagoons have upsets during which odourous gases (hydrogen sulphide, mercaptans, fatty acids, amines and other nitrogenous compounds, or masking agents) may be released on the downwind side of the lagoon. If the condition persists, precipitation of excess sulphide, reestablishment of the active organism or chemical treatment may be required. Addition of sodium nitrate to a concentration of 20% of the oxygen demand is used to control all but the most persistent odours, e.g. from pea processing (W. S. Atkins, 1977). Some food processors have replaced lagoons with spray irrigation plants to advantage and leaves, stalks, and cuttings can sometimes be disposed of odourlessly in adequately designed incinerators. Sanitary landfill is an alternate method.

Special situations arise when processing certain fruits and vegetables by specific methods. Thus corn driers often emit "beeswing" chaff and dust (from shelling the corn). The drying of peaches involves the use of sulphur dioxide, some of which escapes to the atmosphere. Both of these are comparatively minor emissions and may be handled by proper zoning. In plants extracting castor beans, castor bean dust must be minimised. The ricinin in the dust may provoke bronchial asthma.

Table I.(v).6. presents the average characteristics for U.S. plants processing fruits, vegetables, and some specialty foods. Wastewater volumes and waste generation vary significantly between categories and between plants

TABLE I.(v).6.

Raw Waste Loads a) for the Fruit and Vegetable Processing Industry b)

Category	Flow m^3/tonne	BOD kg/tonne	Total suspended solids kg/tonne
Fruit			
Apple Processing	3.09	1.8	0.3
Apple Products except juice	5.77	5.7	0.7
Apricots	25.3	13.8	4.0
Caneberries	6.3	2.5	0.6
Cherries			
sweet	8.3	8.8	0.6
sour	12.9	15.6	1.0
brined	21.2	19.8	1.3
Cranberries	13.2	9.1	1.3
Citrus			
all products	10.8	2.9	1.2
Dried fruit	14.2	11.2	1.7
Grape juice			
canning	7.7	9.8	1.2
pressing	1.7	1.8	0.4
Olives	40.9	39.0	6.7
Peaches			
canned	14.0	12.8	2.1
frozen	5.8	10.7	1.7
Pears	12.8	19.0	2.9
Pickles			
freshed packed	9.1	8.6	1.8
process packed	10.3	16.4	2.9
salting stations	11.2	7.1	0.4
Pineapples	14.0	9.2	2.5
Plums	5.3	3.9	0.3
Raisins	3.0	5.4	1.5
Strawberries	14.1	4.8	1.2
Tomatoes			
peeled	9.6	3.7	5.5
products	5.1	1.2	2.4

continued

TABLE I.(v).6. Continued

Category	Flow m^3/tonne	BOD kg/tonne	Total suspended solids kg/tonne
Vegetables			
Asparagus	7.4	1.9	3.2
Beets	5.4	17.6	3.5
Broccoli	49.0	8.8	5.0
Brussel Sprouts	39.0	3.1	9.5
Carrots	13.0	17.4	10.7
Cauliflower	96.1	4.7	2.3
Corn			
canned	4.8	12.9	6.0
frozen	14.3	18.0	5.0
Dehydrated onion and garlic	21.3	5.8	5.3
Dehydrated vegetables	23.7	7.0	5.2
Dry Beans	19.3	13.7	4.0
Lima Beans	29.1	12.4	9.3
Mushrooms	24.1	7.8	4.3
Onions - canned	24.7	20.1	8.5
Peas			
canned	21.1	19.7	5.0
frozen	155.7	16.3	4.4
Pimentos	30.9	24.3	2.7
Sauerkraut			
canning	3.8	3.1	5.5
cutting	0.5	2.4	0.2
Snap Beans			
canned	16.5	2.8	1.8
frozen	17.1	5.4	2.7
Spinach			
canned	40.5	7.3	6.0
frozen	31.4	4.3	1.8
Squash	6.0	15.0	2.1
Sweet potatoes	4.4	26.9	10.4

continued

TABLE I.(v).6. Concluded

Category	Flow m^3/tonne	BOD kg/tonne	Total suspended solids kg/tonne
White Potatoes	8.9	24.4	33.3
Potatoes - frozen	12.1	20.4	17.3
dehydrated	9.4	9.8	6.6
Specialty Foods			
Baby Food	7.9	40.0	1.5
Chips - corn	12.9	31.4	26.7
potato	25.2	33.1	37.7
tortilla	21.8	26.5	32.2
Jams and Jellies			

a) The raw waste load is in terms of the quantity of wastewater parameter per ton of raw material processed for fruits and vegetables and per ton of final product for the speciality foods. The values noted are the average raw waste loads for the available data in the categories noted. Except where noted, the raw waste loads are those generated from canning processing.

b) Derived from: Environmental Protection Agency, Development Document for Interim Final and Proposed Effluent Limitations Guidelines and New Source Performance Standards for the Fruits, Vegetables, and Specialties Segment of the Canned and Preserved Fruits and Vegetables Point Source Category, "EPA 440/1 - 75/046, Group 1, Phase II, Washington, D.C., October 1975.

Environmental Protection Agency, "Development Document for Effluent, Limitations Guidelines and New Source Performance Standards for the Apple, Citrus, and Potato Processing Segment of the Canned and Preserved Fruits and Vegetable Point Source Category "EPA-440/1-74-027a, Washington, D.C. March 1974.

TABLE I.(v).7.

Average Wastewater Characteristics in the Specialty Food Industry a/

Category	Parameter b/						
	Flow	COD	BOD	SS	Total P	TKN	Grease
Prepared Dinners	12,000	34	17	14	0.19	0.44	15
Frozen Bakery Products	11,000	52	23	14	0.08	0.30	11
Dressings, Sauces, and Spreads	2,800	13	7.5	3.5	0.03	0.04	5.7
Meat Specialities	10,000	19	9.9	6.1	0.10	0.57	4.0
Canned Soups and Baby Foods	22,000	20	12	7.6	0.18	0.47	2.4
Tomato-Cheese-Starch Combinations	29,000	17	7.2	6.0	0.28	0.23	4.7
Sauced Vegetables	85,000	45	25	21	0.33	1.1	-
Sweet Syrups, Jams and Jellies	2,400	8.7	5.1	1.0	0.05	0.04	0.6
Chinese and Mexican Foods	14,000	12	6.9	2.8	0.14	0.28	3.0
Breaded Frozen Products	48,000	53	26	26	0.35	2.6	-

a/ Schmidt, C.J., Farquhar, J., and Clements, E.V., "Wastewater Characterization for the Specialty Food Industry," Environmental Protection Agency, Rept. of Grant R-801684,EPA 660/2-74-075, December 1974, Washington, D.C.

b/ flow - liters/kkg of product; COD, BOD, suspended solids (SS),total P, total Kjeldahl nitrogen (TKN) and grease - kg/kkg of product.

within categories. Table I.(v).7. shows the average waste water characteristics in the speciality food industry.

I.(v).6.1. Specialist Processing

Coffee roasting, production of spices and flavouring, alfalfa dehydration or any process that requires drying or grinding, is likely to require particulate and odour treatment. High BOD effluents are also a likely emission. Sugar refining also produces particulate and gaseous emissions as well as a high BOD effluent.

Cooking of vegetable matter is also likely to produce additional BOD and particulate/gaseous emissions. Odour is also often a significant problem.

I.(v).7. Canning

Preserving food (by drying, canning, freezing, etc.) frees the consumption of perishables from the seasonal pattern of the catch or harvest and permits their stockpiling for future use.

Canning is the principal method of preserving food. The industry has a strong impact on nutrition, uses an easily accessible and relatively labour-intensive technology, and generates singificant quantities of pollutants. See Fig. I.(v).2.

Food canning generates mainly water pollutants, and some odour problems, and cooking and drying operations generate small quantities of air pollutants. The amount and character of the air pollutants depend on the combustion fuel used and operating conditions. Abatement measures may be advisable in sensitive areas and where low-polluting fuels are not available. However, the air pollution problem is relatively small.

There are two significantly different canning processes producing different types and quantities of pollution. They are:

i) fruit and vegetable canning
ii) seafood canning.

Meat products are also canned, as well as other commodities, but are not considered here.

A large proportion of wastes contain an increased Biochemical Oxygen Demand (BOD) and Suspended Solids (SS). Waste treatment often occurs at municipal sewage works. Since cannery wastes are readily biodegradable, they are compatible with biological treatment processes, although in some cases supplementary nutrients (nitrogen and phosphorus) must be added. The major problems encountered are the seasonal nature of the many canneries, which can create over-loads at the sewage-treatment plant, and slug discharges, which can lead to process upset. To minimise these problems, water reuse and proper pretreatment (screens and some equalisation of concentrated wastes) should be instituted.

Wastewater volumes and characteristics from cannery operations will vary markedly depending upon the type of raw product, the extent of hydraulic transport of the product, recirculation of process waters, and in-plant transport of solid waste materials. Significant pollutants will result from hot lye peeling, sorting, slicing, etc.; washing and cooling of cans; and plant cleanup.

I.(v).7.1. <u>Fruit and vegetables</u> -(See also section I.(v).6 and Table I.(v).6.)

Since harvesting and processing of vegetables and fruits is short, many canneries are capable of dealing with more than one variety. The general processing steps include: receiving and washing, preparation, processing, and packaging.

Washing, used for both cleaning and cooling, occurs at several points in the process. Washing and rinsing may use one-half or more of total process water. Wastes from initial washing include soil, sand, stones, insecticides, vegetation, dried juices, and other residues which are washed from the product. The quantity of impurities will depend on the type of harvesting, increasing with mechanical crop picking. Detergents are sometimes added to the wash water to aid cleaning.

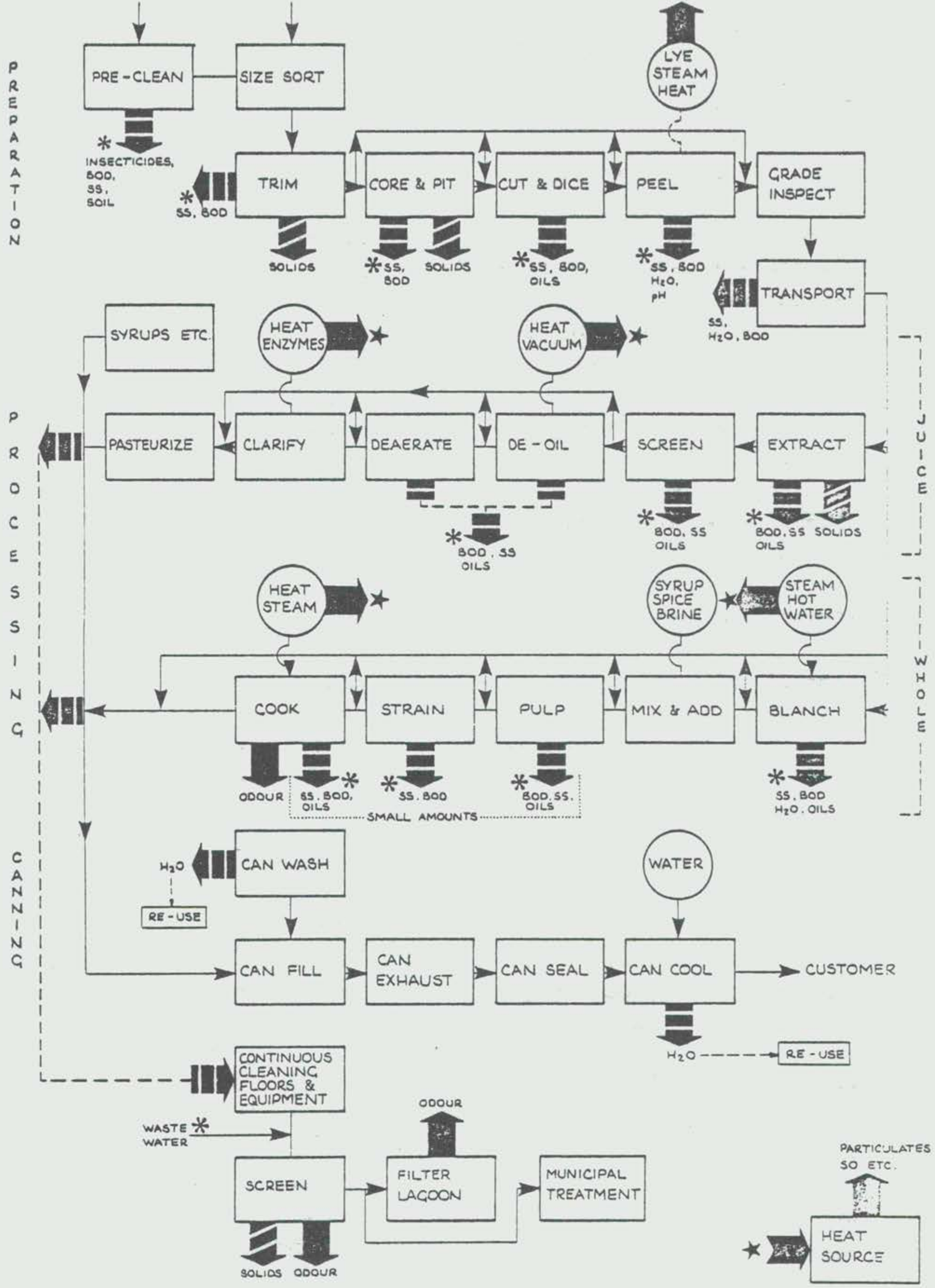

Fig. I(v)2 Vegetable and Fruit Canning

Preparation operations include sorting; stemming, snipping, and trimming; and peeling and coring. Many types of fruit and vegetables are sized to facilitate subsequent operations (such as pitting, peeling, and filling) and to meet final product requirements. Sorting methods include hand sorting, density graders, flotation, and screening. Many fruits and vegetables must be peeled before processing. This also removes any remaining dirt and pesticide residues. Peeling may be done mechanically (by cutting or abrasion), thermally (loosening the peel by applying steam, hot water, hot oil flame, or heated air), or chemically (usually with caustic soda to soften the peel enough to permit removal by high pressure water spray).

Some liquid waste, such as juices and equipment wash water, results from cutting. Peeling by hand, steam, machines, or chemicals yields a large volume of wastewater with a high BOD. Peeling in a lye solution is common, resulting in a wastewater highly alkaline but with a low concentration of dissolved organic matter.

The final step in initial preparation transports the product by conveyor or flume to the converted product-handling process. Flume water is high in volume and organic load and is frequently reused. Intial preparation contributes up to 50 per cent of

TABLE I.(v).8. **Daily Waste Quantities from Unit Processes**

Process	Wasteload,	lb/day/case	(kg/day/case)	Wastewater Volume (gal/case)(l/case)
	BOD	SS	TDS	
Washing	0.050–0.3	0.05–0.4	300–1.500	08.0–25.0
	0.023–0.140	(0.023–0.18)	(140–680)	(30.3–94.7)
Belt conveyor	0.003–0.001	0.01–0.02	30–100	01.0–05.0
	(0.0014–0.00045)	(0.0045–0.0091)	(14–45)	(3.8–18.9)
Sorting, pitting, slicing, and so on	0.005–0.06	0.015–0.070	100–500	01.0–0.75
	(0.0045–0.027)	(0.0068–0.032)	(45–230)	(3.8–28.4)
Blanching and/or peeling	0.1–0.4	0.10–0.4	2.000–4.000	06.0–25.0
	(0.045–0.18)	(0.045–0.18)	(900–1800)	(22.7–94.7)
Exhausting of cans	0–0.015	0–0.015	0–200	0–02.5
	(0–0.0068)	(0–0.0068)	(0–90)	(0–9.5)
Processing	0.005–0.06	0.005–0.0450	40–1.200	01.0–05.0
	(0.0045–0.027)	(0.0045–0.020)	(18–540)	(3.8–18.9)
Cooling of cans	0.005–0.06	0.005–0.0300	300–1.000	06.0–30.0
	(0.0045–0.027)	(0.0045–0.014)	(140–450)	(22.7–113)
Plant cleanup	0.032–0.12	0.030–0.15	230–1,000	06.0–20.0
	(0.0145–0.054)	(0.014–0.068)	(104–450)	(22.7–75.8)
Box washing	0.01–0.025	0.015–0.04	200–500	02.0–05.0
	(0.0045–0.011)	(0.0068–0.018)	(91–230)	(7.6–18.9)
Total	0.26–1.05	0.23–1.17	3,200–10 000	31.0–125.0
	(0.12–0.48)	(0.10–0.53)	(1,400–4,540)	(113–475)
Average	0.7	0.8	7,500	075.0
	(0.32)	(0.36)	(3,400)	(284)

TABLE I.(v).9. **Typical Canning Wastes**

Product	Waste Volume, gal/(l/case)	5-Day BOD		Suspended Solids	
		mg/l	lb/(kg/case)	mg/l	lb/(kg/case)
Apples	29–46 (110–174)	1680–5530	0.64–1.31 (0.29–0.60)	300–600	0.10–0.20 (0.045–0.091)
Apricots	65–91 (246–344)	200–1020	0.15–0.56 (0.068–0.25)	200–400	0.14–0.25 (0.064–0.11)
Cherries	14–46 (53–174)	700–2100	0.16–0.50 (0.073–0.23)	200–600	0.05–0.14 (0.023–0.064)
Cranberries	11-23 (42–87)	500–2250	0.10–0.21 (0.045–0.095)	100–250	0.02–0.05 (0.091–0.023
Peaches	51–69 (193–261)	1200–2800	0.69–1.20 (0.31–0.55)	450–750	0.24–0.34 (0.11–0.15)
Pineapples	74 (280)	26	0.002 (0.00091)	—	—
Asparagus	80 (303)	16–100	0.01–0.07 (0.0045–0.032)	30–180	0.02–0.12 (0.091–0.055)
Beans, baked	40 (151)	925–1440	0.31–0.48 (0.14–0.22)	225	0.07 (0.032)
Beans, green wax	30–51 (114–193)	160–600	0.15–0.67 (0.068–0.30)	60–150	0.02 0.04 (0.091–0.018)
Beans, kidney	20–23 (76–87)	1030–2500	0.19–0.45 (0.086–0.20)	140	0.02 (0.091)
Beans, lima, dried	20–23 (76–125)	1740–2880	0.30–0.60 (0.14–0.27)	160–600	0.05–0.10 (0.023–0.045)
Beans, lima, fresh	57–294 (216–1110)	190–450	0.21–0.47 (0.095–0.21)	420	0.20–1.02 (0.091–0.46)
Beets	31–80 (117–303)	1580–7600	1.00–2.00 (0.45–0.91)	740–2220	0.50–1.00 (0.23–0.45)
Carrots	36 (136)	520–3030	0.11–0.67 (0.05–0.30)	1830	0.40 (0.18)
Corn, cream style	28–33 (106–125)	620–2900	0.17–0.66 (0.077–0.30)	300–675	0.07–0.17 (0.032–0.077)
Corn, whole kernel	29–80 (110–300)	1120–6300	0.74–1.50 (0.33–0.68)	300–4000	0.20–0.95 (0.091–0.43)
Mushrooms	—	76–850	4.77–53.38 (2.16–24.2)	50–240	3.14–15.07 (1.42–6.83)
Peas	16–86 (61–326)	380–4700	0.27–0.63 (0.12–0.29)	270–400	0.06–0.20 (0.27–0.091)
Potatoes, sweet	90 (340)	1500–5600	1.10–4.40 (0.50–2.0)	400–2500	0.31–1.95 (0.14–0.88)
Potatoes, white	—	200–2900	—	990–1180	—
Pumpkin	23–57 (87–216)	1500–6880	0.72–1.31 (0.33–0.59)	785–1960	0.38 (0.17)
Sauerkraut	3–20 (11–76)	1400–6300	0.10–0.30 (0.045–0.14)	60–630	0.01–0.10 (0.0045–0.045)
Spinach	180 (68)	280–730	0.42–1.11 (0.19–0.50)	90–580	0.14–0.88 (0.063–0.40)
Squash	23 (87)	4000–11.000	0.76–2.09 (0.34–0.95)	3000	0.57 (0.26)
Tomatoes	3–114 (11–432)	180–4000	0.11–0.17 (0.050–0.077)	140–2000	0.06–0.13 (0.027–0.059)

the total wastewater flow, almost all the suspended solids, and a significant part of the organic load.

Processing includes such operations as slicing, deaerating, blanching, canning, and sauce or molasses production. Slicing is sometimes done in conjunction with pitting or coring and sometimes separately. The product may be halved, cut into segments or flat rings, or diced. Methods used to puree and juice include hydraulic presses, pulpers, and vibrating screens. Deaeration uses a vacuum to remove oxygen and other gases present in freshly processed fruit and vegetable juices. Deaeration improves colour and flavour and reduced foaming during filling and separation of suspended solids.

Vegetables may be blanched to remove air or solubles, fixate pigment, inactivate enzymes, protect flavour, leach out undesirable flavours or components, shrink tissue, increase temperature, or destroy microorganisms. The several ways to blanch fall into two categories: hot water blanching and steam blanching.

The wastewater from blanching is hot and contains dissolved organic matter. Pulping, straining, and cooking in vats may contribute some wastes from spillage. Considerable waste may result from the washing and cleansing of vats, pulps, etc.

In the canning process, cans are washed before being filled. Depending on the product the fruit or vegetable is put into the can by hand or semi- or fully-automatic machines. The cans are then exhausted to achieve a vacuum and preserve product quality. Finally the containers are sealed (usually mechanically). The can or jar contains a sterilised product which will stay unspoiled indefinitely. Labeling and final packaging complete the canning process.

A large volume of relatively clean water results from the canning and cooling operations. This water can be reused in flume transportation, product washing, and can cooling.

Tables I.(v).8. and I.(v).9. show daily waste quantities per process and typical canning wastes.

I.(v).7.2. Seafood canning   Figure I.(v).3.

Specifics of the process depend on the type of seafood being processed. Receiving the raw proudct and transferring it to the processing area may be done by water flume, conveyor, or container. Although fluming is usually the cheapest and most efficient method, many plants are replacing it with one of the other methods because it is highly polluting.

Preprocessing (preparing the fish or other seafood for subsequent processing steps) involves a variety of steps, including washing dredged crabs, thawing frozen fish, and de-icing shrimp. Seafood is frequently frozen on fishing boats to preserve the catch until the ship returns to port. The catch must then be thawed before processing. In the traditional flow-through system, the catch is put in a large container and water passed through to thaw it. This requires large volumes of water and results in significant pollution. New methods used by some canners to reduce the water flow include heating and recycling the entering water.

After preprocessing, the catch is butchered and eviscerated. The resulting wastes are usually screened from the waste stream and used for by-product production. The butchered fish then are usually precooked to prepare them for picking and cleaning. Precooking facilitates removing the skin, bones, shells, and other unwanted parts. In tuna processing, the steam condensate (stick water) from precooking is usually collected and transferred to a solubles plant for by-product recovery.

Picking and cleaning, the final preparation for canning, separates the edible from the inedible parts of the product. Wastes from this are usually used in by-product processing. The inedible portions may be separated into those fit for human and those fit for animal consumption, with the latter (usually mixed with other food elements) canned as pet food.

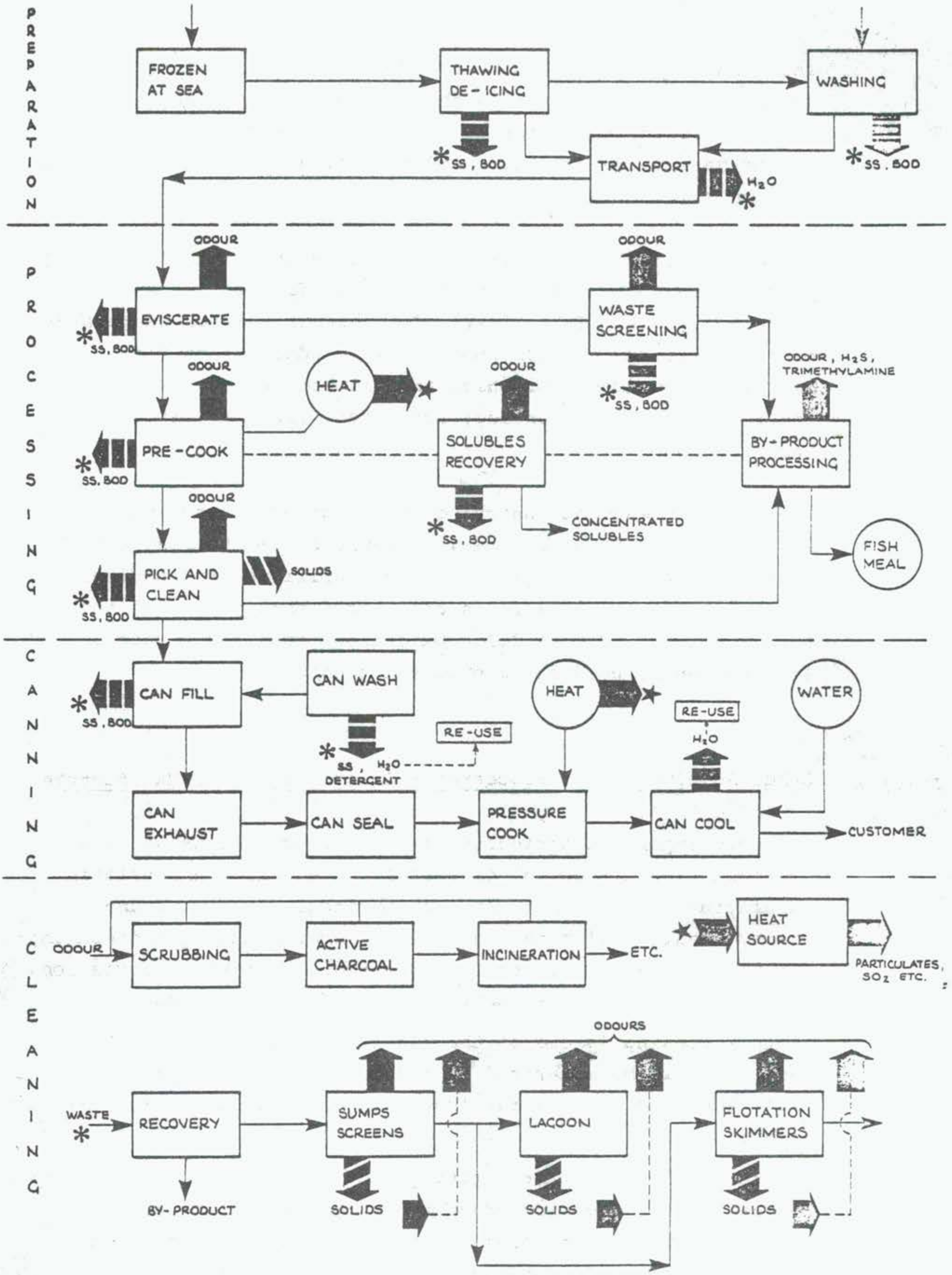

Fig. I(v)3 Seafood Canning

The canning process steps are similar to those for fruit and vegetables. The cans are washed and packed, sealed under a vacuum, washed, and retorted (pressure cooked to kill microorganisms which would lead to spoilage). The final step is labeling.

The major pollutants generated by each step in the production process are BOD and SS, with some odour from the fish meal reduction plant. Table I.(v).10. presents average wastewater characteristics for each subcategory. Odour (resulting mainly from hydrogen sulphide and trimethylamine) can be controlled by wet scrubbing, activated carbon adsorption, or incineration.

Wastewater treatment control options include mechanical, biological and physical-chemical methods. Mechanical control uses screens, centrifuges, gravity clarifiers, and sedimentation. Rotary or tangential screens can remove more than half the total solids, and some COD. Oxidation ponds and aerated lagoons can be used for biological treatment.

I.(v).8. Other Agroindustrial Processes - Tanning and Glue Manufacture

The more important agricultural process operations where a potential for air pollution exists include glue and gelatin manufacturing: leather tanning, particularly liming and bating: curing of hides and pelts: wool scouring and combing: degreasing: hair recovery and cleaning: feather utilization: tobacco curing and the manufacturing of tobacco products.

Leather tanning is one of the oldest industries in the world, and is still characterized by its many small producers. Cattlehide tanning dominates the industry, although there is some sheepskin tanning.

The chief air pollutants arising from the several operations in the tannery are reduced sulphides, protein derivatives, organic sulphides, and organic acids, principally the highly repelling compound, caproic acid. All are highly odourous.

TABLE I.(v).10

AVERAGE WASTEWATER PARAMETERS: SEAFOOD CANNING

Wastewater Characteristic	Industry Subcategory			
	Catfish Species	Blue Crab	Shrimp	Tuna
Flowrate (10^3 liters/kkg)[a]	19	1.2	47	18
pH	6.4	7.6	6.7	6.7
Pollutants (kg/kkg[a])				
Suspended solids	8.46	0.79	37.60	12.06
BOD_5	7.90	5.25	51.70	16.20
COD	16.00	7.64	108.10	39.60
Grease and oil	4.88	0.26	12.22	6.48
Organic nitrogen	0.62	0.94	9.40	1.08
Ammonia - N	0.02	0.06	0.56	0.13

[a] Per kkg of final product.

Sulphides may be removed from emitted air streams by treatment with activated charcoal: caproic acid by incineration. Considerable dust arises from shaving and buffing leather. It may be controlled by a wet dust collector.

Animal and fish glue manufacture entail the hydrolysis of low-purity waste products of meat packers and tanners and the waste from fish canneries. Inasmuch as these wastes are proteinaceous in character, odorous decomposition products are evolved during cooking and drying operations. Scrubbing effluent gases with a solution of sodium hypochlorite is said to be effective in reducing odours.

Wherever spoilage (protein and carbohydrate decomposition) takes place there is a potential for an odour problem. Wherever the material is ground, or where dust or other fine material is handled or processed, there is potential for a dust problem.

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I.(vi). PULP AND PAPER PROCESSING

I.(vi).1. Introduction

Chemical wood pulping involves the removal of cellulose from wood by dissolving the lignin that binds the wood fibres together. Of the principal processes used in pulping, one is by mechanical grinding and the remainder (kraft, sulphite and neutral sulphite semichemical (NSSC)), are by chemical action. The choice of pulping processes is determined by the product being made, by the type of wood species available, and by economic considerations. Chemical pulping is most frequently used and produces greater pollution problems. Most concern therefore centres on this form of pulping.

Pulp and paper mills may include several types of operation relative to the raw material used and the preparation of it. Pulp mills include wood preparation, pulping, washing, screening, thickening and bleaching. Paper mills include stock preparation, paper-machine operation, converting and finishing.

The industry produces two main effluents, pulp mill and paper mill wastes. The waste characteristics will vary depending upon the manufacturing processes used, end products manufactured and degree of product recovery. Pulp mill wastes are generated from debarking, grinding, digester cooking, washing, bleaching, chemical recovery and de-inking (from waste paper pulp production). These effluents can contain spent cooking liquor, fine fibres, ligneous compounds, bleaching chemicals, organosulphur compounds, sodium sulphides, carbonates and hydroxides. Paper mill wastes originate in water which passes through the wire screens, showers and felts of the paper machines. The wastes (white waters) can contain fine fibres, sizing, dye, casein, clay ink, waxes, grease, oil and other materials, depending upon the additives used in the paper production.

Significant effluent characteristics of the pulp and paper industry are suspended solids, BOD_5, COD, colour, toxicity, sulphite and pH. Coliform (Klebsiella pneumoniae) could also be a characteristic that needs consideration.

Toxic compounds can also be present in the form of organic compounds for preservation of wood, as a means to control slime growth on pulp and paper machines or mercury found in traces in the electrolytically produced chemicals (such as sodium hydroxide) used in bleaching; and zinc compounds, as brightening agents for mechanical pulp, still used in a few countries, can also be present. However, the general trend is to replace and substitute both these metals in the manufacturing processes.

Particulate and gaseous emissions also emanate from the processing plants.

The emission of SO_2 in the pulp and paper industry is most acute in sulphite mills, but with sound operating practices and appropriate abatement methods, could be signficantly controlled and reduced. However, difficulties arise with the waste liquor burning plants.

Non viable particulates can be subclassified as dusts, fumes and mists. In kraft pulp mills for example, particulates occur primarily from the recovery furnace, the lime kiln and the smelt dissolving tank. They are caused mainly by the sublimation and condensation of inorganic chemicals. In addition, particulate emissions occur from power boilers and boilers fired with bark in combination with other fuels.

From the lime kiln, particulate emissions consist principally of sodium salts, calcium carbonate and calcium oxide, whilst from the smelt dissolving tanks, particulates are caused primarily by the entrainment of particles in the vent gases.

Depending upon the physical, chemical and biological characteristics of particulates, the effects on human health, vegetation, materials and meteorology can be different. However, the effects on particulates in conjunction with oxides of sulphur have been confirmed to be more pronounced than when considered separately.

Odour is an environmental problem, especially in the kraft industry, where problems arise from the use of sodium sulphide as one component of the digesting liquor. In the digesters, evaporators, recovery boiler, and lime kiln, hydrogen sulphide is evolved. Other organic sulphides such as methyl mercaptan, CH_3SH, dimethyl sulphide, $(CH_3)_2S$, and dimethyl disulphide $(CH_3)_2S_2$ are also formed. These sulphides are extremely malodourous and can be detected at concentrations as low as 1 part per billion.

The pulp industry generates a large amount of solid wastes comprising such components as bark, sludge, ash, etc. The bark content of wood is estimated to represent between 8 and 13 percent by weight and in the pulping industry, about 70-80 percent of barking is carried out at the mill site. Normally, bark is burned to generate steam and hence air pollution abatement equipment would have to be installed to alleviate this form of environmental problem. A growing problem for the industry is to find acceptable means to dispose of the large quantities of sludge that result from its effort to reduce the suspended solids loads.

I.(vi).2. Process and Emissions

Tables I.(vi).1. and I.(vi).2. summarise effluents and emissions from pulp and paper processing.

I.(vi).2.1. Preparation

Wood is initially moved from the stockpile through a

Table I.(vi).1. - Effluents from Pulp and Paper Processing Wasteload in Kg/tonne of Product

	SS		DS		BOD		pH	
	Current	Modern	Current	Modern	Current	Modern	Current	Modern
Wood Preparation	4	1	2	1	1	0.1	7	6.9
Pulping								
Sulphate (Kraft)	8	1.3	63	35	10	9	11	9.5
Sulphite	13	5	170	129	105	31	5	2.5
Semichemical	9	-	66	-	14	-	2.5-4	-
Screening								
Sulphate	2	v. litte	25	v. little	16	v. little	10	v. little
Sulphite	4		8.4		4		5.6	
Semichemical	-		-		-		-	
Washing/thickening								
Sulphate	7	7	56	16	11	4	9	9.5
Sulphite	4	3	55	28	8	5	3	3.9
Semichemical	1	-	40	-	10	-	7	-
Bleaching								
Sulphate	-	(0.9)	-	(55)	-	3	-	4.4
Sulphite	-	(1.3)	-	(84)	-	-	-	-
Paper Making	-	14	-	18	-	4	-	(4.5)
Deinking	-	-	-	-	11-25	-	-	-

TABLE I.(vi).2. - Emission Factors for Sulphate (Kraft) Pulping (Unit Weights of Air-dried Unbleached Pulp)

Source	Type Control	Particulates kg/MT	Sulphur dioxide (SO_2) kg/MT	Carbon monoxide kg/MT	Hydrogen sulphide kg/MT	RSH, RSR, RSSR (S) kg/MT[a]
Digester relief and blow tank	Untreated[b]	-	-	-	0.05	0.75
Brown stock washers	Untreated	-	0.005	-	0.01	0.01
Multiple effect evaporators	Untreated[b]	-	0.005	-	0.05	0.02
Recovery boiler and direct contact evaporator	Untreated[c]	75	2.5	1.30	6[d]	0.5[d]
	Venturi scrubber[e]	23.5	2.5	1.30	6[d]	0.5[d]
	Electrostatic precipitator	4	2.5	1.30	6[d]	0.5[d]
	Auxiliary scrubber	1.5-7.5[f]	1.5	1.30	6[d]	0.5[d]
Smelt dissolving tank	Untreated	2.5	0.05	-	0.02	0.2
	Mesh pad	0.5	0.05	-	0.02	0.2
Lime kilns	Untreated	22.5	0.15	5	0.25	0.125
	Scrubber	1.5	0.1	5	0.25	0.125
Turpentine condenser	Untreated	-	-	-	0.005	0.25
Miscellaneous sources[g]	Untreated	-	-	-	-	0.25

Notes to Table I.(vi).2.

[a] RSH-methyl mercaptan; RSR-dimethyl sulphide; RSSR-dimethyl disulphide

[b] If the noncondensible gases from these sources are vented to the lime kiln, recovery furnace, or equivalent, the reduced sulphur compounds are destroyed.

[c] These factors apply when either a cyclonic scrubber or cascade evaporator is used for direct contact evaporation with no further controls.

[d] These reduced sulphur compounds (TRS) are typically reduced by 50 percent when black liquor oxidation is employed but can be cut by 30 to 99 percent when oxidation is complete and the recovery furnace is operated optimally.

[e] These factors apply when a venturi scrubber is used for direct contact evaporation with no further controls.

[f] Use 15 (7.5) when the auxiliary scrubber follows a venturi scrubber and 3 (1.5) when employed after an electrostatic precipitator.

[g] Includes knotter vents, brownstock seal tanks, etc. When black liquor oxidation is included, a factor of 0.6 (0.3) should be used.

conveyor or log flume to the debarking facilities. The bark is usually mechanically removed from the wood and disposed of by incineration, composting, or by-product recovery. The debarked logs are then mechanically chipped in preparation for pulping.

Gaseous and particulate emissions can result from the incineration process, as well as liquid effluent and solid waste from debarking and chipping (Fig. I.(vi).1.)

I.(vi).2.2. Kraft Process (Fig. I.(vi).2.)

The kraft process involves the cooking of wood chips under pressure in the presence of a cooking liquor in either a batch or a continuous digester. The kraft cooking liquor, or "white liquor", consisting of an aqueous solution of sodium sulphide and sodium hydroxide, dissolves the lignin that binds the wood fibres together.

When cooking is completed, the contents of the digester are forced into the blow tank. The major portion of the spent cooking liquor, which contains the dissolved lignin, is drained. From the blow tank the pulp passes through the knotter where unreacted chunks of wood are removed. The pulp is then washed, screened and, in some mills, bleached.

The kraft process produces a dark coloured pulp that normally represents from 45 to 50 percent of the initial weight of the wood used. Because of its dark colour, the unbleached pulp is used mainly in board, wrapping and bag papers. For use in the manufacture of white papers, the pulp must be treated further in a bleach plant.

It is economically necessary to recover both the inorganic cooking chemicals and the heat content of the spent "black liquor" which is separated from the cooked pulp. Recovery is accomplished by first concentrating the black liquor to a level that will support combustion and then feeding it to a furnace where burning and chemical recovery take place.

Initial concentration of the weak black liquor takes place in the multiple-effect evaporator. Here process steam is passed countercurrent to the liquor in a series of tube evaporators. Further concentration is then effected in the direct contact evaporator. This is generally a scrubbing device (a cyclonic or venturi scrubber or a cascade evaporator) in which hot combustion gases from the recovery furnace mix with the incoming black liquor to raise its solids content further.

The black liquor concentrate is then sprayed into the recovery furnace where the organic content supports combustion. The inorganic compounds fall to the bottom of the furnace and are discharged to the smelt dissolving tank to form a solution called "green liquor". The green liquor is then conveyed to a causticizer where slaked lime (calcium hydroxide) is added to convert the solution back to white liquor, which can be reused in subsequent cooks. Residual lime sludge from the causticizer can be recycled after being dewatered and calcined in the lime kiln.

Many mills need more steam for process heating, for providing electric power, etc., than can be provided by the recovery furnace alone. Thus, conventional industrial boilers that burn coal, oil, natural gas, and in some cases, bark and wood waste are commonly employed.

The kraft recovery furnace system is a major source of reduced sulphur and sulphur dioxide emission. Other emission sources or reduced sulphur include multiple effect evaporators, brown stock washers, lime kilns, digesters, and smelt tanks. Hydrogen sulphide can be formed in the direct contact evaporator, where carbon

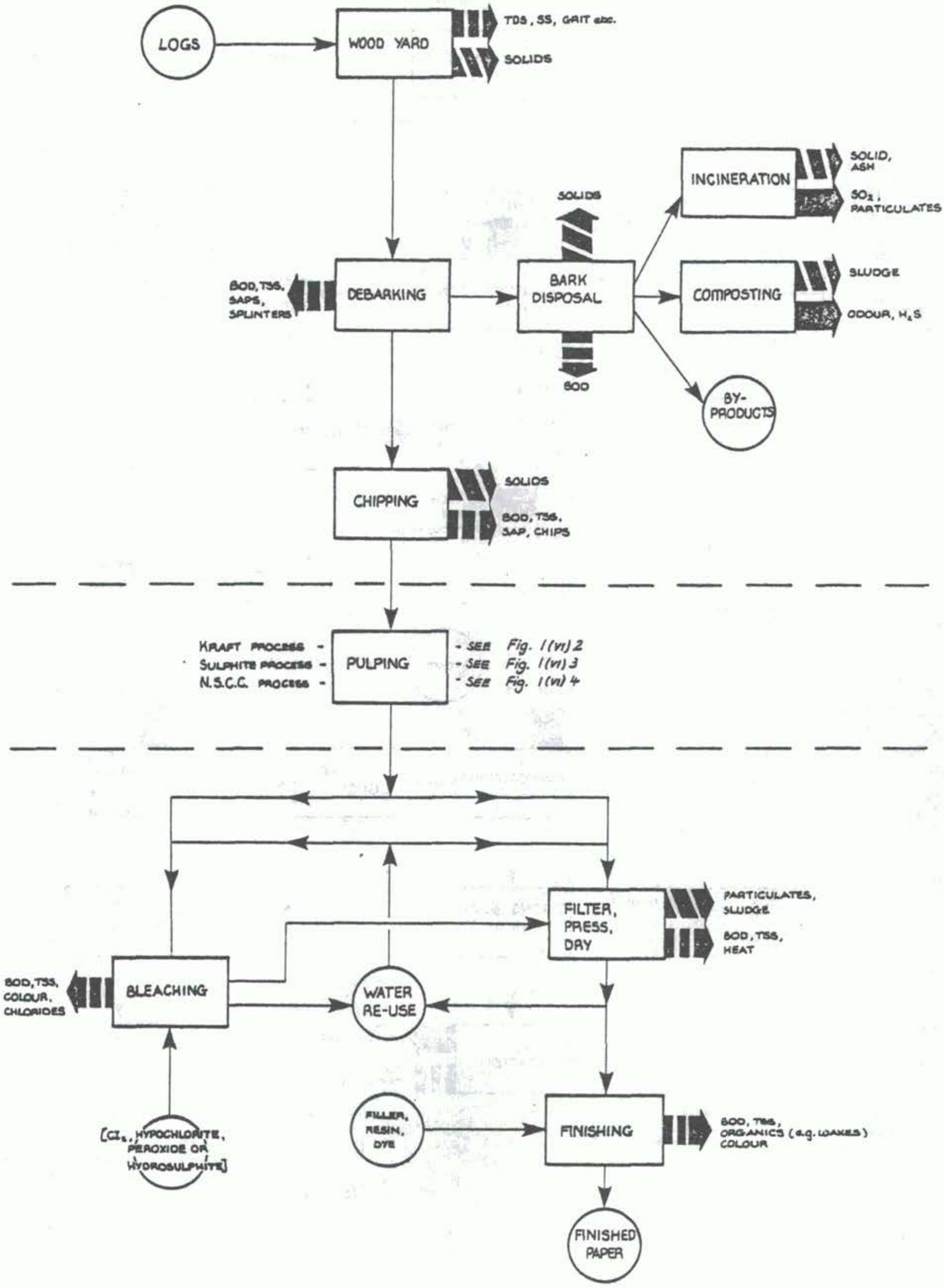

Fig. I(vi)1 Pulp and Paper Processing: Wood Preparation/Bleaching and Paper Manufacture

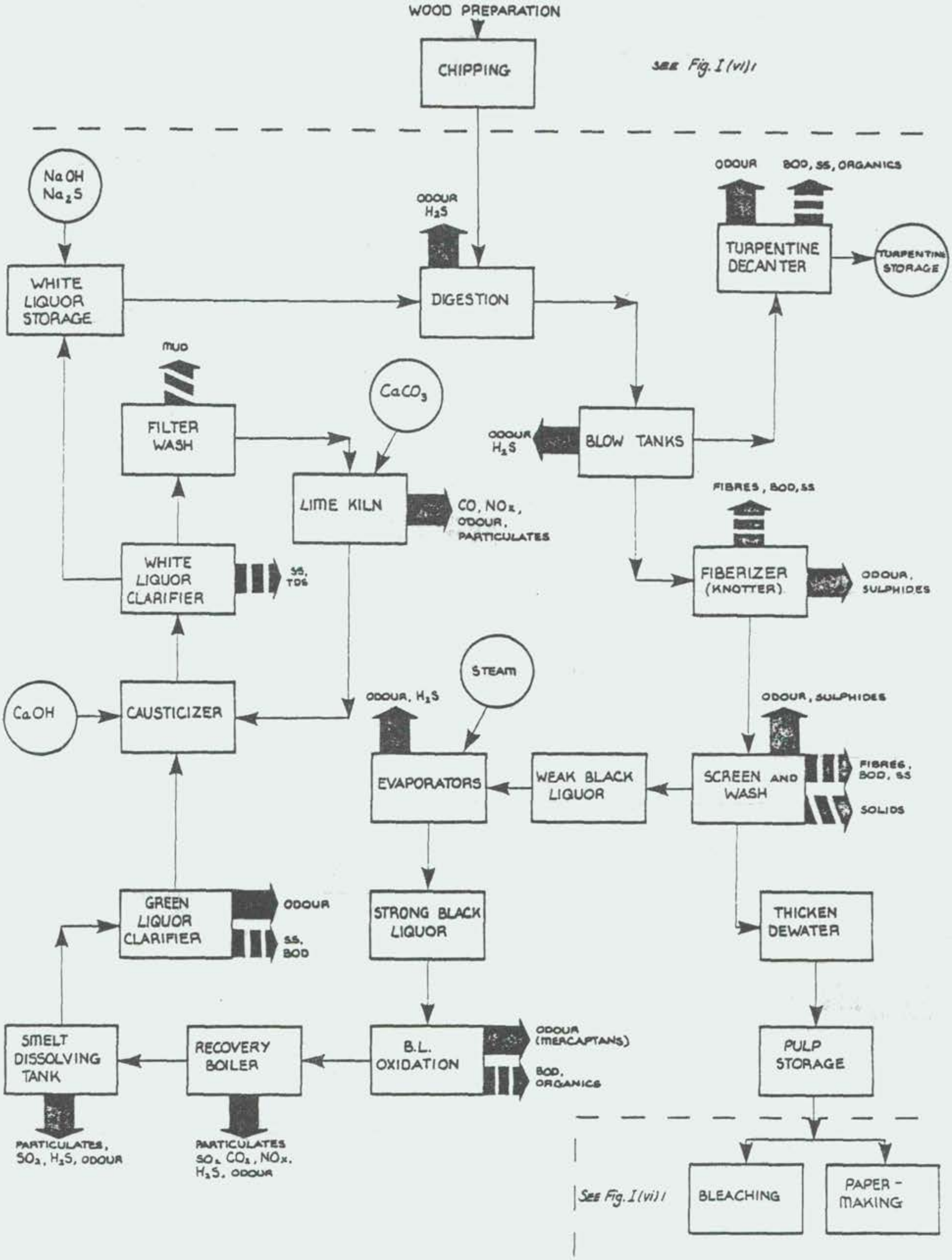

Fig. I(vi)2 Pulp and Paper Processing :
Kraft Pulping Process

dioxide in the flue gas from the recovery furnace reacts with sodium sulphide in the black liquor. It can also be formed in the lime kiln.

Potential sources of carbon monoxide emissions from the kraft process include the recovery furnace and lime kilns. The major cause of carbon monoxide emissions is furnace operation well above rated capacity, making it impossible to maintain oxidizing conditions.

Some nitrogen oxides are also emitted from the recovery furnace and lime kilns although the amounts are relatively small.

Particulates occur primarily from the recovery furnace, the lime kiln and the smelt dissolving tank. Particulates are caused mainly by the carry-over of solids, plus the sublimation and condensation of inorganic chemicals. The particles consist primarily of sodium sulphate and sodium carbonate. From the lime kiln they consist mainly of sodium salts, calcium carbonate and calcium oxide.

In addition, particulate emissions occur from boilers fired with bark and or with other fuels.

Typical values illustrating the range of emissions from kraft mill operations, after control, have been reported and are shown in Table I.(vi).3. below:

TABLE I.(vi).3 KRAFT MILL EMISSIONS
Emission rate, Kg/t Air dried Pulp (ADP)

Process	Particulates	Total Reduced Sulphur (TRS)
Recovery furnaces	0.5 to 12.5	0.025 to 6
Smelt tanks	0.025 to 1.0	0.005 to 0.03
Lime kilns	0.025 to 3.5	0.01 to 0.5
Digesters		0 to 1.0
Multiple effect evaporators		0 to 0.75
Black liquor oxidation		0.025 to 0.10
Brown stock washers		0.005 to 0.045

Source: UNEP (1977(a)

Odour from kraft mills is caused by H_2S and by the reaction of sodium sulphide, a component of the digesting liquor, with various organic side-chain radicals from cellulose and lignin of wood chips. Some of the compounds that are formed and their corresponding thresholds are:

Compound	Odour Threshold, pmm
H_2S, Hydrogen Sulphide	0.0047$^{(a)}$
CH_3,SH, Methyl Mercaptan	0.0021$^{(a)}$
$(CH_3)_2S$, Dimethyl Sulphide	0.0010$^{(a)}$
$(CH_3)_2S_2$, Dimethyl Disulphide	0.0056$^{(b)}$
SO_2, Sulphur Dioxide	0.47$^{(a)}$

(a) Concentration at which all panel members detect odour

(b) Median concentration detected by the individual panel members

The sulfide compounds are extremely odorous, being detectable at concentrations as low as 1 part per billion.

Source: UNEP 1977(a)

The major sources of wastewater are digester blowdown, black liquor leaks, spills, overflows, pump cooling, dreg washing, lime mud washing, white liquor filter washing and lime kiln and gas scrubbing. BOD and suspended solids form a significant fraction of the effluent, but water reuse and recovery can be practiced to minimse chemical losses.

I.(vi).2.3. <u>Sulphite Process</u> (Acid Sulphite) Fig. I.(vi).3.

The production of acid sulphite pulp proceeds similarly to kraft pulping except that different chemicals are used in the cooking liquor. In place of the caustic solution used to dissolve the lignin in the wood, sulphurous acid solution is employed. To buffer the cooking solution a disulphite of sodium, magnesium,

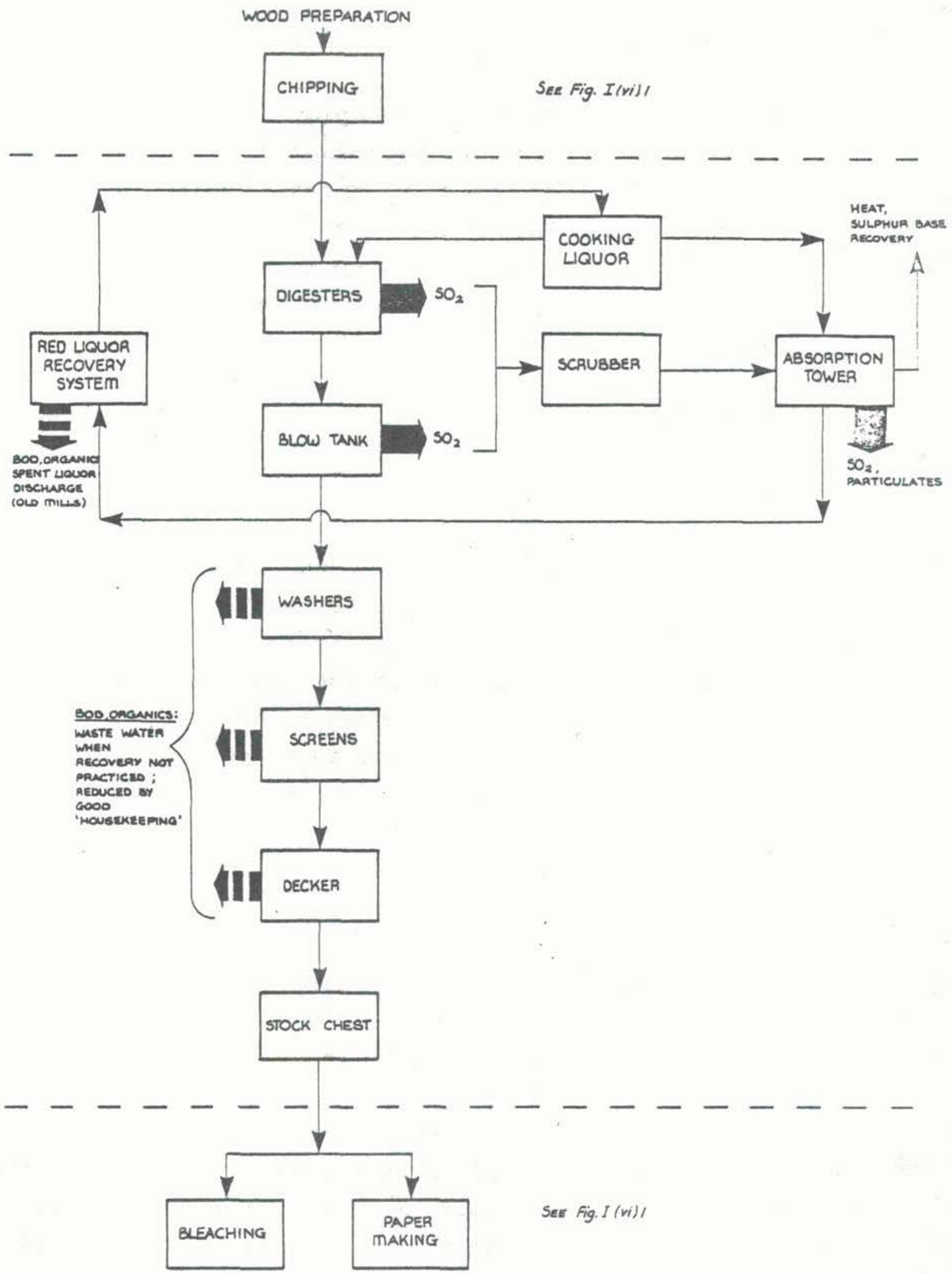

Fig. I(vi)3 Pulp and Paper Processing: Sulphite Pulping Process calcium, or ammonium is used.

Because of the variety of bases employed in the cooking liquor, numerous schemes for heat and/or chemical recovery have evolved. In calcium-base systems, which are used mostly in older mills, chemical recovery is not easy, and the spent liquor is in some cases discharged. In ammonium-base operations, heat can be recovered from the spent liquor through combustion, but the ammonium-base is consumed in the process. In sodium or magnesium-base operations (the latter being utilised most frequently in newer sulphite mills) heat, sulphur, and base recovery are all feasible.

When recovery is practiced, the spent liquor proceeds through a multiple effect evaporator and recovery furnace arrangement similar to that found in the kraft process. The combustion gases from the furnace pass through absorbing (sulphiting) towers where sulphur dioxide is recovered (as bisulphite) for use in subsequent cooks. In magnesium- or sodium-base operations, moreover, the base is recovered by feeding the inorganic residue from the furnace (either as smelt or collected ash) into the regeneration plant.

Significant quantities of particulate emissions will be granted when sodium-, magnesium-, or calcium-base liquors are burned. When ammonium-base liquor is burned, few particulates will result because the combustion products are mostly nitrogen, water vapour, and sulphur dioxide. In magnesium-base recovery systems, effective particulates control is necessary because most of the base is swept out of the furnace in the form of magnesium oxide fumes. No particulate emissions will result from these systems, of course, when the spent liquor is not combusted.

Sulphur dioxide is the main product emitted and the sources are absorption towers, blow pit or dump tank, multiple effect evaporators and liquor burning and chemical recovery systems.

The characteristic "kraft" odour is not emitted from acid sulphite mills because volatile reduced sulphur compounds are not products of the lignin-bisulphite reaction.

Significant quantities of wastewater can be generated if recovery of cooking liquor is not practiced. Other sources include spills, leaks, overflows, digester blow-down, dirty condensate, scrubber shower, acid preparation, chemical losses and recovery to varying degrees. These latter effluent sources can be reduced by "good house-keeping" within mill operations.

I.(vi).2.4. Neutral Sulphite Semichemical Pulping (NSSC) Fig I.(vi).4.

The wood chips are cooked in a neutral solution of sodium sulphite and sodium bicarbonate. The sulphite ion reacts with the lignin in the wood, and the sodium bicarbonate acts as a buffer to maintain a neutral solution. The major difference between this process and other semi-chemical techniques and the kraft and acid sulphite processes is that only a portion of the lignin is removed during the cook, after which the pulp is further reduced by mechanical disintegration. Because of this, yields as high as 60 to 80 percent can be achieved as opposed to 45 to 55 percent for other chemical processes.

The NSSC process varies from mill to mill. Some mills dispose of their spent liquor, some mills recover the cooking chemicals, and some, which are operated in conjunction with kraft mills, mix their spent liquor with the kraft liquor as a source of makeup chemicals. When recovery is practiced, the steps involved parallel those of the sulphite process.

Due to the difference in the chemical attack on the lignin when using sulphite liquors, compounds such as methyl mercaptan and dimethyl sulphide are not formed during digestion. Also, the absence of sulphide ions from the cooking liquor will virtually eliminate hydrogen sulphide

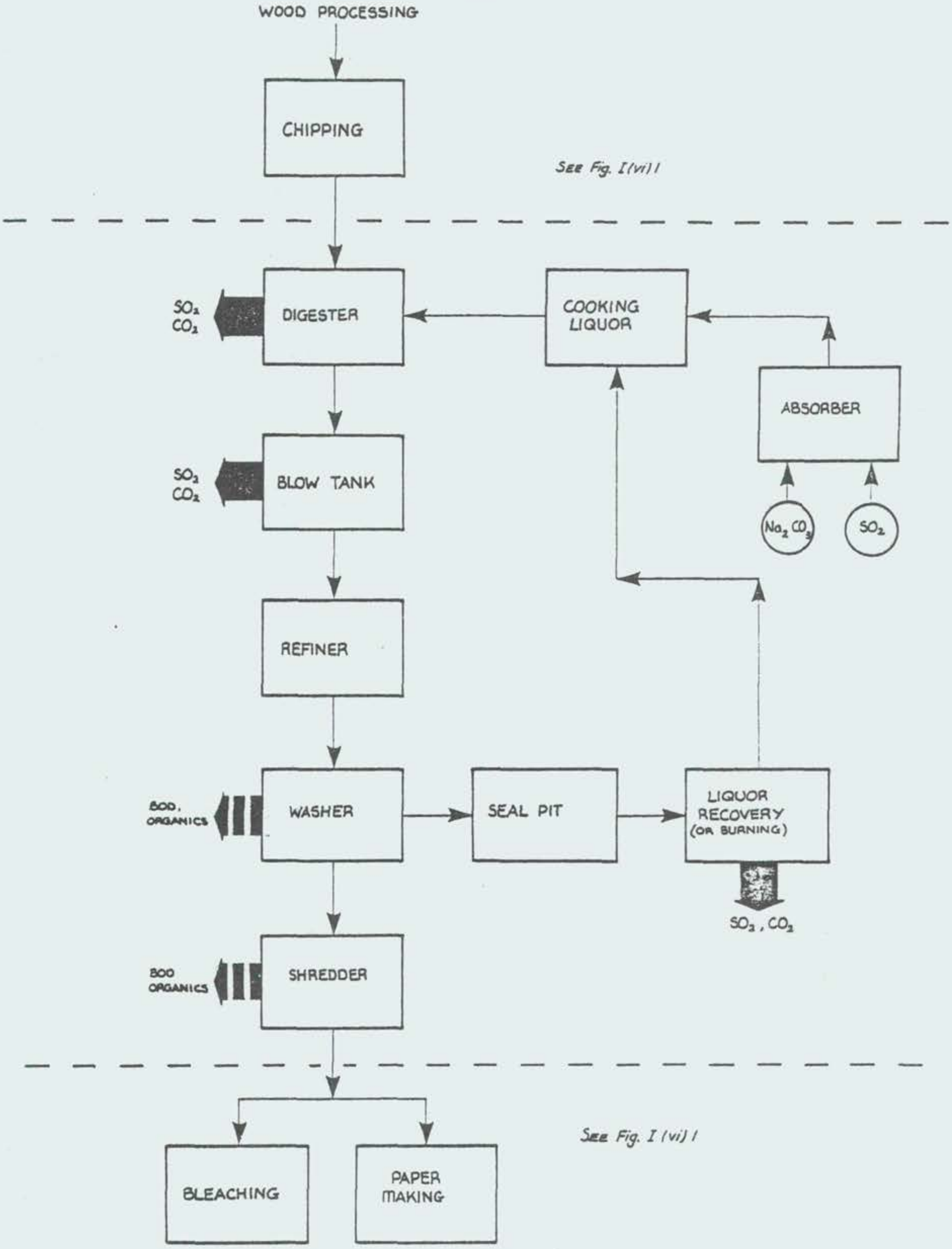

Fig. I(vi)4 Pulp and Paper Processing
NSSC Pulping Process

as a possible emission. Exceptions to this rule might be expected in those systems where liquor is burned in such a manner that the smelt contains sodium sulphide.

Atmospheric emission sources from an NSSC mill will include SO_2 absorption towers, if they are used, blow tanks, spent liquor evaporators and the liquor burning or chemical recovery furnace.

Reported emission data for semichemical processes are:

	SO_2 (kg/t ADP) After Control
Absorption	0.085 to 0.17
Furnace	1.08 to 3.2

Particulate emissions are a potential problem only when necessary systems are employed.

Semichemical pulp wastewaters, with chemical recovery, contain spent brown liquors (with high BOD and SS), digester blowdown, evaporator condensate and liquor preparation.

I.(vi).2.5. Mechanical Pulping

The basic method of mechanical pulping employs grinding or shredding of the wood to free the fibres and in addition, heat and pressure may be applied to assist the process. As with other pulping processes, the logs are prepared by debarking and sawing into manageable lengths. Logs are then fed to grinders where a large rotating grinder reduces the material to a coarse pulp. Large quantities of water are used to act both as coolant and a carrier to sluice the pulp from the body of the grinder (EPA 1979).

The pulp slurry is diluted to a consistency of from 0.6

to 0.8%, then passed through coarse and fine screens followed by a centri-cleaner to remove dirt and schives. Oversize rejects may be passed through a disc refiner and returned to the system ahead of the fine screens. The pulp is then thickened to a 10-15% consistency and discharged for mill use, bleached or thickened further for transport to other mills.

Effluents from the various forms of mechanical pulping - stone, refiner, chemi-groundwood, cold soda and thermo-chemical - contain suspended solids and dissolved organic matter, both of which contribute to the BOD loading (EPA 1976b). Chemi-groundwood and cold soda process waters also contribute electolytes containing some ions of the residual and spent chemicals. Suspended solids loading, however, does not appear to be directly related to the process type; the same EPA study (1976a) found a total suspended solids range of 21 to 80 kg/tonne of product.

The dissolved organic materials in groundwood effluents consist of wood sugars and cellulose breakdown products in addition to resins. A range for BOD loading for U.S. groundwood operations are presented below in Table I.(vi).4. It should be noted that the processes involving the use of chemical conditioning agents show the higher BOD values.

Table I.(vi).4. Range of BOD_5 Loadings in Effluents of Ground Processes

Type of Pulp	kg/tonne	lb/ta
Stone	4.0-9.5	8-19
Refiner	9.0-16.0	18-32
Chemigroundwood	34.5-40.5	69-81
Cold Soda	36.5-50-5	73-101

Source: EPA 1979(b)

The effluent flow from groundwater pulping is relatively low and can be expected to range from 8.3 to 16.7 kl/kgg (8.3 to 16.7 m^3/tonne). However, the flow from groundwood papermaking operations is substantially higher, at approximately 97m^3/tonne. The colour is usually below 100 hazen units.

The U.S. EPA (1979) anticipate that new groundwood mills will be expected to replace traditional zinc hypochlorite bleaching with another process to avoid high effluent concentrations of the metal.

Little or no data are available on air pollution emissions from goundwood operations; it is expected that the potential problems would be much less than in full chemical pulping processes. The lower operating temperatures and pressures in groundwood operations partially avoids the problem; some volatile organics may be expected however.

Solid wastes from groundwood mills consist typically of bark (if this operation occurs on-site), shives (fragments of wood that will not grind properly), screenings, ash and waste paper.

I.(vi).3. Specific Subprocesses and Emissions

Bleaching operations frequently form an integral part of kraft and sulphite pulp mill operations and as such, constitute a significant source of BOD_5 and TSS loading; additionally acidic and alkaline wastes result in pH balance problems. Typical BOD_5 and TSS loadings are quoted by US EPA (1979) as 6.8-7.2 kg/tonne and 3 kg/tonne respectively. Colour extraction by the bleaching operations also produces effluent control problems and finally, chlorides contributed by bleaching represent another major pollutant source.

Deinking - treating printed wastepapers - can sometimes be a major source of contamination but today's technology is geared towards a much greater reuse of washwaters.

Paper making varies in the degree of wastewater production, dependent largely on the grade of the final product. Typical BOD_5 and TSS loadings for integrated mill operations range from 2.0 to 7.0 kg/tonne and 15 to 50 kg/tonne respectively; average figures for US non-integrated paper mills are shown in Table I.(vi).5 below (EPA 1979).

Table I.(vi).5. Water Quality Values for Combined Papermaking Effluents By Grade

Grade	Flow		BOD_5		TSS	
	m^3/tonne	kgal/ton	kg/tonne	lb/ton	kg/tonne	lb/ton
Fine papers	63.4	15.2	10.75	21.5	30.8	61.6
Tissue	95.9	22.9	11.5	22.9	34.7	69.4

Sources of BOD_5 originate mainly from the organic raw materials used as constituents of paper. Cellulose is the most prevelent, representing 80% or more of the weight of most paper. Sizings and starch or protein adhesives also affect the BOD_5 loadings, as do many special organic chemicals such as set strength resins. Some or all of these, including cellulose fibres, are in the solid or precipitated state, and therefore also contribute to TSS loadings. Fillers and coating pigments such as clay and titanium dioxide hardly affect the BOD_5, but add TSS loadings.

Wastewater is produced in any stock preparation operation (mechanical/chemical treatment of pulp prior to paper making). White water from the paper machine operations contains fibres and fillers. Although these are usually reclaimed, a small amount of BOD and suspended solids are discharged.

Finishing operations are usually performed under dry conditions, producing little liquid waste except during coating.

I.(vi).4. Bibliography

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II - FORMAT FOR SPECIFYING ATMOSPHERIC LIQUID, SOLID WASTE AND NOISE CHARACTERISTICS

II. FORMAT FOR SPECIFYING ATMOSPHERIC, LIQUID, SOLID WASTE AND NOISE CHARACTERISTICS

II.1. Atmospheric Emissions

II.1.1. Gaseous emissions

(i) High level sources (stacks, chimneys, flares, etc.) - details in tabular form of the high level gaseous emissions resulting from the operation of each of the process units in the proposed development. Information should be provided for each potential source.

Source	Nature of emission	Maximum amount emitted (mg/m^3)	Av. daily emission (mg/day)	Proposed source height (m)	Int. diam. of exit (m)

Volume of gases (m^3/sec) at normal temp.	Exit velocity of emissions (m/sec)	Exit temp. of emissions (°C)	Frequency of emissions	Duration

(ii) Low level sources (valves, ventilators, etc.) - details in tabular form of the low level gaseous emissions resulting from the operation of each of the process units in the proposed development. Information should be provided for each potential source.

Source	Nature of emission	Maximum amount emitted (mg/m^3)	Av. daily emission (mg/day)	Proposed source height(s) (m)	Type of exit

Volume of gases (m^3/sec) at normal temp.	Exit velocity of emissions (m /sec)	Exit temp. of emissions (°C)	Frequency of emissions	Duration

II.1.2. Particulate emissions

Details in tabular form of particulate emissions resulting from the operation of each of the process units in the proposed development. Information should be provided for each potential source.

Source	Nature of emission	Maximum amount emitted (mg/m^3)	Av. daily emission (mg/day)	Proposed source height (m)	Int. diam. of exit (m)

Volume of particulates (m^3/sec) at normal temp.	Exit velocity of emissions (m /sec)	Exit temp. of emissions (°C)	Max. and min. particle size (μ)	Max. quantity of particles of a given size emitted daily	Frequency of emissions	Duration

II.1.3. Odours

Wherever possible information should be supplied on the types of odours likely to emanate from the process units in the proposed development.

II.1.4. Dust

Details of the maximum dust level expected under dry weather conditions (measured in mg/m^3) during both construction and operational phases.

II.2. Aqueous Discharges

Details in tabular form of the aqueous effluent discharges produced by each of the process units in the proposed development. Information should be provided for each potential source.

Source	Quantity of water	Nature of discharge	Maximum discharge concentration (mg/l)	Daily average	Frequency	Duration

II.3. Solid or Liquid Wastes

Details of toxic liquids and sludges not disposed as effluents and details in tabular form of all solid wastes produced by each of the process units in the proposed development and their method of disposal.

Source	Nature of waste	Max. daily quantity	Mode of transport to be employed	Method of disposal	Proposed disposal site	Frequency	Duration

II.4. Noise

Details in tabular form of noise characteristics of plant within buildings and in the open air.

(i) Existing plant within buildings:

Source (plant item)	Measuring distances	Environmental characteristics (surface finishes, surface areas, volume, reverberation time of room)	Sound level at each measuring point (dB(A)Leq)

Octave-band sound pressure level at each measurement point (Leq)								
31Hz	63Hz	125Hz	250Hz	500Hz	1kHz	2kHz	4kHz	8kHz

(ii) Existing plant within buildings:

Source (Plant item)	Measuring distances	Description of ground over which propagation takes place. Details of measuring area, reflecting surfaces etc.	Sound level at each measuring point (dB(A)Leq)

Octave-band sound pressure level at each measurement point (Leq)								
31Hz	63Hz	125Hz	250Hz	500Hz	1kHz	2kHz	4kHz	8kHz

III - MONITORING AND MEASUREMENT OF POLLUTION

III.(i). AIR POLLUTION MONITORING

III.(i).1. Introduction

There are three general applications in monitoring air contaminants, emission source testing, occupational exposure monitoring, and ambient air quality monitoring. In all three cases the design of a monitoring programme for quantitatively appraising air quality is a difficult task because it involves the consideration of a number of complex interacting factors (U.S. Environmental Protection Agency, 1971; Noll and Miller, 1977; Figure III.(i).1.). Decisions are required, for example, on the pollutants to be measured, the number and location of monitoring sites, the type of equipment, and the duration of sampling. However, the first step in designing any monitoring programme should be to define clearly the objectives of study - the data generated during implementation of the programme should be continuously appraised in the light of these objectives.

III.(i).2. Objectives of Air Pollution Monitoring

III.(i).2.1. Source monitoring

Most industrial processes based on chemical reactions have as their end point a stack through which "waste" products are ejected into the atmosphere. There are two main objectives in monitoring air quality at this point. Firstly, the efficiency of the overall process/operation or of any pollution abatement equipment may be assessed. Secondly, by measuring how much pollution is being discharged to the atmosphere, it is possible to determine whether the emission level complies with emission standards or regulations (see Chapter VIII.).

III.(i).2.2. Occupational monitoring

The most common purpose for sampling air at the workplace is to evaluate accurately the exposure of workers to one or more

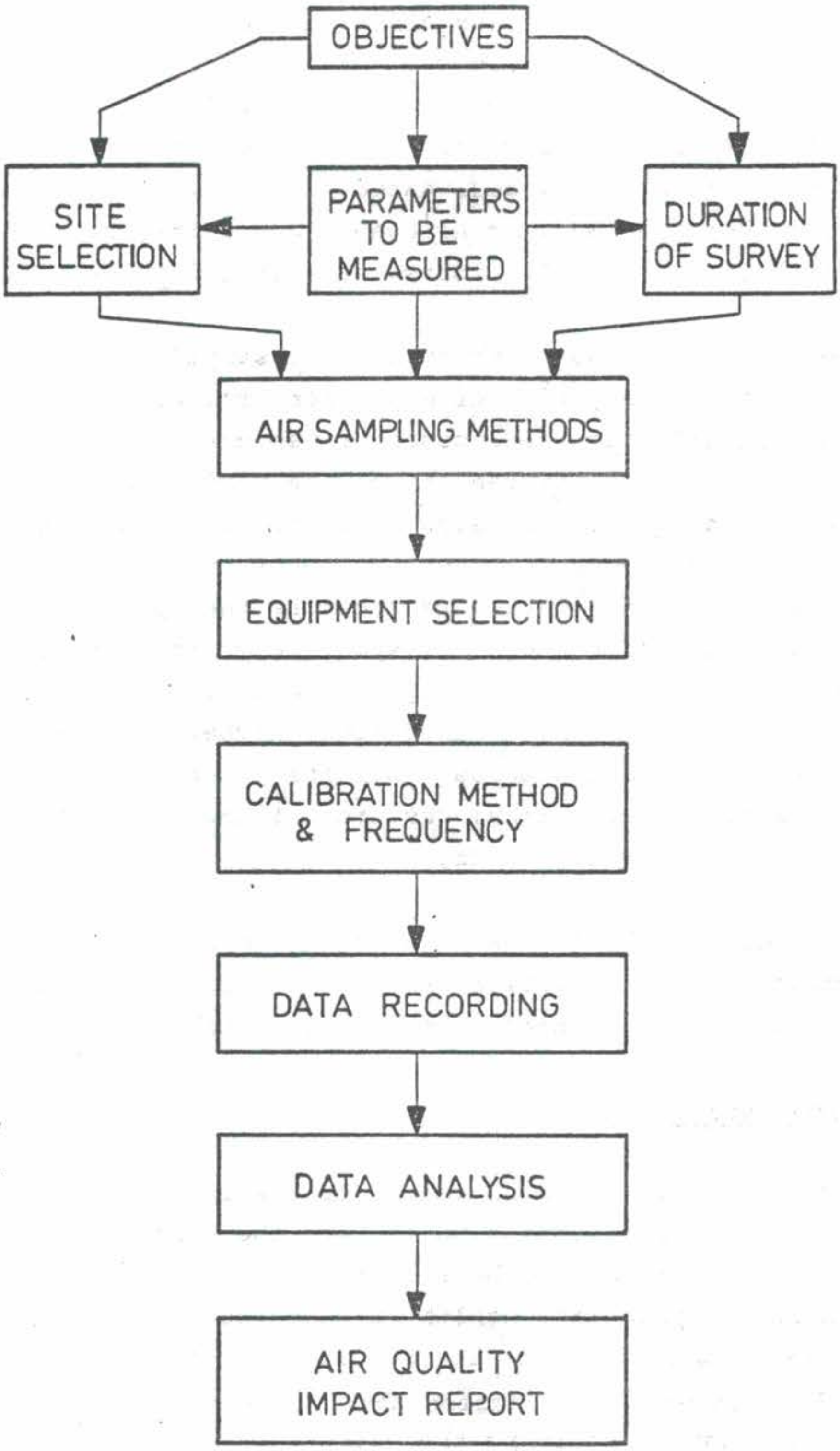

Figure III.(i).1. Steps in the design of an air quality monitoring programme (Noll and Miller, 1977) contaminants for determining compliance with regulations or commonly accepted standards. The latter are generally taken to be the average concentrations in air below which the contaminants are normally harmless on occupational exposure, and have been variously designated as the Threshold Limit Values (TLVs), the Maximum Allowable Concentrations (MACs), the Toxic or Permissible Limits, etc. (see Chapter VIII).

Another basic purpose of workplace air sampling is to indicate whether there is any risk of explosion from particulate or gaseous contaminants. For gases or vapours that form flammable mixtures with air or oxygen, there are maximum and minimum concentrations above and below which the rapid propagation of flame (i.e. an explosion) does not occur on contact with a source of ignition. These are known as the upper and lower explosive units (UEL and LEL respectively) and are usually expressed in terms of percentage by volume. As the LEL of a substance is often many hundred times higher than its TLV, flammable gas detectors need not be as sensitive as toxic gas detectors, but there is the additional requirement that such equipment should be intrinsically safe.

Other important objectives of workplace monitoring may include evaluation of the effectiveness of engineering control measures, process changes or personal protective devices.

III.(i).2.3. Ambient air monitoring

Wherever there is an intentional (or possible accidental) release of airborne contaminants into the community environment, a sampling programme may be required to provide data for assessing the potential health or nuisance effects and to determine compliance with air quality standards or objectives (U.S. Environmental Protection Agency, 1971). However, the biological data concerning the effects of individual pollutants (let alone mixtures of pollutants) on humans, animals, vegetation, etc. are often inadequate. This makes it impossible to fix accurately a practical maximum concentration below which one can be sure no significant adverse effects will occur. For this reason, and because the population at risk is exposed continuously and includes more susceptible individuals (e.g. the old, the infirm and the very young), ambient air quality standards are usually many times lower than occupational standards (see Chapter VIII).

Another common objective of an ambient air pollution monitoring programme is to establish baseline levels of air pollutants prior to construction or development activities. Such a study, whether conducted by an industrialist or a pollution control agency, can help promote good public relations, while the results can be used to evaluate the adequacy of pollution control measures, as well as providing a base upon which the impact of the development on air quality and the validity of any allegations of malpractice or claims for damage can be adequately assessed.

III.(i).3. Equipment and Methods

III.(i).3.1. General

There is a wide range of instrumentation available on the market for monitoring air pollutants, and utilising a variety of sampling and analytical techniques. However, these instruments can be conveniently grouped into two general categories. Firstly, there is the equipment which only collects an air sample (either actively or passively) with analysis being performed away from the site. Secondly, there are the generally more expensive direct-reading instruments which collect and analyse the air sample on site. Both types can be "automatic" which means they are capable of unattended operation for at least 24 hours and normally for more than a week.

There are basically three types of air quality monitoring - short period ("grab"), intermittent and continuous sampling. Grab samples have limited value and are usually used for random checks or where pollution concentrations are known to be constant. Intermitten sampling refers to sampling on a regular but discontinuous basis e.g. every few minutes or few hours, and therefore allows many of the fluctuations in air pollution concentration to be identified. Continuous sampling, however, enables diurnal, seasonal, and annual fluctuations to be measured and therefore allows a more accurate analysis of air quality.

A variety of other factors need to be considered when selecting a measurement method or specific instrument, the final choice probably being a compromise between conflicting demands:

(i) Accuracy - when a measurement is made to a particular accuracy, this means it is made so that a certain tolerance or limit of error is not exceeded. The measurement method therefore should have an accuracy sufficient to satisfy the objectives of the monitoring programme.

(ii) Calibration - accuracy is dependent upon calibration. A method of measurement will give a result either in absolute terms or by adjustment of an indicated value. This adjustment, or calibration, involves checking the accuracy of the indicated value by an independent method of measurement of known accuracy or by adjusting instrument response to gas mixtures of known pollutant concentrations.

(iii) Averaging time - the measuring method should give an accurate average value over a time interval which will be of interest/value to the investigation.

(iv) Response time - the time taken for an instrument to indicate a certain fraction of a change in pollutant concentration (the response time) should be sufficiently short for the proper indication of all significant changes which might occur.

(v) Specificity - the method should be specific in responding only to the pollutant of interest, other substances neither increasing nor decreasing the apparent result by an unacceptable amount.

(vi) Sensitivity and range - the technique should be sufficiently sensitive to detect with certainty the lowest concentration likely to be of interest, and equally should respond accurately to the highest expected concentration.

(vii) Data output - attention to the way in which measurements are obtained and presented can often result in large savings, particularly in large scale studies. Modern computing techniques can simplify analysis enormously, but the data must be in an easily transferable form.

(viii) Practicability - the instrument or method selected has to be practicable for the circumstances in which it will be used Of particular importance is the ease of maintenance and repair of the instrument.

(ix) Costs - in addition to instrument capital costs, there are running costs, maintenance costs, costs of analysis and the associated manpower costs which all have to be balanced with the needs and the resources available.

It is apparent from the above brief discussion that to ensure the use of the optimum monitoring strategy requires a review of current literature on the various combinations of instrumentation and techniques and their inherent limitations. It is only possible, therefore, to outline below a selection of the alternative methods that may be adopted for monitoring emissions, workroom air and ambient air. Recent reviews on measurement techniques include those of Katz (1969),U.S. Environmental Protection Agency (1971), Elfers (1971), Intersociety Committee (1972), American Conference of Governmental Industrial Hygienists (1972), Lawrence Berkeley Laboratory (1973), Hollowell (1973), Stern (1976) and Perry and Young (1976).

III.(i).3.2.Source monitoring

Because industrial processes involve frequent cyclic changes, the timing of source testing or monitoring must be planned accordingly. Process operations should be carefully reviewed so that fluctuations of peak loadings and process peculiarities can be identified. All the variables of source testing must be accounted for so that the final pollutant analysis will be a representative measure of the entire process.

Most sampling devices consist of a vacuum source, a metering device for measuring air volume, an inlet tube, a collection device (usually a filter or cyclone followed by impingers), an overflow trap, a manometer and thermometer . All of these essential components must be constructed of materials which are chemically resistant or abrasion-resistant to the composite air volume being sampled. The types of collection devices vary, depending on the collection efficiency and the type of contaminant being sampled.

Stack gases are usually sampled by one of the following methods:

- absorption of the gas sample by an absorbing liquid;
- adsorption onto activated carbon, alumina or silica gel;
- freeze-out trap, whereby the gas is drawn through a trap immersed in a low temperature bath (such as dry ice and acetone) and the condensed contaminants collected; and,
- grab sampling of gas from the stack by an evacuated metal or glass container.

The gases more commonly sampled include carbon dioxide, carbon monoxide, sulphur oxides, nitrogen oxides, organic vapours and halogen compounds.

The methods most commonly used for particulate contaminant sampling are:

- filtration - fibre filters; granular filters
- impingement - wet or dry impingers; cascade impactors
- sedimentation - sedimentation in stagnant air; thermal precipitators

- centrifugal force - cyclones
- precipitation - electrostatic precipitators; thermal precipitators.

A widely-used method for the sampling of particulates is described in a British Standard (British Standards Institution, 1971). One of the basic requirements is for isokinetic sampling, whereby the velocity of the flue gas entering the collecting device is the same as the gas velocity in the stack itself. This means that streamlines are undisturbed and a true sample can be taken.

Although the most common type of source monitoring involves taking grab (spot) samples, for subsequent off-site analysis, in recent years there has been increasing interest in the development of continuous stack monitors using either point sampling with on-site analysis or analysis at the sampling point (Wolf, 1975). For example, automatic optical smoke density meters have been developed to collect and quantitatively analyse particulates in a combined procedure. Another recent development with tremendous potential is the use of optical techniques which allow in situ or remote analysis by infra-red absorption or laser-based systems. Such techniques are desirable because sampling procedures are eliminated and because concentrations are determined under optimum conditions.

III.(i).3.3.Occupational monitoring

When testing workplace atmospheres for conformity with occupational health standards the aim is to take samples, over an appropriate time interval, either in the breathing zone of the worker using personal samplers and/or at a height of 1.5 m (nominal head height) if a static location is chosen.

For gases and vapours, air samples can be collected on the site and then analysed in the laboratory using chromatography, infra-red, ultra-violet, colorimetric methods, etc. There are three main methods of collecting the air sample:

(i) Liquid bubblers - air is drawn through a suitable liquid at a known rate and the liquid then analysed for pollutants (e.g. benzene in selenous acid; sulphur dioxide in hydrogen peroxide);

(ii) Charcoal adsorbers - used mainly for organic gases and vapours, air is adsorbed onto the surface of charcoal, followed by regeneration or desorption and analysis by gas chromatography;

(iii) Gas bags - air is collected in an evacuated bag normally of 5 to 25 litre capacity. The lining of the bag must be inert and non-porous to the sampled gas.

Alternatively, there is available a wide variety of direct-reading instruments for monitoring gases and vapours, normally utilising one of the analytical techniques outlined in section III.(i).3.5.

For flammable gases and vapours, the technqiue most commonly used is that developed by the Safety in Mines Research Establishment in the United Kingdom. A catalytic sensor (or pellistor) when electrically heated burns any flammable gas present, increasing its temperature and hence its electrical resistance. This change in electrical resistance is measured and is approximately proportional to the gas concentration. Pellistor elements can be made sensitive to specific gases, but electrical and chemical factors can limit their performance.

Gravimetric methods are usually used to determine the concentration of dusts in workplace air. There are two main types of sampling:

(i) Total airborne particulate sampling - personal samplers consist of a miniature pump, clipped to a belt or held in a pocket, and are connected by a thin plastic tube to a filter assembly attached to the worker's lapel. Larger static samplers are also available.

(ii) Respirable dust sampling - size selection is commonly achieved by using horizontal elutriation (for static samplers only) or cyclone separation. Miniature cyclones have been developed for personal selective sampling, with a particle size cut-off at seven microns. A number of purpose-built static respirable samplers are also available.

Direct reading instruments have recently been developed for measuring total or respirable dust, utilising a variety of techniques, e.g. light-scattering, piezoelectric crystal and β-radiation absorption.

III.(i).3.4. Ambient air monitoring

Because the nature of the air pollution problem varies widely from area to area, depending on the peculiarities of meteorology, topography, source characteristics and legal and administrative constraints, monitoring programmes will vary accordingly in scope, content and duration. In general, however, pollutants to be monitored should be selected on the basis of their (a) representing a definite hazard; (b) possibility of becoming hazardous to health or welfare in the near future; and (c) being controlled by existing or proposed standards.

The choice of the number and location of monitoring sites should consider: (a) source-oriented monitoring; (b) zone(s) of highest actual or projected pollutant concentrations; (c) background studies for industrial development; (d) areas of high population density; and (e) other sensitive or critical areas. Detailed site location also depends on such factors as accessibility, availability of space, needs for electric power, water and security, etc. The duration of monitoring is usually governed by the use to be made of the data, financial resources and statistical validation.

Ambient air samples can be collected for subsequent laboratory analysis using the techniques described above (Section III.(i).3.3.). However, as with occupational monitoring, the trend is towards the use of continuous direct reading instruments using a variety of techniques, some of which are outlined in Section III.(i).3.5. Continuous analysers are available for the measurement of ambient concentrations of a range of gases including: carbon dioxide; nitric oxide; nitrogen dioxide; sulphur dioxide; total hydrocarbons; methane; oxidants; ozone; hydrogen sulphide; and, hydrogen fluoride.

Particulate air pollution samples are most commonly collected by filtration. Particles are removed from a known volume of ambient air and can be weighed or analysed microscopically or chemically. High-volume samplers and tape samplers are widely employed for particulate sampling, while electrostatic and thermal precipitators find some special applications. Inertial impaction collectors, e.g. cascade impactors are frequently used for particle size distribution. In addition to suspended particulates, fall-out of grit and dust is commonly measured using dust fall jars, glass slides, trays, etc. For example, dust fall-out is measured in the United Kingdom using either a British Standard deposit gauge or a directional dust deposit gauge (British Standards Institution, 1969 and 1972).

Table III.(i).1. summarises some of the more common measurement methods used in monitoring ambient air quality. However, it is usual when establishing air quality standards to specify a measurement method for each pollutant. For example, the United States Environmental Protection Agency has established official reference measurement methods to accompany their ambient air quality standards (Table III.(i).2; U.S. Environmental Protection Agency, 1971a), and have also listed unacceptable methods of measurements for the same pollutants (U.S. Environmental Protection Agency, 1974).

Finally, mention should be made of an increasingly popular technique for monitoring ambient air quality utilising biological indicators. Lichens and mosses have been found to be particularly suitable monitors, mainly because they derive their nutrients from atmospheric moisture and dust

TABLE III.(i).1. Commonly measured pollutants and methods used in their determination (Rossano & Thielke, 1976)

Pollutant	Method[a]
Grit and dust fall	bucket, jar, British Standard deposit gauge (monthly)
Suspended particulates:	
- total	USA high volume filter (gravimetric; 8 hourly)
- smoke	British Standard smoke filter (soiling index; daily) Tape-filter (soiling index; hourly)
Sulphur dioxide	West-Gaeke (specific for SO_2; daily) H_2O_2 followed by analysis for sulphate (specific for SO_2; daily) H_2O_2 followed by titration or determination of conductivity (not gaseous acidity; daily or continuous) coulometric (specific for SO_2; continuous) Stratmann silica gel (8-hourly)
Sulphuric acid mist	double filtration (daily)
Carbon monoxide	non-dispersive infrared (continuous)
Ozone	chemiluminescence
Oxidants	neutral KI (daily)
Methane	flame ionization (continuous)
Higher hydrocarbons	flame ionization (continuous)
Nitric oxide	chemiluminescence - reaction with O_3 (continuous)
Nitrogen dioxide	Saltzman (daily or continuous) chemiluminescence - reduction to NO, then reaction with O_3 (continuous)

[a] Continuous methods are those operating automatically and producing a continuous record on a recorder chart or a computer input tape. The other methods are operated manually; the frequency of sampling indicated can be varied within limits to suit requirements, e.g. a deposit gauge can be changed at 2-weekly intervals and the H_2O_2 method for sulphur dioxide can be used over 14-day intervals if the pollutant concentration is very low.

Table III.(i).2.- U.S. National Air Quality Standards Reference Methods

Pollutant	Average time	Reference method	Principle of detection
SO_2	3 h, 24 h	Pararosaniline	Colorimetric
Particulate matter	24 h, annual	Hi-vol sampler	Gravimetric
CO	1 h, 8 h	Non-dispersive infrared spectrometry	Infrared
Photochemical oxidants (ozone)	1 h	Gas phase O_3 - ethylene reaction (calibrated against neutral buffered KI method)	Flame ionization
NO_2	Annual	24 h integrated samples collected in alkaline solution	Colorimetric

rather than the substrates on which they are growing. As the majority of species are also adapted to precise ecological niches and have varying sensitivity to air pollutants, it is often possible to correlate species occurence with air quality. For example, a number of scales have been described for estimating average sulphur dioxide concentrations from lichen distribution (Gilbert, 1970; Hawksworth and Rose, 1970).

Biological monitoring also provides a means of obtaining an integrated picture of pollutant emissions over a period of time and subsequent distribution in food-chains leading to livestock and man. Recent studies have demonstrated that moss, for example, is a useful, inexpensive indicator of metal pollution and can be used to monitor changes in airborne metal burdens, both over space and time (Little and Martin, 1974; Goodman and Smith, 1975). Figure III.(i).2. shows how rapidly metal concentrations of the lichen Cladonia deformis decrease with increasing distance from a nickel smelter (Nieboer et al, 1972).

III.(i).3.5. Analysis of pollutants

Analytical methods can be classified as those primarily involving chemical and those primarily involving physical principles of measurement, although these terms can not be used with clear-cut precision. In general, the methods classed as chemical are the so-called "wet chemical" methods which involve interaction between a liquid reagent and the contaminant of interest. Although there is a gradual shift away from such wet chemical techniques because, in general, they suffer from problems of interferences, reagent stability, complex plumbing, relatively slow response time, etc., they are often well characterised and initially less expensive.

Methods used for analysis of gaseous pollutants include:

(i) Colorimetry (spectrophotometry). Analysers based upon colorimetry form a major group of wet chemical instruments. The air contaminant is collected by absorption in a liquid reagent, with subsequent formation of a coloured reaction product, which is then measured colorimetrically or spectrophotometrically and compared to standards of the same solution. The physical law that underlies colorimetric analysis is commonly referred to as the Beer Lambert Law, which states that the degree of light absorption by a coloured solution is a function of the concentration and the length of the light path through the solution. Colorimetric analysis is commonly employed

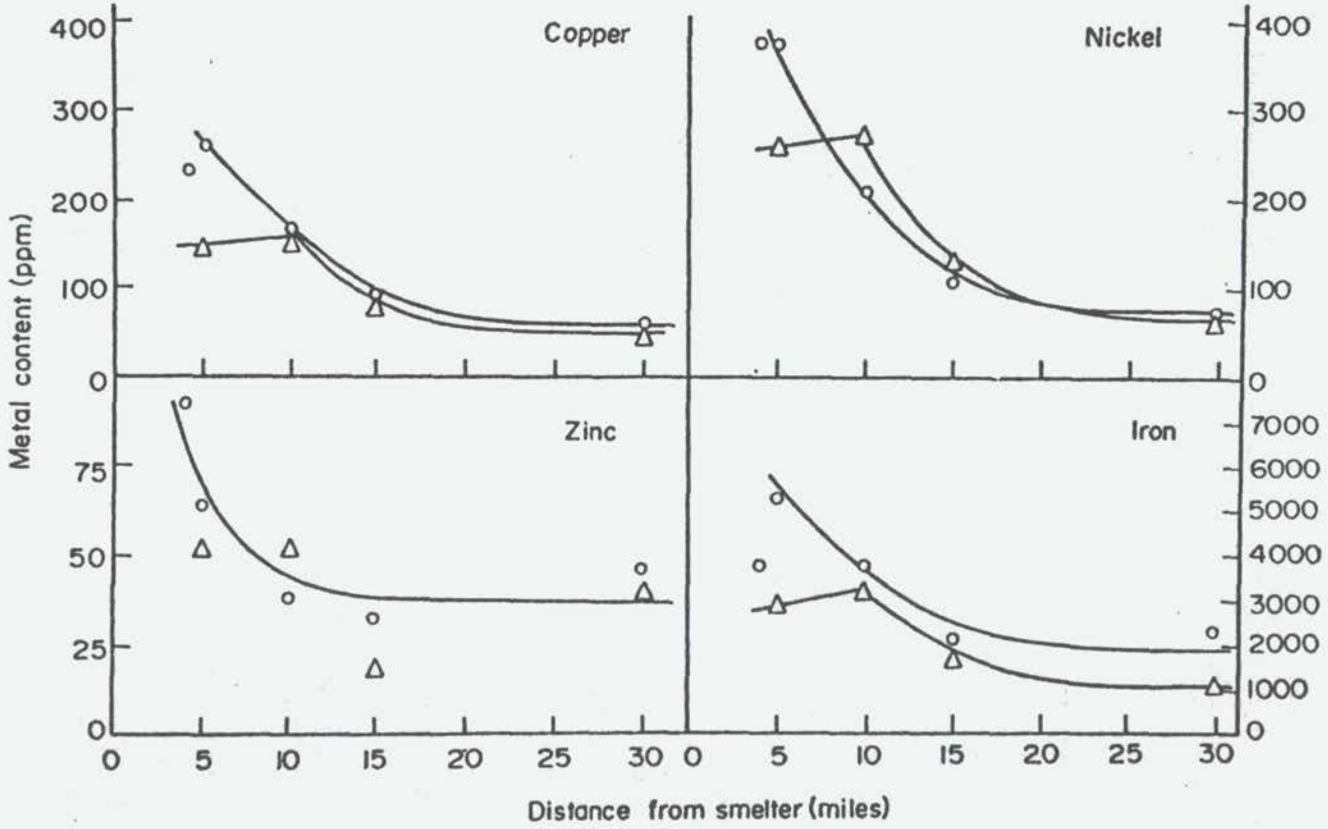

Figure III.(i).2. Metal concentrations of the lichen Cladonia deformis with increasing distance from a nickel smelter (Nieboer et al, 1972).

for the continuous measurement of three air pollutants: sulphur dioxide, nitrogen dioxide and oxidants. Although the technique is simple and specific, it is slow because of colour development times of up to 30 minutes.

(ii) Coulometry (amperometry). Coulometry is a method of analysis in which the quantity of electrons required to oxidise or reduce a substance is measured. According to Faraday's Law, this current is proportional to the mass of the reacted material. Coulometric analysers generally require minimal maintenance but as other reducing or oxidising agents can cause direct interference, they require pre-filtration devices or scrubbers to make them specific. Coulometric analysers have been developed for the continuous measurement of sulphur dioxide, oxidants and nitrogen dioxide.

(iii) Conductimetry. Conductimetric analysers are based on the principle that a solution of a given ionic strength will have a specific measurable resistance. The sample gas passes through an absorbing solution and ionises within it, increasing the conductance. This increase is measurable and is proportional to the concentration of the ionisable gas. Conductimetric analysers are most widely used for measurement of sulphur dioxide. The technqiue is highly sensitive but other pollutants that will dissolve in the absorbent will cause interference.

(iv) Chemiluminescence. In this technique, light emitted as a result of a reaction between two chemical species is detected spectroscopically and the spectrum used to determine the concentration of the reacting molecules. Chemiluminescence techniques are employed for the measurement of ozone (reaction with ethylene) and nitric oxide (reaction with ozone) and have the advantages of specificity, sensitivity, a rapid response time and the absence of liquid reagents.

(v) Infrared and ultraviolet absorption. Infrared or ultraviolet radiation is passed through a chamber containing the air sample after which the radiation is dispersed and detected. Because each chemical compound in the air sample absorbs the radiation in a characteristic pattern, the amount of radiation absorbed at various wavelengths can be used to identify the chemical component. A quantitative analysis can also be obtained as the amount of light absorbed is proportional to the concentration of the component. Non-dispersive infrared analysis is used principally for measuring carbon monoxide while ultraviolet absorption has been used for monitoring ozone.

(vi) Flame photometry. Flame photometric analysers operate on the measurement of light emitted from an element when burned in a hydrogen flame. Characteristic flame emission spectra are produced, the amount of light emitted being proportional to the concentration of the emitting species. The technique has been used almost exclusively for analysis of sulphur compounds, but although it is highly sensitive it is unable to distinguish between the various sulphur compounds.

(vii) Flame ionisation. When hydrogen is burned in pure air the flame is electrically non-conducting but when hydrocarbons are present ions are produced. The flame will then conduct a small current which is proportional to the concentration of hydrocarbons in the sample and which can be amplified and used to drive an indicating meter. Flame ionisation detectors do not discriminate between hydrocarbons, aldehydes, ketones, etc., and if used to monitor hydrocarbons continuously without chromatographic columns to separate the constituents (see below), they are known as total hydrocarbon analysers.

Table III.(i).3Summary of Methods for Studying Particulate Samples (West, 1976)

Method	*Applications*	*Sensitivity*	*Reliability*	*Remarks*
Titrimetry				
General	General (ions)	mg^{+}	Nonspecific; technical skill required unless automated	Slow to rapid, depending on the system
Coulometric	General (ions)	mg–μg	Nonspecific; usually automated systems are quite precise	Quite rapid; equipment cost, $300–3000
Gravimetry	Limited (ions and total mass)	mg^{+}	Selective methods but dependent on technical skill	Slow; equipment cost, $300–1500
Colorimetry and filter photometry	General (ions)	mg–ng	Selective or even specific; quite reliable	Usually rapid and simple; equipment cost, $30–5000; often automated
Turbidimetry and nephelometry	Limited (ions)	mg–μg	Selective	Usually rapid and simple; equipment cost, $300–5000
Spectrophotometry	General (ions)	mg–ng	Selective or even specific; good reliability	Usually rapid and simple; equipment cost, $2000–15,000; may be automated
Fluorimetry	Limited (ions and molecules)	μg–ng	Quite selective but may be subject to interferences	Usually rapid; equipment cost, $5000–16,000
Microscopy				
General	General (ions and molecules)		May be very reliable, depending on skill and experience	Quite rapid; equipment cost, $150–500
Polarized light	General (molecular species)		Very reliable but is dependent on training and skill	Quite slow; equipment cost, $600–2500
Electron	General (molecular species)		Requires training and skill	Quite slow; equipment cost, $30,000–110,000
Microprobe	General (elements)	<pg	Very reliable but dependent on skill	Slow; equipment cost, $30,000–35,000
Polarography	Metals	mg–μg	Quite accurate but requires some skill	Rather slow but 4 or 5 metals may be determined on 1 sample; not automated; equipment cost, $500–3000
Flame photometry	Many metals	mg–μg	Essentially specific with few interferences; quite accurate	Simple and rapid; may be partially automated; equipment cost, $500–3000
Emission spectrometry	Metals	mg–ng	Specific; some interferences due to matrix effects; skill required	Training necessary; rapid for routine studies of many samples; may be automated: equipment cost, $5000–50,000
Atomic absorption spectrometry	Metals	μg–ng	Specific and very reliable	Simple and rapid; not as rapid as emission methods if more than 3 or 4 metals are run per sample; may be partially automated; equipment cost, $2500–8000
Neutron activation	General (elements)	μg–pg	Specific and very reliable	Simplicity and speed dependent on facilities and equipment: equipment cost, $60,000 and up
Ring oven	General (ions)	μg–ng	Highly selective and quite reliable	Simple and quite rapid; equipment cost, $150–200
X-ray fluorescence	Elements (atomic 11 and above)	μg–ng	Specific; subject to some matrix effects	Excellent for multielement determinations on a routine basis; expensive

(viii) Electron capture. Air in a sample cell is ionised by a small radio-active source. When a contaminant is present in the sample, it captures some of the free electrons and reduces the ionisation current in proportion to its concentration. This type of detector is used mainly for halogenated organic solvent vapours.

(ix) Gas chromatography. Chromatography is not a method of detection but is a technique for the separation of closely related compounds, e.g. hydrocarbons, and therefore can be a very useful preliminary step in the analysis of complex mixtures. In gas chromatography, the sample is vapourised and the mixture passed by a stream of inert (carrier) gas through a column containing a packing material, which has different absorption affinities for each component of the sample. The components are therefore held on the column for different lengths of time and emerge separately at the end of the column where they can be detected and measured by a number of techniques, e.g. flame ionisation detection, electron capture, etc.

A general summary of the various analytical methods that can be used for studying particulate samples is given in Table III.(i).3. Gravimetry is the method of measuring air pollutants by direct weighing and can be performed on particulate samples collected by any of the methods referred to above. Another important characteristic of any particulate sample is the range or distribution of particles by size. This can be determined by sieving, optical microscopic, electron microscopic, sedimentation, centrifugal or impaction techniques. Common methods for determining the composition of particulates include:

(i) Atomic absorption spectroscopy. Atomic absorption is probably the most widely used technique for the quantitative measurement of metals because it combines high specificity with high sensitivity. Free metal atoms absorb radiation at discrete wavelengths which are characteristic for each element and are raised from the gound state to an excited state. The relationship between the amount of light absorbed and the concentration of the heavy metal ions follows an exponential law and thus, over a concentration range, the variation in absorbance is linear with metal concentration. The most frequently used method for obtaining metal atoms is aspiration of the metal in solution through a flame. The sensitivity can be increased 10 to 1000 times by using a flameless technique, such as a graphite furnace, to obtain the atomized metal.

(ii) Emission spectrometry. Emission spectrometric methods utilize the characteristic spectra produced when materials are introduced into thermal or electrical sources. When the excited atoms return to the ground state a characteristic wavelength spectrum is produced; no two elements have the same spectrum. The emitted light is analysed by a spectrometer and quantitative analysis is based on the fact that the intensity of spectral lines is a function of the concentration of the element in the emitting source.

(iii) Neutron activation analysis. This is usually carried out by the comparator method, in which a known amount of the element to be determined is bombarded simultaneously with the test sample. The concentration of the element in the sample is determined from the ratio of the radioactivity of the sample to that of the pure element.

III. (i). 4. References

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III.(ii). WATER POLLUTION MONITORING

III.(ii).1. Introduction

The continuously rising demand for water for domestic and industrial purposes and the increased use of rivers, estuaries and coastal waters for fisheries, recreation, waste disposal, irrigation, power generation and navigation have resulted in an urgent need for careful management of aquatic systems. Monitoring programmes can help achieve this by providing information on water flows and water quality. However, the monitoring programmes, whether designed for effluents or receiving waters, must be related to some desired end or objective, otherwise redundant data will be gathered with a concomitant waste of resources and time.

The basic objective of an effluent monitoring programme is to provide a characterisation and understanding of the waterborne waste materials being produced by the industrial processes. Although regulatory agencies normally only require monitoring of the waste streams which leave the factory site, it is now recognised that a comprehensive monitoring programme can locate inefficient and wasteful operations and lead to reduced manufacturing costs. In addition to any legal requirements and the necessity of preventing violations, a monitoring system can provide protection for inaccurate accusations of illegal or harmful waste discharge practices. Adequate monitoring records can document that a facility was operating in conformance with permit requirements.

Thus an effluent/waste monitoring system should become an integral portion of the manufacturing process and be used as a measure of efficient operation. Once incorporated into the production system, it will be an invaluable check on the overall efficiency of plant operations as well as an aid in meeting legal requirements. The monitoring programme will also provide basic data that will be valuable in the design of a wastewater treatment system to meet regulatory requirements. One of the first tasks in establishing a monitoring programme should be an examination of the water usage and waste generation characteristics of the manufacturing process itself. Very often, a simple water conservation survey can eliminate unneeded water uses within the plant even before a formal monitoring programme is initiated. (Figure III.(ii).1.).

Although there can also be many objectives for monitoring receiving water quality, in most cases the main purpose is to assess the suitability of the water, in chemical and biological terms, for the uses to which it is put or is likely to be put in the future. For some parameters, the quality of waters required to support fish, to serve as a source of public supply, to serve industrial purposes, etc. is very different and so it is essential when designing a monitoring programme (and when setting water quality standards) to have details of the present and intended uses of the waters. Other important reasons for water quality monitoring are to assess trends of change in water quality, to determine adherence to or violation of water quality standards and to provide warning of pollution incidents.

When assessing the impact of the construction or operation of new industries and developments on the aquatic environment, it is essential to have as much background or baseline data as possible on the chemical and biological characteristics of the receiving waters. The longer that pre-development monitoring is operative, the greater is the probability of the effects of wastewater discharges being correctly assessed. Any periodic fluctuations in plant and animal numbers, flow regime, temperature, pH and other chemical characteristics may then be identified as natural for the waterbody and not mistakenly attributed to the effect of a discharge.

The techniques used for measuring water flows and for water sampling and analysis (which are, in general, similar for natural and treated waters, sewage effluents, or industrial effluents) are discussed below. Attention is also given to biological monitoring, which is essential for the complete characterisation of aquatic ecosystems.

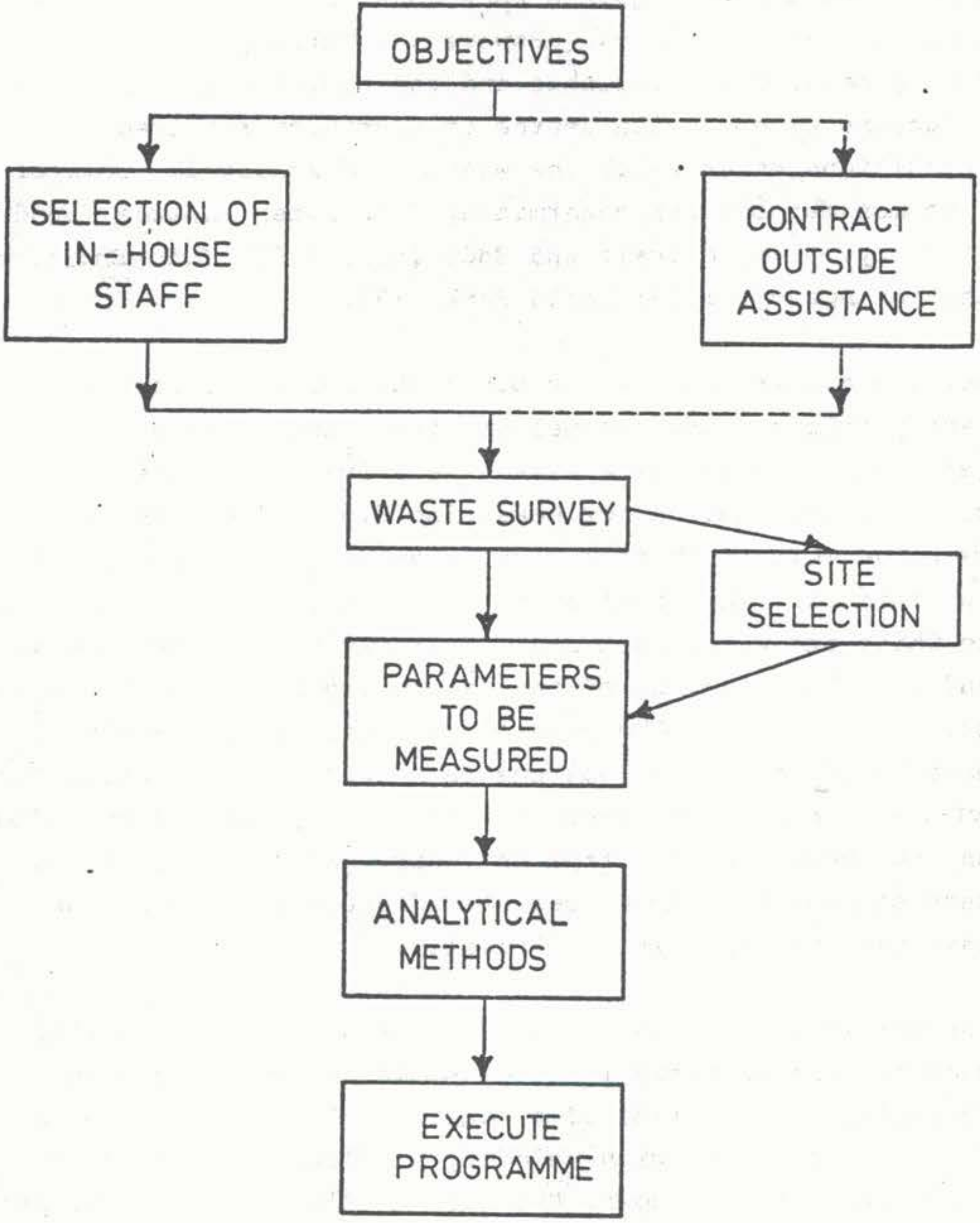

Figure III.(ii).1. - Steps involved in establishing an effluent monitoring programme

III.(ii).2. Measurement of Flow

The collection of flow data is fundamental to the monitoring of water pollution. For example, the design of wastewater treatment facilities requires knowledge of flow rates, flow variability and total flow. However, a variety of flow measuring methods is available and the choice will depend upon such factors as cost, the degree of precision required and the conditions under which the waste is discharged. Some of the more common methods for determining flow rates include (Lund, 1971; Mancy, 1971; Metcalf and Eddy Inc., 1972; U.S. Environmental Protection Agency, 1973; World Bank, 1978):

- Weirs - a weir is a dam or other obstruction placed in a partly filled pipe, channel or stream and, because it is generally easy to install at a relatively low cost, is a commonly used device for measuring flow. The water flows over the weir or through a rectangular or V-shaped notch cut into it. The crest on the weir is defined as the level to which the water must rise before it can go over the weir and is either the top of the dam or the bottom of the notch cut into the dam. The head on the weir is the height of the water surface in the pool upstream from the weir above the crest. Knowing the type of weir (rectangular or V-notched) and the head upstream from the weir, calculations of the rate of flow in volumes per second are a relatively easy task with the appropriate formula.

- Current (velocity) meters - The current meter is usually used to measure flows in streams, large sewers or open channels. It consists of a rotating element whose speed of rotation varies with velocity of flow. If the cross-sectional area is known, the rate of flow or discharge per unit of time can be estimated from the measured average velocity, which is usually estimated to be at a depth of six tenths below the surface. Alternatively, the average velocity is often taken as 85% of the surface velocity.

- Parshall flumes - A Parshall flume is a convenient device for the continuous measurement of open channel flows at or near the ground surface. The Parshall flume is a permanent structure made of metal, concrete, plastic or wood and consists of a converging section, a throat and a diverging section. The floor of the converging section is level but the floor of the throat is inclined downward from the horizontal and the floor of the diverging section is inclined upward at a definite slope from the horizontal. Because the throat width is constant, the discharge can be obtained from a single upstream measurement of depth under free flowing conditions. Flow under submerged conditions requires several measurements of head at various locations for the determination of flow rate. It is not recommended for small flows.

- Calibrated vessel and stopwatch - The time required to obtain a known volume of wastewater in a container is measured, enabling calculations of volume per unit time to be made. This method is usually used for sewers or outfalls where free fall occurs and where flows are small.

- Venturi meters - The venturi meter is normally installed in closed conduits or pipelines under pressure and consists of a converging section, a throat of specific diameter and a diverging section. As part of the static head in the venturi meter is transferred into velocity head, the static head in the throat of the tube is less than the static head in the channel. The difference in pressure head between these two points is measured and is directly related to the flow.

- Orifice meters - These are often used to measure flows in closed pipes. They have a sudden reduction in the pipe diameter, causing a change in pressure which is equated to the flow. These meters result in significant head loss in the system and therefore their use is limited.

- Magnetic flow meters - These consist of a non-magnetic tube of the same diameter as the pipe in which the water or wastewater is flowing and across which a magnetic field is established. Water or wastewater flowing through the magnetic field produces a voltage proportional to the velocity and is converted by electrical and mechanical means to indicate rate of flow.

III.(ii).3. Water Sampling

Many factors are involved in the proper selection of sampling stations including: objectives of the stream study; water uses; access to desirable sampling points; entrance and mixing of wastes and tributaries; flow velocities and times of water travel; marked changes in characteristics of the stream channel; types of stream bed, depth and turbulence; artificial physical structures such as dams and weirs; and, personnel and facilities available for the study.

The ideal sampling station would be a cross section of a stream at which samples from all points on the cross section would yield the same concentrations of all constituents, and a sample taken at any time would yield the same concentrations as one taken at any other time. The former situation, which is not uncommon, occurs when vertical and lateral mixing of any upstream wastes or tributaries are complete at the sampling station. The latter situation, however, occurs only if there is no variation in upstream waste discharges or there is complete mixing longitudinally of any variable waste discharge, and if there are no upstream variations in stream flow, time-of-water travel, temperature, biological activity or other factors that contribute to variation in water quality. This situation never persists in nature for any appreciable period of time. Variations in water quality with time require that samples are collected at appropriate frequencies and times of day to ensure that results are representative of the varying conditions.

A common practice for sampling streams, even when it is believed that vertical and lateral mixing are complete, is to establish sampling points at approximate quarter points, or other equal intervals, across the width of the stream. However, if this proves too time consuming a single mid-current sampling point is often chosen. Sampling usually is at either one metre or mid-depth, whichever is less. (Exceptions are samples taken just below the surface for bacteria and at about 0.3 m for plankton.) When monitoring flows in sewers and channels, a sampling point approximately one-third the wastewater depth from the bottom and as near to the centre of flow as possible is normally appropriate.

A wide range of equipment is available for water sampling varying from manual to fully automatic devices. The selection of the most appropriate sampling equipment is dependent mainly upon the type of sample desired: grab, composite or continuous.

- A grab sample consists of a portion of water taken at one time in a random fashion. Such samples are generally collected manually and only reflect the conditions and characteristics existing at the time of collection.

- "Composite" or integrated samples consist of portions of water taken at regular intervals of time and combined to produce one final volume of sample. Composite samples tend to level off peaks and represent average conditions over the sampling period. Samples may be composited on the basis of time or flow. Those composited on the basis of time are made up of constant volumes collected at even time intervals, regardless of the rate of flow. Those composited on the basis of flow, consist of portions proportional to the flow rate at the time of collection, but at even time intervals. Thus, high flows would demand a higher proportion of sample, and vice versa. Composite samples are either collected manually or automatically. Automatic sampling equipment is available commercially for collecting samples on the basis of flow or time.

- Continuous samples are portions of water abstracted continuously from the source either at fixed or variable flow rates. Such samples have the advantage that nothing in the stream or effluent is missed. Automatic continuous water quality monitors, in which the sample is continuously analysed on-site, have additional advantages: they do not require the very heavy use of trained manpower associated with manual sampling and analysis; they eliminate the sometimes long delays that can occur between sampling and obtaining the results of analysis; and, they provide rapid warning of pollution incidents. An automatic system consists of four basic stages: a continuous sampling device which extracts and supplies the sample at a pre-determined rate to the sensors; the sensors which analyse the sample; facilities for handling the results, which can range from simple chart recorders to sophisticated telemetry systems; and, facilities for automatic cleaning and calibration of the sensors.

The frequency of sampling and the total number of samples taken are dictated by the need to ensure both an acceptable measure of the variations in stream or effluent conditions and an acceptable precision of laboratory analysis. However, in practice these considerations are tempered by inescapable limitations of budget, personnel, facilities and by the amount of time available. However, in general, the use of a few strategic locations and sufficient samples to define the results in terms of statistical significance is more reliable than using many stations with only a few samples from each. The duration of sampling is governed by the objectives of the monitoring programme.

III.(ii).4.Water Analysis

The qualities of natural and treated waters, raw sewage, sewage treatment plant effluent and industrial effluents can all be characterised by the results from various physical, chemical and biological tests. Table III.(ii).1. lists some common tests which, although they may not represent the most modern, sophisticated methods, are capable nevertheless of producing accurate results provided they are performed by a competent analyst with a reasonably equipped laboratory.

A complete analysis of the parameters listed in Table III.(ii).1. could take several days, and would be very wasteful if only two or three tests were crucial. A great deal of time and money can

Table III.(ii).1. - Some important water quality tests, their chief significance and general means of measurement (After Open University 1975)

Quality parameter	Significance	General method of analysis: expression of result
Colour (apparent)	Suspended and dissolved solids	Colorimetric method; comparison with platinum - cobalt standard: unit of colour being produced by 1 mg/l platinum in the form of chloroplatinate ion.
Odour	Most organic and some inorganic chemicals	Subjective Perceived Odour: Threshold Number
Turbidity	Estimate of suspended matter	Jackson candle turbidimeter (Jackson units) or Nephelometric method (Formazin Units)
Dissolved oxygen	Potential for oxidation of organic matter; life support	Titration or electrode: per cent saturation or mg/l
Carbon dioxide	Aerobic/anaerobic decomposition of organic matter; carbonate equilibrium	Nomographic, titration; mg/l of CO_2
Suspended solids	Turbidity; treatment efficiency	Gravimetric: mg/l
Settleable solids	Turbidity; treatment efficiency	Imhoff Cone: ml/l
Dissolved solids	Salinity; may affect ecosystems and domestic and agricultural usefulness	Gravimetric: mg/l
Total solids	General polluting potential	Gravimetric: mg/l
Calcium	Hardness; scale formation	Titration and gravimetric: mg/l of $CaCO_3$

/Continued .....

Quality parameter	Significance	General method of analysis: expression of result
Magnesium	Hardness; taste; possible gastrointestinal irritation; scale formation	Colorimetric; atomic absorption spectroscopy: mg/l of Mg
Hardness	Soap consumption; scale formation	Titration: mg/l of $CaCO_3$
Oil and grease	Toxic potential; physical damage	Chemical and comparometric: mg/l
Acidity/alkalinity	Amount of acid/alkali present; corrosion etc.	Titration: mg/l of $CaCO_3$
pH value	Intensity of acid or alkali present; strength of effluents affects many chemical and biological properties	Titration; electrode; colorimetric:pH values 0-14
Chloride ion	Degree of pollution with sewage; degree of salt water intrusion; taste, corrosion in hot water systems	Titration or colorimetric: mg/l of Cl
Stability/saturation with respect to calcium carbonate	Ability to maintain oxidized condition; tendency to revert to anaerobic conditions with foul odours	Stability/saturation index
Biochemical oxygen demand (BOD)	Extent of biodegradeable organic matter	Measurement of dissolved oxygen before and after incubation for 5 days at 20^{o}C: mg of oxygen consumed per litre
Chemical oxygen demand (COD)	Organic matter susceptible to oxidation by a strong chemical oxidant	Titration: mg/l of oxygen consumed from standard dichromate solution
Permanganate values (3-minute)	Oxidizable inorganic matter; also very easily oxidized organic matter	Titration: mg/l of oxygen consumed from a standard permanganate solution
Permanganate values (4-hour)	Oxidizable inorganic and organic matter	

/Continued .....

Quality parameter	Significance	General method of analysis: expression of result
Total organic carbon (TOC)	Extent of organic matter	Titration: mg/l of organic carbon
Organic nitrogen	Extent of nitrogenous organic matter	Colorimetric or titration: mg/l of organic nitrogen
Ammonia nitrogen	Extent of decomposition nitrogenous organic matter (protein); toxicity	Titration: mg/l of ammonia nitrogen
Nitrate nitrogen	Extent of oxidation of NH_3; plant nutrient; may serve as source of O_2; toxic in excessive amounts (methaeomglobinemia)	Colorimetric or titration: mg/l of nitrate nitrogen
Nitrite nitrogen	In conjunction with ammonia and nitrate, nirites are often indicative of pollution	Colorimetric: mg/l of nitrite nitrogen
Phosphate	Plant nutrient	Colorimetric: mg/l of phosphate as P
Sulphate	Possible reduction to H_2S; corrosion of concrete; possible gastrointestinal irritation	Gravimetric or photometric: mg/l of sulphate as SO_4^{2-}
Cyanides	Toxic potential	Colorimetric or titration: mg/l of cyanide
Phenols	Toxic potential; odour; taste	Titration; chromatography; colorimetric: mg/l of phenol
Synthetic detergents (containing surfactants)	Foam; toxic potential; taste	Colorimetric; titration: mg/l of specific detergent
Pesticides	Toxic potential	Gas chromatographic method: mg/l of pesticide
Iron	Taste; discolouration; turbidity; growth of 'iron' bacteria	Colorimetric; atomic absorption spectroscopy: mg/l of Fe.

/Continued .....

Quality parameter	Significance	General method of analysis: expression of result
Manganese	Taste; discolouration; turbidity	Colorimetric; atomic absorption spectroscopy: mg/l of Mn
Zinc	Taste; turbidity	Colorimetric; atomic absorption spectroscopy: mg/l of Zn
Copper	Taste; discolouration; corrosion	Colorimetric; atomic absorption spectroscopy: mg/l of Cu
Cadmium	Toxic potential	Colorimetric; atomic absorption spectroscopy: mg/l of Cd
Silver	Toxic potential	Colorimetric; atomic absorption spectroscopy: mg/l of Ag
Chromium	Toxic potential	Colorimetric; atomic absorption spectroscopy: mg/l of Cr
Fluoride	Potential for fluorosis at certain concentrations	Colorimetric; electrode: mg/l of F
Lead	Toxic potential	Colorimetric; atomic absorption spectroscopy: mg/l of Pb
Selenium	Toxic potential	Colorimetric: mg/l of Se

be saved by limiting the extent of the analysis to parameters which, through experience, are known to be important. Consequently, a limited number of tests are carried out and these vary according to the source of the sample and the purpose of the analysis.

Routine monitoring of river water would, for example, include measurements of the temperature (taken at the time of sampling), pH value, dissolved oxygen, amount of suspended and total solids, and alkalinity. If the presence of pollution due to sewage effluent is known or suspected, tests for ammonia, organic nitrogen, nitrite and nitrates, chloride, phosphorus, detergents and organic matter would also be made. Other substances, such as toxic metals or particular organic compounds, might be measured if the water is polluted directly with industrial wastes or with effluent from a plant treating sewage with which industrial waste has been mixed.

The number of tests that are routinely carried out with raw and treated water and with effluents has increased in recent years. This is because of the growing demand for and use of water, the increasing variety and concentration of harmful contaminants, and a more complete knowledge of the effects of many pollutants on ecosystems and human health.

There are a wide variety of techniques for the quantitative analysis of waters and wastewaters. Some of the more common techniques are described briefly below, but for detailed procedures the following references should be consulted: Strickland and Parsons (1968); U.S. Environmental Protection Agency (1971, 1972 and 1973); Mancy and Weber (1971); U.K. Department of the Environment (1972); Rodier (1975); Golterman (1969); APHA, AWWA and WPCF (1975).

- Titration - This technique involves the measurement of a volume of a known concentration (standard solution) required to interact exactly with the desired chemical component. In some cases, one or more reagents are added prior to titration, to produce a suitable chemical species. For example, in the

Winkler test for determining the dissolved oxygen concentration in water, manganese hydroxide and an alkaline solution containing iodide ions are added first to the sample. Acidification then causes the formation of molecular iodine, in an amount related to the original quantity of dissolved oxygen. The amount of iodine present can be determined by titrating with a standardised solution of thiosulphate ions which reduces the iodine back to iodide ions.

$$Mn^{2+} + 2OH^{-} + \frac{1}{2}O_2 = MnO_2 + H_2O$$

$$MnO_2 + 2I^{-} + 4H^{+} = Mn^{2+} + I_2 + 2H_2O$$

$$2S_2O_3^{2-} + I_2 = S_4O_6^{2-} + 2I^{-}$$

Titration proceeds to a definitive end point, normally to either a colour change or some electrical metre response. Care has to be taken in such tests to remove substances that may cause interference.

- Gravimetry - Suspended solids are normally determined by passing a known volume of the sample through a standard size filter, and then weighing the retained material to allow calculation of weight per unit volume (e.g. mg/l). This same technique can be used for precipitates produced by converting the component of interest to an insoluble product. For example, the chloride ion can be determined by the addition of silver nitrate which converts the chloride ion to an insoluble white precipitate which is then weighed.

- Spectrophotometry - In this technique, a chemical reagent is added to the sample and reacts quantitatively with the determinant to produce a strongly absorbing coloured reaction product. The absorbance of this solution is then measured and compared to standards of the same solution. The predominant applications of ultraviolet and visible spectrophotometry are the determination of: non-metallic species (e.g. chloride, cyanide, fluoride, silicate, sulphate);

nutrients (e.g. ammonia, phosphate, nitrate); detergents (e.g. anionic and non-ionic surfactants); and, organic compounds such as formaldehyde and amines. Its use for the analysis of metals (at one time almost universally applied) is now declining because of the advent of atomic absorption spectrophotometry (see below).

- Other spectroscopic methods - The long-established standard techniques described above are yielding to ones that are easier and quicker to carry out, but they tend to be more expensive as they normally depend on more sophisticated equipment. In *infrared spectroscopy*, the concentrations of substances are determined by measuring the degree of absorption of particular wavelengths of radiation from an infrared source. *Atomic absorption spectrophotometry* is a related method and is commonly used in analysis for heavy metals. A very small quantity of the water sample is sprayed into a flame producing atomic vapours of the elements in question. These are measured by passing a monochromatic light of the same wavelength through the vapour in the flame, the amount of radiation absorbed being proportional to the concentration of the element. *Flame photometry* is another related technique and is used to detect elements such as sodium and potassium. It depends on the distinctive frequencies of light that different elements emit (rather than absorb) when heated in a flame. Other techniques finding increasing application include gas-liquid chromatography, infra-red spectroscopy, mass spectrometry and neutron activation analysis.

- Biological methods for water analysis include culturing techniques for bacteria and microscopic analysis. In general, the number of pathogenic (disease-carrying) organisms in water are few and difficult to isolate, and so the coliform organism is usually used as an indicator organism. There are two accepted methods of testing for this group: (i) the *Most Probable Number* method, which is based on a statistical analysis of the number of positive and negative results obtained by inoculating multiple portions of equal volume of culture medium with portions of sample, to constitute a geometric series. The result is a statistical estimate of the concentration of organisms present in the sample; and, (ii) the *Membrane Filter* technique, which is accomplished by passing a known volume of sample through a membrane having microscopic pore size, such that the bacteria are not passed through and are retained on the filter. The membrane containing the bacteria is next briefly placed in contact with a moist agar medium, and incubated for a specified time under prescribed conditions of temperature and humidity. The resulting culture is then examined, and a direct count is obtained of the bacteria present in the sample. The membrane filter has three major advantages: (1) results are obtained by a direct reading; (2) results are available within 24 hours, compared with 48 hours or more by other methods; and (3) portable field kits are available for complete sampling and testing on site (World Bank, 1978).

- Probably the most important biochemical method of analysis is the biochemical oxygen demand (BOD) determination. This is used for measuring the oxygen requirements for the decomposition of organic matter in natural waters and waste waters under specified conditions of time (normally five days) and temperature (normally $20^{\circ}C$). The BOD analysis is a biochemical method because it involves the oxygen consumed by aerobic bacteria and by the chemical oxidation of reduced compounds such as H_2S, NO_2, and Fe^{++} that can be oxidized by molecular O_2.

A recent trend in environmental analytical techniques is the development of compact and robust apparatus to allow rapid, convenient and simple measurements in the field. Several portable kits are now available which enable staff with minimal laboratory training to determine over 20 water quality parameters. Although such pre-packaged devices are normally less accurate than precise laboratory techniques and cannot cope as effectively with interferences, they are extremely useful in preliminary surveys and "troubleshooting" exercises.

III.(ii).5.Biological Monitoring

III.(ii).5.1.General considerations

Chemical analysis of water is not wholly satisfactory in determining the baseline conditions of the aquatic environment. The data obtained from analysis hold true for the period of sampling only, e.g. oxygen levels in rivers fluctuate naturally during a daily cycle falling possibly to very low levels during the hours of darkness, when the aquatic flora utilises oxygen produced during the day. Unless chemical analysis can be undertaken either on a continuous or a frequent and regular basis (usually prohibited by expense), an incomplete picture of ambient conditions is obtained. The biota of rivers, on the other hand, because of their prolonged exposure to all the varying environmental parameters, provide integrated water sampling devices for testing intermittent pollution. Chemical data are still required, however, to correlate with any observed changes and to allow identification of specific pollutants. Biological monitoring may also enable the path of a pollutant to be traced both up the food chain and back to its original source, often when chemical traces have long disappeared.

For these reasons, consideration should always be given to concurrent biological surveys. Such surveys usually involve quantification of the number and diversity of organisms and an estimation of primary productivity. Indicator species can be studied which, because of differing senstitivites to specific pollutants, help to delineate environmental baseline conditions by their presence or absence. In addition, by analysing the tissues of biota suspected of being exposed to certain substances and comparing the results with similar analyses of control specimens, it is possible from a knowledge of the processes involved (e.g. uptake, breakdown and excretion rates), to make assessments of the levels of past exposure.

While the above methods are invaluable in the overall assessment of water quality, they cannot reflect acute pollution events until several days have elapsed, and changes in species distribution and/or composition have occurred. Consequently, biological 'early warning systems' capable of providing a more rapid indication of pollution have been developed. These monitor behavioural or physiological responses of single or groups of organisms and are capable of indicating pollutant-loading immediately. The organisms react to environmental stress by rapid alteration of their normal behavioural or physiological patterns, and this is picked up by the monitoring equipment, sounding an alarm or setting into motion some remedial action.

Some of the rapid biological systems currently in use or being developed are reviewed by Cairns, Dickson and Westlake (1977) and their applicability for continuous, rapid and early warning of pollution are evaluated in a paper by Kingsbury and Rees (1978). Provided they are not regarded as the definitive answer to pollution monitoring and provided they are operated and maintained appropriately, these systems have considerable potential for rapid surveillance and are the only way in which synergistic effects of a complex of substances may be evaluated.

III.(ii).5.2.Marine and estuarine studies

The shoreline, water column and bottom sediments are the principal sites for biological baseline monitoring.

III.(ii).5.2.1.On-shore

i) Shore transects: to help detect natural or man-made changes within coastal marine communities, the most easily accessible organisms (e.g. intertidal flora and fauna) can be monitored by periodic survey of their distribution and abundance (Goldberg, 1976). Sub-sampling techniques can be applied to samples from sandy shores to avoid excessive sorting (Baker, 1976).

ii) Seaweed sampling and analysis: a number of recent studies of the heavy metal content of seaweeds have suggested that the concentrations of trace metals in their tissues appear to depend upon the relative and absolute concentrations of metals in the surrounding seawater and consequently form a historical record of ambient dissolved metal concentrations at the site of growth. (Bryan and Hummerstone, 1973).

iii) Shellfish flesh analysis: molluscan shellfish in estuaries, such as mussels or oysters, are particularly susceptible to tainting by oil and, like seaweeds, concentrate metals in tissue. However, as uptake is often selective, careful interpretation of results is necessary (Fossato, 1975; Goldberg, 1978).

III.(ii).5.2.2.Water column

i) Plankton: despite difficulties in detecting short-term pollution effects, long-term trends in the plankton communities need to be monitored as indicators of changing environmental conditions (Figure III.(ii).2.).

ii) Fisheries: the essential feature of fish in their reaction to pollution is their ability to move away from most incidents of pollution. Thus, there have been relatively few reported incidents of massive fish kills. However, the floating eggs of fish and fish larvae are particularly vulnerable and sensitive, especially to refined hydrocarbons, crude oil, and dispersants and surfactants. Other important considerations are the tainting of fish flesh and olfactory barriers.

Because of the great value of fisheries to many coastal and offshore areas, existing and predicted levels of pollutants in the sea-water should be evaluated against published data on acute and chronic toxicities, and flesh taken from a number of fish samples for hydrocarbon and heavy metal analysis before and after project completion.

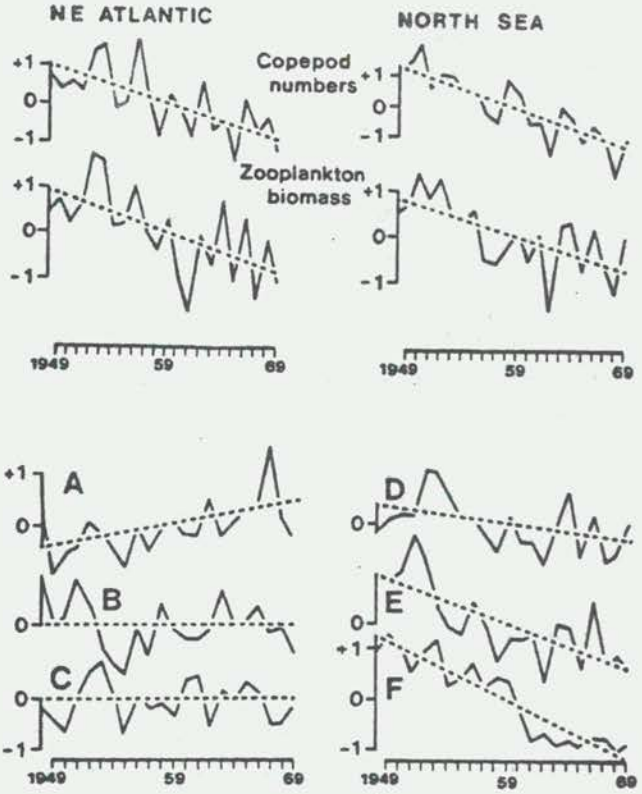

Figure III.(ii)2 Changes in the zooplankton of the north-eastern Atlantic, as seen by regular sampling between 1949 and 1969. Above, numbers of copepods and total biomass of zooplankton; below, fluctuations in abundance of individual organisms in two areas together.

A. *Acartia clausi;* B. *Temora longicornis;* C. *Clione limancina;* D. *Calanus helgolandicus + finmarchicus;* E. *Spiratella retroversa;* F. *Pseudocalanus + Paracalanus spp.* The curves are standardized about a mean of zero; the scale is in units of standard deviation. From Glover, Robinson and Colebrook (1970).

III.(ii).5.2.3. Benthic organisms and sediments

Organisms inhabiting bottom sediments may be subject to sizeable quantities of pollution if it is sunk, or sinks naturally. Of the pollutants to be found in the aquatic environment, hydrocarbons often represent the greatest hazard.

In an offshore area, accepted assessment practice involves a large-scale survey followed by selection of discrete areas for more detailed study. The sampling method utilises a grab or dredge capable of taking bottom samples to a depth of about ten centimetres and in sufficient number to meet the minimum required for statistical treatment. (Holme and McIntyre, 1971).

III.(ii).5.3. Freshwater studies

Riverine ecosystems can be dramatically affected by pollution incidents so that biological data are required to complement chemical analysis data, particularly when detecting the insidious effects of gradual pollutant release and build-up.

The biological components are best studied in three ways: a limnological survey, fisheries population study and planktonic studies (Welch, 1952; Schwoerbel, 1972; Weber, 1973; Whitton, 1975; Hellawell, 1978).

III.(ii).5.3.1. Limnological survey

i) Invertebrate population studies: involves determination of faunal composition via quantitative sampling; specifically number of organisms, species diversity, productivity, and the presence of indicator species.

Interpretation of the results are somewhat complicated by the diversity of microhabitats within freshwater bodies. The analytical methods employed include: *pollution indices*, which have been developed from observed responses of certain 'indicator' taxa to known pollutants; *diversity indices*, which describe the structure of the community and may be used to monitor changes in communities in response to environmental changes; and, *comparative indices*, which may be utilised to assess either spatial changes, by measuring the similarity of the community under investigation with others existing under known or 'control' conditions, or temporal changes such as those which might occur in a conventional 'before and after' study.

ii) Flora and micro-organisms: a survey of plant types and their growth and percentage cover rates. Where appropriate, bacteriological investigations should be undertaken.

III.(ii).5.3.2.Fisheries population study

Where the release and dispersion of pollutants are likely to have detrimental effects on river fisheries, baseline data should be gathered on the population size, age structure, fecundity, growth rates and overall condition (Edmondson & Winberg, 1971; Ricker, 1971).

Further, heavy metal and hydrocarbon analyses should be conducted on fish or other appropriate organisms to determine the rates of uptake and influence of loading. Concurrently, selective sampling of the sediment for metal analysis should be undertaken to delineate the retention rates in the riverine environment.

III.(ii).5.3.3.Plankton

Though more difficult to survey than marine or estuarine plankton, freshwater plankton can still give an indication of river quality, productivity and ecosystem diversity. (Vollenweider, 1969; Kajak and Hillbricht, 1972).

Because of their great importance for the protection of water supplies, and for the estimation of water quality (pollution and self purification of waters), freshwater studies are today one of the most important of the applied sciences (Warren, 1971).

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IV - DISPERSION OF POLLUTION

IV.(i). DISPERSION OF AIR POLLUTANTS

IV.(i).1. Introduction

The discharge of noxious gases and particulate material from a chimney is the beginning of a complex series of processes some of which, being random in nature, are largely unpredictable in the short term. There are four main parts to the dispersion and dilution process:

(i) The upward stream of effluent is usually warmer and lighter than the surrounding air. It therefore continues to rise, quickly at first but slowing down as the effects of its initial momentum and then its buoyancy are lost.

(ii) There is a general drift in the direction of the prevailing air flow, during which the effluent is diluted as it spreads sideways and up and down. This diffusion begins before the plume rise is complete.

(iii) The material undergoes chemical and physical changes in response to the changed conditions.

(iv) The pollutants are finally removed from the atmosphere by the natural wet and dry processes of deposition, which include adsorption and absorption onto surfaces and washing out of the air by rain.

Some of the factors which affect the above processes are considered in more detail in the next section, which is followed by a summary of predictive modelling techniques.

IV.(i).2. Factors Affecting Plume Rise and Dispersion

IV.(i).2.1. Initial momentum and buoyancy

The initial trajectory of an effluent plume depends on the combined effect of the amount of effluent being discharged (the mass flowing) and the velocity at which it is ejected, i.e. the initial trajectory depends upon the initial momentum of the effluent. However, after a short distance buoyancy takes over. Most effluents usually have a lower density than ambient air (i.e. they are at a higher temperature if the plume is mainly air). The difference in density causes a buoyancy force to act on each element of the plume equal to the product of the volume of the element times the density difference times the acceleration due to gravity. This force will therefore tend to make the plume accelerate upwards. The final rise of the plume will be governed by the rate at which buoyancy is lost due to cooling by entrained air.

IV.(i).2.2. Dilution and drag due to relative motion

When a parcel of gas is moving through the surrounding air, the velocity shear produced by the relative motion causes it to grow at a rate proportional to the product of its surface area exposed to the ambient air and the magnitude of the relative velocity. There will also be a frictional drag opposing the relative motion due to the disturbance in the surrounding air and in the parcel itself. Both these effects will slow down the rate of ascent of the plume.

IV.(i).2.3. Ambient vertical temperature gradient (Figure IV.(i).1.)

A rising parcel of air or a plume passes through a region of decreasing pressure and therefore expands. In addition to any effect due to dilution, this expansion dissipates energy and causes the temperature of the air parcel to fall at a rate determined by the adiabatic gas equation (about $1^{\circ}C/100m$). If the fall in temperature of the surrounding air with height above ground level (i.e. the atmospheric lapse rate) is less rapid than this, the buoyancy force on the ascending plume decreases and the air is said to be stably stratified. In these sub-adiabatic conditions, the plume will eventually lose all its buoyancy and will travel horizontally, now having the same temperature as the surrounding air. Thus in stable

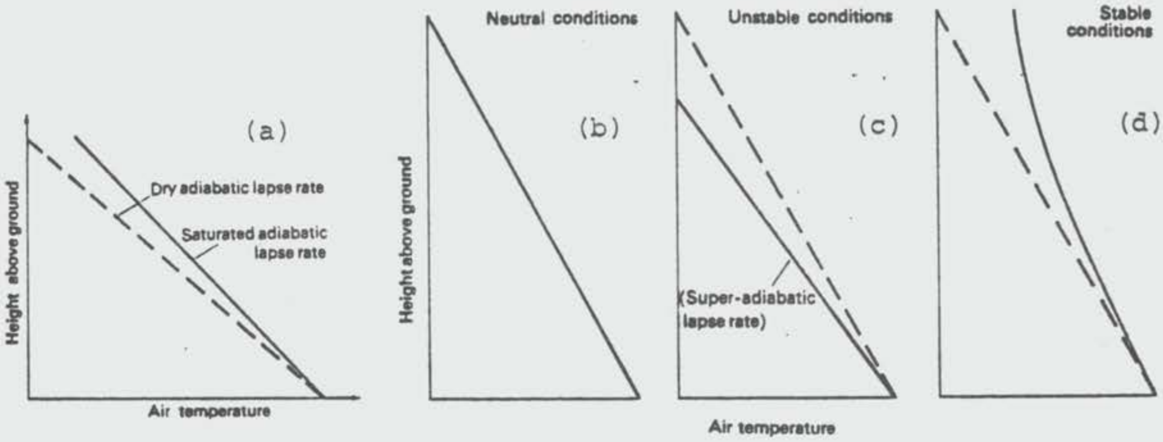

Figure IV.(i).1. The temperature of a parcel of air as it is lifted will decrease with height according to the adiabatic lapse rate(a). If the air remains unsaturated, the adiabatic lapse rate will approximate the rate for dry air, but if it becomes saturated condensation of the moisture will reduce the fall in temperature and the saturated adiabatic lapse rate will be followed. Graphs (b), (c) and (d) are examples of the temperature gradients or lapse rates associated with different conditions of atmospheric stability. (Open University, 1975)

atmospheres, pollutants will only slowly disperse and turbulence is suppressed.

Near the ground in strong sunshine or when very cold air is moving over a warm surface, the fall in air temperature with height occurs more rapidly than the adiabatic lapse rate and a plume will actually gain buoyancy as it rises through such a layer. In this case the air is said to be unstable and pollutants discharged into this layer would be mixed and diluted rapidly. However, these super-adiabatic conditions are seldom observed above about 150m.

When the adiabatic lapse rate is the same as the atmospheric lapse rate, a rising parcel of air will always remain in equilibrium with its surroundings which implies it will have the same density. Therefore its vertical movement will neither be assisted nor resisted. These conditions are described as neutral and are commonly associated with overcast skies and moderate to strong winds, when the atmosphere is well mixed and air is moving freely from one level to another.

IV.(i).2.4. Inversions

There are many occasions when the air temperature increases with increasing height above ground level. Such a condition is referred to as an inversion and is denoted by a negative lapse rate. Such an inversion may extend from ground level or may exist at a substantial height above ground (Figure IV.(i).2.).

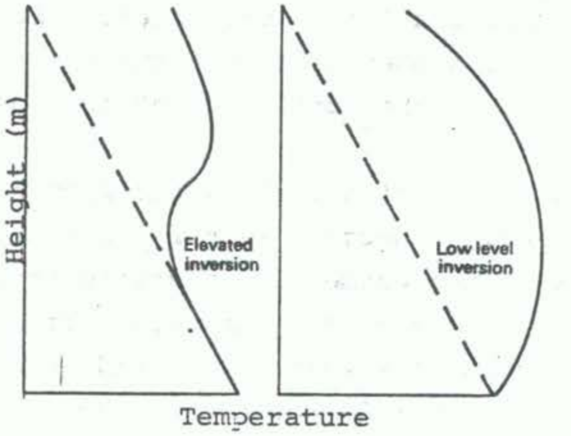

Figure IV.(i).2. An elevated and a low level inversion

Low-level inversions tend to form overnight when winds are light and skies are clear (Figure IV.(i).3.). After a sunny day the ground cools down as the sun declines. Without cloud cover, heat is radiated steadily into space and layers of air just above the ground are cooled by conduction. Under these conditions mist or fog will form if the original air humidity was sufficiently high for the newly cooled air to reach its saturation point. With continued cooling, the depth of the inversion layer will gradually extend

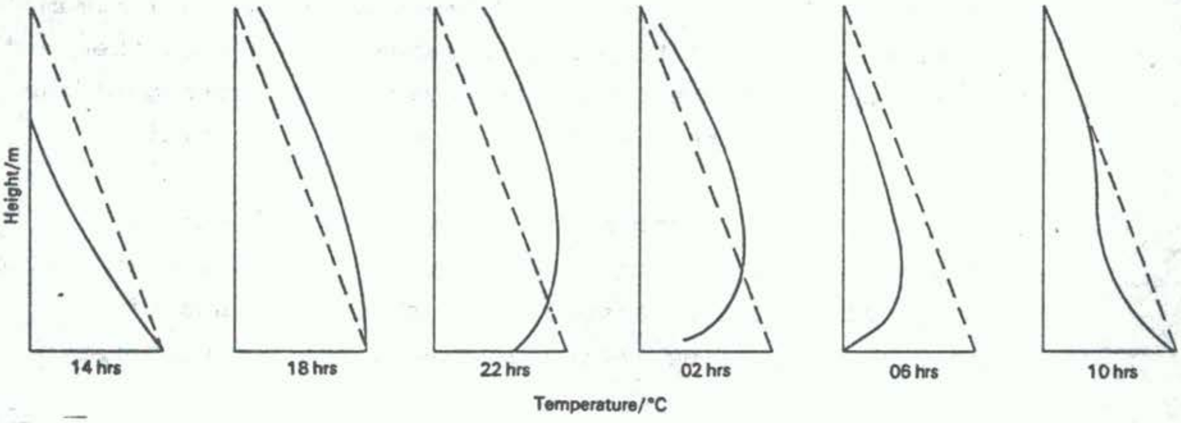

Figure IV.(i).3. Stages in the formation of a low-level inversion overnight.

upwards to greater heights. When the sun begins to warm up the ground again after dawn, air mixing will be renewed and the inversion will normally be dispersed.

Inversions formed in a layer of air some distance above the ground are referred to as elevated inversions and tend to be much more widespread and more persistent. Such inversions can be formed by a number of mechanisms but the first of those given below is the most frequent and most important:

(i) The subsidence of a mass of air from aloft which, by descending, becomes warmer adiabatically. This results in the warmer layer coming to rest above an original cool stagnant air mass. If clouds are present below the warm layer, radiation from their upper surfaces will accentuate the inversion.

(ii) The intrusion of a mass of cool air underneath a mass of relatively warm air. On a weather map, this is the meteorological cold front marked by a line and a series of triangles.

(iii) The small scale 'sea breeze', which introduces a layer of cooler air from the sea underneath a rising mass of warmed air lying over the land.

Inversions are of great importance to studies of the dispersion of air pollutants because the intermixing of air layers lying above and below a 'strong' inversion is virtually excluded. The 'strength' of an inversion depends both on the minimum negative value of the temperature lapse rate and on the effective depth of the inversion layer. The 'stronger' the inversion, the greater is the 'barrier' to intermixing.

If the barrier forms above a chimney, the effluent will usually have insufficient buoyancy to penetrate the inversion and disperse upwards. Ground level concentrations of pollutants may then be increased dramatically. Conversely, if the inversion forms below the point of discharge, the effluent is unlikely to reach the ground in the vicinity of the chimney and the expected pollution at ground level will be much reduced.

IV.(i).2.5. Wind Speed

The wind speed is an important factor in determining the rise of a plume for two reasons:

(a) the amount of effluent material contained within unit length of the plume is inversely proportional to the wind speed; and,

(b) once the plume has been exposed to the wind for a few seconds and has been diluted say ten fold by the mixing produced by its relative motion, its horizontal speed will be very close to the wind speed and consequently the tangent of its angle of rise will be almost equal to (but slightly greater than) its vertical velocity divided by the wind speed.

IV.(i).2.6. Variation of wind speed and direction with height

The combined effect of forces arising from differences in atmospheric pressure and the Earth's rotation cause winds. Above a certain minimum height, the wind blows steadily in a direction parallel to the isobars, the lines of equal pressure on a weather map. Wind speed is proportional to the pressure gradient and winds blowing at the speed calculated on this basis are then called gradient winds. The minimum height at which these winds blow, the gradient height, is usually of the order of 600 metres above the ground. Below the gradient height, the wind is slowed down by the effect of friction with the ground. Thus wind speed varies with height. When it is moving more slowly it can also blow more directly towards the centre of low pressure. Therefore, the wind direction also varies with height.

At any site under conditions of neutral stability, the shape of a graph showing the change of wind speed with height will depend upon the roughness of the ground (Figure IV.(i).4. Thus, as the air mass leaves an area of open sea or country to pass over an urban area, the wind speed profile begins to change. At first the air near the ground is slowed down by the houses and becomes more turbulent. The influence of buildings extends gradually upwards to reduce the mean wind speed and increase the general degree of turbulence.

The effects of change in wind direction with height are shown in Figure IV.(i).5. In the northern hemisphere, an observer standing with his back to the wind would have an area of low pressure on his left (the positions are reversed in the southern hemisphere.). Because the gradient wind blows parallel to the isobars while winds at progressively lower heights are turned towards the centre of low pressure, an emission would tend to be distributed downwind of its source over a track of increasing width but centred on a gently curving arc away to the right.

IV.(i).2.7. Turbulence

Near to the ground, the wind is mechanically stirred by objects such as stones, rocks, vegetation, buildings and hills to form eddies. In this way, some of the energy in the wind is dissipated and the wind slows down. The upper layers of air, now moving faster, have to slide over the lower layers and this causes interlocking, an effect which propagates eddies to progressively greater heights. This stirring process, due to the unevenness of the ground and buildings, thus maintains a state of turbulence, which tends to decrease with height up to gradient height.

The turbulence of eddies, or gusts, is conveniently described as random fluctuations of air velocity, in any direction, which are superimposed on the mean flow. Eddies are also formed during the day when one patch of ground absorbs more heat from the sun than another. Air passing over it is warmed and, becoming lighter, rises through the air mass as a convection

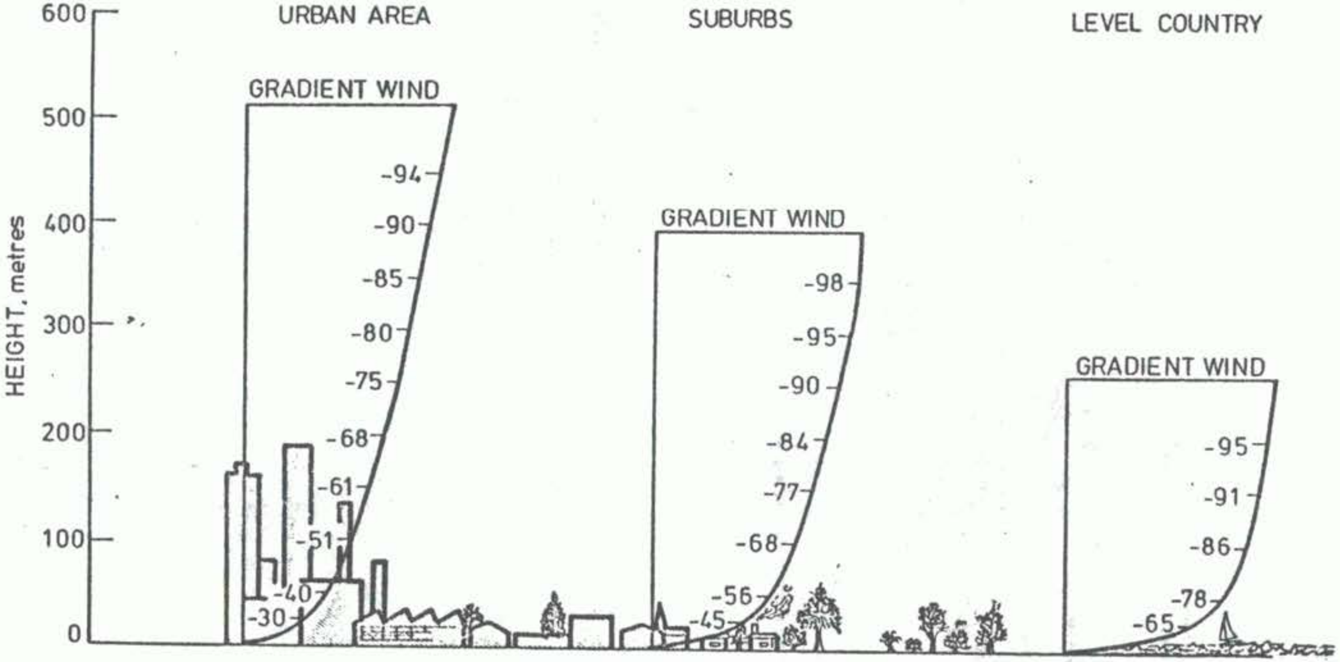

Figure IV(i).4. Examples of variation of wind speed with height over different size roughness elements (figures are percentages of gradient wind). After Turner, 1970.

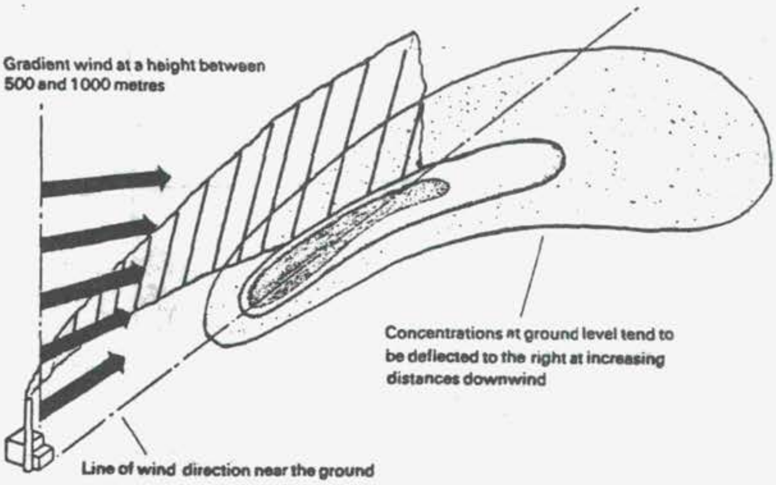

Figure IV.(i).5. Change of wind direction with height affecting the distribution of pollutants from a single source. (Open University, 1975).

current. Such upward streams, or thermals, add to the general level of turbulence by the mixing effect at their boundaries.

The larger eddies of the atmospheric turbulence affect a plume's behaviour because they will break it up into lumps or elements so that it becomes more like a twisted string of beads than a smooth cone. Although initially the dilution of the plume elements will be almost entirely due to relative motion, in a turbulent boundary layer the smaller-scale atmospheric eddies will eventually become important in determining the rate of dilution of the elements themselves.

IV.(i).2.8. Surface topography and location

Surface topography can affect the local wind and hence the transport of pollutants. For example, high concentrations of pollution would be expected to occur on the windward side of a ridge, but in practice the leeward side experiences the more severe pollution due to wind induced eddy formation (Figures IV.(i).6. and IV.(i).7.). Similarly, Figure IV.(i).8. show the complications associated with siting a stack in a valley. When the winds are light the air becomes stagnant and stratified, especially at night and in winter. The pollution emitted at night may be drawn down to the valley floor by cold air sinking down the hillside. During the day most of the air in the valley remains stratified while warm air flows up the hillside, receiving heat from it as its ascends. A recirculation is thus set up where the plume is forced to fan out.

The effects of water bodies on pollutant transport also can be profound. Figure IV.(i).9. for example, shows a buoyant plume rising into a zone where a returning land breeze dominates the wind pattern. This behaviour will vary diurnally and is very difficult to predict.

IV.(i).2.9. Gravity

In addition to physical dispersion or spreading, particulate

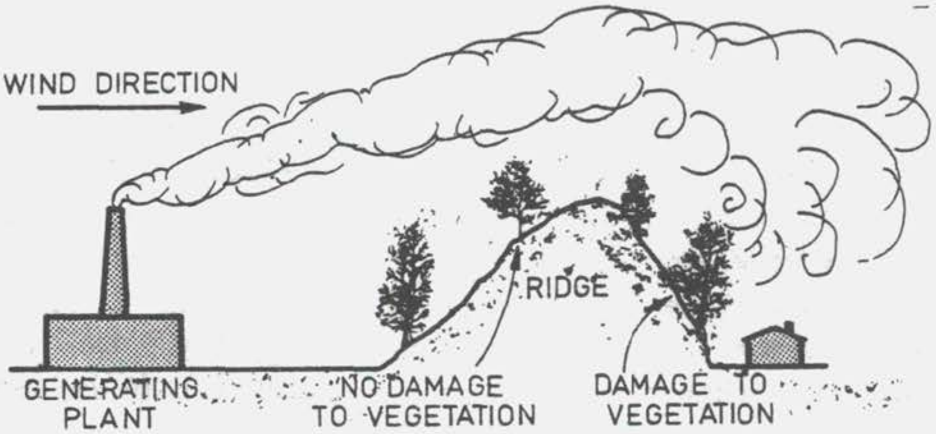

Figure IV.(i).6. Effects of a ridge on pollutant transport

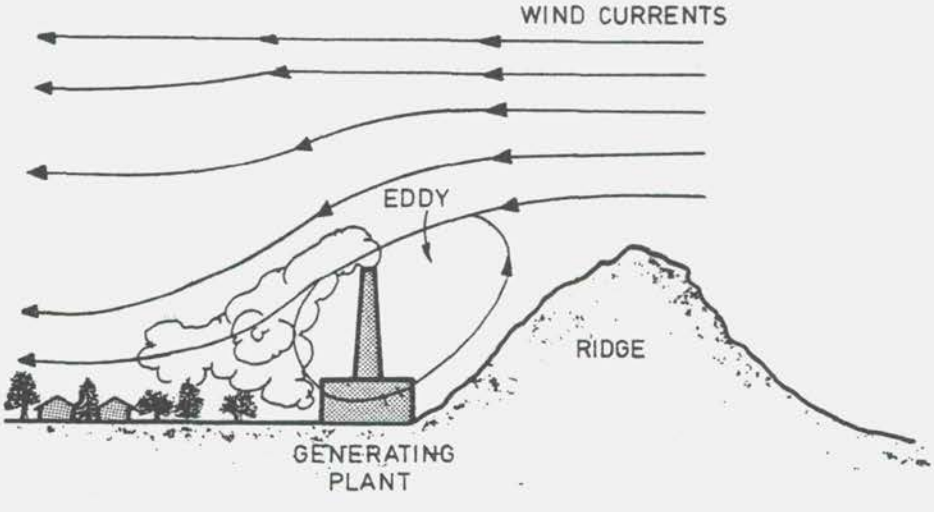

Figure IV.(i).7. Eddy formation in the lee of a ridge

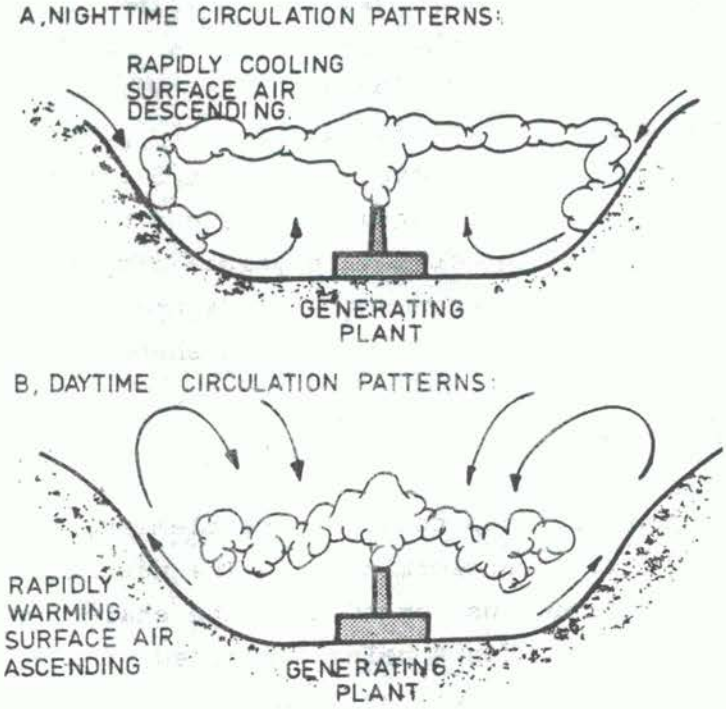

Figure IV.(i).8. Circulation in a valley

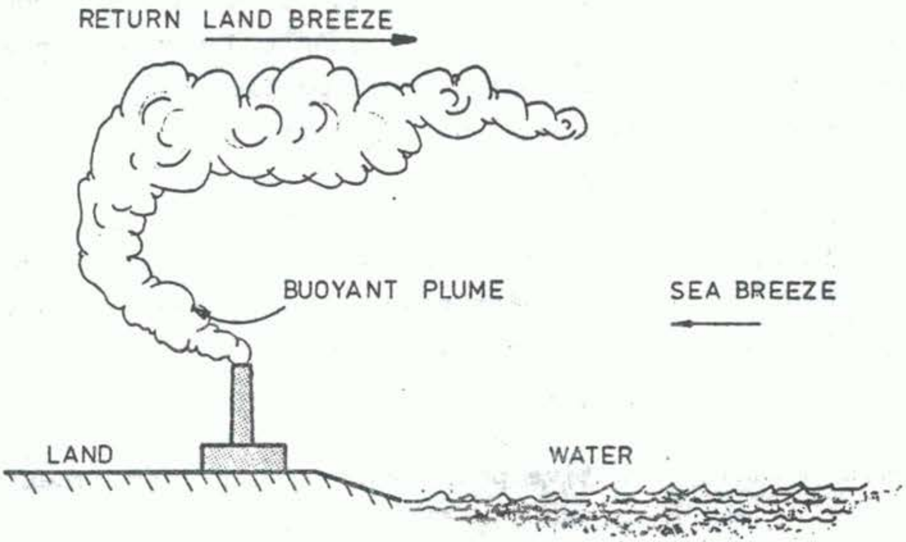

Figure IV.(i).9. The impact of a water body on pollutant transport emissions are subject to gravity, falling to the ground at rates dependent upon their shape, size and density. Thus, a change in size distribution and chemical composition of the suspended particulates with distance is possible. Once the particulates reach the ground they tend to be trapped, although in some circumstances they can be re-entrained by the wind and undergo further physical dispersion at low level. The degree of re-entrainment depends upon the wind speed and the particle size, density, and shape.

IV.(i).2.10. Chemical processes

During transport from source to settlement, pollutants may undergo certain transformations. The nature and degree of these transformations depend upon the characteristics of the pollutant or pollutants being dispersed, the presence of 'reactive' agents in the atmosphere and the meteorological conditions.

If the pollutant is highly reactive with water (e.g. sulphuric acid aerosols and some other sulphur compounds) and the ground surface is 'rough' and wet, some surface absorption may occur. This will reduce the airborne concentration downwind. [Because of the difficulty of predicting partial ground absorption, mathematical models cannot describe the situation accurately. They can only assume perfect ground absorption and thereby over-estimate or under-estimate the concentration.]

Rain can wash-out pollutants from a reactive plume of emissions. Furthermore, because condensation of water vapour may occur as a hot or warm plume containing pollutants rises, expands and mixes with cooler air, a self wash-out or wet scrubbing of the pollutants can take place.

Where mutually reactive pollutants are emitted, chemical reactions may occur during dispersion. The rate of reaction, however, decreases rapidly with distance as the constituents become more and more dispersed and collisions between the components less frequent.

Fuel combustion, especially the burning of petrol in motor vehicles, results in the emission of many compounds including hydrocarbons and nitrogen oxides. The action of sunlight on these compounds produces very toxic pollutants, collectively called photochemical oxidants or photochemical smog. The principal component is ozone (O_3), usually contributing over 90% while other important constituents are peroxyacetyl nitrate (PAN) - $CH_3C(O)OONO_2$ - and aldehydes (Figure IV.(i).10). These substances have unusual odours and can cause intense eye irritation and plant and material damage.

The occurrence of photochemical reactions depends on a variety of factors, e.g. light intensity, spectral distribution, hydrocarbon reactivity, meteorological variables, the ratio of hydrocarbons to nitric oxide and the presence of light absorbers other than NO_2. Of the hydrocarbons, the olefins react most rapidly, followed by those aromatics with sidechains. Paraffins are much less reactive and acetylene is relatively inert.

Sulphur dioxide is believed also to be removed from the atmosphere under the action of photo-oxidation. It has been postulated that in the presence of ultraviolet light, sulphur dioxide is oxidised to sulphur trioxide which then reacts with moisture to form sulphuric acid. Subsequently, the sulphuric acid in the aerosol reacts with other substances to form sulphates which precipitate out. Current estimates of the half-life of sulphur dioxide in the atmosphere range from two hours to several days.

IV.(i).2.11. Characteristic plume dispersion

Some of the principal types of plume dispersion are shown in Figure IV.(i).11. where it is assumed that dispersion is over open level country.

A fanning plume (Figure IV.(i).11a.) typically arises on discharge into a low-level inversion layer. With insufficient buoyancy to rise above the inversion and with atmospheric turbulence

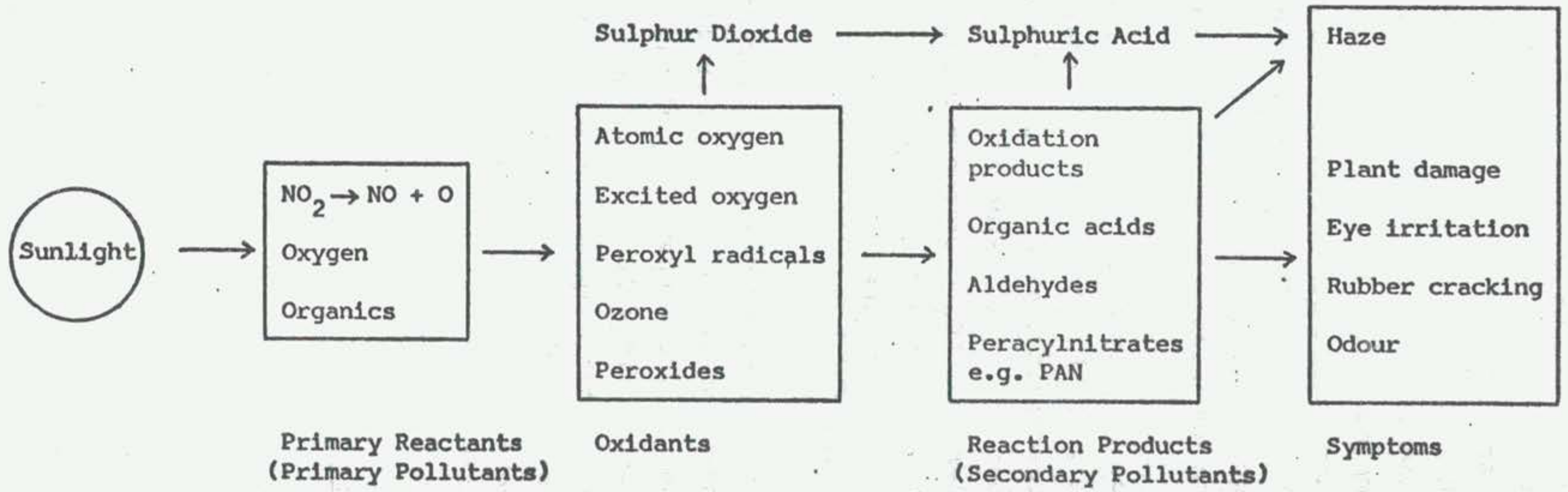

Figure IV:(i).10 The photochemical reactions occurring in oxidizing type smog. (Haagen-Smit, 1969) suppressed, there is little lateral and even less vertical spread and the plume may persist as a narrow cone for a considerable distance downwind. These conditions often occur at night when the stable atmosphere tends to keep the plume clear of the ground.

The coning plume (Figure IV.(i).llb.) commonly occurs in near-neutral stability conditions and especially during moderate to strong winds. Dispersion is controlled entirely by the magnitude of turbulence generated mechanically. This, it is conventionally assumed, acts with equal effect in both the horizontal and vertical directions to give a symmetrical, steadily expanding, conical shaped plume.

Discharge of an effluent into an unstable (super-adiabatic) airflow produces a looping plume (Figure IV.(i).llc.) which can cause pollution at ground level when the depth of the unstable layer is greater than the height of the chimney. Winds are usually light, with strong thermal eddies (set up by solar heating) acting on the plume in a random fashion.

A fumigating plume (Figure IV.(i).lld.) is characteristic of the period when a low-level inversion is breaking up or when there is an elevated inversion above stack height. For example, in the morning breakup of an inversion strong convective bubbles develop upwards until they reach the chimney effluents that have remained aloft during the night. The plume then mixes downwards often bringing substantial quantities of effluent to ground level. This is one of the reasons for the typical morning peak in pollution concentrations. Similarly, if a stable layer is formed above the level of the stack, there is a limit to the rise of the emission which can lead to increased ground level concentrations.

In contrast, when a stable, inversion layer forms below the top of a stack a lofting plume is formed and pollutants are spread over a wide area (Figure I.(i).lle.). This is the aim of operators of large plant such as power stations. The discharge is made from tall chimneys and as it is usually hot, the

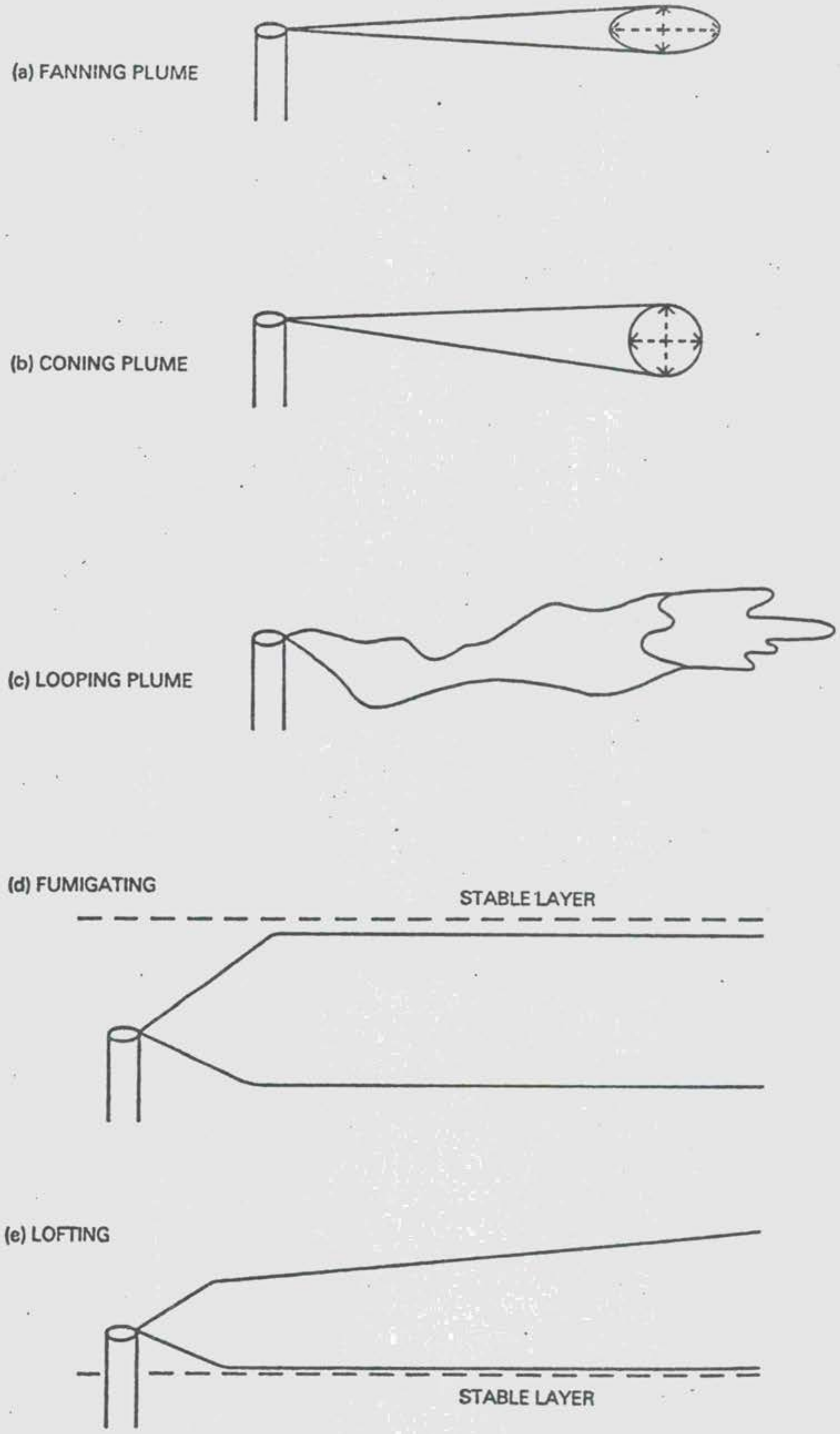

Figure IV.(i).11. Plumes produced by different atmospheric conditions
(U.K. Department of the Environment, 1976)

buoyant plume will penetrate an elevated inversion layer. Because downward mixing is inhibited, dispersion is kept almost entirely above the inversion and it is often several miles before any pollution reaches ground level.

For further information on air pollution meteorology and the factors affecting plume rise and dispersion the following references should be consulted: Scorer (1968); World Meteorological Organisation (1972); and, Munn (1976).

IV.(i).3.Predictive Modelling

IV.(i).3.1.Full scale simulation

Generally, the simplest way of predicting the dispersion pattern from a future source of emission is to take measurements near an existing like source. The difficulty arises in making sure that all of the conditions in the 'model' situation are known and are as close as possible to the situation being modelled. This method can require considerable effort and expenditure, and is prone to variations beyond the modeller's control, particularly the weather. However, it does have obvious advantages in very complex situations where a simple physical or mathematical model cannot simulate the situation accurately.

IV.(i).3.2.Physical models

Laboratory experiments enable the environmental scientist and mathematical modeller to:

- determine the gross behaviour of jet flows;
- examine the validity of the assumptions made in a theoretical model; and,
- provide the numerical values of entrainment and drag coefficients required for most mathematical models.

Although plumes are sometimes modelled by means of smoke in a wind tunnel, most laboratory experiments on plume behaviour are simplified by injecting salt water into a tank of stationary or flowing fresh water (Figure IV.(i).12.) The salt water is injected from the top of the tank to produce a sinking jet. Because of the small density difference between the fluids, the behaviour of sinking jets discharged downwards is almost the same as for buoyant jets discharged upwards, except for the reversal of the gravitational force. Thus, photographs to help analyse a sinking jet may be simply turned upside down to show a buoyant jet.

The salt in solution not only serves to model the gravity effect but is also convenient as a tracer for conductivity measurements by means of probes. By measuring the salt concentration at different positions in the plume, the jet axis and the variation of the width of the jet may be determined. If a dye is added to the jet fluid, photographic techniques can be employed to

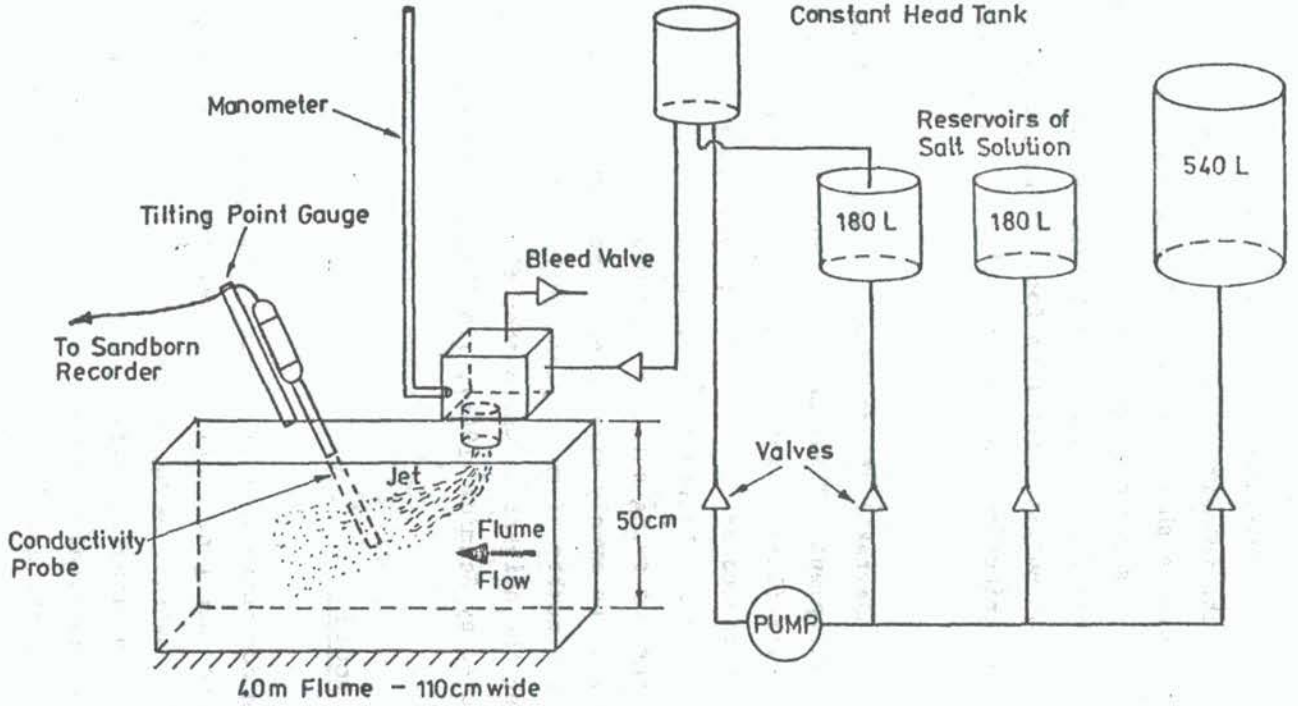

Figure IV.(i).12.Schematic flow diagram of buoyant jet experiments in flowing environments.

determine the trajectories and half widths of the jet. A further advantage of the dye is that it can be used for aligning the probe positions. However, when the concentration measurements are made, a salt solution without dye must be employed.

It is extremely difficult to determine the variation of velocity in the jet from physical models, as the velocity decays rapidly and approaches the value of the ambient velocity over a short distance. The problem is magnified by the fact that the velocity is a vector quantity whose direction should be predicted as well as its magnitude. Consequently few experiments investigate jet velocities; instead, scientists prefer to focus attention on concentration profiles, temperature distributions and the overall height and spread of the plume.

Experiments can also be undertaken to determine the influence of stratification on plume growth and development. These may be achieved by releasing a light fluid in a tank of heavier fluid in which there is a stable density gradient. The stratification is produced by adding successively more concentrated layers of salt solution to the tank. Provided that care is taken not to give any vertical momentum to the inflowing solution, disturbances will be avoided and the resulting layers will be evenly stratified. The stratification can be checked by introducing a number of small glass bubbles of known density into the tank and measuring the heights at which they float. Experiments of this type have been conducted by Schmidt (1941), Yih (1951), and Morton, Taylor and Turner (1956).

IV.(i).3.3. Mathematical models

Methods of estimating concentrations of airborne emissions have been studied for many years and have undergone considerable revision in the light of experimental results. However, owing to the complexity of the problem, it is highly improbable that one single, unifying model will ever be conceived to account for all the combinations of meteorological, topographic and source parameters. This will be the case even if study is confined to the simple dispersion of an inactive source, and other complications are excluded such as those brought about by chemical reactions, fallout, washout and absorption by vegetation.

The most widely used dispersion model to compute pollutant concentration profiles is the Gaussian plume model for single or multiple sources. This model began to receive popularity when Pasquill (1962) first published his dispersion rates for plumes over level terrain. The model enables simplifications to be made to the usual atmospheric advection diffusion equation:

$$\frac{\partial C}{\partial t} = \frac{\partial}{\partial x}\left(K_x \frac{\partial C}{\partial x}\right) - U\frac{\partial C}{\partial x} + \frac{\partial}{\partial y}\left(K_y \frac{\partial C}{\partial y}\right) + \frac{\partial}{\partial z}\left(K_z \frac{\partial C}{\partial z}\right) + W_z \frac{\partial C}{\partial z} \qquad (1)$$

where C is the pollutant concentration in the air at any location (x,y,z) and time, t; K_x, K_y, and K_z are the coefficients of eddy diffusivity in the x, y and z directions, respectively; U is the constant average wind speed; and W_z is the pollutant particle gravitational settling velocity, being positive in the downward negative z direction.

There are two basic assumptions in the Gaussian plume model:

(a) The wind speed is assumed sufficiently large so that diffusive transport in the x-direction can be neglected in comparison to advection by the wind. This makes the x-component of the pollutant particle velocity a constant and equal to the average wind speed, U. The pollutant concentration at any time (t), and distance downwind from the source (x) is therefore proportional to the source strength at time $(t - \frac{x}{U})$. Consequently only a steady state solution to the constant source problem needs to be considered.

(b) The diffusion coefficients in the y- and z- directions are taken to be functions of only the downwind distance from the source. Since the pollutant particles travel downwind at a constant speed, this is equivalent to assuming that the crosswind diffusion coefficients are functions of downwind flight time. Figure IV.(i).13 illustrates the coordinate system.

Turner (1970) has shown that use of the Gaussian plume method yields a downwind concentration at the point (x,y,z) given by:

$$\chi\,(x,y,z,h_e) = \frac{Q}{2\pi\sigma_y\sigma_z\,U} \exp A_1 \,(\exp A_2 + \exp A_3) \qquad (2)$$

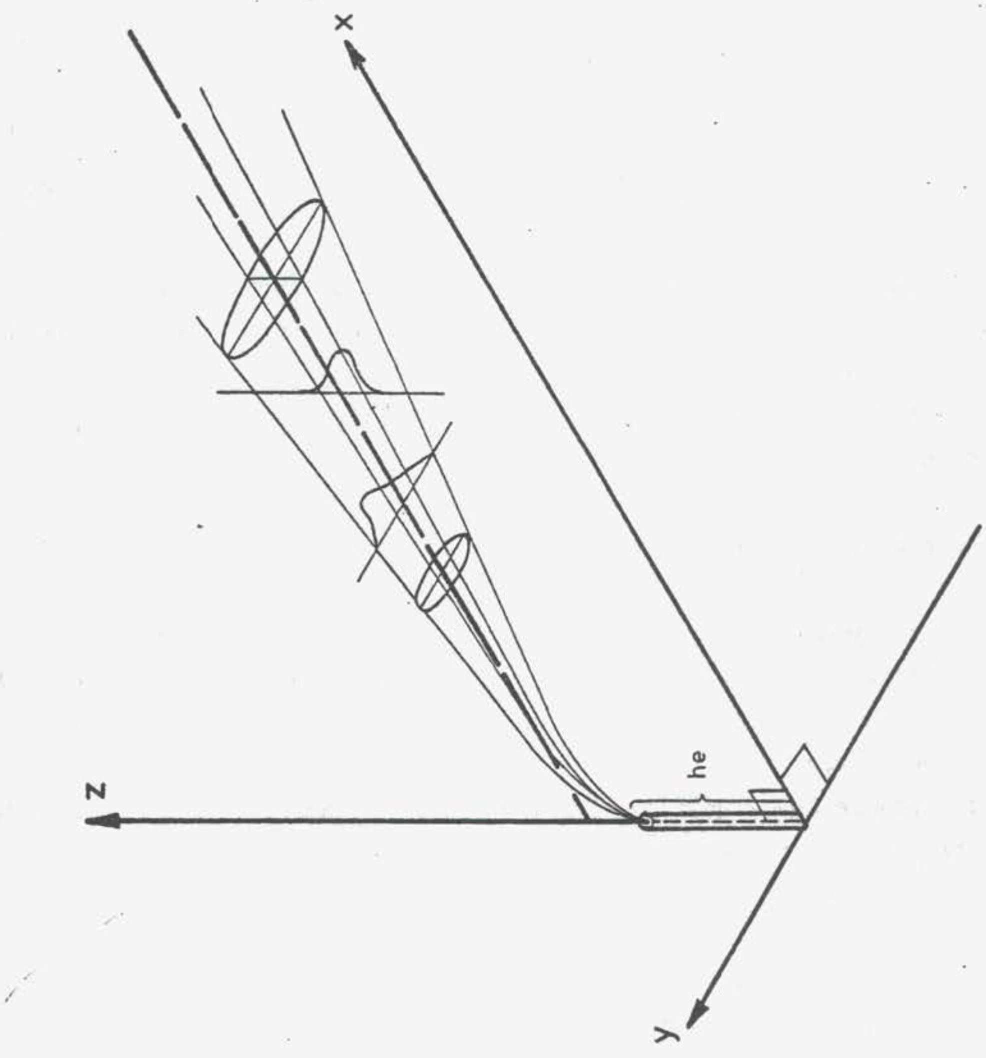

Figure IV.(i).13. Coordinate system showing Gaussian distributions in horizontal and vertical directions

where Q is the heat flux term = CpM $(T_s - T_a)$;
h_e is the stack height;
T_s is the souce temperature;
T_a is the ambient temperature;
M is the mass rate of flow out of the stack;
$\sigma_y \sigma_z$ are the diffusion coefficients in the y and z directions; and,
U is the mean horizontal windspeed.

A_1, A_2, and A_3 (combinations of the above variables) would be given by:

$$A_1 = -\frac{1}{2}\left(\frac{y}{\sigma_y}\right)^2 \qquad (3a)$$

$$A_2 = -\frac{1}{2}\left(\frac{z-h_e}{\sigma_z}\right)^2 \qquad (3b)$$

$$A_3 = -\frac{1}{2}\left(\frac{z+h_e}{\sigma_z}\right)^2 \qquad (3c)$$

When gravitational settling and ground absorption cannot be ignored in problems of atmospheric transport, both the gravitational settling flux and the ground deposition flux are taken to be proportional to the local air concentration (Calder, 1961). The proportionality factors are the gravitational settling velocity and the deposition velocity. These solutions have not been used extensively due to their complicated nature and the difficulty in applying them under a variety of atmospheric stability conditions.

A method for including the effects of surface deposition into a plume transport model is the source depletion approach (Martin, Nelson and Cuny, 1974). This treats ground deposition as a perturbation to the Gaussian plume dispersion model. The shape of the vertical plume profile is assumed to be unaltered by the deposition as a process, but the constant source strength is replaced by a virtual decreasing source stength. The result is a plume which diminishes exponentially with downwind distance but retains the original Gaussian plume shape of the undepleted plume.

Simple formulae are available for the determination of the height to which a buoyant plume will rise with an initial exit velocity. The rise is defined as the distance between the top of the stack and the axis of the centroid of the pollutant distribution, and is dependent upon:

- the exit velocity of the stack;
- the diameter of the stack;
- the mean wind speed;
- the lapse rate $\frac{dT}{dz}$, and,
- the temperature difference between the exit gases and the ambient air.

The most recent work on plume rise has been performed by Briggs (1970) who deduced the following laws:

(a) For a non-buoyant plume the rise is proportional to the 1/3rd power of the downwind distance; and,

(b) For a buoyant plume the rise is proportional to the 2/3rds power of the downwind distance.

He obtained two sets of formulae for the rise, Δh, given by:

$$\Delta h = \frac{0.25 \quad Q^{1/3} \; h_e^{\;2/3}}{U} \qquad (4)$$

for unstable to neutral conditions; and

$$\Delta h = 0.296 \left[\frac{Q}{U \frac{dT}{dz}} \right]^{1/3} \qquad (5)$$

for stable conditions.

Although the simple formulae of equations (2), (4) and (5) give a useful approximation to the actual conditions, a realistic appraisal of their capability for predicting the true concentration would be ± 50%. Topographical irregularities introduce significant additional losses of confidence (Carson and Moses, 1969).

Flows set up by pollutant discharges are governed by the three-dimensional Navier Stokes equations. The complexity of these equations has generally hindered the application of detailed numerical analysis techniques to model the complete flow systems. It is only recently that the solution of this system of non-linear, elliptic (i.e. recirculating) boundary value equations has been attempted. Three possible solution techniques may be adopted, dependent upon the topographical conditions.

(i) Parabolic situation

When the region in the neighbourhood of the pollutant source is flat, parabolic equations may be used to describe the plume behaviour. In terms of a Cartesian co-ordinate system, the governing equations have the typical form:

$$\frac{\partial}{\partial x}(\rho u\phi) + \frac{\partial}{\partial y}(\rho v\phi) + \frac{\partial}{\partial z}(\rho w\phi) = \frac{\partial}{\partial y}\left(\Gamma_{eff,\phi}\frac{\partial\phi}{\partial y}\right) + \frac{\partial}{\partial z}\left(\Gamma_{eff,\phi}\frac{\partial\phi}{\partial z}\right) + S_\phi \qquad (6)$$

where u, v and w are the velocity components in the x, y and z directions, respectively, the first direction being oriented along the main flow direction. As flow reversal is excluded, convective influences from downstream cannot extend upstream.

The variable ϕ may stand for u, v or w in the three momentum equations; the constant 1 in the continuity equation; or c (the mass fraction of species) in the concentration equation. The remaining variables in equation (6) are: S_ϕ, the source term appropriate to each equation (e.g. pressure gradient in the momentum equations); $\Gamma_{eff,\phi}$ the relevant transport property (effective viscosity); and ρ, the density. Equations of this type are usually solved by finite-difference techniques employing a rectangular grid which is moved along the trajectory of the jet. The technique involves the calculation of the velocities, concentrations, etc., at discrete points in the region of the study and is an economical technique as only two-dimensional storage is required and the plume volume is traversed once in a single marching integration.

(ii) Partially parabolic situation

When the effects of valleys and hills must be taken into account, it is not sufficient to employ a parabolic procedure as pressure effects can be transmitted upstream. The pressure field must therefore be stored in a three-dimensional manner, although the other variables can still be stored two-dimensionally. This situation is known as partially parabolic.

(iii) Elliptic situation

In the case when buildings are present in the region immediately downstream of the stack, recirculating regions are created into which pollutants are entrained. There is therefore no direction in which influences are transmitted in only one sense and the problem is fully three-dimensional and elliptic. In a Cartesian system the governing equations take the general form given in equation (6) with the additional term:

$$\frac{\partial}{\partial x} \left(\Gamma_{eff,\phi} \frac{\partial \phi}{\partial x}\right) \qquad (7)$$

on the right hand side of the equation, as the diffusional transport in the x-direction is included. Equations of this type have been solved using either finite-difference techniques (McGuirk and Spalding, 1975) or finite element techniques (Baker, 1975).

It can therefore be appreciated that a variety of situations can be studied by mathematical modelling techniques. However, the accuracy of the results produced by a model is strongly dependent on the suitability of the physical laws and governing equations employed in the model. It is therefore essential that all models are verified against either full scale or experimental measurements as a preliminary to a major study. In addition, the flow situation under analysis should be carefully studied to ensure that the mathematical formulation of the problem is as simple as possible and hence the computer costs are kept to a minimum.

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IV.(ii). DISPERSION OF WATER POLLUTANTS

IV.(ii).1. Dispersion Processes

Pollutants discharged into a body of water are dispersed by a variety of processes, depending on the type of effluent and the nature of the receiving area. Physical mechanisms are the major primary method of dispersion, but chemical and biological mechanisms are the most significant in determining the ultimate fate of pollutants. The combinations and interactions of these processes are numerous and complex, varying considerably with the prevailing conditions at each site and also with the modifications of these conditions with time.

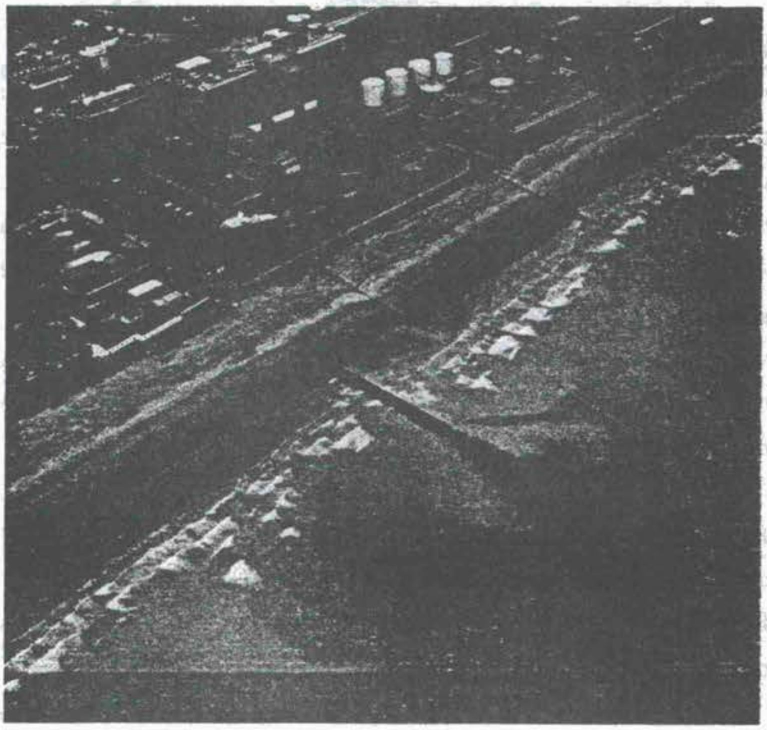


Figure IV.(ii).1. : Pollutant discharge - dispersion from a submarine pipeline

IV.(ii).1.1. Physical dispersion

The physical dispersion of pollutants occurs as a result of natural and artificial mechanisms. The major natural dispersal mechanisms are mixing by eddy diffusion and disturbances caused by surface waves; molecular diffusion is always present but is generally not of the same importance.

IV.(ii).1.1.1.Physical mechanisms enhancing dispersion

Turbulent mixing is related to the current speed and wave size which in turn can be affected by several parameters. In coastal areas currents are usually created by tidal action but wind-driven and density currents may also play a role. In estuaries, similar forces exist but the fresh-water inflow also affects the current regime. Current velocities in non-tidal rivers are controlled by the gradient and fresh-water inflow and consequently susceptible to variations in rainfall.

In addition to their direct effect on dispersion through eddy diffusion, currents are also significant as they enhance the plume momentum, spreading it into fresh 'unpolluted' receiving waters (Wiegel, 1964).

Winds aid dispersion by forming wind-driven currents which may affect the water column to a considerable depth. The impact is greatest near the surface, and pollutants, such as oil, may be formed into striations parallel to the wind direction. The effect of wind is greatly increased by the waves it generates if blowing from a direction with an appreciable fetch. Pollutants in the surface layers are mixed thoroughly and rapidly, especially in breaking seas, because of the physical stirring of the water. The wave particle orbital motion is effective at both the surface and greater depths, although this energy is almost entirely dissipated at a depth of approximately half the wavelength.

Industrial and domestic pollutants are normally discharged in the form of a turbulent jet which entrains surrounding fluid, resulting in increased volume flux and decreased velocity with distance from the outlet. The density of the effluent relative to the receiving medium may accelerate or retard the mixing process. If used advantageously these differences can enhance dispersion by increasing the area of potential mixing within the water column.

Pollutants can be lost at the boundaries of the receiving waters through adsorption and absorption by the sediment and by exchange of gaseous materials at the air/water interface. These gases may be incorporated within the effluent or created by chemical reaction within the receiving water.

The dispersion of an oil slick is promoted by all the factors discussed so far but in quite a different manner. For example, drift and spread are partially controlled by the changes occurring in the properties of the oil caused by the evaporation of the lower density components. This promotes spreading, such that the surface area available for evaporation becomes larger, thereby increasing the rate of evaporation. The resultant density increase induces a greater proportion of the oil to enter the water column where some is dissolved. The surface tension and viscosity are also strongly affected by the process of emulsification. Specifically, the turbulence generated by winds and waves (and also currents when these produce turbulent waves downstream of islands, etc.), produce a water-in-oil emulsion consisting of droplets approximating 15-20 microns. At water concentrations above 40%, this becomes very viscous and stable and is referred to as "chocolate mousse".

These and other actions ensure that the spreading rate is continuously changing and may vary for each compound within the slick. The interaction of the major factors influencing drift and spread are shown in Figure IV.(ii).2. The biological processes are discussed in Sections IV.(ii).1.3. and IV.(ii).1.4.

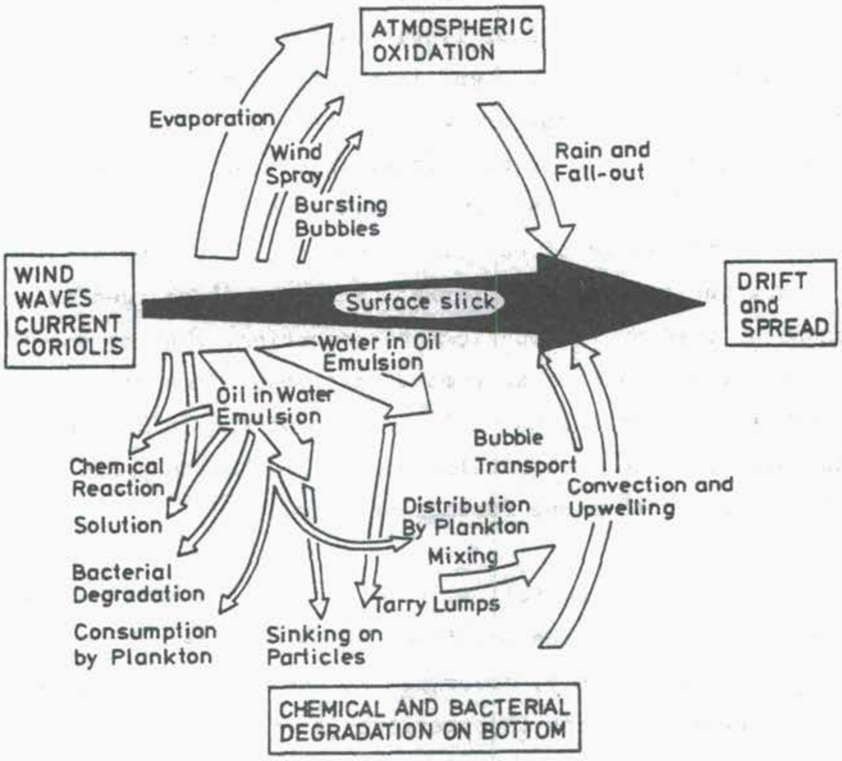


Figure IV.(ii).2. Diagrammatic summary of the processes by which spilt oil is distributed and destroyed at sea.

IV.(ii).1.1.2. Physical mechanisms restricting dispersion

The existence of thermoclines or haloclines, which create an effective barrier to dispersion, may limit the depth of the receiving water and therefore the mixing potential. The bathymetry in the area surrounding the outfall may also affect the local flow field and wave climate.

In coastal waters, the ebb and flood tidal currents flowing parallel to the shoreline can have the effect of returning partially-mixed effluent to the discharge area resulting in a gradual build-up of pollutants. In many estuaries, the flooding tide effectively dams the seaward-flowing effluent increasing pollutant concentrations at certain periods of the tide. Other natural phenomena retarding pollutant dispersion include low volumes of rainwater run-off into rivers during dry periods (resulting in reduced flow velocities and water depths), and the existence of large scale eddies which trap pollutants in a specific area.

IV.(ii).1.1.3. Outlet design

The natural processes of pollutant dispersion can be supplemented, to some degree, by artificial methods. For example, the design of an outfall for the discharge of liquid wastes into rivers, estuaries and inshore waters can have a significant effect on the initial near-field dispersion rates. Parameters which determine jet dilution from submerged outlets include: rate of discharge; angle of discharge; depth of water; current velocity; and, the number, size and shape of the outlets (Agg, 1978). The siting and design of outfalls are normally determined on the basis of satisfying the following criteria: that the discharged material should not reach areas used by the public for recreation; that it should either be sufficiently diffused or so remote that visual impact is controlled; and, that the effects on the natural environment should be minimized. Thus, an outfall close to the shoreline generally has to produce a greater initial dilution than one further offshore.

The simplest type of outfall emits effluent as a horizontal jet. However, increased dilution can be obtained by using a series of outlets or a diffuser. Alternatively, cover plates may be employed to intercept the buoyant effluent causing the emergent jet to spread over a wider area. Further advantages may be obtained by mixing the effluent with ambient fluid before discharge from the outfall (Agg and White, 1974) and by controlling the time of the discharge to coincide with favourable tidal conditions and thereby avoid recirculation.

IV.(ii).1.2.Chemical dispersion

Chemical dispersion invariably involves the localised degradation of compounds to simpler or non-toxic end products which may then be carried further afield by various physical processes. The majority of these processes take place at the air-water interface, the sediment-water interface, or at the boundaries between the water and particles suspended in the water (Horne, 1969).

Petroleum products, chlorinated hydrocarbon pesticides and other volatile hydrocarbons are concentrated at the air-water interface, where they are subjected to oxidation, ultra-violet radiation, evaporation of the more volatile constituents, and polymerisation. If not destroyed by these reactions, the materials become heavier and eventually sink to be incorporated in sediment deposits. Substances with appreciable vapour pressures, such as pesticides or methyl mercury, may evaporate to the vapour phase (Wurster, 1969 and Lofroth, 1969). Bursting bubbles can also inject surface-associated material into the atmosphere (Horne, 1969).

Next to particulate settlement and sedimentation, ion exchange is probably the most important factor in pollutant removal and dispersion. This process requires the presence of particles possessing numerous exchange sites, e.g. clay particles which not only have exchangeable sites on their surfaces, but also exchangeable ions between lattice sheets. Consequently, significant quantities of material can be readily absorbed and, through natural gravitational forces, be incorporated into the sediments (Gross, 1972).

Incorporation of pollutants into sediments is not as permanent a process as chemical oxidation and radiation. Such materials are readily disturbed and resuspended by dredging, the activities of animals, currents (for marine and estuarine conditions), and by flash flooding (river and estuarine conditions), and can be recirculated in the environment many years after their deposition. In some cases the impact on the environment can be considerable.

IV.(ii).1.3.Biological dispersion

Decomposition of organic materials in freshwater, estuaries, and the upper ocean layers is primarily the function of aerobic bacteria, supplemented by fungal activity. In lower levels and bottom sediments, decomposition continues by anaerobic bacteria, e.g. *Pseudomonas*, *Thiobacillus* and *Clostridium* (Fjerdingstad, 1975). These organisms reduce organic material to compounds such as methyl mercaptan, hydrogen sulphide and ammonia, as well as numerous other substances such as organic acids, hydroxy acids, indol, phenol and the gases carbon dioxide, methane and hydrogen.

Such activities result in a deterioration of a water body, producing localised deoxygenation and accompanying reduction in ecosystem diversity. In these circumstances, the dispersion of breakdown products frequently relies on physical factors either to remove pollutants, or to aid purification by increasing the oxygen content of the water.

Bacterial breakdown of hydrocarbons is important in aquatic environments particularly in the degradation of petroleum compounds. Efficient strains of bacteria have been released into an oil-contaminated area to break down those oil fractions unaffected by detergents, dispersants and physical factors.

One of the most significant biological agents of pollutant removal from surface layers is plankton. Phytoplankton readily ingest compounds for metabolic usage or for simple uptake of particles into vacuoles; zooplankton feed on phytoplankton and also ingest compounds from solution. The vertical migrations made daily by the zooplankton and their continual movement in the ocean currents ensure the gradual dispersal of pollutants from the site of their release.

(ii).1.4. Interactions

Specific chemical and biological mechanisms result in pollutant dispersal but it is extremely difficult to separate the two in practical terms. Many of the pathways for pollutant degradation are essentially biochemical, as are the recycling pathways for nutrients. Heavy metal pathways involve frequent biological and chemical interactions and throughout the whole process of pollutant dispersal and removal, physical mechanisms provide the crude tool that initiates dispersion, aids in the biochemical dispersion processes and ultimately determines the resting place of compounds, e.g. gravitational movement and sedimentation.

Although considerable work has been undertaken on chemical and biological interactions our understanding is incomplete. Where there is no physical coupling between pollutant and a component of the system, the causal relationship can be readily established. For instance, the effect of turbidity on plant growth can be modelled mathematically. However, it is more difficult to predict the interaction of physical, chemical and biological mechanisms and the role each plays in dispersion as well as the effect of pollutants on the environment. Consequently, independent assessment of dispersion mechanisms must be undertaken, followed by a 'multi-discipline analysis' of the data to determine the overall impact.

IV.(ii).2. Predictive Modelling

Predicting the dispersion of pollutants and their effects on the natural environment can be of great value to designers and planning authorities. Predictions can be made from a comprehensive set of full scale measurements, physical hydraulic models or by numerical techniques (Figure IV.(ii).3). Both physical and numerical models require full-scale data as a basis for calibration and validation and until these have been acquired, the value of the model is restricted.

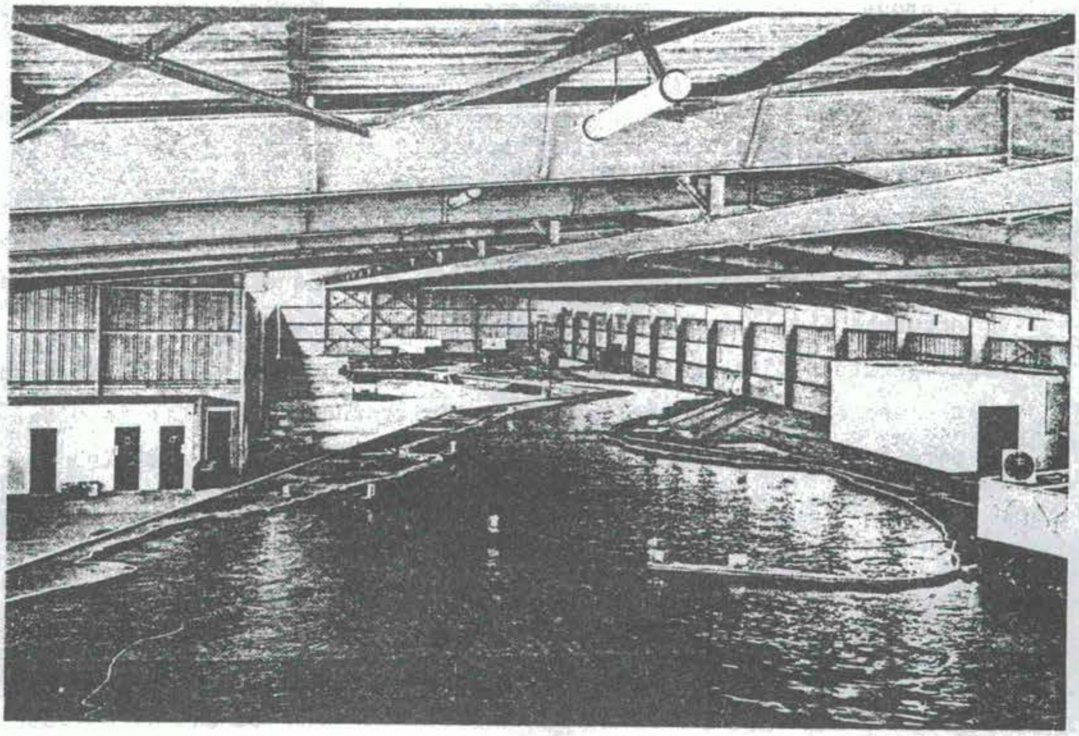


FIGURE IV.(ii).3. Example of a physical hydraulic model (British Transport Docks Board)

IV.(ii).2.1. Physical Methods

At a minimum, a physical model requires data on bottom topography, the variations of currents during neap and spring tidal cycles, the extent of stratification caused by salinity or temperature layering and variations in wind and wave conditions. Although not as flexible and convenient as a numerical model, hydraulic models can be built, tested and modified reasonably quickly to examine alternative solutions to a particular problem.

The relationship between a model and the full-scale situation may be developed from principles of dynamic similarity. Those most commonly used are the dimensionless Froude, Reynolds and Weber numbers, respectively related to gravity, viscosity and surface tension, and the inertial force. Scaling may minimise the effect of one force, while having a critical effect on another, e.g., reducing the size of a body decreases the Reynolds number but increases the effect of surface tension (Yalin, 1971).

As the application of more than one of the dimensionless quantities is required to model accurately a particular problem, a compromise must be reached based on engineering judgment and experience. A fundamental problem is the presence of gravity in both the model and full-scale situation combined with the practical necessity for using water as the model fluid medium. When modelling changes of velocity with distance, for example, Froude number requires that $V \alpha L^{\frac{1}{2}}$, Reynolds number $V \alpha L^{-1}$ and Weber number $V \alpha L^{-\frac{1}{2}}$. It should be observed that it is impossible to reproduce any two of these dimensionless values simultaneously unless the model is full-scale.

Geometric distortion is often necessary in shallow water areas to create sufficient water depth to overcome the effects of bottom friction and permit measurable tidal depth variations. Model surface roughness can be introduced artificially by a number of techniques to facilitate the accurate simulation of tidal elevations, current velocity, salinity and temperature distributions. Further, when modelling pollutant dispersion, the use of water of the correct salinity and temperature is vital to permit simulation of the density distribution. Effluent discharge can be estimated in the model by the release of dye of suitable density and monitoring by sampling techniques or photography.

Wave generation has developed in recent years from the monochromatic wave train to random seas and reproduction of specified spectra. Waves are a major mixing process in coastal seas and estuaries, but the effects of gravity and surface tension must be carefully considered and the associated velocities scaled to the vertical distortion when using them in hydraulic models.

When designed correctly, hydraulic models are of great value for prediction of pollutant dispersion. However, careful consideration must be given to the various scaling factors and their associated effects on the hydraulic behaviour of the model. With the advance of computational techniques a physical model is often combined with a series of tests using a numerical prediction method.

IV.(ii).2.2.Mathematical models

IV.(ii).2.2.1.Physical parameters

Mathematical analysis is usually cheaper than physical experimentation and, provided that the approximations (made to render the problem mathematically soluble) are valid, the results may prove more satisfactory. There are two possible approaches to the mathematical modelling of environmental processes - classical or numerical mathematics.

Classical mathematics employs algebraic expressions, Bessel functions, infinite series, and other similar forms, whereas numerical mathematics utilises tables of numbers and computer-generated plots. Typically, classical mathematics has to 'linearise' the problem and consequently, in most cases, eliminates effects which may be of particular interest, e.g. secondary flows and influences of irregular boundaries have to be neglected. Classical methods are still employed but their reliability is suspect and numerical modelling is becoming increasingly important.

The complexity of the flow patterns created by thermal or waste water discharge has generally hindered the application of detailed numerical analysis techniques to model complete flow systems. This is because these problems are governed by the transient, three-dimensional Navier Stokes equations. It is only recently that the solution of this system of initial valued, non-linear, elliptic (i.e. recirculating), boundary value equations has been attempted. Meanwhile the assessment of the impact of discharges is almost exclusively based on 'near-field' models (Edinger and Polk, 1969; Koh and Fan, 1970; Motz and Benedict, 1970). These models are modified extensions of the classical steady-state, turbulent jet studies of Schlichting (1968), Abramovich (1963) and Harsha (1970).

The advantage of near field models is that the partial differential equations constitute parabolic (i.e. straight-through) systems which can be solved with pseudo-analytical or numerical marching techniques, starting from specified positions along the main flow direction of the jets of heated water or waste water.

In terms of a Cartesian coordinate system, the governing equations have the typical form shown below:

$$\frac{\partial}{\partial x}(\rho u\phi) + \frac{\partial}{\partial y}(\rho v\phi) + \frac{\partial}{\partial z}(\rho w\phi) = \frac{\partial}{\partial y}\left(\Gamma_{eff,\,\phi}\frac{\partial\phi}{\partial y}\right) + \frac{\partial}{\partial z}\left(\Gamma_{eff,\phi}\frac{\partial\phi}{\partial z}\right) + S_{\phi} \qquad (1)$$

where u, v and w are the velocity components in the x, y and z directions respectively, the first direction being oriented along the main flow direction. As flow reversal is excluded, convective influences from downstream cannot extend upstream. In addition, the diffusional transport in the x-direction can usually be neglected due to the high flow velocities. The equations are therefore parabolic.

The main variable in equation (1) is ϕ, which may stand for any one of u, v or w (three momentum equations), the constant 1 (continuity equation), or T (temperature). The remaining variables are: S_{ϕ} the source term appropriate to each equation (e.g. pressure gradient in the momentum equations); $\Gamma_{eff,\,\phi}$, the relevant transport property (effective viscosity); and ρ, the density.

Although these models are simpler and more economical to solve than the full elliptic problems they have several important drawbacks. As a consequence of their parabolic property, regardless of the level of sophistication in the mathematical formulation, they can never account for the influence of the jet on the surroundings. Such a situation is acceptable for an aerodynamic jet engine discharging into a practically limitless and motionless atmosphere, but the same conditions are unrealistic when the receiving water body is in a coastal or estuarine region and thus of limited extent.

The optimum solution is to divide the problem into two components: the near-field problem and the far-field problem. The first, as described above, is concerned with the mixing of the discharges and the ambient fluid in a region whose dimensions are of the order of those of the injection orifice. The second calculation, conducted for the whole expanse of fluid, throws light on the spread and drift of the fluid over a body of water as a whole (Figures IV.(ii).4. and IV.(ii).5.).

The prediction of the tidal influence on temperatures or pollutant concentrations in a bay or estuary is a fully three-dimensional elliptic problem: there is no direction in which influences are transmitted in

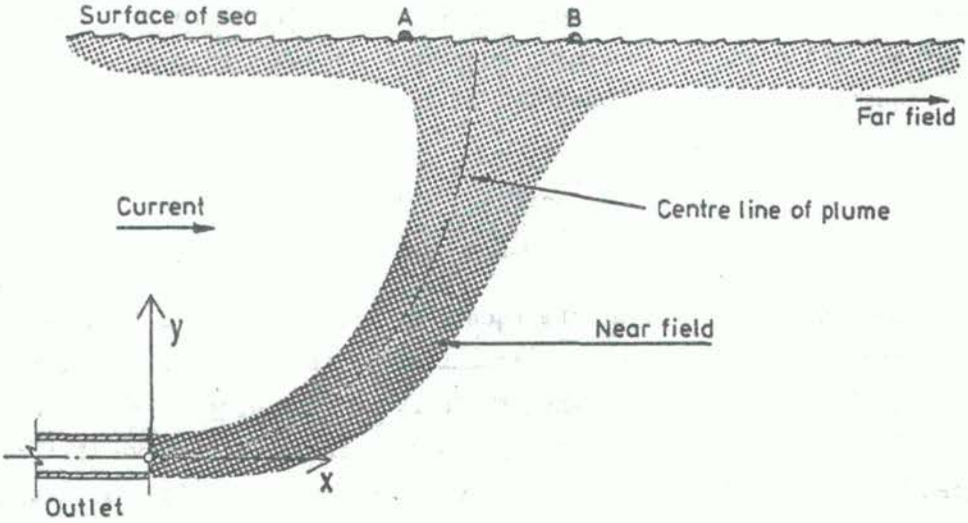
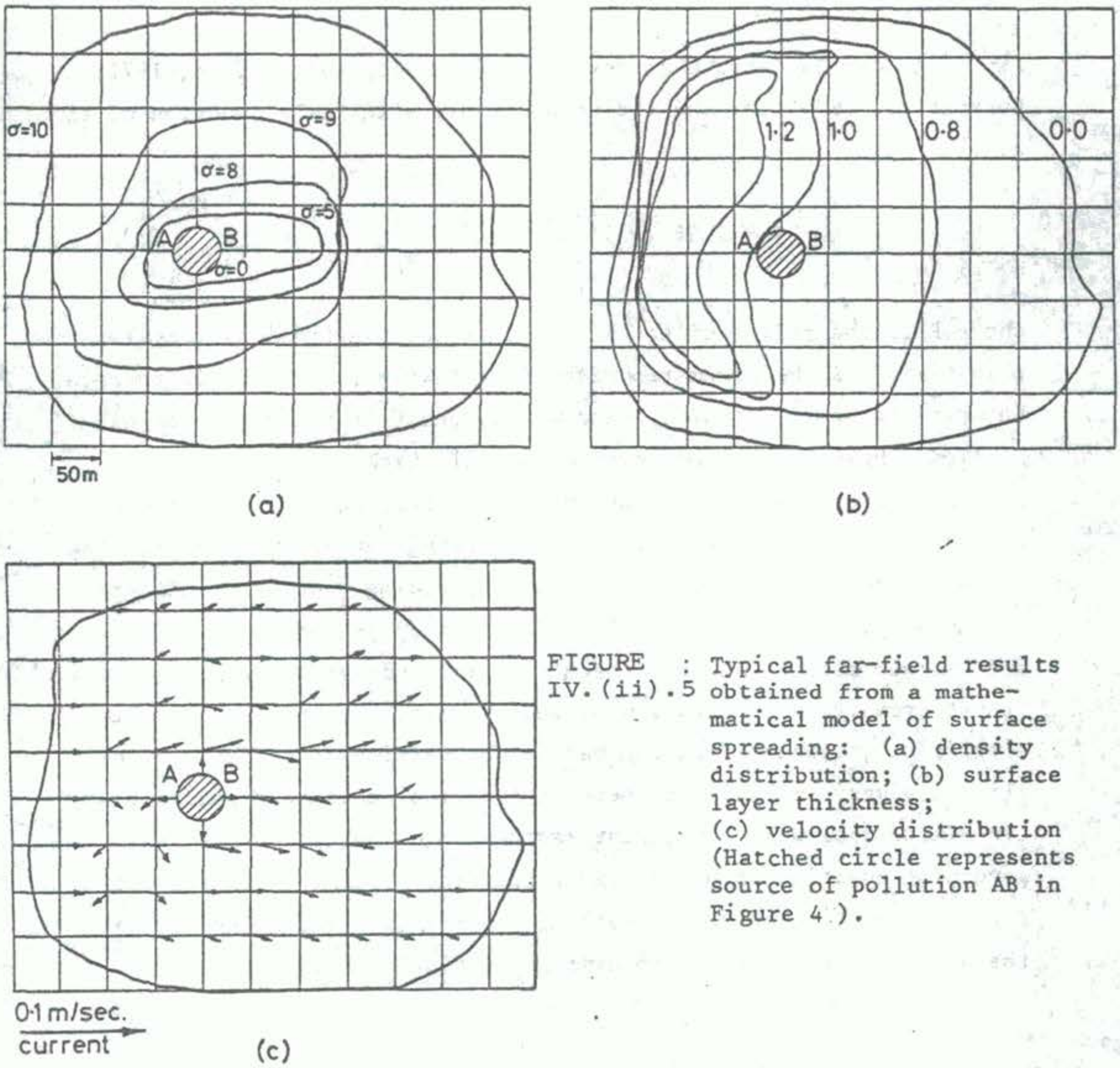


FIGURE IV(ii).4. : Near- and far-field regions of a turbulent discharge.



(a)

(b)

(c)

FIGURE IV.(ii).5 : Typical far-field results obtained from a mathematical model of surface spreading: (a) density distribution; (b) surface layer thickness; (c) velocity distribution (Hatched circle represents source of pollution AB in Figure 4).

only one sense, for tidal and wave effects cause recirculation. In a Cartesian system the governing equations take the general form given in equation (1) with the additional term:

$$\frac{\partial}{\partial x} \left(\Gamma_{\text{eff},\phi} \frac{\partial \phi}{\partial x} \right) \qquad (2)$$

on the right hand side of the equation, since the diffusional transport in the x-direction is included. Equations of this type have been solved using either finite-difference (McGuirk and Spalding, 1975) or finite element techniques (Baker, 1975). Both techniques involve the calculation of the velocities, temperatures and concentrations at discrete points in the region of interest, and can be applied equally well to other problems of pollution, including the drift and spread of an oil slick.

Explicit formulae have been developed (Fannelop and Waldman, 1971; Buckmaster, 1973) for the radius of an oil slick as a function of time, e.g.

$$R = 1.76 \, (g\Delta)^{\frac{1}{4}} \, V^{\frac{1}{2}} \, \nu^{\frac{1}{8}} \, t^{\frac{3}{8}} \qquad (3)$$

where R is the radius of the slick, g is the gravitational acceleration, t is time, ν is the kinematic viscosity of water, Δ is the difference between the densities of oil and water, and V is the volume of oil spilled. However, the movement of an oil slick is an extremely complicated process of heat and mass transfer, being influenced by the shore and sea-bed topography, prevailing currents and wind. The processes requiring attention are the spreading under the influences of buoyancy, the oppositions to this tendency presented by inertia and viscous action, and the changes to the properties of the oil which result from its exposure to wind and weather. The problem can be simplified somewhat since the variations vertically through the oil slick are very small. This permits the problem to be considered as two-dimensional with consequent savings in computer costs. The governing equations are modelled using either finite-difference or finite element techniques, enabling the position and dimension of the oil slick to be determined as a function of time.

Mathematical modelling techniques can also be employed for the calculation of the oxygen balance and salinity levels in estuaries or rivers. The finite-difference method is the most widely employed for this type of problem (Maskell and Odd, 1977), the general form of the conservation equations being, in the one dimensional case:

$$\frac{\partial}{\partial t}(AC) + \frac{\partial}{\partial x}(QC) - \frac{\partial}{\partial x}\left(AD\frac{\partial C}{\partial x}\right) + KAC - F_c - L_c = 0 \qquad (4)$$

where

A is the cross-sectional area;

C is the concentration of solute;

D is the effective coefficient of longitudinal dispersion;

K is the first order decay rate;

F_c is the flux of solute between the flow channel and the stagnant storage zone per unit length;

L_c is the loading of solute from lateral inflows per unit length; and,

Q is the volume flow of water.

It can be appreciated, therefore, that a variety of situations can be studied by mathematical modelling techniques. However, the accuracy of the results produced by a model is strongly dependent on the physical laws and governing equations embodied in the model and it is essential that all models are verified against either full scale or experimental measurements as a preliminary to a major study. In addition, the flow situation under analysis should be carefully studied to ensure that the mathematical formulation of the problem is as simple as possible to keep computer costs to a minimum.

IV.(ii).2.2.2. Chemical parameters

The behaviour of discharged chemicals can be included in mathematical models used to predict the physical dispersion of pollutants. For example, the decay rates of radioactive material and the reaction rates of different chemical species under varying conditions may be specified. In addition, the effect of differing bottom materials, temperature, salinity, dissolved oxygen and pH variation and other relevant factors can be included in the calculations. An example of the type of process which can be simulated by means of a mathematical model is shown in Figure IV.(ii).6. This represents the oxidation occurring

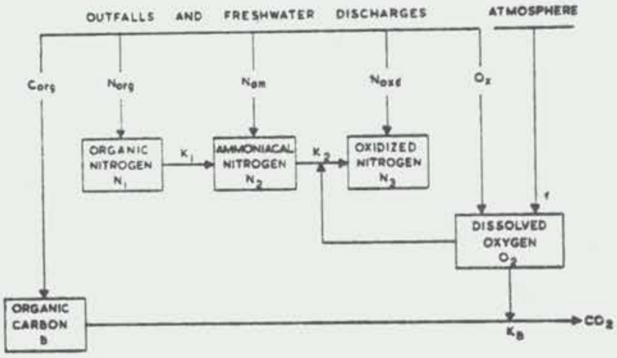


Figure IV.(ii).6. : Schematic diagram showing sources and sinks of dissolved oxygen and associated substances in absence of denitrification.

in an estuary, where each box is equivalent to the mass of the substance in a section of the estuary and the arrows show its sources and sinks. For each substance, the source includes direct waste inputs and formation from other substances, and the sink is the chemical or biological breakdown. As an example, the sources of ammoniacal nitrogen are outfalls and the hydrolysis of organic nitrogen, and the sink is the oxidation of ammonia to oxidized nitrogen. The destruction and formation of the substance may be represented either by first-order kinetics or by more detailed bacterial growth kinetics (Downing and Knowles, 1970).

These sources and sinks can be included, for a three-dimensional problem, via the term S_ϕ appearing in equation (1). In this case the variable ϕ represents the concentration by mass of the chemical species under consideration, and there is one equation for each species.

IV.(ii).2.3.Ecological modelling

Many ecological studies now embrace numerical techniques involving the translation of selected physico-chemical and biological characteristics of ecosystems into mathematical relationships. Such models are abstractions of actual conditions, but they do provide some predictive insight into the structure and function of ecosystems. Initially, the components of the system to be studied must be defined and each component should share some common feature or involve some significant transfer. Next the existing conditions of each component should be established by measurable characteristics, e.g. in terms of biomass in gram calories per square metre or in quantities of nutrients. Finally, it is necessary to quantify the rates of transfer of energy or nutrients across the defined ecosystem boundary and between the components within the system.

A typical example concerns the amount and seasonal distribution of phytoplankton, which can be predicted from a knowledge of certain important limiting factors of the environment and physiological coefficients determined from laboratory experimentation. In a very simplified and non-mathematical form phytoplankton can be estimated from the following relationship:

$$\begin{array}{l}\text{Rate of change of}\\ \text{phytoplankton}\\ \text{density per unit}\\ \text{time}\end{array} = \left[\begin{array}{l}\text{Rate of}\\ \text{photo-}\\ \text{synthesis}\end{array}\right] - \left[\begin{array}{l}\text{Rate of}\\ \text{respiration}\end{array}\right] - \left[\begin{array}{l}\text{Rate of}\\ \text{grazing}\\ \text{i.e. loss to}\\ \text{herbivores}\end{array}\right] -$$

$$\left[\begin{array}{l}\text{Rate of}\\ \text{Sinking}\end{array}\right] + \left[\begin{array}{l}\text{Rate of upward movement due}\\ \text{to turbulent eddies.}\end{array}\right]$$

Respiration is largely determined by temperature, while photosynthesis is largely limited by temperature, light and nutrient concentration. Knowing the density of herbivores, the "grazing pressure" can be determined from data obtained by reference to laboratory cultures. Although the computation is complex, the loss, if any, as a result of the sinking of plant cells below the euphotic zone can be determined from physical oceanographic data.

The model, developed by Riley (1967), has been found to give predicted densities within 25% of the observed densities - remarkably close considering the complexity of the environment - and demonstrates that useful, predictive models of complex ecological situations can be developed on the basis of judicious selection of only a few of the many factors involved.

Although the use of mathematical models has become quite widespread, only a limited number are being employed in environmental assessment (Wiegert, 1975). Chen and Orlob (1975) have developed aquatic ecosystem models to predict the effects of alternative sites for sewage treatment facilities and Kelley (1976) describes a model to predict the effects of waste discharges on an estuary. In 1975, O'Connor et al reported several applications of their phytoplankton model relating waste discharges to eutrophication processes.

IV.(ii).3. References

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V - SOURCES AND EFFECTS OF POLLUTION

V.(i). SOURCES AND EFFECTS OF AIR POLLUTION

V.(i).1. Sources and Emissions

V.(i).1.1. Sources

Air pollutants originate from several sources and are produced over wide areas. They may come from the sea as natural contaminants given off by marine life or from the internal combustion engines of motor vehicles. Identifying these sources is very important as this information makes the control of air pollution possible (Table V.(i).1.).

All sources of air pollutants can be classified by type, location and height (Figure V.(i).1.). The sources that release pollutants into community air are classifiable according to their geographical location within an airshed:

- Point sources - includes smokestacks of industrial and power-generating complexes.
- Line sources - pollutants from narrow strips of land embracing motorways, highways, airline routes and other major traffic arteries.
- Area sources - emissions arising from extensive areas containing homes, commercial buildings, industrial complexes, and vehicles driving about the streets.

By classifying the sources of air pollutants in this manner, it is possible to identify the place where current pollutants are produced and where they may be produced in the future. Such information is critical to urban planning because planners can anticipate the possible effects of new highways, buildings, or other sources of pollution upon the air quality in a given area. New constructions can be sited so that the production of pollutants is dispersed over the airshed rather than concentrated in small areas.

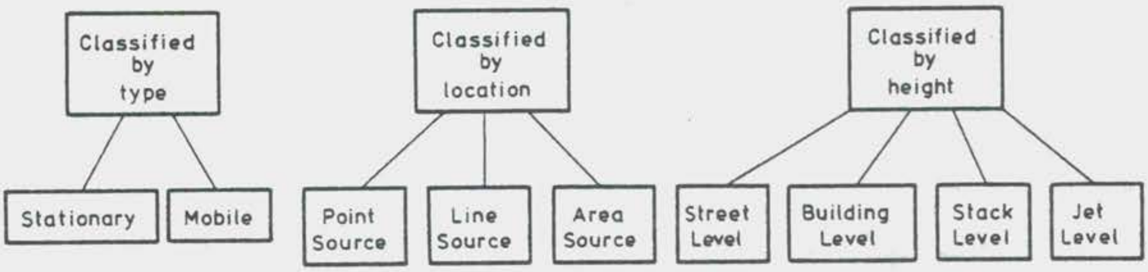


Figure V.(i).1. Classification of air pollutants by source

Pollution sources can also be classified according to their height. At 30,000 feet a jet aircraft is well above any temperature inversion and, except when landing or taking off, does not add much to the pollution over cities. In contrast, vehicle exhausts at street level pollute cities significantly. Between these two extremes are the residential building level and the stack level. Their effect on urban pollution depends on plume rise and the height and persistence of any temperature inversion. Usually, the plume from a residential building has a more adverse impact on air quality than that from an industrial stack which assists dispersion.

Turning to classification by type, in 1974, for example, some 18 million British roa vehicles discharged c. 8.4 million tonnes of carbon monoxide, sulphur oxides, nitrogen oxides, hydrocarbons and aldehydes into the atmosphere. Translated into daily amounts the figures mean that each day British road vehicles exhaust into our atmosphere a variety of pollutants weighing more than a bumper-to-bumper line of Rolls Royce cars stretching some 37 miles.

The principal industrial sources of air pollution are pulp and paper mills, iron and steel mills, petroleum refineries, smelters and chemical plants. Include contributions from burning domestic fuel and rubbish and one may see that in total more than 30 million tonnes of atmospheric pollutants are added to the atmosphere every year, i.e. over half a tonne annually for every man, woman and child in Britain.

V.(i).1.2. Emissions

An emission is any substance discharged into the atmosphere, partially or completely treated or in its natural state, and which may produce undesirable environmental effects. Specific substances produced by the sources categorised above are numerous and will depend upon the individual operation or activity involved. The more common contaminants originating from industrial operations are:

1. Sulphur oxides
2. Nitrogen oxides
3. Ammonia
4. Hydrogen sulphide
5. Mercaptans
6. Methyl amines
7. Carbon monoxide
8. Particulate matter - carbon and dust
9. Radioactive gases
10. Hydrocarbons
11. Chlorine
12. Various organic solvents

Table V.(i).1. Characteristics, Sources and Control of Major Air Pollutants After World Bank

Pollutant	Characteristics	Principal sources	Controls
Total suspended particulates (TSP)	Any solid or liquid particles dispersed in the atmosphere, such as dust, pollen, ash, soot, metals, and various chemicals; the particles are often classified according to size as settleable particles; larger than 50 microns aerosols: smaller than 50 microns; and fine particulates: smaller than 3 microns	Natural events such as forest fires, wind erosion, volcanic eruptions; stationary combustion, especially of solid fuels; construction activities; industrial processes; atmospheric reactions	Cleaning of flue gases with inertial separators, fabric filters, scrubbers, or electrostatic precipitators; alternative means for solid waste reduction; improved control procedures for construction and industrial processes
Sulphur dioxide (SO_2)	A colourless gas with a pungent odour; SO_2 can oxidize to form sulphur trioxide (SO_3), which forms sulphuric acid with water	Combustion of fossil fuels; refining of petroleum; smelting of ores containing sulphur, manufacture of H_2SO_4; burning of S-containing refuse; papermaking; natural events such as volcanic eruptions.	Use of low-sulphur fuels; removal of sulphur from fuels before use; scrubbing of flue gases with lime or catalytic conversion
Carbon monoxide (CO)	A colourless, odourless gas with a strong chemical affinity for haemoglobin in blood	Incomplete combustion of fuels and other carbon-containing substances, such as in motor vehicle exhausts; natural events such as forest fires or decomposition of organic matter	Automobile engine modifications (proper tuning, exhaust gas recirculation, redesign of combustion chamber); control of automobile exhaust gases (catalytic or thermal devices); improved design, operation, and maintenance of stationary furnaces (use of finely dispersed fuels, proper mixing with air, high combustion temperature)
Photochemical oxidants (Ox)	Colourless, gaseous compounds which can comprise photochemical smog, e.g. ozone (O_3), peroxyacetyl nitrate (PAN), aldehydes, and other compounds	Photochemical reaction of hydrocarbon and nitrogen oxides from fuel combustion, refuse burning, and, evaporation from petroleum products and organic solvents.	Reduced emissions of nitrogen oxides, hydrocarbons and possibly sulphur oxides.
Nitrogen dioxide (NO_2)	A brownish-red gas with a pungent odour, often formed from oxidation of nitric oxide (NO)	Motor vehicle exhausts; high-temperature stationary combustion; atmospheric reactions	Catalytic control of automobile exhaust gases; modification of automobile engines to reduce combustion temperature; scrubbing flue gases with caustic substances or urea
Hydrocarbons (HC)	Organic compounds in gaseous or particulate form, e.g. methane, ethylene, and acetylene	Incomplete combustion of fuels and other carbon-containing substances, such as in motor vehicle exhausts; processing, distribution, and use of petroleum compunds, such as gasoline and organic solvents; natural events such as forest fires and plant metabolism; atmospheric reactions	Automobile engine modifications (proper tuning, crankcase ventilation, exhaust gas recirculation, redesign of combustion chamber); control of automobile exhaust gases (catalytic or thermal devices); improved design, operation, and maintenance of stationary furnaces (use of finely dispersed fuels, proper mixing with air, high combustion temperature); improved control procedures in processing and handling petroleum compounds.

The release of emissions to the atmosphere from industrial operations can take various forms:

A. "Planned" emissions

Because it is often economically or technically impossible to remove 100% of the contaminants in a discharge, process operations allow various concentration of pollutants to be emitted continuously to the atmosphere. Such concentrations are known as "planned" emissions (Figure V.(i).2.)

B. Fugitive emissions

The term "fugitive emission" is applied to any gaseous or particulate pollutant entering the atmosphere without first passing through a stack, duct or other device designed to direct or control its flow. Fugitive emissions generally originate from processes or operations or physical arrangements which are uneconomic or impractical to control. Invariably the emissions are at low level, mostly of low concentration, and dependent upon meteorological conditions for their dispersal.

C. Accidental emissions

These are emissions resulting from plant failures, such as a burst filter bag, or from an accident. Accidental emissions can be at a high concentration but they normally occur infrequently.

V.(i).2. Effects

The effects of air pollution will be considered under the following headings:

(i) Human health
(ii) Amenity
(iii) Animals (fauna)
(iv) Plants (flora)
(v) Materials
(vi) Atmosphere

V.(i).2.1. Human health

Any gas or aerosol can damage health at some concentration, if through no other means than dilution of oxygen. However, the specific concentration at which a contaminant will damage health depends on a variety of factors: the nature of the pollutant, the length of time the receptor is exposed to the pollutant, the concentration of the pollutant, and the general health of the receptor.

There are three common methods for determing the effect of various concentrations and dosages of pollutants on people (dose-response relationships): experimental exposures of animals (toxicological studies); clinical studies; and, epidemiological studies. The advantages and disadvantages of each of these approaches are discussed in some detail in Chapter VIII.

Although studies of the above types have not yet produced adequate data to relate specific diseases to specific concentrations of pollutants, they have revealed a number of general relationships (National Air Pollution Control Administration, 1969-1971; Goldsmith and Friberg, 1977.) For example:

(i) People have died as a result of polluted air, e.g. the London smog of December 5-9, 1952 caused 4,000 excess deaths, principally among the old, the infirm and those with respiratory disease (Anon., 1954). Similarly, in the air pollution episodes in Donora, Pennsylvania in 1948, and the Meuse Valley, Belgium in 1930, 20 and 63 people died respectively.

(ii) Chronic pulmonary disease (bronchitis, asthma, emphysema) is aggravated by sufficiently high concentrations of sulphur dioxide, nitrogen dioxide, particulate matter, ozone, etc.

(iii) Some pollutants (e.g. sulphur dioxide, photochemical smog) irritate sensitive membranes, particularly of the eyes, nose, throat and lungs, but the irritation varies greatly from one person to another (see Section V.(i).2.2.).

(iv) Cardiovascular diseases are related to atmospheric pollution in that any pollutant placing sufficient stress on the pulmonary function may affect the heart.

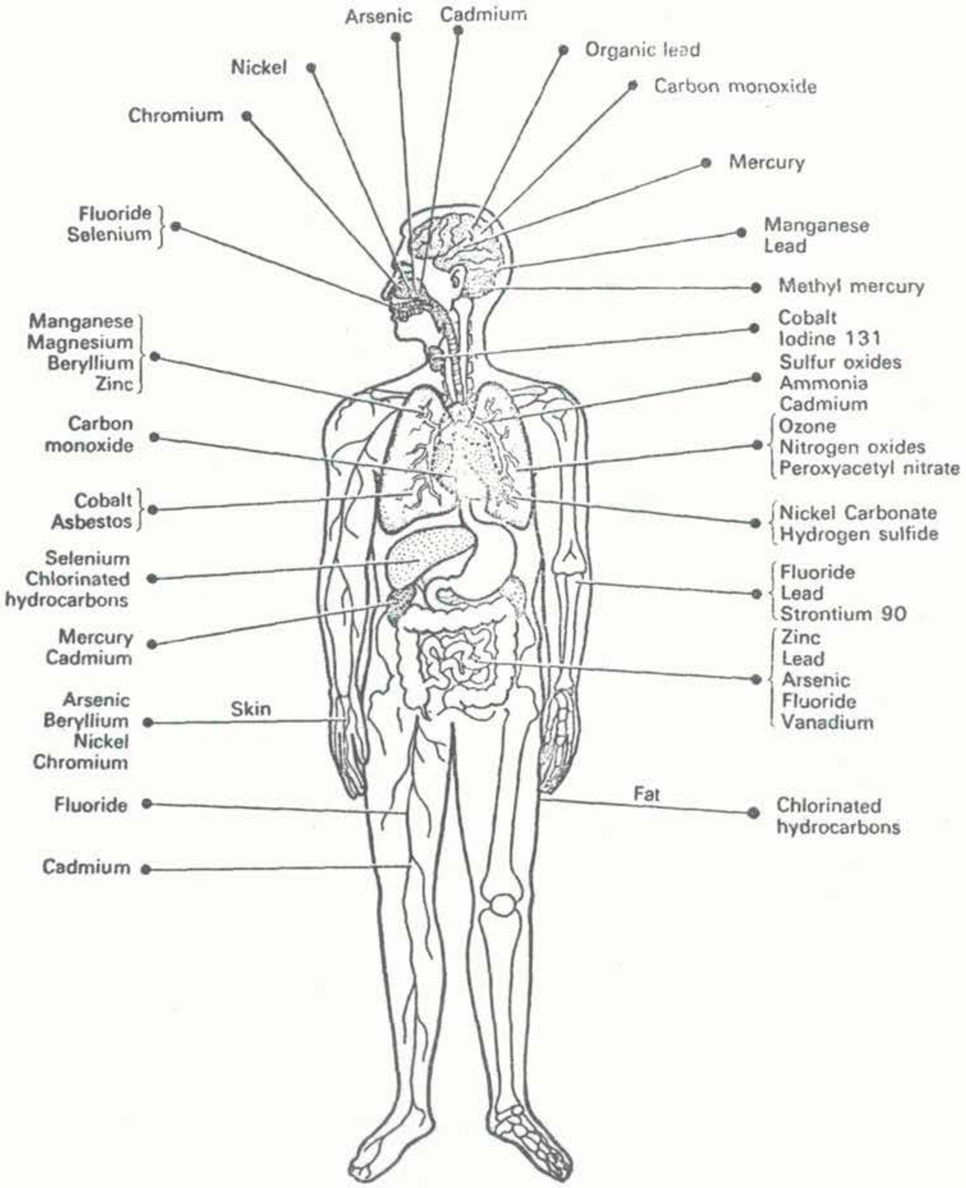
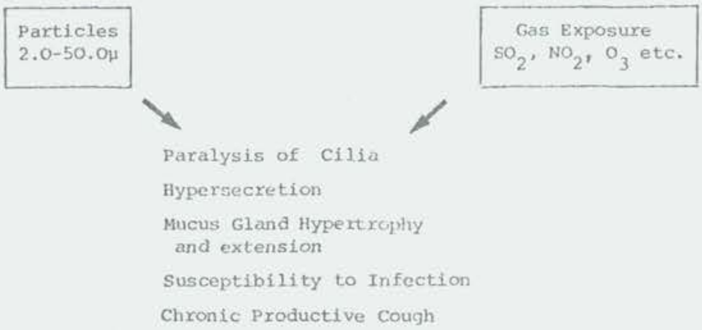
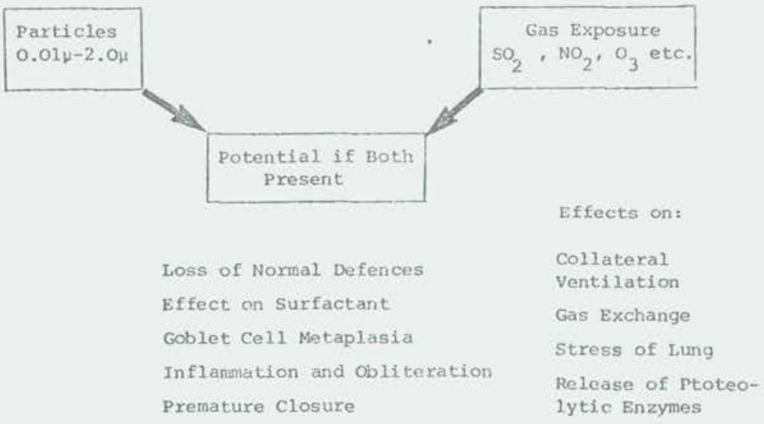


Figure V.(i).3. Main targets of major air pollutants. From Waldbott, 1973.

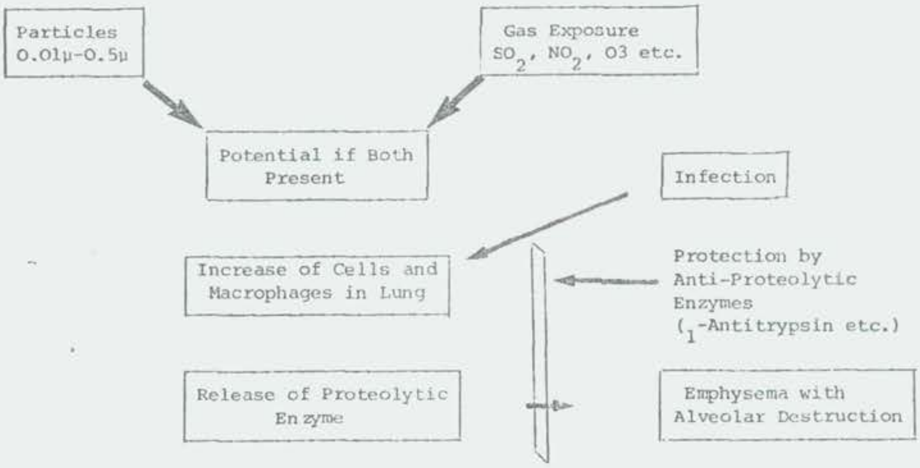
Figure V.(i).4. Model of the Effects of Atmospheric Pollutant Irritants on the Pulmonary System (Bates, 1972)



A. Effect of irritants in major bronchi



B. Effect of irritants in terminal bronchioles



C. Effect of irritants in alveoli

Although the effect of disagreeable odours (or even of agreeable odours over extended periods) on people is primarily one of nuisance, there are occasions when an odour can produce an impact on health either through its intensity (causing headaches or nausea) or by interfering with sleep. Offensive odours, e.g. from refuse tips and slaughter-houses, can also lead to the devaluation of property in the vicinity.

The most common chemical sources of odours are organic compounds that contain nitrogen or sulphur, e.g. amines, mercaptans and the complex decomposition products of proteins. Examples of odorous compounds containing no nitrogen or sulphur are phenols, cresols and fatty acids such as butyric, valeric and caproic acids. A list of odorous industrial operations is given in Table V.(i).2.

Table V.(i).2. Odorous industrial operations. From Faith, 1963.

Industry	Odorous material
Chemical manufacture	Hydrogen sulphide, ammonia, amines, alcohols, aldehydes, phenols, mercaptans, esters, chlorine and chlorinated organics, etc.
Coke ovens	Sulphurous, ammoniacal and phenolic compounds
Fertilizer	Bone meal, organic nitrogen compounds, ammonia
Food and kindred products	Dairy wastes, cannery wastes, fish, baking bread, chocolate, flavours, packinghouse wastes, meat products for rendering, coffee roaster effluents, cooking odours, etc.
Foundries	Core-oven odours, quenching oils
General industrial	Burning rubber, forming and moulding plastics, incinerator smoke, solvents and lacquers, asphalt
Petroleum	Sulphur compounds from crude oil, cresols, asphalt
Pharmaceuticals	Biological extracts and wastes, spent fermentation liquors
Pulp and paper	Sulphurous compounds
Soap and toiletries	Perfumes, animal fats
Tanneries	Hair, flesh, hides

(v) Carbon monoxide binds with haemoglobin in the blood and puts added stress on those suffering from cardiovascular or pulmonary disease (Lawther, 1975).

In short, it is the concensus of opinion that air pollution, rather than acting as a primary agent, aggravates existing disease conditions or puts at higher risk those predisposed to ill-health. Although much work remains to be done, the model proposed by Bates (1972) represents a workable framework of how pollutants can damage the pulmonary system (Figure V.(i).4).

V.(i).2.2. Amenity

This category of air pollution effects includes such reactions as eye, nose and throat irritation, odours, dust and dirt, and reduced visibility (the latter is discussed in Section V.(i).2.6.). However, it is very difficult to define just where annoyance ceases and danger to health begins.

There are two forms of eye irritation caused by air pollution. Firstly, there is the emission into the atmosphere of an irritating substance such as tear gas. While cause and effect are easy to relate when known irritants escape, this is not the case when mixtures of unknown composition and of unsuspected irritability are released. Secondly, there is the formation of an eye irritant in the atmosphere by reaction of otherwise non-irritating pollutants. The well-known high incidence of eye irritation in Los Angeles has been shown to be caused by the photochemical reaction between organic materials and nitrogen dioxide (Section IV.(i).). Although the exact nature of the irritant is not known, formaldehyde, acrolein and peroxyacetyl nitrate (all products) of the reaction) are thought to be involved (National Air Pollution Control Administration, 1969-71).

One of the problems in assessing eye, nose or throat irritation is the subjectivity of the measurement - neither instrumental nor objective methods are available. This is also the case for odour assessment, which is further complicated by the fact that there are tremendous variations in sensitivity among individuals and that people have mixed reactions to the offensiveness of odours. Other factors that have to be considered are the persistence of an odour and when and where it is produced (Phelps, 1976).

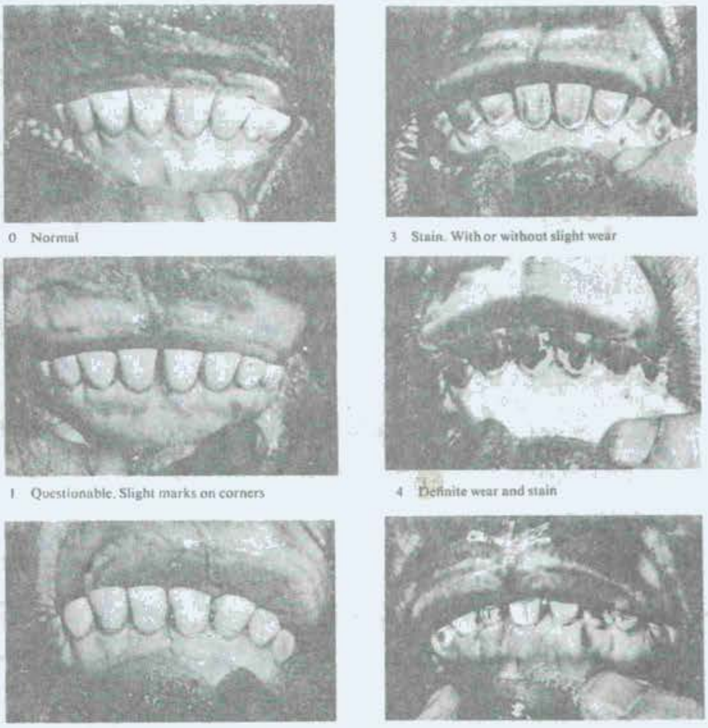
Another nuisance effect of air pollution is the accumulation of dust and dirt on surfaces. If the build up of "dinginess" or change in appearance occurs rapidly then it can lead to complaints. For example, where the dust is light grey (with reflectivities in the order of 30%) complaints become probable when the surface obscuration rate exceeds 0.4%/day. Frequent complaints and severe nuisance can be expected when the obscuration rate is of the order of 5%/day (Shillito, 1978).

Apart from the surface coverage and the appearance of uncleanliness, the deposits can also cause damage to the surface either directly, by abrasion and/or chemical action, or indirectly through the need for frequent cleaning (see Section V.(i).2.5.).

V.(i).2.3. Animals

Although the evidence is not as well documented as it is for humans, it is apparent that many of the acute air pollution episodes have resulted in death or injury to domestic animals. For example, in the London smog disaster of 1952, 52 cattle out of 351 on the ground floor at Smithfield became seriously ill (with symptoms of difficulty in breathing, raised body temperature, refusal to eat, etc.) and eventually five died with nine others having to be slaughtered (Anon, 1954).

In addition to suffering ill-effects from breathing polluted air, animals can become ill by eating fodder contaminated by air pollutants. Although the ambient air concentration of a pollutant may be low, vegetation can often accumulate and concentrate the contaminant to toxic levels. Arsenic, molybdenum, lead, zinc and pesticides have been identified as the responsible agents in several such incidents (Lillie, 1970). However, probably the most widely known problem is that due to fluorine and fluoride dusts. Fluorine is a protoplasmic poison which has a marked affinity for calcium and interferes with normal calcification (Figure V.(i).5.). Animials which eat fluoride-polluted herbage soon develop the early symptoms of fluorosis, a crippling disease which, in its advanced stages, is characterised by hypoplasia of dental enamel, lameness, anorexia, lowered fertility and reduced milk production (National Academy of Sciences, 1971).



0 Normal

1 Questionable. Slight marks on corners

2 Very slight stain. On corners in this case

3 Stain. With or without slight wear

4 Definite wear and stain

5 Excessive wear

Figure V.(i).5. Examples of fluorosis

V.(i).2.4.Plants

It has long been recognised that air pollution causes widespread damage to plants. Such damage can result in a severe economic loss to farmers, horticulturalists, fruit growers and owners of forests or woodlands. The most frequently encountered phytotoxicants are sulphur dioxide, hydrogen fluoride, chlorine, hydrogen chloride, particulates, ammonia, ethylene, ozone and constituents of photochemical smog (Jacobson & Hill, 1970; Mudd & Kozlowski, 1975; Mansfield, 1976; Table V.(i).3.)

Plants tend to be inherently more susceptible to pollution than animals. This is a reflection of their physiology which relies upon an easy gaseous interchange with the atmosphere, mainly through numerous small openings (stomata) in the undersurface of their leaves. As these stomata are unselective, gaseous pollutants will also enter with the air during the normal plant respiration cycle and can then act to the detriment of the plant, e.g. destruction of plant chlorophyll or disruption of photosynthesis or respiration. Particulate materials deposited on the leaf surface can interfere with this gaseous exchange and can reduce the intensity of light reaching the interior of the leaf.

As with people, there is a wide variation in the threshold concentrations of pollutants likely to induce injury in plants. Genetic factors account for large variations in sensitivity not only between species, but also between varieties within a species and between individual plants of the same variety. In addition, the extent of injury and response of a plant is modified by a large number of interacting environmental factors, including light intensity, soil type, relative humidity, food availability, stage of growth, temperature, soil moisture and plant viability. In general, any factor that tends to hold the stomata open increases the susceptibility of the plant.

The nature of the visible injury varies with the pollutant, but is usually some form of chlorotic marking (disappearance of green colour), banding or silvering or bronzing of the underside of the leaf (Figure V.(i).6.). It is normally possible to distinguish between acute injury which becomes obvious within a few hours of exposure to high pollution levels, and chronic injury, which develops slowly as a result of continuous exposure to low concentrations. In addition to visible injury, there has been much speculation about

Table V.(i).3. Effects of selected pollutants on plants

Pollutants	Symptom	Type of Leaf Affected	Part of Leaf Affected	Examples of Sensitive and Tolerant Plants	
				Sensitive	Tolerant
Ozone (O_3)	Fleck, stipple, bleaching, bleached spotting, pigmentation, growth suppression, and early abscission. Tips of conifer needles become brown and necrotic	Old, progressing to young	Palisade	Alder Alfalfa Spinach Potato Tobacco Cereal Crops Lilac	Juniper Yew Geraniums Gladioli Mint
Peroxy-acetyl nitrate (PAN)	Glazing, silvering or bronzing on lower surface leaves	Young	Spongy cells	Petunia Tomato Lettuce	Radish Onion Cotton
Sulphur dioxide (SO_2)	Bleached spots; bleached areas between veins; bleached margin; chlorosis; growth suppression; early abscission; and reduction in yield	Middle-aged	Mesophyll cells	Apple Walnut Lucerne Primulas Blackcurrant Broccoli	Maple Plane Privet Crocus Tulip Lilac
Hydrogen fluoride (HF)	Tip and margin burn; chlorosis; dwarfing leaf abscission; and, lower yield	Young fully developed	Epidermis and mesophyll	Plum Apricot Larch Hyacinth	Tobacco Petunia Sycamore Yew
Chlorine (Cl_2)	Bleaching between veins; tip and margin burn; and, leaf abscission.	Mature	Epidermis and mesophyll	Alfalfa Privet Primrose Sunflower Radish	Begonia Corn Yew Soybean Pepper
Ethylene (C_2H_4)	Sepal withering; leaf abnormalities; flower dropping; and, failure of flower to open properly.	(Flower)	All	Cotton Solanum spp Nettles Orchids	Apple Oats Clover Radish

"invisible injury" or growth retardation of plants as a result of air pollution. However, because so many factors affect growth it is very difficult to isolate the effects of air pollution.

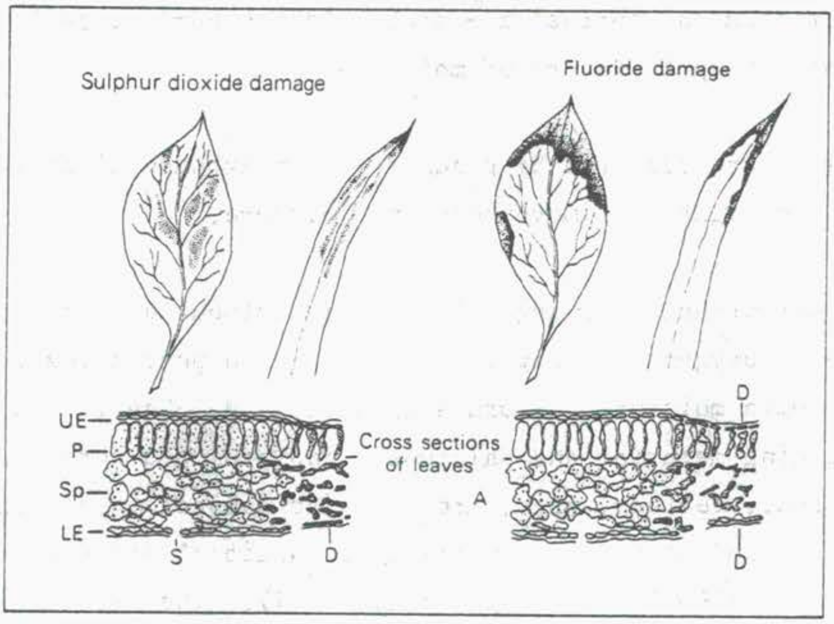


Figure V.(i).6. Schematic drawing of damage to leaves caused by atmospheric pollutants.

Another important aspect of the effects of air pollution on plants, is the possible interaction between pollutants such that the response to simultaneous exposure is greater than the sum of the separate effects. This synergism has been found, for example, with simultaneous exposure to sulphur dioxide and ozone (Menser and Heggestad, 1966), and to sulphur dioxide and nitrogen oxides (Tingey et al, 1971). Conversely, the interaction of sulphur dioxide with ammonia constitutes antagonism since ammonium sulphate is relatively harmless to plants.

V.(i).2.5. Materials

Air pollution can damage materials through a number of ways:

(i) abrasion - solids can have sufficient momentum to cause abrasion;

(ii) deposition and removal - even if the deposited substance does not damage the material, its removal may;

(iii) chemical attack, e.g. corrosion of metal by acid ion; and,

(iv) electrochemical corrosion - small electrochemical cells may be set up in layers of moisture.

These processes are affected by a number of environmental factors such as temperature, sunlight, air movements and moisture.

The most important acid-forming pollutant is sulphur dioxide which, in the presence of oxygen, is slowly converted to sulphur trioxide which, in turn, reacts with moisture to form sulphuric acid. The latter damages most types of building material and paintwork, and promotes corrosion of metals. Textiles, rubber, leather, etc., are likewise subject to deterioration by sulphur dioxide and other air contaminants (National Air Pollution Control Administration, 1969-71; Yocum and Upham, 1977). The effects of air pollution on a variety of materials are summarised in Table V.(i).4.

.(i).2.6. Atmosphere

Restriction of visibility is the most widely noticed and probably least understood of all the effects of air pollution. In addition to smoke and dust clouds which will obviously limit visibility and reduce insolation, there are occasions when horizontal visibility is restricted while the sky overhead is bright. A well-known example is the smog in Los Angeles where horizontal visibility is often less than ¼ mile even when the sun is shining. Such reductions in visibility can have a number of undesirable effects: transportation delays, especially for cars and aircraft; increased transportation hazards; increased use of electricity; public complaints on aesthetic grounds; and, discouragement of tourist trade (Peckham, 1969).

Restricted visibility is caused by the forward scattering of light by minute solid or liquid particles (aerosols) in the size range of 0.4μ to 0.9μ. Smoke, fog and industrial fumes all contain such particles and restrict visibility in proportion to the number of particles present in this size range. A number of generalised formulae have been proposed

Table V.(i).4. Summary of effects of air pollution on materials

MATERIAL	EFFECT
Building Materials:	
Limestone	H_2SO_4 reacts to form soluble sulphates which cause surface erosion while crystals expand and cause exfoliation; Carbonic acid (from CO_2 and moisture) reacts to produce soluble carbonate; grit and dust soiling.
Sandstone	SO_2 and CO_2 little effect; hard black deposit on surface
Brickwork, Granite	Blackening, to limited extent.
Paint	Soiling, pitting, staining, discolouration and blooming. SO_2 and H_2S darkens white paints based on lead carbonate, due to formation of black sulphide.
Electrical insulators	Flash-over in humid conditions due to soiling by hydroscopic pollutants.
Metals:	
Iron	Rate of oxidation and rusting accelerated by traces of SO_2 and particles of carbon, soot, ash and grit, particularly if relative humidity exceeds 80%.
Aluminium	Surface dulled and blackened by soot and dust.
Copper	Green patina formed by SO_2 attack
Zinc	SO_2 action forms soluble sulphate - reduces life of galvanized metal.
Silver, Gold	Abrasion by particulate matter; tarnishing by SO_2.
Lead, Steel	Little effect.
Textiles, Leather etc.:	
Textiles	Soiling and excess wear due to particulate matter discolouration, fading, bleaching and weakening due to action of SO_2, O_3, NO_2 etc.
Leather	SO_2 will cause rotting in humid atmospheres.
Rubber	Ozone and oxidants cause brittleness and cracking, particularly if rubber is under stress.
Paper	Loss of strength and embrittlement due to absorption of SO_2.
Nylon	Laddering due to acidic particles.

relating visibility to atmospheric dust concentration (National Air Pollution Control Administration, 1969 -71; Charlson, 1969). Most of these formulae are in the form:

$$Lv \times M = K$$

where: Lv = visual range in kilometers, M = mass concentration in $\mu g/m^3$ and K = a constant.

In addition to reduced visibility, other recent studies suggest that pollutant emissions are having a number of other effects on global and urban climates (Robinson, 1977; SMIC, 1971):

(i) More frequent longer-lasting fogs occur in urban areas due to an abundance of condensation nuclei;
(ii) Small rainfall increases are usually found downwind of cities - cloud seeding by aerosol air pollutants is thought to be at least part of the cause of this increase;
(iii) The "blanket" of particulates over most large cities significantly reduces the solar energy that reaches an urban complex compared with rural areas; and,
(iv) Increases in atmospheric levels of carbon dioxide could lead to an increase in global temperatures because the carbon dioxide molecules are able to absorb thermal energy that would otherwise radiate from the earth into outer space (the "greenhouse effect"). The estimated average carbon dioxide concentration at the beginning of the century was 290 ppm, but has now increased to about 330 ppm as a result of fossil fuel combustion (Baes et al, 1977). Increased cloud formation and particulate levels are thought to have counterbalancing, "earth-cooling" effects (Singer, 1970). Opinions differ as to how (if at all) global climate will be altered in the long-term by the combined effect of these and other processes (Cloud and Gibor, 1970).

The foregoing brief review has shown that air pollution has a wide range of adverse effects on man's health and welfare, some of which are summarised in Table V.(i).5. In most cases the mechanism of action of a pollutant is poorly understood and this is even more the case when combinations of pollutants are being considered.

Table V.(i).5. Summary of the effects of air pollution on man's health and welfare.

Agents, Pollutants	Effects
Sulphur dioxide (effects of sulphur oxides may be due to sulphur, sulphur trioxide, sulphuric acid, sulphate salts)	Aggravation of respiratory diseases, e.g. asthma and chronic bronchitis Impairment of pulmonary function Irritation of eyes and respiratory tract Leaf injury and reduced growth in plants Corrosion of metals. Deterioration of building materials, textiles, leather etc.
Sulphur oxides and particulate matter from combustion sources	Short-term increase in mortality and morbidity Aggravation of bronchitis and cardiovascular disease Contributory role in etiology of chronic bronchitis and emphysema Contributory role in etiology of lung cancer (?)
Particulate matter (not otherwise specified)	Directly toxic effects or aggravation of effects of gaseous pollutants Increase in chronic respiratory disease Impairment of visibility Alteration in incident sunlight Interference with plant photosynthesis Soils surfaces and materials Abrasion of building materials and textiles
Oxidants (including ozone)	Aggravation of emphysema, asthma, and bronchitis Impairment of cardiopulmonary function Eye and respiratory irritation Impairment of visibility Leaf injury and reduced growth of plants Deterioration of rubber, textiles etc.
Hydrocarbons	Contribution to cancer (?) Contribution to formation of photochemical oxidants Sensory irritation
Carbon monoxide	Increased general mortality and coronary mortality rates Reduced tolerance for exercise Impairment of mental function Causal factor in atherosclerosis (?)
Nitrogen dioxide	Aggravation of respiratory and cardiovascular illnesses. Discolours atmosphere Damage to vegetation Fading of paints and dyes

Table V.(i).5. Continued

Agents, Pollutants	Effects
Lead	Increased storage in body Impairment of haemoglobin and porphyrin synthesis Impairment of learning and intelligence in schoolchildren Lethal to animals eating contaminated feed
Hydrogen sulphide	Increased mortality from acute exposures Sensory irritation and impairment of sensory detection or reflexes Damage to paint
Mercaptans and other odorous compounds	Sensory irritation Headache, nausea, and sinus affections
Fluorides	Damage to vegetation; harms animals Fluorosis of teeth
Ethylene	Damage to vegetation and hastening of fruit ripening
Asbestos	Production of pleural calcification Malignant mesothelioma, asbestosis Contribution to chronic pulmonary disease (asbestosis and lung cancer)
Chlorinated hydrocarbon pesticides	Stored in body, mostly from milk and animal fats Ecological damage

The optimum strategy for the control of air pollution must depend on drawing a balance between the costs to society of all aspects of air pollution damage and the alternative costs of its reduction or prevention. However, with few exceptions, very little has been done to assess the costs of air pollution damage on a national scale (Programmes Analysis Unit, 1972; Environmental Protection Agency, 1976). This means that most air pollution control programmes are being based on subjective "value judgments". Nevertheless, a great deal of research is now being directed towards obtaining quantitative data on the costs and benefits of air pollution control.

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V.(ii). SOURCES AND EFFECTS OF WATER POLLUTION

V.(ii).1. Introduction

Water pollution has been defined as "any alteration of the chemical physical or biological quality of water which results in an unacceptable depreciation of its utility or environmental value" (Fish, 1972). This definition embraces not only the more traditional chemical and bacteriological aspects of water quality associated with human health and disease, but also all the factors which may affect the overall environmental characteristics of the water. As the definition implies, water pollution can be classified into three major types, although it should be realised that there are important inter-relationships between the classes:

- chemical pollution - this occurs when chemicals are added to water resulting in a direct or indirect depreciation of the value of the water. A direct effect may occur through the addition of, for example, high concentrations of toxic metals, whereas the stimulation of heavy algal growths by additions of nutrients would be an indirect effect.

- physical pollution - alterations of the volume, topography or temperature of the water or additions of solids can cause an unacceptable depreciation of the value of the water. Again, the depreciation may be a direct or indirect result of the physical alterations.

- biological pollution - this occurs when certain living organisms (e.g. faecal bacteria or disease-bearing fish) are added to water resulting in a depreciation of its value.

V.(ii).2. Sources of Water Pollution

It is useful to know where and how water pollutants originate as they can usually be controlled most easily at source. Although a list of specific sources and activities would be very long, typical categories include:

- discharges of wastewater to surface waters - these are generally classified as domestic sewage or industrial effluent. The former originates from households, schools, offices, shops, works canteens, etc. and consists of kitchen, bathroom and lavatory wastes. Industrial or trade effluent originates from manufacturing and industrial plants, mines, agricultural premises, research establishments, etc. and generally can be divided into two types - process waters and cooling waters.

- disposal of waste on land - a number of wastes are commonly disposed of on land, e.g. domestic refuse, solid or liquid wastes from industrial processes, sewage sludge, agricultural slurries, etc. Water pollution can occur when contaminants, either directly from the liquid wastes or as a result of rainfall percolating through the solid wastes, reach aquifers or watercourses, adding to the continuous natural leaching of substances from the ground mass associated with the waterbody.

- urban and land run-off - land surfaces rendered impermeable by covering with streets, roads and buildings and provided with surface water drains facilitate the wash-off by rainfall of urban debris, deicing chemicals, spilled pollutants, etc., to watercourses. Similarly, land run-off can carry silt, soil minerals, applied manure and fertiliser residues, etc., to watercourses.

- atmospheric pollution - fall-out of grit and dust emissions can be washed off roads, roofs, paved surfaces, etc., to eventually reach watercourses, while aerosols and gaseous pollutants are removed from the atmosphere by rainfall or washout processes.

- water abstraction - it is being increasingly recognised that water abstraction can have depreciating effects on the quality of water resources, particularly if the water is returned at locations distant from the abstraction point. Reduction of a stream's flow, for example, can affect its

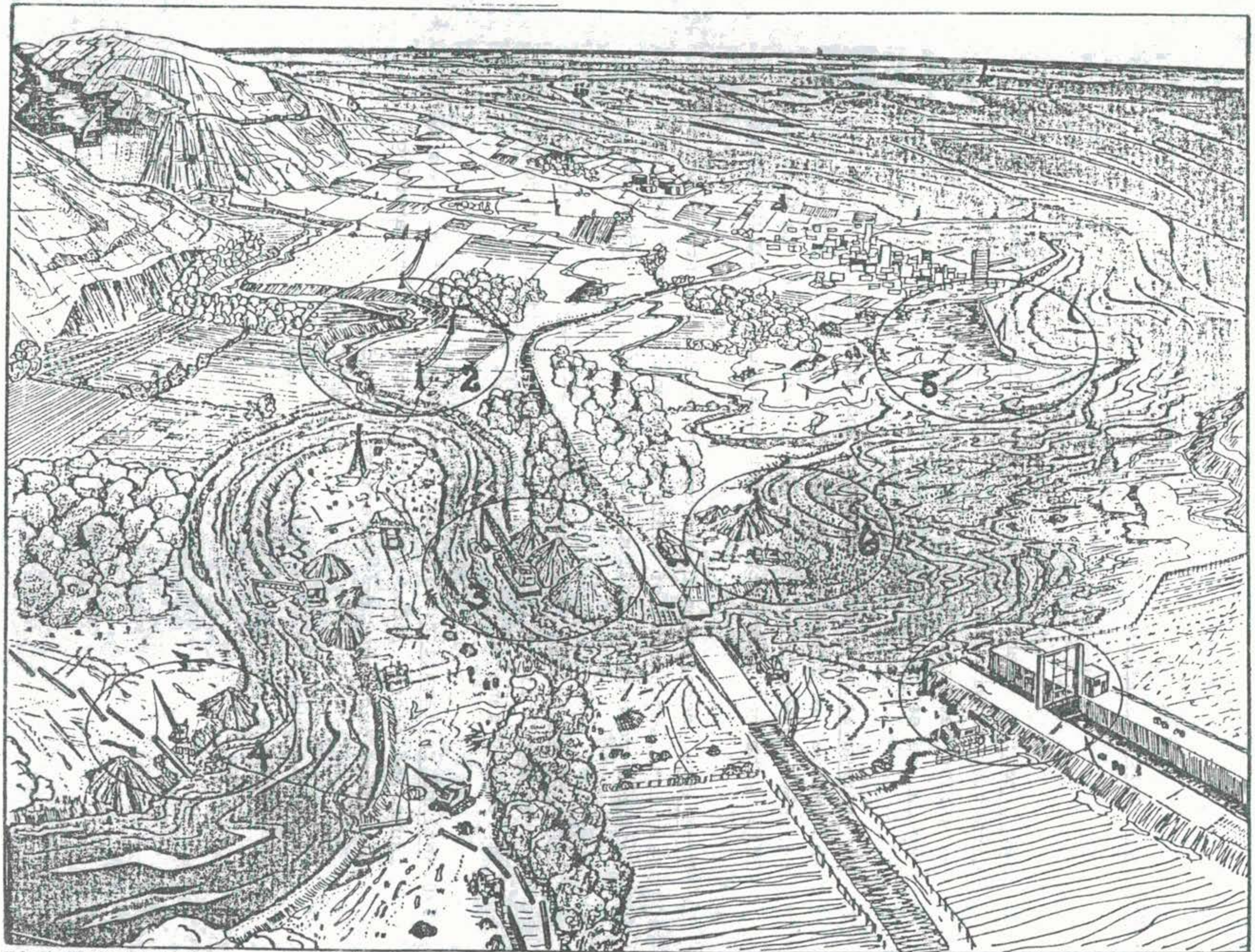


Figure V.(ii).1. - Schematic representation of the possible impact of construction activities upon aquatic environments (See next page for key)

Key to Figure V.(ii).1.

1. Canalization: habitat destruction reducing abundance and diversity of wildlife; possible increased scour of estuarine bed; modification of freshwater/sea water mixing may damage estuarine organisms.

2. River regulation: straightening and dredging of a river and removal of trees and shrubs from the banks. This destroys many habitats that make rivers so rich in wild life. Changed flow patterns may threaten flooding.

3. Dredging: deposition of dredged material downstream with resultant smothering of flora and fauna and spawning sites; possible release of pollutants from river bed sediments.

4. Pipeline crossing: effects similar to dredging activities but more transient; erosion of riverbanks if reinstatement improperly managed.

5/6. Wetland reclamation: habitat loss to detriment of specialised fauna and flora; reduction of the floodplain threatening flooding; increased downstream silt loading.

assimilative/recuperative capacity and this can have implications for the protection of public health, fisheries and aquatic life.

- construction/development activities - operations such as dredging, impounding, diking, channelisation, clearing of vegetation, land reclamation and shoreline modification all have the potential for causing physical pollution of waters and for changing the aquatic habitat of the area (Figure V(ii)1).
- miscellaneous events - placed in this category are accidental spills and leakages resulting from human and technological failures, together with deliberate dumping of materials.

V.(ii).3. Effects of Water Pollution

V.(ii).3.1. General considerations

The routes and processes which determine the fate and distribution of pollutants within aquatic environments are numerous and complex (Figure V.(ii).2.). Under favourable conditions, the pollutants are diluted, dispersed and transported by turbulent mixing, currents and migrating organisms. Unfortunately, bodies of water are often not mixed thoroughly and high levels of pollutants build up in localised areas. In addition, there are physico-chemical and biological processes taking place that concentrate pollutants and lead them back to man. For any pollutant, the relative importance of each of these processes determines the impact that the pollutant will have on different components of the aquatic environment.

It is possible to discuss the effects of water pollution in terms of either the nature of the pollutant or the type of effect produced, but both methods have their limitations mainly because there are inevitable overlaps between the categories chosen. However, with this limitation in mind, the discussion below is based on the classification of pollution outlined in the Introduction.

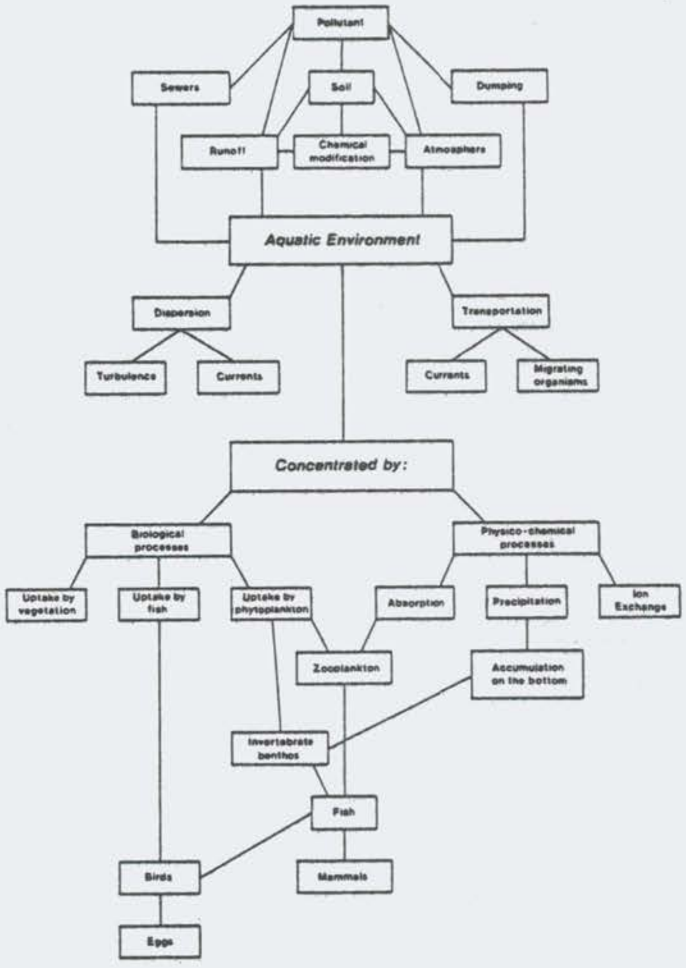


Figure V.(ii).2. Distribution of an aquatic pollutant. A flow diagram of the pathways by which a contaminant enters the aquatic environment and the ways in which it can be concentrated with various lethal and sublethal effects. (Adapted from Ketchum, 1967)

V.(ii).3.2. Chemical pollution

V.(ii).3.2.1. Biodegradability

Chemical pollution is caused primarily by dissolved inorganic or organic material. An important question relating to either category is whether the material is biodegradable. Biodegradable pollutants (e.g. certain organic wastes and nutrients) can be rapidly decomposed by natural processes or via treatment systems enhancing nature's capacity to decompose and recycle. On the other hand, non-biodegradable or persistent pollutants (e.g. certain organic chemicals and metals) either do not degrade or degrade extremely slowly in the natural environment. Such compounds not only accumulate but also are frequently biologically amplified or concentrated as they are transported in biogeochemical cycles and along food chains. Non-biodegradable pollutants can be inert or toxic.

Both biodegradable and non-biodegradable pollutants can induce environmental stress and alter the energy flow available for ecosystem production, but in different ways. For example, toxic non-biodegradable materials if left uncontrolled impair ecosystem energy production until organisms die or the entire ecosystem is rendered lifeless. The introduction of usable energy (biodegradable organic matter) or nutrients (phosphates, nitrates, etc.) at moderate levels may stimulate ecosystem productivity, but an excess can result in severe oscillations and finally lethal conditions Figure V.(ii).3.).

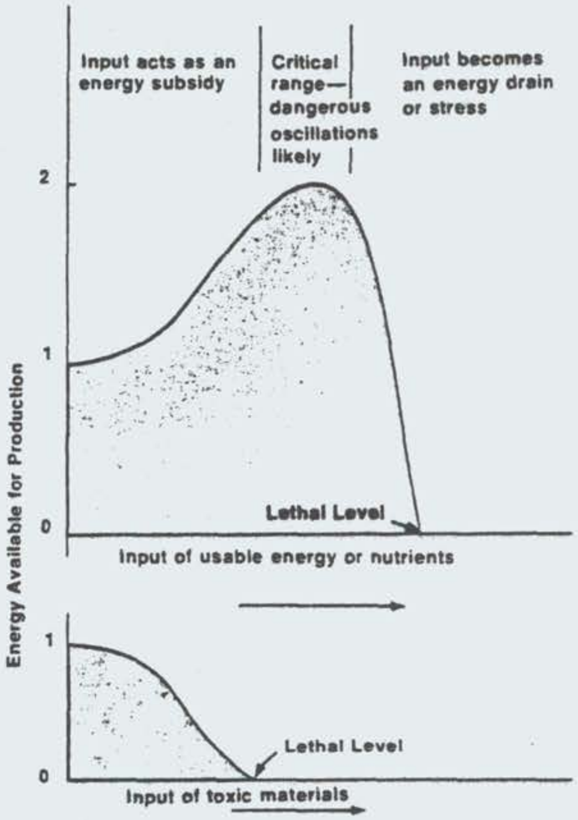


Figure V.(ii).3. Schematic model of the effects of two types of pollution - degradable organic (upper graph) and non-degradable toxic (lower graph).

V.(ii).3.2.2.Toxicity

For a toxic material to influence the survival, reproduction or growth of an organism it must attain an effective concentration at the site or sites of its action within the organism. For an aquatic organism, the attainment of this effective concentration will depend not only on the concentration of the material in the water and in the organism's food (as determined by the processes shown in Figure 2), but also on the rate of absorption of the substance, its distribution about the body, its inactivation through bio-transformation and the rate at which it is excreted.

Because of all the above factors which can modify toxicant effects, it is rare for a poison to affect all species in a habitat. Generally speaking, after a poison enters a river, its concentration slowly declines, either through dilution, precipitation or destruction. Fauna and flora are eliminated and then slowly recolonize. However, a few species usually remain, and freed from the danger of predation by those affected, they may attain enormous population sizes, and behave like members of a developing (immature) community (Figure V.(ii).4.).

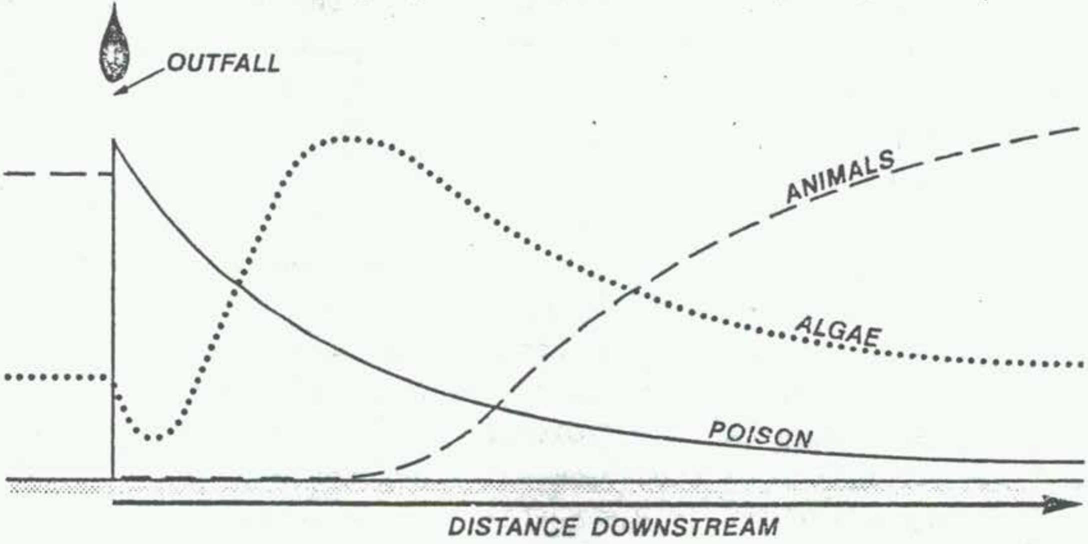


Figure V.(ii).4. - Diagram showing the decrease in concentration of a poison in a river and the corresponding changes in numbers of algae and numbers of species of animals (Modified from Hynes, 1966).

Most toxic materials are believed to produce their effects by combining with enzymes, cell membranes or other specialised functional components of cells. Their mode of action appears to be very much dependent on their structure and often, minor changes in structure can have profound effects on toxicity. In most cases it appears that the toxicant acts on the carboxyl, amino, sulphydryl, phosphate or other similar reactive groups of the cell component.

These initial biochemical actions of the toxicant induce other biochemical or physiological changes or effects which, in turn, may modify digestive, circulatory, respiratory, nervous, osmo-regulatory or behavioural performance of the organism. The significance of these alterations at the populational level, is dependent on how they affect the survival, reproduction or growth of individuals.

Predicting pollutant toxicity is, however, extremely difficult. Different species and different developmental or life stages of the same or different species can vary widely in their sensitivity or tolerance to toxic materials, to ranges in environmental conditions and to the cumulative, synergistic and antagonistic effects of toxicants (see below). In other words, the entire metabolic state of an individual, as determined not only genetically but also by its age, size, present environment and environmental history, will affect its responses to toxic materials.

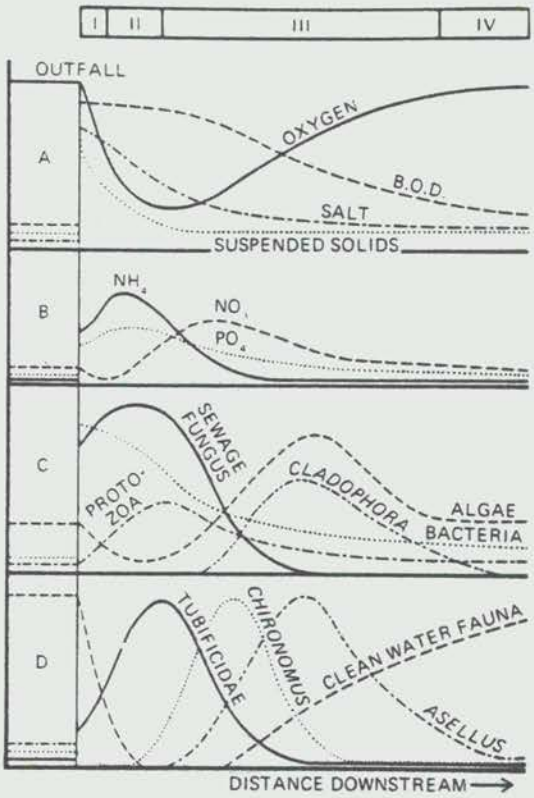
The toxicity of most poisons is dependent upon many environmental factors such as the hardness of water, pH, dissolved oxygen levels and temperature. Perhaps the most striking example is the way pH completely controls the toxicity of ammonia by governing the form present in solution. Beside the characteristics of the water, the physico-chemical condition and behaviour of the pollutant itself can result in considerable variations in toxicity. Thus, the pollutant may occur in different forms such as ionic, particulate, emulsified or as a surface film and may be chelated or absorbed on suspended organic matter or sediments.

Toxic compounds seldom occur in isolation in an effluent - other substances which may or may not be toxic by themselves may be present and affect the potency of toxic substances. When occurring together, some toxicants exert an additive effect while others can exert a "more than additive" (synergistic) effect. A related aspect of considerable importance is the fact that some substances can undergo bio-transformation processes in the environment, creating products which can pose significant threats to human health (see Section 3.2.4.(ii)).

V.(ii).3.2.3. Organic chemical pollution

(i) Biodegradable (e.g. sewage). Of the many forms that pollution take, one of the most destructive and most prevalent is pollution by wastes whose degradation by chemical or bacterial oxidation lowers the oxygen concentration of the water. Most of these wastes are organic and consist of raw sewage and/or industrial effluents such as those from many food-processing plants; but some, like sulphites from pulp and paper mills and ferrous salts from acid mine drainage, are inorganic. In rivers, deoxygenation reaches a peak a short distance from the pollutant outfall, and this coincides with the disappearance of the normal flora and fauna and the appearance of large populations of a few species of organisms that are successful under largely anaerobic conditions (Figure V.(ii).5.).

Immediately below the outfall is the zone of degradation (I) where river water mixes with the effluent. With the development of increasing numbers of decomposers, the water enters the zone of active decomposition (II) where the concentrations of organic materials decrease with a corresponding increase of dissolved inorganic by-products. If the pollutant loading is great enough, the organisms use oxygen faster than it can diffuse through the water/air interface, and the water becomes devoid of dissolved oxygen. This zone is characterised by the absence of clean water fauna



igure V.(ii).5 Changes in the condition of a stream below an outfall of raw sewage. A and B show mostly chemical changes; C shows changes in the abundance of micro-organisms; and D, changes in the abundance of invertebrates. The zones described in the text are shown at the top. (Hynes, 1966).

and the presence of hydrogen sulphide. Eventually, sufficient quantities of the organic materials are consumed to impede bacterial activity and oxygen reappears, being drawn in from the air as the water moves along. In the following <u>zone of recovery</u> (III) processes occur that change the water back to its original condition. The dense population of bacteria provides an abundant food supply for protozoa and small invertebrates. Some of the bottom-dwelling invertebrates are able to survive with little oxygen, and such organisms as Tubificidae (sludge worms) appear in great numbers early in the recovery zone. Further downstream, after more aeration, invertebrates with higher oxygen requirements increase in numbers.

With the relatively high concentrations of carbon dioxide, phosphates, nitrates and other nutrients now present, luxuriant growths of algae and other aquatic plants may develop. Through their photosynthetic activity they contribute dissolved oxygen to the water. They also provide cover and food for invertebrates, and consequently the variety and abundance of species increases downstream within this zone. Eventually, all the decomposable material that entered the river is degraded by biological action and the water is restored close to its original state, the clean water zone (IV).

(ii) Oil. Oil is generally regarded as a biodegradable mixture of hydrocarbons, although some fractions do have a long residence-time in water. Contamination by oil occurs primarily in marine ecosystems, the immediate effects on marine biota being dependent on: (1) the type and amount of oil released into the environment; (2) the rate of evaporation of various fractions; (3) the season in which the oil is released; (4) the partitioning of toxic materials from the environment into the oil and vice versa; and, (5) the species affected and, with littoral organisms, their place in the intertidal zone. Clearly, these factors are related, e.g. a more toxic oil containing refractory components would have more impact than that comprising non-toxic components which are easily biodegraded. Seasonal temperature affects the toxicity of oil for the resident microbial population and its susceptibility to biodegradation. It also affects hydrocarbon solubility - a significant amount of microbial degradation of oil hydrocarbons occurs at low temperature when toxic hydrocarbons are less soluble in sea water (Nelson - Smith, 1972; Food & Agricultural Org, 1977).

The most visible effects of oil spillages on the natural environment are mechanical. The clogging and blanketing of surfaces and fine structures inhibits movement and therefore the respiration and feeding of small animals. Similarly, seaweeds may become encrusted, over-weighted and torn away by waves. Hydrocarbons dissolved or dispersed in the water reach unprotected surfaces, such as the delicate skin covering fish gills. Aromatics in particular often irritate these surfaces, stimulating a copious secretion of mucus, while surfactants induce erosion of gill and gut tissues. These effects have considerable impact because such tissues are essential in the control of water and salt-exchange between body fluids and the external medium, as well as in respiratory exchange. Many hydrocarbons can penetrate plant tissues and, once inside, are thought to damage intracellular membranes which regulate metabolism (Figure V.(ii).6.).

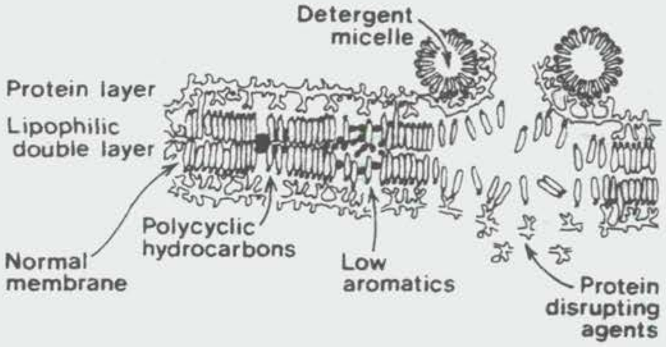


Figure V.(ii).6. The effects of various agents on the plasma (cell) membrane. To the left is the normal structure, with a double layer of fatty molecules stabilised on each side of an outer protein layer. The large molecules of polycyclic hydrocarbons penetrate slowly and push the fatty molecules apart, while low-boiling aromatics penetrate rapidly and become solubilised in the fatty membrane, disrupting its spacing. Detergents (surface-active agents) and some other agents strip off or break up the protein layer. (From van Overbeek and Blondeau, 1954).

Detergents are often employed to disperse the oil through the water rather than leaving it as a thick surface film. However, the detergents can be more toxic than oil, to marine organisms, especially mollusca. Thus, limpets have exhibited a high mortality with certain detergents, when they have survived the oil alone. With oil and detergent, separately or together, species at the extremes of their intertidal range exhibit greater losses. This is the result of oil standing in pools for considerable periods, detergents enabling oil to penetrate deeper into pool water, and because the species are in any case under considerable stress at the extremes of their tolerances.

The most obvious victims of sizeable oil spills are seabirds, and many thousands usually perish. Birds that are rescued and cleaned,frequently exhibit high mortality rates after release, but it is uncertain whether this is due to pneumonia or poisoning.

(iii) Synthetic organic chemicals. In the past few decades, the chemical industry has developed countless new organic chemical products. Consumer acceptance and demand for more plastics, pesticides, synthetic fibres and artificial rubbers have contributed substantially to the increasing output of major petrochemical facilities. Further, the overall volume of synthetic organic chemicals will continue to expand as the diversity of uses of these products increases (Central Water Planning Unit 1977)

While most, if not all, naturally occurring organic chemicals will eventually decompose, it has become apparent during the last decade that many synthetic organic compounds (particularly those with a molecular structure that departs significantly from the types occurring in nature) are not being degraded or are only very slowly degraded. Such nondegradable pollutants not only accumulate at the end of food chains or in soil but are often 'biologically magnified' as they move in biogeochemical cycles and along food chains. Even if the compound possesses only very low acute toxicity, the combination of persistence and biological concentration can pose very serious, chronic environmental problems. Indeed, many of these special purpose chemicals (e.g. insecticides, herbicides, fungicides and bactericides) are designed to be toxic, although they can only be considered as pollutants when they affect organisms with which they were not originally intended to come into contact.

V.(ii).3.2.4.Inorganic chemical pollution

Although harmless at very low concentrations, the presence of more than about 0.1% by weight of dissolved salts will kill many plants and animals. This occurs because of the inability of biological mechanisms to cope with the altered difference in the concentration of dissolved salts between the surrounding environment and the interior of the organism's cells, rather than a specific poisonous effect. High salinity also reduces the value of water for domestic, agricultural and industrial uses.

(i) Nutrients. Certain inorganic substances that are essential for normal plant metabolism can reach such levels that they may then be considered pollutants. The nutrients that are essential for algae and other organisms include carbon, nitrogen, phosphorus, silicon, iron, magnesium, potassium, calcium, sodium, sulphur, copper, manganese, cobalt, molybdenum and vanadium. In aquatic ecosystems, the concentrations of one or more of these nutrients (normally nitrogen and phosphorus) usually limits the size of algal populations. If the concentration of a limiting nutrient exceeds its normal level, a marked proliferation of the number of algae can occur. This large and relatively rapid increase in the algal population is called an algal "bloom", while the process is often referred to as eutrophication. Heavy developments of these growths can have a depreciating effect on fisheries in a number of ways:

- they reduce light transmission into the water, thereby inhibiting the growth of fine-leaved submerged aquatic weeds and thus the availability of fish-food fauna;
- they increase total plant photosynthesis and respiration in the water creating a wide diurnal variation of the dissolved oxygen content. If very low night-time dissolved oxygen levels occur this can directly threaten fish life;
- they add to the total deposit of organic matter from plant decay on the bed of the water, thereby increasing the oxygen demand on the overlying water; and,
- they may produce compounds highly toxic to fish and possibly toxic to mammals.

These effects are much more likely to arise in lakes and ponds rather than in rivers where the flow and turbulence do not normally permit gross phytoplankton blooms to develop. (Nat.Acad. of Sciences, 1969)

(ii) Toxic chemicals. Of the many inorganic compounds that are poisonous to aquatic organisms, the salts of metals and trace elements such as copper, silver, lead, gold, nickel, chromium, zinc, cadmium and mercury are particularly important. This is because they are typically toxic at low levels, nondegradable, and although they occur naturally they are frequently concentrated to unusual levels by human activities, such as mining and smelting operations and in industrial discharges.

Many chemical elements tend to circulate in the biosphere in characteristic paths from environment to organism and back to the environment. These cyclic paths are known as biogeochemical cycles. The movement of those elements and inorganic compounds essential to life can be conveniently designated as nutrient cycles and some of these are known in great detail, e.g. the nitrogen, phosphorus, carbon and sulphur cycles. However, chiefly through man's activities the cycling of many non-essential elements is now of considerable concern, particularly from the toxicological viewpoint. A non-essential, toxic element which has been the subject of much recent study is mercury (Figure V.(ii).7.). Its toxicity has been recognised for centuries but only within the last 15 years has the element accumulated noticeably in the natural environment. High concentrations in birds and fish, signal its ubiquity in the global ecosystem. Aquatic ecosystems, in particular, often receive heavy local influxes of mercurial wastes from the manufacture of plastics, chloride, caustic soda and electrical equipment, from pulp and paper mills, and from the burning of fossil fuels (Joensuu, 1971).

Mercury is generally discharged into the aquatic environment as inorganic mercury compounds or as phenyl-mercury. However, its impact is heightened by the unique ability of mercury to form stable compounds with organic radicals. In bottom sediments, microbes capable of synthesizing vitamin B_{12} can transform inorganic compounds into both monomethyl and dimethyl forms which dissolve in the water (Jensen and Jernelov, 1969). The less volatile monomethylmercury is usually formed under acidic conditions; the highly volatile dimethyl form is favoured under neutral and alkaline pH. Dimethylmercury evaporates into the atmosphere and enters the global cycle. Fish in the methylmercury laden water pick up this pollutant, either by ingestion of contaminated food or by diffusion across the gills and can therefore convey the toxicant back to man (O.E.C.D., 1974; U.K. Department of the Environment, 1976).

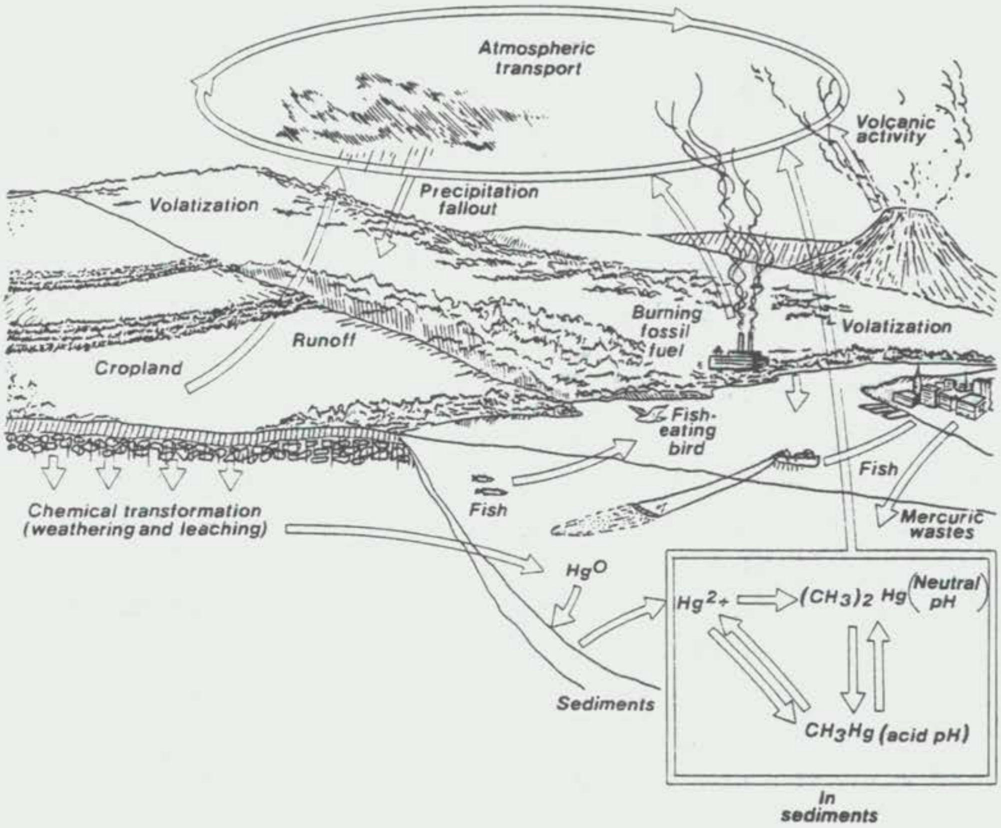


Figure V.(ii).7. The biogeochemical cycle of mercury (After Smith, 1974).

This conversion of inorganic mercury to the potent neurotoxin methylmercury by bacteria is one example of biotransformation, a process that is now recognised as being of vital importance from the standpoint of human health as it is the molecular form of a toxic substance that controls its persistence, bioaccumulation and toxicity. Biogeochemical cycles for mercury, arsenic and tin can now be formulated in some detail (Ridley, Dizikes and Wood, 1977).

In addition to metals and trace elements, compounds of cyanide and sulphide are also toxic to aquatic organisms at low concentrations. They exert their toxic effects by interfering with the utilisation of oxygen in the respiratory process. Free chlorine is also highly toxic and is often used to prevent growth of micro-organisms in, for example, the cooling water intakes of power stations.

V.(ii).3.3.. Physical pollution

Physical pollution occurs when an effluent: (i) contains liquid or solid suspended matter; (ii) significantly alters the temperature of a river, (iii) is sufficient in quantity to cause large variations in the volume and/or flow rate; or, (iv) contains radioactive material.

V.(ii).3.3.1. Suspended material

The effects of the presence of suspended material are varied since it may be present in various states from colloidal suspension to gravel or from emulsions to globules. However, whether the solid matter is inert (e.g. sand) or subject to decomposition by micro-organisms, its physical presence can upset the aquatic ecosystem. For example, an increase in turbidity or colour will, by reducing light transmission and photosynthetic activity, reduce the productivity of submerged rooted plants, phytoplankton in suspension and filamentous algae. This in turn will reduce the numbers and species of animals because of the loss of the favourable weed habitat. The breathing mechanism of fish is also directly affected by high concentrations of suspended solids. Similarly, an increase in silt deposition can produce a reduction in the number of animals characteristic of clean gravel beds as well as a minor increase in the number of animals characteristic of silty habitats. If the deposited solids are also organic, anaerobic decomposition can reduce the numbers and species of animals present by exerting a heavy local oxygen demand on the overylying water.

The most usual cause of increases in turbidity or colour of watercourses is the discharge of industrial, agricultural or sewage effluents. For example, silt and clay occur in effluents from the clay industries (e.g. pottery, brick, tile, fire-clay manufacture) and, with organic matter, in effluents from the processing of root vegetables. Similarly, the washing of coal produces a very opaque effluent, containing coarse and fine black particles, which can have severe detrimental effects on watercourses.

In some cases, chemical reactions between the constituents of effluents and salts already dissolved in the water can lead to physical pollution. For example, iron or aluminium hydroxide (neither of which are toxic) may be precipitated if water containing salts of these metals is discharged into a naturally alkaline river. In the case of iron, a clear effluent discharged into a clear stream can produce a bright orange colouration.

.(ii).3.3.2. Thermal pollution

The impact of thermal pollution depends on the amount of heat released, the mode of release and the conditions in the receiving water. As with nearly all environmental problems, each discharge must be examined on an individual basis to determine the total effect (O'Sullivan and Collinson, 1976).

An increase in water temperature can produce certain physical and chemical changes in the water itself. It may affect the solution rate and solubility of minerals, precipitation of compounds, pH, and the solution of atmospheric gases, the most significant of which is oxygen. Dissolved oxygen in the water, which is vital to fish and other aquatic life, decreases with a rise in temperature. Also, should organic pollutants be present, the increased biochemical oxygen demand (BOD) can further lower oxygen concentration.

Discharged waste heat has significant effects on aquatic life, e.g. on physiology (metabolism, growth rate, fecundity, etc.), and on behaviour, in addition to synergistic effects with pollution and other stress factors. Studies on fish demonstrate that a rise in water temperature increases their oxygen consumption and swimming activity while impairing their efficiency to convert food intake into body weight. Waters above 33°C are considered uninhabitable for most fishes, and still lower temperatures may be necessary for fish reproduction and normal egg development. In addition, increased temperature may shorten the life span of organisms.

Fish kills resulting from thermal pollution are rare, but more subtle effects on community structure such as reduction in species diversity and perhaps stability are becoming more apparent. As with other forms of pollution, a synergistic effect may arise (for example a combination of sewage and thermal pollution) which may inflict greater damage on a biological community than either form by itself.

While the above effects are likely to be experienced in all aquatic ecosystems, the impact is likely to vary. For example, the addition of heated water to an intertidal community is less likely to induce stress because the associated organisms are constantly subject to marked temperature fluctuations.

(ii).3.3.3. Variations in flow rate

Since the organisms that become established in a river will be those which are best suited to the conditions, sudden and repeated fluctuations in the rate of flow will mean that only those organisms that can withstand the changes will survive. For example, plants growing in silt deposits on the bed of a stream may be destroyed when the silt is washed away by a sharp increase in flow. On the other hand, if the flow falls, life which is dependent on a high dissolved oxygen concentration will die if the river reverts to a series of near-stagnant pools.

Sudden flow changes can result from excessive abstractions, or from intermittent discharges of relatively large volumes of effluent as when settling ponds are emptied or as a result of drainage schemes. Wetland and similar marginal land will absorb rainfall and release it gradually: if drainage channels are cut (e.g. to improve the value of the land for farming purposes) this property of absorbing water is diminished and the river will be subjected to larger fluctuations in flow than before. Similarly, the substitution of a paved area for open fields will increase the rate of run-off after rain, although the total quantity may remain almost the same.

V.(ii).3.3.4. Radioactive wastes

Radioactive wastes (artificial radionuclides) enter aquatic ecosystems from three main sources: (1) atmoshperic fall-out from nuclear weapons testing; (2) discharges from nuclear processing plants; and, (3) discharges from reactors. Whereas fall-out radioactivity is uniformly distributed at comparatively low concentrations (except in areas proximal to weapons testing), the contamination from waste disposal is markedly restricted in its distribution and somewhat higher in concentration.

When radionuclides enter the aquatic environment they interact with its physical, chemical and biological components. Physical processes tend to dilute and disperse them, while bioaccumulation tends to concentrate them. Each radionuclide takes its own characteristic route and has its own rate of exchange with the water, biota and sediments.

Many artificially produced radionuclides detected in the marine environment are of extremely short half-life and have been only of local importance over short time scales. Consequently, the longer-lived actinides and those isotopes of elements of biological significance, have been more widely distributed and have received the greatest attention.

The possible physico-chemical forms of radionuclides and trace elements which may occur in the oceans are usually categorised as:

(i) Colloidal species - colloidal matter is much more abundant in coastal waters than in the open ocean and probably plays an important role in the behaviour of radionuclides discharged into coastal waters.
(ii) Particulate species - the filterable suspended matter in seawater is of complex composition and contains both inorganic and organic compounds.

The limiting factor in controlling radioactive waste disposal to aquatic ecosystems is the radiation dose commitment to man ("critical pathway approach") and it is argued that, provided the human radiation exposure is adequately controlled, the consequential dose to aquatic organisms will impart negligible risk (Preston, 1975). The evidence for this conclusion has been reviewed by several workers (Templeton et al, 1971; Woodhead, 1973) and supports the view that fish are the most radiosensitive component of aquatic ecosystems. Damage to these resources, should it occur, would probably stem from the direct effects of radiation on the fish rather than effects produced through ingestion or organisms at lower levels in the food web. The maturing and mature gametes and developing embryos are particularly susceptible to radiation doses (Preston, 1975).

The assumption that "by protecting man one can be sure of protecting nature" is not without its critics, however. It is based on the argument that for man we are concerned with avoiding damage to individuals, so that any dose-levels established as safe by this criterion are bound to be safe for the natural environment, e.g. the marine environment where the concern is for the continuance of populations or of communities. The argument is supported by the observation that there have been no demonstrable effects on marine ecosystems (at prevailing dose rates), that can be clearly attributable to environmental radio-activity (Templeton et al, 1971). Nevertheless, as Bowen (1974) indicates, relatively few populations have been examined and periods of observation have been too short to reveal possible long-term genetic impacts. Also by concentrating the monitoring effort on "critical pathways", it is possible that slow changes in other pathways could go undetected until they result in an unnecessarily critical situation.

V.(ii).3.4..Biological pollution

In addition to the bacteria found naturally in river water, forming part of the natural cycle, there are other bacteria which are less desirable. They are the pathogenic bacteria and can cause disease in a variety of organisms. Since the presence of pathogenic bacteria is generally due to the activities of man, they constitute a form of pollution. Nonpathogenic bacteria, by definition, are harmless and, indeed, many are beneficial to man and form an essential part of the aquatic ecosystem. (Open University, 1975).

The most common source of pathogenic bacteria is sewage. However, sewage treatment processes generally eliminate more than 99% of pathogenic bacteria, so effluents from sewage works contain far less numbers than raw sewage. In addition, because pathogenic bacteria are accustomed to body temperature (i.e. about $37^{o}C$) they do not flourish in river water and die off relatively quickly. For example, 99% of typhoid bacteria are believed to be destroyed if the river water is simply stored for seven days. Part of the removal process is due to the activities of predators.

Most rivers which have received sewage effluents are liable to contain some viable pathogenic bacteria. This poses some degree of risk to bathers, and medical authorities usually advise against bathing in rivers which have passed through urban communities. Illness usually occurs only if large numbers of a particular pathogenic bacteria are ingested, for example, when someone falls in accidentally and swallows a substantial amount of water. The risks are, therefore, much lower than might be imagined.

Escherichia coli occurs consistently in faeces and in far greater numbers than pathogenic bacteria. Their presence in water in concentrations as low as 10 cells per litre can readily be demonstrated within 18 to 48 hours of taking a sample. At such a low concentration of coliform organisms, the possibility of sufficient numbers of associated pathogenic bacteria being present to cause disease is negligible, even supposing that any are present at all, which need not be the case.

Other coliform organisms, closely related to Escherichia coli, can also occur in water, especially under tropical conditions. They need not be of faecal origin, but their presence indicates the existence of some pollution, even though at the time of sampling typically faecal organisms were not present. Escherichia coli itself also occurs in the faeces of organisms other than humans.

There are other forms of life which may be harmful to man and animals. Viruses, which also cause disease, can grow only in living cells. Although they are able to survive in river water, there is little evidence at the present time to show that virus diseases are transmitted via the water supply. Other diseases may be transmitted by protozoa , worms, snails, insect larvae and other orgnaisms which live in rivers or other bodies of surface water (Table V.(ii).1.).

Some of the forms of pollution which have been mentioned previously may also be considered as biological pollutants, e.g. the growth of algal blooms in nutrient-rich waters, which in turn can produce toxic substances and impart tastes and odours to water.

(ii).4. Summary

Table V.(ii).2. summarises the sources, nature and principal effects of the major water pollutants discussed in this Chapter.

Table V.(ii).1. - Pathogens in sewage and polluted streams (Open University, 1975).

Organism	Disease	Remarks
Virus	Poliomyelitis	Exact mode of transmission not yet known. Found in effluents from biological sewage purification plants
Vibrio cholerae	Cholera	Transmitted by sewage and polluted waters
Salmonella typhi (*Bacterium typhosum*)	Typhoid fever	Common in sewage and effluents in times of epidemics
Salmonella paratyphi	Paratyphoid fever	Common in sewage and effluents in times of epidemics
Salmonella spp	Food poisoning	
Shigella	Bacillary dysentery	Polluted waters main source of infection
B. anthracis	Anthrax	Found in sewage. Spores resistant to treatment
Brucella	Brucellosis—Malta fever in man. Contagious abortion in sheep, goats and cattle	Normally transmitted by infected milk or by contact. Sewage also suspected
Mycobacterium tuberculosis	Tuberculosis	Isolated from sewage and polluted streams. Possible mode of transmission. Care with sewage and sludge from sanatoria
Leptospira ictero-haemorrhagiae	Leptospirosis (Weil's Disease)	Carried by sewer rats
Entamoeba histolytica	Dysentery	Spread by contaminated waters and sludge used as fertilizer. Common in warmer countries
Schistosoma	Bilharzia	Probably killed by efficient sewage purification
Taenia spp	Tape worms	Eggs very resistant, present in sewage sludge and sewage effluents. Danger to cattle on sewage-irrigated land or land manured with sludge
Ascaris *Enterobius*	Nematode worms	Danger to man from sewage effluents and dried sludge used as fertilizer

Table V.(ii).2. - Summary of the sources, general characteristics and principal effects of some major pollutants
(After Open University, 1975)

Pollutant (type)	Nature of pollutant	Common sources	Overpollution results in:
1 Suspended solids	Primarily soils and minerals; also some industrial by-products ; mine slurries	Land erosion by storms, flood waters, etc., pulpmill and other plant effluents. (e.g. factories where root crops are washed) ; mines	Obstruction or filling of streams, lakes, reservoirs navigational channels; increases cost of water purification; interferes with manufacturing processes; causes equipment corrosion; reduces fish and plant life.
2 Heat	Heated water returned to streams and lakes.	Steam-electric power plants; steel mills; refineries; other industrial cooling units.	Reduction of dissolved oxygen, resulting in slower or incomplete pollutant decomposition and damage to aquatic life.
3 Inorganic chemicals	Common salt; acids; metallic salts; cyanides; etc.	Mining; industrial processes; natural deposits (e.g. salt).	Interference with manufacturing processes; obvious or insidious toxic effects on humans and wildlife; bad odours and tastes; corrosion of equipment (industrial, navigational power plants).
4 Plant nutrients	Principally nitrogen and phosphorus compounds.	Municipal sewage; industrial wastes; farms (chemical fertilizers).	Excessive growth of aquatic plant life leading to secondary oxygen-demanding pollution, offensive odours, bad taste.
5 Oxygen-demanding wastes	Putrescible organics; normally reduced by aerobic bacteria (which require water-dissolved oxygen).	Domestic sewage; food-processing industries; sulphates from pulp and paper mills.	Excessive depletion of oxygen in water damages fish life; complete oxygen removal causes anaerobic bacterial action on pollutants resulting in bad colours, offensive odours.
6 Toxic organic chemicals	Detergents, pesticides, many industrial by-products.	Domestic and industrial effluents; farms (pesticides, etc.)	Threat to fish and other wildlife; possible long-term ingestion hazards to human beings.
7 Biological pollutants	Disease-causing organisms (bacteria, viruses).	Human and animal wastes, certain industries (e.g. tanning, slaughtering).	Need for stringent purification treatment to obtain potable supplies; losses to fishing industry (especially shellfish); curtailed recreational uses of streams, lakes, etc.

V.(ii).5. References

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V1. TERRESTRIAL POLLUTION

V1.1. Introduction

Land may become polluted not only through the addition of specific contaminants but also through alteration to such a degree and/or in such a manner as to render it unsuitable for its present or planned use. The land may also become a hazard or nuisance to the adjacent population under conditions of uncontrolled use (World Bank, 1978).

Actions which may result in terrestrial pollution include:

- the disposal of domestic solid waste by landfill operations. Domestic refuse consists of dust and ash, paper and cardboard, metals, rags, glass, plastics, and vegetable and putrescible matter.
- the disposal to land of industrial solid and liquid, and hazardous/toxic wastes such as metal-bearing sludges, strongly acidic/alkaline wastes, organic residuals and sludges, waste oils, etc.
- mining and smelting operations including such activities as land stripping, quarrying, formation of slag heaps, disposal of stripped soil and rock.
- the demolition of existing land-based structures yielding residual debris and rubble, e.g. wood, bricks, stones, concrete and other discarded building materials.
- the burning of solid wastes on land sites leaving tyre residuals, cans and ash.
- the storage (either temporarily or permanently) of building materials, oil drums, discarded automobiles, rubble and rock, etc.
- the damming or draining of lands to impound or remove excess water.

When performed in an uncontrolled or inappropriate manner, the above activities can have a number of undesirable effects on the environment. Generally, these effects can be categorised as follows:-

- aesthetic/nuisance effects - producing a general 'unsightliness' by, for example, changing land form, stripping of vegetation, storage of undesirable materials, burning and demolition activities, etc.; also production of unpleasant odours, such as those generated by decomposing organic matter; attraction of pests.
- ecosystem effects - damage to flora and fauna caused by: the direct action of toxic waste; drainage of swamp or marsh areas; increased run-off erosion, flooding and siltation following land clearance or damming; contamination of surface waters by leachates and run-off from waste tips.
- human health and safety - fires or explosions from improper storage of materials; breeding of disease carriers (e.g. rats, flies, mosquitoes) at sites of decomposing organic matter; contamination of food (e.g. vegetables, fish) or drinking water by direct dumping or by leachates/run-off from waste tips.

V1.2. Impact of Disposal of Waste to Land

V1.2.1. Introduction

The treatment and disposal of ever-increasing volumes and types of industrial and domestic wastes represents one of the major problems faced by Governments and municipal and health authorities. Areas for concern include the high costs involved, inefficient, improper or hazardous operations, public opposition to disposal practices, and a shortage of suitable disposal sites (Waller and Bradfield, 1975). This chapter of the supplement discusses the methods of waste disposal to land and identifies potential undesirable environmental effects (WHO Expert Committee, 1971; U.K. Department of the Environment, 1971).

There are five major methods of disposing of waste to land:

- deep well injection, in which liquid waste is deposited in subsurface strata;
- slurry deposition in surface lagoons;
- spoil heaps, in which waste (normally from mineral workings) is deposited on the land surface;
- controlled tipping (sanitary landfill), where waste is deposited in depressions, derelict mineral workings, etc., and covered to produce a new land form;
- uncontrolled tipping, where waste is deposited in a totally random fashion and without regard to local environmental conditions.

V1.2.2. Deep well injection

Deep well injection has been used, particularly in the United States, for the disposal of a wide range of liquid industrial inorganic and organic wastes (Leenheer, Malcolm and White, 1976). However, very little is known about the chemical reactivity and fate of compounds after subsurface injection. The major potential concern is that interactions between the waste water, aquifer water and minerals could not only affect the operation of the well but also lead to contamination of water supplies.

V1.2.3. Lagoons

Lagoons are commonly used for the disposal of wastes with a high water content, e.g. tailings and slurries. In the lagoon, suspended material will settle under the force of gravity thereby allowing the supernatant water to be syphoned-off for recycling or disposal. Care must be taken in the design and construction of the lagoon walls or bunds as these have been known to burst, inundating the surrounding area (Downs and Stocks, 1976).

Another potential impact is that seepage through the lagoon base can lead to groundwater pollution. This is particularly important if the lagoon is used for wastes with, for example, a significant heavy metal content or a high BOD loading.

V1.2.4. Spoil heaps

Spoil heaps are a common method of disposal of waste from the mining and mineral processing industries, their size and location often creating significant visual intrusion. If the spoil heaps contain toxic substances, rain water run-off or seepage through the tip can lead to surface and groundwater contamination. In addition, windblown dispersal of contaminated fine waste materials can result in local air pollution.

V1.2.5. Controlled tipping

Controlled tipping or sanitary landfill is the major method of waste disposal in most countries. The normal practice is that domestic refuse or domestic refuse/ industrial mixtures are deposited and compacted on land in shallow layers and that exposed surfaces are covered with soil or inert material within 24 hours to form a "seal" (Figure V1.2).

However, there are a number of potential problems associated with controlled tipping operations related to effects on public health, fauna and flora, amenity and aesthetics (Table V1.1; Figure V1.3). For example, transport to and from the site can increase the risk of accidents as well as causing a nuisance in terms of noise and exhaust emissions to nearby residents. Other common problems are dust, blowing litter (which is unsightly if caught on hedges or fences), and decaying refuse, which can give rise to unpleasant odours. Rats and other small rodents, finding refuse a rich source of food, can proliferate very quickly in rubbish dumps and spread to neighbouring houses.

This has serious potential health consequences when it is realised that rats are involved in the transmission of such diseases as leptospirosis, histoplasmosis, salmonellosis, murine typhus, rat-bite fever and trichinosis (WHO Expert Committee, 1971).

Controlled tipping operations can also have detrimental effects on the local and regional biota. Thus most vegetation at the site is inevitably destroyed and any animal life is forced to leave the area or is killed. Animal habitats can be disrupted by the noise of equipment and refuse vehicles. Landfill gases, e.g. methane, which can migrate to areas outside the tip boundary can impair the growth of plants and trees by surrounding the root zones. Methane production can also result in fires and explosions at the tip if insufficient ventilation is allowed.

However, the aspect of controlled tipping which has probably received most attention in recent years is the possibility of refuse tip leachate causing water pollution. As rain water passes through a refuse dump it becomes heavily contaminated by bacteria, organic matter and dissolved inorganic salts. This leachate can then run into an adjacent water-course, where it can have detrimental effects on the stream's flora and fauna, or can pollute underground water sources. For example, a study of five refuse tips in Cornwall, England, showed that three of these tips were the cause of gross pollution of the receiving water-courses, resulting in massive growths of sewage-fungus (Nuttal, 1973). It is therefore essential that during the selection of waste disposal sites full hydrological and geological surveys are undertaken (Section V1.4).

The production, composition and migration of leachates are discussed in more detail in Sections V1.3 and V1.5.

V1.2.6. Uncontrolled tipping

Uncontrolled tipping or direct tipping is generally haphazard and can result in a wide range of undesirable environmental impacts, e.g. surface and groundwater pollution from tip leachate, breeding of vermin and pests, nuisance of windblown litter and dust, the continual risk of fire, and damage to sensitive ecosystems and public health.

V1.2.7. Pre-treatment and re-cycling of waste

The nature and character of waste pretreatment can have profound effects on the environmental impact of waste disposal to land. More than 80% of solid waste disposal in the U.K. is by landfill and a relatively small proportion of this is pretreated. The following pre-treatment methods are currently employed:

- pulverising or shredding - refuse is less offensive visually and less attractive to vermin. Volume is not initially greatly reduced but waste is more easily compacted at the tip;
- composting - offers a means of assisting the natural recycling of the compostible content;
- incineration - reduces volume to less than 10% of original and produces a sterile ash; and,
- high density baling - waste is less offensive visually and more easily controlled. Studies have shown that leachate produced from baled waste contains lower concentrations of BOD, total dissolved solids, nitrate and sulphide over a period of 2 years following waste emplacement.

The above are the most common methods of treating waste, the product in each case being destined for disposal to land. Alternative methods and techniques to reduce or eliminate the need for land disposal include the following:

- separate collection;
- resource recovery - materials;
  - fuel (refuse-derived fuel);
- pyrolysis;
- composting with preliminary sorting; and,
- other chemical or biological processes such as hydrolysis, ethanol production, methanation.

These methods of waste treatment are, however, still in their infancy and even when fully developed will never completely eliminate the need for landfill sites for waste disposal. Therefore, continued investigation of the effects of waste disposal to land is necessary.

V1.3. Leachate Production and Migration

V1.3.1. Leachate production and composition

Leachates are generated by the solubilisation of insoluble materials, the dissolution of soluble substances and transport of finely particulate matter present or generated within wastes (Naylor, Rowland, Young and Barber, 1978). The normal dominant primary solvent is infiltration from rainfall, although the disposal of liquid wastes may make a major contribution to the quantity of leachate produced. The leachate may migrate from the landfill either to appear as a surface flow or to percolate through underlying strata and recharge the groundwater.

The volume of leachate produced (of whatever concentration) may be estimated by using the principle that the volume of liquid entering the waste must equal the volume stored and emitted by evaporation plus surface run-off and leachate. Due to storage there may be several years delay between the placing of wastes and the emergence of leachate.

The composition of a leachate is dependent on a variety of factors including: composition of the deposited waste; whether tipping is above or below the water table; the method of disposal, e.g. loose tipping, compaction by vehicles, high density baling; and, hydrological factors (UK Department of the Environment, 1978; Mather and Bromley, 1976; Zanoni, 1972 and 1973). The leachate composition may also change with time as the more soluble components are progressively removed from the waste, and the type or rates of reaction between different materials in the waste alter. In addition, leachate composition will change as the leachate migrates away from the landfill. Thus, in general, the concentration of pollutants will be reduced (attenuated) with distance travelled as a result of natural chemical, biological and physical processes collectively called attenuation process.

V1.3.2. Leachate attenuation

A number of factors are important in leachate attenuation (Mathess, 1972; U.K. Department of the Environment, 1978; Stiff and Young, 1977):

- microbial decomposition - anaerobic and aerobic breakdown of pollutants by micro-organisms;
- neutralisation - acid-base reactions;
- precipitation - conversion of soluble pollutants to insoluble compounds, e.g. hydrogen sulphide to metal sulphides, heavy metals to carbonates;
- oxidation-reduction, e.g. reduction of sulphates to hydrogen sulphide, oxidation of ferrous iron to ferric iron;
- sorption processes (adsorption and ion exchange) - in adsorption, pollutants are bound to the surface of soil and rock particles or to precipitated chemicals; in ion exchange, pollutants occupy electrically charged sites on soil or rock particles;
- gaseous exchange - interchange can occur between the landfill and the atmosphere, between substrata and the groundwater table;
- filtration - suspended solids are filtered within a short distance if the flow is predominantly inter-granular, but may be carried many kilometres in fissured strata;

- dilution - as the volume of leachate produced from a landfill site is generally small compared with the total volume of groundwater moving through an aquifer, the concentration of pollutants is reduced immediately when groundwater and leachate mix.

The physical processes controlling the quantity of leachate generated and its subsequent movement are summarised in Figure V1.4, while Figure V1.5 shows the chemical and biochemical reactions which may influence leachate composition.

The major types of potential pollutants in leachate from domestic waste landfill may be summarised as follows:-

- organic compounds, especially the more persistent, because they can affect the taste and odour of groundwater;
- nitrogen compounds, because of eutrophication problems in surface waters and the harmful effects of high nitrates in drinking water;
- heavy metals, because of toxic effects;
- components such as Cl^- and $SO_4^=$ which increase the hardness of groundwater.

In general, the slower the rate of movement of leachate, the greater the attenuation and the smaller the potential pollution problem. The rate of movement is controlled by the hydraulic gradient, or head, and the mass permeability of the ground. The mass permeability may be the same as the intrinsic soil type permeability as in a sand deposit or may be much higher due to fissuring of the soil or rock mass. Thus, the hydrogeology of the site is most important in determining whether or not pollution will result from tipping.

V1.3.3. Leachate control

The attenuation processes described above are used to advantage in the so-called "dilute and disperse" landfill sites in which leachate is allowed to disperse from the landfill to be diluted by groundwater. If the rate of migration is low and the rate of attenuation high, the pollution plume would only extend a few hundred metres. Unsuitable sites have occasionally been selected where leachate migration has been rapid with low attenuation resulting in plumes up to 3200m from the landfill (Kimmel and Braids, 1974). Corrective measures may be required in these cases.

An opposite philosophy is adopted in "concentrate and contain" sites. At these sites, the disposal area is effectively sealed by the use of impermeable or low permeability materials such as clay, concrete or plastic, through which the rate of migration of pollutants and water is very low. Grouting may also be used in certain circumstances. However, full account must be taken of the long-term sealant properties of the material used. Care must also be taken to prevent the site from being filled with percolating groundwater and rainwater which could lead to pollution discharges to streams. Prevention can be achieved by covering the site with an impervious surface to prevent rainwater and other surface water entering the landfill. In addition, percolating groundwater can be excluded by surrounding the landfill with a drainage network.

A system of drains and culverts may also be used to collect leachate to prevent it reaching surface or groundwaters. The leachate can then be sprayed back over the tip. This has the effect of reducing its volume by evaporation and plant transpiration, as well as helping to control dust. In certain circumstnaces it may be more appropriate to treat the leachate chemically or biologically before disposal; an analysis of the leachate will be needed to help resolve this question.

There are then a number of different approaches to the control of leachates. However, to be economic, control measures should be designed on a case-by-case basis to take advantage of, and be compatible with, the existing geological and hydrogeological nature of the site.

V1.4. Investigation of Landfill Sites

V1.4.1. Site selection

It is evident from the previous Sections that it is essential to assess the pollution potential of proposed waste disposal sites. Each site should be studied on an individual basis as it is unlikely that information on hydrogeology, attenuation potential, etc. for one site will be applicable to another. The basic data required for such an assessment are discussed below.

V1.4.1.1. Geography/geology

Topographic maps of the area should be examined to establish the geographic setting of the site, its position in an upland or lowland area, the proximity of rivers, streams and springs, the location of the site relative to earthquake activity, etc. Aerial photographs may be used to identify significant features.

V1.4.1.2. Surface water

The main objective of a surface water survey around a proposed landfill site include:

- assembling data on rainfall and evapo-transpiration characteristics of the catchment area. Should information be inadequate or unrepresentative of the landfill site area, it may be necessary to install meteorological instruments at the site;
- assembling data on existing land use, soil conditions, drainage and geology of the catchment area, to permit classification of its permeability (e.g. high, low moderate or composite permeability);
- identifying surface water courses in the area around the landfill site and determining their flow characteristics. Should flow records be unavailable from the Regional Water Authority, it may be necessary

to install V-notch or rectangular weirs, velocity meters or other appropriate equipment to monitor the response of the catchment area to rainfall particularly during storm conditions;

- identifying existing surface water abstraction and establishing existing surface water quality. As streams near the proposed site may already be contaminated, "baseline data" on surface water uses and quality are required to allow assessment of the impact of landfill operations and of the validity of possible future claims for damage.

From the above information, it is possible for an hydrologist to make quantitative estimates of the input of surface water to a landfill site and, if necessary, to make recommendations for the diversion and drainage of this surface water. Such recommendations could include, for example: the installation of drainage systems around the site; the engineering of sloping landfills to inhibit filtration; or, the use of vegetation to maximise transpiration and evaporation.

V1.4.1.3. Groundwater

A hydrogeological survey of the landfill area will help quantify many of the factors controlling leachate movement and attenuation. The information required includes:

- the general lithology, structure and dimensions of the strata underlying the landfill site. This information, obtained from published sources, visual inspections of the site and exploratory boreholes, allows estimation of the degree to which filtration of solid particles will take place and of the lengths of flow paths to wells, springs, etc.
- the thickness of any unsaturated zone. Information on water levels may be derived from records of existing boreholes in the vicinity of the site (such information may be available from, for example, the Institute of

Geological Sciences, Regional Water Authorities, Water Research Centre, Central Water Planning Unit, County Surveyors' Departments, local well drillers, etc.). However, it may be necessary to take additional measurements of water levels or to establish more boreholes in the area;

- existing groundwater abstractions in the area. The records of existing boreholes already referred to, should be consulted again;
- the hydraulic properties of the aquifer. Although these may be derived in general terms from a knowledge of the types of soils and rocks present, a combination of detailed pumping tests and of laboratory analyses of recovered soil samples from the boreholes may be required to evaluate the permeabilities, transmissivities and porosities of the media;
- the degree of saturation and distribution of positive and negative pore pressures within the earth media which allows the hydraulic gradient to be defined. This is carried out by emplacing tensiometers or piezometers within boreholes and by undertaking volumetric moisture content analyses in the laboratory;
- the groundwater flow pattern. This should only be deduced from boreholes located within and adjacent to the site; regional scale findings can be misleading at the local level;
- the leachate attenuation potential of the earth media (Section V1.3.2.) This can be determined by a range of laboratory techniques such as column and dispersion studies. In column studies, the anticipated leachate from the waste material is allowed to diffuse through an intact core from the substrata and the uptake of pollutants by the column is determined. However, such studies can take up to one year if porosity is low. In dispersion studies which are comparatively quick, dispersed core samples are shaken with the leachate and uptake of pollutants is measured;
- groundwater chemistry. The background chemical composition of groundwater (sampled from boreholes in

the vicinity of the site) should be determined to enable the impact of waste disposal operations to be clearly identified and assessed. This information also allows assessment of the buffering capacity of the groundwater which is important for applying natural pH correction to leachates.

Together, these hydrogeological studies enable predictions of such factors as: the volume and composition of leachate; the rate of leachate movement through the unsaturated zone and in the groundwater zone; change in leachate composition with time; and, time to travel to, and dilution at, a discharge point (e.g. abstraction well).

V1.4.2. Long-term monitoring

Once a disposal site has been selected, a long-term monitoring programme should be established with the objective of collecting all the data necessary for estimating both leachate movement within and away from the landfill, and leachate composition and attenuation with increasing distance from the landfill. The techniques which may be employed (Naylor, Rowland, Young, and Barber, 1978) include:

(a) the regular collection and analysis of liquid, gaseous and, possibly, solid samples from various depths within the landfill and any underlying unsaturated zone;

(b) the collection and analysis of groundwater samples from the saturated zone at various depths below the water table and at given distances from the landfill, together with routine measurements of groundwater levels.

The analytical results are interpreted and assessed in relation to the baseline data obtained from analyses of solid, gaseous and liquid samples during the preliminary site investigation and in relation to the predictions made concerning pollution potential.

The boreholes established during the preliminary site investigations provide access for the collection of liquid and gaseous samples and allow measurement of groundwater levels. Additional boreholes may be required if leachate has migrated beyond these boreholes or where areas of uncertainty exist. The routine collection of solid samples may be achieved only by repeated drilling.

The frequency of monitoring a site will depend on the rate of movement of the leachate plume and the proximity of groundwater and surface water sources that may be at risk. For example, where minimal risk exists, four-monthly monitoring may be adequate whereas weekly monitoring may be required if water sources are threatened.

V1.4.3. Techniques

V1.4.3.1. General

The special data collected and analytical requirements of the landfill site investigation have been described in Section V1.4.1. It remains the responsibility of those directing and operating investigation work to ensure that personnel involved in fieldwork and sample analysis are fully aware of these requirements. The fact that the investigation is for a landfill site must be made clear to contractors undertaking fieldwork. Further, because certain chemical tests outside the normal scope of laboratory testing for engineering purposes may be necessary, a check on facilities and methods is required. Investigation of landfill sites therefore is essentially a multi-disciplinary exercise involving (amongst others) chemists, biologists and geotechnical engineers. Consequently, in selecting techniques to be used, full account must be taken of information required by these specialists. At the end of the investigations the chemical, biological and engineering properties of the materials involved (together with the groundwater regime), should have been established. A flow chart for technique selection and procedure is shown in Figure V1.6.

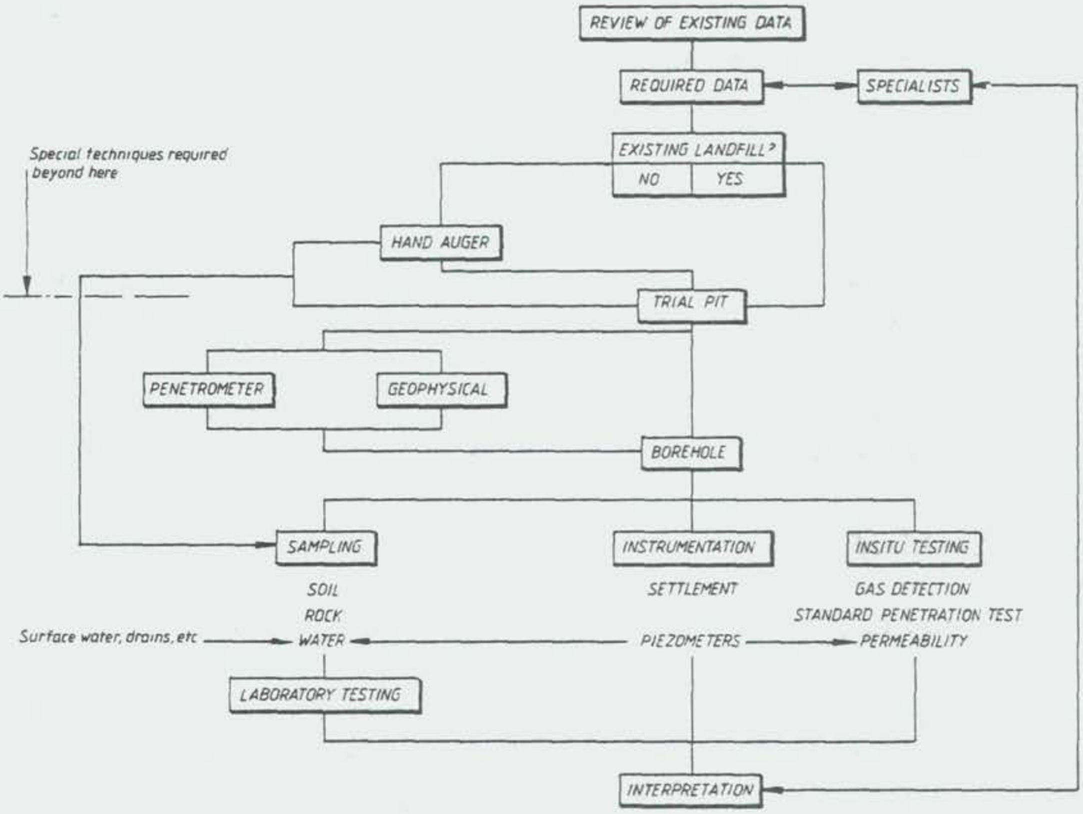

Figure V1.6. Landfill site investigations: a flow chart showing technique selection and procedure.

V1.4.3.2. Selection of technique(s)

Much of the information gathered during preliminary studies for site selection (Section V1.4.1.) will influence the choice of detailed investigation techniques. To optimise on the location, extent, and depth of exploration during fieldwork, therefore, a minimum of basic data must be obtained.

These data should relate to topography prior to landfilling, the estimated location of water courses, and the estimated nature of the fill material and leachate, together with an indication of the possible development (if any) proposed for the site. Guidance for desk studies and the sources of information are given in standard references such as British Standards Institution CP 2001 "Site Investigations" (1957) or proceedings of specialist conferences (for example, Kelley, 1979).

The type and capacity of equipment to be deployed relates to the nature of the ground conditions and, where applicable, the fill material. Special restrictions on equipment usage are identified below.

The zone of interest will extend beyond the planned or actual body of the landfill. For example, engineering design for foundations to support structures built on the landfill demands that the depth of investigation extends well below the base of the fill. In addition, environmental studies often demand an indication of the lateral zone of influence of leachates and gases from the landfill.

At the end of the desk study those responsible for the landfill study should have prepared a carefully planned sequence of investigation, sufficiently flexible to take account of modifications that may be necessary during the fieldwork, and supported by a comprehensive list of laboratory testing requirements.

V1.4.3.3. Trial pits

A basic technique, the excavation of trial pits with a plan area of not less than 2.0m^2, permits a visual examination of the in situ state of natural and landfill materials and should be undertaken prior to the implementation of other fieldwork. Trial pits will identify the scale of variations in type and extent of the soils, or landfill material, which will influence the ability to undertake subsequent fieldwork techniques determined by the desk study. Provided access to the site is suitable, the use of large hydraulic backhoe excavators can enable excavation to be carried down to depths of 6.0m (or more, in some instances); the use of standard tractor mounted backhoe equipment permits excavation to a maximum of about 4.0 m.

The location of the water table is often achieved using trial pit sides. Bulk samples taken at changes in material type or at regular intervals in uniform material should be removed for subsequent laboratory testing. Water samples of at least 1.0 litre need to be taken and preserved in sterilised sealable containers for prescribed analyses. Because trial pits are to be considered unstable, sampling should be by remote means or carried out with the sides of the pit fully supported.

It is essential to take photographs of trial pits particularly of existing landfill. These photographs will provide valuable information for those not involved in site development at the investigation stage - e.g. contractors undertaking piling or ground improvement techniques such as dynamic consolidation or vibroflotation.

V1.4.3.4. Boreholes

Borehole work may involve light cable percussive boring, augering, or rotary core drilling. Where cohesive soil or suitable fill is present, undisturbed samples should be taken for classification, strength and compressibility evaluation and chemical testing (classification and chemical tests can also be made on disturbed samples). However, as undisturbed samples are rarely obtained in landfill, variations in the density and strength of the fill may be determined using the Standard Penetration Test - a test otherwise used in cohesionless soils such as sands and gravels.

Casing should be used to support the sides of boreholes and the possibility of obstructions should be assessed from trial pit exploration. Water samples should satisfy the requirements for trial pit sampling.

Boreholes may need to be advanced below rock-head to establish the structure of the rock particularly where faulting or extensive jointing may provide seepage routes for leachate from the landfill. Information on the nature and strength of the rock may influence the design and construction of containment structures such as diaphragm walls.

In boreholes through landfill, the size of potential obstructions may require the use of large diameter augers to advance the borehole.

The depth of boreholes is thus influenced by a number of factors to be identified early in the study. Further, the number and location should be related to the size and extent of the proposed or placed landfill site.

Standpipes and/or piezometers should be installed to provide information on the water table or aquifers as well as enabling the collection of water samples during and after the fieldwork.

Specifications for the water sampling include:

- compatibility between the diameter of the water sampling device proposed and the diameter of the piezometer tube or standpipe down which the sampler has to be lowered (this latter diameter usually being greater than in conventional use); and
- the use of non-corrodable and inert (as far as possible) materials in the manufacture and assembly of both sampler and piezometer or standpipe (for example, the use of jointing compounds for the standpipe might introduce chemicals that will distort the analysis of

any water samples taken).

When penetrating aquifers used for abstraction purposes, and not installing piezometers, pollution of the aquifer must be prevented by the grouting up of the borehole to a level at or above the surface of the aquifer. The introduction of water to assist boring or drilling or during permeability testing, should be carefully recorded as it affects samples taken during the investigation; likewise, equipment should be free from oil or other contaminants.

At a reduced scale, but with a minimum of equipment access problems, hand auger boring permits inspection and sampling of near surface soils and will provide information on the location of the water table. Disturbed and undisturbed (38 mm) soil samples, and water samples, are obtainable and this method is frequently used to assess the agricultural potential of natural soils where only shallow borings (e.g. 1.5 m) are required. Borings in excess of 4.0 m and with diameters approaching 150 mm are only possible with considerable effort. Obstructions would generally prevent the use of this technique through existing landfill.

V1.4.3.5. Penetrometer soundings

The use of cone penetrometer soundings with (preferably) static, or dynamic, penetrometers, provides a rapid evaluation of ground conditions where sands, silts or clays are present. Penetration through gravels is possible but only where they occur as thin bands. Different parts of the site may be compared directly using the sounding plots and reliable measurements may be obtained particularly from electric static cone penetrometers. Disadvantages of this technique for landfill investigations include the absence of samples and lack of information on the location of the water table or an inability to monitor it in the long-term (some cone penetrometers have contained piezometric elements to overcome these problems). For correlation purposes it is also advisable to allow for at least one borehole adjacent to a penetrometer sounding.

When investigating existing landfill, and when uncertainty surrounds the presence of obstructions, it is unlikely that the penetrometer will be appropriate.

V1.4.3.6. Geophysical surveys

Geophysical surveys provide valuable information of the stratification and existence of soils on rock and assist in the detection of discontinuities within the rock mass. The adoption, however, depends on the size of the site or the need to explore an anomalous feature identified by boreholes, e.g. buried valleys. Geophysical methods at existing landfill sites may be justified for the detection of the interface between the base of the landfill and the surface of the natural ground. This interface is particularly relevant where the topography prior to landfilling is irregular or where parts of quarries or pits have not been fully worked down to the general floor level.

In investigating landfill sites, the interference to a geophysical survey caused by the fill materials and method of placement needs to be carefully evaluated. Further, as geophysical surveys do not provide samples they would need to be supported by data from boreholes.

V1.4.3.7. Laboratory testing techniques

Routine laboratory testing for site investigations is based on British Standard BS 1377, (British Standards Institution, 1975) which includes chemical tests for only organic and sulphate content and pH. Consequently, detailed chemical or biological analysis may require facilities not possessed by the majority of site

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investigation organisations. Results should be expressed in terms that can be understood and interpreted by the various specialists involved in the landfill investigation. Figures V1.7 and V1.8 indicate the differences in sample handling, preparation, and testing that an environmental chemical study demands, when compared to standard engineering practice.

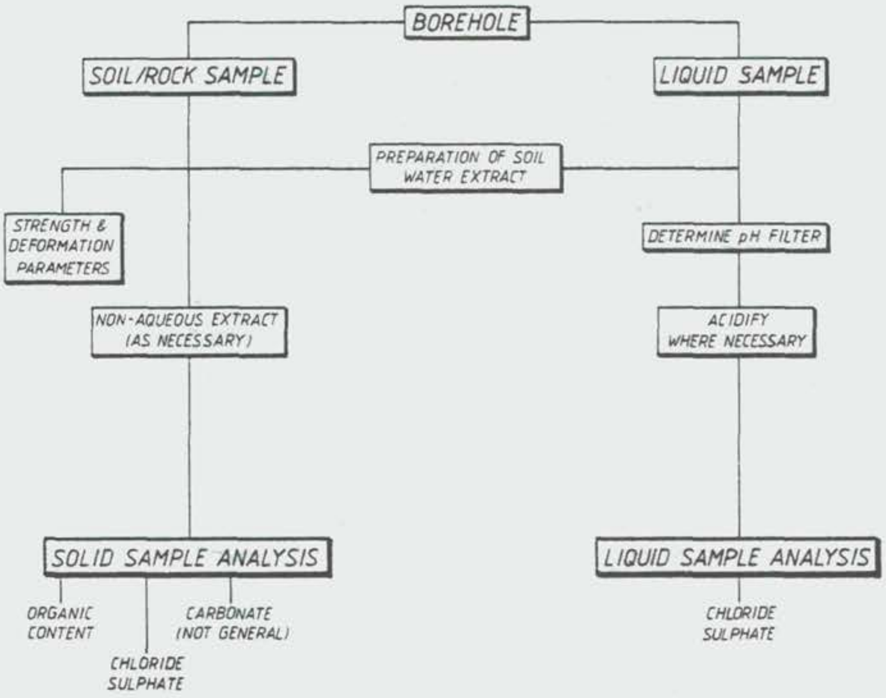

Figure V1.7. Chemical analysis of liquid and solid samples from landfill sites: requirements for standard engineering practice.

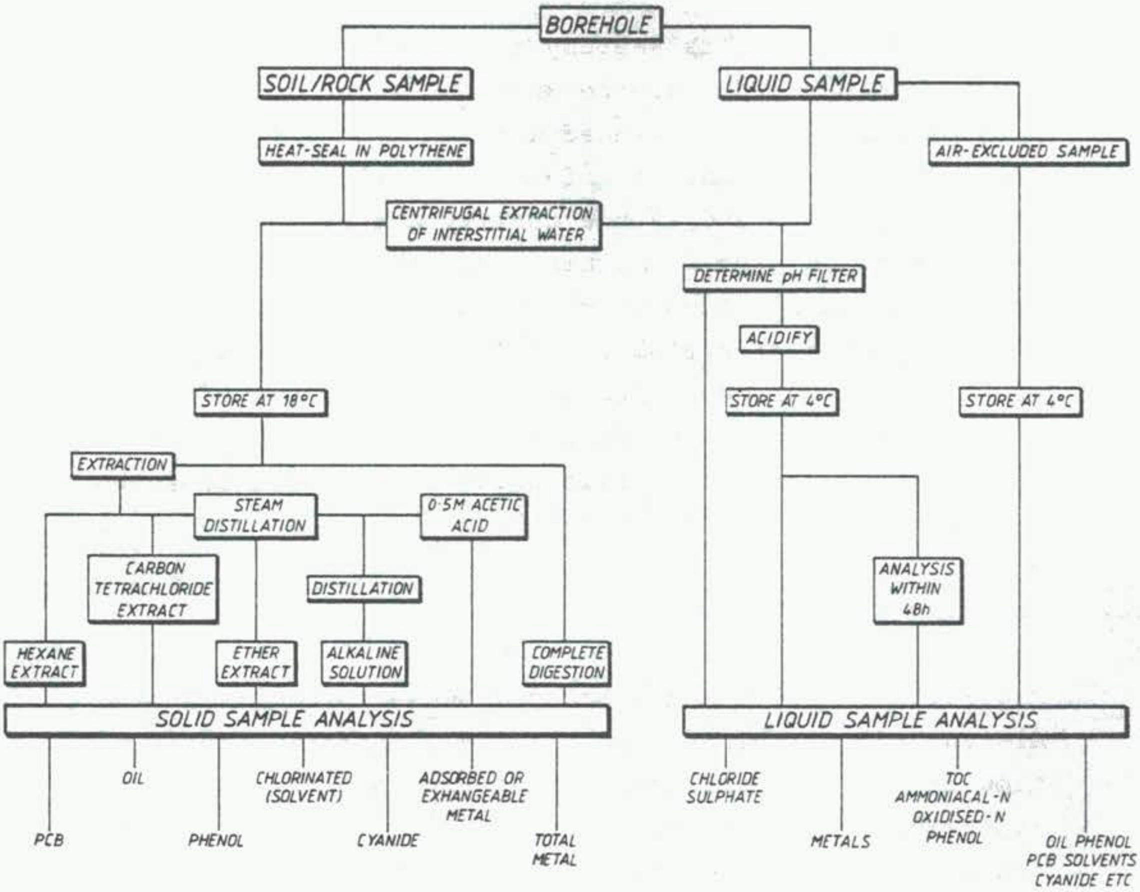

Figure V1.8. Chemical analysis of liquid and solid samples from landfill sites: requirements for environmental impact assessment.

V1.5. Predictive Modelling of Leachate Movement

V1.5.1. Introduction

The ability of landfill leachate to pollute surface and groundwater has been discussed earlier. In order to assess the pollution potential of leachate from an existing or proposed landfill site it is necessary to predict leachate movement within the particular hydrogeological setting of the site and its environs.

In recent years, technological progress in the petrochemical industry and, at the same time, advances in investigations into the processes of geothermal energy have produced methods whereby the flow of fluids through porous media can be analysed effectively. These methods include an increased knowledge of the behaviour of geological strata, and advances in the extraction of geological data, and in the quality and extent of those data. Hand in hand with this progress have come corresponding advances in the processes of mathematical modelling of terrestrial fluid flow. The main impetus of this work has been directed towards the use of digital computers to solve the flow equations. This Section summarises the basic equations and outlines the two main solution methods.

V1.5.2. Defining the problem

Migration of pollutants through the earth occurs in two distinct flow regimes (Figure V1.9). Firstly there is flow in the unsaturated or retention zone; this is typically a three-phase phenomenon, i.e. pollutant, water and air. Ther "intergranular" flow is governed by gravity and capillary forces and by the relative permeabilities of the three phases. The flow may be modified by dispersion and molecular diffusion effects.

The second flow regime is flow in the saturated or groundwater zone. The flow is mainly laminar and in many cases monophasic, the pollutant having dissolved in the host groundwater. Effects of solubility, dispersion, degradation and adsorption will also affect the flow.

Although the mechanisms determining the flow field in these two regimes are not the same, the equations of motion in both cases are of a similar form and are solved by the same methods. In most pollution conditions, however, it is flow in the saturated zone which will be of interest, pollution of the earth in many cases being synonymous with groundwater pollution. For this reason the following equations are presented with particular reference to flow in the saturated zone.

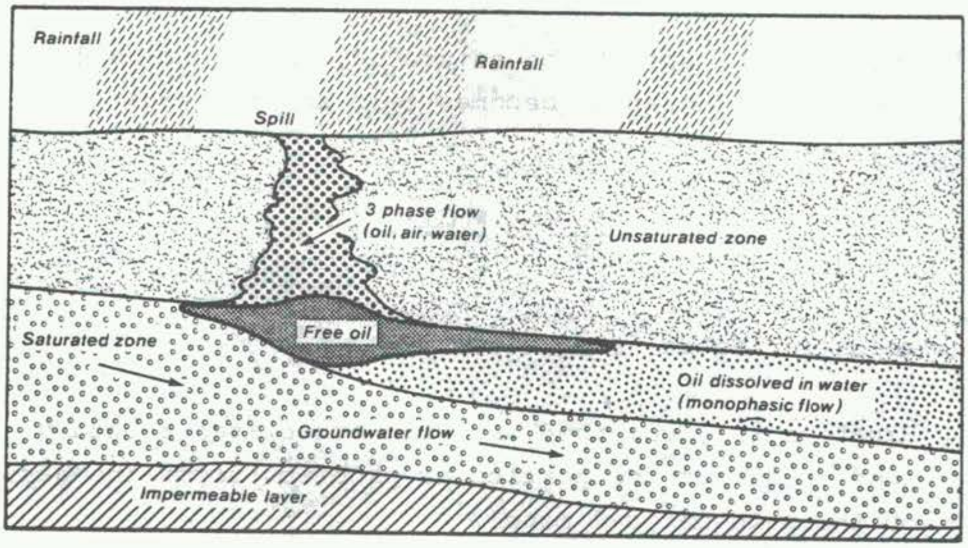

Figure V1.9. Diagram showing flow of an oil spill through an unsaturated zone into a saturated zone.

V1.5.3. Flow equations

For a simple, single-phase flow analysis the soil properties are characterised by the soil permeability k, and are assumed isotropic, homogeneous and independent of the flow. Thus, for a steady state evaluation of an incompressible fluid, the flow is described by Darcy's equation:

$$V = -k\nabla H \tag{1}$$

which states that the flow velocity V, is proportional to the total head gradient, ∇H.

Combination of equation (1) with the continuity equation $\nabla V = 0$ gives: (2)

$$\frac{\partial^2(kH)}{\partial x^2} + \frac{\partial^2(kH)}{\partial y^2} = \frac{\partial w}{\partial t} \tag{3}$$

where $\frac{\partial w}{\partial t}$ represents the change of storage in the pores.

Assuming the soil to be saturated, the right-hand side of the equation becomes zero and the equation reduces to:

$$\frac{\partial^2 (kH)}{\partial x^2} + \frac{\partial^2 (kH)}{\partial y^2} = 0 \qquad (4)$$

which is Laplace's equation.

Equation (4), combined with the associated boundary conditions for the particular problem, forms the basis of the mathematical model.

In deriving the basic Laplace equation (4) several simplifying assumptions have been made and the following points should be noted in establishing a realistic model:

- soils are seldom homogeneous or isotropic
- often "sources" or "sinks" are involved in a pollution problem, e.g. seepage of pollutant into a well, or seepage from a soakaway or landfill site
- it is often not a steady-state solution to a pollutant flow problem which is of interest, but a time-dependent solution
- the above solution does not take account of two- or three-phase effects
- chemical or biochemical processes may play a significant role in the behaviour of the flow field.

Two approaches to the solution of multi-dimensional multiphase seepage problems are widely used: finite difference techniques. Both provide the facility to model changes in soil permeability throughout the region and in both cases "sources" and "sinks" in the system are described by the boundary conditions.

For multiphase flow (McMichael and Thomas, 1973), the Darcy equation can be extended to:

$$V_m = - \frac{\rho_m k k_{rm} \nabla \Phi_m}{\mu_m} \tag{5}$$

where the suffix m, denotes the fluid phase, e.g. pollutant, water, gas, etc., k_{rm} are functions of the phase saturation S, the variables ρ and μ are the density and viscosity of the particular fluid, and Φ is the flow potential. Defining Cm as the mass fraction of the m^{th} phase, the (unsteady) continuity equation becomes:

$$\nabla\left(\Sigma C_m \rho_m V_m\right) = \phi \frac{\partial}{\partial t}\left(\Sigma C_m \rho_m S_m\right) \tag{6}$$

where ϕ is the porosity = $\frac{(\text{pore space})}{(\text{pore volume})}$

Combinations of (5) and (6) give the generalised flow equations:

$$\nabla\left(\Sigma \frac{C_m \rho^2_m k k_{rm}}{\mu_m} \nabla \Phi m\right) = \phi \frac{\partial}{\partial t}\left(\Sigma C_m \rho_m S_m\right) \tag{7}$$

Equation (7) may be further generalised in a particular situation to take account of convective dispersion effects, degradation, and any other mechanisms deemed significant in the flow analysis.

V1.5.4. Finite difference methods

The finite difference method (Mitchell, 1969) divides the region of flow into a rectangular grid (Figure V1.10) and provides a means of inter-relating values of flow potential Φ, between neighbouring nodes of the grid. Laplace's equation

$$\frac{\partial^2 \Phi}{\partial x^2} + \frac{\partial^2 \Phi}{\partial y^2} = 0 \tag{8}$$

for example, is represented by the "five point replacement":

$$\Phi_0 = \frac{1}{4}(\Phi_1 + \Phi_2 + \Phi_3 + \Phi_4)$$

which can be visualised by the grid in Figure V1.10.

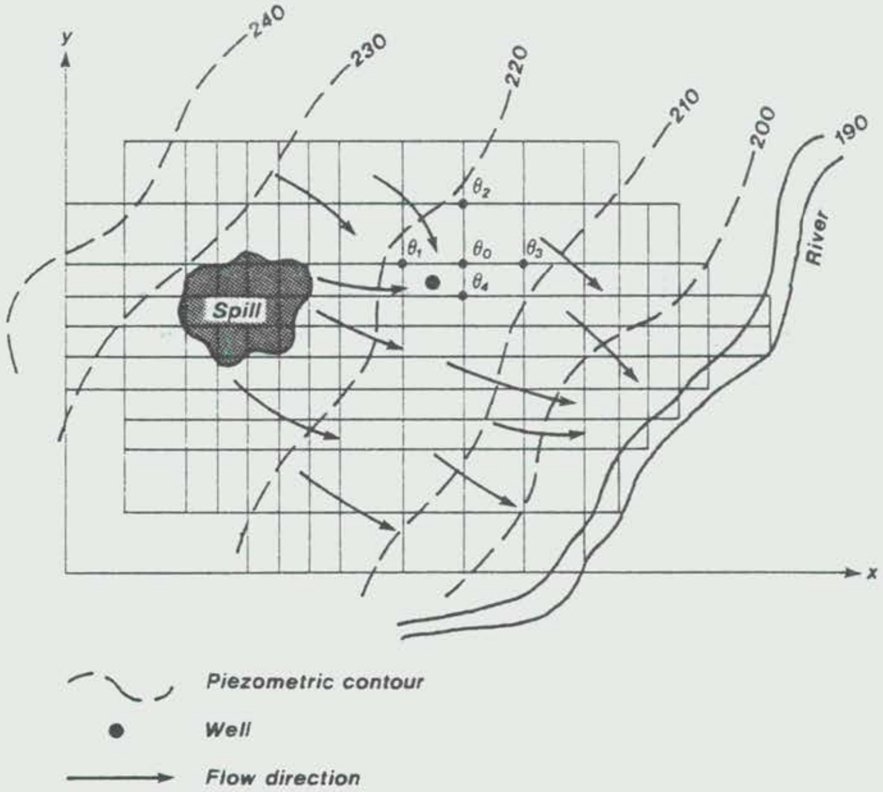

Figure V1.10. Finite difference mesh of a flow field.

The complete grid for the region of flow provides a set of simultaneous equations which, using the known boundary conditions, can be solved to define the complete flow field. The principles involved in the analysis of the simplified, two-dimensional (Laplace) problem are easily extended to deal with the more complex features of a real situation.

V1.5.5. Finite element methods

While finite difference methods are widely used and are capable of coping with a large range of seepage situations, a finite element approach has many advantages (Javendel, Witherspoon and Aime, 1968).

The treatment of complex geometrics, arbitrary boundary conditions and variable physical properties are all dealt with much more easily in a finite element model, as are discontinuities arising between physical interfaces (e.g. between two flow phases, or at a geological fracture). Furthermore, the finite element method is often computationally less clumsy and may be less expensive than the corresponding finite difference solution.

The finite element method separates the region of flow by a series of lines or boundaries into finite elements. Figure V1.11 shows a finite element representation of Figure V1.9 for an oil spillage infiltrating through the unsaturated zone to an aquifer. The interconnection of the lines or boundaries are the nodal points of the system whose potential Φ, will be the unknown parameters. By defining a suitable function to interrelate these nodal points within each element, together with the boundary conditions, the potential distribution and hence the flow field throughout the region, can be calculated.

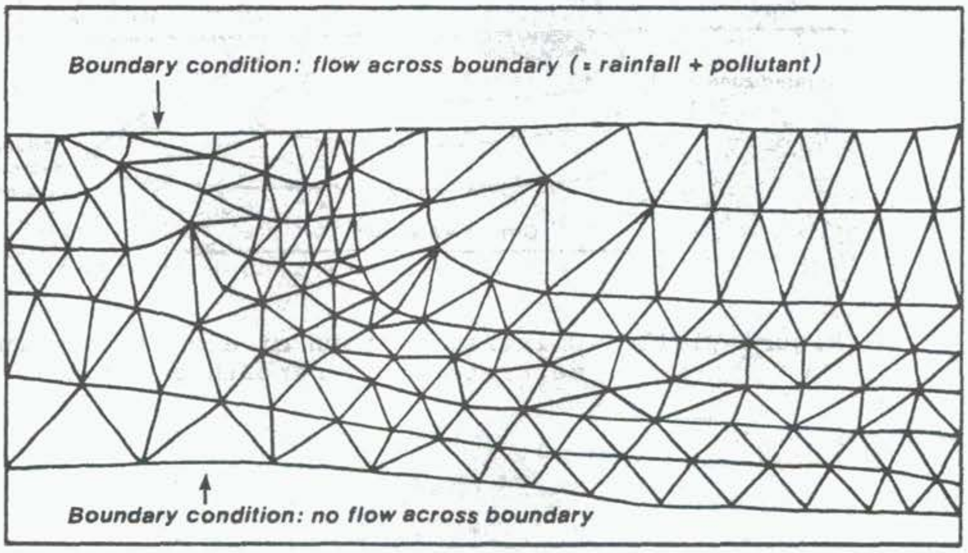

Figure V1.11. Finite element representation of the oil spill depicted in Figure V1.9.

In general, the finite difference approach may be preferred for single phase flows in which the boundaries of the region and the physical conditions on the boundaries are simple and assuming no other discontinuities are likely to arise. In more complex situations, a finite element approach is preferable as the modelling method is more versatile and the analysis is computationally more powerful.

V1.5.6. Forms of results

The form of results obtained from either of the above methods will depend on the complexity and accuracy of the mathematical model used. In general the concentration, chemical state, flow speed and volume of pollutant will be expressed as a function of space and time throughout the flow region. Figure V1.12 shows a typical result for concentration of a pollutant in the groundwater zone beneath a landfill site.

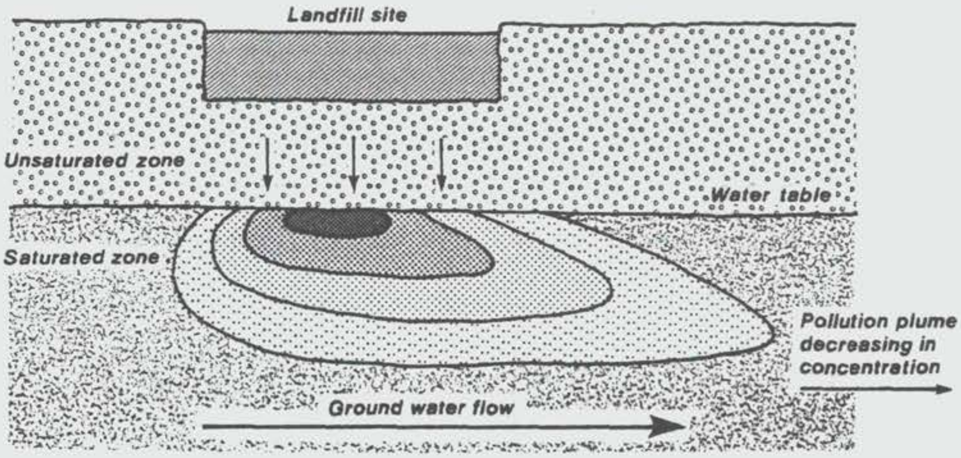

Figure V1.12 Dilution pattern of a pollutant in a saturated zone beneath a landfill site.

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VII - NOISE

VII. NOISE.

VII.1. General Considerations

It has been recognised for many years that regular exposure to high noise levels can cause damage to the hearing organs. The effect is gradual: a worker may not be aware of the effect on his hearing until the cumulative effect of many years exposure leads to difficulty in understanding speech, by which time it may be too late to retard or repair the damage.

The amount of damage which is inflicted by noise is generally thought to be directly proportional to the overall sound energy to which a worker is exposed, i.e. a dose/time relationship applies to noise exposure.

The human ear responds differently to sounds of different frequencies. Consequently, a unit has been developed to assess the likelihood of hearing damage which takes into account both the frequency contact and, because few noises are constant, the amount of sound energy to which a worker is exposed. This unit is called the Equivalent Energy level, Leq dB(A) and represents the energy which would be present in a steady noise level equivalent to the fluctuating noise level which an ear may be exposed to over a period of time.

The dose/time relationship is generally based on a maximum permitted exposure in an 8-hour working day, with corrections being made for different times of exposure and differing noise levels. Two major systems which differ in respect of the maximum permitted level and time/dose relationship are based on those used in the United States of America and the United Kingdom. The American System defines the maximum permitted exposure as 90 dB(A) slow response for an 8-hour working day, the permitted exposure halving (or doubling) with an increase (or decrease) of 5 dB(A) Leq (U.S. Department of Labour, 1976). The United Kingdom, on the other hand, is likely to adopt a standard of 90 dB(A) Leq over the same time period with a 3 dB(A) Leq doubling factor (Health and Safety at Work etc. Act, 1974).

It should, of course, be noted that since there is no 'safe' level of noise the level of exposure may be set at any level depending upon the percentage of the working population which it is hoped to protect. The United Kingdom standard, for example, will protect 85-90% of the exposed population. British Standard 5330 gives useful data on the percentage/noise level relationship (British Standards Institution, 1976).

Similarly, it has been recognised that vibration can have severe effects on structures and can cause physiological damage to the human body e.g. 'white-finger' disease, common among forestry workers, due to chain-saw vibration. Although standards and criteria for vibration are not so precise, a recent Draft British Standard, and an ISO recommendation (International Standards Organisation, 1978) give guidelines on possible time/exposure relationships. In general, vibration effects on human health are likely to be more localised than noise problems, affecting only those workers using, or immediately adjacent to, plant with high levels of vibration.

VII.2. Assessment of Employee Exposure to Noise

The objective is not necessarily to control the noise produced by plant, but to control the exposure of employees so that their overall noise dose does not exceed the selected standard.

There are three major ways in which exposure may be assessed for a proposed plant:

(i) An overall standard for noise level is selected and the specification for new plant is written so that the contribution from each item of plant cannot possibly cause the overall exposure to exceed that standard. For example, if the desired maximum exposure is 90 dB(A) Leq over an 8-hour working day, then a standard of, say, 85 dB(A) at one metre from any machine may achieve that objective. However, this is not a cost-effective method of dealing with the problem, in that many items of plant may not be attended continuously and therefore could be allowed very much higher levels than the standard.

(ii) Plant manufacturers are asked to provide noise levels for each item of plant at a specified distance from it, and using these data and details of plant layout, building structure etc., noise levels may be calculated in each area of the plant. Employee movement and time within each area can then be calculated and the individual exposure estimated.

(iii) A combination of (i) and (ii) may be used, where noisy plant is identified and isolated from the main circulation areas. Noise-reducing enclosures can be used and maximum times within these areas for unprotected workers can be determined.

VII.3. Control Measures

Where exposures are predicted to be excessive, even when alternative patterns of employee movement have been investigated, control measures will need to be instituted. The major options available for physical noise control are described below.

VII.3.1. Reduction at source

Basically, control at source can be considered as two separate, but interrelated areas: reduction due to a change in the physical characteristics or operating parameters of the plant, or palliative measures such as local enclosures. Suppliers and manufacturers of the major plant items will often be able to provide noise reduced units or control packages for their products, but where these are not available, control at source can be difficult, demanding a high degree of technical ability. Additionally, it is unlikely that the results will justify the cost or effort.

VII.3.2. Reduction along transmission path

Here, the possibilities for a high degree of control at reasonable cost are increased. Total and partial enclosures, screens and sound absorption may be used individually or in combination, but their success depends upon the operational requirements of the plant and operators and on the environment in which the plant is sited. Within buildings, enclosures and sound absorptive treatment are likely to lead to more cost-effective results, while plant in the open air can be dealt with by enclosures and screens. The table below gives an indication of the maximum reductions which can be achieved in practice.

		Within Buildings	In Open Air
Enclosures:	total	40 - 50 dB(A)	40 - 50 dB(A)
	partial	5 - 15 dB(A)	5 - 20 dB(A)
Screens		5 - 10 dB(A)	10 - 20 dB(A)
Absorbent material		0 - 10 dB(A)	-

VII.3.3. Reduction at receiver

Here, it is possible to apply similar procedures as noise reduction at source: the receiver can be enclosed, either partially or totally, screened, or, if he cannot be confined to one area, provided with ear protection. The reductions given in the above table also apply in this case, while ear protection can achieve reductions of between 10 and 25 dB(A).

VII.4. Monitoring

The most accurate method of monitoring an employee's exposure to occupational noise is to use a personal dose meter, which is used in a similar fashion to a radiation monitor. The employee is provided with a small (typically pocket-calculator sized) monitor unit to which is attached a microphone fitted at the lapel. For a person who carries out a similar work pattern from day-to-day, it may only be necessary to monitor for one or two days, but for an employee whose exposure varies, it may be necessary to provide a long-term monitoring system. Samples taken only during the exposure period may lead to misleading results, and hence, the monitoring should be carried out over the whole of a working day. Alternatively, sample exposure measurements may be integrated with sample rest and usual break levels.

At a slightly lower level of precision, the predicted or measured noise level exposure in each area of the plant, described in section VII.2.(ii). above can be used. Provided that care is taken in the estimation of exposure times, this method can be a good indication of exposure.

VII.5. General Considerations - Neighbourhood Noise

VII.5.1. Standards

While noise at the workplace can affect the hearing and health of employees, noise transmitted from an industrial plant to the surrounding neighbourhood can cause nuisance, annoyance, and, in extreme cases, may affect the health of area residents. In setting a standard for noise transmitted from a plant, it is necessary to take account of the nature of the area, the existing background noise levels and the likelihood of future area developments, both private and commercial.

Many countries already have some official guideline or standard for estimating basic requirements of noise limits in residential areas. Most assessment methods are similar, and base the standard for any particular area on its use. Two methods of setting standards are in general use: the first sets rigid standards for typical areas, usually based on the average background level to be expected within those areas; the second bases standards on the background noise level existing in the actual area under consideration.

In the absence of a national standards, the recommended practice issued by the International Standards Organisation (I.S.O.) as ISO.R.1996 can be used (International Standards Organisation, May, 1971). This is based on measurements of the typical background noise in the residential area, the maximum level of noise from industry being set at some increment above this (typically 5dB(A)). The benefit of this method, compared with an absolute noise limit for all areas, is that severe restrictions may not be needed in areas which are already relatively noisy due to other causes, (e.g. traffic noise). Problems may occur, however, when industry is located in a remote area where background noise levels tend to be very low (e.g. 20 dB(A)).

The ISO method uses Leq as a measurement index of community noise, which is compared with a statistical measure of the background noise; L_{95}. The latter is the noise level which is exceeded for 95% of the time period sampled.

British Standard 4142, 1967 (British Standards Institution, 1967, amended 1975) uses a predicted or measured noise level corrected for tonal and intermittency characteristics and compares this with L_{90} (the noise level exceeded for 90% of the time).

These methods generally use one part of a statistical distribution (for example L90, the level exceeded for 90% of the time) upon which to base a standard. In some parts of the United States of America standards are based upon the whole statistical distribution, thus limiting the total noise from a development and ensuring it matches with the existing environment.

Naturally, care must be taken in setting a standard to ensure it is compatible with land use. For example, if a rural area with some residential areas is re-zoned for industrial development, noise may well affect a very large area, sterilizing it for residential purposes.

Similarly, the time of day of operation must be taken into account, and it may be relevant to split the day into three sections: night (generally 22.00 or 23.00 hours to 06.00), day (generally 07.00 to 19.00 hours) and evening (19.00 hours to 22.00 or 23.00 hours).

VII.5.2. Methods of Assessment

While, in an ideal situation, a standard would be set by government agencies, and met by the developer, a practical assessment mechanism is required to ensure that the developer understands his responsibilities and can demonstrate that he is able to control noise in his plant to deal with any deleterious effects. Experience has shown that it is vital that the developer can demonstrate such a commitment and ability at an early stage in the project.

The general philosophy of assessment requires that each potential noise source within a plant is considered and the noise level produced by it (including any enclosures, etc.) is predicted at the residential property under consideration. By summation of the industrial sources, an overall noise level can be obtained and the contribution of each individual item ascertained. This enables noise control to be applied to those items which control the overall noise levels in a cost-effective manner.

The prediction of noise levels from an industrial plant affecting nearby properties is a difficult and skilled task: the person predicting such radiation must be aware of the processes and noise sources in the plant and be able to estimate levels for equipment which may not yet be produced. Under these circumstances, the planning authority (who may not have the necessary expertise) will have to insist on a more detailed analysis of the problem than might be required for other items. Alternatively, the analysis may be carried out by a specialist on behalf of the developer. In particular, the impact assessment should include:

(a) a list of major plant items in the development and their associated noise levels, both at a standard distance from the plant item and at sensitive areas external to the plant;

(b) details of the positions of the items within the development; and,

(c) predicted noise levels at sensitive locations outside the plan with details of the remedial treatment proposed where the anticipated noise level exceeds the standard set by the planning authority. It should be noted that noise reductions given in Section VII.3.2 also apply here.

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VII.7. Representative National Guidance Documents for Environmental Noise

Although, as has been pointed out in Section VII.5, methods of setting standards are similar, local conditions vary widely and, thus, tabulation of such numerical standards would not help any particular country. The National Standards/ guideline documents listed below will aid the development and setting of local standards, taking into account methodologies used elsewhere, rather than numerical examples.

ARGENTINA	
4079	Noise evaluation for hearing conservation
AUSTRALIA	
AS.1055.1973	Noise assessment in residential areas
AS.1469-1973	Criteria curves for rating noise and establishing acoustic environment
DR.72084	Australian standard code of practice for hearing conservation

AUSTRIA

Bundesgesetzblatt 15 Stuck 1974 Nr. 39	Gesundheitliche Eignung von Arbeitnehmern für bestimmte Tätigkeiten
Bundesgesetzblatt 288	Kraftfahrverordnung 1955
Bundesgesetzblatt 103	Seenverkehrsordnung 1961
OAL-Richtlinie Nr. 6 (2 Ausg.)	Gesundheitsschäden durch Lärm
OAL-Richtlinie Nr. 15	Sicherung der Nachtruhe
OAL-Richtlinie Nr. 18	Die ärzliche Begutachtung von Störungen durch Lärm
OAL-Richtlinie Nr. 19	Schalltechnische Grundlagen für die Beurteilung von Baulärm
OAL-Richtlinie Nr. 21	Schalltechnische Grundlagen für örtliche und überörtliche Raumplanung

BELGIUM	Institut Belge de Normalisation, 29 av. de la Brabançonne, 1040 Bruxelles
NBN576.11- 1961	Courbes d'évaluation du niveau de bruit

BRAZIL

NB 95 1966	Níveis de Ruido Aceitáveis
Decreto 11.467 30.10.1974	Diário Oficial do Municipio de São Paulo regulamenta a Lei 8106 de 30.08.1974. Dispõe sobre Sons Urbanos

C.S.S.R.

Hygienical Requirements No. 32	Requirements for protection against noise

DENMARK

DS/ISO R.1996	Akustik. Bedømmelse af støj med hensyn til omgivelsernes reaktion
DS/ISO R.1999	Akustik. Bedømmelse af støjeksponering på arbejdspladsen med henblik på hørebeskyttelse

FINLAND

1551	Yleiskirje: Terveydenhoitolain (469/65) ja-asetuksen (55/67) nojalla annetut melua koskevat terveydelliset suositukset
VNP 730/1974	VNP työssä vallitsevan melun torjunnasta

FRANCE

NF S 31-010 1974	Mesure de bruit dans une zone habitée vue de l'évaluation de la gêne de la population
NF S 31-013 1975	Evaluation de l'exposition au bruit au cours du travail en vue de la protection de l'ouïe (remplace S 31-013, avril 1969)

GERMANY

DIN 18005 Vornorm + Neuentwurf	Schallschutz im Städtebau Hinweise für die Planung Berechnungs- und Bewertungsgrundiagen
BDI 2058	Beurteilung und Abwehr von Arbeitslärm; Bl 1: In der Nachbarschaft Bl 2: Am arbeitsplatz hinsichtlich Gehörschäden
VDI 2565 Entwurf	Beurteilung von Lärm in Wohnungen

GREAT BRITAIN

Dept. of Env.	Code of practice for reducing the exposure of employed persons to noise
BS4142: 1967	Method of rating industrial noise affecting mixed residential and industrial areas. With amendment AMD 1661. January 1975.
BS5228: 1975	Code of practice for noise control on construction and demolition sites
H.M. Govt.	Control of pollution act 1974, chapter 40.

HUNGARY

SZOT 6/1965 (IV)	Verordnungen des Landesrates der Geverkschaften
M.SZ 11143T 1970	Max. permitted noise levels by medical instruments and equipment

INDIA	
IS: 4954-1968	Recommendations for noise abatement in town planning
IS: 7179-1973	Specifications for assessment of noise-exposure during work for hearing conservation purposes.
NETHERLANDS	
NEN 20532	Same as ISO R.532
NORWAY	
1975	Retningslinjer for begrensning av støy fra industri m.v.
1975	Forskrifter om begrensning av støy
POLAND	
PN N-01302	Acoustics. Method of determination on the risk of hearing damage (Polish Draft Standard)
PORTUGAL	
NP 302 1964	Ruidos industriais (industrial noise). 2 provisory standards a. Reaction to noise in residential areas b. Estimation of risk for hearing damage.
SOUTH AFRICA	
SABS 083-1970	Code of practice for the rating of noise for hearing conservation
SABS 0103-1970	Code of practice for the rating of noise for speech communication with respect to annoyance
SWEDEN	
SEN 590111	Bedömning av risk för hörselskada vid bullerexponering, (Risk for hearing damage)
Arbetarskyddsstyrelsens anvisningar nr 110	Buller i arbetslivet
Sjöfartsverkets meddelanden nr 27-1973	Bestämmelser och rekommendationer om skydd mot buller på fartyg
Statens Naturvardsverks publikation 1973:5	Riktvärden för externt industribuller

SWITZERLAND	
	Lärmbekämpfung in der Schweiz
13 Marz 1964	Bundesgesetz über die Arbeit in Industrie, Gewerbe und Handel (Arbeitsgesetz)
26 Marz 1969	Verordnung IV zum Arbeitsgesetz
Marz 1965 NR66 und 67	Schweizerische Blätter für Arbeitssicherheit
U.S.A.	
OSHA	Walsh-Healey Code (administered under Occupational Safety and Health Act of 1969)
U.S.S.R.	
Gost 12.1.003 1976	Noise. General safety requirements
Gost 15762-1970	Individual noise-protection devices hyg. requirements
YUGOSLAVIA	
8 July 1971	General precautionary measures and standards for protection at work against noise at working places
INTERNATIONAL (I.S.O.)	
R.1996-1971	Assessment of occupational noise exposure for hearing conservation purposes
R.1999-1975	Assessment of occupational noise exposure for hearing conservation purposes.

VIII - ENVIRONMENTAL CRITERIA AND STANDARDS

VIII. ENVIRONMENTAL CRITERIA AND STANDARDS

VIII. 1. Introduction

It is important to establish at the outset the distinction between environmental criteria and standards, which are not synonymous as is sometimes believed (Sanderson and Watkin, 1975).

Criteria, in their broadest sense, have been defined as "the relationship between exposure of a target to pollution or nuisance and the risk and/or magnitude of the adverse or undesirable effect resulting from the exposure in given circumstances" (Commission of the European Communities, 1973.) Here the word target includes man and any relevant component of the environment. Thus criteria refer to the available medical and scientific knowledge concerning the health and welfare effects of exposure to pollution, commonly called "dose response" or "exposure effect" relationships. The latter are an expression of the quantitative relationship between various concentrations of contaminants or combinations of contaminants and their effects on man, animals, vegetation, materials, etc. Economic and technological considerations of control are therefore not relevant to the establishment of criteria.

The term criterion also is used ambiguously in a more narrow sense, particularly in the water pollution field, to refer specifically to concentrations which, if not exceeded, will not have an adverse effect on a particular use of the (aquatic) environment by man or other organisms. A particular constituent may therefore have more than one such criterion attached to it to ensure more than one environmental (water) use or condition, e.g. protection of human health, protection of fauna and flora, etc., each value being a scientific judgment based usually on extrapolations from literature and research about dose-response relationships (i.e. criteria in the normal sense of the word). The use of the term criterion in this narrow meaning will be avoided in the following discussions.

Criteria are, therefore, descriptive; that is, they describe the effects that will or will not occur whenever and wherever the level of a pollutant reaches or exceeds a specific figure for a specific time period. Standards on the other hand are prescriptive; they prescribe pollutant levels that should not be exceeded during a specific time in a specific geographic area. In general, standards are developed by considering not only criteria but also factors such as cost, technological feasibility of control and social questions. Standards may be established by means of laws, regulations or administrative procedures, by mutual agreement or by voluntary acceptance (UNITAR, 1972).

There are five main types of standard for environmental protection (UK Department of the Environment, 1977):

(i) environmental quality standards, which prescribe the levels of pollution or nuisance not be be exceeded in a given geographical area or medium;
(ii) emission standards, which set levels of pollutants or nuisances not to be exceeded in discharges;
(iii) biological standards, which prescribe levels of accumulation of pollutants that must not be exceeded in a biological system;
(iv) product standards, which set levels of pollutants or nuisances not to be exceeded in the composition of a product, or specify properties or design characteristics to limit pollutant emission levels; and,
(v) operating standards, which specify the way in which an installation is to be operated or a product is to be used, perhaps by means of a "code of practice".

Environmental standards should also be distinguished from objectives (goals). Essentially a quality objective for a medium is a requirement for a degree of quality to be attained in that medium through an environmental specification which is to be fulfilled at a given time, now or in the future. It can therefore be a short or long term objective and be national or reflect specific regional and local conditions; it can also take account of the use to which the medium is to be put. Quality objectives can be expressed either as single values or as a range and can be established with different targets in mind, e.g. protection of human health or of particular fauna and flora. Environmental standards can therefore be regarded as a means of achieving or approaching quality objectives.

VIII.2. Criteria

VIII.2.1. Determination of criteria

Pollutants can affect human health over a broad range of biological responses, as shown in Figure VIII.1. Death and disease are the end products of repeated and cumulative insults from many sources, e.g. diet, cigarette smoking, infections, accidental injury, etc., but because these determinants cannot be adequately measured it is very difficult to isolate and quantify the contribution of air and water pollutants to the mortality and morbidity experience of a community. A variety of other factors also have to be considered when studying the association between pollution and health effects: the physical and chemical properties of the pollutants; the duration, concentration and route of exposure; the general health of the receptor; occupational, psychosocial and climatological aspects; and, the phenomena of tolerance, adaptation, antagonism and synergism.

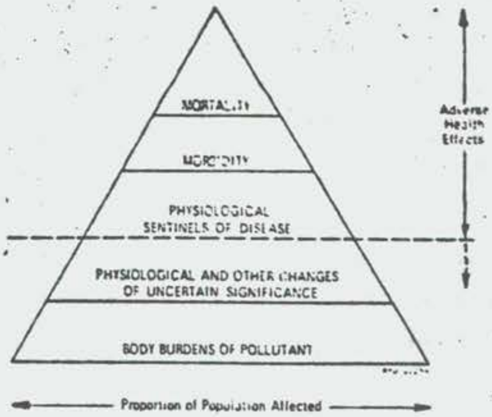


Figure VIII.1. Schematic spectrum of biological response to pollutant exposure (based on a diagram in United States Congress Document No. 92-241, 1972)

Despite these difficulties, environmental quality criteria are not the result of value judgments but are the outcome of detailed and painstaking research work both in the laboratory and in the field. There are three common methods for determining the effect of various concentrations and dosages of pollutants on people (i.e. criteria or dose-response relationships):

(i) Toxicological studies (experimental exposure of animals) - Although animal toxicological studies can use many response systems (whole animal, organs, cells or biochemical systems) to obtain data rapidly on cause-effect relationships and mechanisms of response, there is the major problem of extrapolating animal data to humans. In addition, such studies cannot readily identify delayed responses or chronic cumulative effects of exposure.

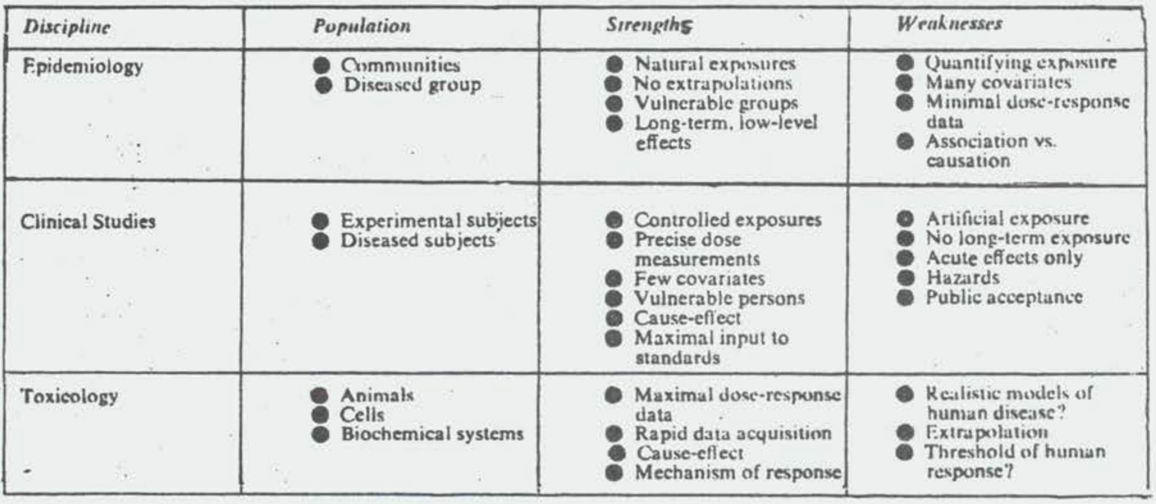
(ii) Clinical studies - clinical research studies can be used to gather human data on either normal or diseased persons regarding absorption, metabolism and excretion of pollutants and can be used for in-depth studies of humans accidentally exposed to high levels of pollutants. Although pollutant exposure and covariates are well controlled and there is no need for extrapolation to humans, there remain problems in that exposure is artificial and that only acute effects are determined. In addition, of course, controlled exposures of humans must be limited to concentrations and dosages of pollutants that do not represent a real hazard or result in serious illness for the exposed person.

(iii) Epidemiological studies - examination of the relationships between the distribution of specific diseases in a population and the factors that determine the distribution. For example, one may compare mortality and morbidity records, hospital admissions, absenteeism and other health-related data from several geographical areas with atmospheric pollutant levels or drinking water

> quality to test for significant correlations. Although epidemiology has the advantages that exposure is natural and that both current and long-term low-level exposures can be evaluated, interpretation of the result is very complicated as there is a need to take account of many covariates (e.g. smoking habits, nutrition, occupational exposure, climate, etc.) and to distinguish between association and causation. Another weakness is that it is impractical to measure all contaminants during the entire exposure period.

The strength and weaknesses of each disciplinary approach are summarised in Table VIII.1.

Table VIII.1 Disciplinary Approaches to Health Effects of Pollution (Newill, 1973)



Discipline	*Population*	*Strengths*	*Weaknesses*
Epidemiology	● Communities ● Diseased group	● Natural exposures ● No extrapolations ● Vulnerable groups ● Long-term, low-level effects	● Quantifying exposure ● Many covariates ● Minimal dose-response data ● Association vs. causation
Clinical Studies	● Experimental subjects ● Diseased subjects	● Controlled exposures ● Precise dose measurements ● Few covariates ● Vulnerable persons ● Cause-effect ● Maximal input to standards	● Artificial exposure ● No long-term exposure ● Acute effects only ● Hazards ● Public acceptance
Toxicology	● Animals ● Cells ● Biochemical systems	● Maximal dose-response data ● Rapid data acquisition ● Cause-effect ● Mechanism of response	● Realistic models of human disease? ● Extrapolation ● Threshold of human response?

Although man is usually the main target of concern, deleterious effects of pollutants on other features and components of the environment (e.g. plants, animals, and materials) should also be considered, particularly when these effects occur at pollutant concentrations lower than those known to produce human effects.

Although numerous studies have been performed with a host of different pollutants and targets, there is still insufficient data to define with certainty the maximum level at which any pollutant will not produce an adverse effect. In other words, while there is generally a consensus on what pollutants cause damage, there is much less agreement on how much is needed to cause damage. As the World Health Organisation (1972) stated: "When using air quality criteria and guides to evaluate risks and set standards, one should ideally have available a complete set of dose/response curves for the different air pollutants, for different effects and for the different types of populations exposed. This requirement, however, has not yet been satisfied for any single substance and it is even further from being met for combinations of substances often found in the ambient air". This statement applies equally well to water-quality criteria. However, this situation need not preclude the use of criteria as the basis for administrative action as long as it is recognised that they are incomplete and that adequate safety margins may need to be incorporated. Any air or water pollution control policy should also be sufficiently flexible to allow for the fact that, as the sum total of knowledge is always increasing, there may be a need to revise criteria from time to time.

VIII. 2.2. Use of criteria to estimate safe exposure limits

As has been explained there are many difficulties and uncertainties inherent in the establishment of dose-response relationships. In addition to the characteristics of exposure (e.g. intensity, frequency, variability, rate, duration), the biological response is conditioned by a variety of receptor factors. However, in spite of these difficulties it is necessary that estimates are made of exposure limits that will provide an adequate level of protection.

To obtain some indication of "safe" levels, i.e. levels where "no-effect" on a receptor is noted, it is generally necessary, because of the lack of data, to have to extrapolate from dose-response curves relating not only to the effect and receptor under consideration (if available), but also to other effects and/or other receptors. The term "derived working level" (DWL) is often usec to indicate the level of a pollutant in a media at which it is estimated that harmful sublethal effects will not occur in the critical receptor. It is important to note that these predicted levels are not strictly criteria; they have been obtained by extrapolation from available data, but the validity of this extrapolation procedure is often questionable. In the water pollution control field, for example, derived working limits are often obtained by applying an "application" or safety factor to acute toxicity data. Thus if the concentration which is lethal to 50% of test organisms over a 96 hour period (96-hour LC_{50}) is known and an application factor of 0.05 is arbitrarily chosen, then the DWL is given by 0.05 x 96-hr LC_{50}.

The preceding discussion assumes, however, that in dose-response relationships there is a gradual reduction in the magnitude of the biological response as the exposure is lowered, the response falling to zero as or before the exposure itself reaches zero (see Figure VIII.2). The existence of a threshold dose below which there is no danger with regard to the particular effects studied would allow an absolutely safe limit to be specified. However, this concept of a threshold of response is not considered as generally valid; biological experiments can never be sufficiently precise to prove or disprove with certainty its existence. For example, it is normally impossible to distinguish between a dose-response curve which shows a true threshold and one where the response follows an asymptotic relationship. The logical consequence of situations in which there are no thresholds, is that zero exposure becomes the safe limit. As this is usually impractical or impossible to enforce in practice, a balance has to be struck between how much damage/ nuisance can be accepted and how much can be spent to reduce exposure.

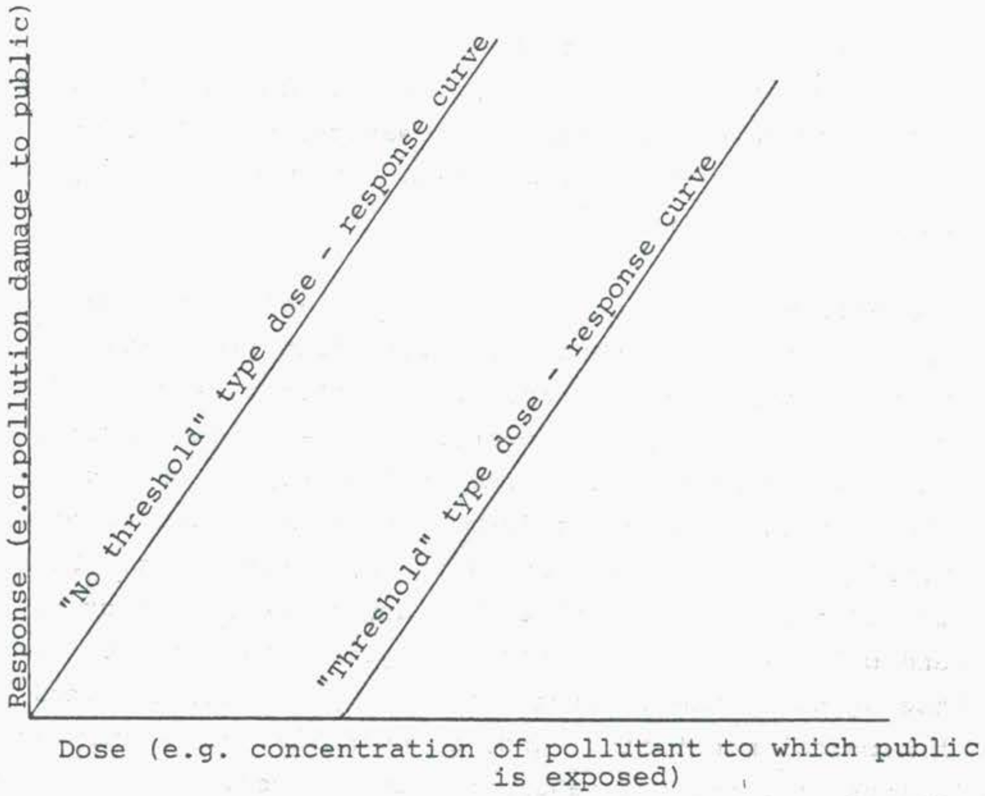


Figure VIII. 2. Dose-response curves of the threshold and no-threshold types

VIII . 2.3. Suitability and availability of criteria

The wide variations in climate, topography, plants, animals, microorganisms, etc. between and within countries means that it is impossible to formulate criteria that cover all receptors and all environmental variables. The problem is compounded by the fact that biological differences between species makes it difficult to extrapolate criteria from one species to another. It is generally hoped, therefore, to have available criteria for the most critical receptors and most sensitive areas of the environment and the pollutants identified as potential threats.

One of the first steps in any environmental assessment procedure is therefore to identify published literature containing effects information relevant to the pollutants, receptors and environment under consideration. While criteria relating to other environments/ receptors or pollutants should also be identified, they should be used only with caution and as a temporary measure until additional more pertinent data become available. To facilitate the full assessment of potential pollutants, a criteria document can be prepared for each, systematically collating all published information. Such a document could take the form outlined in Table VIII.2. (Hart, 1974)

The document would consist of a detailed section containing all the technical and scientific information regarding such aspects as production methods, sources (quantitative figures if possible), chemical and physical properties, fate in the environment, hazards and present environmental levels. The next section would use this information to formulate criteria and to predict, if possible, 'no-effect' levels in the environment. Such criteria formulation would involve the identification of critical receptors and critical effects, transport paths, methods for monitoring the agent in the environment (e.g. physical, chemical or biological monitoring) and, if possible, the environmental implications of certain management alternatives. Because environmental control is always intimately tied to economic and technical feasibility, it is advisable that a section on waste control technology relevant to the agent under consideration should also be included. Such a section would review methods available for the treatment of wastes likely to contain the agent, possible changes in the processes to reduce the contamination of the effluent by the agent, and alternative products if the agent is actually directly applied, as in the case of certain chlorinated hydrocarbon pesticides such as DDT. Finally, the document would contain a summary of the important relevant information and final recommendations.

It is immediately apparent from Table VIII.2. that the tremendous diversity of scientific fields that must be covered in depth when formulating a criteria document makes essential a team approach to such a task. The team should contain specialists in the major scientific fields to be covered (generally chemistry, hydrology, engineering, biology, economics and medicine), as well as generalists to assist in the drawing together of all relevant facts. The compilation of documents in this way permits ready

Table VIII.2. Suggested Format for Criteria Monograph (Hart,1974)

1. INTRODUCTION

2. TECHNICAL AND SCIENTIFIC INFORMATION ON THE AGENT
2.1. Chemical and physical properties
2.2. Sampling and analysis methods
2.3. Sources of the agent in the environment
2.4. Hazards associated with the agent (discussion of effects on reproduction, growth, toxicity (acute, chronic, carcinogenic, mutagenic, etc.); also sources of data, assessment of their validity, field studies
2.5. Environmental data (environmental levels, baseline levels in biota)
2.6. Fate of agent in the environmental (transportation, transformation, accumulation, persistence, identification of environmental pathways)
2.7. Existing regulations and guidelines

3. CRITERIA FORMULATION
3.1. Identification of critical receptors
3.2. Identification of critical effects
3.3. Identification of transport paths (these are the pathways for the agent from its introduction into the environment to its contact with the critical receptor and the subsequent production of a critical effect. Critical transport paths must also be identified. Those are the pathways by which the least amount of agent introduced into the environment can produce a critical effect)
3.4. Monitoring (recommendations for sample collection, handling and analysis to enable the agent concentration in all critical areas of the major transport pathways to be monitored)
3.5. Derived working levels (this section will include recommended derived working levels for the agent at critical stages in the major transport pathways. Much of this information will involve the extrapolation of criteria data in an attempt to provide adequate protection to the critical receptors. This information will be used by protection authorities in setting effluent and receiving water quality standards.

4. TECHNOLOGY FOR WASTE CONTROL
4.1. Current methods available for the treatment of wastes containing the agent
4.2. Possible process changes to reduce the concentration of the agent in effluents
4.3. Assessment of possible alternative products
4.4. Recommendations

5. SUMMARY

Summarise, to assist management, the major points and recommendations made previously.

identification of the areas where criteria information is needed. Appropriate research should be initiated to provide this information, but meantime there is no alternative but to extrapolate from existing data.

A number of bodies are already engaged in systematically and critically reviewing the published literature containing information on the effects of individual pollutants and in summarising and assembling the pertinent information into "background criteria documents". In some cases, therefore, much of the groundwork may already have been performed and "up-dating" may be all that is required. The progress of a number of these bodies is summarised below:

(i) World Health Organisation (WHO): A WHO Expert Committee reported in 1972 on the effects likely to result from exposure to a number of common urban air pollutants: sulphur oxides and suspended particulates; carbon monoxide; photochemical oxidants; and, nitrogen dioxide (World Health Organisation, 1972). For example, in the case of suspended particulates and sulphur dioxide the levels considered by the Expert Committee to bring about adverse health effects are reproduced in Table VIII.3.

More recently, WHO with the assistance of UNEP, has initiated the Environmental Health Criteria Programme. This programme aims to produce guidelines for setting exposure limits consistent with health protection and involves the compilation of environmental health criteria documents for individual pollutants, covering all aspects of their environmental sources, distribution and fate. The first three documents, for example, were concerned with mercury, polychlorinated biphenyls and terphenyls, and lead (World Health Organisation, 1976a, 1976b and 1977). Table VIII.4. summarises the status of the Programme as of March, 1978. (UNEP, 1978).

Table VIII . 3. Expected Health Effects of Air Pollution on Selected Population Groups* (World Health Organisation, 1972)

Pollutant	Excess mortality and hospital admissions	Worsening of patients with pulmonary disease	Respiratory symptoms	Visibility and/ or human annoyance effects
SO_2[a]	500 µg/m^3 (daily average)	500-250 µg/m^{3b} (daily average)	100 µg/m^3 (annual arithmetic mean)	80 µg/m^3 (annual geometric mean)
Smoke[a]	500 µg/m^3 (daily average)	250 µg/m^3 (daily average)	100 µg/m^3 (annual arithmetic mean)	80 µg/m^3 (annual geometric mean)[c]

* The committee specifically urged that this table should not be considered independently of the accompanying text.

[a] British Standard Practice (Ministry of Technology, 1966). Values for sulphur dioxides and suspended particulates apply only in conjunction with each other. They may have to be adjusted when translated into terms of results obtained by other procedures.

[b] These values represent the differences of opinion within the Committee

[c] Based on high-volume samplers.

(ii) U.S. Environmental Protection Agency (USEPA) and U.S. Department of Health Education and Welfare (USDHEW)

The USDHEW and USEPA have published criteria documents for six air pollutants, namely: particulate matter, sulphur oxides, carbon monoxide, photochemical oxidants, hydrocarbons and nitrogen oxides (U.S. Department of Health, Education and Welfare, 1969a, 1969b, 1970a, 1970b, 1970c; U.S. Environmental Protection Agency, 1971). Each report reviews in detail the main findings on the effects of the pollutant on man, animals, vegetation and materials and describes the physical and chemical properties of the pollutant, its sources and methods of measurement. These reports are currently under review.

Table VIII.4. Status of WHO/UNEP Environmental Health Criteria Programme as of March, 1978 (UNEP, 1978)

Pollutant or hazard	Method used*	First draft document	National comments on first draft	Second draft document	Task group meeting	Editing	Publication
antimony	C	completed	-	-	-	-	-
arsenic	A	in preparation	-	-	-	-	-
benzo(a) pyrene	B	completed	-	-	-	-	-
bismuth	C	completed	-	-	-	-	-
cadmium	B	completed	received	completed	July 1975	in progress	?
carbon disulfide	B	completed	received	completed	June 1977	in progress	1978
carbon monoxide	B	completed	received	completed	Oct.1977	in progress	1978
DDT	B	completed	received	completed	Nov.1977	in progress	1978
fluorine & fluorides	C	in preparation	-	-	-	-	-
fuels & fuel additives	C	completed	-	-	-	-	-
germanium	C	completed	-	-	Feb.1975	in progress	?
lead	B	completed	received	completed	April/May 1975		1977
manganese	A	completed	received	completed	Sept.1975	in progress	1978
mercury	B	completed	received	completed	Feb.1975		1976
microwaves	C	completed	-	-	1978	-	1979
molybdenum	C	completed	-	-	July/Aug. 1974	in progress	?
mycotoxins	A	completed	received	completed	March 1977	in progress	1978
nickel	B	completed	-	-	1978	-	-

Table VIII.4 (contd)

nitrates, nitrites & N-nitroso compounds	A	completed	received	completed	March 1976	completed	1978
noise	B	completed	received	completed	Feb.1977	completed	1978
organic vegetable dusts	C	in preparation	-	-	1978	-	-
oxides of nitrogen	B	completed	received	completed	Sept.1976		1977
platinum & palladium	C	completed	-	-	-	-	-
photochemical oxidants	B	completed	received	completed	Sept.1976	in progress	1978
PCBs	A	completed	received	completed	Oct.1975		1977
selected petroleum products	C			in preparation	1978		1979
sulfur oxides & SPM	B	completed	received	completed	Jan.1976	in progress	1978
TCDD	B	completed	received	in preparation	1978		
tellurium	C	completed	-	-	July/Aug. 1974	in progress	
tin	C	completed	-	-	March 1975	completed	1978
titanium	C	completed	-	-	Feb.1975	in progress	1978/9
UV radiation	B	in preparation	-	-	1978	-	1979
vanadium	B	completed	-	-	1979	-	-

* A refers to the "long method", i.e. the criteria documents are prepared on the basis of national contributions (see EHE/EHC/74.1,page5); B refers to the "short method", i.e. the draft documents are prepared by the WHO Secretariat, and C to the preliminary reviews.

A wider range of air pollutants was covered in another series of reports, published in 1969 by the USDHEW, containing similar information to the above criteria documents but in less detail. (Table VIII.5; U.S. Department of Health Education and Welfare, 1969).

Table VIII.5. - Preliminary air pollution survey reports published by the U.S. Department of Health, Education and Welfare, (1969).

- Aeroallergens (pollens)
- Aldehydes (including acrolein and formaldehyde)
- Ammonia
- Arsenic and its compounds
- Asbestos
- Barium and its compounds
- Beryllium and its compounds
- Biological aerosols (microorganisms)
- Boron and its compounds
- Cadmium and its compounds
- Chlorine gas
- Chromium and its compounds (includes chromic acid)
- Ethylene
- Hydrochloric acid
- Hydrogen sulphide
- Iron and its compounds
- Manganese and its compounds
- Mercury and its compounds
- Nickel and its compounds
- Odorous compounds
- Organic carcinogens
- Pesticides
- Phosphorus and its compounds
- Radioactive substances
- Selenium and its compounds
- Vanadium and its compounds
- Zinc and its compounds

In the water pollution field, the USEPA has published a very comprehensive compilation of water quality criteria (Committee on Water Quality Criteria, 1973), which has recently been updated for those contaminants on which new information has become available (U.S. Environmental Protection Agency, 1976). A large quantity of scientific evidence on the effects of water pollution is also summarised in water quality criteria data books, published by the USEPA between 1970 and 1973 (U.S. Environmental Protection Agency, 1970, 1971a, 1972 and 1973).

(iii) North Atlantic Treaty Organisation (NATO): In 1969, NATO established the Committee on the Challenges of Modern Society which sponsored four air pollution studies, one being related to air pollution criteria documents. Documents were produced on five categories of air pollutants: sulphur oxides; particulate matter; carbon monoxide; nitrogen oxides; and, photochemical oxidants and related hydrocarbons (North Atlantic Treaty Organisation, Committee on the Challenges of Modern Society, 1972).

(iv) National Research Council/National Academy of Sciences (NRC/NAS), United States: The NRC/NAS have published a series of documents that review existing knowledge on specific contaminants, which to date include: ammonia; asbestos; arsenic; chlorine and hydrogen chloride; chromium; copper; fluorides; hydrogen sulphide; iron; lead; manganese; nickel; particulate polycyclic organic; ozone and other photochemical oxidants; selenium; vanadium; and, vapour-phase organic pollutants. Reports are planned for aeroallergens, carbon disulphide, infectious aerosols, the platinum group of heavy metals, sulphides and zinc. (National Research Council/National Academy of Sciences, 1971-1978).

(v) European Inland Fisheries Advisory Commission (EIFAC): The EIFAC Working Party on Water Quality Criteria for European Freshwater Fish has to date produced reports on the following: finely divided solids, pH, temperature, ammonia, monohydric phenols, dissolved oxygen, chlorine, zinc and copper (EIFAC, 1964-1976).

(vi) National Research Council (NRC) of Canada: The NRC Associate Committee on Scientific Criteria for Environmental Quality has compiled a number of documents summarising the sources, distribution and effects of various parameters including: lead, chlordane, photochemical air pollution, endosulfan, dissolved oxygen, methoxychlor, fenitrothion, waste heat, chromium, sulphur, alkali halides, nitrilotriacetic acid (NTA), and fluoride (NRC Associated Committee on Scientific Criteria for Environmental Quality, 1973-1977).

VIII.3. Air Quality Management Standards

There are a number of ways of utilising standards to maintain or achieve a pre-determined level of air quality and thereby limit the exposure of populations, ecosystems, etc. to air pollutants. The two most common types of standard are ambient air quality and emission standards.

VIII.3.1. Ambient air quality standards

Ambient air quality standards are limits placed on levels of air pollutants in the ambient air during a given period of time, designed to achieve air quality objectives or an acceptable level of air quality. Although what is considered to be "acceptable" may vary from country to country, there are upper and lower guideline concentrations. For example, air can never have a concentration of any substance lower than the global background concentration of that substance, so standards must be greater than these levels (see Table VIII.6.). On the other hand, standards clearly should be set at levels below those known to represent a substantial danger to human health. The levels shown in Table VIII.7., for example, have been taken by the U.S. EPA to indicate an imminent threat to public health.

Table VIII.6. Natural Source and Background Concentrations for Selected Pollutants (Newill, 1977)

Pollutant	Natural source	Background concentration ($\mu g/m^3$)
SO_2	Volcanoes	1-4
H_2S	Volcanoes; biological decay	0.3
NO	Bacterial action in soil; photodissociation of N_2O and NO_2	0.3-2.5
NO_2	Bacterial action in soil; oxidation of NO	2-2.5
NH_2	Biological decay	4
CO	Oxidation of methane; photodissociation of CO_2; forest fires; oceans	100
O_2	Tropospheric reactions and transport from stratosphere	20-60
Hydrocarbons	Biological processes in swamps	CH_4 = 1000; non-CH_4 <1
Reactive hydrocarbons	Biological processes in forests	<1

Table VIII.7. Significant Harm Levels (Anon. 1974)

Sulphur dioxide - 2620 $\mu g/m^3$ (1.0 ppm), 24 hour average
Particulate matter - 1000 $\mu g/m^3$ or 8.0 COH[a] values, 24 hour average
Sulphur dioxide and particulate matter combined - Product of sulphur dioxide in micrograms per cubic meter, 24 hour average, and particulate matter in micrograms per cubic meter, 24 hour average, equal to 490×10^3, or product of sulphur dioxide in parts per million, 24 hour average, and COH values, 24 hour average, equal to 1.5
Carbon monoxide - 57.5 mg/m^3 (50 ppm), 8 hour average. 86.3 mg/m^3 (75 ppm), 4 hour average. 144 mg/m^3 (125 ppm), 1 hour average.
Photochemical oxidants - 1200 $\mu g/m^3$ (0.6 ppm), 1 hour average
Nitrogen dioxide - 3750 $\mu g/m^3$ (2.0 ppm) 1 hour average. 938 $\mu g/m^3$ (0.5 ppm), 24 hour average.

[a] COH, coefficient of haze.

The World Health Organisation (1972) has issued guidance on this aspect and has proposed the concentrations shown in Table VIII.8. as long-term goals intended to prevent undesirable effects from: sulphur oxides and suspended particulates; carbon monoxide; and, photochemical oxidants. It was emphasised however that these tentative recommendations are subject to change as and when more data on dose-response relationships become available.

Table VIII.8. Recommended Long-Term Goals[a] (World Health Organisation, 1972)

Pollutant and measurement method	Limiting level		
Sulphur oxides[b] - British Standard Procedure[c]	Annual mean	60	$\mu g/m^3$
	98% of observations[d] below	200	$\mu g/m^3$
Suspended particulates[b] - British Standard Procedure[c]	Annual mean	40	$\mu g/m^3$
	98% of observations[d] below	120	$\mu g/m^3$
Carbon monoxide - nondispersive infrared[c]	8-Hour average	10	mg/m^3
	1-Hour maximum	40	mg/m^3
Photochemical - oxidant as measured by neutral buffered KI method expressed as ozone	8-Hour average	60	$\mu g/m^3$
	1-Hour maximum	120	$\mu g/m^3$

[a] The Committee specifically urged that this table should not be considered independently of the accompanying text.

[b] Values for sulphur oxides and suspended particulates apply only in conjunction with one another

[c] Methods are not necessarily recommended but indicate those on which these units have been based. Where other methods are used an appropriate adjustment may be necessary.

[d] The permissible 2% of observations over this limit may not fall on consecutive days.

Ambient air quality standards, in specifying the allowable level of a pollutant in the atmosphere, define the permitted exposure of the population and of ecological systems. Their numerical values are expressions of public policy, being based not only on air quality criteria but also on a broad range of economic, social, technical and political considerations. As natural environments, exposure conditions, socioeconomic situations and the importance of other health-related problems vary enormously from country to country, it is not surprising that ambient air quality standards have evolved differently and similarly show great variability in different countries.

Table VIII.9. is a compilation of national ambient air quality standards and is derived from a recent study of worldwide air quality management standards (Martin and Stern, 1974). It was found that of the 87 countries studied, about half had no legislative standards at all, while the number promulgated by the remaining countries varied widely. For example, the USSR, which became the first country to set air quality standards in 1951, now has standards for 114 substances (Izmerov, 1973), while in contrast several countries only have standards for sulphur dioxide and suspended particulates. The USSR air quality standards are in fact generally more stringent than those for most other countries, prinicpally because they are based on different criteria. Thus the standards represent the lowest pollutant concentrations at which a response to a standardised battery of tests was evoked in man or test animals, there being an a priori assumption that such a response is adverse and therefore to be avoided. Several other eastern European countries make official use of the USSR air quality standards.

Table VIII.9 **National Ambient Air Quality Standards** (Newill, 1977).

	Long-term standard[a]			*Short-term standard*[a]			
Substance and country	*mg/m³*	*ppm*	*Averaging time (hours)*	*mg/m³*	*ppm*	*Averaging time (minutes)*	*Notes*[b]
Acetaldehyde							
Bulgaria, Yugoslavia	—	—	—	*0.01*	0.005	30	—
East Germany	*0.01*	0.005	24	*0.03*	0.015	30	
USSR	*0.01*	0.005	24	*0.01*	0.005	30	—
West Germany (VDI 2306)	*4.0*	*2.0*	½	*12.0*	*6.0*	30	3, 4
Acetic acid							
Bulgaria	—	—	—	*0.2*	0.08	30	—
East Germany, USSR	*0.06*	0.024	24	*0.2*	0.08	30	1, 2
West Germany (VDI 2306)	*5.0*	*2.0*	½	*15.0*	*6.0*	30	3, 4
Acetic anhydride							
Bulgaria	—	—	—	*0.1*	0.025	30	—
East Germany, USSR	*0.03*	0.0075	24	*0.1*	0.025	30	1, 2
Acetone							
Bulgaria, Hungary, USSR, Yugoslavia	*0.35*	0.15	24	*0.35*	0.15	30	2, 5
East Germany	*0.35*	0.15	24	*1.0*	0.42	30	1
Hungary	*12.0*	5.0	24	*180.0*	75.0	30	—
Israel	7.2	*3.0*	24	24.0	*10.0*	30	6
Romania	*2.0*	0.83	24	*5.0*	2.1	30	—
West Germany (VDI 2306)	*120.0*	*50.0*	½	*360.0*	*150.0*	30	3, 4
Acetophenone							
Bulgaria	*0.35*	0.07	24	*0.35*	0.07	30	—
East Germany	*0.003*	0.0006	24	*0.01*	0.002	30	1
USSR, Yugoslavia	*0.003*	0.0006	24	*0.005*	0.0006	30	2
Acrolein							
Bulgaria, Czechoslovakia, Hungary, Romania, Yugoslavia	*0.1*	0.04	24	*0.3*	0.12	30	—
East Germany	*0.01*	0.004	24	*0.02*	0.008	30	1
Israel	0.1	*0.04*	24	0.25	*0.1*	30	6
USSR	*0.03*	0.012	24	*0.03*	0.012	30	—
West Germany (VDI 2306)	*0.01*	*0.005*	½	*0.025*	*0.01*	30	3, 4
Ammonia							
Bulgaria, Hungary, USSR, Yugoslavia	*0.2*	0.28	24	*0.2*	0.28	30	5
Czechoslovakia, East Germany, Romania	*0.1*	0.14	24	*0.3*	0.43	30	1
Hungary	*0.5*	0.71	24	*1.5*	2.14	30	—
Amyl acetate							
Bulgaria, Hungary, USSR, Yugoslavia	*0.1*	0.019	24	*0.1*	0.019	30	5
East Germany	*0.1*	0.019	24	*0.3*	0.057	30	1
Hungary	*30.0*	5.7	24	*90.0*	17.1	30	—
Israel	5.25	*1.0*	24	15.75	*3.0*	30	6
West Germany (VDI 2306)	*30.0*	*5.0*	½	*90.0*	*15.0*	30	3, 4
Amyl alcohol							
West Germany (VDI 2306)	*20.0*	*5.0*	½	*60.0*	*15.0*	30	3, 4
Amylene							
Bulgaria, USSR, Yugoslavia	*1.5*	0.5	24	*1.5*	0.5	30	2
East Germany	*1.0*	0.33	24	*1.5*	0.5	30	1
Aniline							
Bulgaria, Czechoslovakia, East Germany, USSR, Yugoslavia	*0.03*	0.008	24	*0.05*	0.013	30	1
Romania	*0.02*	0.005	24	*0.05*	0.013	30	—
West Germany (VDI 2306)	*0.8*	*0.2*	½	*2.4*	*0.6*	30	3, 4
Arsenic							
Bulgaria, Czechoslovakia, USSR	*0.003*	—	24	—	—	—	7
East Germany	*0.003*	—	24	—	—	—	—
Israel	*0.006*	—	24	—	—	—	6, 7

able VIII.9. *(Continued)*

Substance and country	*Long-term standard*[a]			*Short-term standard*[a]			
	mg/m³	*ppm*	*Averaging time (hours)*	*mg/m³*	*ppm*	*Averaging time (minutes)*	*Notes*[b]
Poland	*0.003*	—	24	*0.01*	—	20	9
	0.002	—	24	*0.005*	—	20	10
Romania	*0.01*	—	24	*0.03*	—	30	—
Yugoslavia	*0.003*	—	24	—	—	—	8
Benzene							
Czechoslovakia, Romania	*0.8*	0.25	24	*2.4*	0.75	30	—
East Germany, Hungary, Yugoslavia	*0.8*	0.25	24	*1.5*	0.46	30	1, 5
Hungary, West Germany (VDI 2306)	*3.0*	0.94	24	*10.0*	3.12	30	3, 4
Israel	1.6	*0.5*	24	4.8	*1.5*	30	6
Poland	*0.3*	0.09	24	*1.0*	0.31	20	9
	0.1	0.03	24	*0.2*	0.06	20	10
Benzene (high alkyl)							
West Germany (VDI 2306)	*5.0*	—	½	*15.0*	—	30	3, 4
Benzine							
East Germany	*0.03*	0.007	24	*0.05*	0.012	30	1, 13
Hungary	*80.0*	20.0	24	*240.0*	60.0	30	—
Hungary, USSR	*1.5*	0.38	24	*5.0*	1.25	30	5, 12
Israel	3.3	*0.8*	24	*10.0*	*2.4*	30	6, 12
Poland	*0.75*	0.19	24	*2.5*	0.63	20	10, 12
Romania	*2.0*	0.48	24	*6.0*	1.45	30	—
West Germany (VDI 2306)	*80.0*	*20.0*	½	*240.0*	*60.0*	30	3, 4, 12
Yugoslavia	*1.5*	0.38	24	*5.0*	1.25	30	11
Benzine (from shale)							
Bulgaria, USSR	*0.05*	0.012	24	*0.05*	0.012	20	11
Benzine (low sulfur)							
Bulgaria	*1.5*	0.38	24	*5.0*	1.25	30	11
East Germany, Yugoslavia	*1.5*	0.38	24	*5.0*	1.25	30	1
Beryllium							
Israel, Yugoslavia	*0.00001*	—	24	—	—	—	6
Butane							
Bulgaria, USSR, Yugoslavia	—	—	—	*200.0*	85.0	30	—
East Germany	*50.0*	21.0	24	*200.0*	85.0	30	1
Butanol							
Bulgaria, Yugoslavia	—	—	—	*0.3*	0.1	30	—
East Germany	*0.1*	0.03	24	*0.3*	0.1	30	1
USSR	—	—	—	*0.1*	0.03	30	—
West Germany (VDI 2306)	*15.0*	5.0	½	*45.0*	15.0	30	3, 4
n-Butyl acetate							
Bulgaria, USSR, Yugoslavia	*0.1*	0.021	24	*0.1*	0.021	30	—
East Germany	*0.1*	0.021	24	*0.3*	0.063	30	1
Israel	4.7	*1.0*	24	14.0	*3.0*	30	6
West Germany (VDI 2306)	*25.0*	*5.0*	½	*75.0*	*15.0*	30	3, 4
Butylene							
Bulgaria, USSR, Yugoslavia	*3.0*	1.2	24	*3.0*	1.2	30	2
East Germany	*2.0*	0.8	24	*3.0*	1.2	30	1
Butyric acid							
Bulgaria, USSR, Yugoslavia	*0.01*	0.003	24	*0.015*	0.004	30	—
Cadmium							
Yugoslavia	*0.003*	—	24	*0.01*	—	30	—
Caproic acid							
USSR, Yugoslavia	*0.005*	0.001	24	*0.01*	0.002	30	—
Caprolactam							
Bulgaria, USSR, Yugoslavia	*0.06*	0.013	24	*0.06*	0.013	30	14
East Germany	*0.06*	0.013	24	*0.1*	0.022	30	1
Caprylic acid							
Bulgaria, East Germany	*0.005*	0.001	24	*0.01*	0.002	30	1

able VIII.9. *(Continued)*

	Long-term standard[a]			Short-term standard[a]			
Substance and country	*mg/m³*	*ppm*	*Averaging time (hours)*	*mg/m³*	*ppm*	*Averaging time (minutes)*	*Notes[b]*
Chlorotetracyclin							
East Germany	0.03	—	24	0.05	—	30	1, 24
USSR	0.05	—	24	0.05	—	30	25
Chromium							
Romania	0.0015	—	24	0.0016	—	30	26
Chromium (hexavalent)							
East Germany	0.001	—	24	0.0015	—	30	1, 27
Israel	0.0015	—	24	—	—	—	6, 27
USSR	0.0015	—	24	0.0015	—	20	27
Yugoslavia	0.0015	—	24	0.0015	—	30	27
Cresol (all isomers)							
West Germany (VDI 2306)	0.2	0.05	½	0.6	0.15	30	3, 4
Cyclohexane							
East Germany	1.0	0.3	24	1.4	0.4	30	1
USSR	1.4	0.4	24	1.4	0.4	30	—
Cyclohexanol							
Bulgaria, USSR, Yugoslavia	0.06	0.015	24	0.06	0.015	30	—
East Germany	0.06	0.015	24	0.15	0.037	30	1
Cyclohexanone							
Bulgaria, Hungary, Yugoslavia	0.04	0.01	24	0.04	0.01	30	5
East Germany	0.04	0.01	24	0.1	0.02	30	1
Hungary	10.0	2.5	24	30.0	7.5	30	—
USSR	—	—	—	0.04	0.01	30	—
West Germany (VDI 2306)	10.0	2.0	½	30.0	6.0	30	3, 4
Cyclohexanon oxine							
East Germany	0.04	0.01	24	0.1	0.025	30	1
USSR	—	—	—	0.1	0.025	30	—
Dichloroethane							
Bulgaria, East Germany, Romania, USSR, Yugoslavia	1.0	0.25	24	3.0	0.75	30	1
Israel	2.0	0.5	24	6.0	1.5	30	6
West Germany (VDI 2306)	8.0	2.0	½	25.0	6.0	30	3, 4
2-3-Dichloro-1-4-naphthaquinone							
Bulgaria, East Germany	0.02	—	24	0.05	—	30	1
USSR, Yugoslavia	0.05	—	24	0.05	—	30	—
Diethylamine							
Bulgaria, Romania, USSR, Yugoslavia	0.05	0.016	24	0.05	0.016	30	—
East Germany	0.02	0.008	24	0.05	0.016	30	1
West Germany (VDI 2306)	0.03	0.01	½	0.05	0.02	30	3, 4
Diethyl ether							
West Germany (VDI 2306)	65.0	20.0	½	155.0	60.0	30	3, 4
Diketene							
Bulgaria, USSR, Yugoslavia	—	—	—	0.007	0.002	30	—
East Germany	0.002	0.001	24	0.007	0.002	30	1
Dimethylamine							
East Germany	0.005	0.003	24	0.015	0.0075	30	1
USSR	0.005	0.003	24	0.005	0.003	30	—
West Germany (VDI 2306)	0.02	0.01	½	0.06	0.03	30	3, 4
Dimethylaniline							
Bulgaria, Yugoslavia	—	—	—	0.0055	0.001	30	—
East Germany	0.005	0.001	24	0.015	0.003	30	1
USSR	0.0055	0.001	24	0.0055	0.001	30	—
Dimethyl Disulfide							
Bulgaria, USSR	—	—	—	0.7	0.18	30	—
East Germany	0.2	0.05	24	0.7	0.18	30	1
Yugoslavia	—	—	—	0.07	0.018	30	—

Table VIII.9. *(Continued)*

	Long-term standard[a]			*Short-term standard*[a]			
Substance and country	*mg/m³*	*ppm*	*Averaging time (hours)*	*mg/m³*	*ppm*	*Averaging time (minutes)*	*Notes*[b]
Carbon disulfide							
Bulgaria, Czechoslovakia, Romania, Yugoslavia	*0.01*	0.0033	24	*0.03*	0.01	30	—
East Germany	*0.003*	0.001	24	*0.03*	0.01	30	1
Israel	0.15	*0.05*	24	0.45	*0.15*	30	6
Poland	*0.015*	0.005	24	*0.045*	0.015	20	9
USSR	*0.005*	0.0016	24	*0.03*	0.01	30	2
Carbon monoxide							
Argentina	11.5	*10.0*	8	57.7	*50.0*	60	—
Bulgaria, East Germany, Hungary, USSR, Yugoslavia	*1.0*	0.9	24	*3.0*	2.7	30	1, 2, 5
Canada—Desirable level	*6.0*	*5.0*	8	*15.0*	*13.0*	60	15, 16
—Acceptable level	*15.0*	*13.0*	8	*35.0*	*30.0*	60	15, 17
Czechoslovakia	*1.0*	0.9	24	*6.0*	5.4	30	—
Finland	*10.0*	*9.0*	8	*40.0*	*35.0*	60	71
Hungary, Romania	*2.0*	1.8	24	*6.0*	5.4	30	—
Israel	11.5	*10.0*	8	35.0	*30.0*	30	—
Italy	23.0	*20.0*	8	57.7	*50.0*	30	18
Japan	11.5	*10.0*	24	—	—	—	19
	23.0	*20.0*	8	—	—	—	19
Poland	*0.5*	0.45	24	*3.0*	2.7	20	9
Spain	*15.0*	13.0	8	*45.0*	39.0	30	20
USA, West Germany	*10.0*	8.6	8	*40.0*	35.0	60	21
Carbon tetrachloride							
East Germany, USSR	*2.0*	0.33	24	*4.0*	0.66	30	1, 2
Romania	*1.0*	0.16	24	*3.0*	0.5	30	—
West Germany (VDI 2306)	*3.0*	*0.5*	½	*10.0*	*1.5*	30	3, 4
Chlorine							
Bulgaria, Czechoslovakia, East Germany, Hungary, USSR, Yugoslavia	*0.03*	0.01	24	*0.1*	0.03	30	1, 5
Hungary	*0.3*	0.1	24	*0.6*	0.2	30	—
Israel	0.1	*0.03*	24	0.3	*0.1*	30	6
Italy	—	—	—	*0.58*	*0.2*	30	18
Poland	*0.03*	0.01	24	*0.1*	0.03	20	9
	0.01	0.003	24	*0.03*	0.01	20	10
Romania	*0.1*	0.033	24	*0.3*	0.1	30	—
Spain	*0.05*	0.016	24	*0.3*	0.1	30	20
West Germany	*0.3*	*0.1*	½	*0.6*	*0.2*	30	22
m-Chloroaniline							
East Germany	*0.01*	0.003	24	*0.03*	0.01	30	1
USSR	*0.01*	0.003	24	—	—	—	—
Yugoslavia	—	—	—	*0.04*	0.013	30	—
p-Chloroaniline							
Bulgaria	—	—	—	*0.04*	0.008	30	—
East Germany, USSR	*0.01*	0.002	24	*0.04*	0.008	30	1
Chlorobenzene							
Bulgaria, USSR, Yugoslavia	*0.1*	0.02	24	*0.1*	0.02	30	—
East Germany	*0.1*	0.02	24	*0.3*	0.06	30	1
West Germany (VDI 2306)	*5.0*	*1.0*	½	*15.0*	*3.0*	30	3, 9
Chloroform							
West Germany (VDI 2306)	*10.0*	*2.0*	½	*30.0*	*6.0*	30	3, 4, 23
m-Chlorophenyl isocyanate							
Bulgaria, USSR, Yugoslavia	*0.005*	—	24	*0.005*	—	30	2
East Germany	*0.003*	—	24	*0.005*	—	30	1
p-Chlorophenyl isocyanate							
Bulgaria, East Germany, USSR, Yugoslavia	*0.0015*	0.0002	24	*0.0015*	0.0002	30	1, 2
Chloroprene							
Bulgaria, USSR, Yugoslavia	*0.1*	0.028	24	*0.1*	0.028	30	—
East Germany	*0.05*	0.014	24	*0.1*	0.028	30	1
Israel	0.14	*0.04*	24	0.5	*0.14*	30	6

ble VIII.9. *(Continued)*

	Long-term standard[a]			*Short-term standard*[a]			
Substance and country	*mg/m^3*	*ppm*	*Averaging time (hours)*	*mg/m^3*	*ppm*	*Averaging time (minutes)*	*Notes*[b]
Dimethylformamide							
Bulgaria, USSR, Yugoslavia	*0.03*	0.01	24	*0.03*	0.01	30	—
East Germany	*0.01*	0.003	24	*0.03*	0.01	30	1
Israel	0.018	*0.006*	24	0.06	*0.02*	30	6
Dimethyl sulfide							
Bulgaria, USSR, Yugoslavia	—	—	—	*0.08*	0.03	30	—
East Germany	*0.05*	0.01	24	*0.08*	0.03	30	1
Dinitrobenzene							
West Germany (VDI 2306)	*0.035*	*0.005*	½	*0.1*	*0.015*	30	3, 4
Dinyl							
Bulgaria, Romania, USSR, Yugoslavia	*0.01*	0.0015	24	*0.01*	0.0015	30	2, 28
East Germany	*0.003*	0.0045	24	*0.01*	0.0015	30	1, 28
Dioxane							
West Germany	*20.0*	*5.0*	½	*60.0*	*15.0*	30	3, 4, 48
Divinyl							
Bulgaria, East Germany, USSR, Yugoslavia	*1.0*	0.4	24	*3.0*	1.2	30	1
Epichlorohydrin							
Bulgaria, USSR, Yugoslavia	*0.2*	0.05	24	*0.2*	0.05	30	—
East Germany	*0.06*	0.016	24	*0.2*	0.05	30	1
Ethanol							
Bulgaria, USSR, Yugoslavia	*5.0*	2.5	24	*5.0*	2.5	30	2
East Germany	*5.0*	2.5	24	*15.0*	7.5	30	1
West Germany (VDI 2306)	*100.0*	*50.0*	½	*300.0*	*150.0*	30	3, 4
Ethyl acetate							
Bulgaria, USSR, Yugoslavia	*0.1*	0.029	24	*0.1*	0.029	30	—
East Germany	*0.1*	0.029	24	*0.3*	0.085	30	1
Israel	14.0	*4.0*	24	42.0	*12.0*	30	6
West Germany (VDI 2306)	*75.0*	*20.0*	½	*225.0*	*60.0*	30	3, 4
Ethylbenzene							
East Germany	*0.02*	0.005	24	*0.06*	0.014	30	1
USSR	*0.02*	0.005	24	*0.02*	0.005	30	—
Ethylene							
Bulgaria, USSR, Yugoslavia	*3.0*	2.3	24	*3.0*	2.3	30	2
East Germany	*2.0*	1.53	24	*3.0*	2.3	30	1
Israel	0.26	*0.2*	24	0.65	*0.5*	30	6
Ethylene oxide							
Bulgaria, East Germany, USSR, Yugoslavia	*0.03*	0.015	24	*0.3*	0.15	30	1
West Germany (VDI 2306)	*4.0*	*2.0*	½	*12.0*	*6.0*	30	3, 4
Ethylenimine							
East Germany	*0.001*	0.0005	24	*0.003*	0.0015	30	1
USSR	*0.001*	0.0005	24	*0.001*	0.0005	30	—
Flourides (as F)							
Bulgaria, East Germany, Romania	*0.005*	0.002	24	*0.02*	0.01	30	1, 29
Czechoslovakia, Hungary, Israel	*0.01*	0.005	24	*0.03*	0.015	30	5, 6, 29
Hungary	*0.03*	0.015	24	*0.1*	0.05	30	—
Italy, Spain	*0.02*	0.01	24	*0.06*	0.03	30	18, 20
Fluorides							
Bulgaria, Poland	*0.01*	—	24	*0.03*	—	20	9, 31, 33, 35
East Germany, Yugoslavia	*0.01*	—	24	*0.03*	—	30	1, 31, 33, 35
Hungary	*0.02*	0.015	24	*0.02*	0.015	30	32
	0.0013	0.001	24	*0.005*	0.004	30	5, 32
Netherlands	*0.01*	0.008	24	—	—	—	—
Poland	*0.003*	—	24	*0.01*	—	20	10, 35
Spain, USSR	*0.01*	0.008	24	*0.03*	0.022	30	2, 20, 32, 33

Table VIII.9. *(Continued)*

	Long-term standard[a]			*Short-term standard*[a]			
Substance and country	*mg/m³*	*ppm*	*Averaging time (hours)*	*mg/m³*	*ppm*	*Averaging time (minutes)*	*Notes*[b]
USSR	*0.005*	0.002	24	*0.02*	0.01	20	2, 29, 30
West Germany	*0.002*	0.001	½	*0.005*	0.004	30	32
Yugoslavia	*0.005*	0.004	24	*0.02*	0.015	30	32
Fluorides (insoluble)							
Yugoslavia	*0.03*	—	24	*0.2*	—	30	—
Fluorides (sparingly soluble)							
East Germany, USSR	*0.03*	—	24	*0.2*	—	30	1, 34
Formaldehyde							
Bulgaria, East Germany, Hungary, USSR, Yugoslavia	*0.012*	0.01	24	*0.035*	0.025	30	1, 5
Czechoslovakia	*0.015*	0.01	24	*0.05*	0.033	30	—
Hungary	*0.03*	0.02	24	*0.07*	0.05	30	—
Israel, West Germany (VDI 2306)	*0.03*	*0.02*	24	*0.07*	*0.06*	30	3, 4, 6
Poland	*0.02*	0.014	24	*0.05*	0.033	20	9
	0.01	0.007	24	*0.02*	0.014	20	10
Romania	*0.01*	0.007	24	*0.03*	0.02	30	—
Furfural							
Bulgaria, USSR, Yugoslavia	*0.05*	0.013	24	*0.05*	0.013	30	2
East Germany, Romania	*0.05*	0.013	24	*0.15*	0.04	30	1
Israel	0.08	*0.02*	24	0.25	*0.06*	30	6
West Germany (VDI 2306)	*0.08*	*0.02*	½	*0.25*	0.06	30	3, 4
Hexachlorocyclohexane							
East Germany	*0.01*	—	24	*0.03*	—	30	1
USSR	*0.03*	—	24	*0.03*	—	30	—
Hexamethylenediamine							
Bulgaria, USSR	*0.001*	—	24	*0.001*	—	30	—
East Germany	*0.001*	—	24	*0.003*	—	30	1
Yugoslavia	*0.01*	—	24	*0.01*	—	30	—
Hydrocarbons (total)							
Israel	2.0	*3.0*	24	5.0	*7.5*	30	6
Italy	26.6	*40.0*	24	53.3	*80.0*	30	18, 36
United States	*0.16*	*0.24*	3	—	—	—	21, 37
Hydrochloric acid							
Bulgaria	*0.2*	0.14	24	—	—	—	39
Bulgaria, USSR, Yugoslavia	*0.006*	—	24	*0.006*	—	30	38
Czechoslovakia	—	—	—	*0.01*	0.007	30	39
	—	—	—	*0.01*	—	30	38
East Germany	*0.015*	0.01	24	*0.05*	0.035	30	1, 39
Hungary	*0.7*	0.5	24	*1.4*	1.0	30	2, 39
Hungary, USSR	*0.2*	0.14	24	*0.2*	0.14	30	2, 5, 39
Israel	0.4	*0.3*	24	1.4	*1.0*	30	6, 39
Italy	0.04	*0.03*	24	0.28	*0.2*	30	18, 39
Poland	*0.1*	0.07	24	*0.2*	0.14	20	9, 39
	0.02	0.014	24	*0.05*	0.035	20	10, 39
Romania	*0.1*	0.07	24	*0.3*	0.21	30	39
West Germany	*0.05*	0.035	½	*0.15*	0.1	30	39
Yugoslavia	—	—	—	*0.2*	0.14	30	39
Hydrogen cyanide							
East Germany	*0.005*	0.004	24	*0.015*	0.014	30	1
USSR	*0.01*	0.009	24	—	—	—	—
Hydrogen sulfide							
Bulgaria, Czechoslovakia, Hungary, USSR, Yugoslavia	*0.008*	0.005	24	*0.008*	0.005	30	2, 5
East Germany	*0.008*	0.005	24	*0.015*	0.01	30	1
Finland	*0.05*	0.03	24	*0.15*	0.1	30	71
Hungary	*0.15*	0.1	24	*0.3*	0.2	30	—
Israel	0.045	*0.03*	24	0.15	*0.1*	30	—
Italy	0.04	*0.03*	24	0.1	*0.07*	30	18

Table VIII.9. (Continued)

Substance and country	Long-term standard[a]			Short-term standard[a]			Notes[b]
	mg/m^3	ppm	Averaging time (hours)	mg/m^3	ppm	Averaging time (minutes)	
Poland	0.02	0.013	24	0.06	0.04	20	9
	0.008	0.005	24	0.008	0.005	20	10
Romania	0.01	0.006	24	0.03	0.02	30	—
Spain	0.004	0.0025	24	0.01	0.006	30	20
West Germany	0.02	0.013	½	0.05	0.03	30	—
Intrathion (M-81)							
USSR	0.001	—	24	0.001	—	30	—
Isooctanol							
East Germany	0.05	—	24	0.15	—	30	1
USSR	—	—	—	0.15	—	30	—
Isopropanol							
East Germany	0.6	0.24	24	2.0	0.82	30	1
Isopropyl benzene							
Bulgaria, USSR	0.014	—	24	0.014	—	30	2
East Germany	0.014	—	24	0.05	—	30	1
Isopropyl benzene (hydroperoxide)							
Bulgaria, USSR	0.007	—	24	0.007	—	30	2
East Germany	0.007	—	24	0.02	—	30	1
Lead							
Bulgaria, Czechoslovakia, East Germany, USSR, Yugoslavia	0.0007	—	24	—	—	—	2, 42
Hungary	0.001	—	24	0.002	—	30	—
	0.0007	—	24	0.0007	—	30	5
Israel	0.005	—	24	—	—	—	—
Italy	0.01	—	8	0.05	—	30	18
Poland	0.001	—	24	—	—	—	9
	0.0005	—	24	—	—	—	10
Romania	0.001	—	24	—	—	—	—
Lead sulfide (as Pb)							
Bulgaria	0.0007	—	24	—	—	—	—
East Germany, USSR, Yugoslavia	0.0017	—	24	—	—	—	—
Israel	0.0035	—	24	—	—	—	6
Malathion							
Bulgaria, USSR, Yugoslavia	—	—	—	0.015	—	30	45
Maleic Anhydride							
Bulgaria, East Germany, USSR, Yugoslavia	0.05	0:012	24	0.2	0.05	30	1, 2
Manganese							
Bulgaria, Czechoslovakia, East Germany, Yugoslavia	0.01	—	24	—	—	—	43
Israel, Romania	0.01	—	24	0.03	—	30	6
USSR	0.01	—	24	—	—	—	—
Mercury							
Bulgaria, East Germany, Hungary, USSR, Yugoslavia	0.0003	—	24	—	—	—	—
Israel, Romania	0.001	—	24	—	—	—	6
Mesidine							
Bulgaria, Yugoslav	—	—	—	0.003	—	30	44
USSR	0.003	—	24	0.003	—	30	44
Methanol							
Bulgaria, Czechoslovakia, East Germany, Hungary, USSR, Yugoslavia	0.5	0.38	24	1.0	0.77	30	1, 2, 5
Hungary	15.0	10.0	24	40.0	27.0	30	—
Israel	1.5	1.0	24	4.5	3.0	30	6
Romania	1.0	0.77	24	3.0	2.3	30	—
West Germany (VDI 2306)	15.0	10.0	½	40.0	30.0	30	3, 4
Methyl acetate							
Bulgaria, USSR, Yugoslavia	0.07	0.023	24	0.07	0.023	30	—
East Germany	0.07	0.023	24	0.2	0.066	30	1
Israel	3.0	1.0	24	9.0	3.0	30	6
West Germany (VDI 2306)	15.0	5.0	½	45.0	15.0	30	3, 4

able VIII.9.(*Continued*)

	Long-term standard[a]			*Short-term standard*[a]			
Substance and country	*mg/m³*	*ppm*	*Averaging time (hours)*	*mg/m³*	*ppm*	*Averaging time (minutes)*	*Notes*[b]
Methyl acrylate							
Bulgaria, Yugoslavia	—	—	—	0.01	0.003	30	—
East Germany	0.01	0.003	24	0.03	0.009	30	1
USSR	0.01	0.003	24	0.01	0.003	30	—
Methylaniline							
USSR	0.04	0.01	24	0.04	0.01	30	—
Yugoslavia	—	—	—	0.04	0.01	30	—
Methyl ethyl ketone							
West Germany (VDI 2306)	30.0	10.0	½	90.0	30.0	30	3, 4
Methyl isobutyl ketone							
West Germany (VDI 2306)	20.0	5.0	½	65.0	15.0	30	3, 4
Methyl mercaptan							
Bulgaria, USSR, Yugoslavia	—	—	—	9×10^{-6}	—	30	—
East Germany	—	—	—	10^{-5}	—	30	1
Methyl methacrylate							
Bulgaria, USSR Yugoslavia	0.1	0.025	24	0.1	0.025	30	—
East Germany	0.1	0.025	24	0.3	0.075	30	1
Israel	0.2	0.05	24	0.6	0.15	30	6
Methylparathion							
Bulgaria, USSR, Yugoslavia	—	—	—	0.008	—	30	46
Methylene chloride							
West Germany (VDI 2306)	20.0	5.0	½	55.0	15.0	30	3, 4
α-Methylstyrene							
Bulgaria, USSR, Yugoslavia	0.04	0.01	24	0.04	0.01	30	—
East Germany	0.03	0.0075	24	0.05	0.0125	30	1
Monoethylamine							
East Germany	0.01	0.005	24	0.03	0.015	30	1
West Germany (VDI 2306)	0.02	0.01	½	0.06	0.03	30	3, 4
USSR	0.01	0.005	24	0.01	0.005	30	—
Monomethylaniline							
Bulgaria	—	—	—	0.04	0.009	30	—
East Germany	0.03	0.007	24	0.05	0.01	30	1
Naphthalene							
East Germany	0.001	0.0002	24	0.003	0.0006	30	1
USSR	0.003	0.0006	24	0.003	0.0006	30	—
West Germany (VDI 2306)	2.5	0.5	½	7.5	1.5	30	3, 4
α-Naphthaquinone							
Bulgaria, USSR, Yugoslavia	0.005	0.001	24	0.005	0.001	30	2
East Germany	0.002	0.0004	24	0.005	0.001	30	1
Nitric acid							
Bulgaria, USSR, Yugoslavia	0.006	0.0024	24	0.006	0.0024	30	2, 3
Bulgaria, Yugoslavia	—	—	—	0.4	0.16	30	47
Czechoslovakia	—	—	—	0.01	0.004	30	38
East Germany	0.06	0.024	24	0.14	0.056	30	1
Hungary	1.3	0.5	24	2.6	1.0	30	—
	0.4	0.16	24	0.4	0.16	30	5
Israel	0.42	0.17	24	1.3	0.5	30	6
USSR	0.4	0.16	24	0.4	0.16	30	47
West Germany (VDI 2106)	1.3	0.5	½	2.6	1.0	30	3, 40
Nitrobenzene							
Bulgaria	—	—	—	0.04	0.008	30	—
East Germany	0.005	0.001	24	0.01	0.002	30	1
Hungary	0.3	0.06	24	0.85	0.17	30	—
	0.008	0.0016	24	0.08	0.016	30	5
USSR, Yugoslavia	0.008	0.0016	24	0.008	0.0016	30	—
West Germany (VDI 2306)	0.3	0.005	½	0.85	0.15	30	3, 4

Table VIII.9. **(Continued)**

	Long-term standard[a]			*Short-term standard*[a]			
Substance and country	*mg/m³*	*ppm*	*Averaging time (hours)*	*mg/m³*	*ppm*	*Averaging time (minutes)*	*Notes*[b]
o-Nitrochlorobenzene							
East Germany	*0.004*	—	24	*0.008*	—	30	1
p-Nitrochlorobenzene							
East Germany	*0.004*	—	24	*0.008*	—	30	1
o- and *p*-Nitrochlorobenzene							
USSR	*0.004*	—	24	—	—	—	—
Nitrogen dioxide							
Argentina	—	—	—	0.85	*0.45*	60	—
Bulgaria, Hungary, USSR, Yugoslavia	*0.085*	0.045	24	*0.085*	0.045	30	2, 5
Canada—Desirable level	0.06	0.03	1 yr	—	—	—	15.16
Acceptable level	0.1	0.05	1 yr	0.4	0.21	60	15.17
Acceptable level	0.2	0.11	24	—	—	—	15.17
Czechoslovakia, Romania, West Germany	*0.1*	0.05	24	*0.3*	0.16	30	—
Finland	*0.2*	0.1	24	*0.56*	0.3	30	71
Hungary	*0.15*	0.08	24	*0.5*	0.27	30	—
Japan	0.04	*0.02*	24	—	—	—	19
Nitrogen monoxide							
West Germany	*0.4*	—	½	*0.8*	—	30	—
Nitrogen oxides							
Argentina	0.9	*0.45*	1	—	—	—	49
East Germany	*0.004*	0.002	24	*0.1*	0.06	30	1, 49
Hungary	*0.15*	0.075	24	*0.5*	0.25	30	49
	0.05	0.025	24	*0.15*	0.075	30	5, 49
Israel	0.6	*0.3*	24	1.0	*0.5*	30	49
Italy	0.2	*0.1*	24	0.6	*0.3*	30	18, 49
Poland	*0.2*	0.1	24	*0.6*	0.3	20	49
	0.05	0.025	24	*0.15*	0.075	20	10, 49
Spain	*0.2*	0.1	24	*0.4*	0.2	30	20, 49
United States	*0.1*	0.05	1 yr	—	—	—	21, 37, 49
West Germany (VDI 2105)	*1.0*	0.5	½	*2.0*	1.0	30	3, 41, 49
Nitrogen pentoxide							
Yugoslavia	*0.1*	—	24	*0.3*	—	30	—
Oxidants							
Argentina	—	—	—	0.2	*0.1*	60	51
Canada—Acceptable level	*0.05*	*0.025*	24	*0.16*	*0.08*	60	15, 17, 51
Acceptable level	*0.03*	*0.015*	1 yr	—	—	—	15, 17, 51
Desirable level	*0.03*	*0.015*	24	*0.1*	*0.05*	60	15, 16, 51
Israel	0.2	*0.1*	8	0.4	*0.2*	30	51
Japan	—	—	—	0.12	*0.06*	60	50
Romania	*0.03*	0.015	24	*0.1*	0.05	30	51
United States	—	—	—	*0.16*	*0.08*	60	21, 37, 51
Ozone							
Israel	0.1	*0.05*	24	0.2	0.1	30	6
Pentane							
Bulgaria, East Germany, USSR, Yugoslavia	*25.0*	8.5	24	*100.0*	33.9	30	1
Perchlorethylene							
West Germany (VDI 2306)	*35.0*	*5.0*	½	*110.0*	*15.0*	30	3, 4
Phenol							
Bulgaria, Hungary, Yugoslavia	*0.01*	0.0026	24	*0.01*	0.0026	30	5
Czechoslovakia	*0.1*	0.026	24	*0.3*	0.079	30	—
East Germany	*0.01*	0.0026	24	*0.03*	0.0079	30	1
Hungary	*0.2*	0.052	24	*0.6*	0.16	30	—
Israel	0.1	*0.025*	24	0.3	*0.075*	30	6
Poland	*0.01*	0.0026	24	*0.02*	0.0052	20	9
	0.003	0.0008	24	*0.01*	0.0026	20	10

able VIII.9. ***(Continued)***

Substance and country	*Long-term standard*[a]			*Short-term standard*[a]			*Notes*[b]
	mg/m^3	*ppm*	*Averaging time (hours)*	*mg/m^3*	*ppm*	*Averaging time (minutes)*	
Romania	*0.03*	0.0079	24	*0.1*	0.026	30	—
USSR	*0.01*	0.0026	24	*0.01*	0.0026	20	2
West Germany (VDI 2306)	*0.2*	*0.05*	½	*0.6*	*0.15*	30	3, 4
Phosphoric acid							
Romania	*0.1*	—	24	*0.3*	—	30	—
Phosphoric anhydride							
East Germany	*0.05*	0.0085	24	*0.15*	0.026	30	1
Israel	0.1	*0.017*	24	0.05	*0.0085*	30	6
Phosphorus pentoxide							
USSR, Yugoslavia	*0.05*	0.0085	24	*0.15*	0.026	30	—
Phthalic anhydride							
Bulgaria	*0.1*	0.015	24	*0.2*	0.03	30	—
East Germany	*0.03*	0.005	24	*0.1*	0.015	30	1
USSR	*0.1*	0.015	24	*0.1*	0.015	30	2, 14
Yugoslavia	*0.2*	0.03	24	*0.4*	0.06	30	—
Propane-2-ol							
USSR	*0.6*	—	24	*0.6*	—	30	—
Propanol							
Bulgaria	—	—	—	*0.3*	0.12	30	—
East Germany	*0.3*	0.12	24	*1.0*	0.36	30	1
USSR, Yugoslavia	*0.3*	0.12	24	*0.3*	0.12	30	—
West Germany (VDI 2306)	*50.0*	*20.0*	½	*150.0*	*60.0*	30	3, 4
Propyl-isobenzene hydroxide							
Yugoslavia	*0.007*	—	24	*0.007*	—	30	—
Propylene							
Bulgaria, USSR	*3.0*	1.5	24	*3.0*	1.5	30	2
East Germany	*2.0*	1.0	24	*3.0*	1.5	30	1
Pyridine							
Bulgaria, USSR, Yugoslavia	*0.08*	0.023	24	*0.08*	0.023	30	—
East Germany	*0.03*	0.009	24	*0.08*	0.023	30	1
Romania	*0.05*	0.014	24	*0.15*	0.04	30	—
West Germany (VDI 2306)	*0.7*	*0.2*	½	*2.1*	*0.6*	30	3, 4
Silica							
Italy	*0.02*	—	24	*0.1*	—	120	18
Soot							
Bulgaria, Czechoslovakia, East Germany, Romania, USSR	*0.05*	—	24	*0.15*	—	30	1
Hungary	*0.1*	—	24	—	—	—	—
	0.05	—	24	—	—	—	5
Israel	*0.1*	—	24	*0.3*	—	30	6
Styrene							
Bulgaria, Hungary, USSR, Yugoslavia	*0.003*	0.0007	24	*0.003*	0.0007	30	5
East Germany	*0.003*	0.0007	24	*0.01*	0.0023	30	1
Hungary	*20.0*	4.6	24	*50.0*	11.7	30	—
West Germany (VDI 2306)	*20.0*	*4.6*	½	*65.0*	*15.16*	30	3, 4
Sulfur dioxide							
Argentina	*0.07*	*0.03*	30 days	—	—	—	—
Belgium, Spain	*0.15*	*0.06*	1 yr	—	—	—	20, 76
Bulgaria, USSR	*0.05*	0.02	24	*0.5*	0.2	30	2
Canada—Acceptable level	*0.06*	*0.02*	1 yr	—	—	—	15, 17
Acceptable level	*0.3*	*0.11*	24	*0.9*	*0.34*	60	15, 17
Desirable level	*0.03*	*0.01*	1 yr	—	—	—	15, 16
Desirable level	*0.15*	*0.06*	24	*0.45*	*0.17*	60	15, 16
Columbia	*0.07*	0.03	1 yr	—	—	—	70
Czechoslovakia, East Germany, Hungary, West Germany, Yugoslavia	*0.15*	0.06	24	*0.5*	0.2	30	1, 5

Table VIII.9. *Continued)*

	Long-term standard^a			*Short-term standard*^{a}			
Substance and country	*mg/m^3*	*ppm*	*Averaging time (hours)*	*mg/m^3*	*ppm*	*Averaging time (minutes)*	*Notes*^{b}
Finland	*0.25*	0.1	24	*0.72*	0.28	30	71
	0.18	0.07	1 yr	—	—	—	71
France	*1.0*	0.38	24	—	—	—	—
Hungary	*0.5*	0.2	24	*1.0*	0.38	30	—
Israel	0.26	*0.1*	24	0.75	*0.3*	30	—
Italy	0.38	*0.15*	24	0.75	*0.3*	30	18
Japan	0.1	*0.04*	24	0.26	*0.1*	60	19
Netherlands	*0.075*	0.03	24	—	—	—	52, 53
	0.25	0.1	24	—	—	—	52, 54
	0.35	0.13	24	—	—	—	56, 57
	0.125	0.05	24	—	—	—	56, 58
	0.275	0.1	24	—	—	—	56, 59
Netherland, Turkey	*0.15*	0.06	24	—	—	—	55, 56, 63, 64
Poland	*0.35*	0.13	24	*0.9*	0.35	20	9
	0.075	0.03	24	*0.25*	0.1	20	10
Romania	*0.25*	0.1	24	*0.75*	0.3	20	—
Spain	*0.4*	0.15	24	*0.8*	0.3	30	20
	0.256	0.1	30 days	—	—	—	20
Sweden	*0.25*	*0.1*	24	*0.625*	*0.25*	30	60
	0.125	*0.05*	30 days	—	—	—	60
Switzerland	*0.75*	0.3	24	*1.25*	0.5	30	62
Switzerland, West Germany (VDI 2108)	*0.5*	0.2	24	*0.75*	0.3	30	3, 40, 61
Turkey	*0.30*	0.12	24	—	—	—	63, 65
United States	*0.08*	0.03	1 yr	—	—	—	66
	0.365	0.14	24	—	—	—	37, 66
	1.3	0.5	3	—	—	—	37, 67
West Germany	*0.4*	0.15	½	*0.75*	0.3	30	—
Sulfuric acid							
Bulgaria, Romania, USSR, Yugoslavia	*0.1*	—	24	*0.3*	—	30	2, 68
Bulgaria, Yugoslavia	*0.006*	—	24	*0.006*	—	30	38
Czechoslovakia	—	—	—	*0.01*	—	30	38
East Germany	*0.02*	—	24	*0.05*	—	30	1
Hungary, Israel	*0.1*	—	24	*0.3*	—	30	6
Poland	*0.1*	—	24	*0.3*	—	20	9
	0.05	—	24	*0.15*	—	20	10
USSR	*0.002*	—	24	*0.006*	—	30	2, 38
Suspended particulates							
Argentina	*0.15*	—	30 days	—	—	—	—
Bulgaria, Czechoslovakia, East Germany, Finland, Romania, USSR	*0.15*	—	24	*0.5*	—	30	1, 71, 73
Canada—Acceptable level	*0.07*	—	1 yr	—	—	—	15, 17, 69
Acceptable level	*0.12*	—	24	—	—	—	15, 17
Canada (Desirable level), United States,	*0.06*	—	1 yr	—	—	—	15, 16, 67, 69
Colombia	*0.1*	—	24	—	—	—	70
Hungary	*0.2*	—	24	—	—	—	15, 17
Hungary, Turkey, United States	*0.15*	—	24	—	—	—	5, 63, 64, 67
Israel	*0.2*	—	24	—	—	—	—
Israel, United States	*0.075*	—	1 yr	—	—	—	66
Italy	*0.3*	—	24	*0.75*	—	120	18
Japan	*0.1*	—	24	*0.2*	—	60	19
Poland	*0.2*	—	24	*0.6*	—	20	9, 72
	0.075	—	24	*0.2*	—	20	10, 72
Spain	*0.13*	—	1 yr	—	—	—	20
	0.202	—	30 days	—	—	—	20
	0.3	—	24	*0.6*	—	30	20

le VIII.9 *(Continued)*

Substance and country	*Long-term standard*ᵃ *mg/m³*	*ppm*	*Averaging time (hours)*	*Short-term standard*ᵃ *mg/m³*	*ppm*	*Averaging time (minutes)*	*Notes*ᵇ
Sweden	—	—	—	*0.1*	—	60	73
United States	*0.26*	—	24	—	—	—	66
West Germany	—	—	—	*0.48*	—	30	73
	0.1	—	½	*0.3*	—	30	—
Tar							
Israel	*1.0*	—	24	*3.0*	—	30	6
Tetrachloromethane							
Bulgaria	—	—	—	*4.0*	—	30	—
Tetrahydrofuran							
East Germany	*0.2*	0.07	24	*0.6*	0.21	30	1
USSR	*0.2*	0.07	24	*0.2*	0.07	30	—
West Germany (VDI 2306)	*30.0*	*10.0*	½	*90.0*	*30.0*	30	3, 4
Thiophene							
Bulgaria, USSR, Yugoslavia	—	—	-	*0.6*	0.17	30	—
East Germany	*0.2*	0.06	24	*0.6*	0.17	30	1
Toluene							
Bulgaria, East Germany, Hungary, USSR, Yugoslavia	*0.6*	0.16	24	*0.6*	0.16	30	1, 5.
Hungary	*20.0*	5.3	24	*50.0*	13.3	30	—
West Germany (VDI 2306)	*20.0*	*5.0*	½	*60.0*	*15.0*	30	3, 4
Toluene diisocyanate							
Bulgaria, East Germany, Romania, USSR, Yugoslavia	*0.02*	0.0029	24	*0.05*	0.0071	30	1
West Germany (VDI 2306)	*0.009*	*0.001*	½	*0.021*	*0.003*	30	3, 4
Tributyl phosphate							
Bulgaria	—	—	—	*0.01*	—	30	1 —
USSR	*0.01*	—	24	*0.01*	—	30	—
Trichlorfon							
USSR	*0.02*	—	24	*0.04*	—	30	74
Trichloroethane							
West Germany (VDI 2306)	*30.0*	*5.0*	½	*90.0*	*15.0*	30	3, 4
Trichlorethylene							
Bulgaria, East Germany, USSR, Yugoslavia	*1.0*	0.18	24	*4.0*	0.74	30	1
Hungary	*30.0*	5.6	24	*50.0*	9.3	30	—
	0.2	0.04	24	*0.2*	0.04	30	5
West Germany (VDI 2306)	*30.0*	*5.0*	½	*90.0*	*15.0*	30	3, 4
Triethylamine							
East Germany	*0.05*	0.012	24	*0.14*	0.035	30	1
USSR	*0.14*	0.035	24	*0.14*	0.035	30	—
West Germany (VDI 2306)	*0.04*	*0.01*	½	*0.12*	*0.03*	30	3, 4
2,4,6-Trimethylaniline							
East Germany	*0.003*	—	24	*0.01*	—	30	1, 75
Turpentine							
West Germany (VDI 2306)	*25.0*	*5.0*	½	*75.0*	*15.0*	30	3, 4, 41
n-Valeric acid							
Bulgaria, East Germany, USSR, Yugoslavia	*0.01*	0.003	24	*0.03*	0.008	30	1
Vanadium pentoxide							
Bulgaria, East Germany, USSR	*0.002*	—	24	—	—	—	—
Czechoslovakia, Yugoslavia	*0.003*	—	24	—	—	—	—
Vinyl acetate							
Bulgaria, Czechoslovakia, Yugoslavia	*0.2*	0.006	24	*0.2*	0.006	30	—
East Germany	*0.15*	0.0045	24	*0.4*	0.012	30	1
Israel	4.0	*1.0*	24	12.0	*3.0*	30	6
USSR	*0.15*	0.0045	24	*0.15*	0.0045	30	—
West Germany (VDI 2306)	*20.0*	*5.0*	½	*60.0*	*15.0*	30	3, 4
Xylene							
Bulgaria, Hungary, USSR, Yugoslavia	*0.2*	0.05	24	*0.2*	0.05	30	5
East Germany	*0.2*	0.05	24	*0.6*	0.14	30	1
Hungary	*20.0*	4.6	24	*50.0*	11.5	30	—
West Germany (VDI 2306)	*20.0*	*5.0*	½	*60.0*	*15.0*	30	3, 4

[a] Italicized concentrations represent the standards listed in promulgated regulations; those not italicized are approximate conversions.

[b] NOTES:

1. Short-term averaging time 10–30 minutes for East Germany.
2. In USSR:

   A. If several substances with synergistic toxic properties are present in the air, the maximum permissible concentration (MPC) of the mixture is calculated from the formula $X = (A/M_1) + (B/M_2) + (C/M_3)$, where X is the (relative) MPC; A, B, C are the concentrations of the substances in the mixture, and M_1, M_2, M_3, are their respective maximum permissible concentrations.

   B. If this formula is applied to the following two, three, or four component systems, the value X should not exceed 1.0 for (a) acetone and phenol; (b) sulfur dioxide and phenol; (c) sulfur dioxide and nitrogen dioxide; (d) sulfur dioxide and hydrogen fluoride; (e) sulfur dioxide and sulfuric acid aerosol; (f) hydrogen sulfide and "dinyl"; (g) isopropyl benzene and isopropyl benzene hydroperoxide; (h) furfural, methanol, and ethanol; (i) strong mineral acids (sulfuric, hydrochloric and nitric—concentrations expressed as H^+); and (j) ethylene, propylene, butylene and amylene. The value X should not exceed 1.3 for acetic acid and acetic anhydride, and should not exceed 1.5 for (a) acetone and acetophenone, (b) benzene and acetophenene, (c) phenol, and acetophenone.

   C. If (a) hydrogen sulfide and carbon disulfide; (b) carbon monoxide and sulfur dioxide; (c) phthalic anhydride, maleic anhydride and α-naphthoquinone are present in the mixture, the MPC values of individual substances should not be exceeded.

   D. If *p*-chlorophenyl isocyanate is present together with *m*-chlorophenyl isocyanate, the MPC is determined by the presence of the more toxic substance, i.e., of *p*-chlorophenyl isocyanate.
3. VDI = Verein Deutscher Ingenieure—Kommission Reinhaltung der Luft, VDI-Verlag GmbH, Duesseldorf, Federal Republic of Germany.
4. Short term = Short-term exposure limit, not to be exceeded more than once in any 4 hours in West Germany.
5. Highly protected and protected areas in Hungary.
6. Tentative standards in Israel.
7. Also the inorganic compounds, except arsine, AsH_3.
8. As AsH_3.
9. Protected areas in Poland.
10. Specially protected areas in Poland.
11. As C.
12. Listed in Regulations as <10% aromatics.
13. Also benzine from oil shale.
14. Fumes and aerosols.
15. National Air Quality Objectives in Canada.
16. Desirable level in Canada.
17. Maximum acceptable level in Canada.
18. Once in 8 hours in Italy.
19. Average of hourly means for 24 hour value in Japan.
20. Proposed standard in Spain.
21. Primary and secondary ambient air quality standards in the United States.
22. 0.6 mg/m³ once as a 30 minutes average in a time period of 8 hours in West Germany.
23. Also called trichloromethane.
24. Also called aureomycin.
25. For mixing with animal feed.
26. As Cr_6.
27. As CrO_3.
28. Diphenyl plus its oxide.
29. HF, SiF_4.
30. As F, gaseous compounds.
31. Gaseous plus salt combined.
32. As HF.
33. NaF, Na_2SiF_6.
34. AlF_3, $NaAlF_6$, CaF_2.
35. Readily soluble inorganic fluoride.
36. As hexane, for hydrocarbons emitted by oil refineries.
37. Not to be exceeded more than once a year.
38. As H^+.
39. As HCl.
40. Short-term standard not to be exceeded more than once in 2 hours in West Germany.
41. Short-term standard = short-term exposure limit, not to be exceeded more than once in any 8 hours.
42. Lead and its compounds, except tetraethyllead.
43. As MnO_2.
44. 2-Amino-1,3,5-trimethylbenzene.
45. Also called Carbophos.
46. Also called Metaphos.
47. As HNO_3.
48. Diethylene dioxide.
49. As NO_2.
50. By KI.
51. As O_3.
52. For areas with low smoke level.
53. Percentile of the cumulative frequency distribution of consecutive 24 hour samples: 50%.
54. Percentile of the cumulative frequent distribution of consecutive 24 hour samples: 38%.
55. Soot level <0.03 mg/m³, frequency 50% in Netherlands.
56. Interim limit value in Netherlands for areas designated by commission.
57. Soot level <0.09 mg/m³, frequency 98%.
58. Soot level <0.04 mg/m³, frequency 50%.
59. Soot level <0.125 mg/m³, frequency 98%.
60. Guideline.
61. Summer—March 1–October 31 guideline in Switzerland.
62. Winter—November 1–February 28/29 guideline.
63. Recommended standard in Turkey.
64. Residential areas in Turkey.
65. Industrial areas.
66. Primary standard in United States.
67. Secondary standard in United States.
68. As H_2SO_4.
69. Annual geometric mean.
70. Reference level.
71. Not national legal norms, communal health councils can enforce them.
72. Particle size <20 μm.
73. Basis for stack height calculation.
74. Also called Chlorophos.
75. Also called Mesidine.
76. Protected area in Belgium.

Not shown in Table VIII.9. are the air quality standards for sulphur dioxide and suspended particulates as proposed by the EEC in February, 1976. These are given in Table VIII.10 (Commission of The European Communities, 1976).

Table VIII.10 - Health Protection Standards for Sulphur Dioxide and Suspended Particulates in Urban Atmospheres

Sulphur dioxide:

Reference Period	Maximum Concentrations ($\mu g/m^3$)	Associated Concentrations Suspended Particulates ($\mu g/m^3$)
Year	80 (1)	>40 (1)
Year	120 (1)	<40 (1)
October - March	130 (1)	>60 (1)
October - March	180 (1)	<60 (1)
24 hours	250 (2)	>100 (2)
24 hours	350 (2)	<100 (2)

Suspended Particulates:

Reference Period	Maximum Concentrations ($\mu g/m^3$)
Year	80 (1)
October - March	130 (1)
24 hours	250 (1)

(1) Median of daily means (2) Arithmetic mean

During the period 1982-1987 in the event of unfavourable meteorological conditions, concentrations exceeding the daily levels set out in Table VIII.10. may be tolerated provided this does not happen for more than three consecutive days and daily levels do not exceed the 'exceptional concentrations' set out in Table VIII.11 (Commission of the European Communities, 1976).

Table VIII.11 - Exceptional Concentrations for Sulphur Dioxide and Suspended Particulates in Urban Atmospheres

Sulphur dioxide:

Reference period	Maximum concentrations* ($\mu g/m^3$)	Associated concentrations* of suspended particulates ($\mu g/m^3$)
24 hours	350	>100 $\mu g/m^3$
24 hours	500	<100 $\mu g/m^3$

Suspended Particulates: *Concentrations are daily average values

Reference period	Maximum concentrations*
24 hours	300 $\mu g/m^3$

The variation between standards, which is readily apparent from Table VIII.9. can be further highlighted by comparing, as in Figure VIII.3., sulphur dioxide standards from selected countries. The fact that the data bases for these standards (except those for the USSR and Czechoslovakia) are the same, again demonstrates that standards are in general politically rather than scientifically based (Newill, 1977).

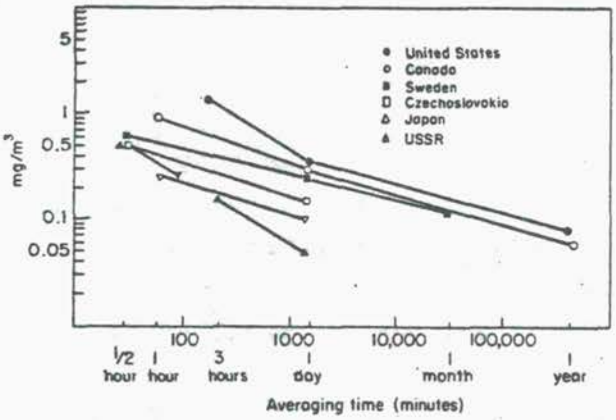


Figure VIII.3. National ambient air quality standards (mg/m^3) for selected countries for various averaging times (Newill, 1977)

It should be noted in Table VIII.9. and Figure VIII.3. that there are several ways of expressing a standard e.g. as a maximum, a mean or a value related to the frequency of occurrence (percentile), and that standards are often set on widely different timescales. However, interconversion of such values is an extremely complicated task. To effectively compare standards also requires a knowledge of any specified methods of measurement and assessment ("reference methods")including details on accuracy, specificity, limits of detection, etc.

There are a number of advantages and disadvantages in using air quality standards as a means of controlling air pollution - the "air quality management" philosophy. This approach has the advantage that the general public knows the limits of air pollution to which it might be exposed. It also has the virtue of concentrating pollution control expenditures in the areas with the worst pollution problems and allowing higher emission rates (and lower pollution control expenditures) in areas with less serious problems. This does mean however that air tends to be polluted up to the limit set by the standard. The flexibility of the approach is quite good in that administering bodies can normally select those methods it considers best from the many available for meeting the standards. However, if standards are revised then this will probably require a complete new set of regulations which could be expensive and time-consuming.

The main disadvantages of ambient air quality standards are that a fairly substantial monitoring network is required and that when the standard is exceeded it may not be easy to identify the source of pollution. Ambient air concentrations of pollutants are influenced by a wide variety of emitters, some nearby and some far away. The connection between emissions and air quality at a given point depends on the meteorological transport and dispersion of pollutants and atmospheric reactions of the pollutants. However, neither of these subjects is understood sufficiently to allow unequivocal calculations of the contributions of individual emitters to specific location concentrations in urban areas. This difficulty in enforcement often leads to the adoption of non-selective control measures.

VIII.3.2. Emission standards

Emission standards for stationary sources are limits specifying maximum allowable levels of pollutants in discharges from a site, process, chimney, vent, etc. with the intention of helping achieve a desired air quality. As with ambient air quality standards, emission standards are often a reflection of not only technological (i.e. process and equipment) considerations but also economic, sociological and political considerations. Emission standards may be either officially promulgated, i.e. legally prescribed, or "presumptive" which means that, although they have not gone through a formal promulgation procedure, they are used by control agencies in reviewing plans and specifications for new installations and testing existing ones.

In the study of information from 87 countries referred to above, it was found that 17 countries had emission standards covering a total of 42 substances (Martin and Stern, 1974). These standards are shown in Table VIII.12 (standards for particulate emissions) and Table VIII.13. (standards for emissions of pollutants other than particulates). As can be seen, the standards may be related to a unit of feed or product of a given industry or based upon the volume of gas generated.

The use of emission standards in an air pollution control programme (the "emission standards philosophy")has a number of advantages and disadvantages. As the standards relate to the point of discharge of the pollution, once the standards have been set and test methods defined, it is relatively simple to sample, analyse and determine compliance of individual emitters. In addition, violation criteria and penalty schedules can easily be formulated. However, in some forms the emission standards philosophy is not very cost-effective. For example, the application of the same, uniform emission standards to an emitter in a rural location and an emitter in the centre of an industrial, densely populated area may, if the standard is stringent, cause the rural plant to make a large expenditure with a small reduction in damage to receivers and hence a small benefit. Conversely, if the standard is lax, the plants in the urban area may not be controlled to the degree which minimizes the damage to the surrounding environment. Similarly, the costs of rigorously pursuing a philosophy of always using the "best technology" to produce the lowest possible emission rate to produce, in turn, the cleanest possible air, may eventually far outweigh the benefits accrued.

For these reasons, the emission standards philosophy is often applied in forms which take costs and/or the location of the source into account, e.g. the "best reasonable technology" and "best practicable means" approaches. Even if the permitted pollutant discharge is related to the cost of pollution control equipment, an overriding consideration must always be the subsequent effect of the discharge on ambient air quality. However, the latter is a complex calculation involving factors such as chimney height, physical and chemical properties of the emissions, meteorological conditions, local topography and the contributions from other sources in the area. The use of computer techniques can be of great assistance in this area.

Table VIII.12

National Emission Standards for Particulate Matter in Effluent Air or Gas from Stationary Sources[a] (Newill , 1977)

Source	Countries	Standard		Notes
		Original units	*mg/m³*	
All	Australia; New Zealand	0.25 gm/m³	250.0	1, 2, 3, 4, 5
	Czechoslovakia	5.0 kg/hour	—	6
	East Germany	—	—	7
	Israel	—	—	12
	Mexico	—	—	9
	Philippines	0.40 grains/ft³	915.3	10
	Singapore	0.40 gm/m³	400.0	11
	West Germany	—	—	8
Arctic mining plants	Canada	0.04 gm/m³	40.0	—
Combustion of fuels				
All fuels	Great Britain	—	—	13
>10⁶ kcal/hour	Italy	0.25 gm/m³	250.0	14
Home heating	Spain	1.2 gm/1000 kcal	—	—
Steam power plants	United States	0.10 pound/MMBTU	—	—
Bark burning				
Kraft pulp mills	Sweden	mg/m³	250.0	15
Blast furnace gas burning	West Germany	mg/m³	50.0	—
Central stations				
>20% ash	Belgium	mg/m³	500.0	—
<20% ash	Belgium	mg/m³	350.0	—
Boiler	Japan—special	0.20 gm/m³	200.0	20
	Japan—other	0.40 gm/m³	400.0	—
>40 MMkcal/hour	Mexico	1.0 kg/MMkcal	—	—
<40 MMkcal/hour	Mexico	1.5 kg/MMkcal	—	—
<1000 kg/hour	Switzerland	mg/m³	75.0	21, 22
>1000 kg/hour	Switzerland	mg/m³	150.0	21, 22
>1000 kg/hour	Switzerland	mg/m³	100.0	23
Coal burning	Australia	0.25 gm/m³	250.0	4, 5, 16, 17
<20% ash coal	France	0.35 gm/m³	350.0	—
>20% ash coal	France	0.50 gm/m³	500.0	—
Domestic heating	Belgium	mg/m³	300.0	—
	Special protection zone	mg/m³	150.0	—
Mixed burning	Switzerland	mg/m³	100.0	21
Oil burning				
>2000 therms/hour	Belgium	mg/therm	250.0	—
<100 MW	Denmark	2.0 gm/kg oil	—	25
<300 MW	Denmark	1.5 gm/kg oil	—	—
>300 MW	Denmark	1.0 gm/kg oil	—	—
>63 MMkcal/hour	Mexico	45.0 gm/MMkcal	—	—
<63 MMkcal/hour	Mexico	80.0 gm/MMKcal	—	—
>50 MW	Sweden	1.5 g/kg oil	—	26, 27
>300 MW	Sweden	1.0 g/kg oil	—	28
>1000 kg/hour	Switzerland	mg/m³	50.0	29
Programmed soot blow	Switzerland	mg/m³	150.0	29
Hand soot blow	Switzerland	mg/m³	200.0	29
Heavy oil burning				
<40,000 m³/hour gas	Japan—special	0.20 gm/m³	200.0	20
<40,000 m³/hour gas	Japan—other	0.30 gm/m³	300.0	—
>40,000 m³/hour gas	Japan—special	0.05 gm/m³	50.0	20
40,000 to 200,000	Japan—other	0.20 gm/m³	200.0	—
>200,000 m³/hour gas	Japan—other	0.10 gm/m³	100.0	—
Solid fuel burning	Czechoslovakia	—	—	30
<30 MW (new)	Denmark	mg/m³	300.0	24
<30 MW (existing)	Denmark	mg/m³	500.0	24
>100 MW (All)	Denmark	mg/m³	150.0	24, 89
30-100 MW (All)	Denmark	—	—	24
	West Germany	mg/m³	300.0	31

Table VIII.12

(Continued)

Source	Countries	Standard: Original units	Standard: mg/m^3	Notes
<500,000 m^3/hour	West Germany	mg/m^3	150.0	31
>500,000 m^3/hour				
Brown coal	West Germany	mg/m^3	100.0	31
Hard coal	West Germany	mg/m^3	150.0	31
Incineration of refuse				
<300 kg/hour	Australia; New Zealand	0.50 gm/m^3	500.0	3, 4, 5, 16
>300 kg/hour	Australia; New Zealand	0.25 gm/m^3	250.0	3, 4, 5, 16
General	Belgium	mg/m^3	150.0	35
<1 ton/hour	France	1.0 gm/m^3	1000.0	35, 38, 39
1–4 tons/hour	France	0.60 gm/m^3	600.0	35, 38, 39
4–7 tons/hour	France	0.25 gm/m^3	250.0	35, 38, 39
>7 tons/hour	France	0.15 gm/m^3	150.0	35, 38, 39
Continuous furnace				
<40,000 m^3/hour	Japan—other	0.7 gm/m^3	700.0	—
>40,000 m^3/hour	Japan—other	0.2 gm/m^3	200.0	—
<40,000 m^3/hour	Japan—special	0.2 gm/m^3	200.0	20
>40,000 m^3/hour	Japan—special	0.1 gm/m^3	100.0	20
Other furnaces				
<40,000 m^3/hour	Japan—other	0.70 gm/m^3	700.0	—
>40,000 m^3/hour	Japan—other	0.40 gm/m^3	400.0	—
Batch operation	Japan—special	0.40 gm/m^3	400.0	43
	Japan—other	0.70 gm/m^3	700.0	—
>15 tons/hour	Sweden	mg/m^3	180.0	15, 40, 41
<15 tons/hour	Sweden	mg/m^3	250.0	15, 40, 41
<3 tons/hour	Sweden	mg/m^3	500.0	15, 40, 42
<1 ton capacity	Switzerland	0.20 gm/m^3	200.0	35
1–5 tons capacity	Switzerland	0.15 gm/m^3	150.0	35
>5 tons capacity	Switzerland	0.10 gm/m^3	100.0	35
Municipal incinerators	United States	0.08 grains/ft^3	80.0	16
Sewage sludge incinerators	United States	mg/m^3	70.0	15, 44
General	West Germany	mg/m^3	100.0	19
With component recovery	West Germany	mg/m^3	100.0	35
Preparation facilities	West Germany	mg/m^3	150.0	—
Refuse shredding	West Germany	mg/m^3	100.0	—
Asphalt plants				
Asphalt paving plants	Canada	0.1 grains/scf	230.0	5
<500 m from house				
New	Denmark	mg/m^3	250.0	—
Existing	Denmark	mg/m^3	500.0	—
<1 km from community and more than 2 years in one location	Denmark	mg/m^3	5000.0	—
Hot-mixing plants	France	0.150 gm/m^3	150.0	45
	France	0.800 gm/m^3	800.0	46
All	France	2.0 gm/m^3	2000.0	32
≥200 tons/hour	France	0.150 gm/m^3	150.0	45, 47
<200 tons/hour	France	0.800 gm/m^3	800.0	45, 47
≥150 tons/hour	France	0.150 gm/m^3	150.0	45, 48
<150 tons/hour	France	0.500 gm/m^3	500.0	45, 48
>500 m from built-up area				
New	Sweden	mg/m^3	250.0	15, 39, 49
Existing	Sweden	mg/m^3	500.0	15, 49, 87
>1 km from a single house	Sweden	mg/m^3	5000.0	15, 50
All plants	United States	mg/m^3	70.0	15, 50
Asphalt concrete	West Germany	mg/m^3	100.0	51, 52
if feasible	West Germany	mg/m^3	75.0	52
Carbon black manufacture				
Wash tower	VDI 2580	mg/m^3	50.0	37

Table VIII.12

(Continued)

Source	*Countries*	*Standard* *Original units*	 *mg/m^3*	*Notes*
Wet gas filter	VDI 2580	mg/m^3	60.0	37, 53
With thermal after-burner	VDI 2580	mg/m^3	40.0	37
Thermal burning in boiler	VDI 2580	mg/m^3	50.0	37
Cement production				
Clinker coolers	Canada	0.6 pound/ton clinker	—	5, 83
	United States	0.10 pound/ton feed	—	—
Crushing, grinding (new)	Denmark	mg/m^3	250.0	—
Crushing, grinding (existing)	Denmark	mg/m^3	500.0	—
	Sweden	mg/m^3	250.0	15
Crushing, grinding (new)	Great Britain	0.10 grains/ft^3	22[illegible].0	39
Crushing, grinding (existing)	Great Britain	0.20 grains/ft^3	457.6	18
Crushing, grinding	West Germany	mg/m^3	150.0	54
Dust handling	Great Britain	0.20 pound/k pound gas	457.6	—
Finish grinding	Canada	0.1 pound/ton clinker	—	5, 83
Sources other than kiln, clinker cooler, finish grinding	Canada	0.2 pound/ton clinker	—	5, 83
Coal processing				
Briquetting plants	VDI 2292	0.15 gm/m^3	150.0	37
Preparation plants	VDI 2293	0.15 gm/m^3	150.0	37
Coke manufacture (metallurgical)				
Battery stacks	Canada	0.03 grains/scf	69.0	5, 83
Charging	Canada	100.0 gm/metric ton coke	—	5, 83, 87
Crushing and Screening	Canada	0.02 grains/scf	46.0	5
Pushing	Canada	0.02 grains/scf	46.0	5, 83
Quenching	Canada	50 gm/metric ton coke	—	5, 83, 88
Electrode manufacture	West Germany	mg/m^3	150.0	59
	VDI 2100	0.15 gm/m^3	150.0	37
Fluid catalyst regeneration	United States	mg/m^3	50.0	15, 58
Furnaces				
Calcination	West Germany	mg/m^3	150.0	55
Calcium carbide manufacture	West Germany	mg/m^3	150.0	—
Catalyst regeneration	Japan—special	0.40 gm/m^3	400.0	20
	Japan—other	0.60 gm/m^3	600.0	60
Drying				
Heat treatment				
>40,000 m^3/hour	Japan—special	0.10 gm/m^3	100.0	—
<40,000 m^3/hour	Japan—special	0.20 gm/m^3	200.0	—
Heat treatment				
>40,000 m^3/hour	Japan—other	0.20 gm/m^3	200.0	—
<40,000 m^3/hour	Japan—other	0.40 gm/m^3	400.0	—
Others	Japan	Same as reaction furnace		—
Expanding clay and slate	West Germany	mg/m^3	150.0	33, 56
Gas generating	Japan	Same as catalyst regeneration furnaces		—
Gas producing	Japan—special	0.10 gm/m^3	100.0	20, 61
	Japan—other	0.20 gm/m^3	200.0	61
Glass melting	West Germany	mg/m^3	150.0	—
Tank type	Japan	Same as reaction furnace		—
Other types	Japan	0.50 gm/m^3	500.0	—
Gypsum with filters	West Germany	mg/m^3	75.0	—
Petroleum heating	Japan	Same as gas producing		—
Reaction furnace				
<40,000 m^3/hour gas	Japan—special	0.20 gm/m^3	200.0	20
<40,000 m^3/hour gas	Japan—other	0.40 gm/m^3	400.0	—
>40,000 m^3/hour gas	Japan—special	0.10 gm/m^3	100.0	20
>40,000 m^3/hour gas	Japan—other	0.20 gm/m^3	200.0	—
Refinery combustion furnace	Japan	Same as gas producing		—

Table VIII.12

(Continued)

Source	Countries	Standard Original units	 mg/m^3	Notes
Kilns				
Cement (new)	Canada	0.91 pound/ton clinker	—	5
Cement (existing after 12/1/79)	Canada	1.6 pounds/ton clinker	—	5
Cement (new)	Denmark	mg/m^3	250.0	—
Cement (existing)	Denmark	mg/m^3	500.0	—
Cement	France	1.0 gm/m^3	1000.0	39, 63
<1500 tons/day	Great Britain	0.20 $grains/ft^3$	457.6	64
1500–3000	Great Britain	Sliding scale 0.1–0.2	—	—
>3000 tons/day	Great Britain	0.10 $grains/ft^3$	229.0	64
Cement (all plants)	Japan	Same as reaction furnace		—
Cement (all plants)	Spain	0.80 gm/m^3	800.0	—
Cement (all plants)	United States	0.30 pound/ton feed	—	—
High-resistivity dust	West Germany	mg/m^3	150.0	62
Low-resistivity dust	West Germany	mg/m^3	120.0	—
No electrostatic precipitator	West Germany	mg/m^3	75.0	—
Cement and lime				
<25 tons/hour product	Czechoslovakia	120.0 kg/hour	—	—
25–50 tons/hour product	Czechoslovakia	160.0 kg/hour	—	—
50–100 tons/hour product	Czechoslovakia	250.0 kg/hour	—	—
100–150 tons/hour product	Czechoslovakia	270.0 kg/hour	—	—
New plants	Denmark	mg/m^3	250.0	65
Existing plants	Denmark	mg/m^3	500.0	—
New plants	Sweden	mg/m^3	250.0	15, 65
Existing plants	Sweden	mg/m^3	500.0	15
New plants	Switzerland	mg/m^3	230.0	—
Existing plants	Switzerland	mg/m^3	155.0	—
Ceramic				
All types	West Germany	mg/m^3	150.0	33
Continuous	Japan	Same as drying, heat treatment		—
Other types	Japan—special	0.30 gm/m^3	300.0	20
	Japan—other	0.60 gm/m^3	600.0	—
Lime kilns at pulp mills	Sweden	mg/m^3	250.0	15, 65
Kraft pulp mills				
Recovery furnaces				
New plants	Sweden	mg/m^3	250.0	15, 65
Existing plants	Sweden	mg/m^3	500.0	66
Rock crushing	Denmark	mg/m^3	150.0	—
Sulfite pulp mills				
New plants	Denmark	mg/m^3	250.0	—
Existing plants	Denmark	mg/m^3	500.0	—
Trisodium phosphate manufacture	Japan	Same as reaction furnace		—
Metallurgical processes—ferrous and nonferrous				
Metal heating	Australia	0.10 gm/m^3	100.0	3, 4, 5, 17
	Japan	Same as reaction furnace		—
	New Zealand	0.10 gm/m^3	100.0	5
	Singapore	0.20 gm/m^3	200.0	4, 17
Metal melting	Japan	Same as reaction furnace		—
Metal smelting	Mexico	—	—	9, 67
Sintering plants	Japan—special	0.20 gm/m^3	200.0	20
<40,000 m^3	Japan—other	0.40 gm/m^3	400.0	—
>40,000 m^3	Japan—other	0.30 gm/m^3	300.0	—
Ferrous metallurgical processes				
Blast furnace gas				
Bled	West Germany	mg/m^3	20.0	—
Burned	West Germany	mg/m^3	50.0	68
Bessemer converters	Japan	Same as sintering plants		—

able VIII.12

(Continued)

Source	Countries	Standard		Notes
		Original units	mg/m^3	
Casting and shakeout				
>2,500 tons/year	Sweden	mg/m^3	150.0	15, 33
<2,500 tons/year	Sweden	mg/m^3	300.0	15, 74
Converters	Denmark, Sweden	0.3 kg/ton steel	—	90
Crucibles				
>2000 ton production/year	Denmark	—	—	92
Cupolas	West Germany	—	—	71
<2 ton capacity	France	2.0 kg/ton iron	—	39
2–10 ton capacity	France	kg/ton iron	—	39, 69
>10 ton capacity	France	kg/ton iron	—	39, 70
Existing plants	Sweden	kg/ton iron	—	73
New plants	Sweden	kg/ton iron	—	72
Upper limit	VDI 2288	2 kg/ton iron	—	37, 71
Sandblasting (foundry and nonfoundry)				
New plants	Denmark, Sweden	mg/m^3	150.0	—
Existing plants	Denmark	mg/m^3	300.0	—
Furnaces				
Blast	Great Britain	0.20 $grains/ft^3$	457.6	—
	Japan—special	0.05 gm/m^3	50.0	20
	Japan—other	0.10 gm/m^3	100.0	—
	Sweden	0.30 kg/ton iron	—	—
Electric arc				
New plants	Denmark	0.3 kg/ton steel	—	90
Existing plants	Denmark	1.0 kg/ton steel	—	91
New plants	Sweden	0.30 kg/ton steel	—	—
Existing plants	Sweden	0.60 kg/ton steel	—	—
All	United States	mg/m^3	12.0	—
	West Germany	mg/m^3	150.0	—
Ferroalloy				
>40% other metals	Japan—special	0.30 gm/m^3	300.0	20
	Japan—other	0.60 gm/m^3	600.0	—
<40% other metals	Japan—special	0.20 gm/m^3	200.0	20
	Japan—other	0.40 gm/m^3	400.0	—
Calcium silicon	United States	0.45 kg/MW-hour	—	—
Ferrosilicon				
Silicomanganese zirconium				
Silicon metal				
Calcium carbide	United States	0.23 kg/MW hour	—	—
Charge chrome				
Ferrochrome silicon				
Ferromanganese silicon				
High carbon ferrochrome				
Silicomanganese				
Silvery iron				
Standard ferromanganese				
All foundries	West Germany	mg/m^3	100.0	—
Ferrochromium affiné	Sweden	5.0 kg/ton alloy	—	—
Ferromolybdenum	Sweden	3.0 kg/ton alloy	—	—
Ferrosilicon				
New plants	Sweden	10 kg/ton alloy	—	93 —
Existing plants	Sweden	15 kg/ton alloy	—	93 —
Ferrosilicon manganese	Sweden	0.30 kg/ton alloy	—	39
Ferrochromsilicon				
New plants	Sweden	15.0 kg/ton alloy	—	—
Existing plants	Sweden	20.0 kg/ton alloy	—	—
Furnace (electric) ferroalloy				
Ferrochrome	VDI 2576	mg/m^3	250.0	37
Ferrosilicon				
15, 25 or 45% Silicon	VDI 2576	mg/m^3	200.0	37
75% or 90% Silicon	VDI 2576	mg/m^3	300.0	37

Table VIII.12

(Continued)

		Standard		
Source	*Countries*	*Original units*	*mg/m^3*	*Notes*
Ferrotungsten	VDI 2576	mg/m^3	150.0	37
Silicochromium	VDI 2576	mg/m^3	250.0	37
Silicon metal, 97% Silicon	VDI 2576	mg/m^3	300.0	37
Other furnaces				
Ferrochrom "affine"	VDI 2576	mg/m^3	200.0	37
Ferrochrom "surraffine"	West Germany	mg/m^3	150.0	37
Iron smelting	France	0.15 gm/m^3	150.0	39
Open hearth				
New plants	Denmark	0.5 kg/ton steel	—	90 —
Existing plants	Denmark	1 kg/ton steel	—	93 —
All plants	Japan—special	0.20 gm/m^3	200.0	20
>40,000 m^3/hour	Japan—other	0.30 gm/m^3	300.0	—
<40,000 m^3/hour	Japan—other	0.40 gm/m^3	400.0	—
New plants	Sweden	0.5 kg/ton steel	—	—
Existing plants	Sweden	1.0 kg/ton steel	—	—
Oxygen-steel processes	West Germany	mg/m^3	150.0	51
BOF	United States	mg/m^3	50.0	15, 44
Kaldo	Sweden	0.15 kg/ton steel	—	—
LD	Sweden	0.30 kg/ton steel	—	—
Blowing cycle	France	0.12 gm/m^3	120.0	39, 75
Loading ore	France	0.15 gm/m^3	150.0	39
Loading or pouring	France	0.12 gm/m^3	120.0	39
Refining processes	Great Britain	0.05 grains/ft^3	114.4	—
Miscellaneous grit and dust	Great Britain	0.20 grains/ft^3	457.6	—
Refining processes—no oxygen	Great Britain	0.20 grains/ft^3	457.6	—
Scarfing—oxygen	Great Britain	0.05 grains/ft^3	114.4	—
Scarfing	West Germany	mg/m^3	150.0	—
Sintering plants	France	0.50 gm/m^3	500.0	39, 76
Sintering plants	Great Britain	0.05 grains/ft^3	114.4	—
All plants	Japan—special	0.2 gm/m^3	200.0	20
>40,000 m^3/hour	Japan—other	0.3 gm/m^3	300.0	—
<40,000 m^3/hour	Japan—other	0.4 gm/m^3	400.0	—
Existing plants	Sweden	1.0 kg/ton sinter	—	—
New plants	Sweden	0.50 kg/ton sinter	—	—
Continuous operation	West Germany	mg/m^3	150.0	—
Special cases	West Germany	mg/m^3	300.0	77
Slag remelting	West Germany	mg/m^3	150.0	—
Nonferrous metallurgical processes				
Aluminum alloy production	West Germany	mg/m^3	75.0	—
New plants	Denmark	1 kg/ton product	—	—
Existing plants	Denmark, Sweden	1.5 kg/ton product	—	—
Aluminum reduction	West Germany	—	—	57
Alumina calcining	VDI 2286	mg/m^3	100.0	37
Alumina grinding	West Germany	mg/m^3	150.0	—
Primary reduction	West Germany	mg/m^3	75.0	—
	VDI 2286	0.10 gm/m^3	100.0	37
Secondary recovery				
Rotary furnaces	VDI 2441	—	—	37, 78
Other furnaces	VDI 2241	0.3 gm/m^3	300.0	37
Smelters	Great Britain	0.05 grains/ft^3	114.4	79
Brass and bronze ingots				
Blast cupola furnaces				
>250 kg/hour capacity	United States	—	—	44
Electric furnace				
>1000 kg/hour capacity	United States	—	—	44
Reverberatory furnaces				
>1000 kg/hour capacity	United States	mg/m^3	50.0	15, 44
Copper smelting				
New plants	Denmark, Sweden	2.0 kg/ton product	—	—
Existing plants	Denmark, Sweden	4.0 kg/ton product	—	—

Table VIII.12

(Continued)

Source	Countries	Standard		Notes
		Original units	*mg/m³*	
Primary				
Roasting, smelting, converting	United States	mg/m^3	50.0	—
Refining furnaces	VDI 2101	0.30 gm/m^3	300.0	37
Reverberatory furnaces	VDI 2101	0.30 gm/m^3	300.0	37
Shaft furnaces	VDI 2101	0.30 gm/m^3	300.0	37
Secondary				
Blast furnaces	VDI 2102	0.30 gm/m^3	300.0	37
Converters	VDI 2102	0.30 gm/m^3	300.0	37
Refining furnaces	VDI 2102	0.30 gm/m^3	300.0	37
Copper, lead, and zinc refining				
Blast furnaces	Japan	Same as reaction furnace		—
Bessemer converters	Japan	Same as sintering plants		—
Other types	Japan	Same as gas producing		—
Drying	Japan	Same as reaction furnace		—
Foundries	West Germany	mg/m^3	100.0	—
Hydrometallurgical refining				
Cobalt calcination	VDI 2287	1.0 gm/m^3	1000.0	37, 80
Inhibition plant	VDI 2287	0.5 gm/m^3	500.0	37, 80
Roasting plant	VDI 2287	0.1 gm/m^3	100.0	37, 80
Zinc calcination	VDI 2287	—	—	37, 80
Zinc with scrubbing	VDI 2287	3.0 gm/m^3	3000.0	37, 80
With dust extraction	VDI 2287	0.5 gm/m^3	500.0	37, 80
Melting	Japan	Same as reaction furnace		—
Roasting and sintering	Japan	Same as sintering plants		—
Lead pigment manufacture				
Smelting furnaces	Japan	Same as reaction furnace		—
Lead smelting				
Blast and reverberatory furnaces, sintering machine discharge	United States	mg/m^3	50.0	—
Furnaces	West Germany	mg/m^3	20.0	81
Refining furnaces	West Germany	mg/m^3	400.0	81
Secondary smelting	Japan	Same as reaction furnace		—
Battery manufacture	Japan	Same as reaction furnace		—
Blast or cupola >250 kg	United States	mg/m^3	50.0	15, 44
Blast furnaces, cupola, and reverberatory furnaces	Canada	0.02 grains/scf	46.0	85
Miscellaneous operations	Canada	0.01 grains/scf	23.0	85, 86
Pot furnace >250 kg	United States	mg/m^3	—	44
Slag blowing	West Germany	mg/m^3	100.0	81
Zinc smelting				
Distillation process	West Germany	mg/m^3	200.0	82
Electrothermal process	West Germany	mg/m^3	100.0	82
Rotary process	West Germany	mg/m^3	500.0	82
Sintering machine	United States	mg/m^3	50.0	—
Stationary retorts	West Germany	mg/m^3	400.0	82
Miscellaneous processes				
Conveying, grinding, classifying, filling				
>3 kg/hour	West Germany	mg/m^3	75.0	—
<3 kg/hour	West Germany	mg/m^3	150.0	—
Phosphate concentrate sintering	West Germany	mg/m^3	75.0	—
Wood fiber board production	West Germany	mg/m^3	50.0	34, 84
	West Germany	mg/m^3	150.0	34, 36

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[a] NOTES:

1. Other than incinerators burning less than 300 kg/hour and furnaces for heating of metals, except cold blast foundry cupolas.
2. At 12% CO_2 for boilers burning solid fuel and incinerators.
3. Intended for application to new plants.
4. STP at 0°C and 1 atm, dry.
5. National guideline.
6. Maximum SiO_2 content; 20% Emission rate above which it is necessary to submit a report to the government; where the discharge is for less than 1 hour, there is a proportionate reduction in emission permissible without such reporting.
7. See Tables XXX, XXXI, and XXXII and Figure 15.

Notes to Table VIII.12 (Continued)

8. See Figure 7.
9. See Table XXV.
10. See Table XXVI.
11. Except metal heating furnaces.
12. See Table XXV.
13. See Table XVIII.
14. See Figure 19.
15. Dry gas.
16. Proposed standards for new plants.
17. Except cold blast foundry cupolas.
18. Existing units.
19. At 11% O_2 by volume in gas.
20. See Table XXXIII.
21. As wet gas.
22. >500 kg/hour, smoke density-monitoring required.
23. Using two or more fuels, combined.
24. At 12% CO_2; linear from 30 to 100 MW.
25. For existing plants to be met by 1988.
26. Flue gas velocity greater than 8 m/second at minimum load.
27. Also a requirement for maximum soot (combustible particulate) emission.
28. Separate flues for each boiler with gas velocity greater than 25 m/second at full load.
29. Maximum average 4 hours during 24 hours.
30. See Table XXIX.
31. At 13% O_2 for wood, 7% O_2 for grate-fired coal, 6% O_2 for dry-bottom pulverized coal, and 5% O_2 for wet-bottom pulverized coal.
32. For plants >300 m from dwellings but <1000 m from agglomeration.
33. At 3% CO_2.
34. See Figure 12.
35. At 7% CO_2.
36. Chip drying.
37. VDI = Verein Deutscher Ingenieure—German Association of Engineers, Dusseldorf, West Germany.
38. Excess tolerated for a continuous 16 hours or a total of 200 hours/year.
39. New units.

40. At 10% CO_2.
41. Space should be left for scrubber.
42. Velocity of flue gases greater than 8 m/second at all operating conditions.
43. Distance to built-up area at least 1 km. Permitted only if adopted by regional planning authority.
44. 10% opacity (except for recombined water) permitted for 2 minutes per hour.
45. For plants <300 m from dwellings.
46. For plants >300 m from dwellings but <1000 m from agglomeration.
47. Effective January 1, 1977.
48. Effective January 1, 1980.
49. Applicable to dryers, conveyors, elevators, etc.
50. Accepted only for temporary location.
51. Also VDI 2112 (see Note 37).
52. At 4 volume % CO_2.
53. If diameter <30 μm, emission may be an additional 10 mg/m^3.
54. Also VDI 2094 (see Note 37).
55. Dolomite, magnesite, limestone, corundum, gypsum.
56. Additional 20 mg/m^3 allowed when organic expansion aid is used.
57. With membrane filter—pore size 3 μm—20 kg/ton aluminum.
58. 20% opacity (except for uncombined water) permitted for 3 minutes per hour; where auxiliary liquid or solid fuels are burned in an incinerator-waste heat boiler, particulate matter in excess of this standard may be permitted. except that the incremental rate of emission shall not exceed 0.18 gm/million calories (0.10 pound/million BTU) of heat input attributable to such fuel.
59. At 8 volume % CO_2.
60. Also continuous ceramic kilns.
61. Also petroleum heating furnaces; sulfur combustion furnaces in petroleum refineries; converters other than Bessemer; copper, lead, and zinc refining converters other than Bessemer.
62. Also VDI 2094 (see Note 37).
63. 0.15 gm/m^3 excess tolerated for a continuous 48 hours or for a 1.0 gm/m^3 total of 200 hours/year.
64. Older kilns, up to 0.5 grains/standard cubic foot.
65. Electrical precipitators on new kilns should have at least two independent sections, the maximum emission with one section out of operation is 500.0 mg/m^3 STP (dry gas).
66. Total, excluding wood-burning boilers and recovery stacks, monthly monitoring.
67. Smelting furnaces must be equipped with gas-cleaning equipment to remove 80% by weight of particulates from exhaust gas.

Notes to Table VIII.12 (Continued)

68. Also VDI 2099 (see Note 37).
69. 2.3 × 0.15 × capacity in tons (kg/ton iron).
70. 28/[(4 × capacity in tons) − 5] (kg/ton iron).
71. See Figure 11: >14 tons/hour iron–0.25 kg/ton iron.
72. $0.7 \leq 35/(\text{Annual production in thousands of tons} + 3) \leq 7$.
73. $1 \leq 50/(\text{Annual production in thousands of tons} + 3) \leq 8$.
74. Less than 2500 tons of gray iron per year production.
75. No visible color.
76. 0.15 gm/m^3 excess tolerated for a total of 200 hours/year.
77. Where, for instance, raw material is to be used in the form of fine dust and the applicant is able to show that although the present state of technical development does not permit keeping with the 150 mg/m^3 limit, no objectionable effects need be feared in the neighborhood. Also VDI 2095 (see Note 37).
78. Total dust emission not to exceed 1% of aluminum production.
79. Fume emission from use of salt as a flux.
80. Recovery after chloridizing roasting.
81. Also VDI 2285 (see Note 37).
82. Also VDI 2284 (see Note 37).
83. New plants and existing plants after December 1, 1979.
84. Pulping and conveying.
85. Proposed national guidelines.
86. Holding and kettle furnaces; lead oxide production; scrap and material handling and crushing; furnace tapping, slagging, cleaning, and casting operations.
87. 0.2 pound/short ton coke.
88. 0.1 pound/short ton coke.
89. And 99.7% dust collection efficiency.
90. Also 150 mg/m^3.
91. Also 500 mg/m^3
92. New [35(A + 3)] kg/ton; existing, [50(A + 3)] kg/ton where A is thousands of ton/year.
93. Also 300 mg/m^3.

able VIII.13.

National Emission Standards for Specific Pollutants in Effluent Air or Gas from Stationary Sources[a] (Newill, 1977)

Substance and country	*Source*	*Standard*		*Notes*[b]
		Original units	*mg/m^3*	
Acid gases				
Australia	New H_2SO_4 manufacture	3.0 gm/m^3	3000.0	1, 2, 3
Great Britain	Superphosphate fertilizer manufacture	0.1 grains/ft^3	228.8	1, 4
Ireland	H_2SO_4 manufacture	4.0 grains/ft^3	9153.0	1
New Zealand	New H_2SO_4 manufacture	5.0 gm/m^3	5000.0	1, 3
Singapore	H_2SO_4 manufacture	6.0 gm/m^3	6000.0	1, 2, 5
Acrolein				
Czechoslovakia	All	3 kg/hour	—	6
Aldehydes				
West Germany	Gas-burning furnaces	mg/m^3	20.0	7
Ammonia				
Czechoslovakia	All	3 kg/hour	—	6
Antimony				
Australia	New plants	mg/m^3	10.0	2, 3, 8, 9, 10
Great Britain	Less than 5000 cfm	0.05 grains/ft^3	114.4	9, 11
	More than 5000 cfm	0.02 grains/ft^3	45.7	9, 11
Singapore	All	0.02 gm/m^3	20.0	2, 8, 9, 12
Arsenic				
Australia	All	mg/m^3	10.0	2, 3, 8, 9, 10
Czechoslovakia	All	0.03 kg/hour	—	6, 13
Great Britain	Less than 5000 cfm	0.05 grains/ft^3	114.4	9, 11
	More than 5000 cfm	0.02 grains/ft^3	45.7	9, 11
Singapore	All	0.02 gm/m^3	20.0	2, 8, 9, 12
Benzene				
Czechoslovakia	All	24.0 kg/hour	—	6
Beryllium				
Australia	All	mg/m^3	0.1	2, 3, 9, 14
Cadmium				
Australia	All	mg/m^3	3.0	2, 3, 8, 10, 15
Great Britain	Maximum, 30 pounds/168 hours	0.017 grains/ft^3	38.9	8, 9
Japan	Cadmium pigment, cadmium carbonate, and glass manufacture; copper, lead, and cadmium refining	mg/m^3	1.0	9, 16
Singapore	All	0.02 gm/m^3	20.0	2, 8, 9, 12
Carbon				
West Germany	Graphite electrode manufacture	mg/m^3	250.0	17
	Refuse incineration	mg/m^3	50.0	49, 60
Carbon black				
Czechoslovakia	Amorphous carbon	1.5 kg/hour	—	6
Carbon dioxide				
Italy	Thermal installations	10% by volume	—	—
Switzerland	Oil burners			
	<3 kg/hour	8.0% by volume	—	3
	3–9 kg/hour	10.0% by volume	—	3
	>10.0 kg/hour	12.0% by volume	—	—
Carbon disulfide				
Czechoslovakia	All	0.3 kg/hour	—	6
Carbon monoxide				
Australia	All	0.5 gm/m^3	500.0	2, 3
Czechoslovakia	All	60.0 kg/hour	—	6
France	Electric generating plants	0.05% by volume	—	—
	Incinerators	0.1% by volume	—	—
United States	Fluid catalyst regenerator	0.50% by volume	—	—
	Ferroalloy manufacture	20% by volume	—	—
West Germany	Solid fuel burning	mg/m^3	250.0	61
	Gas burning	mg/m^3	100.0	7

able VIII.13

(Continued)

Substance and country	Source	Standard		Notes^b
		Original units	mg/m^3	
	Oil burning	mg/m^3	175.0	7
	Refuse burning			
	Household	1.0 gm/m^3	1000.0	62
	Other	mg/m^3	100.0	49
West Germany (VDI 2117E)	Vaporizer oil burners	0.1 by volume	—	18
Chlorine				
Australia	All	0.2 gm/m^3	200.0	2, 3, 8, 9
Czechoslovakia	All	1.0 kg/hour	—	6
Denmark, Sweden	Mercury cell	mg/m^3	3.0	—
Great Britain	All	0.1 grains/ft^3	228.8	8
Japan	Ferric chloride, chlorinated ethylene, activated carbon, and other chemical manufacture	mg/m^3	30.0	19
Singapore	All	0.2 gm/m^3	200.0	2
West Germany	All sources >3 kg/hour	mg/m^3	30.0	—
	Aluminum reduction	mg/m^3	3.0	49
	Refuse burning			
	Household (<0.75 tons/hour)	kg/hour	6.0	—
	Household (>0.75 tons/hour)	mg/m^3	100.0	49
	Other	mg/m^3	100.0	63
	Chlorine manufacture	mg/m^3	3.0	—
	Chlorine manufacture	mg/m^3	6.0	20
	Chlorine manufacture—Mercury cells	1 gm/ton Chlorine	—	—
Copper				
Singapore	All	0.02 gm/m^3	20.0	2, 8, 9, 12
Formaldehyde				
Czechoslovakia	All	0.5 kg/hour	—	6
Fluorine				
Czechoslovakia	Gaseous inorganic compounds	0.3 kg/hour	—	6
Japan	Aluminum reduction—ducts	mg/m^3	3.0	—
	Aluminum reduction—vents	mg/m^3	1.0	—
	Calcium superphosphate manufacture	mg/m^3	15.0	—
	Phosphoric acid fertilizer manufacture	mg/m^3	20.0	—
	Trisodium phosphate, phosphoric acid, and glass manufacture	mg/m^3	10.0	21
Singapore	All	0.1 gm/m^3	100.0	2, 22
Sweden	Ferromolybdenum manufacture	1 kg/ton of product	—	—
United States	Aluminum reduction			
	Prebake plant	0.95 kg/ton Al	—	—
	Soderberg plant	1.0 kg/ton Al	—	—
	Phosphate fertilizer manufacture			
	Diammonium phosphate manufacture	30.0 gm/ton P$_2$O$_5$	—	—
	Superphosphoric acid manufacture	5.0 gm/ton P$_2$O$_5$	—	—
	Triple superphosphate			
	Manufacture	100.0 gm/ton P$_2$O$_5$	—	—
	Curing	0.25 gm/hour/ton equivalent P$_2$O$_5$	—	—
	Wet process phosphoric acid manufacture	10.0 gm/ton P$_2$O$_5$	—	—
West Germany (VDI 2286)	Aluminum reduction	0.05 gm/m^3	50.0	18
Fluorine compounds				
Australia	New aluminum reduction	0.02 gm/m^3	20.0	2, 3, 22
	All other new processes	0.05 gm/m^3	50.0	2, 3, 22
Fluorine inorganic compounds				
Singapore	All	0.1 gm/m^3	100.0	2, 22
Heavy metals (total)				
Australia	All	mg/m^3	10.0	15
Hydrochloric acid				
Czechoslovakia	All	0.1 kg/hour	100.0	6, 23

'able VIII.13
(Continued)

Substance and country	*Source*	*Standard*		*Notes*[b]
		Original units	*mg/m*^{3}	
West Germany	Hydrogen chloride manufacture	mg/m^3	10.0	—
Hydrogen chloride				
Great Britain	Alkali (salt cake) works	0.2 grains/ft^3	4576.0	—
Great Britain; Ireland	Hydrogen chloride manufacture	0.2 grains/ft^3	4576.0	—
Japan	Ferric chloride, chlorinated ethylene, activated carbon, and other chemical manufacture	mg/m^3	80.0	19
Singapore	All	0.4 gm/m^3	400.0	2
Sweden	Cable burning	mg/m^3	250.0	—
West Germany	Incinerators (all)	mg/m^3	100.0	24
West Germany (VDI 3451E)	Absorption	0.025 gm/m^3	25.0	18, 25
	Sulfate methods	0.40 gm/m^3	400.0	18, 25
	Hydrogen chloride electrolysis	0.10 gm/m^3	100.0	—
	Filling and transfer	0.10 gm/m^3	100.0	18, 25
	Zinc chloride manufacture	0.16 gm/m^3	160.0	18, 25
	Silicon tetrachloride manufacture	0.20 gm/m^3	200.0	18, 25
	Vinyl chloride manufacture	0.17 gm/m^3	170.0	18, 25
	α-Chlorpropionic acid manufacture	0.18 gm/m^3	180.0	18, 25
	Sintering crude phosphate	0.35 gm/m^3	350.0	18, 25
	Burning organic by-products	0.30 gm/m^3	300.0	18, 25
	Hydrogen chloride absorption	0.33 gm/m^3	330.0	18, 25
Hydrofluoric acid				
Singapore	All	0.1 gm/m^3	100.0	2, 22
Hydrogen fluoride				
Great Britain	All	0.1 grains/ft^3	229.0	26
Japan	Aluminum reduction—ducts	mg/m^3	3.0	—
	Aluminum reduction—vents	mg/m^3	1.0	—
	Calcium superphosphate manufacture	mg/m^3	15.0	—
	Phosphoric acid fertilizer manufacture, baking furnace	mg/m^3	30.0	—
	Trisodium phosphate, phosphoric acid, and glass manufacture	mg/m^3	1.0	21
Hydrogen fluoride (as F)				
West Germany	Incinerators, iron ore sintering	mg/m^3	5.0	27
	Gases and vapors >5 kg/hour	mg/m^3	5.0	59
	Refuse burning			
	Household (<0.75 tons/hour)	kg/hour	0.2	—
	Household (>0.75 tons/hour)	mg/m^3	5.0	49
	Other	mg/m^3	5.0	49
	Ceramic kilns	mg/m^3	30.0	7, 28
	Aluminum reduction	mg/m^3	2.0	—
	Closed furnaces	1 kg/ton Al	—	—
	Open furnaces	0.8 kg/ton Al	—	—
	Glass manufacture	mg/m^3	15.0	—
	Sintering crude phosphate concentrates	mg/m^3	10.0	—
	Slag remelting	mg/m^3	1.0	—
Hydrogen sulfide				
Australia	All	mg/m^3	5.0	2, 3, 29
Czechoslovakia	All	0.08 kg/hour	—	6
Great Britain; Singapore	All	5.0 ppm	7.5	—
Sweden	Kraft recovery furnace	mg/m^3	10.0	30
United States	Petroleum refineries	mg/m^3	230.0	31
West Germany	Refineries	mg/m^3	10.0	32
	Claus sulfur plant	mg/m^3	10.0	—
	Coke oven gas	1.5 gm/m^3	1500.0	34

able VIII.13

(Continued)

Substance and country	Source	Standard: Original units	Standard: mg/m^3	Notes[b]
Lead				
Australia	All	mg/m^3	10.0	2, 3, 8, 9, 10, 15
Canada	Secondary lead smelting	—	—	48
Czechoslovakia	Except tetraethyllead	0.007 kg/hour	—	6
Great Britain	Up to 3000 cfm of exhaust	0.05 grains/ft^3	114.4	8
	3000–10,000 cfm	0.05 grains/ft^3	114.4	8, 35
	10,000–140,000 cfm	0.01 grains/ft^3	22.8	8, 36
	Over 140,000 cfm	0.005 grains/ft^3	11.4	8, 37
Japan	Refining copper, lead, or zinc; blast and sintering furnaces	mg/m^3	30.0	9
	Glass manufacture using lead oxides, baking furnace	mg/m^3	20.0	9
	Pipe, sheet, wire, pigment, and storage battery manufacture and secondary refining	mg/m^3	10.0	9
	Refining copper, lead, and zinc; other furnaces	mg/m^3	10.0	9
New Zealand	All	mg/m^3	100.0	3, 9
Singapore	All	0.02 gm/m^3	200.0	2, 8, 9, 12
Manganese				
Czechoslovakia	All	0.1 kg/hour	—	6, 38
Mercury				
Australia	All	mg/m^3	3.0	2, 3, 8, 9, 10, 15
Czechoslovakia	All	0.003 kg/hour	—	6, 39
Singapore	All	0.02 gm/m^3	20.0	2, 8, 9, 12
Sweden	In ventilation air from new Cl manufacture	0.001 kg/ton	—	—
	In H_2 vented from new Cl manufacture	0.0001 kg/ton	—	—
Nickel				
Australia	All	mg/m^3	20.0	2, 3, 8, 9, 14, 40
Nickel carbonyl				
Australia	All	mg/m^3	0.5	2, 3, 8, 14
Nitric acid				
Australia	New HNO_3 or H_2SO_4 manufacture	1.0 gm/m^3	1000.0	2, 3, 41
	Any other process except new gas-fired power plants	0.5 gm/m^3	500.0	2, 3,41
Czechoslovakia	All	0.1 kg/hour	—	6, 23
Singapore	HNO_3 manufacture	4.0 gm/m^3	4000.0	1, 2
	Any other process	2.0 gm/m^3	2000.0	1, 2
Nitrogen oxides				
Australia	New HNO_3 and H_2SO_4 manufacture	1.0 gm/m^3	1000.0	2, 41
	New gas-fired power plants	0.35 gm/m^3	350.0	2, 3, 41
	Any other new process	0.5 gm/m^3	500.0	2, 3, 41
Czechoslovakia	All	3.0 kg/hour	—	6, 41
Great Britain	HNO_3 manufacture	1000.0 ppm	1800.0	41, 42
	All other processes	1.0 grains/ft^3	2288.3	2, 41
Japan	All	—	—	43
Singapore	HNO_3 manufacture	4.0 gm/m^3	4000.0	1, 2
	Any other process	2.0 gm/m^3	2000.0	1, 2
United States	New gas-fired power plants	0.2 pound/MMBTU	—	—
	New liquid-fuel-fired power plants	0.3 pound/MMBTU	—	—
	New solid-fuel-fired power plants	0.7 pound/MMBTU	—	—
	New HNO_3 manufacture	3.0 pounds/ton acid	—	—
West Germany	HNO_3 manufacture	—	—	44, 46
	Concentrated HNO_3 manufacture	—	—	45, 46
Organic compounds				
West Germany	Fluid incineration	mg/m^3	50.0	49
Organic gases and vapors				
West Germany	Petroleum refining	0.04% of crude	—	—

Table VIII.13

(Continued)

Substance and country	Source	Standard		Notes[b]
		Original units	mg/m^3	
Phenol				
Czechoslovakia	All	3.0 kg/hour	—	6
Silicon fluoride				
Japan	Aluminum reduction—ducts	mg/m^3	3.0	—
	Aluminum reduction—vents	mg/m^3	1.0	—
	Calcium superphosphate manufacture	mg/m^3	15.0	—
	Phosphoric acid fertilizer manufacture	mg/m^3	20.0	—
	Trisodium phosphate, phosphoric acid, and glass manufacture	mg/m^3	10.0	21
Sulfur dioxide				
Canada	Burning coke oven gas	1300 gm/metric ton of coke	—	3, 64
	Combustion of fuel oil in Arctic mining plants	1.1 gm/1000 kcal	—	—
Czechoslovakia	All	—	—	50
Denmark	Sulfite pulp mills (new)	10 kg/ton pulp	—	—
	Sulfite pulp mills (existing)	20 kg/ton pulp	—	—
	Sulfuric acid manufacture (new)	5 kg/ton acid	—	—
	Sulfuric acid manufacture (existing)	20 kg/ton acid	—	—
East Germany	All	—	—	51
Great Britain	H_2SO_4 concentration	1.5 $grains/ft^3$	3432.4	1
	New contact H_2SO_4 manufacture	0.5% of the sulfur burned	—	—
	Old sulfur-burning H_2SO_4 manufacture	2% of the sulfur burned	—	—
	Old H_2SO_4 manufacture other than sulfur burning	4.0 $grains/ft^3$	9153.2	1
Italy	Heating plants	0.20% by volume	—	52
Japan	All	—	—	53
Sweden	New H_2SO_4 manufacture	5 kg/ton acid	—	54
	Existing H_2SO_4 manufacture	20.0 kg/ton acid	—	54
	NH_3 manufacture	—	—	55
	New sulfite pulp mills	10.0 kg/ton pulp	—	—
	Existing sulfite pulp mills	20.0 kg/ton pulp	—	—
	Oil steam-electric power plants over 300 MW	20.0 kg/ton fuel	—	—
United States	New liquid-fuel-fired power plants	0.8 pound/MMBTU	—	—
	New solid-fuel-fired power plants	1.2 pounds/MMBTU	—	—
	Primary copper smelters			
	Roaster, smelting furnace, converter	0.065%	—	—
	Primary lead smelters			
	Sintering machine, electric smelting furnace, converter	0.065%	—	—
	Primary zinc smelters			
	Roasters	0.065%	—	—
	Sulfuric acid manufacture	4.0 pounds/ton	—	—
West Germany	SO_2 manufacture	mg/m^3	30.0	—
	Natural gas burning	mg/m^3	50.0	7
	Coal gas burning	mg/m^3	100.0	7
	Nonferrous smelting	3 gm/m^3	3000.0	—
West Germany (VDI 2110)	Waste coke oven gas	2.54 gm/m^3	2540.0	18
	Waste coke oven gas	0.59 gm/m^3	590.0	18, 56
	H_2SO_4 (100%) manufacture	1.5 gm/m^3	1500.0	18
Sulfuric acid				
Australia	All	0.1 gm/m^3	1000.0	3
Czechoslovakia	All	0.1 kg/hour	—	6, 23
Singapore	Other than combustion or H_2SO_4 manufacture	0.2 gm/m^3	200.0	1, 2
United States	New H_2SO_4 manufacture	0.15 pound/ton acid	—	57
West Germany (VDI 2298)	SO_3 and H_2SO_4 manufacture	mg/m^3	5.0	18
		2 kg/ton acid	—	18

Table VIII.13 (continued)

		Standard		
Substance and country	*Source*	*Original units*	*mg/m³*	*Notes*[b]
Sulfur trioxide				
Australia	All new plants	0.1 gm/m³	100.0	1, 2, 3
Singapore	Other than combustion or H_2SO_4 manufacture	0.2 gm/m³	200.0	1, 2
Sweden	New H_2SO_4 manufacture	0.5 kg/ton acid	—	54
	Existing H_2SO_4 manufacture	0.8 kg/ton acid	—	54
West Germany (VDI 2298)	SO_3 and H_2SO_4 contact manufacture	0.4 kg/ton acid	—	18, 47, 58
West Germany	SO_3 and H_2SO_4 manufacture	0.6 kg/ton acid	—	33
Sulfur trioxide and sulfuric acid mist				
Denmark, Sweden	Sulfuric acid manufacture (new)	0.5 kg/ton acid	—	—
	Sulfuric acid manufacture (existing)	0.8 kg/ton acid	—	—
Tar				
West Germany	Graphite electrode manufacture	mg/m³	50.0	—
Vinyl chloride				
United States	Ethylene dichloride purification, vinyl chloride formation, purification, stripping, recovery, mixing, weighing, holding, venting, leakage	10 ppm	—	—
	Oxychlorination reactor	0.2 gm/kg product	—	—
	PVC (polyvinyl chloride) plants			
	Reactor opening loss	0.02 gm/kg product	—	—
	Stripping Technology			
	Dispersion PVC resins	2000 ppm	—	—
	Other PVC resins	400 ppm	—	—
	Other than stripping technology			
	Dispersion PVC resins	2 gm/kg product	—	—
	Other PVC resins	0.4 gm/kg product	—	—

[a] See also Table IXA for standards for Spain, and Table X for both organic and inorganic compounds, Federal Republic of Germany.

[b] NOTES:

1. As SO_3.
2. STP at 0°C and 1 atm (dry).
3. National guideline.
4. Or efficiency of condensation of acid gases greater than 99%.
5. Discharge free from persistent mist.
6. Emission rate above which it is necessary to submit a report to the government. Where discharge is for less than 1 hour, there is a proportionate increase in emission rate permissible without such reporting. For permissible emission, see Table XXIX.
7. As formaldehyde; at 3% O_2 by volume.
8. As the element
9. Also compounds of the element.
10. Total of antimony, arsenic, cadmium, lead, mercury, or their compounds may not exceed this limit.
11. As the trioxide.
12. Total of antimony, arsenic, cadmium, copper, lead, mercury, or their compounds may not exceed this limit.
13. Inorganic compounds except arsenic.
14. Tentative standard.
15. Addition of each metal or compound expressed as the metal in each case.
16. Glass manufacture using cadmium sulfide or carbonate as raw materials.
17. At 8% CO_2 by volume.
18. Verein Deutscher Ingenieure.
19. Includes chlorine quick cooling for chlorinated ethylene manufacture.
20. If complete liquification; also short-term peaks.
21. Glass manufacture using fluorite or sodium silicofluorate as raw materials.
22. As HF.
23. As hydrogen ion.
24. Applies to sources with 3 kg/hour hydrogen chloride or more.
25. Wet.
26. As SO_2 equivalent in original units.
27. Applies to sources with 150 gm/hour hydrogen fluoride or more.
28. If on crest or valley, 5 mg/m³.
29. As H_2S.
30. Ninety-nine percent of the time per month for new units; 90% for existing units; also (concentration in stack gas/concentration at odor threshold) = at least 10,000.
31. Unless burned to SO_2 in a manner that prevents release of SO_2 to atmosphere.
32. 0.4% H_2S by volume must be cleaned.

Notes to Table VIII.13 (continued)

33. $<6\%$ SO_2 in input and <100 tons/day.
34. Other sulfur-bearing compounds, 0.5 gm/m^3 hourly average.
35. One hundred pounds/week mass emission limit.
36. Four hundred pounds/week mass emission limit.
37. One thousand pounds/week mass emission limit.
38. As MnO_2.
39. Metallic.
40. Except nickel carbonyl.
41. As NO_2.
42. And the emission shall be colorless.
43. See Table XI.
44. See Figure 4.
45. See Figure 5.
46. Decolorization of nitric acid plant effluent $= (6100 \cdot 2.05/d)$ mg/m^3, where d = inside exit stack diameter.
47. $>6\%$ SO_2 in input.
48. Proposed national guideline $<63\%$ Pb in particulate matter. If $>63\%$, limit particulate matter to 63% of particulate matter limit for process in Table XVI.
49. 11% volume O_2 in gas.
50. See Table XXIX.
51. See Tables XXX, XXXI, and XXXII.
52. For heating installations burning liquid fuels with viscosity $>5°$ Engler and $>4\%$ S.
53. See Table XXXIII.
54. Sulfur or pyrite as raw material.
55. Equipment for releasing sulfur required.
56. By using partly desulfurized coke oven gas.
57. As H_2SO_4.
58. At least 99% SO_2 has to be recycled.
59. See Figure 6.
60. In combustible organic matter in flue gas.
61. At 13% O_2 for wood, 7% O_2 for grate-fired coal, 6% O_2 for dry-bottom pulverized coal, and 5% O_2 for wet-bottom pulverized coal.
62. At 17% O_2 for <0.75 tons/hour refuse and 11% O_2 for >0.75 tons/hour refuse.
63. At 7% CO_2.
64. 2.6 pounds/short ton (equivalent to 50 grains/standard cubic foot).

VIII.3.3. Other air pollution standards

(i) Point of impingement standards. When exhaust gases leave a chimney they disperse in the form of a diverging plume. Point of impingement standards set a limit on the concentration of pollutants where the plume intersects the ground and are normally used in diffusion computations to determine limits of emission. Enforcing such a standard is extremely difficult as it is hard to locate the point of impingement of a plume particularly when two or more chimneys are in the neighbourhood. Martin and Stern (1974) found that only three countries (France, Italy and the Philippines) have set national point of impingement standards, as shown in Table VIII.14.

(ii) Chimney height standards. A common method for keeping ambient air quality within specified limits is to disperse the air pollutants far and wide by means of a chimney. This is very effective unless there are too many chimneys in the one area or the chimneys are of inadequate height. Chimney height standards can apply generally to all emitted substances and all processes or to specific pollutants and/or specific processes. They are usually produced in the form of equations, tables, graphs, or nomograms. An example is the British "Memorandum on Chimney Heights" which includes nomograms for sulphur dioxide emissions from any process in five types of district: A - undeveloped; B - partially developed; C - built-up residential; D - mixed industrial/residential; and, E- mixed heavy industrial-residential (Ministry of Housing and Local Government, 1967). Two nomograms from the Memorandum are reproduced in Figure VIII.4.

(iii) Emergency procedure standards. A number of countries have established "episode action" or "emergency procedure" standards on the assumption that it is better to avoid an emergency such as imminent danger to public health, rather than react to one. Normally a four-stage sequence has been adopted. The first stage is generally activated by an adverse weather forecast which warns the control agency and public of a potential problem. The next three stages are activated by deteriorating air quality and the prediction of continued poor atmospheric dipsersion, with each stage prompting more stringent control measures. The latter usually take the form of repressive measures on industry as this is easier to control than householders or motorists. National emergency procedure concentration levels for Argentina, Israel, Japan and the United States are shown in Tables VIII.15 and VIII.16.

(iv) Fuel standards. Here the amount of sulphur dioxide discharged from fuel burning installations is limited by the sulphur content of the fuel burned or the amount of lead emitted from motor cars is limited by the lead content of the petrol. The use of fuel standards can be a very effective means of controlling emissions, although they are not cost-effective when ambient levels are already well within acceptable limits. Table VIII.17 summarises the measures outlined by some European countries for the reduction of sulphur in fuel oils.

(v) Buffer zone standards. A buffer zone or protection zone is a required separation distance between a source of environmental nuisance or hazard and areas inhabited or frequented by the general public. Normally there are several factors, in addition to air pollution, that determine the width of the buffer zone including noise, vibration, radioactivity and fire or explosion hazard. The concept of a buffer zone is popular in Russia, Poland and Israel. For example, in Russia industrial processes must be located downwind of nearby residential areas (using spring and summer prevailing winds as the criterion) and separated from them by a "sanitary protection zone" of 1000m, 500m, 300m, 100m or 50m width. A total of 409 industrial processes have been classified into one or more of these protection zone categories depending on activity, flow rate, storage capacity, etc. (Izmerov, 1973).

Table VIII.14. National Point of Impingement at Ground Level Standards (Newill, 1977)

	Standard		
Substance and country	*Original units*	*Averaging time (hours)*	*Notes*[a]
Ammonia			
Philippines	20.0 ppm	1	—
	10.0 ppm	24	—
Carbon Monoxide			
France	50.0 ppm	8	1
	100.0 ppm	Peak	1
Italy	57.24 mg/m³	½	2
	22.89 mg/m³	8	—
Philippines	100.0 ppm	1	—
	30.0 ppm	24	—
Chlorine			
Italy	0.58 mg/m³	½	2
Philippines	1.0 ppm	1	—
	0.2 ppm	24	—
Ethylene			
Philippines	5.0 ppm	½	—
	0.2 ppm	24	—
Fluorides			
Italy	4.5 μg/m³	½	2
	0.02 mg/m³	24	—
Hydrogen chloride			
Italy	0.30 mg/m³	½	2
	0.05 mg/m³	24	—
Philippines	1.0 ppm	1	—
	0.5 ppm	24	—
Hydrogen sulfide			
Italy	0.10 mg/m³	½	2
	0.04 mg/m³	24	—
Philippines	0.2 ppm	1	—
	0.1 ppm	24	—
Lead			
Italy	0.05 mg/m³	½	2
	0.01 mg/m³	8	—
Nitrogen dioxide			
Italy	0.56 mg/m³	½	2
	0.19 mg/m³	24	—
Nitrogen Oxides			
France	200.0 mg/m³	24	3
Philippines	2.0 ppm	1	—
	0.3 ppm	24	—
Organic substances			
Italy	80.0 ppm	½	4
	40.0 ppm	24	—
Ozone			
Philippines	0.3 ppm	1	—
	0.1 ppm	24	—
Silica (free)			
Italy	0.10 mg/m³	2	2, 5
	0.02 mg/m³	24	5
Sulfur dioxide			
France	250.0 μg/m³	24	3
Italy	0.79 mg/m³	½	2
	0.39 mg/m³	24	—
Philippines	2.0 ppm	1	—
	0.3 ppm	24	—
Suspended particulate			
France	150.0 μg/m³	24	3
Italy	0.75 mg/m³	2	2
	0.30 mg/m³	24	—
Philippines	900.0 μg/m³	1	6
	300.0 μg/m³	24	6
	600.0 μg/m³	1	7
	200.0 μg/m³	24	7

[a] NOTES: (1) Underground parking lots. (2) Peak concentration allowable once in 8 hours. (3) Basis for stack height calculations. (4) As hexane—derived from refineries. (5) As SiO_2. (6) Industrial area. (7) Residential area.

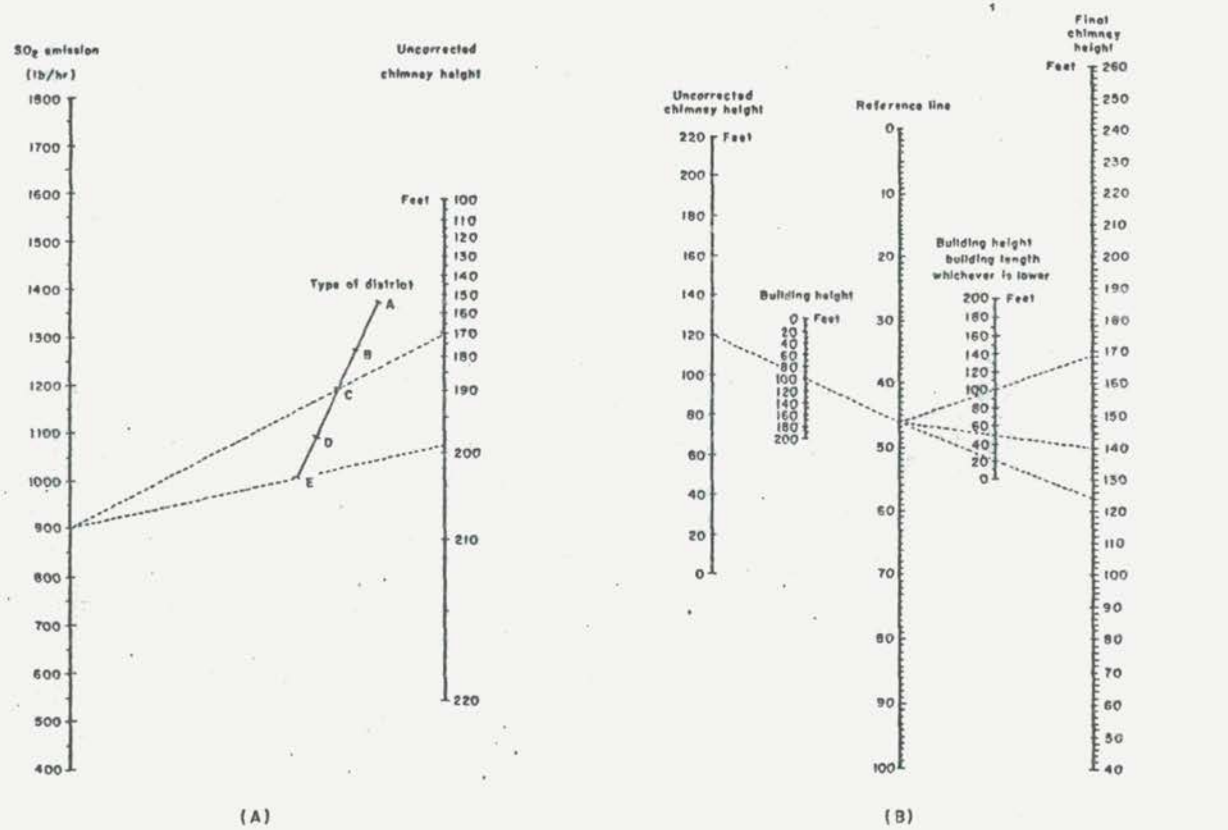


Figure VIII 4. Stack height standard for sulphur dioxide (as SO_2) emission - Great Britain. (A) Uncorrected height for large installations, (B) final stack height.

Table VIII.15. National Emergency Procedure Concentration Levels for United States (Tyler, 1977)

a. Air pollution forecast

An internal watch by the department of air pollution control shall be actuated by a national weather service advisory that atmospheric stagnation advisory is in effect or the equivalent local forecast of stagnant atmospheric condition.

b. Alert

The alert level is that concentration of pollutants at which first stage control actions are to begin. An alert will be declared when any one of the following levels is reached at any monitoring site:

Sulfur dioxide	800 $\mu g/m^3$ (0.3 ppm), 24 hour average.
Particulate matter	3.0 COHs or 375 $\mu g/m^3$, 24-hour average.
Sulfur dioxide and particulate matter combined	Product of sulfur dioxide ppm, 24-hour average, and COHs equal to 0.2; or product of sulfur dioxide $\mu g/m^3$ 24 hour average, and particulate matter $\mu g/m^3$, 24 hour average equal to 65×10^3.
Carbon monoxide	17 mg/m^3 (15 ppm), 8 hour average.
Oxidant (ozone)	200 $\mu g/m^3$ (0.1 ppm), 1 hour average.
Nitrogen dioxide	1130 $\mu g/m^3$ (0.6 ppm), 1 hour average; 282 $\mu g/m^3$ (0.15 ppm), 24 hour average.

and meteorological conditions are such that pollutant concentrations can be expected to remain at the above levels for 12 or more hours or increase, or in the case of oxidants, that the situation is likely to recur within the next 24 hours unless control actions are taken.

c. Warning

The warning level indicates that air quality is continuing to degrade and that additional control actions are necessary. A warning will be declared when any one of the following levels is reached at any monitoring site:

Sulfur dioxide	1600 $\mu g/m^3$ (0.6 ppm), 24 hour average.
Particulate matter	5.0 COHs or 625 $\mu g/m^3$, 24 hour average.
Sulfur dioxide and particulate matter combined	Product of sulfur dioxide ppm, 24 hour average and COHs equal to 0.8; or product of sulfur dioxide $\mu g/m^3$, 24 hour average and particulate matter $\mu g/m^3$, 24 hour average equal to 261×10^3.
Carbon monoxide	34 mg/m^3 (30 ppm), 8 hour average.
Oxidant (ozone)	800 $\mu g/m^3$ (0.4 ppm), 1 hour average.
Nitrogen dioxide	2260 $\mu g/m^3$ (1.2 ppm), 1 hour average; 565 $\mu g/m^3$ (0.3 ppm), 24 hour average.

and meteorological conditions are such that pollutant concentrations can be expected to remain at the above levels for 12 or more hours or increase, or in the case of oxidants, that the situation is likely to recur within the next 24 hours unless control actions are taken.

d. Emergency

The emergency level indicates that air quality is continuing to degrade toward a level of significant harm to the health of persons and that the most stringent control actions are necessary. An emergency will be declared when any one of the following levels is reached at any monitoring site:

Sulfur dioxide	2100 $\mu g/m^3$ (0.8 ppm), 24 hour average.
Particulate matter	7.0 COHs or 875 $\mu g/m^3$, 24 hour average.
Sulfur dioxide and particulate matter combined	Product of sulfur dioxide ppm, 24 hour average and COHs equal to 1.2; or product of sulfur dioxide $\mu g/m^3$, 24 hour average and particulate matter $\mu g/m^3$, 24 hour average equal to 393×10^3.
Carbon monoxide	46 mg/m^3 (40 ppm), 8 hour average.
Oxidants (ozone)	1000 $\mu g/m^3$ (0.5 ppm), 1 hour average.
Nitrogen dioxide	3000 $\mu g/m^3$ (1.6 ppm), 1 hour average; 750 $\mu g/m^3$ (0.4 ppm), 24 hour average.

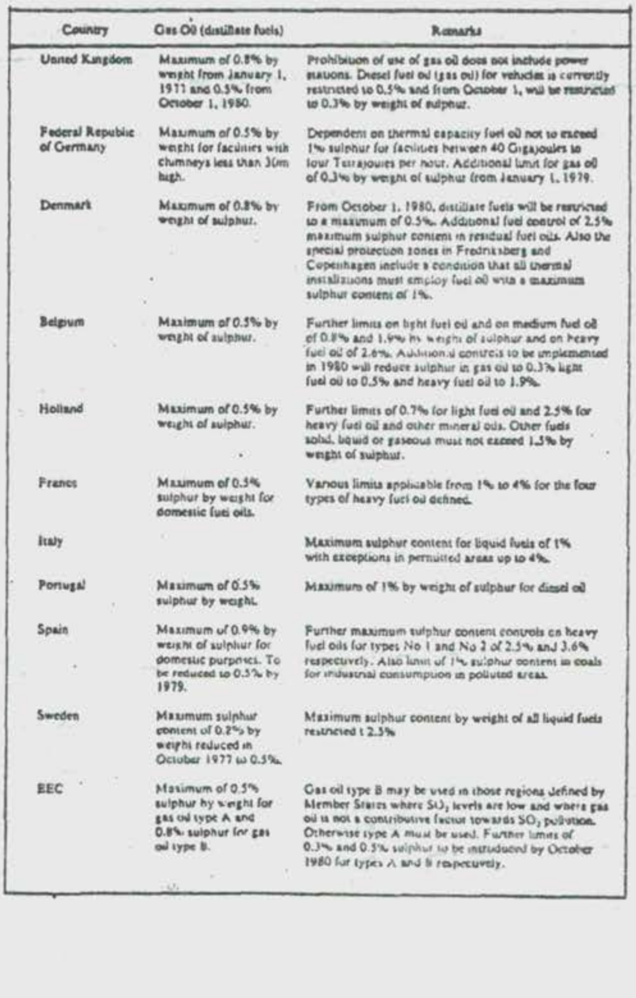
and meteorological conditions are such that pollutant concentrations can be expected to remain at the above levels for 12 or more hours or increase, or in the case of oxidants, that the situation is likely to recur within the next 24 hours unless control actions are taken.

Table VIII.16. National Emergency Procedure Concentrations for Argentina, Israel and Japan (Newill, 1977)

Country	*Sulfur dioxide (ppm)*	*Suspended particulate (coefficient of haze)*	*Carbon monoxide (ppm)*	*Nitrogen dioxide (ppm)*	*Oxidants (ppm)*
		Alert Levels			
Argentina	1.0 (1 hr) 0.3 (8 hr)	—	15.0 (8 hr) 100.0 (1 hr)	0.6 (1 hr) 0.15 (24 hr)	0.15 (1 hr)
Israel[a]	3.5 (24 hr) 1.5 (6 hr) 2.0 (6 hr)	10.0 (24 hr) 2.5 (6 hr)	—	—	—
Japan	0.2 (3 hr) 0.3 (2 hr) 0.5 (1 hr) 0.15 (48 hr)	2.0 mg/m^3 (2 hr)	30.0 (1 hr)	0.5 (1 hr)	0.14 (1 hr)
		Alarm Levels			
Argentina	5.0 (1 hr)	—	30.0 (8 hr) 120.0 (1 hr)	1.2 (1 hr) 0.3 (24 hr)	0.25 (1 hr)
Israel[a]	Operational Status A				
	5.0 (24 hr) 2.0 (6 hr) 3.0 (6 hr)	10.0 (24 hr) 2.5 (6 hr)	—	—	—
	Operational Status B				
	7.5 (24 hr) 3.0 (6 hr) 4.5 (6 hr)	10.0 (24 hr) 2.5 (6 hr)			
		Emergency Levels			
Argentina	10.0 (1 hr)	—	50.0 (8 hr) 150.0 (1 hr)	0.4 (24 hr)	0.4 (1 hr)
Israel[a]	12.5 (24 hr) 7.5 (6 hr)	20.0 (24 hr)	—	—	—
Japan	0.5 (3 hr) 0.7 (2 hr)	3.0 mg/m^3 (3 hr)	50.0 (1 hr)	1.0 (1 hr)	0.5 (1 hr)

[a] If stagnation period is forecast for an additional 12 hours.

Table VIII.17. Levels of Sulphur permitted in Fuels in some European Countries (Manifold, 1977)



Country	Gas Oil (distillate fuels)	Remarks
United Kingdom	Maximum of 0.8% by weight from January 1, 1977 and 0.5% from October 1, 1980.	Prohibition of use of gas oil does not include power stations. Diesel fuel oil (gas oil) for vehicles is currently restricted to 0.5% and from October 1, will be restricted to 0.3% by weight of sulphur.
Federal Republic of Germany	Maximum of 0.5% by weight for facilities with chimneys less than 30m high.	Dependent on thermal capacity fuel oil not to exceed 1% sulphur for facilities between 40 Gigajoules to four Terajoules per hour. Additional limit for gas oil of 0.3% by weight of sulphur from January 1, 1979.
Denmark	Maximum of 0.8% by weight of sulphur.	From October 1, 1980, distillate fuels will be restricted to a maximum of 0.5%. Additional fuel control of 2.5% maximum sulphur content in residual fuel oils. Also the special protection zones in Fredriksberg and Copenhagen include a condition that all thermal installations must employ fuel oil with a maximum sulphur content of 1%.
Belgium	Maximum of 0.5% by weight of sulphur.	Further limits on light fuel oil and on medium fuel oil of 0.8% and 1.9% by weight of sulphur and on heavy fuel oil of 2.6%. Additional controls to be implemented in 1980 will reduce sulphur in gas oil to 0.3% light fuel oil to 0.5% and heavy fuel oil to 1.9%.
Holland	Maximum of 0.5% by weight of sulphur.	Further limits of 0.7% for light fuel oil and 2.5% for heavy fuel oil and other mineral oils. Other fuels solid, liquid or gaseous must not exceed 1.5% by weight of sulphur.
France	Maximum of 0.5% sulphur by weight for domestic fuel oils.	Various limits applicable from 1% to 4% for the four types of heavy fuel oil defined.
Italy		Maximum sulphur content for liquid fuels of 1% with exceptions in permitted areas up to 4%.
Portugal	Maximum of 0.5% sulphur by weight.	Maximum of 1% by weight of sulphur for diesel oil
Spain	Maximum of 0.9% by weight of sulphur for domestic purposes. To be reduced to 0.5% by 1979.	Further maximum sulphur content controls on heavy fuel oils for types No 1 and No 2 of 2.5% and 3.6% respectively. Also limit of 1% sulphur content in coals for industrial consumption in polluted areas.
Sweden	Maximum sulphur content of 0.2% by weight reduced in October 1977 to 0.5%.	Maximum sulphur content by weight of all liquid fuels restricted t 2.5%
EEC	Maximum of 0.5% sulphur by weight for gas oil type A and 0.8% sulphur for gas oil type B.	Gas oil type B may be used in those regions defined by Member States where SO_2 levels are low and where gas oil is not a contributive factor towards SO_2 pollution. Otherwise type A must be used. Further limits of 0.3% and 0.5% sulphur to be introduced by October 1980 for types A and B respectively.

(vi) Visible emission standards. Visible emission standards are intended to control the emission of black, dense or dark smoke from chimneys or vehicle exhausts. A means of assessing plume opacity was devised by Maximillian Ringelmann in 1898 and has been the accepted standard since then (see Figure VIII.5). Stationary source smoke emission limits expressed as Ringelmann number or per cent opacity, have been adopted by a number of countries (see Table VIII.18), provinces and cities around the world. However, such standards are not widely applied nowadays mainly because of the development of objective emission standards which more effectively achieve the same result.

(vii) Odour emission standards. There are few standards of this type because of the problems inherent with the subjective evaluation of odour nuisance and intensity. However, a number of states of the United States have established odour control regulations (reviewed by Leonardos, 1974). Commonly, the odour observer uses a five-step scale of odour intensity, similar in concept to the Ringelmann scale for smoke density.

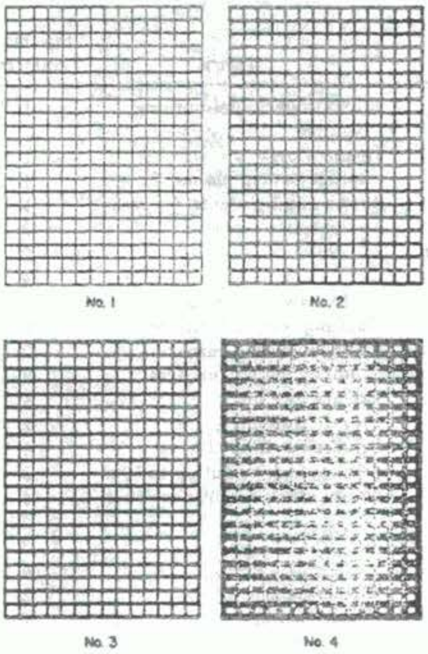
(viii) Fluoride in herbage standards. Another approach to managing air quality is to set limits on the concentration of a pollutant in a target or receptor. This has been done, for example, in Canada where the provinces of New Foundland, Ontario and Manitoba have established a standard of 35 ppm of fluoride in forage for the purpose of protecting livestock. Similar standards have been set by several states in the United States, (Martin and Stern, 1974).

(ix) Deposited particulate matter standards. Deposited grit and soot are among the most objectionable forms of air pollution and a number of countries have set standards for particulate matter deposited by sedimentation, washout or dust fall onto or into exposed receptacles (see Table VIII.19). However, although dustfall is easy to measure it is difficult to relate to its source and hence to effect appropriate control action.

(x) Workroom air standards. The concentration in air below which a contaminant is normally harmless on occupational exposure has been variously designated as the Threshold Limit Value (TLV), the Maximum Allowable Concentration (MAC), the Toxic or Permissible Limit, etc. In the United States, TLV's are published for about 500 industrial materials and revised annually by the American Conference of Governmental Industrial Hygienists (ACGIH) (1977). Similarly, the health legislation of the USSR specifies MAC's for about 700 contaminants (USSR State Committee of Standards, 1976).

There are three categories of TLV specified by the ACGIH: (i) time-weighted average concentrations (TLV-TWA), which refer to a normal 8-hour workday and a 40 hour workweek and which represent conditions under which it is believed nearly all workers may be repeatedly exposed day after day without adverse effect. Timeweighted averages allow for excursions (up to a specified maximum) above the limit provided they are compensated by equivalent excursions below the limit during the workday; (ii) short-term exposure limits (TLV-STEL), which are maximum concentrations to which workers can be exposed for a period of up to 15 minutes without suffering from intolerable irritation, materially reduced work efficiency, etc; and, (iii) ceiling concentrations (TLV-C), which are concentrations that should not be exceeded even instantaneously.

Many countries adopt or accept as a guide to good practice either the TLV's of the ACGIH or the MAC's of the USSR. The latter, as the name suggests, indicate levels not to be exceeded and therefore theoretically correspond to TLV ceiling concentrations. A comparison of the USSR and ACGIH lists shows, however, that there is a considerable variation in the permissible limits for a comparatively large number of toxic substances, in some cases the values differing by as much as a factor of 90. These differences arise from different concepts of what constitutes damage to health and from the different experimental and epidemiological methods used to establish the limits. For



Spacing of Lines on Ringelmann Chart

Ringelmann chart no.	*Width of black lines (mm)*	*Width of white spaces (mm)*	*Percent black*
0	All white		0
1	1	9	20
2	2.3	7.7	40
3	3.7	6.3	60
4	5.5	4.5	80
5	All black		100

Figure VIII.5. Ringlemann Smoke Chart

Table VIII.18. National Emission Standards for Effluent Opacity of Gas from Stationary Sources (Newill, 1977)

Country	*Category*	*Ringelmann number*	*Not to be exceeded more than (minutes/hour)*	*Notes*[a]
Australia	All stationary fuel-burning sources	1	—	1, 2
Belgium	Incinerators	2	—	—
Canada	Asphalt paving plants	1	—	8
	Arctic mining plants	1	—	—
Columbia	—	3	—	3
Great Britain	—	2	—	—
Guam	—	4	3	—
Hong Kong	All furnaces or ovens	2	—	4
Ireland	Chimney with 2 furnaces	2	16 min/8 hr	—
	Chimney with 3 furnaces	2	22 min/8 hr	—
	Chimney with 4 furnaces	2	27	—
	Private dwelling	4	4 min	—
	Private dwelling	2	8 min/8 hr	—
	Private dwelling	4	2 min/30 min	—
Italy	Smoke stack height up to 50 m	3	5	—
	Smoke stack height over 50 m	4	—	—
	—	2	5	—
	—	3	—	—
Malta	—	4	4	—
Mexico	Incinerators	2	3	—
	Other existing	2	5	—
	Other new	2	3	5
New Zealand	Clean air zones	1	—	—
	Other zones	2	4	—
Philippines	—	3	2	—
Singapore	—	2	5	6
West Germany	Solid fuel	1	—	7
	Graphite electrode manufacture	1	—	—
	Nonferrous alloys (other than aluminum)	1	—	—
	Aluminum reduction	1	—	—
	Refuse disposal	1	—	—
	Charging coke ovens	3	—	—

Country	*Category*	*% opacity*	*Not to be exceeded more than (minutes/hour)*	*Notes*[b]
United States	Asphalt concrete plants	20	—	—
	Coal preparation plants			
	Thermal dryers, processing, conveying, storing, transferring and loading	20	—	—

Table VIII.18. (Continued)

Country	*Category*	*% opacity*	*Not to be exceeded more than (minutes/hour)*	*Notes*[a]
United States	Pneumatic cleaning equipment	10	—	—
	Ferroalloy production	15	—	—
	Electric arc furnaces—			
	From control devices	3	—	—
	From shop roofs	0	—	—
	Except while charging	20	—	—
	Except while tapping	40	—	—
	Fossil fuel fired boiler furnaces	20	—	—
	Iron and steel mills dust-handling equipment	10	—	—
	Nitric acid plants	10	—	—
	Oil fired boiler furnaces	40	2	—
	Petroleum refineries	30	3	—
	Portland cement kilns	20	—	—
	Primary aluminum reduction plants			
	Anode baking	20	—	—
	Potrooms	10	—	—
	Primary copper smelters			
	Drying, roasting, smelting, converting	20%	—	—
	Primary lead smelters			
	Blast, reverboratory or electric furnaces, sintering machines and converters	20	—	—
	Primary zinc smelters			
	Roasters and sintering machines	20	—	—
	Secondary brass and bronze smelters			
	Blast and electric furnaces	10	—	—
	Secondary lead smelters	20	—	—
	Sewage treatment plants	20	—	—
	Sulfuric acid plants	10	—	—

[a] **NOTES:** (1) No. 3 Ringelmann acceptable for lighting-up or soot-blowing; (2) national guideline for new plants; (3) except for 15 minutes in 24 hours; (4) not to exceed 6 minutes/4 hours or 3 minutes continuously at any one time; (5) start-up; (6) not more than three times per day; (7) also during soot-blowing, but not hand-firing coal; (8) national guideline.

Table VIII.19. National Deposited Particulate Matter Standards (Newill, 1977)

Countries	*Original units*
Argentina	1.0 mg/cm^2/month
Colombia[a]	0.5 mg/cm^2/month
Finland	
Lead	10.0 mg/m^2/month
Chromium	10.0 mg/m^2/month
Vanadium	10.0 mg/m^2/month
Total	10.0 g/m^2/month
Hungary, Romania	200.0 $tons/km^2$/year
Hungary[b]	150.0 $tons/km^2$/year
Poland[b]	250.0 $tons/km^2$/year
Poland[c]	40.0 $tons/km^2$/year
Poland[c]	6.5 $tons/km^2$/month
Spain[d]	200.0 mg/m^2/day
West Germany[e]	0.35 gm/m^2/day
West Germany[f]	0.65 gm/m^2/day

[a] Set by PAHO and adopted by Colombia.

[b] Protected Areas.

[c] Specially protected areas.

[d] Proposed standard.

[e] Yearly average of the 12 monthly averages.

[f] Monthly average.

example, the MAC's of the USSR tend to be based more upon the detection of minimum functional or physiological changes rather than upon adverse effects (World Health Organisation, 1975)

The International Labour Organisation has also compiled a very comprehensive list of 1116 chemical substances and compared and reviewed exposure limits for these substances in Australia, Belgium, Bulgaria, Czechoslovakia, Finland, German Democratic Republic, Hungary, Italy, Japan, Netherlands, Poland, Romania, Sweden, Switzerland, USSR, U.S.A., Yugoslavia as well as the Council of Europe (International Labour Organisation, 1977).

Occupational exposure to toxic substances differs considerably from exposure to atmospheric pollutants. In occupational exposure, for example, the daily duration of exposure is comparatively short, the exposed population is highly selected and the total number of air contaminants is potentially much greater, whereas the general population is exposed continuously and contains susceptible individuals, e.g. the old, infirmed and very young. In addition, when establishing limits for occupational exposure, it is unnecessary to consider adverse environmental effects such as reduction in visibility and damage to vegetation. Consequently, workroom air standards should never be used as a substitute for ambient air quality standards and should be used as guides in the assessment or control of public health hazards only after evaluation of the data on which they are based (American Conference of Governmental Industrial Hygienists, 1971).

VIII.4. Water Quality Management

There are two main types of water quality management standard, namely water quality standards (stream standards) and emission standards (effluent standards), differing principally in the point at which control is exercised, i.e. in the receiving water or at the point of discharge, respectively. Examples of these different types of standards are given below.

VIII.4.1. Water quality standards

Waters are often classified by regulatory agencies according to the actual or potential uses of the water which depend, in turn, largely on the natural characteristics of the waters and the history of their use. As different uses normally require water of different qualities, it has become necessary to investigate and define standards of quality for each significant use. In general the most demanding uses are for potable supply and fisheries, and if the requirements for these are satisfied, the quality is usually sufficient for other purposes. Standards or requirements for the protection of the following water uses will be considered: drinking water supply, aquatic life, agricultural supply, recreation and industrial supply.

(i) Drinking water standards. Standards for substances in drinking water have been set by several national authorities and international bodies. The World Health Organisation, for example, has established two types of standards: "International Standards for Drinking water" (World Health Organisation, 1971) and the somewhat stricter "European Standards for Drinking Water" (World Health Organisation, 1970) which lay down the minimum hygienic quality recommended for all countries and all European countries respectively (see Tables VIII 20 and VIII 21).

In 1975, the United States' Environmental Protection Agency carried out a provisional revision of drinking water standards and published interim standards to take effect from December 1976 (U.S. Environmental Protection Agency, 1975). Standards were set for eleven inorganic chemicals (arsenic, barium, cadmium, chromium, cyanide,

Table VIII.22. Proposed EEC Drinking Water Standards
(Commission of the European Communities, 1975)

Table A: Organoleptic factors

Table B: Physicochemical factors

Table C: Biological factors

Table D: Undesirable or toxic factors

Table E: Microbiological factors

A. Organoleptic factors

Parameters (1)	Expression of the results (2)	Community values			Comments (6)
		Guide level (GL) (3)	Maximum admissible concentration (MAC) (4)	Minimum required concentration (MRC) (5)	
Colour	Pt units mg/l	5	20		Possible recourse to EMAC
Turbidity	SiO_2 degrees mg/l	5	10		Or in Jackson units GL 0·1 MAC 0·3 replaced in certain circumstances by a transparency test, with Secchi disc reading in meters indicative values GL 6 MAC 2
Odour	Dilution rate	0	2 at 12°C 3 at 25°C		Relate to palatability tests
Palatability	Dilution rate	0	2 at 12°C 3 at 25°C		Relate to odour tests
Temperature (coolness)	Degrees C	12	25		Possible recourse to EMAC

Table VIII.22. (Continued)

B. Physicochemical factors

Parameters (1)	Expression of the results (2)	Community values: Guide level (GL) (3)	Community values: Maximum admissible concentration (MAC) (4)	Community values: Minimum required concentration (MRC) (5)	Comments (6)
pH	pH units	6·5–8·5	9·5	6·00	pHsi = 0 (saturation index)
Conductivity	μS/cm	400	1 250		Possible recourse to EMAC corresponding resistivity values in ohms/cm 2 500–800
Total mineral content	Dry residue mg/l		1 500		Possible recourse to EMAC
Total hardness	Hydrometric title	35		10	
Calcium	Ca: mg/l	100		10	
Magnesium	Mg: mg/l	30	50	5	
Sodium	Na: mg/l	⩽ 20	100		Possible recourse to EMAC
Potassium	K: mg/l	⩽ 10	12		Possible recourse to EMAC
Aluminium	Al: mg/l		0·05		Possible recourse to EMAC
Alkali level	CO_3H-mg/l	30			
Sulphates	SO_4–mg/l	5	250		Possible recourse to EMAC
Chlorides	Cl-mg/l	5	200		Possible recourse to EMAC
Nitrates	NO_3- mg/l		50		< 15 mg/l for bottled or other water used for mixing babies' bottles; possible recourse to EMAC
Nitrites	NO_2- mg/l		0·1		
Ammonia	NH_4+ mg/l	0·05	0·5		
Kjeldahl-Nitrogen	N+ mg/l (excluding N in NO and NO_3)	0·05	0·5		

Table VIII.22. (Continued)

Parameters (1)	Expression of the results (2)	Community values			Comments (6)
		Guide level (GL) (3)	Maximum admissible concentration (MAC) (4)	Minimum required concentration (MRC) (5)	
Silica	SiO_2 mg/l				5 mg/l above the natural level
Substances extractable in chloroform	Dry residue mg/l	0·1			

C. Biological factors

Parameters (1)	Expression of the results (2)	Community values			Comments (6)
		Guide level (GL) (3)	Maximum admissible concentration (MAC) (4)	Minimum required concentration (MRC) (5)	
Dissolved oxygen	O_2 mg/l	5			
Oxidability	O_2 mg/l ($KMnO_4$)	1	5		Possible recourse to EMAC measured when heated and in acid medium
Biochemical Oxygen demand (BOD_5)	O_2 mg/l	50 % of initial dissolved oxygen content			
Total carbon (TOC)	C mg/l				The reason for any increase in the usual concentration must be investigated

D. Undesirable or toxic factors

Parameters (1)	Expression of the results (2)	Community values			Comments (6)
		Guide level (GL) (3)	Maximum admissible concentration (MAC) (4)	Minimum required concentration (MRC) (5)	
Silver	Ag µg/l		10		
Arsenic	As µg/l		50		
Barium	Ba µg/l		100		Possible recourse to EMAC

Table VIII.22. (Continued)

Parameters (1)	Expression of the results (2)	Community values			Comments (6)
		Guide level (GL) (3)	Maximum admissible concentration (MAC) (4)	Minimum required concentration (MRC) (5)	
Cadmium	Cd µg/l		5		
Cyanides	CN- µg/l		50		
Total chromium	Cr µg/l		50		
Copper	Cu µg/l		50 1 500		Possible recourse to EMAC 1 500 µg/l: after 16 hours contact at consumer outlet
Fluorine	F µg/l		700 at 1 500		MAC varies according to average temperature in geographical area concerned
Iron	Fe µg/l	100	300		Possible recourse to EMAC
Mercury	Hg µg/l		1		
Manganese	Mn µg/l	20	50		Possible recourse to EMAC
Nickel	Ni µg/l	5	50		
Phosphorus	P µg/l	300	2 000 after isolation		
Lead	Pb µg/l		50		
Hydrogen Sulphide	S— µg/l		nil		
Antimony	Sb µg/l		10		
Selenium	Se µg/l		10		
Zinc	Zn µg/l		100 2 000		2 000 after 16 hours of contact at consumer outlet
Mineral oils	Residue µg/l		10		
Polycyclic aromatic hydrocarbons	Residue µg/l		0·2		
Phenol index	C_6H_5OH µg/l		0·5		
Anionic detergents	lauryl sulphate µg/l		100		

Table VIII.22. (Continued)

Parameters (1)	Expression of the results (2)	Community values: Guide level (GL) (3)	Community values: Maximum admissible concentration (MAC) (4)	Community values: Minimum required concentration (MRC) (5)	Comments (6)
Pesticides and related products	µg/l				By pesticides and associated products is meant:
— Total	....	....	0·5		— insecticides: — persistent organochlorine compounds
— Substances considered separately	....	....	0·1		— organophosphorous compounds — carbamates — herbicides — fungicides
Other organochlorine compounds	µg/l		1·0		

E. Microbiological factors

Parameters		Basic	Supplementary	Results: Volume of the sample in ml	Tap water (1): Not disinfected MAC	Tap water (1): Desinfected MAC	Surface water: Disinfected MAC	Treated water: Not disinfected MAC	Comments
Total coliforms		+		100	5 (3)	0	0	0 (1)	(1) At consumer outlet
Fecal coliforms		+		100	0	0	0	0 (1)	(2) At catchment
Fecal streptococci		+		100	0	0	0	0 (1)	(3) On condition that enough samples are analysed and results are 95 % uniform
Total at count	37°	+		1	10	—	—	10 (2)	
	22°	+		1	100	—	—	100 (2)	(4) Per type of bacteriophage
	37°		+	1	—	0	0	—	(5) Qualitative research result
	22°		+	1	—	20	20	—	
Clostridium (sulphite reducing)			+	20	2	2	2	0 (1)	
Salmonella			+	5 000	0	0	0	0 (1)	
Pathogenic staphylococci			+	100	0	0	0	0 (1)	

Table VIII.22. (Continued)

Parameters	Basic	Supplementary	Results	Community values				Comments
				Tap water (1)		Surface water	Treated water	
			Volume of the sample	Not dis-infected	Desin-fected	Disin-fected	Not disin-fected	
			in ml	MAC	MAC	MAC	MAC	
Fecal Bacteriophages		+	100	0 (4)	0	0	0 (1)	(1) At consumer outlet (4) Per type of bacteriophage (5) Qualitative research result.
Enteropathogenic viruses		+	10 000	0	0	0	0 (1)	
Protozoa		+	—	nil (5)	nil	nil	nil (1)	
Animalcules		+		nil (5)				

Table VIII.20. WHO Limits for Toxic Substances in Piped Water Supplies Compared with the Corresponding U.S.S.R., U.S.A. and proposed EEC Values (mg/l) (see text for references)

Substance	WHO limits		USSR values	USA values	EEC (maximum admissible concentrations)
	European	International			
Lead (as Pb)	0.1[a]	0.1	0.1	0.05	0.05
Arsenic (as As)	0.05	0.05	0.05	0.05	0.05
Selenium (as Se)	0.01	0.01	0.001	0.01	0.01
Chromium (Cr^6)	0.05	-	0.1	0.05	0.05
Chromium (Cr^3)	-	-	0.5	-	
Cadmium	0.01	0.01	0.01	0.01	0.005
Cyanide (as CN)	0.05	0.05	0.1	0.2	0.05
Mercury (as Hg)	-	0.001	0.005	0.002	0.001
Barium	1.0	-	4.0	1.0	0.1

[a] Where water undertakings still use lead piping, concentrations may be higher, but in no instances higher than 0.3 mg/l after 16 h contact with the pipes.

fluoride, lead, mercury, nitrate, selenium and silver), nine pesticides, the total concentration of organic chemicals, turbidity and microbiological contaminant levels.

In the USSR, the latest drinking water standards (referred to as GOST 2874-73) were published in 1973 covering several bacteriological, toxic substances and organoleptic parameters (USSR State Committee of Standards, 1973). Standards are given for substances found mostly in natural waters or those added to the water in the process of its treatment. Permissible concentrations for many other chemicals which are industrial or agricultural pollutants of water sources must not exceed standards

Table VIII.21 - WHO Limits for Substances Affecting the Acceptability of Water for Domestic Purposes Compared with the Corresponding USSR, USA and Proposed EEC Values (mg/l)

(See text for references)

Substance	WHO limits			USSR limits	USA limits	Proposed EEC limits	
	European	International				Guide level	Maximum admissible concentration
		Highest desirable	Maximum permissible				
Phenolic compounds (as phenol)	0.001	0.001	0.002	0.001	–	–	0.0005
Fluoride (as F)	1.0-1.7[a]	–	0.8-1.7[a]	0.7-1.5[b]	1.4-2.4[a]	–	0.7-1.5[a]
Nitrate (as NO_3)	50-100	–	–	10 (as N)	10 (as N)	–	50
pH	–	7.0-8.5	6.5-9.2	6.5-8.5	–	6.5-8.5	9.5
Copper (as Cu)	0.05[c]	0.05	1.5	1.0	–	–	0.05[c]
Iron (as Fe)	0.1[c]	0.1	1.0	0.3	–	0.1	0.3
Manganese as Mn)	0.05	0.05	0.5	0.1	–	0.02	0.05
Zinc (as Zn)	5.0	5.0	15.0	5.0	–	–	0.1[c]
Magnesium (as Mg)	30-125[d]	30-150[d]	150	–	–	30	50
Sulphate (as SO_4)	250	200	400	500	–	5	250
Hydrogen sulphide (as H_2O)	0.05	–	–	Sulphides: nil	–	–	nil
Chloride (as Cl)	200-600	200	600	350	–	5	200
Chlorine, free	–	–	–	Nil	–	–	–
Anionic detergents	0.2	0.2	1.0	Individual limits	–	–	0.1
Ammonia (as NH_4)	0.05	–	–	2.0 (as N)	–	0.05	0.5
Carbon dioxide, free	nil	–	–	–	–	–	–
Calcium (as Ca)	–	75	200	–	–	100	–
Mineral oil	–	0.01	0.3	0.5	–	–	0.01
Mineral oil with high S content	–	–	–	0.1	–	–	–
Turbidity (units)	–	5	25	1.5	1[e]	5	10
Organics[e]	0.2-0.5	–	–	–	0.7	0.1	–

(a) Depending on temperature
(b) Varies according to climatic zone
(c) Under certain circumstances higher levels
(d) Depending on sulphate concentration
(e) Carbon chloreford extract

established by the USSR Ministry of Health (1973) for drinking water sources (see below).

The Commission of the European Communities (1975) have also published a proposed directive relating to the quality of water for human consumption with which it is suggested the health authorities of member states should fall into line. Standards were proposed for the following: 5 organoleptic factors, 18 physicochemical factors, 4 biological factors, 25 undesirable or toxic factors, and 11 microbiological factors (see Table VIII.22).

It is interesting to note that the WHO, USA, USSR and proposed EEC standards compare favourably in most respects (see Tables VIII.20 and VIII.21.), which is in contrast to the situation with many air quality management standards.

It should be realised that the standards discussed so far refer to maximum concentrations of certain pollutants in <u>final</u> potable water after it has undergone some form of treatment. To stipulate maximum and desirable concentrations in sources of drinking water (i.e. rain waters or receiving waters) requires information about the extent of removal of contaminants during various water treatment processes. For example, conventional treatment by coagulation and filtration will significantly reduce the concentration of most pollutants, but to achieve very low levels additional treatment with powdered activated carbon or by filtration through a bed of granular activated carbon may be necessary. Consequently, most standards for waters to be used as sources of drinking water supply assume a certain defined level of treatment.

For comparison purposes Table VIII.23 lists a number of state or national drinking water source standards or recommended standards: for the USA (Committee on Water Quality Criteria, 1973), the Saskatchewan Province of Canada (Water Resources Commission, 1970), the Sao Paulo state of Brazil (Anon, 1976), the Federal Republic of Germany (German Federation of Gas and Water Engineers, 1975) and Switzerland (Anon, 1975). In addition,

Table VIII.23. - Selection of State and National Standards for Surface Waters used as Sources of Drinking Water (See text for references)

Parameter	U.S.A.- EPA recommended maximum	Canada - Saskatchewan State (2)	Brazil - Sao Paulo State (3)	Federal Republic of Germany A(4)	B(5)	Switzerland (6)
pH	5.0-9.0	6.5-8.5	-	-	-	Natural pH
Colour (Pt scale)	75	≮30 above natural	Note (c)	5	50	Nil
Ammonia (as N)	0.5	-	0.5	0.2(d)	1.5(d)	0.5
Arsenic	0.1	0.01	0.1	0.01	0.03	0.01
Barium	1.0	1.0	1.0	1.0	1.0	0.5
Cadmium	0.01	0.01	0.01	0.005	0.01	0.005
Chloride	250	-	-	100	200	100
Chromium	0.05	0.05	0.05	0.03	0.05	0.06
Cobalt	-	-	-	0.05	0.05	0.05
Copper	1.0	0.02	1.0	0.03	0.05	0.01
Cyanide	0.2	0.01	0.2	0.01	0.05	0.01
Fluoride	1.4-2.4(a)	1.5	1.4	1.0	1.0	1.0
Foaming agents	0.5	0.5	-	-	-	-
Iron (Fe^{2+})	0.3	0.3	-	0.1	1.0	1.0
Lead	0.05	0.05	0.1	0.03	0.05	0.05
Magnesium	-	-	-	30.0	-	-
Manganese (Mn^{2+})	0.05	0.05	-	0.05	0.5	-
Mercury	0.002	0.0001	0.002	0.0005	0.001	0.001
Nitrate (as N)	10.0	-	10.0	25(e)	50(e)	25(e)
Nitrite (as N)	1.0	-	1.0	-	-	No toxicity
Nitrogen (total)	-	1.0	-	-	-	-
Organics	0.3 (b)(f)	0.2(b)(f)	-	Note (f)	Note (f)	Note (f)
Oil and grease	Note (c)	Note (c)	Note (c)	-	-	-
Phenolic compounds	0.001	0.005	0.001	0.005	0.01	0.005
Selenium	0.01	0.01	0.01	0.01	0.01	-
Sulphate	250	-	-	100	150	100
Zinc	5.0	0.05	5.0	0.5	1.0	0.2
Boron	-	0.5	-	1.0	1.0	1.0
Sulphide	-	0.05	-	-	-	No toxicity
Silver	-	0.05	-	-	-	0.01
Nickel	-	-	-	0.03	0.05	0.05
Vanadium	-	-	-	0.05	0.05	-
Tin	-	-	2.0	-	-	0.5
Beryllium	-	-	-	0.0001	0.0002	-

Notes on Table VIII.23.

(a) dependent upon temperature
(b) carbon-chloroform extract
(c) virtually absent
(d) as NH_4^+
(e) as NO_3^-
(f) consult sources for limits on individual and group parameters

(1) assumes coagulation, sedimentation, rapid sand filtration and disinfection with chlorine
(2) levels for protection of water supplies and preservation of fish and wildlife
(3) assumes conventional water treatment
(4) normal abstraction and refinement procedures
(5) currently available physical-chemical treatment but safety margin is small
(6) Receiving water quality objectives.

Table VIII.24. gives the maximum permissible concentrations for 420 chemicals in surface waters used as sources of drinking water as defined in the USSR (USSR Ministry of Health, 1973) and Table VIII.25. the mandatory and guide levels laid down by the Commission of the European Communities (1975a).

It is interesting to note that the USSR standards are basically toxicological in concept and are derived from the results of three kinds of test carried out on each substance: (i) the toxicity of the chemicals to various species of mammal as determined in a series of laboratory tests; (ii) the organoleptic properties of the chemical, i.e. their effect on taste, smell and colour of water; and, (iii) determination of the threshold of action on biochemical processes in water including biochemical oxygen demand and nitrification (called "self-purification" tests). The maximum permissible concentration is then based on the lowest value obtained in any one of these tests.

(ii) *Standards for protection of aquatic life*. Another common water quality standard is that aimed at the protection of aquatic ecosystems as a whole or sensitive individual species within the ecosystem. Water pollutants may alter natural conditions in a variety of ways: by reducing the dissolved oxygen content, by changing the temperature or by direct toxic action that can be lethal or, more subtly, affect the behaviour, reproduction and physiology of the organisms. It has also been recognised that, although a substance may not directly affect a species, it may endanger its continued existence by eliminating essential sources of food and metabolites.

Several national and regional authorities have laid down or recommended water quality standards for the purpose of protecting fish life. For example, the Commission of the European Communities (1978) has laid down standards for salmonid and cyprinid waters (see Table VIII.26.). Because different species can vary quite widely in their sensitivity to pollutants, standards are often expressed in relation to the most susceptible local species. In such cases, recommended maximum concentrations are determined by multiplying the acute toxicity values (the 96-hour LC_{50} where available) for the more sensitive species by an application factor. Table VIII.27, for example, shows the recommended application factors for toxic agents that may be present in the Australian aquatic environment, and Table VIII.28 the maximum pesticide concentrations derived using an application factor of 0.01 (Hart, 1974).

Similarly the Committee on Water Quality Criteria (1973) has recommended maximum concentrations and application factors for various toxic substances in freshwater and marine environments and these are shown in Table VIII.29.

iii) Standards for agricultural uses of water. Irrigation is one of the largest uses of water in the agricultural industry. Differences in crop sensitivity to salinity and toxic substances necessitate the need for evaluating water quality criteria for irrigational purposes. Additionally, polluted water can be detrimental to animal health and to the safety and value of agricultural products. For these reasons, a number of authorities have established limits of substances in waters used for irrigation and/or for consumption by livestock.

Table VIII.24. Maximum permissible concentrations of harmful substances in the water of water bodies to be used for sanitary-domestic use. U.S.S.R. (Central Water Planning Unit, 1978)

Substance	*USSR list no.*	*MPC (mg/l)*	*Basis* ‡
acetaldehyde	211	0.2	O
acetic acid	194	*	S
acetone	144	*	S
acetone cyanohydrin [2-hydroxy-2-methylpropionitrile]	6	0.001	T
acetonitrile	212	0.7	O
acetophenone	7	0.1	T
acrylic acid	2	0.5	T
acrylonitrile	80	2.0	T
adipic acid, Na salt	1	1.0	T
adiponitrile	37	0.1	T
aldrin †	203	0.002	O
aliphatic acids, C_5-C_{20} (synthetic)	180	*	S
'Alkomon OS–20'	202	0.5	O
alkylamines, C_7-C_9	205	0.1	O
alkylamines, C_{10}-C_{15}	206	0.04	O
alkylamines, C_{15}-C_{20}	207	0.03	O
alkylbenzenesulphonates, branched-chain	404	0.5	O
alkyl sulphates	405	0.5	O
alkyl sulphonates	406	0.5	O
alkyl sulphosuccinate, disodium salt	407	0.5	O
allyl alcohol	200	0.1	O
2-aminoethanethiol (β-mercaptoethylamine)	285	0.1	O
o-aminophenol	208	0.01	O
p-aminophenol	209	0.05	O
ammonia (as N)	142	2.0	S
ammonium perchlorate	95	5.0	T
aniline	5	0.1	T
anisole	4	0.05	T
antimony	108	0.05	T
arsenic (inorganic)	74	0.05	T
atrazine †	143	0.5	S

Table VIII.24. (Continued

Substance	*USSR list no.*	*MPC (mg/l)*	*Basis* ‡
barium	214	4.0	O
benzene	8	0.5	T
benzoic acid	145	*	S
benzoic acid, K salt	216	7.5	O
p-benzoquinone dioxime	91	0.1	T
beryllium	9	0.0002	T
BHC † (Hexachloran)	227	0.02	O
bismuth (III)	13	0.5	T
bismuth (V)	14	0.1	T
bromine (Br_2)	10	0.2	T
1,3-butadiene	218	0.05	O
1-butanol	222	1.0	O
2-butanone (methyl ethyl ketone)	299	1.0	O
3-butenenitrile (allyl cyanide)	3	0.1	T
butyl acetate	146	0.1	S
butyl acrylate	219	0.01	O
butylbenzene	220	0.1	O
butylene	221	0.2	O
butyl *O*-ethyl dithiocarbonate (butyl xanthogenate)	281	0.001	O
butyl methacrylate	223	0.02	O
butyric acid	169	*	S
cadmium	58	0.01	T
ε-caprolactam	166	1.0	S
carbaryl † (Sevin)	343	0.1	O
carbon disulphide	344	1.0	O
carbon tetrachloride	138	0.3	T
catechol (pyrocatechol)	332	0.1	O
chloral	130	0.2	T
chlorate, Na salt	383	20.0	O
chlorendic anhydride	390	1.0	O
chlorfenson † (Ester Sulphonate)	403	0.2	O
chlorine, free	196	absent	S
m-chloroaniline	127	0.2	T
p-chloroaniline	128	0.2	T

Table VIII.24. (Continued)

Substance	*USSR list no.*	*MPC (mg/l)*	*Basis* ‡
chlorobenzene	131	0.02	T
p-chlorobenzenesulphonic acid, Na salt	75	2.0	T
p-chlorobenzoic acid	92	5.0	T
2-chloro-1,3-butadiene (chloroprene)	385	0.1	O
chlorocyclohexane	391	0.05	O
1-chloro-2,3-dibromopropane (Nemagon)	314	0.01	O
chlorodifluoromethane (Freon 22)	124	10.0	T
1-chloro-3,4-dinitrobenzene	247	0.5	O
1-chloro-2,3-epoxypropane (epichlorohydrin)	139	0.01	T
7-chloroheptanoic acid	389	0.05	O
α-chloromethyl-4-nitrobenzyl alcohol	320	0.2	O
o-,*m*- & *p*-chloronitrobenzene	86	0.05	T
chloronitrosocyclohexane [isomer not stated]	384	0.005	O
9-chlorononanoic acid	387	0.3	O
3-chloro-1,2-propanediol (monochlorohydrin)	304	0.7	O
3-chloropropene (allyl chloride)	201	0.3	O
2-chloropropionic acid	307	0.8	O
2-chloropropionic acid, Na salt	309	2.0	O
1-chloro-3,3,3-trifluoropropane (Freon 253)	116	0.1	T
11-chloroundecanoic acid	388	0.1	O
chlorpropham † (ChlorIPK)	275	1.0	O
chromium (III)	393	0.5	O
chromium (VI)	392	0.1	O
cobalt	60	1.0	T
copper	284	1.0	O
m-cresol	62	0.004	T
p-cresol	63	0.004	T
crotononitrile	59	0.1	T
cyanide	132	0.1	T
1-cyanoguanidine (dicyandiamide)	262	10.0	O
cyanuric acid	395	6.0	O
cyanuric acid, Na salt	302	25.0	O
cyclohexane	133	0.1	T

Table VIII.24. (Continued)

Substance	*USSR list no.*	*MPC (mg/l)*	*Basis* ‡
1,4-cyclohexanedione (tetrahydroquinone)	352	0.05	O
cyclohexanol	134	0.5	T
cyclohexanone	135	0.2	T
cyclohexanone oxime	136	1.0	T
cyclohexene	137	0.02	T
2,4-D †, Na salt	311	1.0	O
dalapon †	233	2.0	O
dazomet † (Mylon)	300	0.01	O
DD (mixture of 1,2-dichloropropane and 1,3-dichloropropene)	26	0.4	T
'DDB'	27	0.4	T
DDT †	28	0.1	T
demeton † (Mercaptofos)	286	0.01	O
demeton-S-methyl † (Methylsystox)	296	0.01	O
di-allate † (Avadeks)	199	0.03	O
4,5-dibromo-1,5,5-trichloro-1-pentene (Bromtan)	217	0.04	O
dibutyl phenyl phosphate	151	*	S
dibutyl phosphorodithioate, K salt	235	27.0	O
dibutyl phosphorothioate, K salt	234	0.1	O
dibutyl phthalate	152	0.2	S
dibutyltin dichloride	41	0.002	T
dibutyltin dilaurate	25	0.01	T
dibutyltin sulphide	109	0.02	T
dichlone † (2,3-dichloro-1,4-naphthoquinone)	42	0.25	T
dichloral urea (DTsU)	160	*	S
2,5-dichloroaniline	253	0.05	O
3,4-dichloroaniline	252	0.05	O
2,5-dichloro-*p*-anisic acid (Dianat)	29	15.0	T
o-dichlorobenzene	254	0.002	O
m-dichlorobenzene (Karbin)	277	0.03	O
p-dichlorobenzene	255	0.002	O
1,3-dichloro-2-butene	256	0.05	O
dichlorocyclohexane [isomer not stated]	260	0.02	O
dichlorodifluoromethane (Freon 12)	123	10.0	T
1,2-dichloroethane	261	2.0	O

Table VIII.24. (Continued)

Substance	*USSR list no.*	*MPC (mg/l)*	*Basis* ‡
1,2-dichloro-2-methylpropane	43	0.4	T
1,3-dichloro-2-methylpropene	44	0.4	T
3,3-dichloro-2-methylpropene	45	0.4	T
2,4-dichlorophenol	259	0.002	O
dichlorophenyl phosphate [2,4-?]	159	*	S
1,2-dichloropropane	46	0.4	T
1,3-dichloro-2-propanol (dichlorohydrin)	257	1.0	O
1,3-dichloropropene	47	0.4	T
2,3-dichloropropene	48	0.4	T
dichlorvos † (DDVP)	240	1.0	O
diethanolamine	263	0.8	O
diethylamine	49	2.0	T
N,N-diethyl-2-benzothiazolesulphenamide (Sulfenamide BT)	350	0.05	O
diethylene glycol	52	1.0	T
diethylene glycol dinitrate	38	1.0	T
diethyl ether	267	0.3	O
diethyl *S*-ethylcarboxymethyl phosphorothiolate (Acetofos)	213	0.03	O
diethyl maleate	53	1.0	T
diethylmercury	54	0.0001	T
1,1-diethyl-3-phenylurea (Tsentralit)	266	0.5	O
diethyl phosphorodithioic acid	264	0.2	O
diethyl phosphorodithioic acid, K salt	265	0.5	O
diethyltin dichloride	51	0.002	T
diethyltin dioctanoate	50	0.01	T
diisobutylamine	236	0.07	O
diisopropylamine	30	0.5	T
m-diisopropylbenzene	31	0.05	T
p-diisopropylbenzene	32	0.05	T
m-diisopropylbenzene hydroperoxide	173	0.6	S
p-diisopropylbenzene hydroperoxide	174	0.3	S
diisopropyl phosphorothiolothionate, K salt	237	0.02	O
dimethoate † (Fosfamid)	379	0.03	O
dimethylamine	33	0.1	T

Table VIII.24. (Continued)

Substance	*USSR list no.*	*MPC (mg/l)*	*Basis* ‡
4,4-dimethyl-1,3-dioxane (Dimethyldioxan)	34	0.005	T
dimethyl disulphide	242	0.04	O
N,N-dimethyldithiocarbamic acid	35	0.5	T
dimethyl *S*-ethylcarboxymethyl phosphorothiolate (Methylacetofos)	290	0.03	O
dimethylformamide	154	10.0	S
dimethyl phosphorodithioic acid	239	0.1	O
2,5-dimethylpyridine (2,5-lutidine)	61	0.05	T
dimethyl sulphide	241	0.01	O
dimethyl terephthalate	243	1.5	O
m-dinitrobenzene	245	0.5	O
dinitrobenzenethiocyanate [isomer not stated]	155	0.5	S
1,5-, 1,8-dinitronaphthalene	246	1.0	O
2,4-dinitrophenol	40	0.03	T
2,4-dinitrotoluene	39	0.5	T
dioctyl phthalate	156	1.0	S
1,3-diphenylguanidine	157	1.0	S
1,3-diphenylguanidine hydrochloride	183	1.0	S
dipropylamine	248	0.5	O
'Dispergator NF'	158	*	S
disulfiram (Tiuram E)	365	absent	O
2,2′-dithiobis(benzothiazole) (Al'taks)	204	absent	O
diuron †	250	1.0	O
divinyl adipate	153	0.2	S
DTsM (a polymer between chloral and a Cu-urea complex, used in the textile industry)	268	0.5	O
'Dye, blue, Z'	167	10.0	S
'Dye, brown, B/M'	280	0.8	O
EPTC† (Eptam)	398	0.1	O
erbon† (Pentanat)	93	2.5	T
ethanolamine	71	0.5	T
2-ethoxyethanol (ethylene glycol monoethyl ether)	175	1.0	S
ethyl acrylate	399	0.005	O
ethylamine	305	0.5	O
ethylbenzene	401	0.01	O

Table VIII.24. (Continued)

Substance	*USSR list no.*	*MPC (mg/l)*	*Basis ‡*
malathion † (Karbofos)	278	0.05	O
maleic acid	283	1.0	O
malonodiamide	150	1.0	S
malonodinitrile	64	0.02	T
MCPA † (Dikoteks)	238	0.25	O
menazon † (Saifos)	102	0.1	T
2-mercaptobenzothiazole (Kaptaks)	276	absent	O
mercury (inorganic)	101	0.005	T
methacrylamide	65	0.1	T
methacrylic acid	67	1.0	T
metham † (Karbation)	292	0.02	O
methanethiol (methyl mercaptan)	294	0.0002	O
methanol	66	3.0	T
methyl acetate	68	0.1	T
methyl acrylate	289	0.02	O
methylamine	73	1.0	T
methyl benzoate	291	0.001	O
2-methyl-1,3-butadiene (isoprene)	271	0.005	O
methylene chloride	258	7.5	O
methyl methacrylate	69	0.01	T
2-methyl-1-propanol (isobutyl alcohol)	162	1.0	S
1-methyl-2-pyrrolidone	172	0.5	S
5-methylresorcinol	298	1.0	O
α-methylstyrene	297	0.1	O
methyl vinyl adipate	147	0.2	S
molybdenum	72	0.5	T
monuron †	306	5.0	O
morpholine	308	0.04	O
naphthenic acid	312	0.3	O
α-naphthol	313	0.1	O
β-naphthol	76	0.4	T
nickel	77	1.0	T
nitrate (as N)	79	10.0	T
nitrobenzene	78	0.2	T

Table VIII.24. (Continued)

Substance	*USSR list no.*	*MPC (mg/l)*	*Basis* ‡
hexachloro-1,3-butadiene	228	0.01	O
hexachlorobutane (a chlorinated butane, average Cl content 81.3%)	229	0.01	O
hexachlorocyclopentadiene	230	0.001	O
hexachloroethane	231	0.01	O
hexahydro-1,3,5-trinitro-1,3,5-triazine (Hexogen)	19	0.1	T
hexamethylenediamine	16	0.01	T
hexamethylenetetramine (Urotropine)	119	0.5	T
1,6-hexanediaminehexanedioate (hexamethylenediamine adipate)	148	1.0	S
hydrazine	21	0.01	T
N(2-hydroxyethyl)-*N*(4-nitrophenyl)acetamide	321	1.0	O
4-hydroxymethyl-3-butenoamide (methylolmethacrylamide)	70	0.1	T
2-hydroxysimazine	346	absent	O
'Indotoluidin' (a raw material for dyestuffs)	57	1.0	T
iron (ferric)	269	0.5	O
isobutyl acetate	161	*	S
isobutylamine	301	0.04	O
isobutylene	270	0.5	O
isocrotononitrile	55	0.1	T
isopropylamine	56	2.0	T
isopropylbenzene	272	0.1	O
isopropylbenzene hydroperoxide	22	0.5	T
4,4′-isopropylidenediphenol (diphenylolpropane) [Bisphenol A]	251	0.01	O
'Karbamol'	164	*	S
'Karbamol TsEM'	165	*	S
'Karbozon-O'	163	1.0	S
kerosene	279	0.1	O
'Khloramp'	129	10.0	T
'Khromolan'	197	*	S
lactic acid	170	*	S
lead	103	0.1	T
'Ludigol'	168	*	S

Table VIII.24. (Continued)

Substance	*USSR list no.*	*MPC (mg/l)*	*Basis* ‡
ethylene	400	0.05	O
ethylenebisdithiocarbamate, diammonium salt (EDTK)	397	0.04	O
ethylene glycol	140	1.0	T
ethylmercuric chloride	141	0.0001	T
O-ethyl *S*-phenyl *N*-butylphosphoramidodithioate (Fosbutyl)	378	0.03	O
fenchlorphos † (Trichlormetafos-3)	369	0.4	O
fenitrothion † (Methylnitrofos)	293	0.25	O
ferrocyanide	120	1.25	T
Flocculants:			
VA-2 (polystyrene)	416	0.5	T
VA-2-T (polyvinyltoluene)	417	0.5	T
VA-102 (cationic; polymethacrylic)	418	2.0	T
VA-212 (cationic; polymethacrylic)	419	2.0	T
polyacrylamide	420	2.0	T
Flotation Agents:			
ANP-2	408	0.4	O
APN	409	0.05	O
OP-7 (an ethoxylated alkylphenol)	410	0.4	O
OP-10 (an ethoxylated alkylphenol)	411	1.5	O
OPS-B (mixed monomethyl esters of polypropylene glycol)	412	2.0	S
OPS-M	413	0.5	T
T-66	414	0.2	T
'Gidrolizovannyĭ Butyilovyĭ Aėroflot'	415	0.001	O
fluoride	125	1.5	(for fluoridated water)
formaldehyde	122	0.05	T
formic acid	171	*	S
2-furaldehyde (furfural)	381	1.0	O
furan	126	0.2	T
heptachlor†	23	0.05	T
1-heptanol	24	0.005	T
hexachlorobenzene	18	0.05	T

Table VIII.24. (Continued)

Substance	*USSR list no.*	*MPC (mg/l)*	*Basis* ‡
nitrocyclohexane	87	0.1	T
nitroethane	85	1.0	T
nitromethane	318	0.005	O
o-nitrophenol	82	0.06	T
m-nitrophenol	83	0.06	T
p-nitrophenol	84	0.02	T
N(4-nitrophenyl)-2-aminoethanol	319	0.5	O
nitropropane	81	1.0	T
p-nitrosophenol	317	0.5	O
1-nonanol	88	0.01	T
noruron† (Herban)	20	2.0	T
1-octanol	324	0.05	O
oil, polysulphide	315	0.1	O
oil, other types	316	0.5	O
parathion † (Thiofos)	362	0.003	O
parathion-methyl † (Metafos)	288	0.02	O
pentachlorobutane (a chlorinated butane, average Cl content 76.3%)	326	0.02	O
pentachlorophenol	328	0.3	O
pentachlorophenol, Na salt	329	5.0	O
pentachloropropane [isomer not stated]	327	0.03	O
pentaerythritol	94	0.1	T
petrol (benzine)	215	0.1	O
phenol	376	0.001	O
p-phenylenediamine	90	0.1	T
phenylhydrazine	121	0.01	T
2-phenyl-2-propanol (dimethylphenylcarbinol)	36	0.05	T
N-phenylsalicylamide	210	2.5	O
phosalone †	377	0.001	O
phosmet† (Phthalofos)	380	0.2	O
phthalic acid	195	0.5	S
2-picoline	96	0.05	T
picric acid	330	0.5	O
piperidine	98	0.06	T

Table VIII.24. (Continued)

Substance	*USSR list no.*	*MPC (mg/l)*	*Basis* ‡
polychlorobenzoic acid (2KF)	89	5.0	T
polychloropinene	99	0.2	T
'Preparat AM'	178	*	S
'Preparat OS-20'	325	0.1	O
prometryne †	337	3.0	O
1,2-propanediol (propylene glycol)	179	*	S
1-propanol	341	0.25	O
2-propanol (isopropyl alcohol)	273	0.25	O
propazine †	338	1.0	O
propham † (IPK)	274	0.2	O
propionic acid, Na salt	176	*	S
propylamine	303	0.5	O
propylbenzene	339	0.2	O
propylene	340	0.5	O
pyridine	97	0.2	T
pyrogallol	331	0.1	O
quinol (hydroquinone)	232	0.2	O
resorcinol	181	0.1	S
saponin[s]	342	0.2	O
selenium	104	0.001	T
silicate, Na salt (as SiO_3)	105	50.0	T
Silicones:			
'GKZh-10' (sodium polyethylsilicone)	402	2.0	O
'GKZh-11' (sodium polymethylsilicone)	295	2.0	O
'GKZh-12' (sodium polyvinylsilicone)	225	2.0	O
'GKZh -94' (polyethylhydrosilicone)	335	10.0	O
'GKZh-94M' (polymethylhydrosilicone)	333	2.0	O
'KhS-2-1' (polymethyldichlorophenylsilicone)	334	10.0	O
'Smazka' (polyethylsilicone)	336	10.0	O
simazine †	345	absent	O
'Stearoks-6'	348	1.0	O
strontium	106	2.0	T
styrene	349	0.1	O

Table VIII.24. (Continued)

Substance	*USSR list no.*	*MPC (mg/l)*	*Basis* ‡
succinonitrile	107	0.2	T
'Sulfadimezin' (*N*(4,6-dimethyl-1,3,5-triazinyl)sulphanilamide)	187	1.0	S
sulphadimidine (Metazin)	287	0.3	O
sulphaguanidine (Sul'gin)	185	0.01	S
sulphanilamide (Streptotsid)	184	0.5	S
sulphathiazole (Norsul'fazol)	177	1.0	S
sulphide	186	absent	S
3-sulpholene	182	0.1	S
tellurium	110	0.01	T
terephthalic acid	188	0.1	S
1,2,4,5-tetrachlorobenzene	111	0.01	T
2,3,5,6-tetrachloro-*p*-benzoquinone (Chloranil)	382	0.01	O
1,1,2,2-tetrachloroethane	359	0.2	O
1,1,1,7-tetrachloroheptane	354	0.0025	O
1,1,1,9-tetrachlorononane	355	0.003	O
1,1,1,5-tetrachloropentane	356	0.005	O
1,1,1,3-tetrachloropropane	357	0.01	O
1,2,3,4,7,7-tetrachloro-*N*(*o*-tolyl)-2-norbornene-5,6-dicarboximide (Heximide)	149	0.1	S
1,1,1,11-tetrachloroundecane	358	0.007	O
tetraethyllead	113	absent	T
tetraethyltin	112	0.0002	T
tetrahydrofurfuryl alcohol	189	0.5	S
tetrahydrothiophene 1,1-dioxide (Sul'folan)	351	0.5	O
tetranitromethane	353	0.5	O
thiocyanate	100	0.1	T
thiometon † (M-81)	323	0.001	O
thiophene	361	2.0	O
'Thiozol' Korichnevyĭ BS' (a sulphur dye)	360	0.5	O
thiram † (Tiuram D)	364	absent	O
titanium	190	0.1	S
toluene	363	0.5	O
'tolyl phosphorodithioate' [isomer not stated]	249	0.001	O
tributyl phosphate	366	0.01	O

Table VIII.24. (Continued)

Substance	*USSR list no.*	*MPC (mg/l)*	*Basis* ‡
tributyl phosphorotrithioate (Butifos)	224	0.0003	O
trichloroacetic acid, Na salt	192	5.0	S
1,2,4-trichlorobenzene	368	0.03	O
2,3,6-trichlorobenzoic acid	115	1.0	T
trichloroethylene	374	0.5	O
trichloropentene [isomer not stated]	370	0.04	O
2,4,6-trichlorophenol	375	0.0004	O
2,4,5-trichlorophenoxyethyl trichloroacetate (Hexanat)	17	5.0	T
trichloropropane [isomer not stated]	371	0.07	O
3,3,3-trichloropropionic acid	372	0.01	O
3,3,3-trichloropropionic acid, Na salt	310	1.0	O
trichlorphon † (Khlorofos)	386	0.05	O
triethanolamine	373	1.4	O
triethylamine	117	2.0	T
triethylene glycol	193	*	S
triethylene glycol dinitrate	118	1.0	T
trinitromethane (nitroform)	322	0.01	O
2,4,6-trinitrotoluene	191	0.5	S
tritolyl phosphate	114	0.005	T
trixylenyl phosphate [isomer not stated]	367	0.05	O
'Tselatoks'	394	0.5	O
tungsten	15	0.1	T
turpentine	347	0.2	O
vanadium	11	0.1	T
vinyl acetate	12	0.2	T
'Vyravnivatel' A'	226	0.3	O
xylene [isomer not stated]	282	0.05	O
3,4- & 3,5-xylenol	244	0.25	O
zinc	198	1.0	S
zineb †	396	0.03	O

* The concentration, by calculation, that allows the maintenance of BOD and dissolved oxygen levels. [These substances are those which have a BOD in natural waters, and do not pose a toxicological or organoleptic hazard or affect self-purification.]

† Pesticide, common name (British Standard 1831 : 1969); 'erbon' is ISO name.

‡ Basis: O – organoleptic; S – self-purification; T – toxicological.

Table VIII.25. Characteristics of surface water intended for the abstraction of drinking water*
(Commission of the European Communities, 1975a)

	Parameters		A1 G	A1 I	A2 G	A2 I	A3 G	A3 I
1	pH		6·5 to 8·5		5·5 to 9		5·5 to 9	
2	Coloration (after simple filtration)	mg/l Pt scale	10	20 (O)	50	100 (O)	50	200 (O)
3	Total suspended solids	mg/l SS	25					
4	Temperature	° C	22	25 (O)	22	25 (O)	22	25 (O)
5	Conductivity	μs/cm^{-1} at 20 °C	1 000		1 000		1 000	
6	Odour	(dilution factor at 25 °C)	3		10		20	
7*	Nitrates	mg/l NO_3	25	50 (O)		50 (O)		50 (O)
8 (1)	Fluorides	mg/l F	0·7 to 1	1·5	0·7 to 1·7		0·7 to 1·7	
9	Total extractable organic chlorine	mg/l Cl						
10*	Dissolved iron	mg/l Fe	0·1	0·3	1	2	1	
11*	Manganese	mg/l Mn	0·05		0·1		1	
12	Copper	mg/l Cu	0·02	0·05 (O)	0·05		1	
13	Zinc	mg/l Zn	0·5	3	1	5	1	5
14	Boron	mg/l B	1		1		1	
15	Beryllium	mg/l Be						
16	Cobalt	mg/l Co						
17	Nickel	mg/l Ni						
18	Vanadium	mg/l V						
19	Arsenic	mg/l As	0·01	0·05		0·05	0·05	0·1
20	Cadmium	mg/l Cd	0·001	0·005	0·001	0·005	0·001	0·005
21	Total chromium	mg/l Cr		0·05		0·05		0·05
22	Lead	mg/l Pb		0·05		0·05		0·05
23	Selenium	mg/l Se		0·01		0·01		0·01
24	Mercury	mg/l Hg	0·0005	0·001	0·0005	0·001	0·0005	0·001
25	Barium	mg/l Ba		0·1		1		1
26	Cyanide	mg/l Cn		0·05		0·05		0·05

Table VIII.25. (Continued)

	Parameters		A1 G	A1 I	A2 G	A2 I	A3 G	A3 I
27	Sulphates	mg/l SO_4	150	250	150	250 (O)	150	250 (O)
28	Chlorides	mg/l Cl	200		200		200	
29	Surfactants (reacting with methyl blue)	mg/l (laurylsulphate)	0·2		0·2		0·5	
30* (²)	Phosphates	mg/l P_2O_5	0·4		0·7		0·7	
31	Phenols (phenol index) paranitraniline 4 aminoantipyrine	mg/l C_6H_5OH		0·001	0·001	0·005	0·01	0·1
32	Dissolved or emulsified hydrocarbons (after extraction by petroleum ether)	mg/l		0·05		0·2	0·5	1
33	Polycyclic aromatic hydrocarbons	mg/l		0·0002		0·0002		0·001
34	Total pesticides (parathion, BHC, dieldrin)	mg/l		0·001		0·0025		0·005
35*	Chemical oxygen demand (COD)	mg/l O_2					30	
36*	Dissolved oxygen saturation rate	% O_2	> 70		> 50		> 30	
37*	Biochemical oxygen demand (BOD_5) (at 20 °C without nitrification)	mg/l O_2	< 3		< 5		< 7	
38	Nitrogen by Kjeldahl method (except NO_3)	mg/l N	1		2		3	
39	Ammonia	mg/l NH_4	0·05		1	1·5	2	4 (O)
40	Substances extractable with chloroform	mg/l SEC	0·1		0·2		0·5	
41	Total organic carbon	mg/l C						
42	Residual organic carbon after flocculation and membrane filtration (5 µ) TOC	mg/l C						
43	Total coliforms 37 °C	/100 ml	50		5 000		50 000	
44	Faecal coliforms	/100 ml	20		2 000		20 000	
45	Faecal streptococci	/100 ml	20		1 000		10 000	
46	Salmonella		Not present in 5 000 ml		Not present in 1 000 ml			

I = mandatory.
G = guide.
O = exceptional climatic or geographical conditions.
* = see Article 8 (d).

(¹) The values given are upper limits set in relation to the mean annual temperature (high and low).

(²) This parameter has been included to satisfy the ecological requirements of certain types of environment.

Table VIII.25. (Continued)

* Standard Methods of Treatment

Category A1

Simple physical treatment and disinfection, e.g. rapid filtration and disinfection.

Category A2

Normal physical treatment, chemical treatment and disinfection, e.g. pre-chlorination, coagulation, flocculation, decantation, filtration, disinfection (final chlorination).

Category A3

Intensive physical and chemical treatment, extended treatment and disinfection e.g. chlorination to break-point, coagulation, flocculation, decantation, filtration, adsorption (activated carbon), disinfection (ozone, final chlorination).

Table VIII.26. Water Quality Standards for Salmonid and Cyprinid Waters - Annex 1
(Commission of the European Communities, 1978)

<table>
<tr><th rowspan="2">Parameter</th><th colspan="2">Salmonid waters</th><th colspan="2">Cyprinid waters</th><th rowspan="2">Methods of analysis or inspection</th><th rowspan="2">Minimum sampling and measuring frequency</th><th rowspan="2">Observations</th></tr>
<tr><th>G</th><th>I</th><th>G</th><th>I</th></tr>
<tr><td rowspan="7">1. Temperature (°C)</td><td colspan="4">1. Temperature measured downstream of a point of thermal discharge (at the edge of the mixing zone) must not exceed the unaffected temperature by more than:</td><td rowspan="7">Thermometry</td><td rowspan="7">Weekly, both upstream and downstream of the point of thermal discharge</td><td rowspan="7">Over-sudden variations in temperature shall be avoided</td></tr>
<tr><td></td><td>1·5°C</td><td></td><td>3°C</td></tr>
<tr><td colspan="4">Derogations limited in geographical scope may be decided by Member States in particular conditions if the competent authority can prove that there are no harmful consequences for the balanced development of the fish population</td></tr>
<tr><td colspan="4">2. Thermal discharges must not cause the temperature downstream of the point of thermal discharge (at the edge of the mixing zone) to exceed the following):</td></tr>
<tr><td></td><td>21·5 (0)
10 (0)</td><td></td><td>28 (0)
10 (0)</td></tr>
<tr><td colspan="4">The 10°C temperature limit applies only to breeding periods of species which need cold water for reproduction and only to waters which may contain such species</td></tr>
<tr><td colspan="4">Temperature limits may, however, be exceeded for 2 % of the time</td></tr>
</table>

Table VIII.26. (Continued)

Parameter	Salmonid waters		Cyprinid waters		Methods of analysis or inspection	Minimum sampling and measuring frequency	Observations
	G	I	G	I			
2. Dissolved oxygen (mg/l O_2)	50 % > 9 100 % > 7	50 % > 9 When the oxygen concentration falls below 6 mg/l, Member States shall implement the provisions of Article 7 (3). The competent authority must prove that this situation will have no harmful consequences for the balanced development of the fish population	50 % > 8 100 % > 5	50 % > 7 When the oxygen concentration falls below 4 mg/l, Member States shall implement the provisions of Article 7 (3). The competent authority must prove that this situation will have no harmful consequences for the balanced development of the fish population	Winkler's method or specific electrodes (electro-chemical method)	Monthly, minimum one sample representative of low oxygen conditions of the day of sampling However, where major daily variations are suspected, a minimum of two samples in one day shall be taken	
3. pH		6 to 9 (0) (¹)		6 to 9 (0) (¹)	Electrometry calibration by means of two solutions with known pH values, preferably on either side of, and close to the pH being measured	Monthly	
4. Suspended solids (mg/l)	< 25 (0)		< 25 (0)		Filtration through a 0·45 µm filtering membrane, or centrifugation (five minutes minimum, average acceleration of 2 800 to 3 200g) drying at 105 °C and weighing		The values shown are average concentrations and do not apply to suspended solids with harmful chemical properties Floods are liable to cause particularly high concentrations

Table VIII.26. (Continued)

Parameter	Salmonid waters		Cyprinid waters		Methods of analysis or inspection	Minimum sampling and measuring frequency	Observations
	G	I	G	I			
5. BOD_5 ($mg/l\ O_2$)	<3		<6		Determination of O_2 by the Winkler method before and after five days incubation in complete darkness at 20 ± 1°C (nitrification should not be inhibited)		
6. Total phosphorus (mg/l P)					Molecular absorption spectrophotometry		In the case of lakes of average depth between 18 and 300 m, the following formula could be applied: $L < 10 \frac{\bar{Z}}{Tw}(1 + \sqrt{Tw})$ where: L = loading expressed as mg P per square metre lake surface in one year $\bar{Z}$ = mean depth of lake in metres Tw = theoretical renewal time of lake water in years In other cases limit values of 0·2 mg/l for salmonid and of 0·4 mg/l for cyprinid waters, expressed as PO_4, may be regarded as indicative in order to reduce eutrophication
7. Nitrites ($mg/l\ NO_2$)	< 0·01		< 0·03		Molecular absorption spectrophotometry		

Table VIII.26. (Continued)

Parameter	Salmonid waters		Cyprinid waters		Methods of analysis or inspection	Minimum sampling and measuring frequency	Observations
	G	I	G	I			
8. Phenolic compounds (mg/l C_6H_5OH)		[2]		[2]	By taste		An examination by taste shall be made onyl where the presence of phenolic compounds is presumed
9. Petroleum hydrocarbons		[3]		[3]	Visual By taste	Monthly	A visual examination shall be made regularly once a month, with an examination by taste only where the presence of hydrocarbons is presumed
10. Non-ionized ammonia (mg/l NH_3)	< 0·005	< 0·025	< 0·005	< 0·025	Molecular absorption spectrophotometry using indophenol blue or Nessler's method associated with pH and temperature determination	Monthly	Values for non-ionized ammonia may be exceeded in the form of minor peaks in the daytime
	In order to diminish the risk of toxicity due to non-ionized ammonia, of oxygen consumption due to nitrification and of eutrophication, the concentrations of total ammonium should not exceed the following:						
11. Total ammonium (mg/l NH_4)	< 0·04	< 1 [4]	< 0·2	< 1 [4]			
12. Total residual chlorine (mg/l HOCl)		< 0·005		< 0·005	DPD-method (diethyl-*p*-phenylenediamene)	Monthly	The I-values correspond to pH = 6 Higher concentrations of total chlorine can be accepted if the pH is higher

Table VIII.26. (Continued)

Parameter	Salmonid waters		Cyprinid waters		Methods of analysis or inspection	Minimum sampling and measuring frequency	Observations
	G	I	G	I			
13. Total zinc (mg/l Zn)		< 0·3		< 1·0	Atomic absorption spectrometry	Monthly	The I-values correspond to a water hardness of 100 mg/l $CaCO_3$ For hardness levels between 10 and 500 mg/l corresponding limit values can be found in Annex II
14. Dissolved copper (mg/l Cu)	< 0·04		< 0·04		Atomic absorption spectrometry		The G-values correspond to a water hardness of 100 mg/l $CaCO_3$ For hardness levels between 10 and 300 mg/l corresponding limit values can be found in Annex II

(1) Artificial pH variations with respect to the unaffected values shall not exceed ± 0·5 of a pH unit within the limits falling between 6·0 and 9·0 provided that these variations do not increase the harmfulness of other substances present in the water.

(2) Phenolic compounds must not be present in such concentrations that they adversely affect fish flavour.

(3) Petroleum products must not be present in water in such quantities that they:
- form a visible film on the surface of the water or form coatings on the beds of water-courses and lakes,
- impart a detectable 'hydrocarbon' taste to fish,
- produce harmful effects in fish.

(4) In particular geographical or climatic conditions and particularly in cases of low water temperature and of reduced nitrification or where the competent authority can prove that there are no harmful consequences for the balanced development of the fish population, Member States may fix values higher than 1 mg/l.

General observation:

It should be noted that the parametric values listed in this Annex assume that the other parameters, whether mentioned in this Annex or not, are favourable. This implies, in particular, that the concentrations of other harmful substances are very low.

Where two or more harmful substances are present in mixture, joint effects (additive, synergic or antagonistic effects) may be significant.

G = guide.
I = mandatory.
(0) = derogations are possible in accordance with Article 11.

Table VIII.26. (Continued) - Annex II

PARTICULARS REGARDING TOTAL ZINC AND DISSOLVED COPPER

Total zinc

(see Annex I, No 13, 'Observations' column)

Zinc concentrations (mg/l Zn) for different water hardness values between 10 and 500 mg/l $CaCO_3$:

	Water hardness (mg/l $CaCO_3$)			
	10	50	100	500
Salmonid waters (mg/l Zn)	0·03	0·2	0·3	0·5
Cyprinid waters (mg/l Zn)	0·3	0·7	1·0	2·0

Dissolved copper

(See Annex I, No 14, 'Observations' column)

Dissolved copper concentrations (mg/l Cu) for different water hardness values between 10 and 300 mg/l $CaCO_3$:

	Water hardness (mg/l $CaCO_3$)			
	10	50	100	300
mg/l Cu	0·005 (1)	0·022	0·04	0·112

(1) The presence of fish in waters containing higher concentrations of copper may indicate a predominance of dissolved organo-cupric complexes.

Table VIII.27. - Application factors for toxic agents in Australian freshwater and marine environments [(a)] (Hart, 1974).

Agent	Fresh Water		Marine	
	Application Factor	Level at which some investigations should commence (μg/l)	Application Factor	Level at which some investigations should commence (μg/l)
Ammonia	0.1	50	0.1	-
Arsenic	0.01	50	0.01	50
Cadmium	0.01 [(c)]	(b)	0.01 [(c)]	-
Chromium	0.01	10	0.01	10
Copper	0.05	10	0.01	10
Cyanide	0.1	10	0.1	10
Detergents/ Oil Dispersants	0.05	200 [(d)]	0.05	-
Lead	0.01	20	0.01	20
Mercury		0.2		0.2
Nickel	0.05	50	0.05	100
Oil & Petroleum Products	0.05	-	0.05	-
Pesticides	0.01	(e)	0.01	-
Phenolic Compounds	0.05	(f)	0.05	(f)
PCB's	-	0.002	-	0.002
Zinc	0.005	100	0.01	10

(a) The recommended maximum concentrations can be calculated for each agent by multiplying the 96-hr LC_{50} value by the application factor.

(b) Cadmium concentrations should be less than 30 μg/l in hard water (hardness greater than 100 mg/l as $CaCO_3$) and less than 4 μg/l in soft water. In waters where crustacea and eggs and larvae of salmonids develop, levels should be less than 3 μg/l in hard water and less than 0.4 μg/l in soft water.

(c) Use application factor of 0.001 if waters have concentrations of copper and/or zinc in excess of 1 mg/l.

(d) For linear alkylate sulphonates

(e) See Table VIII.28 for recommended maximum concentrations

(f) Chlorophenols at concentrations as low as 1 μg/l can cause tainting of fish and crustacea.

Table VIII.28.- Recommended maximum concentrations of pesticides in freshwater for protection of aquatic life. (Hart, 1974).

Compound	Recommended maximum concentrations (μg/l)	Compound	Recommended maximum concentrations (μg/l)
Chlorinated Hydrocarbons:		Oxydemeton Methyl	0.4
Aldrin	0.01	Parathion	0.001
DDT	0.002	Phosphamidon	0.03
DDE	0.006	TEPP	0.3
Dieldrin	0.005	Trichlorophon	0.002
Chlordane	0.04	Carbamates:	
Endosulphan	0.003	Carbaryl	0.02
Endrin	0.002	Zectran	0.1
Heptachlor	0.01	Herbicides:	
Lindane	0.02	Aminotriazole	300.0
Methoxychlor	0.005	Dalapon	110.0
Toxaphene	0.01	Dicamba	0.2
Organophosphates:		Dichlobenil	37.0
Azinphosmethyl	0.001	Dichlone	0.7
Ciodrin	0.1	Diquat	0.5
Coumaphos	0.001	Diuron	1.6
Diazinon	0.009	2,4-D (BEE)	4.0
Dichlorvos	0.001	Fenac (Sodium salt)	45.0
Dioxathion	0.09	Silvex (BEE)	2.5
Disulfonton	0.05	Silvex (PGBE)	2.0
Dursban	0.001	Simazine	10.0
Ethion	0.02	Botanicals:	
EPN	0.06	Allethrin	0.002
Fenthion	0.006	Pyrethrum	0.01
Malathion	0.008	Rotenone	10.0
Mevinphos	0.002		
Naled	0.004		

Table VIII.29. Recommended application factors and maximum concentrations of toxic substances in American aquatic environments (Committee on Water Quality Criteria, 1973).

Parameter	Freshwater		Marine		
	Application factor	Recommended maximum concentrations	Application factor	Level below which there is minimal risk	Level which may constitute a hazard
Ammonia	0.05	0.02	0.1	0.01	0.4
Antimony	-	-	0.02	-	0.2
Arsenic	-	-	0.01	0.01	0.05
Barium	-	-	0.05	0.5	1.0
Beryllium	-	-	0.01	0.1	1.5
Boron	-	-	0.1	5.0	5.0
Cadmium	-	(a)	0.01 (b)	0.0002	0.01
Chlorine	-	0.003	0.1	-	0.01
Chromium	-	0.05	0.01	0.05 (c)	0.1
Copper	0.1	-	0.01	0.01	0.05
Cyanides	0.05	0.005	0.1	0.005	0.01
Detergents	0.05	0.2	-	-	-
Fluorides	-	-	0.1	0.5	1.5
Iron	-	-	-	0.05	0.3
Lead	-	0.03	0.02	0.01	0.05
Manganese	-	-	0.02	0.02	0.1
Mercury	-	0.0002	-	-	0.0001
Molybdenum	-	-	0.05	-	-
Nickel	0.02	-	0.02	0.002	0.1
Phenolics	0.05	-	-	-	-
Phosphorus	-	-	0.01	-	0.0001
Selenium	-	-	0.01	0.005	0.01
Silver	-	-	0.05	0.0001	0.0005
Sulphides	-	0.002	0.1	0.005	0.01
Thallium	-	-	-	0.05	0.01
Vanadium	-	-	0.05	-	-
Zinc	0.005	-	0.01	0.02	0.1

Notes to Table VIII.29.

(a) 0.03 mg/l if hardness >100 mg/l as $CaCO_3$ or 0.004 mg/l if hardness <100 mg/l. For crustaceans or eggs and larvae of salmon: 0.003 mg/l in hard water, 0.0004 mg/l in soft water.

(b) In presence of copper and/or zinc should be lower by at least one order of magnitude.

(c) Concentration should be less than 0.01 mg/l in oyster areas.

For example, the National Academy of Sciences Committee on Water Quality Criteria (1973) recently recommended maximum permissible levels of various trace elements in irrigation waters (see Table VIII.30). Guidelines have also been developed on such aspects as salinity, sodium concentration, pH, temperature, pesticide concentrations and the re-use of effluents for agricutural purposes (Committee on Water Quality Criteria, 1973; Hart, 1974; World Health Organisation, 1973).

Recommended maximum concentrations of toxic substances in livestock waters as adopted in the USA (Committee on Water Quality Criteria, 1973) and Australia (Hart, 1974) are shown in Table VIII.31.

iv) Standards for protection of recreational uses. A number of authorities have established the level of water quality needed to preserve the aesthetic appeal of recreational waters and to allow the recreational activities of swimming, boating, fishing, etc., to be pursued without risk or interference. Table VIII.32 shows, for example, the quality requirements for bathing water as laid down by the Commission of the European Communities (1976a), while Table VIII.33 summarises the Australian requirements for the preservation of aesthetic and recreational water quality (Hart, 1974).

v) Industrial water supply requirements. Although water quality requirements for different industries, for various industrial processes within a single plant and for the same process in different plants vary widely, modern water treatment technology is capable of treating almost any raw water to render it suitable for any industrial use. However, it is evident that the closer the composition of an available water supply is to the quality required, the more desirable that water becomes because treatment costs will be low.

Table VIII.30. - Recommended maximum concentratons of trace elements in irrigation waters* (mg/l) (Committee on Water Quality Criteria, 1973)

Element	For waters used continuously on all soil	For use up to 20 years on fine textured soils of pH 6.0 to 8.5
Aluminium	5.0	20.0
Arsenic	0.10	2.00
Beryllium	0.10	0.50
Boron	0.75	2.0-10.0
Cadmium	0.010	0.050
Chromium	0.10	1.0
Cobalt	0.050	5.0
Copper	0.20	5.0
Fluoride	1.0	15.0
Iron	5.0	20.0
Lead	5.0	10.0
Lithium	2.5+	2.5+
Manganese	0.20	10.0
Molybdenum	0.010	0.050‡
Nickel	0.20	2.0
Selenium	0.020	0.020
Vanadium	0.10	1.0
Zinc	2.0	10.0

* These levels will normally not adversely affect plants or soils. No data available for mercury, silver, tin, titanium, tungsten

\+ Recommended maximum concentration for irrigating citrus is 0.075 mg/litre

‡ For only acid fine-textured soils or acid soils with relatively high iron oxide contents

Table VIII.31. - Recommended maximum concentrations of toxic substances in livestock drinking water supplies in USA and Australia (Committee on Water Quality Criteria, 1973; Hart, 1974).

Parameter	U.S.A.	Australia
Aluminium	5.0	-
Arsenic	0.2	1.0
Boron	5.0	-
Cadmium	0.05	0.01
Calcium	-	1,000
Chromium	1.0	1 to 5
Cobalt	1.0	-
Copper	0.5	0.5 to 2.0
Fluoride	2.0	2.0
Iron	-	10.0
Lead	0.1	0.5
Magnesium	-	250 to 500
Mercury	0.01	0.002
Molybdenum	-	0.01
Nitrate (as NO_3)	-	90 to 200
Nitrite (as N)	10	-
Nitrate + Nitrite (as N)	100	-
Selenium	0.05	0.02
Sulphate	-	1,000
Vanadium	0.1	-
Zinc	25	20

Table VIII.32. Quality Requirements for Bathing Water (Commission of the European Communities, 1976a)

	Parameters	G	I	Minimum sampling frequency	Method of analysis and inspection
	Microbiological:				
1	Total coliforms /100 ml	500	10 000	Fortnightly (1)	Fermentation in multiple tubes. Subculturing of the positive tubes on a confirmation medium. Count according to MPN (most probable number) or membrane filtration and culture on an appropriate medium such as Tergitol lactose agar, endo agar, 0·4 % Teepol broth, subculturing and identification of the suspect colonies. In the case of 1 and 2, the incubation temperature is variable according to whether total or faecal coliforms are being investigated.
2	Faecal coliforms /100 ml	100	2 000	Fortnightly (1)	
3	Faecal streptococci /100 ml	100	—	(2)	Litsky method. Count according to MPN (most probable number) or filtration on membrane. Culture on an appropriate medium.
4	Salmonella /1 litre	—	0	(2)	Concentration by membrane filtration. Inoculation on a standard medium. Enrichment — subculturing on isolating agar — identification.
5	Entero viruses PFU/10 litres	—	0	(2)	Concentrating by filtration, flocculation or centrifuging and confirmation.
	Physico-chemical:				
6	pH	—	6 to 9 (0)	(2)	Electrometry with calibration at pH 7 and 9.
7	Colour	—	No abnormal change in colour (0)	Fortnightly (1)	Visual inspection or photometry with standards on the Pt.Co scale.
		—	—	(2)	

Table VIII.32. (Continued)

	Parameters	G	I	Minimum sampling frequency	Method of analysis and inspection
8	Mineral oils mg/litre	— ≤ 0·3	No film visible on the surface of the water and no odour —	Fortnightly (1) (2)	Visual and olfactory inspection or extraction using an adequate volume and weighing the dry residue.
9	Surface-active substances reacting with methylene blue mg/litre (lauryl-sulfate)	— ≤ 0·3	No lasting foam —	Fortnightly (1) (2)	Visual inspection or absorption spectrophotometry with methylene blue.
10	Phenols (phenol indices) mg/litre C_6H_5OH	— ≤ 0·005	No specific odour ≤ 0·05	Fortnightly (1) (2)	Verification of the absence of specific odour due to phenol or absorption spectrophotometry 4-aminoantipyrine (4 AAP) method.
11	Transparency m	2	1 (0)	Fortnightly (1)	Secchi's disc.
12	Dissolved oxygen % saturation O_2	80 to 120	—	(2)	Winkler's method or electrometric method (oxygen meter).
13	Tarry residues and floating materials such as wood, plastic articles, bottles, containers of glass, plastic, rubber or any other substance. Waste or splinters	Absence		Fortnightly (1)	Visual inspection.
14	Ammonia mg/litre NH_4			(3)	Absorption spectrophotometry, Nessler's method, or indophenol blue method.
15	Nitrogen Kjeldahl mg/litre N			(3)	Kjeldahl method.
	Other substances regarded as indications of pollution				
16	Pesticides mg/litre (parathion, HCH, dieldrin)			(2)	Extraction with appropriate solvents and chromatographic determination

Table VIII.32. (Continued)

	Parameters	G	I	Minimum sampling frequency	Method of analysis and inspection
17	Heavy metals such as: — arsenic mg/litre As — cadmium Cd — chrome VI Cr VI — lead Pb — mercury Hg			(2)	Atomic absorption possibly preceded by extraction
18	Cyanides mg/litre Cn			(2)	Absorption spectrophotometry using a specific reagent
19	Nitrates and mg/litre NO_3 phosphates PO_4			(2)	Absorption spectrophotometry using a specific reagent

G = guide.

I = mandatory.

(0) Provision exists for exceeding the limits in the event of exceptional geographical or meteorological conditions.

(1) When a sampling taken in previous years produced results which are appreciably better than those in this Annex and when no new factor likely to lower the quality of the water has appeared, the competent authorities may reduce the sampling frequency by a factor of 2.

(2) Concentration to be checked by the competent authorities when an inspection in the bathing area shows that the substance may be present or that the quality of the water has deteriorated.

(3) These parameters must be checked by the competent authorities when there is a tendency towards the eutrophication of the water.

Table VIII.33. Australian requirements for preservation of aesthetic and recreational water quality (Hart, 1974)

Aesthetic Water Quality

a) Surface waters should not be altered in any way that reduces their ability to support aesthetically valuable flora and fauna. Such alterations may be physical, such as dredging, or may be due to the addition of toxic wastes to the water.

b) Surface waters should themselves be aesthetically pleasing. They should be free from:

- floating debris, oil, grease, scum or other objectionable matter;
- substances that produce undesirable colour, odour, taste, turbidity or foaming;
- undesirable aquatic life such as 'water-blooms' or heavy growths of attached plants or animals.

Recreational Water Quality

Body Contact Use:

In determining the factors that should be considered for water quality requirements for swimming, bathing and other direct water-contact sports, health criteria are most important although aesthetic considerations are also significant. The following criteria are recommended:

a) The general criteria applicable to the aesthetic quality of the water are also applicable for recreational waters.

b) Faecal coliforms (possibly in conjunction with faecal streptococci) should be used as the indicator organisms for evaluation of the bacteriological quality of the water. If faecal coliform levels are in excess of 200 organisms/100 ml, further investigations of the health risks associated with the water should be conducted. Such investigations may include surveys of the water for pathogenic bacteria and virus occurrence, a survey of conditions existing in the local watershed, and a consideration of disease and illness prevalent in the community at the time.

With the present state of knowledge it is stressed that the above bacteriological criteria are a guide based on the *possibility* of health hazards rather than *probability* of actual danger to the health of the swimmer.

c) The pH of the water should be within the range of 6.5 to 8.3. pH values between 5.0 and 9.0 may be acceptable if due to natural causes. Discharges of substances that could cause unfavourable increases in the acidity or alkalinity of the water should be limited if the pH of the receiving water is less than 6.5 or greater than 8.3.

d) Clarity of the water should be such that a Secchi disc is visible at a minimum depth of 1.2 m (4 ft); this will correspond to a turbidity of around 50 JTU. Any human activities that decrease the water clarity below these levels should be controlled.

e) As far as is possible water temperatures for most body contact recreational activities should be between 20 and 30°C.

f) The water should not contain concentrations of toxic chemicals or toxic algae that could constitute a health risk to the user.

Table VIII.33. (Continued)

Boating

This activity is taken to include cruising for pleasure, water-skiing, sailing and canoeing. The following criteria are recommended:

a) Water used for boating should meet the criteria recommended for aesthetic water quality.

b) Since there are few, if any, water bodies where boating activities occur to the total exclusion of body contact recreation and there appears no valid reason to allow the present generally low bacterial levels to deteriorate, the establishment of an additional bacteriological criteria over those given for primary contact use is not recommended.

c) The water should be free from floating or submerged logs that could damage boats or injure water skiers.

d) The water should not contain excessive growths of algae or other aquatic plants which could pose a hazard to water-skiers and cause fouling problems with boats.

Fishing

a) Water used for fishing should meet the criteria suggested for aesthetic water quality.

b) The quality of water used for fishing should be maintained so that there are minimal changes in species composition and minimal alteration of fisheries habitat.

c) As far as is possible hindrances to fishing, such as excessive weed growth, and floating and submerged debris, should be absent.

In general, industry's intake water quality requirements are not as stringent as those for public water supplies, support of aquatic life or agricultural or recreational use. On the other hand, water quality at the point of use is critical for many industrial processes and, in some cases, can be so stringent that treatment of domestic water supplies is required.

The water quality requirements of various industrial processes have been discussed in a number of reviews (McKee and Wolf, 1963; National Council on Water Quality, 1968; Eller, Ford and Gloyna, 1970; Committee on Water Quality Criteria, 1973; Hart, 1974). By way of example, summary tables from either the Committee on Water Quality Criteria (1973) or Hart (1974) are given for the following industries:

(a) Steam generation and cooling (Table VIII.34)
(b) Textile industry (Table VIII.35)
(c) Pulp, paper and allied industries (Table VIII.36)
(d) Chemical and allied products (Table VIII.37)
(e) Iron and steel industry (Table VIII.38)
(f) Leather tanning and finishing industry (Table VIII.39)
(g) Food and beverage industries (Table VIII.40) and
(h) Miscellaneous industries: petroleum refining, concrete, cement, electroplating, laundering and photograph processes (Table VIII.41)

It must be stressed, however, that although data in Table VIII.34 to VIII.41 give general guidelines to water quality requirements in the various industries, each plant must be considered in light of the manufacturing processes and other circumstances specific to that installation.

The preceding discussions have shown that a wide range of standards can be established for receiving waters depending on the desired or intended use for the water. Caution should be exercised, however, when classifying waters and setting standards to take account of natural "contamination". Thus waters can vary widely in quality depending on location and other factors such as climate, topography and geological formation. Although, as mentioned previously, preservation of public water supplies generally affords protection for other water uses, successful river management involves the maintenance of a balance between competing use requirements, such that the imposition of drinking water source standards in a blanket fashion may be an unnecessarily stringent approach leading to a wasteful allocation of resources. Consequently, agencies responsible for large or many bodies of water often specify different standards for different stretches of water. Table VIII.42 shows, for example, the New York State classifications and standards for surface waters.

Used in this manner, receiving water quality standards would avoid unnecessary expenditure on waste treatment and, as the emphasis is on the quality of the receiving water, they are likely to be viewed as just by industry who would then tend to be motivated to comply with them. However, although such standards in theory can be scientifically based, adequate data are lacking at present. Other disadvantages are that it is often difficult to know where and when to sample and that if the standards are not met, it is difficult (in the absence of effluent monitoring) to identify the industry responsible and to enforce appropriate action.

VIII.4.2. Effluent standards

Water quality management systems based on the use of effluent standards require that monitoring is carried out by sampling the effluent at the point of discharge. However, there are three main different approaches to the setting of effluent standards (Water Research Centre, 1977):

(i) Best available technology approach. This system requires that the removal of pollutants should be as complete as current technology allows. While this system affords maximum available protection to the environment and means that improvements in water quality should closely follow technical innovations in effluent treatment, it does not take into accout relative toxicities, the different fates of substances and the differences in the assimilative

Table VIII.34. Quality Requirements of Water at Point of Use for Steam Generation and Cooling in Heat Exchangers*

(Unless otherwise indicated, units are mg/l and values that normally should not be exceeded. No one water will have all the maximum values shown).

Characteristic	Boiler feedwater				Cooling water			
	Quality of water prior to the addition of chemicals used for internal conditioning							
	Industrial			Electric utilities	Once through		Makeup for recirculation	
	Low pressure 0 to 150 psig	Intermediate pressure 150 to 700 psig	High pressure 700 to 1,500 psig	1,500 to 5,000 psig	Fresh	Brackish[a]	Fresh	Brackish[a]
Silica (SiO_2)	30	10	0.7	0.01	50	25	50	25
Aluminum (Al)	5	0.1	0.01	0.01	(b)	(b)	0.1	0.1
Iron (Fe)	1	0.3	0.05	0.01	(b)	(b)	0.5	0.5
Manganese (Mn)	0.3	0.1	0.01	0.01	(b)	(b)	0.5	0.02
Calcium (Ca)	(b)	0.4	0.01	0.01	200	420	50	420
Magnesium (Mg)	(b)	0.25	0.01	0.01	(b)	(b)	(b)	(b)
Ammonia (NH_4)	0.1	0.1	0.1	.07	(b)	(b)	(b)	(b)
Bicarbonate (HCO_3)	170	120	48	0.5	600	140	24	140
Sulfate (SO_4)	(b)	(b)	(b)	(d)	680	2,700	200	2,700
Chloride (Cl)	(b)	(b)	(b)	(b, d)	600	19,000	500	19,000
Dissolved solids	700	500	200	0.5	1,000	35,000	500	35,000
Copper (Cu)	0.5	0.05	0.05	0.01	(b)	(b)	(b)	(b)
Zinc (Zn)	(b)	0.01	0.01	0.01	(b)	(b)	(b)	(b)
Hardness ($CaCO_3$)	350	1.0	0.07	0.07	850	6,250	650	6,250
Alkalinity ($CaCO_3$)	350	100	40	1	500	115	350	115
pH, units	7.0-10.0	8.2-10.0	8.2-9.0	8.8-9.4	5.0-8.3	6.0-8.3	(b)	(b)
Organics:								
Methylene blue active substances	1	1	0.5	0.1	(b)	(b)	1	1
Carbon tetrachloride extract	1	1	0.5	(b, e)	(e)	(e)	1	2
Chemical oxygen demand (COD)	5	5	1.0	1.0	75	75	75	75
Hydrogen sulfide (H_2S)	(b)	(b)	(b)	(b)	....	....	(b)	(b)
Dissolved oxygen (O_2)	2.5	0.007	0.007	0.007	present	present	(b)	(b)
Temperature, F	(b)	(b)	(b)	(b)	(b)	(b)	(b)	(b)
Suspended solids	10	5	0.5	0.05	5,000	2,500	100	100

[a] Brackish water—dissolved solids more than 1,000 mg/l by definition 1963 Census of Manufacturers.

[b] Accepted as received (if meeting other limiting values); has never been a problem at concentrations encountered.

[c] Zero, not detectable by test.

[d] Controlled by treatment for other constituents.

[e] No floating oil.

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* Committee on Water Quality Criteria (1973)

Table VIII.35. Quality Requirements of Water at Point of Use for the Textile Industry (Hart, 1974)
(Water quality prior to addition of substances used for internal conditioning, units are mg/l and values that normally should not be exceeded)

Characteristic	Cotton, Wool, Synthetics				Viscose Rayon	
	Sizing Suspension	Scouring	Bleaching	Dyeing	Pulp Manufacture	Manufacture
Iron (Fe)	0.3	0.1	0.1	0.1	0.05 (Fe+Mn)	0.0
Manganese (Mn)	0.05	0.01	0.01	0.01	0.03	0.0
Copper (Cu)	0.05	0.01	0.01	0.01	<5	
Filterable Residue	100	100	100	100	100	
Suspended Solids	5	5	5	5		
Hardness ($CaCO_3$)	25	25	25	25	8	55
pH, units:						
Cotton	6.5 - 10	9.0 - 10.5	2.5 - 10.5	7.5 - 10.0		
Synthetics	6.5 - 10	3.0 - 10.5	not applicable	6.5 - 7.5		7.8 - 8.3
Wool	6.5 - 10	3.0 - 5.0	2.5 - 5.0	3.5 - 6.0		
Colour, units	5	5	5	5		
Turbidity, units				15	5	0.3
Aluminium (Al)					<8	
Silica (SiO_2)					<25	
Alkalinity ($CaCO_3$)					50 - 75	50 - 75

Table VIII.36. Quality Requirements of Water at Point of use for the Pulp, Paper and Allied Industries (Hart, 1974)

(Unless otherwise indicated, values are in mg/l and should normally not be exceeded)

Reference	Groundwood or Mechanical Pulp	Groundwood Paper	Bleached		Unbleached.		Fine Paper
			Kraft	Chem. Pulp & Paper	Kraft	Chem. Pulp & Paper	
pH, units	6-10			6-10		6-10	
Colour, units	30	30	25	10	100	30	5
Turbidity, units		50*	40		100		10
Calcium (Ca)	X			20		20	20
Magnesium (Mg)	X			12		12	12
Iron (Fe)	0.3	0.3	0.2	0.1	1.0	1.0	0.1
Manganese (Mn)	0.1	0.1	0.1	0.05	0.5	0.5	0.05
Aluminium (Al)	X			X		X	
Zinc (Zn)	X			X		X	
Sulphate (SO_4)	X			X		X	
Chloride (Cl)	1 000	25-75	200	200	200	200	
Silica (SiO_2)	X	50	50	50	100	50	20
Hardness ($CaCO_3$)	X	200	100	100	200	100	100
Alkalinity ($CaCO_3$)		150	75		150		40-75
Filterable Residue	X	500	300	X	500	X	200
Suspended Solids	X			10*		10*	
Temperature °C	X			35		X	
Free Carbon Dioxide		10	10		10		10
Corrosion Tendency		NO	NO	NO	NO	NO	NO
Residual Chlorine		NO	NO		NO		2.0

* No gritty or colour-producing solids present

X Accepted as received; has never been a problem at concentration encountered

Table VIII.37. Quality Requirements of Water at Point of the Use for Chemical and Allied Industries (Hart, 1974)
(Unless otherwise indicated, values are in mg/l and should normally not be exceeded)

Reference	Alkalies and Chlorine	Organic Chemicals	Inorganic Chem.	Clear Plastics	Synthetic Rubber	Drugs &[+] Pharmaceuticals	Soap & Detergents	Paints	Fertilisers
pH, units	X	6.5-8.7	X	X	6.2-8.3	X	X	X	X
Colour, units	X	X	X	2	20	X	X	X	X
Turbidity, units				2					
Taste & Odour (threshold no.)	X	X	X	X	X	X	X	X	X
Calcium (Ca)	2	68	X	X	80	X	X	X	X
Magnesium (Mg)	2	19	X	X	35	X	X	X	X
Iron (Fe)	0.1	0.1	X	0.02	0.1	X	X	X	X
Manganese (Mn)	0.1	0.1	X	0.02*	0.1	X	X	X	X
Bicarbonate (HCO_3)	X	128	X	X		X	X	X	X
Sulphate (SO_4)	X	X	X	X	X	X	X	X	X
Chloride (Cl)	X	X	X	X	X	X	X	X	X
Nitrate (NO_3)	X	X	X	X	X	X	X	X	X
Silica(SiO_2)	X	X	X	X	X	X	X	X	X
Hardness ($CaCO_3$)	low	250	X	X	350	X	X	X	X
Alkalinity ($CaCO_3$)	X	125	X	X	150	X	X	X	X
Filterable Residue	X	X	X	200	X	X	X	X	X
Suspended Solids	X	X	X	X	5	X	X	X	X
Dissolved Oxygen (O_2)	X	X	X	X	X	X	X	X	X
Chemical Oxygen Demand (O_2)	X	X	X	X	X	X	X	X	X
Biochemical Oxygen Demand (O_2)	X	X	X	X	X	X	X	X	X

* Fe and Mn total

X Accepted as received; has never been a problem at concentration encountered

\+ Australian practice generally requires low colour (<5 Hazen units), low turbidity (<1 unit) and low filterable residue (<10 mg/l)

Table VIII.38. Quality Requirements of Water at Point of Use for the Iron and Steel Industry
(Committee on Water Quality Criteria, 1973)

(Unless otherwise indicated, units are mg/l and values that normally should not be exceeded. Table indicates quality of the water prior to the addition of substances used for internal conditioning).

Characteristics	Quenching, hot rolling, gas cleaning	Cold rolling	Selected rinse waters	
			Partially Softened	Demineralized
Settleable solids	100	5.0	5.0	0.1
Suspended solids	(a)	10	5.0	0.1
Dissolved solids	(a)	(a)	(a)	0.5
Alkalinity ($CaCO_3$)	(b)	(b)	(b)	0.5
Hardness ($CaCO_3$)	(b)	(b)	100	0.1
pH, units	5-9	5-9	6-9	(d)
Chloride (Cl)	(a)	(a)	(a)	0.1
Dissolved Oxygen (O_2)	(c)	(c)	(c)	(c)
Temperature, F	100	100	100	100
Oil	(a)	1.0	1.0	0.02

[a] Accepted as received if meeting other limiting values: has never been a problem at concentrations encountered.

[b] Controlled by treatment for other constituents.

[c] Minimum to maintain aerobic conditions.

[d] Concentration not known.

Table VIII.39. Quality Requirements of Water at Point of Use by Leather Tanning and Finishing Industry
(Committe on Water Quality Criteria, 1973)

(Unless otherwise indicated, units are mg/l and values that normally should not be exeeded. Table Indicates quality of the water prior to the addition of substances used for internal conditioning).

Characteristic	Tanning processes	General finishing processes	Coloring
Alkalinity ($CaCO_3$)	(a)	(a)	(a)
pH, units	6.0-8.0	6.0-8.0	6.0-8.0
Hardness ($CaCO_3$)	150	(b)	(c, d)
Calcium (Ca)	60	(b)	(c, d)
Chloride (Cl)	250	250	(e)
Sulfate (SO_4)	250	250	(e)
Iron (Fe)	50	0.3	0.1
Manganese (Mn)	(e)	0.2	0.01
Organics: carbon chloroform extract	(e)	0.2	(c)
Color, units	5	5	5
Coliform bacteria	(f)	(f)	(e)
Turbidity	(c)	(c)	(c)

[a] Accepted as received (if meeting other listed limiting values); has never been a problem at concentrations encountered.

[b] Lime softened.

[c] Not detectable by test.

[d] Demineralized or distilled water.

[e] Concentration not known at which problems occur.

[f] PHS Drinking Water Standards (1962).

Table VIII.40. Quality Requirements of Water at Point of Use for Foood and Beverage Industries (Hart, 1974)

Unless otherwise indicated, values are in mg/l and should normally not be exceeded)

Reference	Baking	Brewing Light Beers	Brewing Dark Beers	Confectionery	Dairy	Fermentation Industry	Food Canning and Freezing Dried & Frozen Fruits & Vegetables	Food Equipment Washing	Food Process. General	Soft Drinks	Sugar Manufacture
pH, units		6.5-7.0	6.5-7.0	>7.0		Gin & Spirits - See Brewing Light Beers Whiskey - See Brewing Dark Beers	6.5-8.5			C	
Colour, units	10	0-10	0-10		0		5	5-20	5-10	5-10(DWS)	
Turbidity, units	10	0-10	0-10				DWS	1	1-10	1-2	
Taste & Odour (threshold no.)	low	0-low	0-low	low	0		ND	0	0-low	0(DWS)	
Calcium (Ca)		100-200	200-500				100				20
Magnesium (Mg)		30	30								<10
Iron (Fe)	0.2	0.1-1	0.1-1	0.2	0.1-0.3		0.2		0.2	0.1-0.2	<0.10
Manganese (Mn)	0.2*	0.1*	0.1*	0.2*	0.03-0.1		0.2	0.2*	0.2(0.3)	0.05*	0.1
Copper (Cu)					0					<0.1	
Ammonium (NH₄)					Trace						
Bicarbonate (HCO₃)		0									100
Carbonate (CO₃)		50-68	50-68							5	
Sulphate (SO₄)					<60		250			250+	20
Chloride (Cl)		60-100	60-100	250	<30		250	250		250+	20
Nitrate (NO₃) ++		10 (30)	10(30)		<30		(10)				
Fluoride (F) ++		1	1				1	1	1	1.0	
Silica (SiO₂)		(50)	50				50			200-250	
Hardness (CaCO₃)	***		250		<180		250.	10	10-250	200-250	low
Alkalinity (CaCO₃)		75-80	80-150				250	10	30-250	50-70	
Filterable Residue		1 500**		50-100	<500		500	850	850	400-500	
Suspended Solids							10				0
Hydrogen Sulphide (H_2S)	0.2	0.2	0.2	0.2						0-0.2	
Oxygen Consumed (O_2)					<12					1.5	
Carbon Tetrachloride Extract							0.2	Very slight		0.5	
Carbon Chloroform Extract							DWS			0.2	
Algae & Protozoa										none	
Coliform Bacteria/100 ml	DWS		ND	DWS			DWS			none	sterile
Phenol							ND				
Total Bacteria Count/ml							low			<25	

* Total Fe and Mn
** 300 mg/l for any one substance
*** Some hardness necessary for yeast action; too much retards fermentation (50 - 100 mg/l suggested)
\+ If present with equivalent amounts of magnesium and calcium, sulphates and chlorides etc., limit may be somewhat lower

++ Fluorides, nitrites and nitrates should be low in water used for baby foods
DWS Drinking water standard quality; PHS, 1962
C Controlled by treatment for other constituents

N.D. Not detectable by test

Table VIII.41. Quality Requirements of Water at Point of Use for Miscellaneous Industries (Hart, 1974)

(Unless otherwise indicated, values are in mg/l and should normally not be exceeded)

Reference	Concrete	Cement (Hydraulics)	Electroplating		Laundering	Photographic Processes	Petroleum Refining
			Metal finishing	Rinse			
pH, units		6.5-8.5			6.0-6.8	7.0-8.5	6.0-9.0
Colour, units		X				none	x
Turbidity, units						low	
Calcium (Ca)		X					75
Magnesium (Mg)	low	X					30
Iron (Fe)		25		low	0.2 (1.0)	0.1	1
Manganese (Mn)		0.5			0.2* (1.0*)	0.1	
Copper (Cu)						0.1	
Bicarbonate (HCO_3)					low	150	
Carbonate (CO_3)				low			x
Sulphate (SO_4)	low	250		low		200	x
Chloride (Cl)		250				**	300
Nitrate (NO_3)				low			x
Silica (SiO_2)		35				20	x
Hardness ($CaCO_3$)		X		low	0-50	40-150	350 (7) (a)
Alkalinity ($CaCO_3$)		400			60		
Acidity ($CaCO_3$)		0					
Filterable Residue		600	low			250	1,000
Suspended Solids	(C)	500				low	10
Hydrogen Sulphide (H_2S)						0.1	
Chemical Oxygen Demand		X					
Carbon Tetrachloride Extract		1					
Free Carbon Dioxide	20			15			
Corrosion Tendency	NO						

* Fe and Mn total

** For black and white reversal 25 mg/l, for colour processing 100 mg/l

(C) Free from acids, alkalies, oil and decayed vegetable matter; SO_3 should be less than 25 mg/l

X Accepted as received; has never been a problem at concentration encountered

Table VIII.42, - New York State Classification and Standards for Surface Waters

Class and best use*	Water Standards†				
	Minimum dissolved oxygen ml/liter	Coliform bacteria median no/100 ml	pH	Toxic wastes, deleterious substances, colored wastes, heated liquids, odor-producing substances ‡	Floating solids, settleable solids, oil, and sludge deposits
AA - Source of unfiltered public water supply and any other usage	5.0 (trout) 4.0 (nontrout)	Not to exceed 50	6.5–8.5	None in sufficient amounts or at such temperatures as to be injurious to fish life or make the waters unsafe or unsuitable.	None attributable to sewage, industrial wastes or other wastes.
A - Source of filtered public water supply and any other usage	5.0 (trout) 4.0 (nontrout)	Not to exceed 5000	6.5–8.5		None which are readily visible and attributable to sewage, industrial wastes or other wastes.
B - Bathing and any other usages except as a source of public water supply	5.0 (trout) 4.0 (nontrout)	Not to exceed 2400	6.5–8.5		
C - Fishing and any other usages except public water supply and bathing	5.0 (trout) 4.0 (nontrout)	Not applicable	6.5–8.5	None in sufficient amounts or at such temperatures as to be injurious to fish life or impair the waters for any other best usage.	
D - Natural drainage, agriculture, and industrial water supply	3.0	Not applicable	6.0–9.5	None in sufficient amounts or at such temperatures as to prevent fish survival or impair the waters for agricultural purposes or any other best usage.	

*Class B and C waters and marine waters shall be substantially free of pollutants that: unduly affect the composition of bottom fauna; unduly affect the physical or chemical nature of the bottom; interfere with the propagation of fish. Class D and SD (marine) will be assigned only where a higher water use class cannot be attained after all appropriate waste-treatment methods are utilized. Any water falling below the standards of quality for a given class shall be considered unsatisfactory for the uses indicated for that class. Waters falling below the standards of quality for Class D or SD (marine) shall be Class E or SE (marine), respectively, and considered to be in a nuisance condition.

†These Standards do not apply to conditions brought about by natural causes. Waste effluents discharging into public water supply and recreation waters must be effectively disinfected. All sewage-treatment plant effluents shall receive disinfection before discharge to a watercourse and/or coastal and marine waters. The degree of treatment and disinfection shall be as required by the state pollution control agency. The minimum average daily flow for seven consecutive days that can be expected to occur once in ten years shall be the minimum flow to which the standards apply.

‡Phenolic compounds cannot exceed 0.005 mg/liter; no odor-producing substances that cause the threshold-odor number to exceed 8 are permitted; radioactivity limits are to be approved by the appropriate state agency, with consideration of possible adverse effects in downstream waters from discharge of radioactive wastes, and limits in a particular watershed are to be resolved when necessary after consultation between states involved.

capacity of rivers with the result that there may be unnecessary expenditure on effluent treatment.

This approach has been adopted in major part in the United States. Thus, the Environmental Protection Agency has established effluent limitations for existing industrial sources which had to be met by July 1, 1977 through application of the "best practicable control technology currently available" and by July 1, 1983 through application of the "best available technology economically achievable". The basis for standards of performance for new sources is that the "best available demonstrated technology" is used. This system is designed to reach two goals of the 1972 Federal Water Pollution Control Act, namely that by July 1983, water should be clean enough for swimming, boating and protection of fish, shellfish and wildlife and that by 1985, there will be no more discharges of pollutants into the nation's waters (U.S. Environmental Protection Agency, 1976a). Interim and final effluent standards have been promulgated for many industrial categories and subcategories (Council on Environmental Quality, 1977).

(ii) Uniform emission standards approach. In this approach, pollutant concentrations in discharges are established by the pollution control agency, irrespective of the location of the discharge. Such standards are usually based on the pollution potential of effluents and/or the effectiveness of current treatment technology. They have the advantage of being easy to administer and implement and of imposing the same unit costs throughout industry for control of pollution from a given manufacturing process. However, as no account is taken of the volume and location of the discharge or the volume and nature of the receiving water, uniform effluent standards can result in overprotection in some areas and underprotection in others.

A number of national and regional authorities have issued uniform emission standards either as legal requirements or as guidelines. These standards can relate to the discharge of industrial effluent to sewers and/or to the discharge of sewage and industrial effluent to surface waters. Table shows standards established in Singapore by Trade Effluent Regulations, 1976 under the Water Pollution Control and Drainage Act, 1975. Limits are prescribed for discharges of trade effluent into sewers, water courses and "controlled water courses". For comparison, waste water discharge limits are given for Italy, Switzerland and Denmark in Tables VIII.44, VIII.45 and VIII.46 respectively.

(iii) Local effluent standards. In this approach discharge standards are set with reference to local conditions to achieve a pre-determined water quality objective. Such standards therefore are set with the needs of the whole river system in mind and, as they take into accout differences in flow and water use requirements, they may vary widely from one part of a river to another. Local effluent standards can be readily updated in the light of new knowledge and techniques and, as effluents are not required to be treated to a level higher than that shown not to result in environmental damage, the standards are likely to be viewed more favourably by industry than those established under the "best available technology" or "uniform effluent standards" approaches. However, disadvantages of the approach are that it is much more difficult to administer and implement, requiring skilled local river management. It is also argued that some manufacturers who do not have to bear such high treatment costs as others are placed at an unfair advantage, but this situation appears to be no different from those which arise as a result of differences in transport costs or in the availability of labour or raw materials.

This approach has been adopted in large measure in the United Kingdom where each proposed discharge is considered in relation to local circumstances before effluent standards

Table VIII.43.- Trade effluent standards in Singapore, 1976

Parameter	Limit for Discharge into a Public Sewer (mg/l)	Limit for Discharge into a Watercourse other than a Controlled Watercourse (mg/l)	Limit for Discharge into a Controlled Watercourse (a) (mg/l)
PH	6-9	6-9	6-9
Temperature	45°C	45°C	45°C
Total Suspended Solids	400	50	30
Total Dissolved Solids	3,000	2,000	1,000
Chloride (as chloride ion)	1,000	600	400
Sulphate (as SO_4)	1,000	500	200
Sulphide (as sulphur)	1	0.2	0.2
Cyanide (as CN)	2	0.1	0.1
Chlorine (free)	-	1	1
Phosphates (as PO_4)	-	5	2
Nitrate (as NO_3)	-	-	20
Calcium and Magnesium	-	200	150
Detergents(b)	30	15	5
Grease and Oil	60	10	5
Arsenic	5	1	0.05
Barium	10	5	5
Tin	10	10	5
Iron (as Fe)	50	20	1
Beryllium	5	0.5	0.5
Boron	5	5	0.5
Manganese	10	5	0.5
Phenolic Compounds (expressed as phenol)	0.5	0.2	Nil
BOD (5-day)	400	50	20
COD	600	100	60
Metals:			
Cadmium	1	0.1	0.01
Chromium (trivalent and hexavalent)	5	1	0.05
Copper	5	0.1	0.1
Lead	5	0.1	0.1
Mercury	0.5	0.05	0.001
Nickel	10	1	0.1
Selenium	10	0.5	0.01
Silver	5	0.1	0.1
Zinc	10	1	0.5
Total metals	10	1	0.5

Notes:

(a) Water course from which water supplied by the Public Utilities Board under the Public Utilities Act is obtained

(b) Linear alkylate sulphonate as methylene blue active substances

Table VIII.44. Effluent Standards for discharge into Surface Waters - Italy (a) (b)

parameters	table a	table b	table c	remarks
PH	5.5-9.5	6.5-8.5	5.5-9.5	for tables a and c: 6.5-8.5 in receiving water
Temperature °C	see remarks	30	see remarks	For tables a and c: Δt of receiving water <3°C; 30°C max for discharge into lakes and 35°C into the sea
Colour	Not visible if diluted 1:20	Not visible if diluted 1:20	Not visible if diluted 1:40	through a layer of 10 cm
Odour	—	—	—	
Floating Matter (larger than 1 cm ϕ)	absent	absent	absent	
Settleable ml/l Sediment mg/l	0.5	0.5	2	measured in Imhoff Cone after 2 hours
Suspended Solids total mg/l	80	80	80-200	Table c: less than 40% of the value upstream of waste water treatment plant
BOD$_5$ - mg/l	40	80	40-200	Table c: less than 70% of the value upstream of waste water treatment plant
COD - mg/l	160	—	160-500	
Total Toxic Metals - mg/l	3	3	3	
Aluminum - mg/l	1	—	2	
Arsenic - mg/l	0.5	—	0.5	
Barium - mg/l	20	—	—	
Boron - mg/l	2	—	4	
Cadmium - mg/l	0,02	•	0.02	
Chromium $^{+3}$ - mg/l	2	•	4	
Chromium $^{+6}$ - mg/l	0.2	•	0.2	
Iron - mg/l	2	•	4	
Manganese - mg/l	2	•	4	
Mercury - mg/l	0.005	•	0.005	
Nickel - mg/l	2	•	4	
Lead - mg/l	0.2	•	0.3	
Copper - mg/l	0.1	•	0.4	
Selenium - mg/l	0.03	•	0.03	
Tin - mg/l	10	•	—	
Zinc - mg/l	0.5	•	1	
Cyanides - mg/l	0.5	•	1	
Chlorine - mg/l	0.2	•	0.3	
Sulphides - mg/l	1	•	2-	

Table VIII.44. (Continued)

parameters	table a	table b	table c	remarks
Sulphites - mg/l	1	*	2	
Sulphates - mg/l	1.000	*	1.000	not applying to discharges into the sea
Chlorides - mg/l	1.200	*	1.200	
Fluorides - mg/l	6	*	12	
Phosphorus - mg/l	10	*	10	for tables a and c: 0.5 max for discharges into lakes
Total Ammonia - mg/l of NH_4^+	15	—	30	for discharges into the lakes total Nitrogen must be less than 10 mg/l
Nitrogen as N in NO_2^- - mg/l	0.6	—	0.6	
Nitrogen as N in NO_3^- - mg/l	20	—	30	
Oils + Greases - (animal + vegetable mg/l)	20	*	40	
Mineral Oils - mg/l	5	*	10	
Phenols - total mg/l	0.5	*	1	
Aldehydes - mg/l	1	*	2	
Aromatic Solvents - mg/l	0.2	*	0.4	
Nitrogenated Solvents - mg/l	0.1	*	0.2	
Clorinated Solvents - mg/l	1	*	2	
Surfactants - mg/l	2	*	4	
Pesticides - Clorinated mg/l	0.05	*	0.05	
Pesticides - Phosphorates mg/l	0.1	*	0.1	
Toxicity	see remarks	*	see remarks	after 50/50 dilution, the sample must support the life of at least 50% of the Salmo gairdnerii Rich. for 24 hr.
Coliform (total MPN/100 ml)	20.000	*	20.000	these limits are applied only if requested by the local authorities
Coliform Fecal (MPN/100 ml)	12.000	*	12.000	
Streptococii Fecal (MPN/100 ml)	2.000	*	2.000	
				general notes The analysis must be carried out on an average sample composed of spotsamples taken at an interval of less than 3 hours. For the tests the methods published by IRSA (National Institute of the Water Research) must be applied

(a) Water Pollution Law, number 319 dated 10th May, 1976. "Measures for the Protection of Waters from Pollution".

(b) Table A: These limits are required of all existing industries discharging effluents into surface waters within 9 years and of new installations from the start up of their operations.

Table B: These limits are required of municipalities only within 3 years.

Table C: These limits are required of all existing industries with 3 years and for a further period of 6 years.

* When not restricted by local authorities the limits are the same as in Table A.

Table VIII.45. Standards for Effluents discharged into Surface Waters and Public Sewers - Switzerland (a)

Parameters	Quality standards for effluents discharged into surface waters	Quality standards for effluents discharged in public sewers
	The limit values must be met at all times during dry periods. Under certain conditions derogations are permitted.	The limit values are applicable to artisanal and industrial waste water and must be met always. In justified cases derogations can be permitted.
Temp.	Max. 30° C	Max. 60° C In sewer max. 40° C
Transparance Method Snellen	30 cm	No limit
Colour	May not cause colouration of receiving water	Dyes may be discharged if they are eliminated in the municipal treatment plant
Odour and taste	May not cause alteration of odour and taste of receiving water	Odour may not cause nuisance
Toxicity	No toxicity towards fish after 24 hours for undiluted to 5 x diluted effluent, depending on dilution ratio in receiving water	Effluent may not affect negatively the efficiency of the biological waste water treatment plant
Salts	Quality of the receiving water may not be detoriated	The sewer system and treatment plant, as well as the efficiency may not be detoriated
Total unsoluble matter	4 out of 5 composite samples must be lower than 20 mg/l (24 hr average)	To be set case by case
Settleable solids	Max. 0.3 mg/l after 2 hr settling time.	To be set case by case
pH	6.5 - 8.5 Up to 9.0 may be permitted if river flow is high enough	6.5 - 9.0 6.5 - 9.5 if prevailing conditions permit
Oxygen	In receiving water min. 6 mg O_2/l	No lower limit.
Surface tension	In receiving water: > 65 dyn/cm at 20° C	To be set case by case.
Al	10 mg Al/l	20 mg Al/l in influent to municipal treatment plant.
As	0.1 mg As/l	0.1 mg As/l
Ba	5 mg Ba/l (dissolved)	To be set case by case.

continued

Table VIII.45. (Continued)

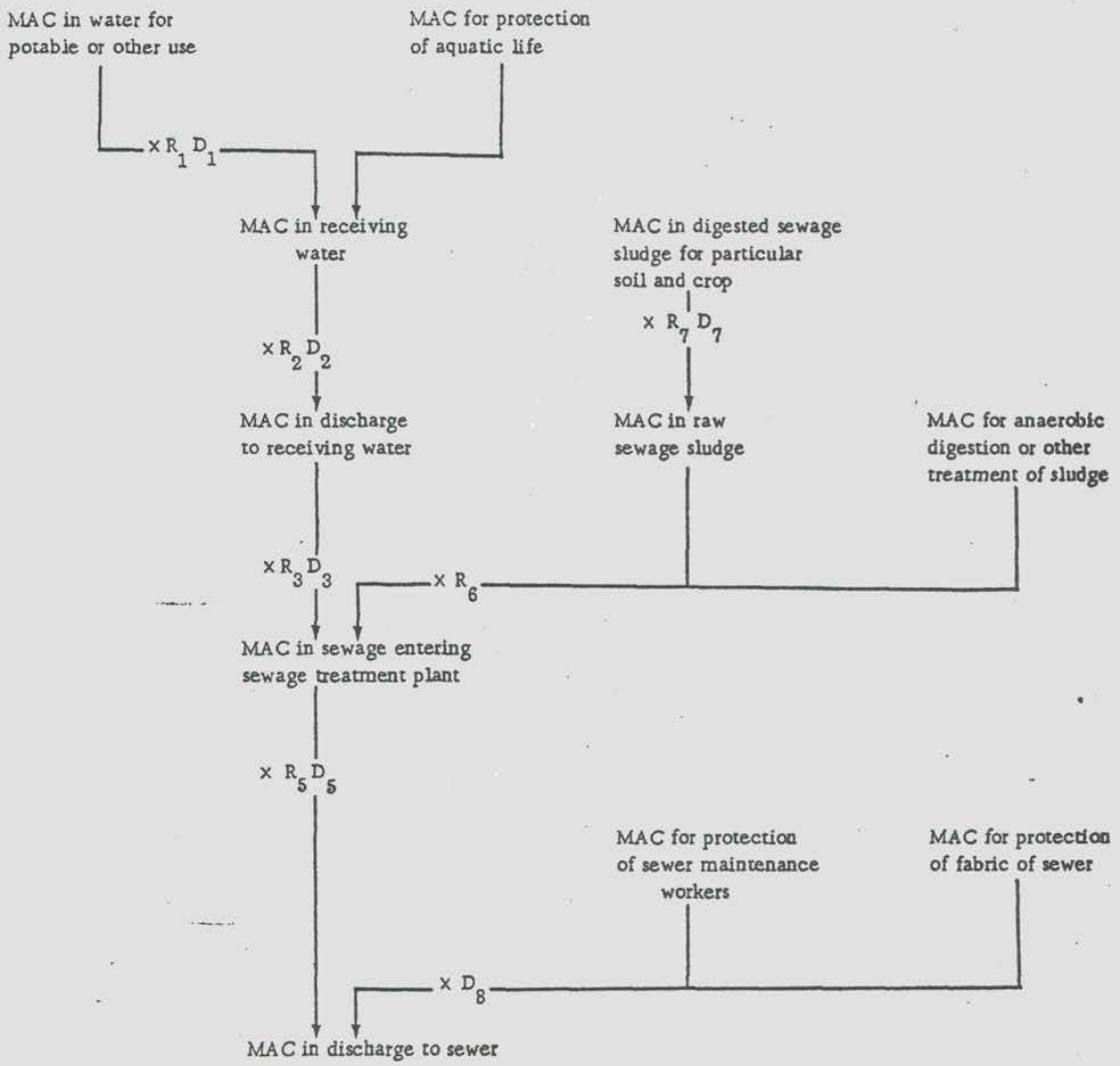
Parameters	Quality standards for effluents discharged into surface waters	Quality standards for effluents discharged in public waters
Pb	0.5 mg Pb/l	0.5 mg Pb/l
B	To be set case by case	To be set case by case
Cd	0.1 mg Cd/l	0.1 mg Cd/l
Cr^{+3}	2 mg Cr^{+3}/l	2 mg Cr^{+3}/l
Cr^{+6}	0.1 mg Cr^{+6}/l	0.5 mg Cr^{+6}/l
Fe	2 mg Fe/l (4 out of 5 composite samples, average time 24 hr)	20 mg Fe/l in influent to municipal treatment plant
Co	0.5 mg Co/l	0.5 mg Co/l
Cu	0.5 mg Cu/l	1 mg Cu/l
Ni	2 mg Ni/g	2 mg Ni/l
Hg	0.01 mg Hg/l	0.01 Hg/l
Ag	0.1 mg Ag/l	0.1 mg Ag/l
Zn	2 mg Zn/l	2 mg Zn/l
Sn	2 mg Sn/l (except when organotin fungicides are present)	2 mg Sn/l (except when organotin fungicides are present)
Active Cl	0.05 mg Cl_2/l	3 mg Cl_2/l
Active Br	0.1 mg Br_2/l	3 mg Br_2/l
NH_3/NH_4^+	To be set case by case	To be set case by case
ClO_2	0.02 mg ClO_2/l	3 mg ClO_2/l
Cl^-	To be set case by case	To be set case by case
CN^-	0.1 mg CN^-/l	0.5 mg CN^-/l
F^-	10 mg F^-/l	10 mg F^-/l
NO_3^-	To be set case by case	To be set case by case
NO_2^-	1 mg NO_2^-/l	10 mg NO_2^-/l

continued

Table VIII.45. (Continued)

Parameters	Quality standards for effluents discharged into surface waters	Quality standards for effluents discharged in public sewers
Total P	-In lake bassins: max. 1 mg P/l (4 out of 5-24 hr composite samples) min. P elimination:85% -Outside lake bassins: see column 1	As low as possible
SO_4^-	As low as possible	300 mg SO_4^-/l
S^-	0.1 mg S^-/l	1 mg S^-/l
SO_3^-	1 mg SO_3^-/l	10 mg SO_3^-/l
Dissolved organic carbon	10 to 15 mg/l	To be set case by case
Total organic carbon (TOC)	17 to 22 mg C/l Higher values may be specified if intake water has high TOC content	To be set case by case.
COD	To be set case by case	To be set case by case.
$KMnO_4$ Value	To be set case by case	To be set case by case
BOD_5	20 mg O_2/l (4 out of 5 24 hr composite samples).	To be set case by case.
Aromatic amines (as dichloro-aniline)	To be set case by case.	To be set case by case.
Oil and fatty acids	20 mg/l	Oil separator required
Total hydrocarbons	10 mg/l	20 mg/l
Chlorinated solvents	0.1 mg/l (as Cl)	0.1 mg/l (as Cl)
Non-volatile lipophilic chlorinated compounds	To be set case by case.	To be set case by case
Total organochloro-pesticides	To be set case by case.	To be set case by case.
Phenols: – volatile	0.05 mg/l (up to 0.2 mg/l may be admitted as an exception)	5 mg/l
– non-volatile	0.05 mg/l	1 mg/l

(a) Waste water regulations (1975.12.8.)



R - Factor to allow for reduction in concentration of substance arising from processes other than dilution.
D - Factor to allow for reduction in concentration of substance (not effluent water) by dilution. Concentration of substance in dilution water must be known.

D_1 relate to reduction and dilution during water treatment.
R_2, D_2 relate to reduction and dilution during flow in stream.
R_3, D_3 relate to reduction and dilution during sewage treatment.
R_4, D_4 relate to reduction and dilution during primary sedimentation of sewage.
R_5, D_5 relate reduction and dilution during flow in sewer.
R_6, D_6 relate to reduction and dilution during separation of sewage sludge: value will usually be less than 1 since many substances are concentrated in sludge.
R_7, D_7 relate to reduction during anaerobic digestion of sludge.
D_8 relates to immediate dilution in the sewer.

Figure VIII.6. Information required to decide on the maximum allowable concentration (MAC) of a substance in a discharge to a sewer or watercourse (Water Research Centre, 1977)

Table VIII.46. Guidelines for Effluent Qualities of Waste Water - Denmark (a)

receiving water parameter	a lakes and streams to lakes and narrow fjords	b streams to open bays, sounds and the open sea	c narrow fjords	d open bays, sounds and the sea	remarks
pH	6,5-8,5	6,5-8,5	6-9	–	d to be fixed individually
temperature	30°C	30°C	30°C	30°C	
BOD$_5$	20 mg/l	20 mg/l	100 mg/l	400 mg/l	d higher limit values may be acceptable, to be discussed
COD	–	–	–	–	limit values to be fixed individually
N : $(NH_3 + NH_4^+)$	2 mg/1	–	–	–	higher values may be accepted during winter period
total N	–	–	–	–	to be fixed after investigation of the receiving water system
total P	1 mg/l	–	1 mg/l	–	
sediment (after 2h.)	0,5 ml/l	0,5 ml/l	1 ml/l	1 ml/l	
floating matter		should not be visible			
dispersed material (total)	30 mg/l	30 mg/l	80 mg/l	–	
Hg	–	–	–	–	specially restricted
Cd	–	–	–	–	
$(Cr^{+3} + Cr^{+6})$	0,2 mg/l	0,2 mg/l	0,2 mg/l	0,2 mg/l	all emissions of metals should be reduced as low as possible; limit values should be followed by a max. total for grams/day
Cu	0,1 mg/l	0,1 mg/l	0,2 mg/l	0,5 mg/l	
Zn	0,5 mg/l	0,5 mg/l	1 mg/l	1 mg/l	
Pb	0,1 mg/l	0,1 mg/l	0,5 mg/l	0,5 mg/l	
Ni	0,2 mg/l	0,2 mg/l	0,5 mg/l	0,5 mg/l	
Ag	0,05 mg/l	0,05 mg/l	0,05 mg/l	0,1 mg/l	
As	0,5 mg/l	0,5 mg/l	0,5 mg/l	1 mg/l	

continued

Table VIII.46. (Continued)

receiving water parameter	a lakes and streams to lakes and narrow fjords	b streams to open bays, sounds and the open sea	c narrow fjords	d open bays, sounds and the sea	remarks
CN	0,1 mg/l	0,1 mg/l	0,1 mg/l	0,2 mg/l see remark	d to be fixed individually, max. limit 2,0 mg/l
H_2S	2 mg/l	2 mg/l	5 mg/l	–	
Free Cl_2	0,3 mg/l	0,3 mg/l	0,5 mg/l	–	amount of free chlorine in effluent to fresh water systems should be reduced as low as possible
halogenated phenols	–	–	–	–	subject to special permission
phenols	0,2 mg/l	0,2 mg/l	0,2 mg/l	–	d to be fixed individually, max. limit 1 mg/l
stable oil emulsions of mineral oil	5 mg/l	5 mg/l	5 mg/l	10 mg/l	visible oil should be avoided
anionic detergents 80% degradable	2 mg/l	2 mg/l	5 mg/l	10 mg/l	
other synthetic detergents	–	–	–	–	to be fixed individually
halogenated hydrocarbons	–	–	–	–	to be kept at min. as specially restricted
organic solvents	–	–	–	–	to be fixed individually

(a) Danish Environmental Conservation Act ("consent conditions") are imposed. Although each case is considered individually on its merits, the U.K. water pollution control authorities from time to time do issue guidance on the standards likely to be attached to permits for discharges of sewage or industrial effluents. For example, Table VIII.47 shows guideline standards for industrial effluent discharges to rivers and sewers for the Yorkshire Regional Water Authority area (Tench, 1977). It should be stressed that the standards actually imposed on an effluent may show significant variation from Table VIII.47, depending on relevant local circumstances.

Table VIII.47 Guideline Standards for Industrial Effluents - Yorkshire Regional Water Authority, U.K. (Results in mg/l except pH and temperature)

Parameter	Discharged to:	
	River	Sewer
Temperature (°C)	30	40
pH	6-9	6-10
Biochemical oxygen demand	20	*
Permanganate value	25	*
Suspended Solids	30	500
Ammonia	10	*
Phenols	1.0	*
Hydrogen cyanide	0.1	10
Hydrogen sulphide	-	10
Metals exluding Iron, zinc, sodium, potassium, etc. Total:	1.0	30
Soluble:	-	10
Mercury	-	0.001
Cadmium	0.2	2
Copper	0.5	5
Lead	0.5	5
Chromium	0.5	5
Nickel	0.5	4
Arsenic	0.5	-
Zinc	2.0	10
Iron	5	-
Silver	-	5
Zinc equivalent (Zn + 2 Cu + 8 Ni)	-	35
Oil	5	200
Free Chlorine	0.1	100

In addition to the above, standards may be set to control the concentrations of organo-halide compounds, synthetic detergents, flammable vapours in sewers and colour. A toxicity fish standard may also be imposed, and consideration given to the bio-degradability of the materials discharged

* Standards to be set as appropriate

To set scientifically-based limits for the concentration of a specific contaminant in a sewage or trade effluent discharged to a sewer or watercourse requires a wealth of information about its toxicity, behaviour, etc. For example, the following data may be required (Water Research Centre, 1976):

1. The maximum allowable concentration (MAC) of the pollutant in:
    (a) potable water;
    (b) raw water to be treated for a potable supply;
    (c) industrial process water; and,
    (d) river water.
    (It may be necessary to consider limits for hard waters and soft waters)

2. Minimum dry-weather flows in rivers used for water supply.

3. The persistence of the pollutant in river water

4. Toxicity of the pollutant to fish and other aquatic life.

5. The percentage of pollutant destroyed in various unit processes of sewage treatment.

6. The degree to which the pollutant is concentrated in sludge and further concentrated during sludge treatment.

7. The maximum allowable concentration in sludge under specified conditions.

8. An indication of the most likely critical factor in respect of the concentration of the pollutant.

The way in which such data may be used to establish maximum allowable concentrations (MAC) in discharges can be expressed diagrammatically in Figure VIII.6. Such an approach should allow a pollution control authority and industrialists to agree on the reasonableness of any limit. An additional consideration, however, is that of deciding how much of the self-purifying potential or assimilative capacity of the sewerage, sewage treatment and river systems should be allocated to existing industrial or sewage discharges and how much should be retained for future discharges and as a margin of safety.

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