UNEP BMFT

SOLID WASTE MANAGEMENT

Proceedings of the International Symposium on Solid Waste Management for Developing Countries

26 September to 7 October 1983
(Karlsruhe, Federal Republic of Germany)

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for Developing Countries

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Preface

Solid Waste Management in Developing Countries

The International Symposium on Solid Waste Management for Developing Countries was organised by the United Nations Environment Programme (UNEP) and the Federal Republic of Germany's Ministry for Research and Technology (BMFT), the Federal Environment Agency (UBA) (as BMFT project agency for solid waste) and the Nuclear Research Centre, Division of Water Technology (KFK), Karlsruhe. The symposium was jointly funded by UNEP and BMFT.

The Symposium forms an element of the human settlements component of the Environment Programme which has the aim:

> "to promote the inclusion of sound environmental considerations in human settlements policies and planning as part of the overall policies for the improvement of the human environment".

The project was also expected to help in the provision of guidelines and advice on appropriate and environmentally sound technology.

Sixty delegates from 30 countries were invited to participate in the symposium and papers on solid waste management in developed and developing countries were presented. The Symposium brought together administrators, policy makers and professional technicians from the participating countries, the intention was to have roughly equal numbers of representatives with technical as opposed to administrative/management backgrounds. All delegates had a significant responsibility in the field of solid waste management.

Papers were presented by international experts and technical visits were organised to a number of solid waste treatment facilities in the Federal Republic of Germany. A series of case studies were provided for participants to work on and a synopsis of the country monographs submitted by participants was presented.

A review of solid waste management in participating countries, prepared by ERL, an independent consultancy operating in the fields of waste management and environmental planning provided information on current approaches and practices. This has been published in a separate volume as an annex to this report, under the title "Synopsis of Country Monographs".

The ERL report provides information at the national level and also for selected 'typical' cities, usually country or regional capitals, and rural regions.

Although the publication of the proceedings have taken some time, it was felt useful to reproduce it because of the lack of up-to-date information on this topic.

Solid waste management has become a critical problem to authorities in local and municipal areas. Decision makers struggle to address the problem, unfortunately, with less and less success. As a consequence the impact of solid waste on the urban environment becomes more and more intractable.

UNEP and the BMFT have had a long standing co-operation in the area of waste management. The BMFT has been most generous in funding three international symposia in the past decade for the benefit of developing countries. It is fitting to express our appreciation to the many individuals in the Federal Republic of Germany that have made the co-operation so fruitful. It is appropriate to single out a few persons who have played a major role in this regard: Dr. Ekkehard Abel, Dr. S.H. Eberle, Dr. Wolfgang Robel, Professor George Goosmann and Dr. K. Komorowski. I also wish to recognize the valuable services of Mr. Michael Betts formerly of ERL, without whose guidance the symposium would not have been the success it was.

Naigzy Gebremedhin
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3. SPONSORING AND EXECUTING ORGANIZATIONS

The Symposium was sponsored and executed by the:

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2. Scope of the Symposium

The programme consisted of four parts:

Part I (one day)

Following the opening at the Nuclear Research Centre, Kalrsuhe, a series of general presentations introduced the subject of solid waste management. This was followed by a summary of the country reports on this subject.

Part II (7 days)

Visits to some 15 different plants and facilities for solid waste management in different parts of the Federal Republic of Germany to provide direct insight into waste management practices ("Technical Visits Tour Guide" page).

Part III (2 days)

A seminar held at the Nuclear Research Centre, Kalrsruhe, presented lectures and discussions on different solid waste technologies, legal, economic, social and other aspects of waste management, and case presentations by representatives of participating countries.

Part IV (2 days)

A Case Study Workshop attempted to simulate a concrete planning and decision making process dealing with solid waste management in the hypothetical "Puedam-Region".

In 5 working groups, different aspects of a comprehensive waste management concept were discussed involving exchange of experience programme contributions. The group work findings were then presented and discussed in a plenary session which attempted to form a comprehensive concept.

After final presentations on research and international co-operation the programme ended with an evaluative discussion including consideration of possible future co-operation.

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PREFACE

The wastes produced by development can threaten its sustainability. The increasing volumes of pollutants arising from human activities have become a major threat to the environment and human life.

In recent years, the Federal Republic of Germany has realized important achievements in the area of environmentally sound wastes management. In recognition of the fact that environmental problems know no borders, the Federal Republic has readily shared its experience in this area with the developing countries.

In this regard, in 1980 the Government of the Federal Republic sponsored a joint symposium, on waste water technologies for developing countries. Following the success of that symposium, the Federal Republic of Germany offered to sponsor an International Symposium on Solid Waste Management for Developing Countries.

The symposium held on 24 September to 7 October 1983 brought together some 60 representatives of Governments, municipalities and other institutions in 25 countries of Africa, Asia and the Pacific, Europe, Latin America and the Caribbean, and West Asia.

The symposium aimed at:

- Information exchange among participating countries on current policy, management, technological and operational practices in solid waste management and related environmental impacts.

- Presentation of the Federal Republic of Germany's experience in solid waste management.

- In-depth examination of current and new methods of waste management with special regard to their relevance to developing countries.

- Identification of possible future co-operation in this area with emphasis on resource recovery and recycling of solid waste and environmental conservation.

The symposium gave rise to a rich collection of papers representing important experience in solid wastes management in developed and developing countries. The papers are published here as the proceedings of the International Symposium on Solid Waste Management for Developing Countries.

ADDRESS BY STATE SECRETARY HANS-HILGER HAUNSCHILD AT THE OPENING OF THE UNEP/FEDERAL MINISTRY OF RESEARCH AND TECHNOLOGY INTERNATIONAL SYMPOSIUM ON SOLID WASTE MANAGEMENT FOR DEVELOPING COUNTRIES

Karlsruhe, 26 September 1983

Three years ago a first joint UNEP/Federal Ministry of Research and Technology symposium was held here in Karlsruhe on waste water technologies for developing countries. Its success in providing participants with useful information and experience encouraged us to suggest to UNEP the organization of this new symposium.

During the next two weeks, you will primarily deal with questions of waste disposal. You might therefore find it of interest to start off with an idea of the overall situation of environmental protection and the political objectives pursued by the Government of the Federal Republic of Germany in this field.

Securing peace, protecting the environment and fighting hunger in the world are closely interrelated problems. The destruction of tropical forests, soil erosion, which is observed in many countries and gives rise to great concern, possible climatic changes caused by the accumulation of carbon dioxide in the atmosphere due to growing energy consumption and many other factors threaten to further reduce the areas of arable soil and thereby to narrow the food base in many countries. The use of fertilizers, pesticides and herbicides, which are in the first place designed to improve growth and protect plants, in turn, constitute new pollution loads for the soil as does the increasing input of heavy metals. Many of these pollutants are not easily degradable or not degradable at all and accumulate in the soil. For this reason efforts are made in the Federal Republic of Germany to develop a comprehensive soil protection concept with the aim of keeping the soil healthy as water storage and filter, and as habitat for plants and animals.

Environmental problems do not stop at national borders. This is quite evident with air pollution as well as the pollutant loads of rivers and oceans, but more and more this also applies to questions of waste treatment and disposal. Only recently has the search for the toxic wastes from the Italian city of Seveso made it painfully clear to people in many European countries that strict licensing procedures should be required for the transport of wastes across national borders. In our opinion, wastes must, in principle, be disposed of in their country of origin.

For the first time in Europe, this postulate is to be made law in the Federal Republic of Germany. In order to live up to our own demands, we have, in recent years, built a number of facilities which permit technically advanced and environmentally sound treatment and disposal of problematic wastes. You will visit some of these facilities on your trip.

Furthermore, the Federal Government advocates the systematic development of waste recycling in this country. In this respect it has set itself some ambitious goals:

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By the end of the 1980 we intends to recover 50 per cent of household refuse and completely put an end to dumping of wastes on the high seas.

Given the fact that most solid municipal waste is at present still dumped in landfills, we provide intensive support for the development and testing of new waste treatment concepts, helping local authorities responsible for waste disposal.

We are watching with great concern the increasing pollution of the North Sea. Large rivers carry huge amounts of pollutants into this sea. Unless all of the affected countries take anticipatory action, it can lead to irreparable damage.

For this reason, in 1984 the Federal Government will invite the North Sea states to attend an International Conference on the Protection of the North Sea, with the aim of reaching international consensus on concrete measures aiming at reduction of pollution loads discharged via inland and coastal waters, termination of dumping and incineration of wastes at sea and prevention of oil pollution.

In order to protect inland waters, discharge of pollutants must be reduced or totally eliminated at the source. Thanks to the increased efficiency of water purification techniques the level of pollution of water with easily degradable substances is now much lower than it was in the past.

Air pollution is a particularly critical problem in this country and in Europe. Only a few days ago, a major European Community symposium on forest damage was held here at Karlsruhe. The large-scale damage suddenly occurring in German forests has alarmed the population and calls for immediate action. The exact causes are still unclear. There is substantial evidence, however, that air pollution, possibly in combination with other causes, is responsible.

For years now the eutrophication of lakes in Scandinavia and parts of North America has alarmed the public. Impairment of human health, in particular respiratory tract diseases, or decaying buildings are possibly less spectacular, but they are no less alarming.

This is why we have recently established more stringent levels for air quality. The new provisions improve protection of human health and for the first time also protect particularly sensitive plants and animals.

We are also preparing other measures: state of the art, industrial exhaust gas purification systems and a considerable reduction in discharge of dusts, heavy metals and hydrocarbons. Other provisions, which have only recently entered into force, are designed to reduce the discharge of sulphur dioxide from power and district heating plants by about 40 per cent.

To reduce air pollution by car exhaust gases the European Community last June lowered maximum levels by 20 per cent, a measure we consider as still not sufficient. This is why the Federal Government decided to create the legal basis for the introduction of unleaded gasoline as from 1 January 1986. With unleaded gasoline, it will be possible to reduce the level of car exhaust gases by up to 90 per cent.

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Ladies and gentlemen, by giving you a brief outline of German environmental policy, I do not want to suggest that this is a model policy. We are well aware that we still have a long way to go, and there are many who think that we should take far more drastic action. Also we recognize that it would be entirely wrong to try the simple transfer of technical, legal or administrative solutions from one country to another.

However, I would like to show that my Government is determined to act, even though this may not always be easy or convenient. We face up to the responsibility resulting from the global character of environmental problems and from the fact that we, as an industrialized country, are among the greatest polluters of the environment - despite strict legislation. We are first of all trying to put our own house in order and we are, if necessary, prepared to act on our own.

Experience gained in a European industrialized country can probably be applied to only a limited extent to Third World countries which are just beginning to become industrialized. But these countries have the opportunity to avoid the mistakes we have made provided that they are willing to take anticipatory action early enough to protect their environment instead of trying, belatedly and at great expense, to contain or reverse damage already done.

This is in fact one of the most important responsibilities for our large international organizations, which have done very valuable work in the past, assisting Third World countries in shaping and implementing their environmental policie. The present symposium is part of this major undertaking.

Science and technology can contribute to shaping and implementing environmental policy in three ways. They help:

- to throw light on ecological interrelations by scientific analysis and to recognize potential hazards at an early stage;

- to define the limits of pollution to be tolerated, thus providing a scientifically sound yardstick for regulatory measures; and

- to develop technical processes and equipment which reduce or prevent environmental pollution.

The dimensions and the complexity of the problems awaiting solution particularly in the developing countries open up a wide field for international co-operation. One of the possibilities seen by the Federal Government is the provision of focal points for development and testing of low-pollution industrial production processes design as well as for waste water purification and recycling.

Bilateral co-operation of my Ministry with Third World countries includes:

- New techniques for the purification of wastewaters resulting from production of cellulose from reeds - a project carried out jointly by German and Egyptian industries;

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- New techniques for waste water purification in the Cairo area aiming at the utilization of waste water for agriculture;

- New techniques for recovering nutrients from waste waters resulting from maize processing in Latin America;

- Research into the possibilities of reducing industrial emissions in crowded urban regions in Mexico.

My Government is very interested in extending and intensifying its co-operation with suitable partners in the Third World. We consider it particularly important that, in addition to the scientific and technological success of such co-operation, its jointly elaborated results are eventually applied in practice and passed on to others. This is why we concentrate, above all in the industrial sector, on the development of technical solutions that are both more environmentally sound and economical than traditional production methods. This type of solution has the greatest chance of being voluntarily accepted for practical application.

For the same reason, we consider it important that not only scientific institutions but also future users, i.e. industrial firms and local institutions, participate in the joint development and testing of new techniques. This is the best way of ensuring a smooth transition to the subsequent phase of practical application.

However, success depends upon those responsible in our countries being determined to face up to the potential hazards and take action. This is our common goal. We may achieve it by different means, but to achieve it we must all work together.

ADDRESS BY DR. RUDOLPH SCHMIDT AT THE OPENING OF THE UNEP/FEDERAL MINISTRY OF RESEARCH AND TECHNOLOGY INTERNATIONAL SYMPOSIUM ON SOLID WASTE MANAGEMENT FOR DEVELOPING COUNTRIES

Karlsruhe, 26 September 1983

Dr. Rudolph Schmidt, Assistant Executive Director of the United Nations Environment Programme (UNEP) delivered an opening address on UNEP policy and international co-operation in the area of solid waste management.

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INTRODUCTION TO THE UNEP/BMFT SYMPOSIUM ON SOLID WASTE MANAGEMENT FOR DEVELOPING COUNTRIES

by Dr. Ekkehard Abel

The opening speeches which we have just heard, have given us the views of the international community and of the Federal Republic of Germany on the general environmental situation, existing problems and on policy goals aiming to provide solutions.

During the coming two weeks, a large number of major issues concerning solid waste management will be discussed in the course of general presentations, technical visits and case studies. I should now like to briefly highlight only two general aspects of particular importance among those to be discussed. The first aspect is the role played by research and development, and the second concerns distribution of responsibilities.

Awareness of the impacts of industrialization and urbanization on our natural environment and knowledge of the restricted self-purifying power of nature led to initial action by the early seventies while from the mid-sixties, increasing importance was attached to research and development pgorammes. The 1971 Environmental Programme declared environmental policy to be an independent public task, and a programme was drawn up to reduce the extraordinary backlog of demand for environmental protection. Many basic legislative measures were introduced at that time.

Research and development provide the scientific basis for environmental policy. The complexity of ecological facts and conditions and the interdependence between the various environmental sectors (especially between environmental media) call for interdisciplinary planning and research approaches. In order to preserve a safe environment for mankind and permit future environmental protection, it is not only necessary to reduce or eliminate perceivable impacts on man and his environment, on soil, air, water, nutrition, flora and fauna and the natural balance, but also to work towards an ecologically sound utilization of resources. Due to the long-term effects and frequent irreversibility of the results of interference in the environment, research and development cannot be content with providing a solution to short-term and limited problems, but must stress investigation of long-term problems and their possible remedies.

The task of research and technological development in the service of the environment is therefore to:

- identify ecological interrelationships;
- identify future environmental problems and assess the consequences of interference in the environment and of the strains placed upon it;
- make available techniques for the efficient monitoring of sources of emission and of the purity of air, soil and water;
- further develop the state of the art and improve techniques already applied with a view to reducing the environmental pollution they cause;

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- identify new technical approaches, particularly with regard to low-pollution industrial production processes, to the replaceent of former products by new products entailing less environmental pollution and to cleaning up polluted areas (e.g. waste tips) in order to avert recognized risks and keep environmental pollution to a minimum.

State Secretary Haunschild has already pointed out that, in the Federal Republic of Germany, the Federal Minister of the Interior is responsible for environmental protection and relevant legislative measures. It is precisely in the sector of environmental protection, however, that close partnership should exist between legislators and researchers. On the one hand, limits for permissible pollution levels based upon investigation into ecological interrelations and causal chains of effect must serve as the criteria to be observed by technological processes. On the other hand, we must provide new technological solutions in order to be better able to improve environmental protection in the future. In this connection, special importance is attached to new low-emission techniques which prevent environmental pollution from the very outset, rather on costly remedial measures later on, this being the better course from both the ecological point of view and that of the national economy. Morever, it is conducive to modernizing the national economy.

According to the figures recorded in the Federal Government's 1982 Report on Environmental Research, government departments currently spend approximately DM 450 million annually on environmental research and environmental technology. Of this sum, approximately two thirds are provided by the Federal Ministry for Research and Technology, and the remainder by the Ministry of the Interior, the Ministry for Youth, Family Affairs and Health, the Ministry of Transport and the Ministry of Food, Agriculture and Forestry. Somewhat less than half this amount is distributed among the 12 national research centres and a number of Federal research institutions. The remaining funds serve to promote research projects at universities and in industry. In this connection, it should be noted that when research and development projects are contracted out to industry, the industrial firms concerned usually contribute considerably from their own funds to the costs involved. Industry's participation is a form of implementing the polluter pays principle, which in the Federal Republic of Germany constitutes a corner-stone of environmental policy. In this connection, industry's commitment has to be the greater the more obvious the technical problems involved and the greater the likelihood of commercial success. Government must step in to help by providing research promotion particularly where basic developments entailing considerable technical and economic risks are at stake, where industry is unable for structural reasons (i.e. small and medium-sized businesses) to carry out such development unaided, or where the government itself bears responsibility for preserving the environment. This is the case, for example, with regard to municipal waste water and waste disposal, in which respect the municipalities are unable by their own efforts to develop advanced low-pollution waste management technologies.

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This brings me to the second general aspect, namely, the distribution of responsibilities. At first glance you will be surprised to find industrial firms, universities, cities, rural districts and administrative associations listed on the programme of visits. During the presentations at this symposium you will be hearing even more about these in detail. The intention is that you should know something in advance about the basic structure, namely, that the Federal Government alone is responsible for enacting legislation in the field of waste disposal and waste management, whereas enforcement of the laws passed falls within the jurisdiction of the Federal States. Federal Government legislation leaves room for independent provisions by the states, however, which cater to the special regional and organizational circumstances prevailing in the individual states. The latter have transferred responsibility in a number of areas to the municipalities. Responsibility for research and development rests as a matter of principle with the Federal Government.

In drawing up the present programme, we have attempted to do justice to this broad range of responsibilities in order to provide you with a good insight into the situation in the Federal Republic of Germany. We are happy to see that so many eminent experts from almost 30 countries and from several international organizations have accepted our invitation and will place their experience at the disposal of this symposium.

When, a few years ago, the first internatinal Waste Recycling Conference was held in the Federal Republic of Germany, a euphoric newspaper headline read: "Die Zukunft auf der Kippe". In German, the word "Kippe" has two meanings. First, the headline bore the message that wastes which had previously ended up on tips may constitute an important resource (say, of raw materials or energy). But the phrase can also mean that the steadily growing accumulation of dangerous wastes may be putting the prospect of a safe environment in jeopardy. International co-operation can make a major contribution towards preventing such a development and towards ensuring that the encouraging message can be made reality - at least, to a certain extent.

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RELEVANCE AND GOALS OF WASTE MANAGEMENT

Dr. Bernd Wolbeck

In principle the problem of waste management affects nearly all fields of economic activity. Waste materials occur as residuals, by-products, or end products in the production, distribution, or consumption of commodities. To the extent that these materials are fed back into the production-consumption cycle which for economic reasons - has become widespread - they do not present serious environmental or economic problems. Increased attention in technical and policy discussions is, rather, focused on those materials which have to be disposed of as "waste".

A waste management policy will not be adequate if it is confines itself solely to aspects of recycling or final disposal. Indeed, the relevant consideration should include all those processes related to the generation, utilization, and disposal of primary and secondary materials. Only through such a comprehensive approach will it be possible to avoid inadequate co-ordination of individual measures, the occurrence of undesirable problem shifting, and economic misallocations of public and private initiatives (e.g., investments).

2. Aims

With regard to the twin objectives "resource conservation" and "protection of the environment", the policy for waste management has the following aims:

1. Reduction of wastes generation at the production and consumer levels through more efficient and environmentally sound production techniques extending the life of products, and increasing recycling;

2. Substitution of scarce raw materials by more easily available ones in the production process (while retaining the purpose for which the product is to be used);

3. Increased utilization of wastes by recycling during the production process (recovery of materials), recovery of the energy content of wastes and feedback into biological cycles; and

4. Environmentally sound disposal of wastes.

These objectives are not separate and isolated tasks. They should be part of a joint approach, taking into account the materials concerned. Thus, for example, increased recycling of wastes does not replace efforts made towards direct saving of raw material but only complements such efforts as part of raw material management and environmental policy.

The direct reduction of consumption of materials by producers and consumers must be considered as the most urgent challenge both on a medium and long-term basis. The following conclusion is valid: curtailment of absolute consumption and appropriate application of raw-material-saving technologies have a much more positive effect on the conservation of raw material resources than recycling.

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Disposal, in turn, often provides an economically and ecologically reasonable solution of the problem in those cases where appropriate materials, being "dispersed" in terms of time and location or having been put to multiple uses, occur as a mixture of varied substances and materials.

3. The environmental problem associated with wastes

Increased production and consumption of commodities have in the past resulted in ever-growing quantities of wastes. At the same time, due to production techniques and changing consumer attitudes, a substantial change has taken place in the composition of the substances concerned. For the member countries of the European Community alone, the EC Commission at present estimates the annual amount of unused secondary materials a more than 1.8 billion tons.

A direct consequence of this development is the occurence of bottlenecks in the disposal of wastes as well as considerable financial expenditure on the part of public authorities and industry for the solution of their waste problems. In the Federal Republic of Germany alone, approximately DM 4 billion a year are spent on domestic waste disposal.

Hazardous industrial wastes, with their high concentrations of pollutants pose a particular threat to the environment. Methods needed for their proper treatment and monitoring are either insufficiently available or inadequately applied. Moreover, this situation is influenced by more stringent laws on air and water pollution control, which inevitably result in new accumulations of pollutants.

Taking these effects into account it must be emphasized that the hazardous waste disposal problem will be a continuous and, probably in the future, even more challenging problem from the environmental point of view. This is particularly true for developing countries moving towards industrialization.

This challenge requires that treatment and disposal plants for hazardous residues/wastes be established on a priority basis. Moreover, intensive efforts have to be made so that the quantities of hazardous residues and wastes no longer utilized should be reduced or at least should not be allowed to increase without effective control.

At the same time, the necessary regulatory framework for disposal has to be developed. This means above all that the flow of wastes from generation to final disposal has to be controlled and that disposal facilities have to be licensed before they accept wastes.

4. Aspects relating to raw materials

The recycling of wastes or secondary materials is gaining importance with a view to the supply of raw materials. At present, this is due to an increase in the prices of raw materials largely contingent upon political factors and increasing costs of exploitation rathen thar to any basic scarcity of raw materials.

The use of secondary raw materials is already very important. In the Federal Republic of Germany, for example, statistics show that up to 80 per cent of production residuals are being utilized by the plastics industry, while paper mills are using waste paper at an average rate of about 43 per cent. In the case of lead and copper, approximately 45 per cent of the demand is covered by scrap. The high potential of wastes produced by consumers has so far remained largely unused. This should be a point of special concern for future recycling efforts.

In view of worldwide economic interdependence, policies on utilization of secondary materials should carefully consider the situation in regard to supply of with primary raw materials. According to the rules of supply and demand, the international market for primary raw materials influences the markets for secondary raw materials. Despite this influence, however, the policy concerning waste materials is much more nationally oriented than in the case of primary raw materials. Policy on secondary raw materials may contain an important political element aiming at national self-sufficiency.

5. Energy aspects

The "recycling of wastes" is nearly always linked to the question of energy balance. This effect, which is directly apparent for energy recovery from wastes, likewise applies to the recovery of materials.

Comparison between energy use for the extraction and processing of primary raw materials, and energy use connected with appropriate processing of wastes, provides an important criterion in assessing the value of recycling. Considering that energy use and its adverse effects on the environment (e.g., air pollution) are correlated factors, it is also possible simultaneously to make an ecological assessment in addition to the economic evaluation.

Energy consumption and residue generation in processing materials is dependant on the "state of dispersion" of the system under consideration.

For instance, it decreases to the extent to which the purity and concentration of raw material resources or the homogeneity of the waste increases. Studies undertaken in the field of recycling often reveal a trend in the direction of energy conservation as compared with the use of virgin raw materials. Reference may here be made, by way of example, of corresponding comparisons in respect to aluminium, copper, scrap steel, glass, or paper. In some cases the differences are considerable, up to a factor of 10. On the other hand, energy consumption may also consitute a limiting factor for recycling. For example, in the case of highly mixed wastes with low concentrations of valuable materials.

6. Basic principles

In the framework of the private market economy system, economic processes such as those taking place in the field of secondary materials management are in the first place subject to decisions of producers, distributors, and consumers. In the light of this principle, governments and public authorities should concentrate on supporting measures and provision of guiding principles and information in order to direct the efforts of these groups toward the politically desired objectives. Waste management should thus constitute an integrated partial domain of the economic system as a whole.

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As far as support by the State is concerned, the following priority measures will be necessary:

1. Improvement of statistics as well as development of forecasting models;

2. Education of producers and consumers;

3. Promotion of basic and further training of specialized manpower;

4. Promotion of research and development projects as well as demonstration plants;

5. Improvement of conditions for the marketing of secondary materials by eliminating discriminatory policies with regard to recycling products and by establishing quality criteria;

6. Financial aid in particular cases (i.e., tax incentives);

7. Improved organization of waste management;

8. Further development of legislation on waste management (e.g., separate collection of materials, prohibition of certain production techniques, control of waste streams, licensing and surveillance of disposal facilities).

7. Some facts

At lease four basic "facts of life" must be considered in the economic analysis of recycling - first, the value of any raw material, primary or secondary, is a function of a number of factors. The important characteristics which affect the value of a raw material are location, quantity, and quality. Large mass of high quality (i.e., high concentration) close to the locus of production and/or market are desired characteristics. This is as true for a secondary material as it is for a virgin raw material. A high-grade iron ore in comparison to low-grade iron ore is similar to the comparison of high-grade used newspapers with low-grade used newspapers. The quantity and quality affect the cost of processing and the quantity of residuals generated in that processing and hence the residuals management costs associated therewith. There is likely to be a wider variety of contaminants or nonusable materials in secondary materials than in many virgin materials. In some cases these contaminants, while small in quantity may be difficult to remove and thus increase the cost of processing for reuse.

From the first fact of life follows the second, and obvious fact. The extent of use of waste materials (and the extent of recycling) in both national and international contexts, is a function of the relative prices of the alternative materials as factor inputs into economic activities. Relative prices are affected by a number of factors, including such governmental policies as depletion allowances, severance taxes, and capital gains tax provisions on virgin materials, or tax credits for using secondary materials.

Third, there are economics of scale in materials/energy recovery and by-product production, just as in basic production processes.

Fourth, because all of the factors affecting relative prices of secondary and primary materials are dynamic the extent of recycling changes with time, in both the short-term and the long-term. In the short-term, there is some flexibility, both in individual plants in an industry and for the given installed technological mix in an industry as a whole, to use different proportions of secondary and virgin materials. In the longer-term this flexibility can shift, as old capacity is retired and new capacity added - with the mix of new capacity based on estimated relative prices of secondary and virgin materials.

8. Problems

8.1 Information and Distribution

The collection, and provision of relevant information on wastes are essential prerequisites for any systematic planning of recycling and disposal.

As regards the establishment and further development of relations between producers, users and disposers of such materials, adequate knowledge of the type, quantity, and place of production of the materials, the factors influencing their generation and possibilities for their use and marketing are of utmost importance. Information of this kind can be made available, through periodic publications such as "waste exchange", through circulars and meetings of specialized associations, by advanced training courses or by the establishment of information systems with inquiry facilities.

Practical solutions regarding the use of secondary materials require much more detailed information than those relating to disposal. Apart from technical data, organizational and economic issues are of equal interest, the latter frequently being sensitive to regional and even local needs. With rising demands on the substance of the information, the difficulties in making it available increase. Often adequate knowledge of the composition of wastes, for example, does not exist even at the factory where these wastes are generated.

Moreover, existing information is often unavailable due to economic competition or fear of public reaction - for example, in the case of waste with harmful effects on the environment. There is a need for improved training and advice and closer co-operation within the economic sectors concerned.

The distribution of waste materials is a decisive factor in determining the economic efficiency of recycling outside the plant. The transport routes in particular affect cost and level of utilization of capacity of recycling and disposal plants. Where the sources of secondary materials are scattered, as in the case of metal surface treatment or consumer wastes, new possibilities of recycling often can only be put into practice if the various interests of individual plants are reconciled so as to achieve what may be called "re-cycling in a combined system".

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8.2 Collection of secondary materials - the rate of secondary materials in the production process

Even among experts, the impression is often given that increased recycling of secondary materials depends mainly on the raising of collection and reprocessing rates - that is, the degree to which such materials are separately collected or sorted for onward processing. It is an important factor, but not the basic problem. The most important factor in recycling is the rate of utilization of secondary materials in the production of appropriate products. Recycling and reuse of materials as compared to the amount of raw materials used - is determined by manufacturing technology, product design, and price levels. This dependence shows little variability, at least in the short-term. Recycling of secondary materials is closely linked to the total production. Consequently, for example, changes in the demand for steel are usually reflected in the scrap market; a decline in consumption of paper generally results in a corresponding decrease in the demand for waste paper.

Taking into account the linkages between product design and product requirements expanded utilization of secondary materials will mainly depend on:

1. Development of new production techniques;

2. Development of new products and marketing potentials; and

3. Change of requirements for products, frequently in the sense of reducing certain quality requirements.

This dependence shows that research and development should be considered as key tasks in the field of waste management.

Whereas the development of new production techniques or products in many cases is a long-term objective, the reduction of certain quality requirements can be achieved at relatively short notice. Products with and without waste content are frequently offered to the same market and are often designed for the same purpose.

8.3 Recycling design

Recycling design concentrates on:

1. Designing products with a view to facilitating their recycling after use; and

2. Designing and developing new products with the aim of increasing the portion of secondary materials (prior to use) in the products.

Both tasks tend to raise the rate of utilization of secondary materials in the production process which is dependent on technical and economic requirements.

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"Recycling design" is subject to a very different set of factors and questions. For example, new developments in the field of research play an important role, as does consumer attitudes. On the basis of the considerable know-how already available, it will be necessary, to promote new means of recycling by improving products and by recalling former patterns that are no longer used. In this connection, there is a high degree of dependence on the type of material under consideration.

In view of the readjustments sought in the field of secondary raw materials management, the systematic treatment of questions connected with "recycling design" is an important task. Only in this way will it be possible to clarify the situation for decision makers, not least in the political sphere. Of particular importance is the demand for binding or recognized assessment and quality criteria for the economic and environmental "usefulness" of recycling. Their quantification is of particular importance if cost-benefit analysis is to be usefully applied in this field. Recycling is not an end in itself but must be economically and ecologically defensible.

8.4 Consumer behavior

The consumer has an important role to play in the future development of secondary materials management. For instance, his behavior, will determine whether the use of shortlived disposable commodities will continue to increase. Consumer demand will also determine the marketing prospects of a recycled product. Furthermore, the success of the separate collection of residual materials will depend to a considerable extent on the co-operation of individual citizens. This might be accomplished for example, by buying particulary durable products, by giving preference to returnable instead of disposable containers, or by using certain paper products with a higher content of waste paper. In many cases a price benefit is linked to such behavior.

Secondary raw materials and products manufactured from such materials are still considered inferior by large part of the population. Here a basic change in thinking must be encouraged. At present, products that can be manufactured from waste materials often do not meet existing standards or use-specifications, although the qualities of such products may well be sufficient for the intended purpose. The elimination of prejudice and impediments to recycling should become an important task for consumer associations and public authorities.

9. Political aspects

Developments and needs in the field of waste management are not only subject to purely technical factors. On the contrary, the influence of political parameters is making itself felt to a decisive extent.

Economic growth, with the ensuing increase in production and consumption, will remain an indispensable political factor in the near future. Recent experience with economic recession has made this quite obvious. The demand for conservation of resources must be reconciled with this fact. Employment policies, international trade relations agreements, technical and economic adjustment processes and so on - make it politically difficult to enforce any

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radical short-term changes in production and consumption structures. The compromise between short-term economic policy and long-term safeguarding of resources is not yet defined as clearly as is frequently supposed and implied in statements on public policy. In this context more efforts are needed on a worldwide basis. One should keep in mind: What we fail to do today can cost us dearly tomorrow.

10. Concluding comment

Waste Management and in particular recycling cannot be adequately analyzed, nor rational policies with respect to it developed without a clear understanding of the multiplicity of factors that affect the issue as they relate to different materials/energy and to different economic activities. It is particularly important to recognize that:

1. Policies not specifically directed toward recycling such as tax "pollution control" can have important effects on it;

2. Changes in prices of inputs, such as energy and services can have major impacts on waste management.

The impacts can induce more or less recycling, or can make recycling more or less physically and economically feasible. In turn, the necessity for disposal may increase or decrease.

For example, the increase in price of crude petroleum, and the concomitant increase in price of lubricating oil, has stimulated a substantial increase in recycling of used lubricating oil from industrial sources. The increased price of lubricating oil for vehicles, coupled with higher lubrication costs in service stations and garages, has stimulated increased "do-it-yourself" oil changes by vehicle owners in many countries.

This practice disperses the generation of used oil and makes recycling more difficult.

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HEALTH AND ENVIRONMENTAL ASPECTS OF SOLID WASTE MANAGEMENT IN DEVELOPING COUNTRIES

Dr. Günter Bachmann

1. Objectives and Problems

Solid waste management is an important element of public health and environmental protection. Its purpose is to provide hygienic, efficient and economic collection, transportation, and treatment or disposal of solid wastes without pollution of the atmosphere, soil or water system.

Careful identification of present and future waste disposal problems is necessary to establish the objectives of proper management be it at local, regional or country level. In some countries where the generation of solid wastes is low, the main objective may be to achieve adequate disposal of all wastes. The objectives become more extensive in countries where waste generation rates are high, where many communities maintain separate collection and disposal systems, where there are competing demands for the use of land, or where certain methods of disposal are prohibitive, such as composting and incineration.

But all these objectives, whether considered separately or in combination, aim essentially at protection of health and prevention of environmental degradation of the environment.

The following objectives may be applicable to most countries (1):

Protection of health

This will have two aspects: protection against short-term direct and indirect health risks due to improper wastes collection and disposal, as well as protection from the long-term effects on public health of possible ecological changes resulting from unsafe disposal methods.

Aesthetic standards

Next in importance to a healthy environment is a beautiful one. Disposal methods must not mar beauty. On the contrary, every opportunity must be sought to use solid wastes as materials for the correction of former mistakes, e.g., for restoring the landscape where there are disused open-cast mines.

Restriction of production of solid wastes

It may be necessary to create conditions for the reduction of refuse production at source by incentives or legislative restrictions.

Efficiency and economy of disposal

Because solid wastes services may absorb local or national funds it is important to provide an efficient collection and disposal service at minimum cost.

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Recycling of materials

There is need to recycle and conserve certain raw materials in some countries. But in all countries there exist opportunities to re-use solid wastes as land-filling material, as a source of compost, or as a low-grade fuel.

2. Focus on Developing Countries

In regard to public health, the primary consideration in the treatment and disposal of solid wastes is the prevention of communicable diseases transmitted by enteric, parasitic and vector-borne diseases caused by toxic substances. These dangers are far greater in developing countries than in industrialized ones because of the greater prevalence of disease organisms.

To illustrate the impact of public health measures on human life, it may be noted that life expectancy at birth in developing countries rarely exceeds 50 years, and infant mortality commonly surpasses 75 to 100 deaths per 1000 live births (2). Lack of a healthful environment is a major cause of high morbidity and mortality, and those responsible for the treatment and safe disposal of solid wastes must therefore be fully aware of potential health hazards and the need for precautions.

In March 1980 the World Bank published a policy paper on health (3) which reported that most deaths in developing countries are caused by diseases transmitted by human wastes (intestinal parasitic and infectious diarrhoeal diseases), by airborne infection (tuberculosis and pneumonia) and by malnutrition.

Percentage distribution of deaths, by cause, in developing and developed countries

Causes of death	Developing countries	Developed countries
Infectious, parasitic and respiratory diseases	43.7	10.8
Cancer	3.7	15.2
Circulatory diseases	14.8	32.2
Traumatic injuries	3.5	6.8
All other causes	34.5	35.0

As seen in the above table, the basic health problems of the less developed countries, problems likely to prevail for some time to come, are essentially those related to faecal-oral transmission (diarrhoeal diseases, dysentery, cholera, shigellosis, typhoid), and vector-borne diseases.

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More specifically, in tropical and subtropical countries, higher temperature and humidity favour the proliferation of insects and accelerate the decomposition of organic matter. Consequently, more frequent waste collection or exceptionally careful storage is required; densely populated areas in which direct access by vehicles is difficult necessitate the use of hand collection methods.

There are wastes collection problems which are more obvious at present in the industrialized countries; however, they are latent or already present in several developing countries, which should seek to avoid some of the mistakes made by the industrialized countries by planning for solid wastes disposal at an early stage of industrialization:

(a) The greatest increase in the volume of domestic wastes results from the increased pre-packaging of food and other goods. Although there are resulting improvements in hygiene, the necessity for some forms of packaging is questionable;

(b) There are difficult problems in the recovery of raw materials, such as metals, from solid wastes in areas where labour costs make this unprofitable. Apart from doubts as to whether such activity should be subsidized, it implies additional risks to the health of workers in the various processing stages;

(c) Incineration of industrial wastes has, at its early stages of development, resulted in deterimental, harmful emissions into the atmosphere requiring expensive re-adjustment to the installations originally built;

Nightsoil disposal is a special aspect of solid wastes disposal. In some countries nighsoil has to be collected from house to house. Since the faecal matter is not digested and methods of collection and transport are not satisfactory, handling such waste involves serious health hazards. Nightsoil is sometimes brought to a compost heap, where it is mixed with domestic refuse to add to the fertilizing value of the product. Close control is necessary to minimize health risks. If composting of refuse is not practised, nightsoil should be digested separately before being used on land.

The handling of nighsoil brings up the question of nightsoil utilization. Human excreta is the principal source of the pathogenic organisms carried by water, food and insects. (4). More than 100 different virus types are known to be excreted in human faeces. More than 1,000,000 infectious virus particles may be excreted per gram of faeces by infected persons, regardless of whether or not they manifest illness. Concentrations as high as 100,000 infectious virus particles per litre have been detected in raw sewage. These viruses may survive for several months in wastewater, tapwater, soil and shellfish. Furthermore, they may resist conventional water and wastewater treatment procedures, including chlorination, and may be found far from the original source of contamination. The term "enteric virus" - an epidemiological concept - is applied to any viruses disseminated by the faecal route. They multiply primarily in the alimentary tract and are excreted in substantial amounts in the faeces for varying periods of time, with a mean shedding period of up to 50 days.

The best studied of these enteroviruses are the polioviruses. Studies have widely demonstrated the presence of enteroviruses in wastes, in effluents from sewage treatment plants and in contaminated streams. Polioviruses can cause serious nervous system diseases. Actually clinically manifest disease occurs only in between 1 and 100 and 1 in a little over 1,000 cases of infection, depending chiefly on the virulence of the virus and the age of the host. In developing countries, in which wild polioviruses are prevalent, infections are typically acquired very early in life, when the risk of serious disease is lowest. Most older children and adults are thus immune.

Having mentioned the health implications of nighsoil handling one must again refer to human faeces utilization by composting. Pathogen survival in compost systems depends upon the time temperature characteristics of the compost pile. Research has shown (5) that enteric viruses and Ascaris ova are the most hardy, but the following time-temperature combinations will guarantee their destruction: one hour at 62°C; one day at 50°C; one week at 46°C; or one month at 43°C. Therefore, if all parts of a compost pile can be brought to a time-temperature state within a certain zone of safety, complete pathogen destruction should be guaranteed. There are are two possible exceptions to this; first, spore-forming bacteria are more resistent but present little risk and second, hepatitis A virus appears to be resistant to rapid heating to temperatures of up to 100°C, but its ability to survive temperatures only slightly above 60°C for several hours is not known. In summary, literature indicates that a well-designed system under good management produces a pathogen-free, or almost pathogen-free compost. Where some sections of the pile do not reach the required temperature for the required time, however, there will be pathogen survival. The organism most likely to survive is Ascaris and therefore Ascaris ova may be used as the indicator of successful composting.

3. WHO Activities and Policies

The World Health Organization has for many years given attention to the health implications of solid wastes treatment and disposal, and has published documents and guidelines referring to the most critical and imminent problems in this respect (see references to literature at the end of this paper). The first WHO Expert Committee to consider solid wastes, which was convened in 1971 discussed the impact of solid wastes; outlined recommendations for research and development; discussed planning and operation of solid wastes systems, including the training of personnel, and set down a number of guidelines for policy and action at different levels. In conclusion, the Committee recommended that:

> "International, bilateral and private agencies should assist governments in planning and implementing solid wastes programmes through the provision of professional expertise in engineering, management, health education, and legal and financial questions, as well as by organizing training activities and providing direct financial assistance."

The first step in the implementation of the programme was the establishment, in September 1968, of a WHO International Reference Centre for Wastes Disposal at the Federal Institute for Water Resources and Water Pollution Control (EAWAG), associated with the Swiss Federal Institute of Technology, Zurich, Switzerland. Among the many functions of the WHO International Reference Centre are the following:

1. To collect, evaluate and disseminate technical and scientific information on wastes-disposal practices;

2. To test the practical usefulness of new methods and procedures evolved for the collection, processing, re-use or disposal of liquid and solid wastes;

3. To conduct research investigations, experiments, pilot demonstrations and other studies on wastes-disposal practices;

4. To collaborate with, and give the maximum of technical assistance to, WHO regional reference centres and national reference centres that may be set up in the future and other national institutes and laboratories studying methods for treating and disposing of wastes;

5. To train personnel, particularly for developing countries, and to prepare manuals for training courses, seminars, and field developmental investigations in wastes-disposal techniques.

Thus, by facilitating the exchange of information on successful practices and by eliminating duplication of effort, the Centre contributes to the most efficient use of the limited number of scientific, technical and administrative personnel employed in wastes-management work.

In the meantime, WHO has entered into agreement with institutes in all parts of the world to collaborate with the International Reference Centre. The collaborating institutions have been invited by the Centre to send publications and to provide information or comments on specific matters, such as research under way or planned, methods of analysing solid wastes, methods of costing solid wastes facilities, legislation on solid wastes, etc. Collaborating institutions regularly receive all WHO publications in the field of environmental health. More recent publications of the WHO International Reference Centre for Wastes Disposal have been on analysis methods (6) and an annotated bibliography on compost and related matters (7).

WHO Regional Offices have contributed to solving solid wastes management problems, within their areas of responsibility, by organizing courses, e.g. in the Eastern Mediterranean Region (8), seminars, e.g. for South East Asian countries (9) and publishing a code of practice (10) for European Region countries. The South East Asian Regional Office, in 1976 published a textbook (11) intended to provide a reference source for engineers, municipal officers, administrators etc. not only working in these countries but also in other parts of the world. The same applies to the "Glossary on Solid Waste" published by the European Regional Office in 1980 (12).

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Sanitary disposal of human wastes is generally necessary to eliminate contamination of water and food, and to enable people to avoid direct contact with disease organisms. Especially in hot climates where conditions for multiplication of these organisms are ideal, good personal and household hygiene is indispensible to disease control. Thus, to maximize the effectiveness of efforts, WHO has been engaged to execute pre-investment projects consisting of long-term plans for the development of water supplies, sewerage and solid waste disposal aiming at the fullest possible inclusion of the latter in the subsequent implementation of facilities. Outstanding examples for these comprehensive types of projects have been (as of 1981/81) master plans for the cities or regions of:

Ibadan	(population - 1.00 million)
Nairobi	(" - 0.65 ")
Tananarive	(" - 0.55 ")
Kabul	(" - 0.40 ")
Malta	(" - 0.35 ")
Lebanon	(on national basis)

As technological development progresses, international organizations, including WHO, although not directly associated with research work, have a role to play by assisting developing countries in identifying their technical, economical and environmental health requirements in respect of solid wastes management. It has, therefore, been WHO's policy:

(a) To review existing knowledge of the impact on health and on socio-economic factors of improper handling of solid wastes;

(b) To make an appraisal of current practices in solid wastes management; and

(c) To identify areas for future action.

A good description of the background to WHO policy is contained in the report of a WHO Scientific Group on the Treatment and Disposal of Wastes:

> "The disposal of wastes must take place within a closed environment comprising only earth, air, and water. When the liquid, solid or gaseous residues from waste treatment are disposed of, they must be discharged into one or more of these phases of the environment. Any or all of the phases may be polluted, and any solution to the general problem of the disposal of wastes therefore involves a decision as to which part of the environment can accept residues with least damage to the whole. In other words, in deciding on a site for the disposal of residues, their total effect on the environment must be studied. Wastes must no longer be transferred from one environmental phase to another without adequate study. This is particularly important in view of the fact that some residues persist permanently."

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4. Health Risks with Solid Wastes Handling

Risks to public health arising during storage and collection of solid wastes are usually indirect ones: the propagation of those insects and rodents which are disease vectors. Thus public health is safe-guarded if the wastes are stored in a closed container from which they are transferred direct (without contact with the ground and without exposure for more than a few seconds) into an enclosed vehicle and if the frequency of collection is substantially shorter than the life cycle of insect vectors.

Because the wastes in cities are often stored in open street bins for two days or more, insects have complete access for food and egg-laying, while rats and mice have free access to the food content.

There may be also a direct risk to health arising out of dust and droplets to which people may be exposed. A direct risk is also involved when ashes or inflammable matter may set collected wastes on fire.

Direct health risks concern the workers in the wastes collection and disposal field. The methods by which wastes are removed from street bins and loaded into vehicles involve soiling the hands, arms and feet of the collectors; the squatting or stooping posture adopted to fill baskets causes the inhalation of contaminated dust and droplets.

There is evidence that, when exposed to infection in this way, such workers suffer a higher than normal incidence of intestinal parasites. In India, a study showed that 94 per cent of refuse workers were infected with selected parasites as against slightly more than 4 per cent in the control groups. The same study indicated that the infection rate with worms and related organisms was three times that in the control group. Contamination of this kind is liable to occur at all points where waste is handled. However, although it is certain that vector insects and rodents can transmit various pathogenic agents of diseases (amoebic and bacillary dysenteries, typhoid fever and salmonellosis, various parasitoses, cholera, yellow fever, plague, leptospirosis, etc.) it is often difficult to demonstrate the precise relationship between the sources of infection and the health of the population affected (1).

As regards the health risks propagated by insects and rodents, it is obvious that fly breeding takes place around houses when refuse is left lying about particularly during hot weather. Breeding also takes place at refuse dump sites when moist refuse is left unburnt for some time. This occurs very rapidly in tropical and semi-tropical countries as the heat and humidity accelerate the decomposition of refuse giving rise to bad smells and providing ideal breeding sites for flies.

In areas where controlled tipping is practised, flies are sometimes discovered breeding in solid wastes which have been neglected and left uncovered for more than forty-eight hours.

Refuse composting is a more recent development. One of the most important problems of composting is the control of flies. as various types of refuse, including animal manure, abattoir wastes and other food processing wastes provide excellent media for fly breeding.

Fly breeding however can be satisfactorily controlled during composting operations. The most effective method of destroying fly larvae is frequent turning over of the compost, in this way the larvae will be turned into the centre of the compost heap, where the heat will destroy them.

With regard to the attraction and harbourage of rodents, well organized refuse collection is of major importance for all rodent control work. The open dump is all too common and needs no explanation. The main source of food for rats and other small rodents is refuse and in rubbish dumps they quickly proliferate and spread to neighbouring houses or uncontrolled collection places.

These vectors are an importance cause of disease and controlling the disposal of solid wastes will reduce the number of vectors. This has been proven by various studies which also showed a significant reduction of gastro-intestinal diseases in communities using sanitary landfill for the disposal of solid waste as compared to similar communities using open dumps for disposal.

Of the various disposal methods in use or under consideration for application in developing countries, the most popular is disposal on land. Many important archaeological excavations are diggings of old landfills or dump sites. Considering the limits of the biosphere, it is logical that man disposed of his unwanted, used-up goods on land rather than in the air or waters, and today solid wastes disposal on land represents, in terms of quantity, the most important disposal method in use.

There are many ways of wastes disposal on lands including indiscriminate dumping, dumping in selected locations, controlled open dumping, and sanitary landfilling. Under proper conditions or within prescribed limits, each of these methods could be acceptable environmentally and with regard to public health. However, the only land disposal method for community-generated solid wastes recognized as generally acceptable with regard to the environment and to public health is sanitary landfilling or controlled tipping. More specifically; a sanitary landfill should not cause air or water pollution, it should not pollute the land on which it is constructed; it should be operated in a manner so as to restrict the attraction and reproduction of disease-bearing insects and rodents detrimental to public health.

Without referring to the full range of modern disposal methods, whether mechanized or relying on manual labour, in the context of this review another method should also be highlighted - composting. Composting has been thoroughly reviewed in previous WHO publications (14) and in more recent manuals (15). It can be concluded that a wide range of composting technologies is available. They all incorporate the mixing of night soil or sludge with a carbon source such as refuse or sawdust to achieve a C/N ratio or approximately 20 to 30. Moisture content (20 to 60 per cent) must also be regulated for optimal performance with wetting or turning (to dry) at appropriate intervals.

The most important feature of composting, from the health viewpoint (5), is the temperature achieved, and this depends on the oxygen content of the pile, as well as the C/N ratio, the moisture content, particle size, and pH. If the process is anaerobic, temperatures will remain at, or only a little above, atmospheric levels and mesophilic organisms will predominate. Foul smelling gases are usually produced and the process or degradation proceeds slowly. If the process is aerobic, substantial heat is generated by proliferating thermophilic microorganisms and degradation is more rapid and usually free of odour.

A compost pile, newly erected, will contain entrapped oxygen and, if other factors mentioned above are correctly regulated, thermophilic aerobic processes will be established and the temperature at the centre of the pile will rapidly rise to 55°C or above. Although there is some evidence to suggest that mesophilic composting, below 45°C, is more rapid and efficient than the thermophilic stage, which may reach 70°C, there are practical difficulties in trying to limit the process to the former type of organism. Of greater importance, however, is the fact that the high temperatures of the thermophilic phase are necessary to achieve the destruction of pathogens, insect eggs and larvae, and weed seeds. This is accomplished, with an adequate margin of safety, provided that every particle of the wastes is exposed to a temperature of 60°C for a few hours. To attain such a temperature in the centre of the mass presents no difficulty; but to ensure that it applies to every particle does present problems except when the wastes are being treated within a totally enclosed vessel. Thus an important aspect of the management of a composting process is to ensure that such problems are overcome.

Finally, risks to health as well as to the human environment, may be caused by industry. Industrialization introduces dangers of a different kind; hazardous wastes from industry present risks during transport and disposal. Accidents can result in toxic wastes being spilled: they may cause death and injury to people in the vicinity. Improper disposal of such wastes can result in the contamination of crops or water supplies. There is the specific danger of the concentration of heavy metals in the food chain, a problem that illustrates the relationship between solid and other wastes. It has sometimes happened that liquid industrial effluents containing heavy metals have been discharged into a drainage system and contaminated the sludge leaving the treatment plant.

5. Environmental Criteria

Solid wastes collection and disposal is an important part of environmental hygiene and needs to be integrated with environmental planning and policies (16). Improper collection, storage, treatment and disposal can lead to serious environmental damages caused by pollution of various kinds. Particularly detrimental, and often unrecognized, is the transfer of pollution to water, including ground water. Air pollution can be caused from the inefficient burning of wastes, either in the open air, or in plants that lack effective treatment facilities for the gaseous effluents.

There are also aesthetic damages to the environment, for example the dumping of litter on streets or the destruction of the beauty of the countryside by uncontrolled refuse tipping.

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Water pollution occurs through contact of deposited wastes with ground-water, surface water, leachate from dumps, static water in dump sites, and the use of streams and canals for solid wastes disposal by residents not provided with proper services. Surface water drainage is frequently impaired by blockage of ditches, gullies, and sometimes major waterways are blocked by solid wastes (17).

The pollution of static water, ditches, rivers or the sea can occur when a sanitary landfill adjoins a body of water. The normal source of the leachate causing this pollution is rain falling on the surface of the fill, percolating through it, and passing over an impermeable base to water at a lower level. In arid areas there may be insufficient rainfall to create a leachage, but in all other cases the production of leachate from rainfall is unavoidable during the early stages of filling. The quantity of leachate can be substantially increased when upland water drains across the site of landfill, particularly if a stream crosses the site.

Large quantities of industrial solid wastes are deposited in landfills and some of these are toxic. Certain highly toxic wastes are dumped at sea. Solid wastes buried in a sanitary landfill will decompose if moisture is present. The liquid residue is the leachate, the major gaseus emissions are methane and carbon dioxide, depending upon the solid wastes composition and the source of water infiltrating the landfill. Landfill gases can damage vegetation, particularly if they reach the root system of vegetation adjoining sanitary landfill sites.

The developing countries need to pay greater attention to air pollution. In most of the industrialized communities, the major sources of air pollution arise from the production and use of coal, coke, oil and petrol as fuel. Often as well, there is serious local air pollution from special industrial activities such as petroleum refining, production of cement and other materials. The disposal of household and industrial waste materials by incineration is also a source of air pollution.

Refuse incineration whether on-site or by incinerators can cause an unaceptable degree of air pollution through smoke if not properly designed and operated.

Burning of wastes cause considerable nuisance by generating gases such as carbon monoxide. Putrefaction also takes place in portions of refuse which have not been fully burnt and this adds to pollution of air by foul smells.

In summary, controlled and incomplete combustion of solid waste materials can result in the release into the atmosphere of a number of undesirable pollutants, including particulate matter, sulfur dioxide, nitrogen oxide, various hydrocarbons, and other noxious gases that may have deleterious effects on the health of those who inhale them (18).

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6. Conclusions and Recommendations

Although only limited study has been made of the direct effects of solid wastes handling, available evidence shows that improper handling adversely affects health and environment, and hampers the recycling of natural resources, besides being aesthetically undesirable. It may also lead to dangerous concentrations of toxic substances in food chain organisms through physical and biological processes. As regards the problems to be solved in developing countries, in the light of present practices, the following points would need attention:

1. The problem of acute poverty, which may lead to the recovery of food from garbage;

2. The importance of using wastes as resource materials wherever possible, for example, as fertilizer or a source of energy;

3. The need to employ labour intensive methods;

4. The use of cheap, standardized easily repaired vehicles;

5. The desirability of having portable containers to avoid ground pollution and double handling; and

6. The importance of overcoming prejudice against landfill by intensive work on public awareness.

Collection methods should satisfy the following health-related requirements:

(a) Hygiene: the exclusion of insects, rodents and odours;

(b) Capacity: adequate volume for storage between collections;

(c) Weather resistance and impermeability;

(d) Portability: use of containers which can be emptied or exchanged by one man without spillage;

(e) Accessibility to the collection point.

In selecting the most favourable disposal method and site the criteria for protecting the environment must be met. This will, as a rule, require careful pre-investigation of various types. Particular attention should be given to protection of surface water and ground water resources. The main environmental surveys would, therefore include, but not be limited to the following:

(a) The level of the water table, if high enough to be of consequence, together with the direction and rate of flow, should be ascertained and recorded. At sites where tidal conditions exist, details of these should also be recorded;

(b) Where the site is located within a water protection area, and where there is a risk of water pollution, the quality of the ground water should be determined and recorded before tipping begins, to establish a standard of comparison for future monitoring. Monitoring should continue during the operational life of the site and until tests show that the refuse has become chemically and bacteriologically inert;

(c) The percolate from a controlled tip can be highly polluting. Where there is a risk that water sources may be polluted, measures must be taken to prevent the percolate from reaching the ground water, or entering a river or stream. At some sites an impermeable lining such as puddled clay or hard plastic sheeting has been interposed between the refuse and the ground and a drainage system provided to collect the percolate.

(d) An investigation by specialists is a necessary prerequisite to the use of a site for the deposit of solid wastes. Potential sites can be divided into three main groups: impermeable sites, sites on which subsoils such as sand and gravel may provide a measure of filtration, fissured sites from which a leachate may be able to travel many kilometres;

(e) The selection of sites for controlled tipping should be undertaken in conjunction with the water supply authority, and geological advice should be sought. Should the operation of a site require the collection and treatment of run-off or percolate, this should be supervised by a qualified chemist.

Many studies have been made to try to determine how pollution may be avoided by careful site selection and methods of control. In general, it is accepted that:

(a) Risks of bacterial pollution by leaching are remote and seldom persist beyond 10 to 15 metres of the source;

(b) Chemical pollution is a much more serious problem and has been found at distances up to 30 kilometres in fissured limestone;

(c) Intensive pollution is limited to a period of about three years after deposit and by that time is only a very small proportion of the original level;

(d) The pollution of surface water is avoidable if culverts are dug in water-courses crossing the site before the project commences, and adjacent streams separated from refuse by an impermeable barrier.

In evaluating waste disposal methods on their operational requirements, the three methods - landfill, composting and incineration may illustrate the range of problems.

(a) Landfill: At a sanitary landfill, vectors are controlled by the operating method. Ground water pollution is avoided by careful site selection and surface water pollution is avoided by preliminary site engineering. Thus a well-managed site involves no risks of pollution transfer to water or atmosphere. Some short-term environmental degradation may be unavoidable.

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(b) Composting: Composting systems, both manual and mechanised can be designed and operated so as to provide effective control over disease vectors, but it is rarely possible entirely to avoid occasional offensive odours. The solution to this lies in careful site selection.

(c) Incineration: Incineration has no obvious environmental advantages and it sometimes presents environmental problems. A very tall chimney is necessary to ensure that the effluent gases do not descend over the surrounding area; water consumption for gas cooling and clinker quenching may be very high; particle emission can seldom be controlled to better than 99 per cent, and even this is inadequate.

A number of special waste materials involve increased risk in their handling, namely, wastes from hospitals and clinics. This waste should not normally be received at controlled tips. However, in exceptional cases it may be safely disposed of if contained in closed bags which should be deposited on the tip and immediately covered. The same would apply to animal carcasses.

With respect to insects and rodents control, the surface of the tip should be maintained in a level condition to avoid ponding which could give rise to the breeding of insects. If, in exceptional circumstances, it is necessary to employ insecticides, these should be used sparingly and according to prescribed procedures. Particular attention should be paid to exposed refuse and to any area where cracks have appeared in the covering material.

Tip operators should be trained to recognize signs of rat infestation. At the commencement of a tipping operation arrangements should be made with the local public health authority for rat control procedures so that safe and effective methods may be practised. Generally, rodents are more difficult to control, but rodenticides used on a regular basis have been found effective if the landfill operation is good.

In terms of health, cost and environmental protection, sanitary landfill and composting emerge as the most suitable methods of solid wastes disposal for developing countries. In the case of sanitary landfill, this conclusion is the same as that reached by the great majority of cities in the industrialized countries. Composting, however, has sometimes been excluded because of high production cost, but primarily because of the ready availability of artificial fertilizers. None of these factors apply at present in many of the developing countries. Thus in most cases both sanitary landfill and composting may be equally worthy of consideration.

As a resumé to the findings and conclusions made, a few items should be pointed out:

1. In selecting the most suitable type and size of solid waste disposal methods, sanitary and environmental safety, simplicity and economy should be aimed at, and locally favourable methods should be exploited.

2. As health issues are linked with environment, so are organizational requirements connected with solid waste disposal, and these should be taken into account at an early stage.

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3. Responsible agencies in developing countries should be encouraged to request WHO and other international agencies' expertise for the solution of problems, the reduction of constraints and the elimination of shortcomings that may inhibit the development of solid waste disposal systems.

4. It is recommended that national health agencies should be closely involved in policy making with respect to solid wastes disposal and should promulgate codes of practice for sanitary disposal.

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INTERNATIONAL CO-OPERATION IN SOLID WASTE MANAGEMENT

Werner Knipschild

I should like to try to suggest priorities and possibilities of solid waste management in the context of development co-operation between the Federal Republic of Germany and the countries of the Third World, in particular in the area of water supply and sanitation.

We are all aware of the importance of orderly disposal of solid waste. However, the methods employed must match the social, economic and political needs and conditions of the region concerned. During the next week you will see a number of different possibilities for waste disposal and recycling which have been developed under, and for, the socio-economic conditions of the Federal Republic of Germany. I should like to point out that while these methods generally suit the needs of an industrialised country, they may not all suit the needs existing in your countries in the foreseeable future.

In the autumn of 1980, the years 1981 to 1990 were declared the "International Drinking Water Supply and Sanitation Decade" by the United Nations. I wonder if any of the politicians concerned at that time had considered that this also involved the problems of rational solid waste management.

But, if the aim of the decade is to provide everybody with hygienically acceptable drinking water plus basic sanitary services by 1990 - or by the year 2000 to which the representatives of some Third World countries more modestly, but more realistically aspire - it must include the orderly disposal, or better, use of waste.

If the waste problem which gets worse as economic development advances, particularly in the urban centres of population, cannot be solved, it will not be possible:

1. To contain the growing threat to the environment;

2. To protect water resources from sewage and refuse; or

3. To protect the population from disease.

Development planners must therefore be aware that water supply, sewerage systems and refuse disposal form an integrated whole, and must be dealt with through co-ordinated planning and implementation. Unfortunately, there are very few cases of a single authority being responsible for these three areas. Usually there are two, three, or even more, ministries and/or local authorities responsible for their planning and implementation.

Even in the area of supply of drinking water where part of the cost can be recovered by levying charges according to quantity consumed, it is rarely possible to cover the full cost. The areas of waste water and solid waste, have to cope with considerably worse financial problems.

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As an indication of the magnitude of this worldwide problem, I will give a few global figures on costs. According to estimates from the World Health Organisation, about 300 billion US $ are needed to achieve the target of the decade in the countries of the Third World; that would be 30 billion US $ in each year of the decade. In fact only one third of this amount can be raised at the current time, about 8 billion US $ by the affected countries themselves and about 2 billion US $ in the form of external support. These sums already include the contributions made by the people concerned. Moreover, a high percentage of these funds goes on re-investment, that is - first of all - to replace obsolete equipment.

The fitures I have mentioned represent the situation at the beginning of the eighties. But we should remember that, while the financial input required should rise, in practice the available input is likely to suffer a decline. For, despite a steady rise in population, especially in the countries of the Third World, financial resources are becoming scarcer as a result of a worldwide decline in economic activity. This means that, while the developing countries face growing economic constraints, aid from external donors is also more likely to be reduced than expanded.

In other words the "target of the decade" is unlikely to be achieved in the foreseeable future. Given these financial constraints, the funds available for an economically "unproductive" sector such as solid waste disposal will be even more limited in almost all countries than they already are, and only the most urgent disposal projects will be implemented on the smallest scale.

In future, therefore, it will be increasingly necessary - when planning waste disposal systems - to take full account of the economic capacity, needs and capabilities of the country, region or community concerned, in particular of the people themselves. There is little use in a technically optimal plant for a limited purpose with which a part of the waste can be disposed of, if the rest of the disposal equipment needed cannot also be financed. What is the use of this sort of equipment if the running costs cannot be raised and the spare parts cannot be made available? Or what is the use of modern technical equipment, which may be quite appropriate to the purpose, if the country has insufficient qualified personnel to service it?

II

Under bilateral development co-operation, we have often found in the past that technical equipment has been planned and set up in Third World countries in the same way as it has in the industrial countries. And in many cases the equipment ceased to be operational after a disproportionately short time for a wide variety of reasons. Particularly in the field of solid waste, the different requirements in the industrial countries and the developing countries, deriving from different socio-economic conditions, become apparent.

Society in industrialised countries is characterised by excessive use of raw materials and production of excessive amounts of waste. The use of aluminium cans, of one-way bottles, of plastic bags and materials, of fancy wrapping and packaging materials is still part of western society. The pre-capita production of waste is very high in western countries and consequently the elimination of domestic waste is a heavy financial burden for the community. In many cases, the financial burden of the producer or consumer of a product is shifted to the community by way of, for example, one-way packaging.

For the manufacturer it is usually cheaper and easier to package foood and drinks in plastic and disposable bottles than in re-usable containers or bottles which would have to be collected, returned to the factory and cleaned. For the economy of a country or the community affected, disposing of these waste materials involves an unreasonably high outlay. In terms of sound economic sense, the waste should not occur at all; valuable raw materials and the scarce energy required to manufacture one-way packaging would be saved through multiple use. If such wastage of raw materials and energy is questionable in the industrial countries, it is quite unreasonable given the financial burden facing the countries of the Third World.

I stress this economic wastage of raw materials and energy resources not because I believe that any of us is in a position to change this "throw-away mentality" in his own country, but only to show that waste disposal systems are planned in this country according to concepts which may not necessarily be the most suitable solutions for your own countries.

III

When planning waste disposal projects in Third World Countries, engineering consultants should, therefore, take account of factors very different from those relevant to planning similar systems in industrial countries. From the experience of our co-operation, I would like to give a few examples:

1. A wide variety of social patterns and economic factors must be taken into account in solid waste collection, transport and disposal. Since waste patterns vary widely from region to region, the collection systems must also be different. If waste in a humid tropical climate, has twice the density of waste in Central Europe, waste disposal cannot use Central European solutions. Vehicles which in any case may be complicated to operate and service may be unsuitable for local conditions; In countries with low wage costs, with high rates of unemployment or underemployment and/or with hardly any technical traditions, simple vehicles, even ones drawn by animals, may be preferable to hydraulic waste collection vehicles;

2. Where the "throw-away mentality" of the industrial countries at the stage of project design has been transferred to the developing countries leading to generation of unnecessary quantities of waste, these valuable materials where possible should be recycled.

   An incinerator such as would perhaps be built under those circumstances in urban areas of industiral countries, would be precisely the wrong solution.

3. From the point of view of saving resources, therefore, waste recycling plants have been developed in the industrial countries in which different types of waste such as metals, glass paper and cardboard, plastics and organic waste are separated and, as far as possible, recovered for further use. At present, such systems are still so expensive, on account of investment and running costs, that, despite the increasing cost of raw materials and energy, they only operate economically in industrial countries. Here, by recycling raw materials - as much as 70 per cent of the volume - the limited tipping space available, which can thus be used longer, is a determining cost factor.

For developing countries with a completely different cost structure for capital goods and labour, such waste recycling plants are not viable at present. Moreover problems of spare parts and maintenance are particularly relevant to systems of this type due to their unfamiliarity and technical complexity.

Given the situation in the large cities of your countries, the engineering consultants should take into account that recycling has long been practised by large armies of workers. These people must be integrated in plans to improve waste disposal. On no account should the work of these people be replaced by machinery merely to improve the hygienic situation at waste dumps, with the result that 70 or 80 per cent of the workers become redundant.

For economic, social and political reasons consideration should be given only to improving, as far as possible, the working conditions of these people.

So far the examples

IV

In the context of the Federal Republic of German's economic co-operation with the developing countries, totalling about US$ 2.5 billion each year, between US$ 100 and 120 million are allocated on a bilateral basis for the support of projects in the field of drinking water and sanitation. Only a fraction of this money is used for solid waste disposal and recycling projects. In the sphere of technical co-operation in particular, extensive experience has been collected in the last few years with respect to the design of economically and technically appropriate waste disposal projects. I have endeavoured to explain the broad outline of this experience relevant to sector policy. In a review of selected solid waste projects in developing countries the representative of the German Agency for Technical Co-operation will report on special findings on the last day of your programme here in Karlsruhe.

This agency implements the German part of technical co-operation projects on behalf of the Federal Ministry for Economic Co-operation, while the "Kreditanstalt fur Wiederaufbau" (Reconstruction Loan Board) deals especially with financing investment in fixed assets, also on behalf of the Federal Ministry for Economic Co-operation.

In this presentation I have compared the attitudes to waste disposal existing in industrial countries with the different conditions existing in Third World countries. I have tried to show that the methods employed here do not necessarily apply in your countries. And I have tried to indicate priorities which should be set in order to match the methods of waste disposal to the social, economic and political needs of the region concerned.

I would like to discuss your experience in your countries and the impressions you have of the different waste disposal systems presented to you during the next week in our country when we meet again in Karlsruhe, after your technical visits.

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SOLID WASTE TECHNOLOGY IN THE FEDERAL REPUBLIC OF GERMANY

Georg Goosmann

1. General

Solid waste technology is a peculiar mixture of bits and pieces from alsmost all sectors of technology; in its diversity it resembles, a mixture of materials and objects from each and any area of human activity that it deals with as solid waste.

The various technologies employed in solid waste maagement include storage, collection and transport methods, thermal, mechanical, chemical, physical and biological processing and pertinent pollution abatement techniques as well as final residue storage, on the surface or underground.

Most of the processes and pieces of equipment employed in solid waste management were originally borrowed from other sectors of processing technology and modified for - in most cases more difficult - tasks in waste treatment.

Typically, the introduction of a technological process into solid waste management is not achieved once and for all, but modifications and variations are more or less required for each application and for each individual project even within the same country, to adjust to local conditions with regard to waste composition, collection system and a wide range of factors relevant to plant operation.

It therefore appears necessary to briefly outline the german waste management situation in terms of waste arisings and characteristics before reviewing the status and development trends in waste technology.

2. Some Basic Data

In the Federal Republic of Germany, with a total area of approximately 150,000 km^2 and a population of about 61.5 million, annual production of the main types of waste solid is shown in Table 1.

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Table 1

Type/source of waste	Annual production in million tonnes
Domestic and commercial wastes[(1)]	25
Hospital wastes[(2)]	0.9
Hazardous wastes[(3)]	3-4
Sewage sludges - as dry matter -[(4)]	2.1

(1) Domestic refuse and wastes of similar nature suitable for disposal in municipal disposal facilities.

(2) Wastes for which special treatment is required; not including normal domestic wastes collected by routine services from hospital premises.

(3) Wastes from industrial, commercial and municipal sources requiring special supervision by provision of the 1972 Waste Disposal Act. and disposed of in generally accessible licensed facilities operated by or in association with public bodies. An additional 15 to 16 million tonnes arise from industrial sources but are treated and disposed of in industry-owned on-the-premises facilities.

(4) Sludge from municipal sewage treatment plants. The figure for the corresponding quantity of liquid sludge at 95 per cent water content would for instance be 42 million tonnes.

Other types of wastes, such as industrial production wastes not falling under (2), demolition and mining wastes, excavation and dredge spoil and agricultural wastes far exceed the above quantities.

The average rate of production of domestic and commercial wastes: the main types dealt with by municipal solid waste management is approximately 410 kg per capita per day.

After significant increases in waste production over the last decades, the tendency in recent years is towards stagnation, partly due to slow or stagnant overall economic development but also - hopefully - to waste reduction and waste avoidance measures, in accordance with the Federal Government's 1975 Waste Management Programme giving first priority to waste reduction.

The "quality" of german 'household and commercial wastes' is described in Table 2.

Table 2

Main components	Composition Average	Percentage by weight, typical range
Paper and board	24	20-30
Glass	8	6-10
Metals	15	4-6
Plastics and textiles	9	8-10
Wood, leather, rubber	9	8-10
Putrescible matter (kitchen and garden wastes)	32	28-36
Fines	13	10-20

Moisture content	30-40 per cent
Calorific value	1,800-2,500 kcal/kg (7,500-10,500 kJ/kg)
Density (- in containers as collected)	0,1-0,2 t/m^3

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3. Municipal Waste Disposal

3.1 Collection and Transport

Economically the most relevant aspect of waste disposal is collection and transport. About 98 per cent of the population of the Federal Republic of Germany is presently served by regular - in most areas weekly - waste collection.

The technical system most widely used is collection in standardized containers (mostly used volumes 110, 240 and 1,100 litres) mechanically emptied in highly specialized collection vehicles using "dust-free loading systems".

One of the most remarkable recent developments in collection, is the increase of various methods of materials recovery through separation at source and separate collection. With remarkable voluntary co-operation of private households, increasing amounts of glass (1982 a total of 700,000 tonnes), waste paper and textiles are being recovered, mostly as a result of growing public concern. From commercial sources plastics and metal are also separated.

3.2 Treatment and Disposal

The refuse treatment and disposal methods employed in the Federal Republic of Germany are disposal by landfilling, incineration and composting, both necessarily combined with residue landfilling, and newer technologies such as pyrolosis and mechanical processing aiming either at materials recovery or the production of waste derived fuel. These newer methods are still in an early phase of implementation.

The following table gives a general overview of the present situation in solid waste treatment and disposal in the Federal Republic of Germany:

Table 3

Method	Number of plants	Portion of waste arisings handled
Landfill	530	67 per cent
Incineration	46	30 per cent
Composting	16	>2 per cent
Newer methods	a few	>1 per cent

As a result of a combination of realistic assessment of development trends and a good portion of optimism and confidence the corresponding situation 10 years from now is anticipated in Table 4.

Table 4

Method	Portion of total refuse handled
Landfill	50 per cent
Incineration	40 per cent
Composition and newer processes	10 per cent

The obvious reason for decreasing reliance on landfill disposal foreseen, is scarcity of space, in particular, of space suitable for environmentally safe disposal in view of growing concern about groundwater conservation in the densely populated Federal Republic.

In principle, landfilling is quite a simple technique, but has been developed to fairly high standards since licensing of new landfills became obligatory in 1972.

Some of the technical features of an up-to-date landfill are:

- leachate barriers, leachate collection and treatment facilities;
- compaction by special heavy equipment;
- groundwater quality, monitoring;
- landfill gas control and as a newer item gas collection and utilization facilities where feasible.

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As a result, landfilling has become a more acceptable through costly disposal method. However, it is still cheaper than alternative methods.

The general trend is towards recognizing available landfill capacity as an asset to be conserved. Technical and organizational measures are taken to keep recoverable materials away from landfills, thereby accomplishing both, extension of the lifetime of existing sites and a contribution to resource recovery.

While for landfill disposal, suitability of the wastes is not a decisive criterion, it can be, in the case of incineration. Considering the above waste characteristics, german household and commercial wastes appear suitable, equalling brown coal in calorific value, and nearly all of the refuse incinerators in Germany are equipped for energy recovery. However, energy generated from waste incineration is extremely expensive. Incineration is mainly used for volume reduction, particularly where insufficient landfill space is the critical constraint. Energy generation is only a useful by-product, though not a negligible one.

With incineration, the main environmental concern is air pollution. Sophisticated techniques have been developed for exhaust gas treatment to meet the ever stricter emission standards and add considerably to the cost of refuse incineration.

One interesting development is the combination of incineration with mechanical pre-treatment designed to provide for a more homogeneous incinerator input and admixture of sewage sludge for co-disposal in incinerators.

An international outlook on the utilization of incineration in municipal waste management is presented in Table 5.

Solid waste composting so far plays a minor role so far in solid waste management in the Federal Republic, although quite a number of very different processes have been developed. Some of the reasons for this are: limited volume reduction achievable with the given waste characteristics; lack of demand for the soil conditioner resulting as an end product (this is in many cases due to the neglect of marketing activities), concern about possible contamination of refuse derived compost.

The trend in Germany is expected to be towards using composting not as the main method but as a unit process to treat selected specificly suitable waste fractions in combined resource recovery plants.

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Table 5

Utilization of Incineration in Municipal Waste Management (1980)

	Portion of total waste arisings – incinerated (all plants)	– incinerated in plants with energy recovery	Portion of primary energy demand contributed by waste incineration
	per cent	per cent	per cent
Federal Republic of Germany	29	27.4	0.46
European Community	23	13.1	0.24
Japan	65	23.5	0.28
USA	10	2.0	0.04

Source: Barniske, Federal Environment Agency, Berlin.

A newer and so far quite promising application of composting is in combination with at -source-separation of compostable fractions (-also called "bio-refuse" or "wet fraction") resulting in considerably lower heavy metal concentrations in the end product as compared to compost from conventionally operated plants.

With regard to the feasibility of refuse composting abroad, the situation is quite different, but there is probably a great deal of potential for increased application of composting in waste management in most countries.

Of the newer technologies, pyrolosis has a theoretical future potential similar to that of incineration at present, but for small plants. It achieves about the same volume reduction and can be combined with a number of different energy recovery systems (e.g. heat and power, gas, gas/liquid fuel). Also, pyrolosis is claimed to be less critical in view of environmental protection.

It is still too early to confirm or denounce the expected advantages of this new technology. The first plants now in trial operation in the Federal Republic of Germany will be visited and discussed in depth during the symposium. However, solid waste pyrolosis will certainly prove to be a sophisticated and costly technology.

Another new concept in municipal waste management is mechanical sorting. This technology is in a similar state of development to pyrolosis. The products aimed at are either recoverable materials such as paper and board, glass, metals, plastics etc., and possibly a compostable fraction or waste/refuse-derived-fuel (WDF, RDF), to be used as a substitute for or in combination with conventional solid fuels.

Mechanical processes are best used as units to be combined with other methods, for instance composting. Depending on waste composition, the achievable volume reduction is only between 30-50 per cent. A decisive prerequisite for application of this method in waste management is suffient demand for the products. A first plant of this type will be visited within the programme.

Mechanical sorting is expected to prove a useful, comparatively simple and quite flexibly applicable new element of resource recovery technology, which will not replace but may supplement existing methods in the future.

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COLLECTION AND TRANSPORT OF SOLID WASTE

Dr. Joachim Knoch

1. Intoduction

The following paper deals with the principal techniques for the colletion and transport of household and similar solid waste in the Federal Republic of Germany.

The technical status of refuse disposal is the result of 70 years experience. In the last 25 years, important innovations in the organisation and development of technical systems have resulted from:

1. Strict laws for the protection of the environment;

2. The demand to make work more humane;

3. Pressure to rationalize in order to reduce costs (increasing wage, energy and material costs);

4. Changes in the legal regulations concerning roads and vehicles;

5. The changed characteristics of waste matter itself.

When refuse disposal was first organised on a technical basis, it dealt mainly with combustible household waste (waste collection bins were called in the jargon of the day "ashbins", and the refuse disposal worker was known as the "ashman"). Today refuse disposal services have to collect and transport much larger amounts of waste. Above all, the most important characteristics of waste, as far as transport technology is concerned, are completely different.

While the volume of waste has increased, the weight per volume of waste is ever decreasing (when collecting in 240 litre and 1100 litre containers, it is ca. 0.1 - 02. t/m^3). While compressibility has increased, the waste itself is less easy to shape in terms of plasticity. This means that waste matter in collection vehicles has to be compressed using a relatively high amount of energy, in order to reach the permissible payload of the vehicle. In order to maximize the payload while maintaining a constant permissible maximum weight, the tare weight of the vehicle must be minimized. Therefore the construction of the vehicle must take up the smallest possible volume in relation to the compression unit.

An example here can be seen in the influence of plastic foams found in waste: while they have a very small weight per volume, they can only be compressed by using a great deal of energy (loading vehicle), and when decompressed (unloading the truck), take on almost the same original volume (spring-back-effect).

Refuse collection is the essential pre-requisite for the effective handling of waste. The tasks connected with the collection and transport of waste must, be solved first; treatment of waste is the second step; for example, waste treatment plants can only be correctly planned when the amount of waste is known. This is only possible through a perfect refuse collection system - questioning or similar methods cannot be used to assess these values.

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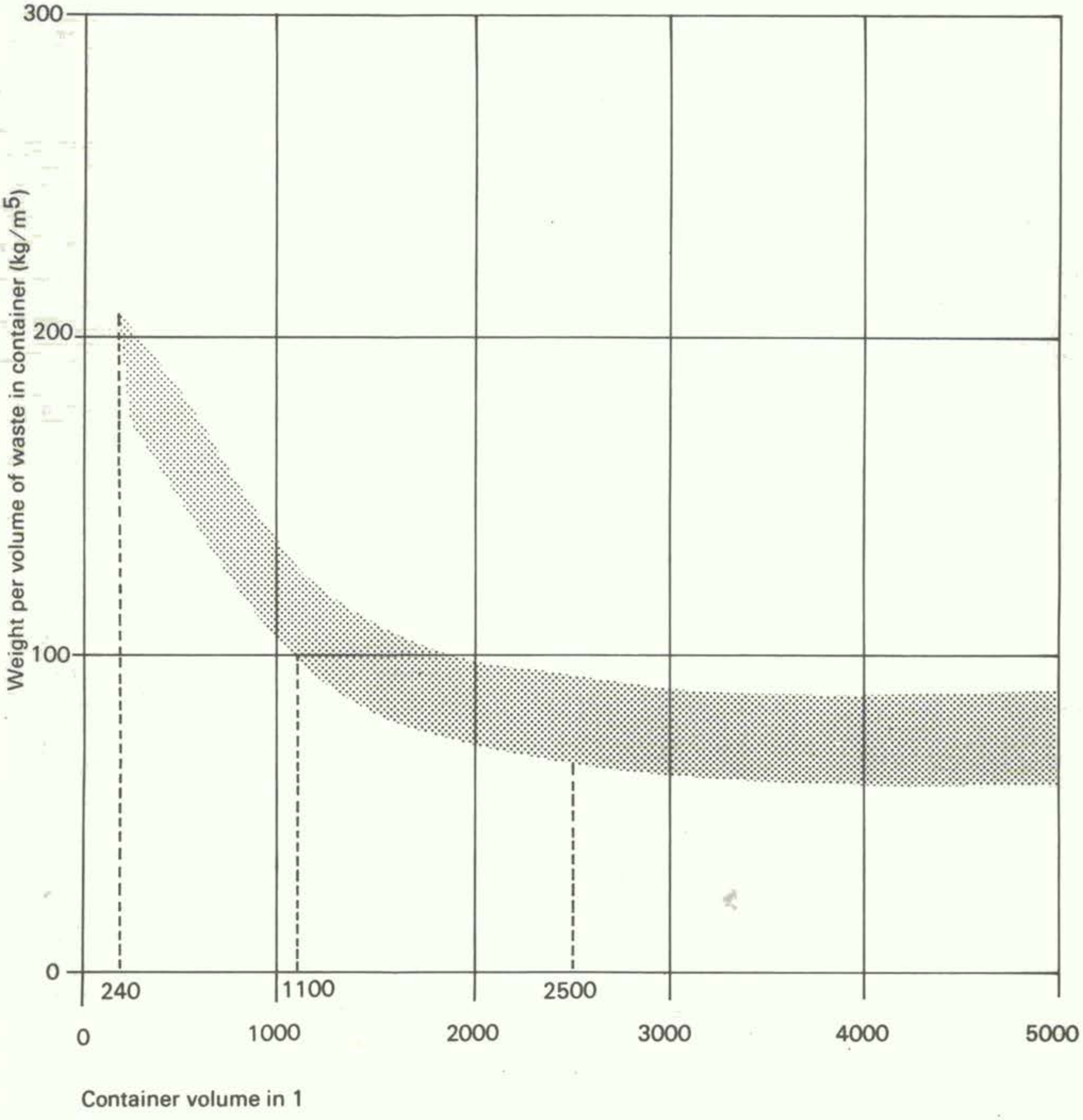
Fig. 1 Relationship between weight per volume and container volume



The techniques used in collection and transport are particularly important in connection with efforts to recycle waste. In order that recycling should not be impeded, refuse collection must be brought into the concept of waste re-cycling . When, for example, waste matter has to be sorted, then additional mixing and breaking up of the waste matter during collection and transport should be prevented. In order to achieve this, collection vehicles with pressing rather than mixing units should be used.

It may be necessary to sort the waste out at its place of origin. This will reduce the amount of technical procedure costs arising from recycling, but will make refuse collection more expensive.

Of particular importance to achieving a successful concept for recycling waste is the integration of collection, transportation and recycling - both technically and in terms of organization. It should be noted here that recycling waste has the manufacture of products as a goal, (e.g. paper, scrap, compost). These have to be marketed if they are not to become waste products themselves. These tasks have to be carried out in a commercially viable manner in order to achieve long-term success.

As a result of experience gained with technically complicated waste treatment plants, (e.g. combustion, decomposition), centrally placed plants in the Federal Republic of Germany are experiencing a trend which is putting the use of simple forms of technology to the test in decentralized plants, and can be regarded as a competitor of perfectionist, centralized technology.

Here it is possible that economic and ecological success will be achieved when a uniform concept for the collection, transport and treatment of waste matter is develped and used consistently. The most important aspect of this concept is adaption of technology to a changed task. It is also inevitable that the administrative area will have to be flexible in order to permit this (law, regulations, contracts and scales for charges).

2. Collection

Here, the aim is to register and collect all waste. Various technical systems are used for this purpose and consist for the main part of containers and vehicles with technical units adapted to the containers.

Emptying system: (or Collection the System)	Waste is collected in the system containers; these are emptied at regular periods of time into collection vehicle and put back in their places, ready to collect further refuse; the collected refuse is compressed in the collection vehicle.
Exchange system: (or Skip System)	Waste is collected in the system containers by the refuse collection; according to demand - or at regular periods of time - the containers are exchanged by the vehicle for empty containers; compression of waste does not occur, or it is carried out by stationary or mobile compression units at the exchange container.

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Disposal system: Waste is contained in disposable containers (generally sacks) which are collected, as waste; the compression of the waste material occurs in the collection vehicle.

The containers which are used to collect the waste and which are passed on to the refuse collection are of particular importance. The containers must generally fulfil the following conditions:

- they have to be practicable for the waste producer;
- they have to be strong enough to withstand the waste (chemical and mechanical strains);
- they have to be practicable for carrying out the refuse collection (management);
- maintenance-free (construction, material).

Experience in the Federal Republic of Germany has shown that all waste is collected only when the waste producer is given a container with a large enough volume to deal with the waste without it having to be reduced or pressed together. It would seem that collection using 4 waste bins each of 60 litres volume would be just as good as using one container of 240 litres volume. In fact, collection using a 240 litre container is more successful as a result of its geometry of space which allows larger (bulky) waste to be dealt with better than in 4 waste bins each of 60 litres in volume.

2.1 Containers

Emptying system

The following containers are used:

Round containers (bins, barrels) made of galvanized steel or plastic (generally of PE) with volumes of:

- 35 l and 50 l — with uniform lid shape for even tipping into the collection vehicle;

60 l, 90 l and 110 l — with a uniform lid shape for even tipping into the collection vehicle.

For 35/50 and 60/90/110 containers different tipping procedures are necessary. Emptying is more difficult when different container types are used together.

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Square-type containers made of galvanized steel, ungalvanized steel, aluminium or plastic with volumes of:

120 1 and 240 1	with uniform lid shape for even tipping into the collection vehicle;
1100 1	special tipping necessary;
2500 1 and 5000 1	special tipping necessary.

The containers with 120 1, 240 1 and 1100 1 can be emptied in one tipping which means the collection of waste with the aid of these three types of container, and with a uniform vehicle technology, can be carried out; (advantage: greater flexibility in route planning, exact adaptation of the container volume to the amount of refuse, rationalization when collecting waste and the maintenance of technical equipment such as the vehicle, tipper unit, containers etc.).

In order to make the work easier and to aid rationalization, the containers are generally equipped with rollers so that they can be moved with relative ease when they are completely full.

Tipping to empty the containers takes place generally at the rear of the vehicle. This means that containers have to be brought from their location to the place where the vehicle is stopped, either by carrying them, rolling them on the ground or by a process using the rollers mounted on the container.

In order to simplify matters (particularly to save on labour), the following systems have been developed for emptying containers:

Front-loader

For containers with a volume up to 4.5 mm^3; the vehicle drives up to the container; the container is raised using a fork device over the front of the vehicle, emptied into the collector from above and finally replaced back on the ground; the driver can observe the pick-up procedure; apart from the driver, no further employees are necessary.

Side-loader

For containers up to ca. 300 litres in volume; on the side of the vehicle a grab unit is mounted which can pick up the container, empty it into the vehicle, and replace it.

Which of these two systems best fulfil the requirements has not yet been finally determined.

The current trend in the Federal Republic of Germany, is as follows:

The use of containers - transportable on rollers - with a volume of 120 l, and 1100 litres (emptied with the aid of a tipping unit on the vehicle); use of containers with a volume of 2500 l to 5000 litre (emptied using a special tipping unit on the vehicle); by mounting the tipper on the rear of the vehicle, they can also be used for the collection of bulky refuse which can be loaded directly (this is not possible with front-loaders).

Application

The emptying system is mainly used in order to collect refuse which occurs regularly in many different places (for example, residential areas); the waste is generally compressible.

Exchange system

Containers of the most varying types of construction and size (volume) are used here; generally they are made of steel.

The volume of the containers is between 5 m^3 and 40 m^3. A complete list of all systems used is not possible; in principle the following divisions can be made:

Filling the container

Containers with stationary or mobile compression units for waste;

Containers without compression units.

Container handling

Lifting up/setting down containers in a horizontal position (moveable with chains on swinging arms); Picking up/setting down of containers on an inclined plane (sliding onto a cradle which can be tipped).

Application

The exchange system can generally be used when large amounts of waste occur over short periods of time, or when waste is not compressible (e.g. building site rubble). The exchange system is effective particularly when collecting during peak periods, at events or when waste is seasonably defined. For some time now, with the aid of the exchange system, in the Federal Republic of Germany an attempt has been made to separate waste, e.g. using containers for glass or paper.

Disposal system

Here sacks are used generally as containers; these are made of paper, plastic or paper and plastic.

Experience has shown that the use of sacks can present problems because:

- they can easily be destroyed by sharp or pointed parts in the waste;
- the danger of injury for the refuse disposal worker is relatively large;
- the physiological requirements from the refuse disposal worker are very unfavourable (all waste that has to be collected has to be lifted and carried by the employee);
- relatively large amounts of "bulky" refuse result (the refuse which does not fit into the sacks);
- a relatively large amount of raw material used as sacking has to be discarded as refuse.

In its favour is:

- the very small initial investment required (vehicle, no containers).

Application

In the Federal Republic of Germany, refuse collection with sacks is only carried out in individual cases.

Location of the containers

The location of the containers must be so designed that:

- the containers can be filled in safety;
- the containers - in the emptying system - can be moved safely and if possible on level ground (free of steps), or can be carried over this ground;
- the containers - in the case of the exchange system - can be reached by the vehicle directly - with a clearly visible access;
- the containers, where possible, should stand in the shade;
- cleaning and care should be easy to carry out.

2.2 Vehicles

Vehicles used for collection, together with the containers used, make up a uniform system for the collection of waste. For lifting and emptying containers, special equipment is required which has to be firmly mounted onto the vehicle; in the case of exchange containers, according to the system of containers used, the suitable technical equipment (lifting gear) has to be available on the vehicle. It is not possible to combine at will vehicles with a fixed tipping/lifting gear and containers.

The vehicles used can be placed into the following construction categories:

<u>For the emptying system</u>

Chassis with drive unit;
Collector with compressing equipment for the waste, tipper.

<u>For the exchange system</u>

Chassis with drive unit;

Lifting equipment for picking up and settling down exchange containers.

<u>For the disposal system</u>

Chassis with drive unit;
Collector with compressing unit for the waste, (practically the same vehicle as in the emptying system, but without tipping gear).

In order to carry out the collection of refuse in the best way possible, the vehicle has to fulfil contradictory requirements:

1. For collections - mainly in urban areas - a small and manoeuverable vehicle is required; payload ca. 6 t (with a total weight ca. 16 t with 2 axles).

2. For transport to the treatment plant a vehicle with the highest possible payload is needed which does not have to be so manoeuverable; payload 17 t (total weight ca. 38 t with 5 axles).

A 3 axle vehicle with a payload of ca. 9 t can be regarded as a compromise which needs more time when collecting than a 2 axle vehicle, but which, however, is better in terms of transportation. The use of transferable units - from 2 axle to 5 axle vehicles - is considered the most suitable solution at present.

The development of a collection vehicle with an exchangeable collector used as an exchange container would be consistent with this. This would optimize collection with a manoeuverable vehicle, allow transference onto a vehicle with a higher carrying capacity and allow intermediate storage of empty and full containers. Prior knowledge about the waste concerned is essential in the choice of vehicle. In relation to the size of the collectors, the weight per volume of the waste is ca. 0.1 - 0.2 t/m^3, with a mid-range of ca. 0.15 t/m^3. The compression performance which can be reached using the body mounting of the collection vehicle is ca. E = 3.5 - 4.5 with a mid-range of ca. 4.0 (that is the relationship of the weight per volume before and after compression). At a given payload, it is possible to calculate the necessary volume of the body mounting of the collection vehicle (VA) (Collector):

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payload: 6 t VA = 6/4.0 x 0.15 = 10 m^3

payload: 9 t VA = 9/4.0 x 0.15 = 15 m^3

There is a relationship between the compression capacity and payload as, on increasing the compression capacity, the energy needed from the equipment increases, the tare of the vehicle increases and the payload thus decreases. Furthermore, the distribution of the axles has to be taken into consideration. In the Federal Republic of Germany, the maximum permitted axle weights have been laid down and may not be exceeded. When, as a result of the vehicle's construction, the rear axle is loaded to its full permissible weight when only partly filled with waste, no further loading may be carried out. That vehicle then has a "reduced payload". Such vehicles should not be used.

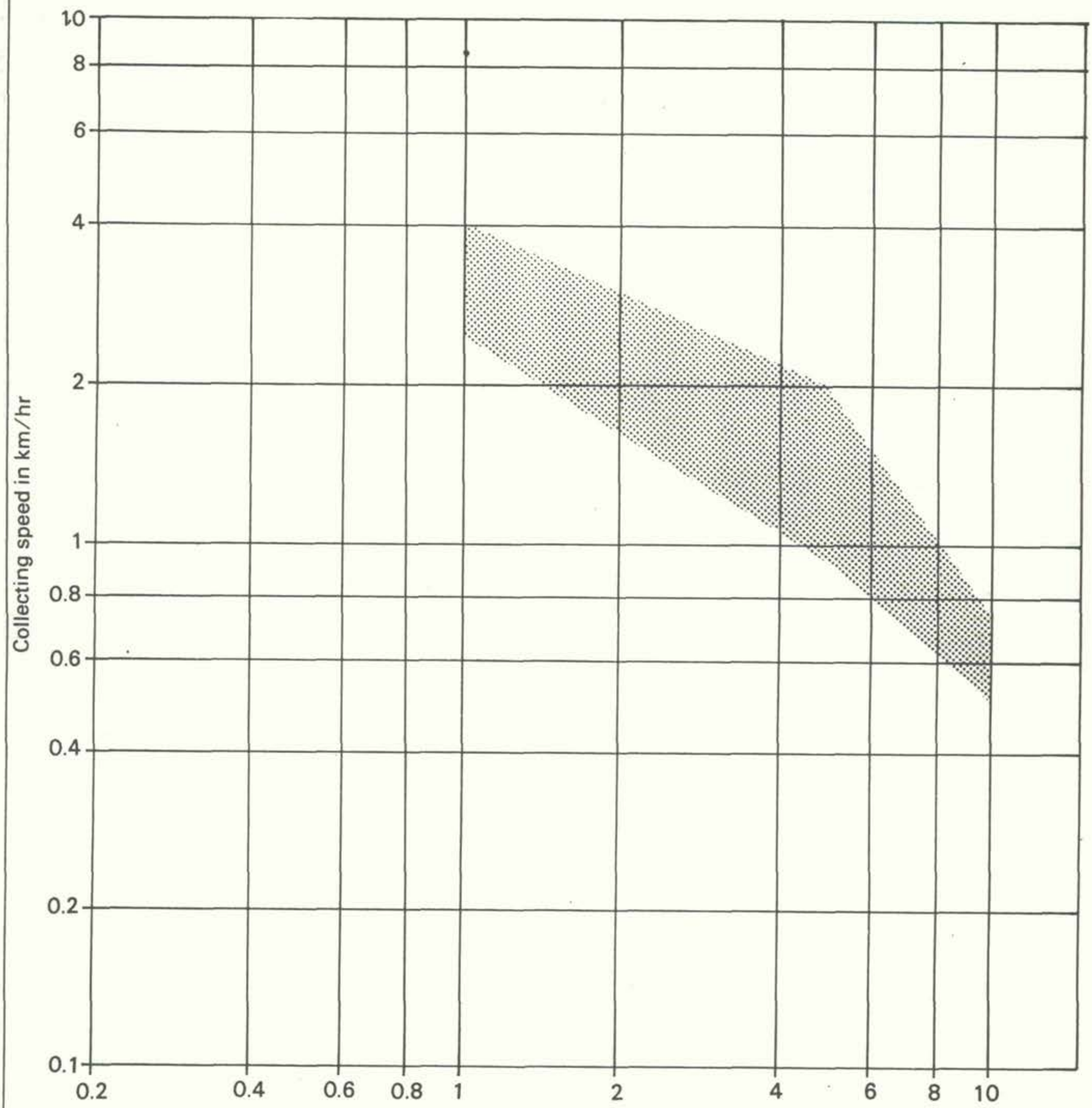
The technical information about the collection vehicles is produced by the vehicle manufacturer. The use of a particular type of vehicle for a job can only be decided by test, like e.g. driving behaviour and manoeuverability during pre-set traffic and topographical situations; or the compressibility of waste etc.

3. District planning

The planning and organisation of refuse collection is only possible when the amount of the total work can be described (the amount of waste according to time and type) as well as when it is possible to divide up the area where waste management is to be carried out (town, region). A division into districts is absolutely essential in order to make easily comprehensible organisation units (technical equipment, staff). This permits a team to work in a particular district and to obtain the necessary knowledge of the area. The size of the district has to be calculated from the type of container system, the type of vehicle, the density of population as well as the collection and transport vehicles. It is not possible to "calculate" in a mathematical sense, like an equation, these factors and their relationship. The specific performance of the collection vehicle has to be established empirically (O speed km/hr, O collected waste t/hr or t/km in relation to the container system). In order to achieve this, test areas must be established. This can be based on experience from another area and with different requirements and conditions, but which is still suitable to serve as a base for the conception of other tests. What is important is that the data and experience used, as a result of refuse collection in these test districts, improve the tests and can be examined as to their suitability for other regions/districts.

The following data could be used in order to establish a test district. It contains average values resulting from a series of running statistics kept by the company Edelhoff Städtereinigung (Town cleaning) GmbH & Co.:

Fig. 2 Relationship between stops and collecting speed



Stops per 100 m of collecting distance

Fig. 3 Relationship between weight of waste and collecting speed

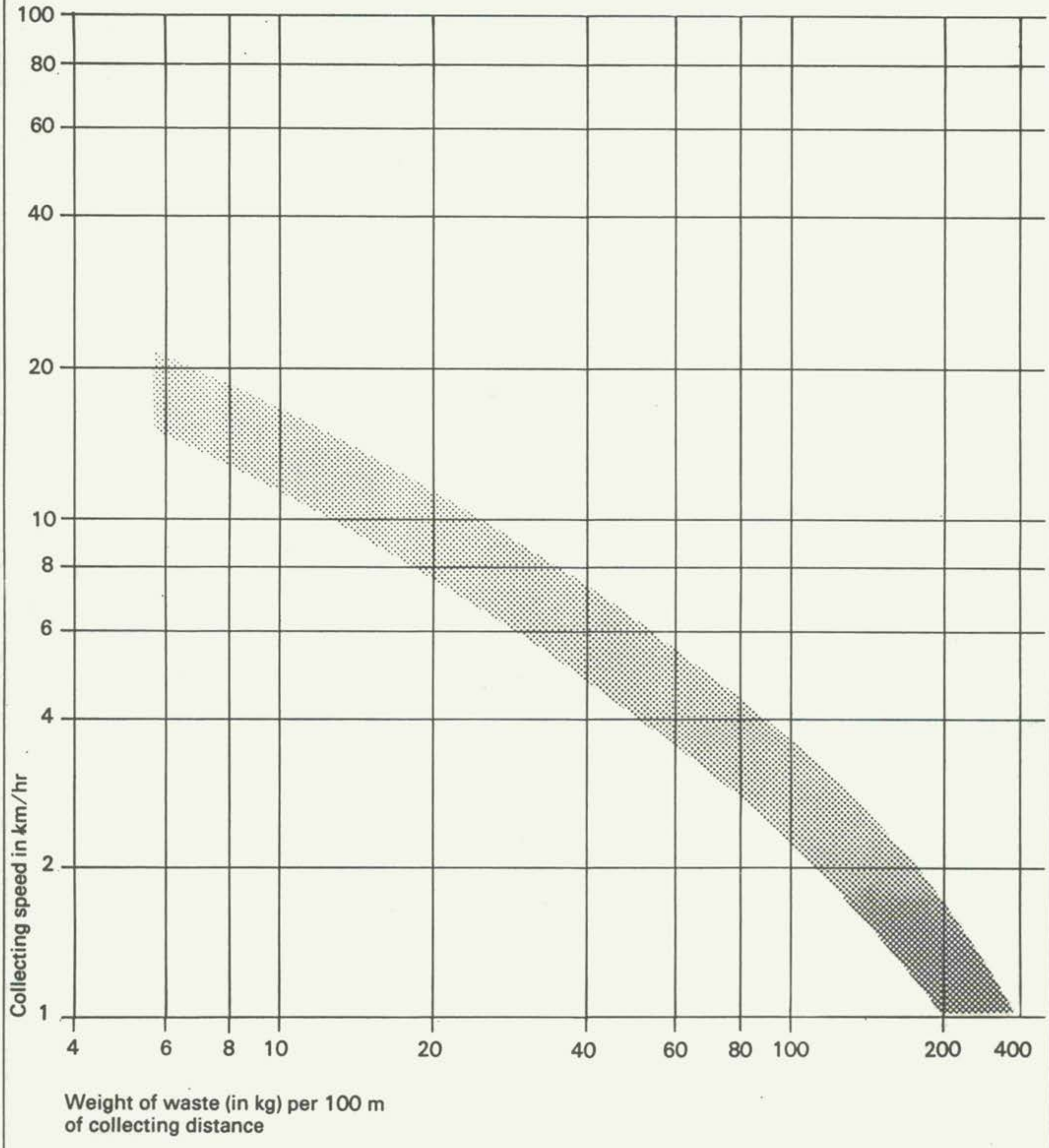
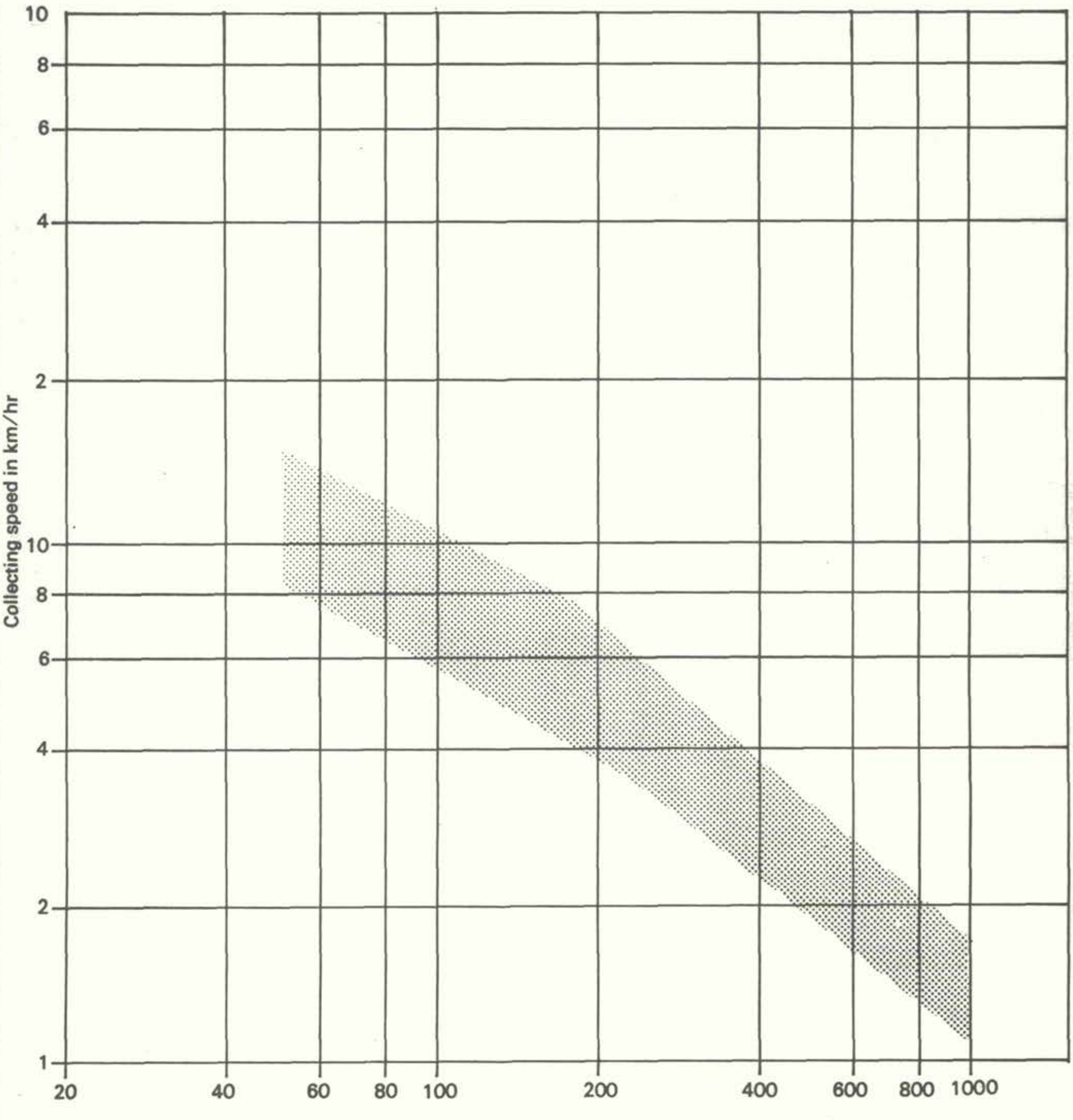


Fig. 4 Relationship between container volume and collecting speed



Container volume (in 1) per 100
of collecting distance

Fig. 5 Relationship between weight of waste and collecting rate

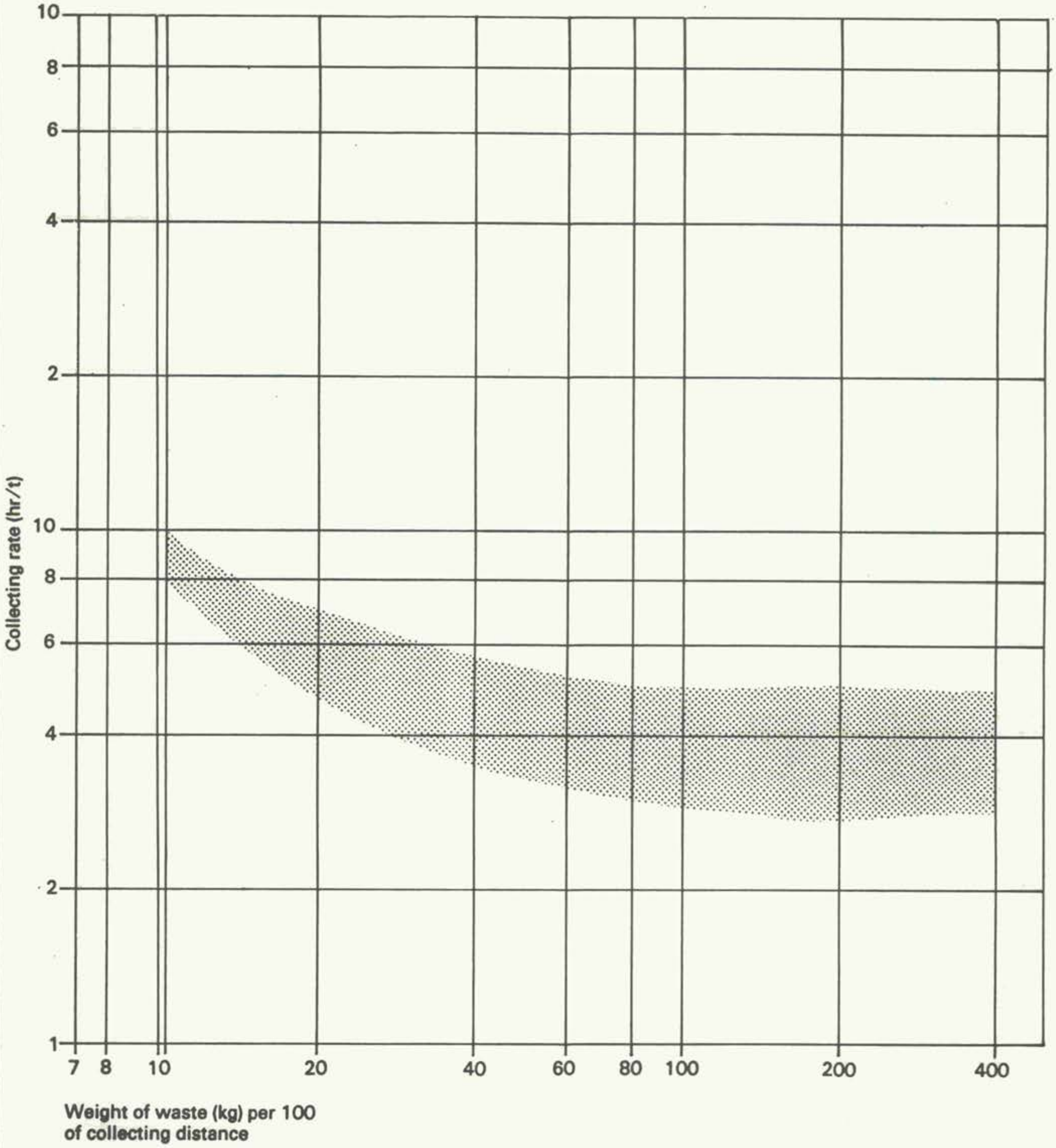
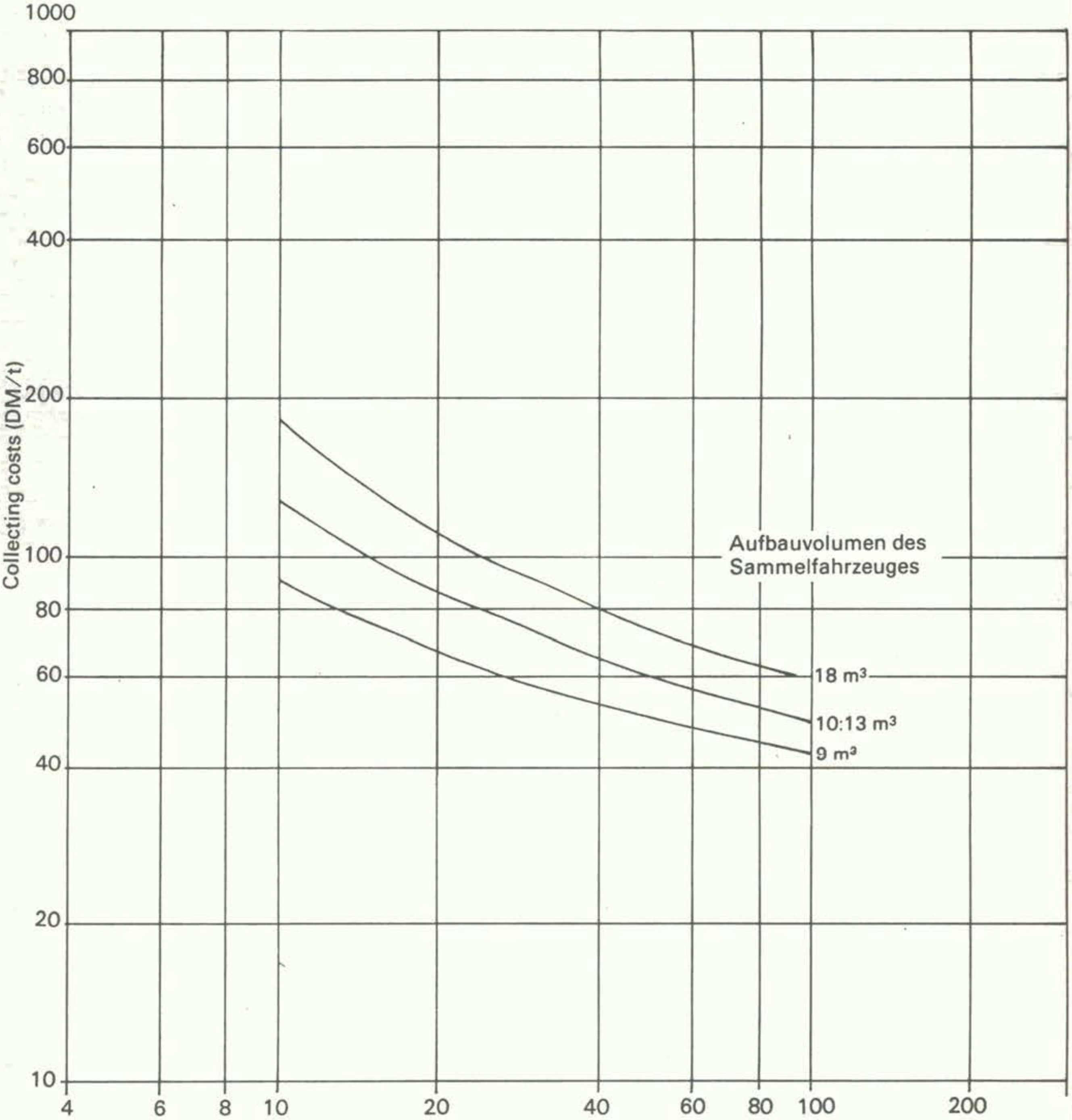


Fig. 6 Relationship between size of collecting vehicle and collecting costs



Body volume of collecting vehicle

Weight of waste (kg) per 100 m of collecting distance

1.	population per district:	ca. 9000 inhabitants
2.	refuse per inhabitant:	ca. 7 kg/person/week
3.	container volume per person:	ca. 40 l/week
4.	collection cycle:	1 x week
5.	emptying of collection vehicle per day:	2
6.	payload of collection vehicle:	6 t
7.	working days per week:	5

In the following pictures, the connection between collection capacity and collection technique and cost is shown, obtained as a result of calculations. With the help of this experience, it is possible to plan out a test district.

- One restriction which must be borne in mind in this procedure is that this experience has been obtained through observation of a perfectly functioning example of refuse collection in the Federal Republic of Germany.

Should one, at the very beginning, want to avoid these very high expenses, it is conceivable that the following concept could be used:

At central positions, exchange containers are placed to which people bring their waste. This means that the people concerned have to forego the comfort of having waste collected by the refuse collection service. However, the advantage of this system can be seen in the very small initial investment required, and that it can be put into practice relatively quickly. It can be adapted to demand by changing the volume of the container, and by the frequency of collection. In order to ascertain the type of dimensions involved, an estimation of the amount of waste must be made, as well as the furthest acceptable distance between the exchange container and the area of residence. Exact observation would show whether this distance was too great and needed to be reduced (this cannot be corrected by raising the frequency of collection). The system has one serious disadvantage. In general, the permissible payload cannot be reached when the exchange container is loosely filled. It might therefore be more effective if large volume emptying containers are used instead of the exchange containers. These can be emptied into the collection vehicle and the waste could then be compressed.

In using emptying containers with a volume of 5 m^3 it would be possible to place them at a short distance from the area of residence. As opposed to the use of exchange containers, more containers are used. The location of the containers must be accessible to the collection vehicle and kept clean.

4. Transshipment

Transshipment is a good idea when many small amounts can be combined into one single large quantity, and when the transport costs for direct transportation are less than for small amounts. Here, driving time (dependant on the road network, road condition and traffic situation) as well as payload have to be taken into consideration. It could be more suitable e.g. when a collection vehicle with a 6 t payload travels 3 x daily to the treatment plant (depot), than transshiping into a transport vehicle with a 18 t payload. The transshipment of waste in stationary plants in the Federal Republic of Germany is practiced mainly because:

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1. The treatment plants have been centralized, giving transport routes of up to 100 kms;

2. Vehicle technology does not at the moment allow for mobile transference units, e.g. for exchangable collectors of the collection vehicle.

Although this technology, both for vehicle and collection, is urgently required, its development has been hindered by the operation of stationary transshipment plants. The aim in planning a transshipment plant should be:

1. Quick processing (emptying) of the collection vehicle;

2. Transport vehicles with a higher payload and simpler vehicle technology;

3. Loading the transport vehicles either directly from a collection vehicle (funnel, slide methods), or with loaders on rollers or something similar;

4. The use of normal trade equipment which can be exchanged, repaired and is reliable;

5. The adaptability of the plant to changed loads (organisation, technology).

As delivery of refuse does not run synchronously to its being transported away, an interim stage has to be incorporated. This storage capacity must be generous in size so that amounts during peak periods, as well as operational breakdowns, repairs etc. can be dealt with without delay, when emptying collection vehicles. The collection and transshipment of waste can be integrated when the same technology is used for collection and transport. This then means that vehicles and containers are interchangeable. This, in turn, means a reduction in investment, simplification of maintenance, increased operational reliability and better organisation (technical equipment, maintenance and staff).

The use of compressing equipment with hydraulic presses and specially designed enclosed containers for this, demands equipment expensive in terms of its construction, its machine technology and its control units. Because of the expensive technology and the complicated organisation and maintenance needed, such units tend not to be so reliable in operation. The payload of the transport vehicle is greatly reduced by the heavy "pressing container". On the whole, the technology of transshipment plants has come under criticism because, in spite of the considerably higher investment costs and greater expense, no better results have been achieved than in transshipment plants using normal trade equipment and with a large storage capacity. Furthermore, these plants are not flexible enough to be able to adapt to changed requirements.

In this connection, transshipment plants, for example, could carry out simple sorting of waste. However, this would not be possible in the case of technically highly complicated plants.

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Evaluation of experience:

Operating a transshipment plant can be effective when the distance between treatment plants lies between ca. 30 - 50 kms.

The cost of transshipment is around DM 15 - 30 per tonne. The relationship between transport costs and distance can be seen in the pictures.

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Fig. 7 Relationship between transport distance and time required

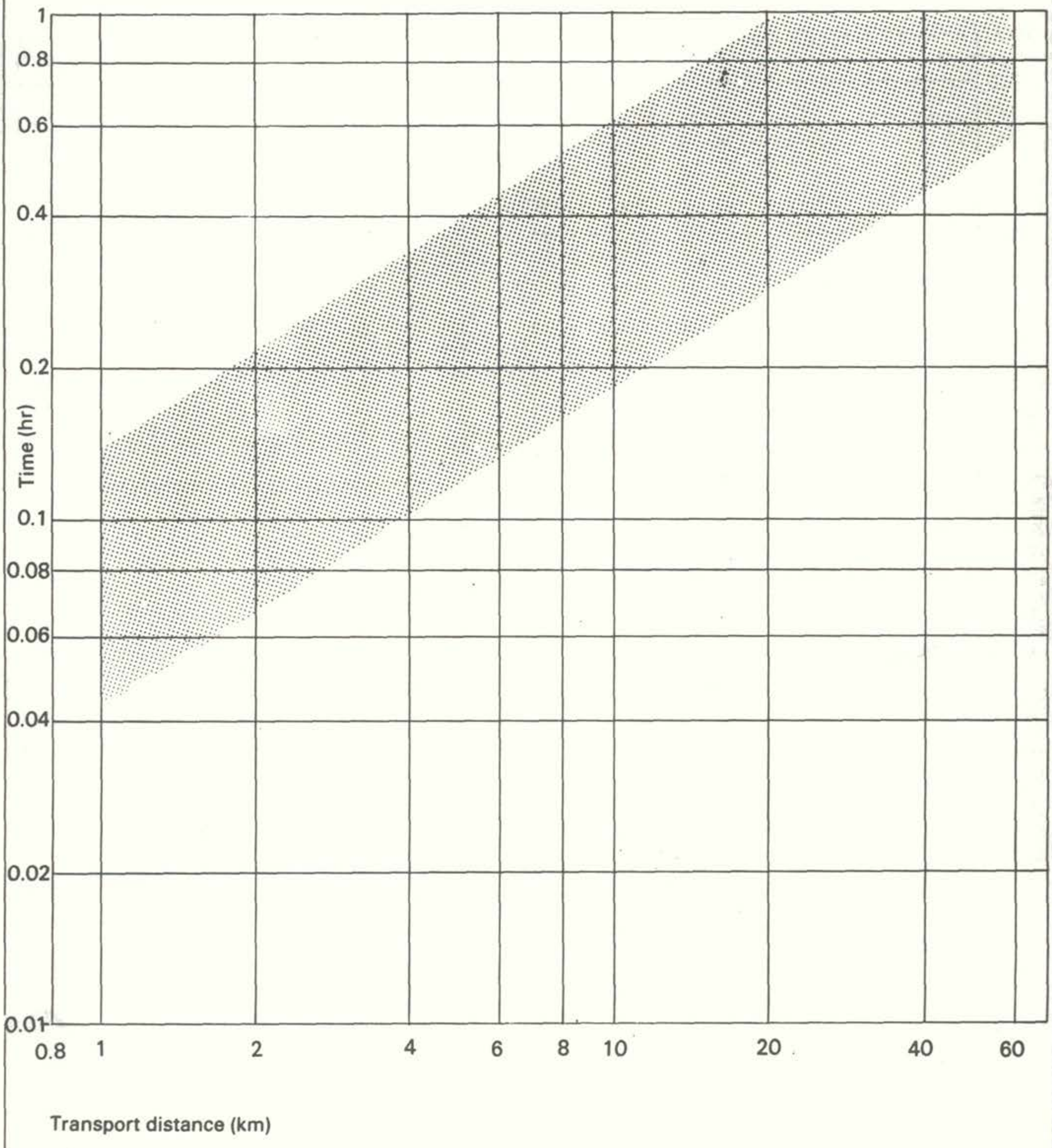
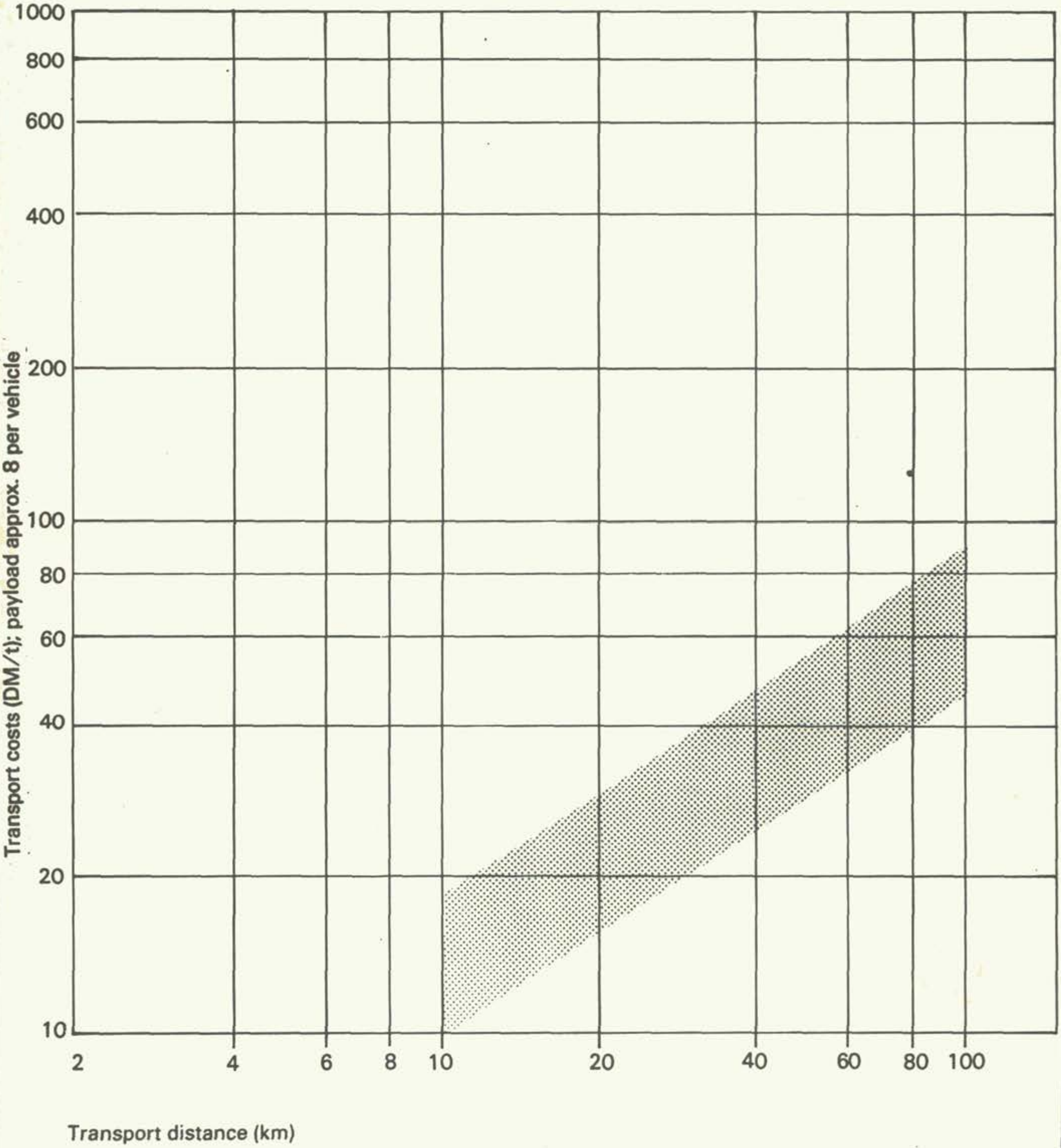
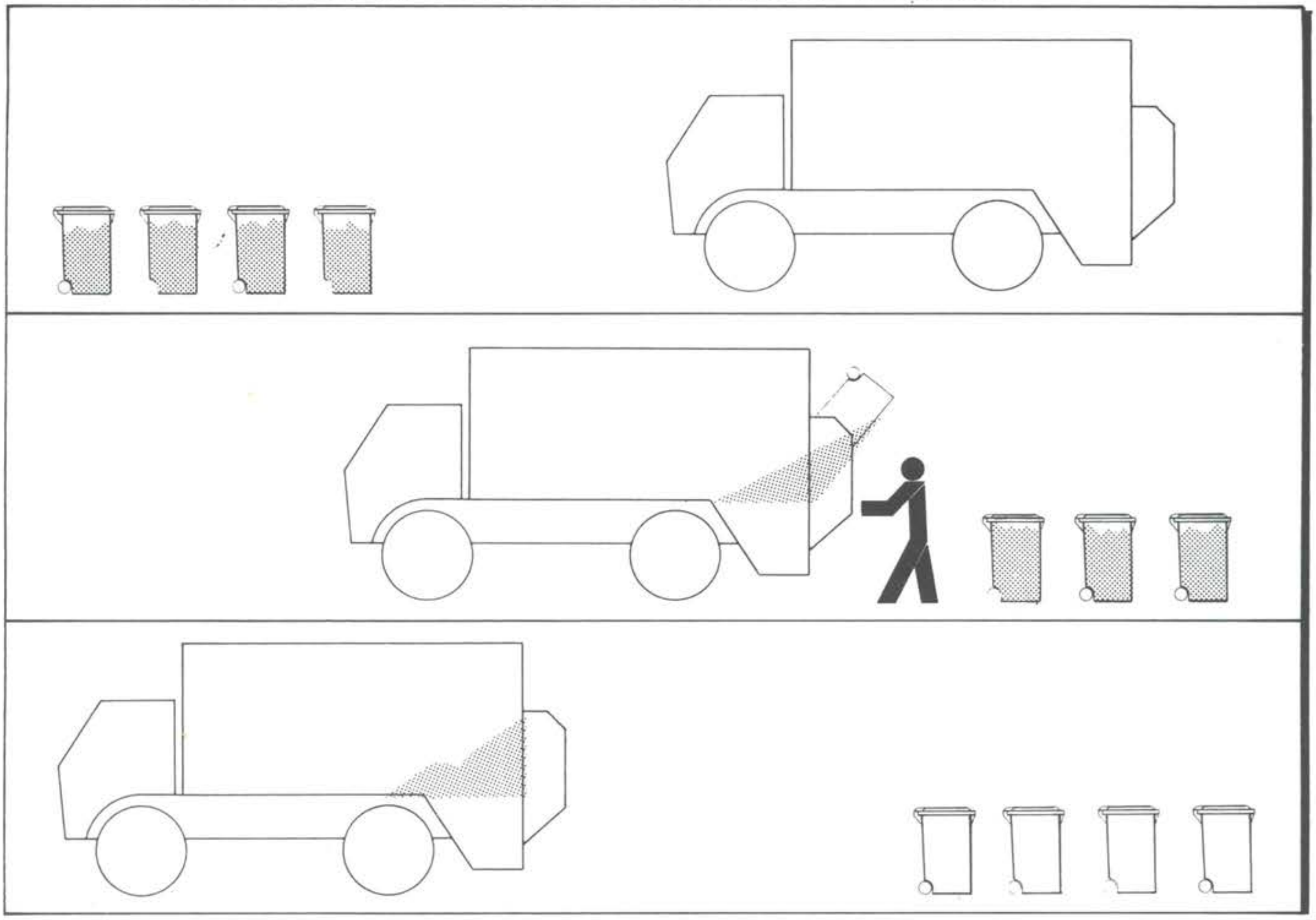


Fig. 8 Relationship between transport distance and transport costs

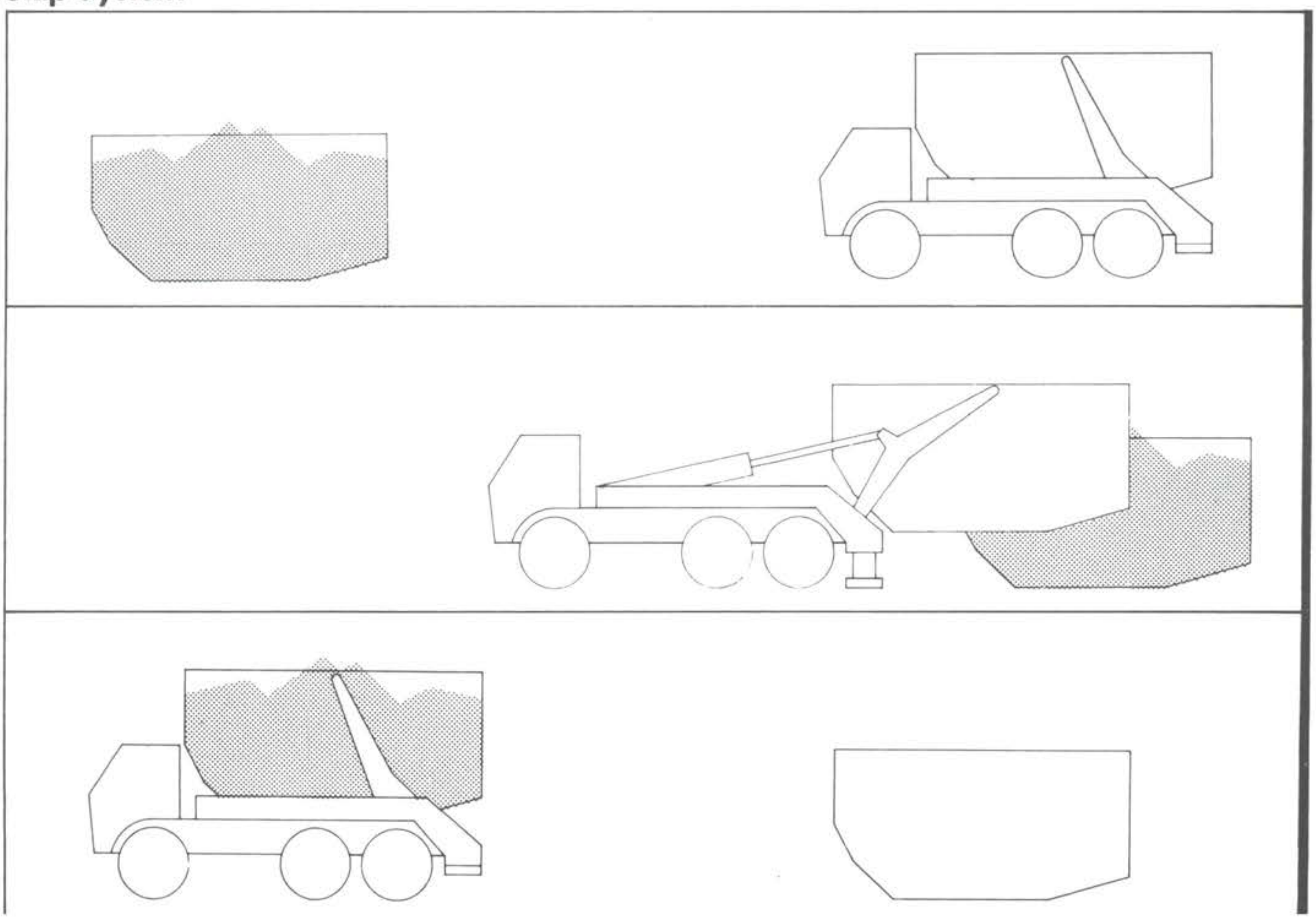


Annex

Example of a modern solid waste collection system of a private company operation in Nordrhein-Westfalen, Federal Republic of Germany.



Skip System



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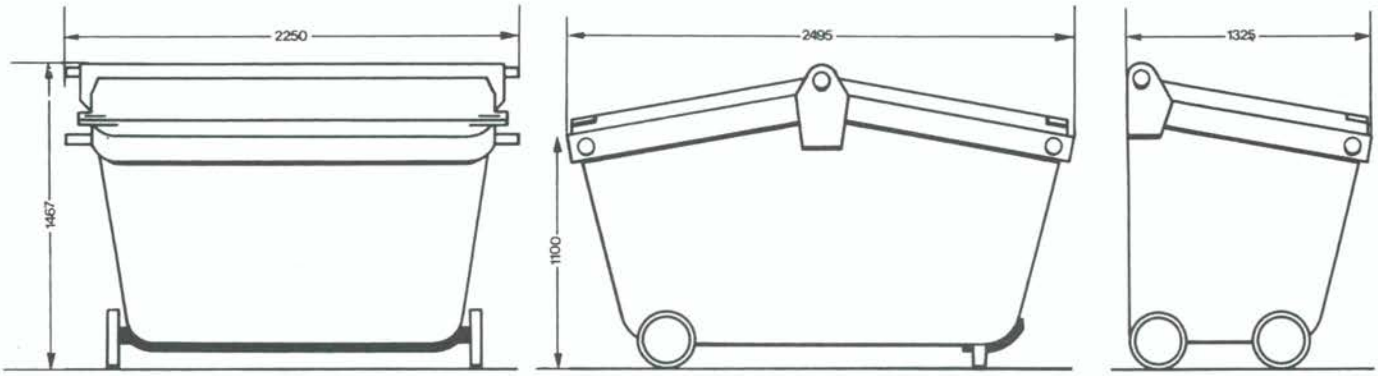
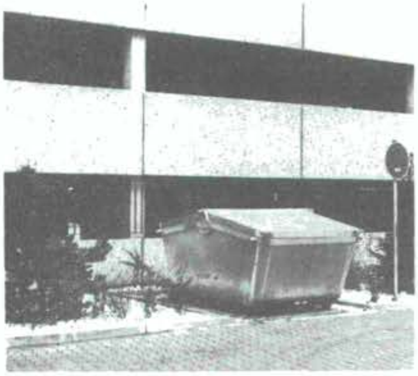
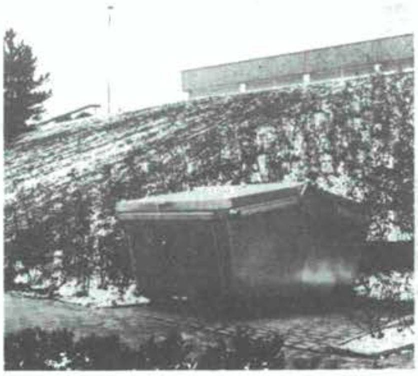


The MGB 2500/ 5000 in operation





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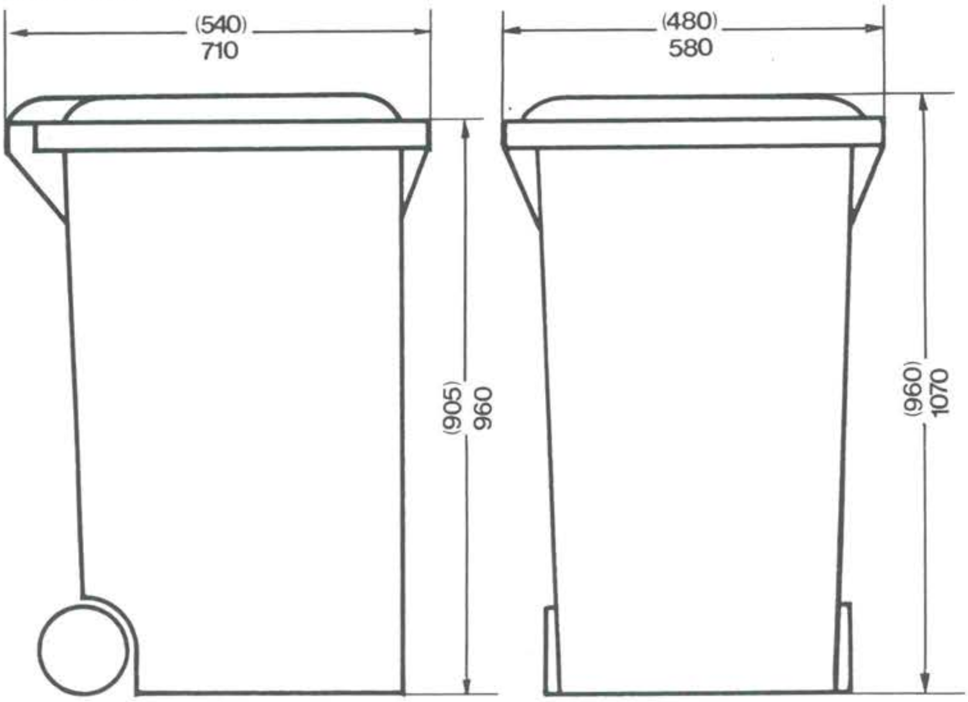
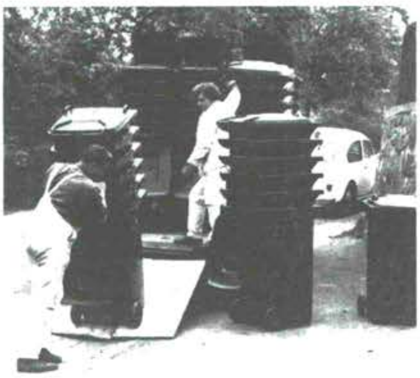
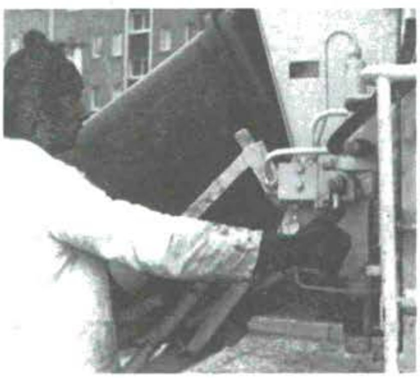
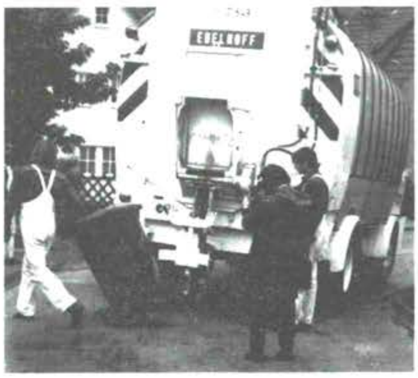
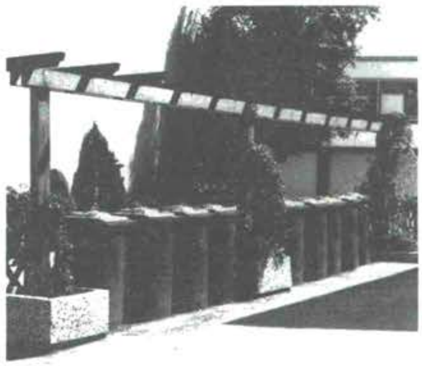
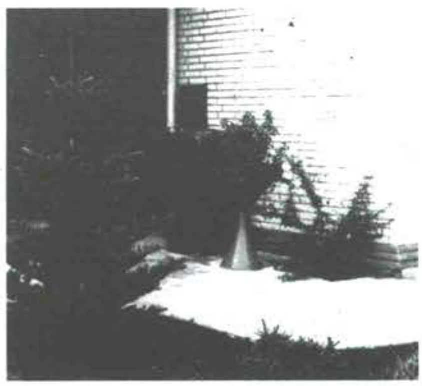


The MGB 120/240 in operation





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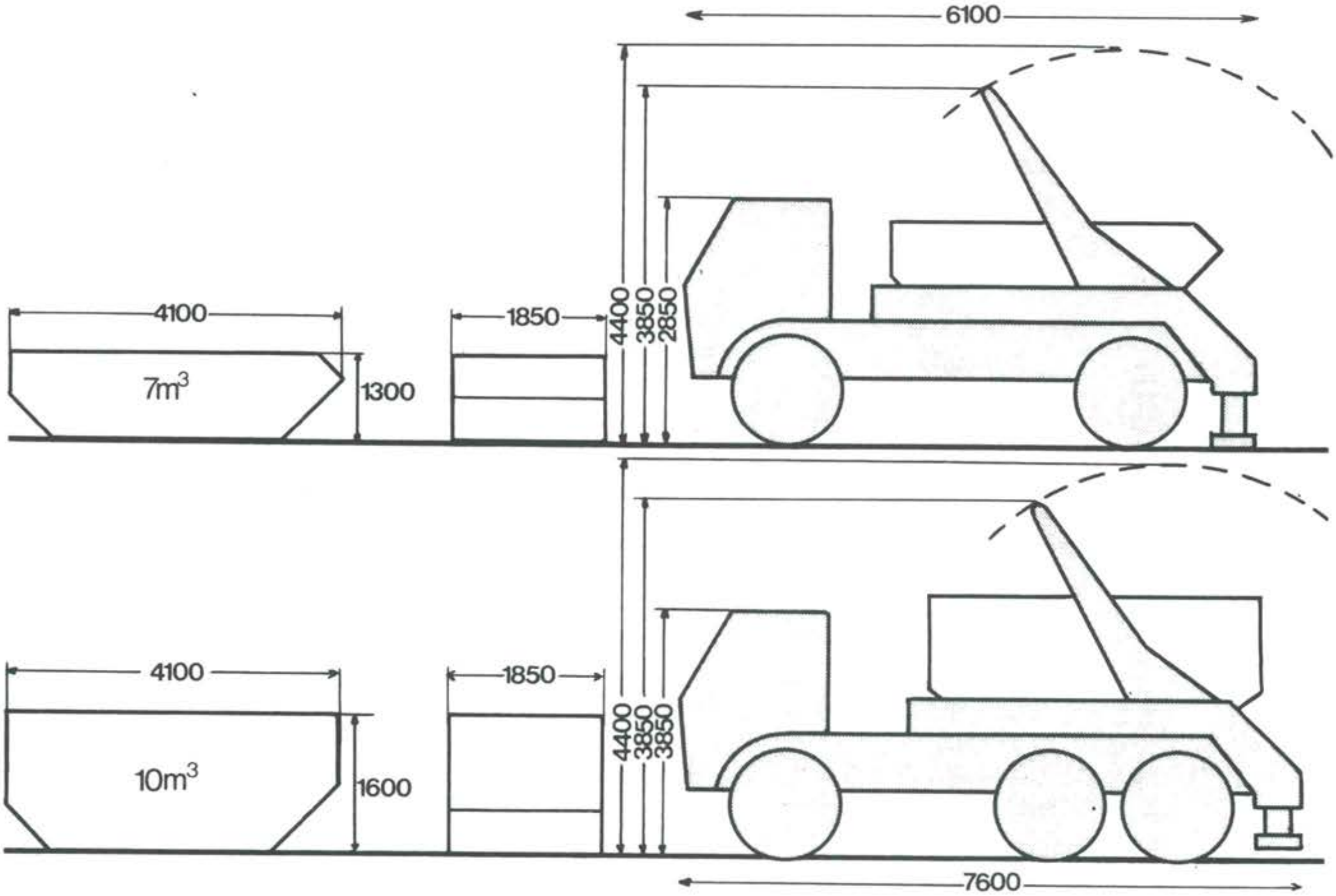
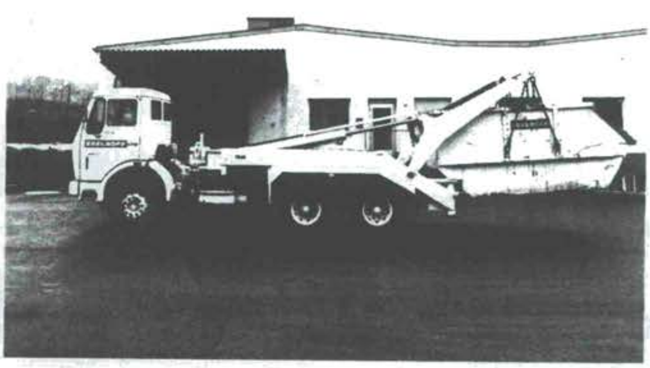
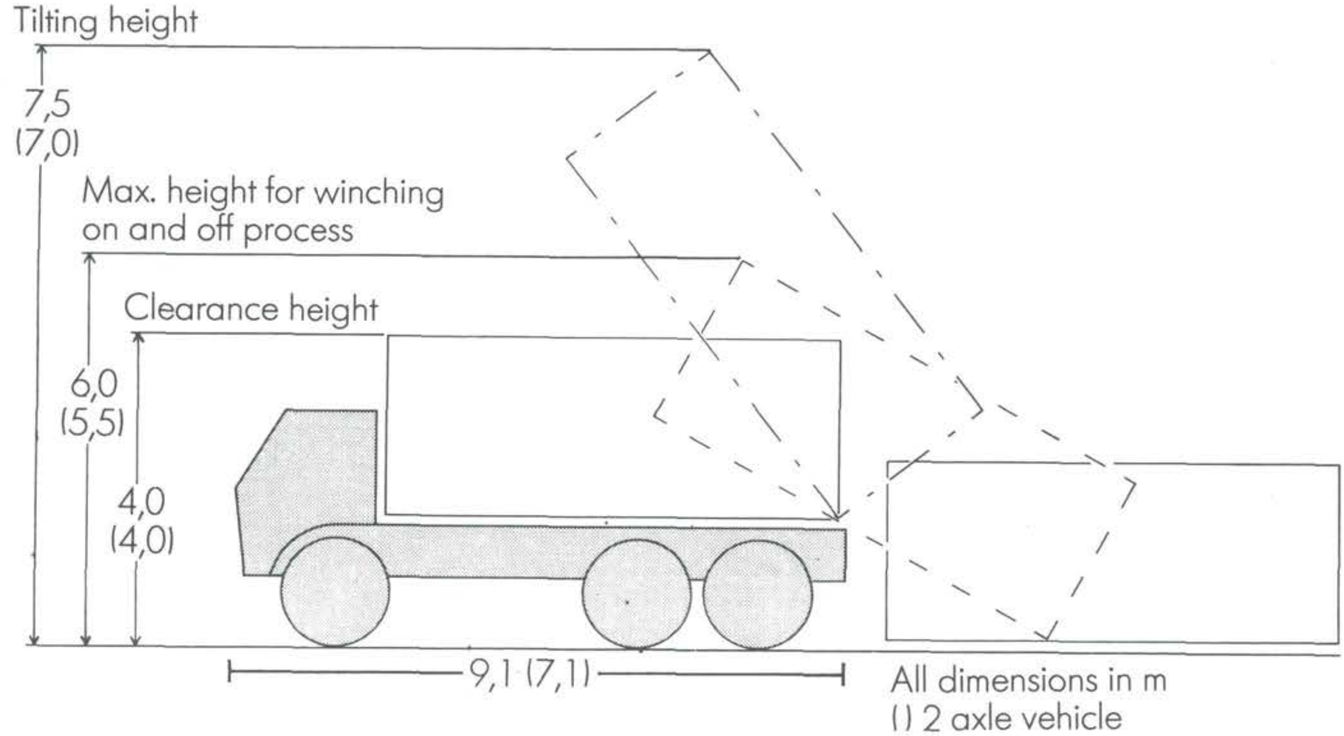
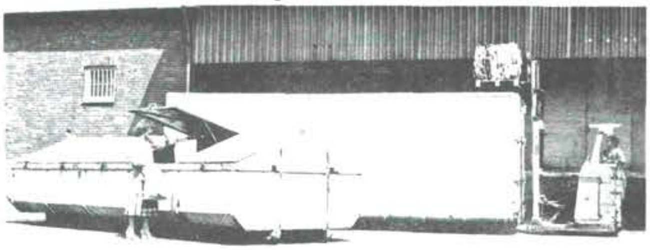


MGB 7 and 10 in operation





MGB 10 – 40 in operation



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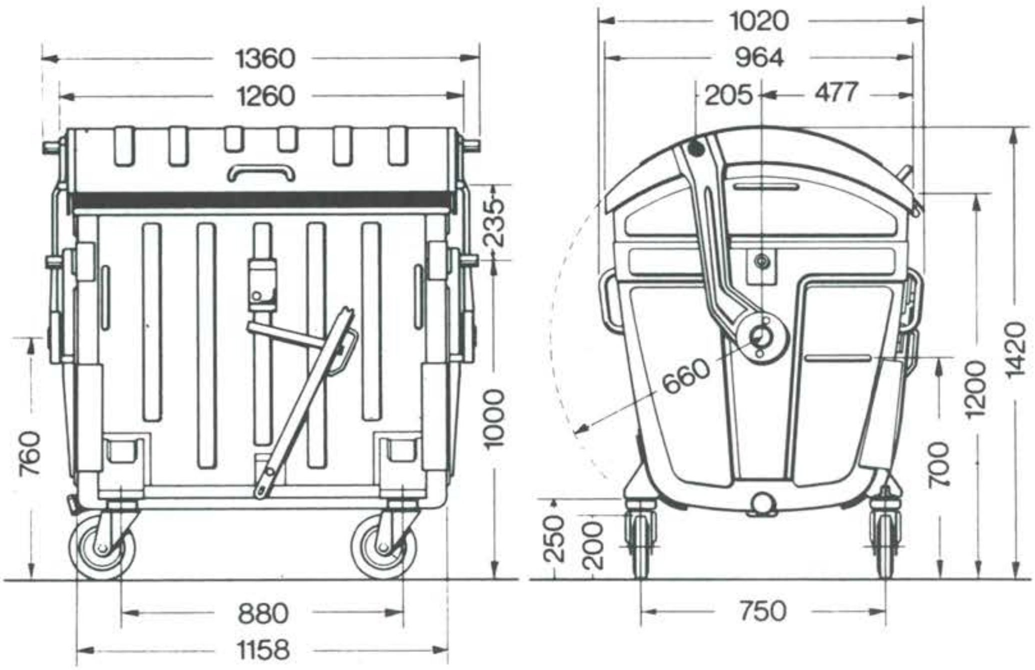
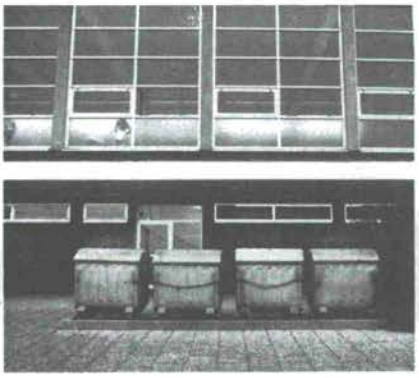
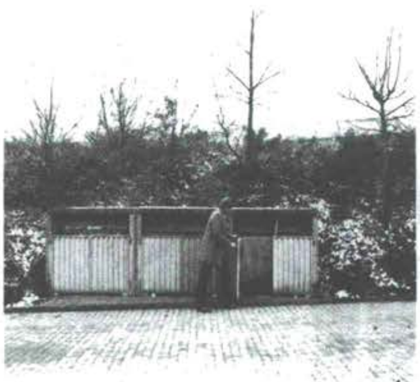


The MGB 1100 in operation









MATERIALS RECOVERY AND RECYCLING IN BRAZIL

Professor Luiz Edmundo H.B. Da Costa Leite

I. INTRODUCTION

Materials recovery and recycling is becoming a matter of nationwide concern, despite the abundance of Brazil's own resources. This concern is due to the ever growing and uncontrolled consumption of these resources and to the need to reduce energy consumption in any way possible. The world oil crisis has deeply affected Brazil.

At present, recycling of materials in Brazil is being encouraged by the Ministry of Industry and Commerce, through the Industrial Development Council. This council has just made public a preliminary study on recycling entitled "Recycling and Recovery of Materials" which analyses the main cycles of generation and reuse of secondary raw materials and the market potential of these materials.

The report deals mainly with minerals and urban waste. It suggests the need for studies aiming at development of a nationwide program of residue recovery.

Materials most suitable for recycling were identified as ferrous and non-ferrous metals (aluminium, copper, lead and zinc), paper, plastic, rubber and glass.

These materials have traditionally been recycled on a limited scale it being possible to increase the levels of recovery as is shown in Fig. 1, where one can find the amounts that are being processed today, a projection for 1987 and the amounts that are considered to be achievable with improved recovery practices.

The Ministry of Industry and Commerce is thus engaged in the development of technologies and marketing techniques so as to increase the activities of the recycling industry as a whole. This effort will result in direct benefits to the industry and to the consumers. There will also be a reduction in energy consumption due to the fact that in the industrial process, less energy is needed when secondary materials are used instead of virgin raw materials.

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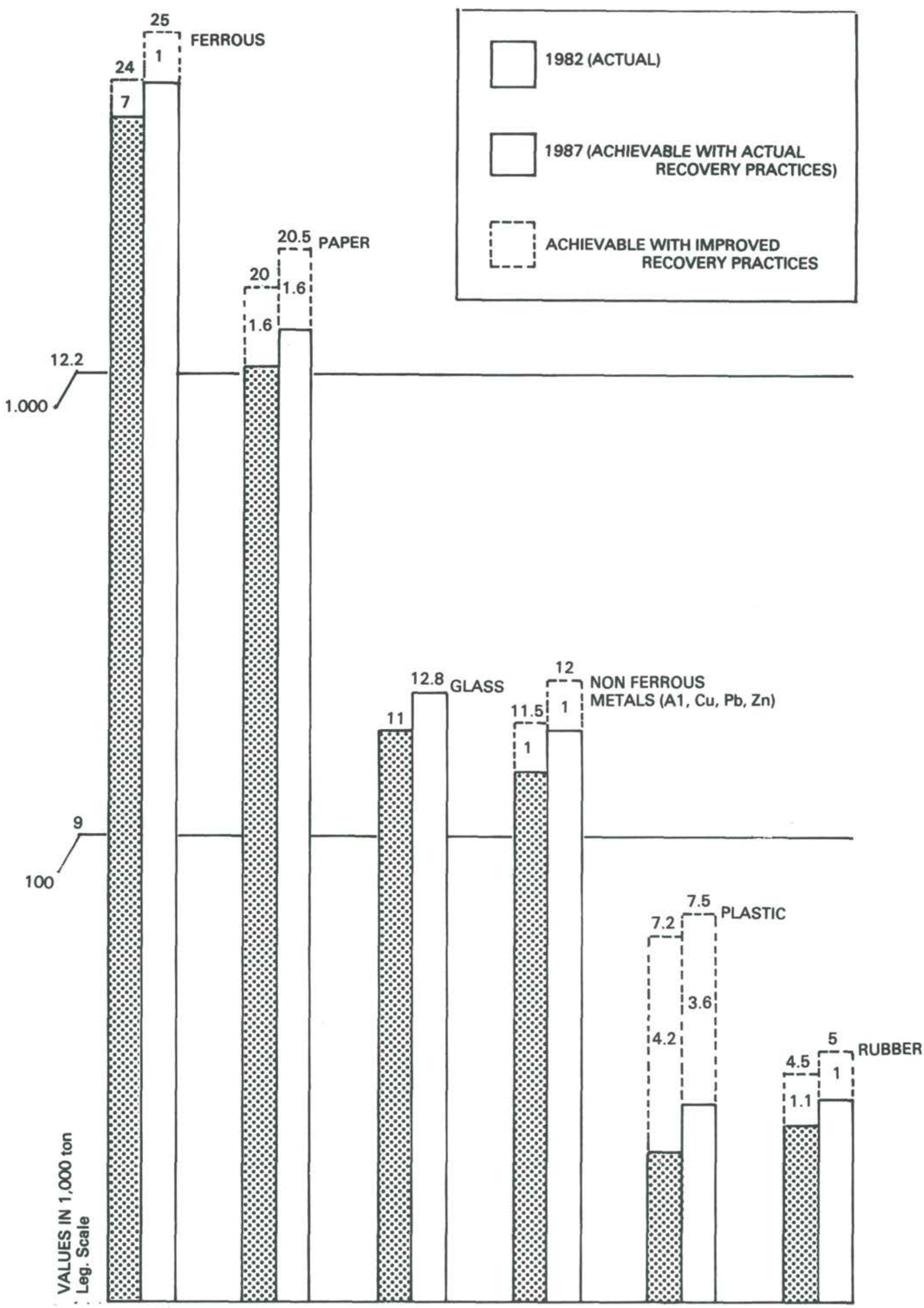
FIG. 1 RECOVERY LEVELS — ACTUAL; PROJECTED ACHIEVABLE



REFERENCE: SANIPLAN S/C — "PROPOSTA PARA O ESTUDO DO APROVEITAMENTO RACIONAL DOC RESIDUOS URBANOS INDUSTRIAIS A MINERAIS" — RIO DE JANEIRO, 1983

Recycling levels in Brazil are quite low: copper 24 per cent; aluminium 12 per cent; zinc 15 per cent; lead 47 per cent; iron and steel 27 per cent and paper 30 per cent. An increase of 50 per cent in the present level of recycling of paper could save energy equivalent to 2,300,000 barrels of crude oil per year.

This paper deals basically with recycled materials from municipal solid waste. The growth in solid waste generation has been increasing, the product packaging components of municipal wastes have more than doubled since the early 1950's. Use of discardable containers has become common practice. Population growth versus solid waste generation is shown in fig. 2.

High rates of solid waste production are a consequence of high rates of virgin raw material extraction, processing and fabrication - the most significant sources of energy consumption and environmental damages.

Though slowed during these last couple of years, due to economic recession, waste generation rates in Brazil are projected to grow substantially once the economy recovers.

This paper looks at composting as a recycling process, because it deals with organic matter, resulting from food processing, cooking procedures, garden trimmings etc., used to generate a "humus" type material utilized in agriculture to grow food again.

Also, during the composting operation, materials not suitable for the process such as plastics, metals and glass are sorted out and recovered for recycling.

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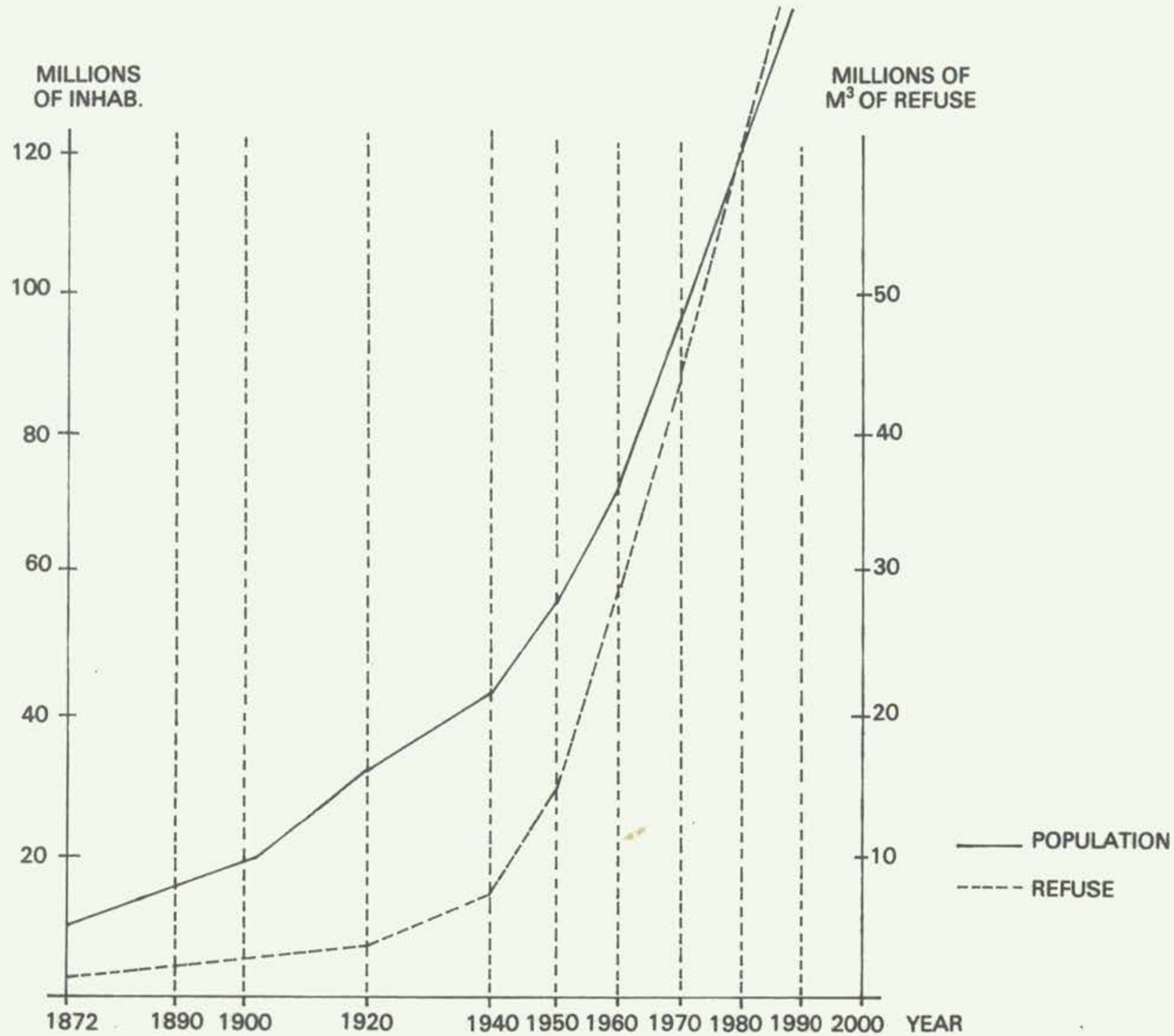
FIG. 2 POPULATION GROWTH IN BRAZIL AND REFUSE GENERATION



REFERENCE: PERFIL DE VIABILIDADE ECONOMICO INDUSTRIAL DE RECICLASEM NO BRASIL — JANIPLAN S/C 1974

2. HISTORICAL BACKGROUND

Salvage is the material sorted from refuse and prepared for sale as a raw material which can be incorporated in the manufacture of commodities by the appropriate branch of industry.

Salvage of materials such as bottles, paper, plastics and metals from solid waste has long been a common practice in large cities. Such activities are carried out often, in open dumps or even before the normal refuse collection routine. Some people make a living out of this practice, often prohibited by public works officials.

There are only three recorded examples in Brazil of large scale industrial enterprises for recycling of materials from municipal waste: one in Porto Alegre, State of Rio Grande do Sul, another in Niterói, State of Rio de Janeiro and the last in Recife, State of Pernambuco.

The oldest recycling plant reported in Brazil was a composting plant built in 1929 in the city of Porto Alegre. The plant utilizing the Beccari cells process consisted of cells shaped in the form of a rectangular block, built with concrete and covered by a roof. The leachate was drained through perforated bricks in the floor which also allowed the circulation of air.

The decomposition period of the organic material was 50 to 70 days with temperatures reaching 45 to 75^{o}C. The plant was enlarged in 1937 to process 60m^3/day of refuse.

A simple conveyor belt was used for hand-picking and sorting of materials such as paper, rags, bones and cans, before depositing the organic refuse in the cells.

The plant operated until 1949, when it was shut down. The city's refuse was then disposed of in a landfill site in a close-by low land area.

In the Niterói plant, built in 1954, refuse was hand sorted on a conveyor belt and the ferrous metal removed by a magnet. The refuse then passed through a mill where it was shredded and dumped into 20 Beccari cells to be transformed into compost.

Each concrete cell had a volume of 275 m^3 with circulation of air through holes in the floor.

The fermentation period was 18 to 20 days, with temperatures reaching 75 to 80^{o}C. After fermentation the compost was removed through the bottom and passed through a vibrating screen.

The resulting compost had the following characteristics: Humidity: 15 to 20 per cent; pH: 7.85; C/N rate: 21.4; Organic Matter: 38 per cent; Nitrogen (total): 1.15 per cent; Phosphorous (total): 1.58 per cent; Potassium (total): 0.15 per cent.

Materials sorted from the waste stream consisted of 3 per cent of paper, 1 per cent rags, 2 per cent tin-cans and 1.5 per cent glass.

Recife had two composting plants. The Beccari Curado and Caçote plants, both using the Beccari process.

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The Curado plant had a nominal capacity of 12 tons/day and was in operation from 1963 to 1980. The Caçote plant with a nominal capacity of 45 tons/day. Also operated from 1963 to 1980. Most of the compost produced by these plants was used by the municipality, in gardens and public squares. There was also salvage of certain materials such as plastics, ferrous metals and glass. The plants were closed because their technology was considered outdated, and the new offices of the Sanitation Department were built on the site of the old Caçote plant.

One practice very common in Brazil from the 1930s to the 1960s was the use of crude waste for feeding pigs. Also, in many cities primarily in the state of Sao Paulo, crude urban wastes were sold or given free of charge to small farmers for use as fertilizer.

Today, this practice has been almost entirely discontinued, probably due to transportation costs and changes in the composition of the refuse.

3. PRESENT STATUS OF COMPOSTING-RECYCLING PLANTS

At present there are 12 plants in Brazil for processing solid urban waste into compost; these plants also salvage materials that are not suitable for composting, but, have some value as scrap. Figure 3, next page, shows a map that indicates the cities where the plants are located.

Following is a brief description of the plants from the oldest, to the newest.

3.1 Brasilia, Federal District

In Brasilia, capital of Brazil, there is a plant built in 1963 that utilizes the Dano process. The plant has four bio-stabilizers, two, each of 50 tons per day capacity of refuse, and the other two of 75 tons per day capacity, making a total processing capacity of 250 tons per day.

The DANO plant in Brasilia consists basically of a reception area with receiving hoppers that convey the refuse to a conveyor belt. This belt passes through sorting stations where salvageable materials are picked up manually, and ferrous metals removed by means of a magnetic overbelt.

In the next step the material is fed into a rotating bio-stabilizer where the wastes are moved slowly forward, aeration is achieved by means of two rows of air holes abrasion of the rotating particles and by biological action. The refuse remains in the stabilizers for three to five days, depending on the characteristics of the refuse, the temperature of the material being in the thermophilic range during most of the time. The compost is passed through a 3/8" mesh screen at the discharge end of the bio-stabilizer, and is then stabilized further, if necessary, by stacking it in piles prior to preparing it for the market.

Materials recovered monthly from this operation are: Plastics - 55 tons; Ferrous Metal - 40 tons; Glass - 35 tons; Cardboard - 30 tons; Aluminium - 1 ton; Copper - 60 to 80 kilos; Paper - 20 tons. All these products are shipped to Rio de Janeiro or Sao Paulo more than 1000 km away where the scrap materials processing plants are located.

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FIG. 3: MAP OF BRAZIL – CITIES WITH COMPOSTING RECYCLING PLANTS

The compost itself consists of an average of 42 per cent of the incoming refuse and is sold for about United States. The markets for this compost are mainly municipal parks and vegetable gardens, located 30 to 40 kilometers from the plant.

The plant has operated normally since its beginning without any major interruption. It is run by a staff of 97 employees. At the present moment there are plans for building a new plant with a capacity of 600 ton/day. This unit when in operation will replace the old one.

3.2 Maceió - State of Alagoas

The Maceió composting plant is located in the urban area, 40 km away from the city's landfill site. Despite its central location, there have been no significant complaints from the population since the plant was opened in 1968. The plant belongs to the Municipality and is operated by a public enterprise called Companhia Beneficiadora de Lixo - COBEL.

The Maceió plant utilizes the Beccari process having 60 cells. The refuse is dumped directly into the cells that are loaded and unloaded twice daily and remains in the cells for 30 days, moving forward from one cell to another, and downwards from one level to another in manual operations. At the discharge end of the cells the material goes through a rotating screen and is then further stabilized by stacking it in piles, for 30 days, prior to preparing it for the market.

The plant's throughput is around 60 ton/day and finished compost is sold at US$50/ton by the municipality to a franchise contractor which mixes it with chemical fertilizer, puts it in bags and sells it at US$150/ton, mainly to sugar cane and tobacco plantations.

There is some recycling activity at the plant. Paper, cardboard, plastics, glasses (all colors) and ferrous metals are sorted in small quantities.

The plant is run by one agricultural engineer and 20 workmen and has been in operation, without any significant interruption since 1968.

3.3 Sao Paulo - State of Sao Paulo

The city of Sâo Paulo has two composting plants, the Sâo Matheus plant and the Vila Leopoldina plant. Both units use the Dano process.

The Sâo Matheus plant has a nominal capacity of 200 tons of refuse per day. It is a modular unit using four bio-stabilizers in parallel. It started operations in 1970, with three bio-stabilizers, and added a fourth one in 1971.

The Vila Leopoldina plant opened in 1974 and has a nominal capacity of 400 tons of refuse per day. It uses six bio-stabilizers in parallel.

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The plants were constructed in Brazil and all the equipment was locally manufactured.

The stages of the process are similar to that of the plant in Brasilia and consist of the following:

- refuse reception;
- sorting stations;
- screens;
- compost discharge.

Raw refuse is deposited into receiving hoppers from which it is passed by inclined conveyors to hand sorting stations, where, paper, cardboard, plastics, rags, glass, and other salvageable items are extracted, and at a lower level undergoes magnetic separation. The separated tins are discharged into a hopper for baling at ground floor level.

The remaining refuse enters the bio-stabilizers, where the temperature is kept at 45° to 60°C. After going through the bio-stabilizers the material passes through vibratory screens.

There is a continuous demand for compost in the state of Sâo Paulo. All that is produced is immediately sold. In the spring, when soil is prepared for sowing it is a common sight to see several trucks standing in line the whole night in order to garantee their load for the next day.

The plant's Administration has more than 3,000 indexed customers, some of them located up to 500 km away. The municipality is responsible for operation and maintenance of the Sâo Matheus plant, while a private contractor manages the Vila Leopoldina plant.

3.4 Belém - State of Pará

Belém's composting plant is located on the outer perimeter of the city. The plant belongs to the municipality. This plant was initially opened in 1974, and reopened in 1979, shut down for two years, started operating again in 1982 and has been running continuously since then.

The plant consists of two Dano bio-stabilizer units of 75 tons per day capacity each, with a total throughput of 150 ton/day.

The Dano process has already been described in this report. Of the incoming refuse, about 53 per cent of the total, by weight comes out as compost.

The compost goes into a silo at the discharge end of the stabilizer. From there, it is hauled 18 km away and then stabilized further, by stacking in piles (from 30 to 45 days) prior to selling it to the market.

The actual operation and maintenance costs run around US$10,000/mo, including a staff of one professional engineer, one supervisor, 48 workmen and two scalemen.

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The product is sold either as raw compost or finished (cured) compost; having a price of US$1.5 per ton and US$3.5 per ton respectively. The major buyers are pepper and "dende" oil plantations.

There is some recycling activity taking place at the plant and the major recycled items are:

- Plastic - 800 kg/day (possibility);
- Bottles - 2,000/3,000 pieces - US$16 per ton;
- Bones - 5 to 8 ton/month - US$16 per ton;
- Tin Cans (compacted) - 5 to 7.5 ton/month - US$12 per ton;
- Ferrous metals - 500 kg/month - US$12 per ton;
- Aluminium - 800 kg/month - US$170 per ton.

3.5 Manaus - State of Amazonas

In the Amazon region there are three composting plants: one in the city of Manaus another in the city of Boavista and the third in the city of Belém. The Manaus plant started operations in 1975, its construction being financed by the Federal Government.

The plant was furnished on a turn-key basis by a Brazilian firm licensed by Impianti dei Bartolomei, Italy. It is operated by a professional engineer with 40 workers.

This unit has a capacity of 400 tons of refuse per day, working on two shifts but usually processes only 100 ton/day. From this amount of refuse, the following materials are recovered daily: Plastics - 600 kg; Tin Cans - 2,000 kg; Non ferrous - 10 kg; Compost - 50,000 kg. The composting process begins on a Fairfield Bio-digester and continues on windrows in open air. Due to maintenance problems this operation has been shut down. When in operation, all the compost was sold, at a price of US$5.00/ton.

3.6 Belo Horizonte - State of Minas Gerais

In the Municipality of Belo Horizonte, Minas Gerais, the Municipal Sanitation Department operates a composting plant, located on highway BF-40. The plant started its operations in 1975 and has been running continuously since then. It is a Dano technology process consisting of two bio-stabilizers with capacity of 75 tons/day each, and a total throughput of 150 tons/day. After leaving the bio-stabilizer the compost is placed in windrowed piles, on paved ground for completing stabilization, over a period of 60 to 70 days. The compost is turned weekly to ensure the necessary aeration. About 55 per cent of the incoming refuse comes out as raw compost. Some sorting is being done. The major items being recycled are:

- plastic - 25 tons/day - US$57 per ton;
- ferrous metal - 30 tons/day - US$10 per ton;
- non ferrous metal - 500 kg per day - US$150 per ton (aluminium).

Paper, cardboard and glass have not yet been recycled. The final product is so raw and after prices being US$4 per ton and US$5 per ton respectively. At the present, the whole production is selling well, very little stock remaining available. The major customers are vegetable and coffee plantation farmers, some located upto 120 km away from the plant.

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The total plant capital investment costs were (1975 basis) US$30,000 and plant operation and maintenance run around US$900 per month.

Manpower consists of 5 supervisors and 40 workmen.

3.7 Sao José dos Campos - State of Sao Paulo

In Sao José dos Campos, State of Sao Paulo, there is also a Bano Composting plant, operating since 1976; this plant has two bio-stabilizers, each having a capacity of 75 ton per day of refuse.

Compost production averages 40 per cent by weight of the incoming refuse. This compost sells at US$2 per ton when crude, and at US$10 when fully processed. The processing includes 60 days of curing in the open air.

Materials salvaged for recycling are plastics, ferrous and non-ferrous metals, glass and paper.

Most of the compost is sold for coffee plantations, horticulture and citrics in places up to 70 to 80 km away from the plant. According to customers, the compost has some problems linked to odours and pieces of glass.

Personnel employed include one professional engineer, one technician, 25 production workers and 12 maintenance workers.

3.8 Boa Vista - Roraima Territory

The Boa Vista unit is DANO process plant, in operation since 1977; this plant processes an average of 12 tons of refuse daily and produces about 8 tons per day of compost, used mainly in gardening, public squares and vegetable gardens.

The only material salvaged is ferrous metal (tin cans), sold at US$6 per ton, the compost is sold at US$2 per ton, to places within a radius of 50 km of the city.

Personnel employed in operations are limited to 12 workers and mechanical maintenance is considered to be the most important factor to keep the plant running, recently, the plant was out of operation for 2 months due to lack of spare parts for the bio-stabilizer.

3.9 Rio de Janeiro - State of Rio de Janeiro

The Rio de Janeiro experience; design, inversions, operational and economics data; maintenance control; personnel distribution; marketing systems for recycled products are presented as follows.

Around 90 per cent of all 4,000 tons of refuse collected daily in Rio de Janeiro is disposed of in three sanitary landfills.

In 1975, the Municipal Public Cleansing Company, "COMUTE - Companhia Municipal de Limpeza Urbana" started a medium and long range solid waste plan for the city, based on the latest technologies available.

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A consequence of these studies was the construction of a plant for waste recycling, based on a design developed by the Company's technical staff aided by an international consultant. The consultant's work was sponsored by the United Nations Development Programme through the Organizacion Panamericana de la Salud/OPS/CMS.

The plan was designed for a capacity of 20 tons/hour using an old building that had once been an incineration plant, located in an area that was an important source of refuse.

The contract was signed on December 1976 and regular operations started in October 1977.

The investment costs are shown in Table 1.

Table 1

Item	Costs - US$	%
Engineering	24 080.00	3.37
Equipment	537 480.00	25.25
Civil Construction	152 660.00	21.38
TOTAL	714 220.00	100.00

The composting plant started its operation in April 1978 at a cost for equipment and construction costs of US$110,000.00, not including the auxiliary equipment (truck and shovel).

The industrial system

Reception and control

All collection trucks arriving at the plant are identified and weighed in on a 30 tons/scale to register the net weight of the waste, the collection trucks dispose of their waste into two pits each one of 6 meters depth and with a storage capacity of 150 tons (210 m^3). A drainage system at the bottom of the pit is provided to collect the leachate or the water used in the weekly cleaning. A travelling crane supports a hydraulic shell that transfers the waste from the pits to a metalic plate conveyor with variable speed from 0 to 15 meters/minute.

The feeding conveyor then takes waste up to a rubber belt along which are placed 14 sorters, 7 on each side of the belt. All materials are sorted (hard plastic and plastic film - high and low density polyethilene respectively; PVC; cardboard; white and coloured glass; non ferrous metals and some materials that could harm the shredder and placed in containers (1 m^3 capacity). These containers are pulled by a small wheel loader up to the scale to be weighed.

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The plastic film and cardboard are packed in two presses forming bales weighing around 200 kg.

The refuse is shredded in a hammer mill, with a capacity of 22 ton per hour. This hammer mill has two 300 HP electric motors. The shredder is manufactured in Brazil, as well as all the equipment in the plant under license from a French manufacturer.

Below the main shaft that supports the 102 hammers is installed a grate which determines the granulometry of the shredded waste.

Shredded waste transportation and ferrous metal sorting

Underneath the mill there is a metalic belt that receives the shredded waste from the grate and takes it to another rubber belt over which is instaled an electro-magnetic over band that collects the ferrous metal.

The shredded waste is then taken up to a screen feeder, 5.5 meters long, which distributes it into 30 m^3 trailers. The ferrous materials are stored in a 9 m^3 capacity rotatory bin that when full discharges them into trucks.

The shredded waste is transported by the 30m^3 trailers to the composting station, 10 km away from the recycling plant, where it is spread in long windrows which are mixed daily over a two-month period by an articulated wheel loader. The material is then strained in a simple mechanical system which includes conveyor belts and a steel trommel 7 meters long, 1.5 diameter and 7/8" holes.

The decomposed part of the shredded waste (organic matter) is then separated from the inert materials and stored in the open air, ready for use in agriculture.

The inert materials (fractions of plastics, wood, leather, rubber, paper, tc.) are now being sold as extra fill for a cement plant located 5 km from this composting facility.

Personnel Distribution is shown in Tables 2, 3 and 4.

Recycling plant

Table 2

Functions	Number
Supervision	4
Sorting	14
Operation	7
Maintenance	4
Cleaning	6
Total	35

Table 3

Recycling plant - sorters

Material	Number of Sorters
Plastic	6
Cardboard	1
Textiles	4
White glass	1
Coloured glass	1
Total	14

- At the composting plant, the following personnel distribution is as follow:

Table 4

Composting plant personneal

Function	Number
Superviser	1
Scale operator	1
Operation	4
Loader operator	2
Driver	1
Total	9

- Commercialization of Recyclables and Compost

Table 5 shows the average production and selling price of each material sorted at the recycling plant:

Table 5

Material		Monthly Average Production (kg)	Selling Price US$/100 kg
Cardboard		26,690	4.5
Hard plastic		10,700	8.9
Plastic film		13,990	7.5
White glass		10,230	2.05
Coloured glass		7,680	1.5
Textiles		10,500	0.7
Aluminium	Non		54.8
Copper	ferrous	820	147.3
Brass	metal		78.6
Ferrous Metal		44,640	3.8
Compost		880,000	1.0

3.10 Novo Horizonte - State of Sao Paulo

The Novo Horizonte composting plant is located in the state of Sao Paulo, 430 km away from the capital, and has a nominal daily capacity of 50 tons of refuse. It uses a very simple process, consisting of a receiving hopper, a rotating trommel belt conveyor and an area where the compost is placed in windrowed piles for curing. The piles are turned every week to provide aeration and the curing process takes 90 days. The total daily throughput of 50 tons of refuse produces 10 tons of compost.

A public enterprise entitled Cia. Estadual de Tecnologia de Saneamento Básico - CETESB, has operated this pilot plant since its start up in 1980. The plant represented a total capital investment of US$1,500,000; and its monthly operation and maintenance costs are around US$1,500; the plant's personnel consist of two supervisors, 5 workmen, 1 wheel loader driver and 1 truck driver.

The customers are mostly located within a radius of 20 km from the plant and the entire production is sold to them.

As a pilot plant new developments are projected by CETESB including a shredder, forced aeration and a vibrating screen to better the final product before selling. Some sorting has been done, mainly cardboard and glasses, but in no significant amounts.

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3.11 Santo André - State of Sao Paulo

The municipality of Santo André, through the Secretaria de Serviços Urbanos has operated a Composting Plant since 1982. This plant, based on DANO technology consists of three bio-stabilizers, 150 ton/day capacity each, with total overall capacity of 450 ton/day.

The compost leaves the stabilizers and is placed in windrowed piles, for further stabilization, on concrete paved ground, for a minimum period of 60 days. The compost is turned, on a weekly basis to provide the needed aeration. Part of the compost also goes through a screen right after leaving the stabilizers.

Compost production amounts to 40 per cent by weight of the in coming refuse. Production, in terms of screened compost reaches a maximum of 600 tons.

The plant also carries out some recycling activity, as shown in Table 6.

Table 6

Recycling

	Monthly Production (ton)	Price US$/ton	Note
Plastic (film)	20	37	baled
Plastic (hard)	13	48	
Cardboard	30 up to 35	10	
Ferrous Metal (tin cans)	80	16	
Ferrous Metal (gross)	4	18	
Non Ferrous Metal	2	15	aluminium
Glass (mixture)	15	15	

The screened comopost is sold at US$7/ton and the material stabilized in the biodigester at US$2/ton.

The product is being used in vegetable gardens and coffee plantations, some of them located upto 200 to 300 km from the plant.

Although the compost is well accepted in the region, the plant is still operating below its full capacity; the present production is 25 tons per day.

A private contractor, takes care of the maintenance and operation of the plant, at a monthly cost of US$35,000.00.

The total capital invested was US$900,000.00 in 1979.

A staff of 1 supervisor, 2 office workers and 70 workmen are responsible for operating the plant.

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4. CONCLUSION

Materials recovery and recycling in Brazil is a highly important practice, not only because of the savings in raw materials and energy consumption, but also because it is another way of employing semi-skilled personnel, and contributes to environmental protection.

Recovery of materials has been dictated up to now by local markets and economic forces, and has therefore been on very limited scale with no effort being made to plan and develop markets for recyclable materials. As a result recycling is still on a very low level.

Only now, the Federal Government has become aware of this problem and is starting a program to increase the recovery levels mainly of metals, paper and plastics.

With regard to municipal solid waste, there is still much to be done. At present only 66 per cent of the residues generated are regularly collected and of this, only 26 per cent is disposed of properly.

The composting-recycling plants in operation in Brazil show that this is a possible option for waste disposal, and as well, an important way of recovering recyclable materials. Furthermore, these plants produce organic compost which is vital to the development of large areas of poor soil, needed food production.

The Dano process is the most widely used method of composting in Brazil. Nevertheless the current trend is towards processes where recycling operations are the major activity.

This means that there is a large market for recovery-composting operations in Brazil, using technologies adapted to Brazilian conditions.

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MATERIALS RECOVERY AND RECYCLING GERMAN AND EUROPEAN DEVELOPMENT TRENDS

Dr. Eckhard Willing

1. Introduction

There is nothing new about the basical technical processes applied in resource recovery models. Almost all of them have been known since the beginning of this century. What is new are the targets under which conventional, rediscovered old and new elements of waste technology and economy are being combined in new models.

Within the 1975, Waste Management Programme of the Federal German Government, these aims have been comprehensively formulated and expressed as a political programme:

- reduction of waste at poroduction and consumer levels;
- increase of waste utilization;
- environmentally safe disposal of non-recyclicable.

In this order of objectives lies a valuation: The reduction, i.e. the avoidance or minimization of wastes has the utmost priority. The utilization of inevitable wastes (recycling) comes in the second place. Only the wastes neither evitable nor usable should be disposed of and this should be done without causing damage to the environment.

The more recent developments aiming at the utilization of wastes on the municipal level in the Federal Republic of Germany can be arranged according to the following system:

1. Waste utilization by material separation

   Aim: Separation of the components of mixed wastes without material conversion and utilization as secondary raw materials or for energy recovery (solid fuels);

1.1 Material separation at source
Separate collection or integrated collection systems;

1.2 Material separation after conventional collection in centralized plants by handsorting and/or mechanical sorting and processing;

2. Waste utilization by material conversion:

   Aim: Generation of products by transformation (solid, liquid, gaseous) and utilization as raw materials or fuels.

2.1 Thermal transformation:

   - pyrolysis
   - gasification.

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2.2 Biotechnical/chemical transformation:

- fermentation;
- hydrolysis;
- biogas generation.

It has to be stated beforehand: none of these utilization methods mentioned above can be expected to bring forth global solutions; the chances of success are rather in a combination of all of them, together with conventional disposal methods.

In the Federal Republic of Germany separate collection has been practised for some years with relative success. The greatest technological progress has been achieved in the fields of mechanical sorting of domestic waste, production of refuse-derived fuels and pyrolysis. While pyrolytic processing needs a good deal more research and development to be applicable on a large technical scale, the other methods mentioned above are already in use for waste disposal in certain regions.

2. <u>Separate collection</u>

Separate collection of such secondary raw materials as paper cardboard, glass and tin plate has a very long history in Germany and throughout Europe. This is not a technical, but an organisational means of resource recovery.

In the area of separate collection a fundamental distinction is made on the basis of the container type and container location between delivery and collection systems and, so-called non-systematic collection.

The delivery systems mainly consist of slightly modified skips with a capacity of 4 - 10 m^3 such as are used for industrial waste removal. For glass collection there are also metal or plastic containers specially developed for this purpose which can be emptied into trucks in place.

The delivery system is used in the Federal Republic of Germany predominantly for separate glass collection, and in a few instances larger units are also being used for paper collection. The containers are usually sited in locations with easy road access as well as in the immediate vicinity of shopping centres.

Through use of this system it has been possible to increase the separate collection of waste glass from 150,000 tons in 1974 to 600,000 tons in 1982. The number of people covered by the system rose in the same period from 3,045 to more than 42.0 million. This means that in 1982 approximately 70 per cent of the population of the Federal Republic of Germany could deliver their waste glass to the installed separate glass collection system.

Non-systematic collection is used predominantly for the recovery of waste paper and cardboard. Non-systematic means that the recyclable materials are left in bundles or suitable receptacles at the roadside for collection. These collections from house to house are organized and conducted either directly by waste paper dealers or by charitable bodies. We may assume a figure of 400,000 tons as the total volume of separately collected waste paper and cardboard each year. This volume resulted approximately equally from the activities of waste paper dealers and charitable organizations.

There are no separate collections of tin plate in the Federal Republic of Germany using the systems described. There have been some experimental activities for tin plate collection that were given up because of the high collection costs. However, 120,000 tons of tin plate was recovered in 1978 mainly through use of magnetic separators in refuse incinerators and composting plants. Questions concerning the possible incorporation of the metal group (ferrous and non-ferrous) into systems of separate collection are currently still being examined in the context of research and development projects.

The high costs of labour in the area of collection and transport and the fluctuating returns for secondary raw materials have led to development of several different integrated collection systems. One of them, the so-called green waste container is more and more used by communities and by private waste handling contractors. Another one, the multi-compartment refuse collection system has been developed within a special research programme, but must still be tested under practical conditions. In the first system each household has two waste containers, a grey one for non-returnable and non-recoverable wet waste and a green container for recoverable materials. Both containers are collected transported separately, one to the sanitary landfil or to an incinerator, the other one to a recovery plant. In the concept of multi-compartment refuse collection system each container is divided into two chambers, one of them for secondary raw materials the other for the non-recoverable wet waste. In this system, the collection vehicle also has to be divided into two chambers. Both integrated collection systems collect mostly a mixture of secondary raw materials, like paper and cardboard, glass, tin plate and plastics. Therefore this system has to be supported by a manual or mechanical sorting system to achieve marketable and recyclable products.

3. Mechanical Processing of Municipal Waste

3.1 Introduction

Apart from the optimization of existing processes of waste treatment (sanitary landfill, composting and incineration) various technological possibilities for the recycling of municipal waste are being tested in the Federal Republic of Germany on experimental and commercial scales. The most important point of emphasis is the process of recovering secondary raw materials or refuse-derived fuels.

It may be assumed that the following secondary raw materials (in per cent by weight of total refuse) can be recovered from German municipal waste of average composition:

Paper and cardboard	15 - 25 per cent weight
Mixed plastics	3 - 7 per cent
Glass	8 - 12 per cent
Iron	3 - 5 per cent
Organic residue (useful as raw material for compost)	25 - 35 per cent

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It has been shown that paper, cardboard and iron can be recovered by mechanical sorting systems at an acceptable quality level. Glass however must be recovered by separate collection systems and mixed plastics can be recovered, but not at acceptable and marketable quality levels.

The essential process stages which in various combinations permit the mechanical recovery of these secondary raw materials are:

Screening (trommel screens, vibrating screens, corrugated tension screens);

Crushing (rotary mills, hammer mills, cutting/shearing mills, impact pulverizers);

Sorting
- Air classifying (zig zag separators, vertical tube classifiers, stone separators);
- Magnetic separation (magnetic rollers, cylindrical magnets, conveyor belt magnets);
- Heavy media separation (sink float separator);
- Optical separation;
- Special mechanical processes for separation of paper-plastic-mixtures;
- Drying;
- Compacting.

After development and testing of appropriate overall processes of domestic refuse treatment, application is envisaged in the following situations:

- Sorting of domestic refuse on existing landfills to prolong the useful life of the landfill;
- Incorporation upstream of existing incinerator plants as an alternative to further extension stages;
- Installation in existing compost plants to process refuse fractions containing recyclable materials or to sort out non-compostable or toxic materials;
- Establishment of centralized domestic refuse processing plants to replace older treatment plants. In this case the new plants will probably always be in combination with other recycling or treatment processes.

3.2 Research and Development Projects

In recent years two overall methods for the mechanical processing of municipal wastes have been developed in the Federal Republic of Germany:

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- As a result of a commission from the Federal Ministry of the Interior, the Institute for Processing, Briquetting and Coking of the Technical College, Aachen has developed a domestic waste sorting system and tested it in an experimental plant with a throughput of 1.5 t/h. This process, which also makes use of wet heavy media separation stages for fine sorting, has not been put into operation on a commercial scale but has provided important stimuli for the processing of domestic refuse.

- The Krauss-Maffei company in Munich has developed another household waste sorting process and tested it in a 5 t/h pilot plant with original domestic refuse from the city of Munich. Since this process is aimed solely at the recovery of paper and plastic, exclusive use is made of dry sorting stages. In the spring of 1979 a commercial plant with a throughput of 8 t/h was commissioned at Landskrona in Sweden.

- Sorting exclusively with the aid of screening and air classifying has been tested with domestic waste in Berlin. This process, which was originally aimed at the extraction of fuel from refuse, has yielded good recyclable materials with the aid of trommel screens.

- As a result of these tests in Berlin, in the district of Ludwigsburg in South-west Germany an experimental plant for the classification and sorting of rural household waste has been tested. The aim of these investigations is the recovery of recyclable raw materials on existing landfills with the minimum outlay.

- With the same aim, a private company has developed a special mobile trommel-screen that is combined with a simple bag-opener and a air-classification for sorting out the light fractions of paper, cardboard and plastics. This very compact and effective machine is now located at the sanitary landfill of Bochum and will be tested under realistic conditions. After the first test runs it is planned to use this new resource recovery scheme for sorting out burnable materials as alternative fuel or for recovering raw materials for the cardboard industry.

In numerous research and development projects detailed questions concerning the mechanical processing of wastes are being investigated. Only a few of them will be mentioned here:

- Possibilities of separating plastic/paper mixtures which yield storable and recyclable qualities of both materials.

- Sorting of plastics mixtures by means of heavy media separation with the aim of high grade use of the plastic fractions.

- Investigation of various crushing units as initial stages in the process of separation and composting.

- Development of qualitatively and quantitatively efficient processes and units for the colour sorting of mixed cullet.

- Processing into cardboard of paper obtained from domestic refuse treatment.

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Some of these investigations have been finished and have led to new equipment for resource recovery schemes, some of them are still going on.

3.3 Operational Plants

There are at present only a few commercial resource recovery plants under construction or in operation in the Federal Republic of Germany, most of them financially supported by the Federal Government. One of them processes domestic and commercial waste for the recovery of secondary raw materials on an existing landfill, one separates the mixture of paper, glass and metals that is collected in an integrated sorting system.

- Resource recovery plant on the landfill of the City of Neuss:

This plant has been planned and built by a private waste handling contractor, which has many years experience in waste disposal and in recovery and marketing of waste products.

Throughput: 35 - 45 t/h; 1 shift/day;

Types of waste: household, bulk and commercial waste;

Process: one manual sorting line for commercial waste and one mechanical sorting line for domestic waste: primary screening, handpicking belt, hammer-mill, magnetic separator, secondary screen, air-classifier, bunker belts, crushing and composting of the organic material;

Products: Paper for cardboard-industry, paper mixed with plastics for energy recovery, tin-plate for steel-industry, clean plastic foils for plastic industry, compost for recultivation and landfill-covering;

Stage of the project: in operation since May 1981.

During the last two years it has been shown in Neuss, that it is economically and technically possible to process household waste into marketable products. On the other hand it has been shown, that many of the waste processing machines have not been adapted to the special conditions of waste handling.

- Resource recovery plant Issum

This plant has been designed by another private waste handling contractor for the separation of waste product-mixtures that are daily collected with the integrated collecting system called "green container".

Throughput: 5 t/h

Types of wastes: Mixtures of paper, cardboard, glass, metals and plastics from private households;

Process: trommel-screening, magnetic separation, manual sorting, baling;

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Products: Paper for cardboard-industry, mixed papers of lower quality for energy recovery, metals for steel-industry, glass for container-glass industry;

State of project: beginning operations.

This type of resource recovery plants shows a very simple and cheap technology and can be reproduced in several versions, all of them based on a combination of screening and manual sorting.

Another full scale resource recovery plant has been planned since 1975, but has not been built because of organisational problems:

- Federal Waste Recycling Model Reutlingen/Tübingen

In this plant in the districts of Reutlingen and Tübingen in the State of Baden-Württemberg it is proposed to test and further develop various sorting processes in combination with composting and sale of recovered products.

Throughput: 150,000 - 180,000 t/y

Types of waste: domestic, bulk and commercial waste, sewage sludge;

Process: two different mechanical sorting lines: screening, crushing, magnetic separation, air-classifying, ballistic separation; one composting line for organic materials;

Products: paper and cardboard, metals, glass and plastics as far as possible, refuse-derived fuel and compost;

Stage of project: under construction.

Besides solving technical problems of resource recovery, the most important task is to meet quality specifications for the recovered secondary raw materials. If it is not possible to separate marketable products, the best technology of domestic waste sorting systems will fail. Therefore, a great deal of research and development is necessary on waste-derived products and their marketing.

4. Production of Refuse Derived Fuels

4.1 Introduction

In recent years the production of fuel from municipal wastes has received increased attention, especially in the United States of America and in Great Britain. Numerous processes have been developed and, in some cases, tried out on a commercial scale. The common aim of all these processes is to recover solid fuel concentrates through mechanical treatment of refuse. These new fuels have come to be known by the abbreviations RdF or WdF (Refuse or Waste-derived Fuel).

There is basically nothing new in the attempt to recover the energy content of municipal waste. For many years refuse incinerator plants with heat recovery have been in operation. The principal difference between energy recovery by means of refuse incineration and energy recovery through the use of RdF is, however, that in the first case the furnace is adapted to refuse as the input material, while in the second case RdF is given as the well defined input material and is adapted by means of special methods of treatment to given furnace systems, for examples an alternative to conventional fossil fuels. In addition, energy recovery from wastes in incinerator plants takes place in a single stage, i.e. in one plant; with the RdF porocess, by contrast, there are two stages, fuel production and fuel use.

4.2 Requirements of RdF

In order to ensure as wide and as economical a range of application as possible the fuel must meet the following requirements:

- high calorific value;
- low water content;
- low ash content;
- low pollution;
- homogeneous composition, grain size and grain size distribution;
- storability and transportability;
- use in existing fossil fuel combustion plants.

The quality characteristics may show wide differences due to local factors. They are chiefly dependent on the type and composition of the raw waste and on the desired area of application. It is on these factors that the production process and the related operating conditions must depend. The fuel product should be of a sufficient high grade to allow it to be burnt not only in conventional refuse incinerator plants with flue gas scrubbing systems but also, for example, together with bituminous coal in industrial pulverized coal furnaces.

4.3 Fuel Production

The production of refuse derived fuel utilizes processes of mechanical treatment, or processes already developed for the recovery of secondary raw materials from municipal wastes. In practice the design of familiar RdF-processes differes considerably in complexity and in the number of stages in the process. Simple systems are essentially limited to coarse crushing, the separation of iron and rough sorting, while complex processes such as for example the American Eco-Fuel II process consists of many distinct stages.

Theoretically fuel production can be subdivided into three stages which, however, are not necessarily all present or clearly manifested in all processes:

- Preliminary treatment with the aim of adapting the input material as far as possible to the requirements of the process in order to achieve full utilization of the operation and properties of the plant components; e.g.

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  - Preliminary sorting of particularly suitable groups of materials in households and industrial plants (at the point of waste generation);

  - Exclusion of large, difficult items on acceptance (domestic appliances, mattresses, etc.);

  - Preliminary magnetic separation of ferrous metals;

  - Coarse crushing and/or coarse classifying.

- Classifying with the aim of concentrating the components of high calorific value and low water, ash and pollutant content in the refuse in one fraction, e.g. by air or ballistic classifying or by trommel-screening, often in combination with crushing-stages;

- Final treatment with the aim of bringing the fuel fraction into the form required for use, e.g.

  - Screening;
  - Final crushing or milling;
  - Drying;
  - Compacting (briquetting);
  - Cooling;
  - Mixing with other fuels.

The ultimate design of the individual processes, however, depends in the last resort very much on the type and composition of the wastes and the desired quality of the fuel.

4.4 Fuel Use

An essential factor for the implementation of the RdF concept is guaranteed use of the fuel. In this connection, both technical and organizational requirements must be borne in mind.

An initial distinction may be made between:

- centralized use by one consumer (or a small number of similar consumers); and

- decentralized use by numerous consumers.

In the first case fuel production can be "tailor-made" to meet the individual requirements of the particular consumer and a contract can be drafted individually for the producer and consumer of the fuel.

The second case amounts to launching onto the fuel market a new product, the use of which is widely spread over small and medium-sized consumers. This results in more exact requirements for the storability, handling and quality consistency of the product. An initial decision would have to be taken as to the existing kinds of furnace systems (e.g. pulverized fuel furnaces, grate furnaces) for which the new fuel is to be supplied, or whether special furnace systems (e.g. fluidized bed reactors, special grates, etc.) are to be developed as a necessary prerequisite for the use of RdF.

It is at present impossible to estimate whether the problems standing in the way of launching RdF for widely spread decentralized use (absence of quality standards, pollutant content, requirements of the Technical Directives on the maintenance of air purity, etc.) can be surmounted and whether this is suitable from the points of view of economy and the market situation. From the technical point of view a fuel in dust form which could theoretically be used in modified oil and pulverized coal furnaces would certaintly have the greatest prospects.

On the other hand, coarser RdF types, e.g. briquets or uncompacted and non-pulverized material, have poorer prospects because they could probably only be used in the older design of grate-type furnaces which, at least in the Federal Republic of Germany, are now in operation only in small numbers. Modern automated coal-fired furnaces can scarcely be considered for these low-grade types of RdF.

A further interesting possibility for RdF use is in the cement and brick industry in the production of sinter pellets and possibly in blast furnaces. In these cases RdF serves as an auxiliary raw material in endothermic physico-chemical production processes to reduce the energy requirements, the ash constituent being bound into the product (cement or brick).

4.5 Pilot and Operational Plants

At present there are in the Federal Republic of Germany one pilot plant for RdF-production, one full-scale plant beginning operations and one in the planning stage. These projects are financially supported by the Federal Government. Besides these plants several RdF-processes are offered by industrial companies or will be tested on a pilot scale. Many municipalities are interested in these new technologies, but they cannot decide on them before the operational results of the first full-scale plants are published.

- Pilot-plant in Herten

This plant has been built as a testing plant for the Ruhr Raw Material Recovery Centre in Herten and the Eco Fuel II- and Eco Briquette-processes. Therefore it has been completely financed by the Federal Government.

Throughput: 5 t/h;

Types of waste: municipal waste;

Process: Screening, Crushing, Magnetic separation, drying - air-classifying, embrittling, grinding, screening, cooling;

Products: Eco Fuel II or Eco-Briquette (powdered or densified RdF);

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State of project: Research projects since 1979.

- Ruhr Raw Material Recovery Centre in Herten

This resource recovery centre in Ruhrgebiet consists of 2 lines of RdF-production, one line of bulky waste-incineration and one line of industrial waste- and of hospital waste-incineration. The RdF-lines have been planned with the results and experiences of the above mentioned pilot-plant.

Throughput: 2 x 150,000 t/y, 3 shifts/day;

Types of waste: municipal, commercial and presorted municipal waste;

Process: Trommel-screening, crushing, magnetic-separation, drying-air-classifying, screening, grinding, densifying, cooling;

Products: densified RdF (Eco Briquette), tin plate;

State of project: in testing operation.

In the first stage it is planned to burn the produced Eco-Briquette as an additional fuel in some cement kilns only. Later on it would be burnt in conventional boiler types of energy-intensive industries.

- RdF-production at Cement Works Erwitte

A sanitary landfill for the whole rural area will be installed in an old limestone quarry close to the cement works. On this landfill a pilot-plant for RdF-production will be operated. Within a research project financed by the Federal Government the following technical objectives will be investigated:

- to determine the necessary outlay on preliminary sorting and treatment in order to achieve suitable fuel qualities;

- to establish data on the combustion characteristics of RdF and the maximum rate of addition to conventional fuels;

- to determine effects on the service life of the furnace lining; and

- to determine the composition and concentration of the flue gas.

Throughput: 15 - 20 t/h;

Types of waste: household and commercial waste;

Process: a mobile trommel-screen including bag-opening and air-classifying of the light, burnable materials, magnetic separation, grinding;

Products: non-densified RdF, tin plate;

Stage of project: in planning.

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Furthermore, several private waste handling enterprises and waste paper-dealers are working on projects to reuse waste paper, cardboard, wood and plastics as alternative fuel.

4.6 Prospects

In comparison with developments in the United States of America and in Great Britain the production of waste derived fuel is a relatively new technology in the Federal Republic of Germany.

There are at present no clear data available concerning the correlation of raw waste properties, in particular the minimum content of combustible material and the maximum moisture content, with the economy of production, extent of pollutant emissions and range of application. The answer to such questions, among others, will have a decisive effect on whether RdF-processes in the Federal Republic of Germany can develop into methods of waste treatment which can exist in competition with municipal waste incineration with heat recovery, with composting, mechanical raw material recovery or sanitary landfill. A decisive contribution to the provision of these answers is expected from the above mentioned research projects and full-scale plants.

5. State of Resource Recovery in Europe

Though there have been some resource recovery plants in Europe since the beginning of this century, most pilot- and full scale-plants for domestic mechanical sorting and RdF-production have been planned and built since 1970. In 1976 we had in Europe six experimental- and pilot-plants and only 2 full scale plants, that separated paper, glass, metals and plastics out of municipal solid waste. One operational plant with a capacity of 8 t/h for the production of RdF had just begun its test run.

The development of new waste handling systems was concentrated mostly on the recovery of secondary raw materials. In the following years many operational plants were planned and built. Most of them did not use the results and experiences of national experimental plants, but imported foreign technologies that had been designed for completely different types of wastes, of collection and transport systems. So the Swedish system of Fläkt AB was transferred to the Netherlands, the Dutch system of Esmil to Austria, the Spanish system of Enadimsa to France, a German system to Sweden.

In the planning stage of these plants nobody took into consideration the different local conditions and the absolutely different waste-compositions. In nearly all cases this resulted in enormous difficulties in process and mechanical engineering and in some cases led to overall failure of the whole resource recovery plant. In contrast in Great Britain and in Sweden original processes of both countries have been implemented as full scale plants.

Simultaneous with the first experiences of these plants, we observed in Europe a change of the tendency from the recovery of secondary raw materials to the production of refuse-derived fuel. This was a result of the difficulties of adapting the technologies to the local conditions and of reaching the demanded product qualities of paper, glass and plastics. In particular the qualities of these products and their marketing became more and more important. The paper, steel and plastics industry got sufficient quantities of cheap secondary raw materials from industry, from commerce and

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from separate collection activities. Therefore they were not ready to accept mechanical sorted products of lower quality at acceptable prices. However, in various pilot-plants, it has been found possible to produce densified or non-densified fuels of relatively uniform qualities out of extremely different waste compositions. This refuse derived fuel could be used in cement kilns and power stations as a supplementary fuel.

Because of these experiences, the resource recovery plants of Tournan-en-Brie (France) and Landskrona (Sweden) were shifted to the production of densified and non-densified RdF. Parellel, in England, Spain and Sweden a big number of RdF-plants was planned and built, some of them in combination with composting- and incineration plants.

In spite of the large number of such RdF-plants in Europe, many problems of production and marketing of refuse derived fuels remain unsolved. In particular more research and development are required in the following areas:

- the suitabiity of special machines for handling, i.e. screening, crushing and sorting municipal and commercial wastes;

- energy consumption and running costs of RdF-production with different process schemes;

- the contents of heavy metals and other harmful substances of the fuels and the resulting emissions;

- the ash contents and the burning conditions of the fuels in conventional boiler systems.

After some years of euphoric expectations from resource recovery systems we have learnt to be more realistic about their possible contributions to waste management. Now we are working on the technical, economical and organizational details of resource recovery technologies to optimize these new waste sorting systems, to fit them into the local waste management systems and to solve problems of product quality and marketing. In Germany as well as in the other European countries the different systems of resource recovery are considered as an appropriate addition to the well-known waste handling and waste disposal systems. Only in a very few cases can they solve the waste disposal problems alone, normally they have to be combined with incineration, composting or biogas production, in each case they need a sanitary landfill for the unrecyclable components.

6. Conclusions

The introduction of new resource recovery concepts into the practice of waste management has already begun. This applies in the first place to resource recovery through mechanical sorting and separate collection. In this field the step from initial investigations and first pilot plants towards the second generation of large demonstration plants is presently being taken - still with governmental aid - in order to find the answers to the still open questions, such as economy of operation and above all, product marketing.

To a still larger extent, the new thermal processing systems need more research and development work to be done, before consent can be given to the broad application in large scale plants for domestic refuse processing. This applies even more to biological and chemical processes.

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An important aspect of the future development of waste management which has to be discussed, is the most appropriate form of organization. Also for this, new solutions can be tested within the model and demonstration projects. To an increasing extent private companies will probably prove more suitable, at least in the field of the marketing of waste derived fuels.

Altogether, the new models of resource recovery will only gradually lead to major changes in municipal waste management. The new processes are more likely to complement than replace present waste disposal methods.

LANDFILL TECHNOLOGY

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A controlled landfill means a systematic, compacted depositing of layers of refuse which are covered daily. The ground and surface waters should therefore not be affected. Even where composting plants or incinerators are used, a landfill site is necessary for disposal of their residues. About 70% of the municipal waste in the Federal Republic is deposited in landfills.

In 1975 there were about 4,500 (mostly small) landfill sites. This number has now decreased considerably due to the establishment of large new central landfill sites which can be operated economically and without impacts on the environment. In 1990 the number of landfill sites should not exceed 400.

Solid wastes deposited in a landfill degrade chemically and biologically to produce solid, liquid, and gaseous products. Ferrous and other metals are oxidized and organic and inorganic wastes are utilized by microorganisms through aerobic and anaerobic synthesis. Liquid waste products of microbial degradation, such as organic acids, increase chemical activity within the fill. Food wastes degrade quite readily, while other materials, such as plastics, rubber, glass and some demolition waste are highly resistant to decomposition. Some factors that affect degradatioon are the heterogenous character of the wastes, their physical, chemical, and biological properties, the availability of oxygen and moisture whin the fill, temperature, microbial populations, and the type of synthesis. Since the solid wastes usually form a very heterogeneous mass of non-uniform size and variable composition and because other factors are complex, variable, and difficult to control, it is not possible to accurately predict contaminant quantities and production rates.

Biological activity within a landfill generally follows a set pattern. Solid wastes initially decompose aerobically, but as the oxygen supply is exhausted, facultative and anaerobic micro-organisms predominate and produce methane gas which is odourless and colourless. Temperatures rise to the high mesophilic-low thermophilic range (60^{o} to 150^{o} Fahrenheit) because of microbial activity. Characteristic products of aerobic decomposition of waste are carbon dioxide, water, and nitrate. Typical products of anaerobic decomposition of waste are methane, carbon dioxide, water, organic acids, nitrogen, ammonia, and sulfides of iron, manganese and hydrogen.

In a stabilized condition, the methane to carbon dioxide ratio is roughly 2:1. Very roughly the energy recovery potential can be estimated on the basis of a total gas generation (spread over 10 to 20 years) of 100 to 150 cubic metres per cubic metre of fill (in place after compaction) and a raw gas heating value of 10,500 to 18,900 kilo joules per cubic metre.

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The landfill body being of a porous and heterogeneous texture, readily absorbs moisture from precipiltation. As the water percolates through the deposited material, it washes out organic and inorganic substances which eventually reach the bottom of the landfill. The quantity of this leachage depends on the annual deposited amount of refuse, the size of the depositing surface, the annual rate of precipitation and the measures taken to immediately lead away the surface water.

The organic burden of leachate lies at a BOD-5 of 3,000 to 5,000 milligrams per litre. For the drainage and purification of such waters appropriate equipment must be provided. Leachate composition is important in determining its potential effects on the quality of nearby surface water and groundwater. Contaminants carried in leachage are dependent on solid waste composition and on the simultaneously occurring physical, chemical and biological activities within the fill. Identification of leachage composition has been the object of several laboratory lysimeter and field studies.

The tipping and spreading of refuse should be limited to a narrow strip in order to keep the exposed landfill face as small as possible. The following techniques are used:

- Edge-tipping, in which the refuse loads are deposited along the tipping edge, driven over several times by the compactor to be reduced and are then pushed over the edge, and

- Surface-tipping, in which the face is formed into a broadly expanded sloped surface on which the compactor reduces and densifies the material by driving over it.

Domestic and commercial wastes are usually highly compactible. They contain a heterogeneous mixture of such materials as paper, cans, bottles, cardboard and wooden boxes, plastics, lumber, metals, yard clippings, food waste, rocks and soil. When exposed, boxes, plastic and glass containers, tin cans and brush can be compressed and crushed under relatively low pressue. In a landfill these items are incorporated within the mass of solid waste, which acts as a cushion or bridge, protecting the relatively low strength materials from being crushed under the load of the compaction equipment.

Cushioning and bridging can be reduced and greater volume reduction achieved if the waste is spread in layers less than 60 centimetres deep and then compacted by tracked, rubber-tired, or steel-wheeled vehicles that pass over it two to five times. Solid waste that contains a high percentage of brush and yard clippings requires the expenditure of more compactive effort. If entire loads of these items are received, they should be spread and compacted near the bottom of the cell so that less resilient wastes can be compacted on top. The equipment operators should try to develop the working face on a slope between 20 and 30 degrees. Waste is spread against the slope and the machine moves up and down it, tearing and compacting the waste and eliminating voids. The equipment operators should make passes until they can no longer detect that the surface of the waste layer is being depressed more than it is rebounding.

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The important control functions of daily cover are vector, litter, fire, and moisture. Generally, a minimum compacted thickness of six inches of soil will perform these functions. The cover is applied to the compacted waste at least at the end of each operating day. If possible, it should be spread and compacted on the top and sideslopes as construction of the cell progresses, thus leaving only the working face exposed. At the end of the operating day the working face is also covered.

Seneral equipment manufacturers are making landfill compactors equipped with large trash blades. In general, these machines are modifications of road compactors and log skidders. Rubber-tyred dozers and loaders have also been modified. The power train and structure of landfill compactors are similar to those of rubber tyred machines, and their major asset is their steel wheels. The wheels are either rubber tyres sheathed in steel or hollow steel cores. Both types are studded with load concentrators. Steel-wheeled machines probably impart greater crushing and compactive effort than the rubber-tyred or crawler machines. No burning of wastes is permitted at a sanitary landfill, but fires occur occasionally because of carelessness in the handling of open flames or because hot wastes are disposed of. Salvaging usable materials from solid waste is laudable in concept, but it should only be allowed if a sanitary landfill has been designed to permit it and appropriate processing and storage facilities have been provided. All salvage proposals must be thoroughly evaluated to determine their economic and practical feasibility. Salvaging is usually more effectively accomplished at the point where waste is generated or at specially built plants. The capital and operating costs of salvage operations at a disposal site are usually high, even if properly designed and operated. If salvaging is practised, it should be done at a specially designed facility away from the operating area, at the working face.

Scavenging, sorting through waste to recover seemingly valuable items, must be strictly prohibited. Scavengers are too intent on searching to notice the approach of spreading and compacting equipment and they risk being injured. Some of the items collected may be harmful and contaminated, such as food waste, canned or otherwise. Vehicles left unattended by scavengers interfere with operations at the fill.

REQUIREMENTS FOR A LANDFILL

For a controlled, sanitary landfill operation the following is required:

Border-fencing of site	Consolidation of main access roads
Workshop and garages	Amenity and operation or administration building(s)
Weighbridge in reception area	Tyre-washing facility
Compactor(s)	Caterpillar
Turning machine	Degassing equipment
Transport vehicles or leachate-purification faciliy	Bottom-sealing with drainage
Electricity/Telephone	Water

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The leachate must be drained away separately from the surface water. The site therefore needs:

- Bottom-sealing with drainage system;
- Drains must be arranged independently of each other;
- Clay piping, to be laid out without kinks;
- Drainage piping to be laid in gravel bed;
- Piping protected from incrustation.

Degassing the landfill can be done using gas domes, towers with perforated tubbing rings filled with gravel. The diameter of these should be at least 1 metre. The gas can be collected in the domes or at the upperside, and led to a utilization facility, e.g., for green-house heating.

At the planning stage of a landfill, the future use of the ground must be taken into account. The configuration of the surface and the new vegetation arrangement should be discussed and worked out with a landscape architect for eventual recultivation.

Special solutions

Digesting landfill

The refuse is deposited loosely in order to undergo a partial digestion under aerobic conditions. The object of this measure is a further volume reduction of refuse and a lower burden of leachate.

Transfer at the landfill

To prevent the delivery vehicles from becoming dirty, the refuse is transferred, in the entrance area, into 100 cubic metre skips which are then carried by special vehicles to the tipping area. thus the delivery vehicles need only drive on firm roads. Also, in addition to dispensing with the tyre-washing facility, the tipping operation will not be obstructed by the delivery traffic.

The costs for a sanitary landfill are on the average, 10 to 40 DM per ton of refuse.

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PLANNING LANDFILL OPERETION IN AMMAN, JORDAN

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One of the most serious and urgent problems facing urban areas today is the proper and safe disposal of large volumes of solid waste which would otherwise degrade the total environmental system. One aspect of particular importance in this total environmental system is the water resource sub-system (surface and groundwaters).

Sanitary landfilling has been widely used for land disposal of wastes. As presently located, designed, and operated, however, many sanitary landfills can become or have already become a source of environmental contamination. The number of protected surface and groundwater resources is diminishing. Most instances of groundwater contamination have been discovered after drinking water is contaminated. The remaining acceptable water resources will be threatened by actions and policies initiated without adequate supporting studies. It is not sufficient to limit the discussion of protection of water resources to the hydrogeological and hydrological aspects of selection of solid waste disposal sites. It is also necessary to briefly discuss some other aspects of land application of wastes.

This paper includes an analysis of the factors which control and affect selection of sanitary landfill sites. The case history concerns the evaluation of existing sites and selection of new potential safe sites for the Greater Amman Area.

Aspects of land application of wastes

An important aspect of the evaluation of a disposal site should be consideration of the composition of the waste (or refuse) to be deposited. The waste components may be derived from domestic wastes - vegetables, cans, ashes and industrial sources. In practice, the large variation in waste composition and the difficulty of obtaining representative samples limits the amount of reliable information that can be obtained.

Rainfall and groundwater can percolate into and through the wastes and facilitate their decomposition. Gases are generated during decomposition of organic wastes, such as CO^2 (acid), methane and nitrogen. Leachate, the water that has had contact with landfilling wastes, can obtain a wide variety of potential pollutants and may result in higher salinities, hardness, iron NO^3, SO^4, ph changes, heavy metals and toxic materials.

Initial decomposition of organic matter is aerobic. However, very soon after burial anaerobic processes predominate. The most rapid decomposition is known to take place in saturated fills with moisture content of 40 to 80 per cent.

The principal mechanisms involved in the introduction of contaminants from the landfill to surrounding water resources include: refuse docomposition, gas and leachate production, infiltration and percolation of solutions to ground and surface waters.

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The stabilisation of landfills depends primarily on the rate of decomposition of organic matter. After completion of decomposition a landfill is called stabilised or inert.

For the natural purification of leachate, several physical, chemical and biological processes are envisaged as playing important roles in purifying waste waters in the vadose zone (unsaturated zone). These are: dilution, buffering of pH, ion-exchange, chemical precipitation by oxidation reduction reactions, physical adsorption, mechanical filtration, biological degradation and, radioactive decay. Usually, not all of these processes will occur under all conditions.

Methods for protecting groundwater from contamination from sanitaryy landfills include investigation of sites possessing natural protective features, considering the geological, hydrogeological hydrological and topographical conditions. In places where such natural protective features do not exist, a well designed leachate control system should be provided, which may involve impermeable liners and covers facilities for collection, treatment and disposal of leachate and reuse of proved safe sites. The first method is the main topic of this paper.

Site selection

The selection of a waste disposal site is a complex procedure involving many factors ranging from social acceptance and economics, to air and water pollution. Geological, hydrological, and hydrogeological factors are of great importance in the selection of a safe site.

Leachate from wastes travels in the same direction as that of the groundwater in the saturated zone. The principles governing leachate movement are therefore the same as those governing the groundwater flow. (As described by Hubbert, 1940, Toth, 1962-1963 and Freeze and Witherspoon 1966, 1967). Groundwater flow is governed by geological, topographical and hydrogeological factors. Various combinations of these factors may lead to three types of flow systems (Fig.1): local, intermediate, regional.

Figure 1, indicates the importance of good understanding of the groundwater flow pattern in a given area before selecting a sanitary landfill site. It the leachate does not enter a naturally existing groundwater flow system, a new flow system will be developed at the site; the type of which is controlled by the same factors controlling the natural flow systems. The location of a landfill site in relation to the distribution of recharge and discharge area for a given flow system is also important. Where the groundwater gradient is upward (in discharge areas), the groundwater system will oppose any leachate trying to enter this system and it will soon be rejected to the surface.

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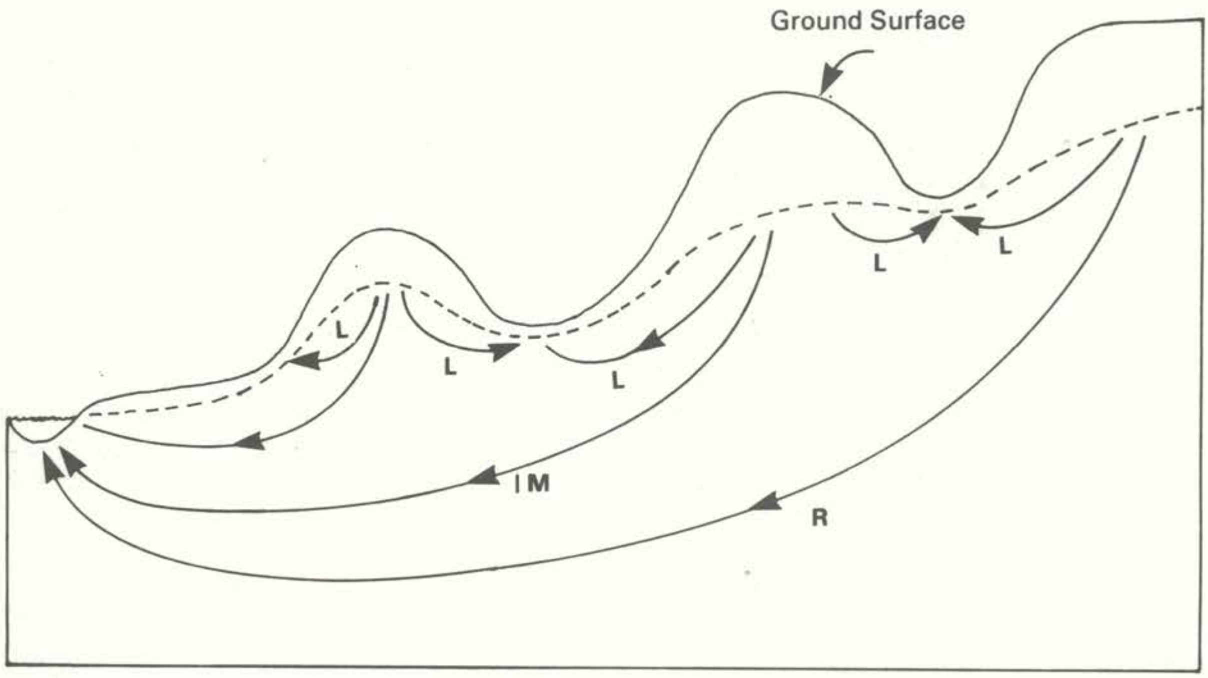
Fig. 1 Two dimensional flow pattern in hummocky water table conditions



Flow Line

Water Table

L Local Flow System

IM Intermediate Flow System

R Regional Flow System

The permeability of the materials through which water is flowing affects both the velocity and direction of groundwater flow. Clays, shales and marls are less permeable than sand, gravel and fractured indurated rocks. The water table configuration and the hydraulic gradient are also important hydrogeological factors on the characteristics of any groundwater flow system. Less dilution and dispersion takes place in groundwater than in surface water because of the relatively smaller groundwater flow velocity, (10 feet per year in some clays and shales) as well as because of the laminar flow as compared with th turbulent flow in surface water. Changes in the groundwater flow pattern due to groundwater extraction by man should also be considered in site selection.

Rainfall characteristics will determine the amount of water available from infiltration and percolation into and through the landfill to produce leachate as well as the contribution of rainfall to groundwater recharge. Run-off characteristics will determine how much surface runoff would be generated at the site, as well as the amount in the upstream part of the catchment from the site.

Catchment physical characteristics; the type and size of the catchment upstream from the site is important, because of its impact on the distribution of rainfall into surface runoff, groundwater recharge, and evapotranspiration. Stream characteristics; the characteristics of streams in the catchment have an important impact on the type of streams, and stream flow characteristics. Some of these characteristics are the flow rate type (perennial, intermitten or ephemeral), stream water quality, velocity of flow, the occurrence of rapids or falls along its course, stream channel losses by infiltration, stream length, and its natural purification capacity.

Climate conditions: temperature, humidity and potential evapotranspiration are factors which affect the rate of stabilisation of waste. A warm and humid climate will facilitate stabilisation.

Underlying geology is an important consideration in selecting a landfill site, because it must provide a structural base for the site, and a conveyance medium for the leachate leaving the soil zone. The main geological parameters affecting the selection process are: stratigraphy: the areal distribution of the outcrop areas of pervious and impervious rock materials or formation. Structure: regional and local structures such as faults, folds, fractures, and joints should be investigated. The relationship of such structures to the groundwater occurrence and movement on both the local and regional levels should be clearly understood.

The waste characteristics are also important in selecting disposal sites because these will affect the quantity, rate and quality of leachate to be produced. Liquid and semi-solid wastes are more hazardous than solid wastes. In addition, chemically contaminated wastes are much less susceptible to natural purification. The selection of sites for these types of wastes should therefore be more conservative.

The following are the most important criteria for the selection of a sanitary landfill:

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Favourable conditions

Dry conditions which cause rapid stabilisation of sanitary landfills. Saturated or moist sites are acceptable if leachate does not interfere with a useful flow system.

Geologically favourable sites include types of bedrock and unconsolidated material is important in areas where rocks of low permeability and no or very little jointing and fracturing are favourable. Examples are:

- Thick soil cover;
- Outcrops of shale, clay and marl and silt;
- Limestone and dolomite if covered by thick soil;
- Areas where sand, gravel or fractured hard rocks are exposed on the surface should be avoided, areas where geological structures do not provide an easy access for the leachate to the ground water reservoirs;

Areas where leachate may create a new flow system where leachate discharges back to ground surface in the nearby vicinity is acceptable provided a full knowledge of the expected flow pattern is available and a monitoring system is provided;

Areas where groundwater gradient is upward (towards the ground surface). Under such conditions percolating water will be opposed by the groundwater system and rejected back to the surface;

Recharge areas of regional flow systems where the points of groundwater use are far enough away to allow natural purification.

Discharge areas of small local flow systems where the discharged water is not in direct use for domestic supplies, or does not reach a main stream, or when the discharge of such a flow system is too far away to be a hazard to the population;

Anywhere in the mode of transfer of deep flow systems or aquifers away from pumpage areas;

Groundwater divide areas of regional or intermediate flow systems;

Flat upland areas, ridges above heads of gullies and ravines, dry open pit mines and quarries;

Areas where groundwater aquifers are deep and overlain by impervious rocks;

The catchments for streams with a high capacity for natural purification of their water.

Unfavourable conditions

All conditions which are different from those mentioned in favourable conditions above.

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Areas where leachate interferes, with existing used flow systems.

Depressions where water accumulates, lower reaches of gullies and ravines, sites near surface water, bodies and major discharge areas are unfavourable for such sites.

Perennial streams and their major tributaries used for important purpose; particularly if the flow is small and the rate fluctuates significantly throughout the year.

Liquid and semi-solid wastes are more hazardous than solid wastes. In addition, chemically contaminated wastes are much less susceptible to natural purification. The selection of sites for these types of wastes should be more conservative.

Case History

SELECTION OF WASTE DISPOSAL SITES FOR GREATER AMMAN

Hydrological setting

The Greater Amman Region includes the southern part of the Zarqa River catchment, the rift side catchments between Salt and Madaba, the upper-most part of Wadi Wala catchment and a small part of Azraq catchment (Figs. 2 and 3). The weather in this area varies from moist and cool during the winter to dry with relatively high temperatures in the summer. The mean annual rainfall varies from 600 millimetres in the north-western part to 100 millimetres east and south-east of Muwaggar, about 20 kilometres south-east of Amman (Fig.3) shows the distribution of 30-year average annual rainfall.

The annual open surface evaporation (Class A Pan) varies from 2500 mm to 3000 mm as shown in Figure 4. The region constitutes catchments or parts of catchments for important perennial streams; the River Zarqa and the Wadis of Shuaib, Kafrein, Hisban Zarqa, Ma'in and Wala. A significant number of base and flood flows originate in this region. An analysis of the hydrological cycle for two small experimental catchments within the Amman Region was given by MacDonald (1965) for the years 1962 to 1964 as follows (in percentages):

Catchment area	Rainfall	Evaporation percentage	Groundwater recharge percentage	Surface run-off percentage
1. Murug (10 km north of Amman	100	86	11.5	2.5
2. Um El-Amad (20 km south of Amman	10	88	9.6	2.4

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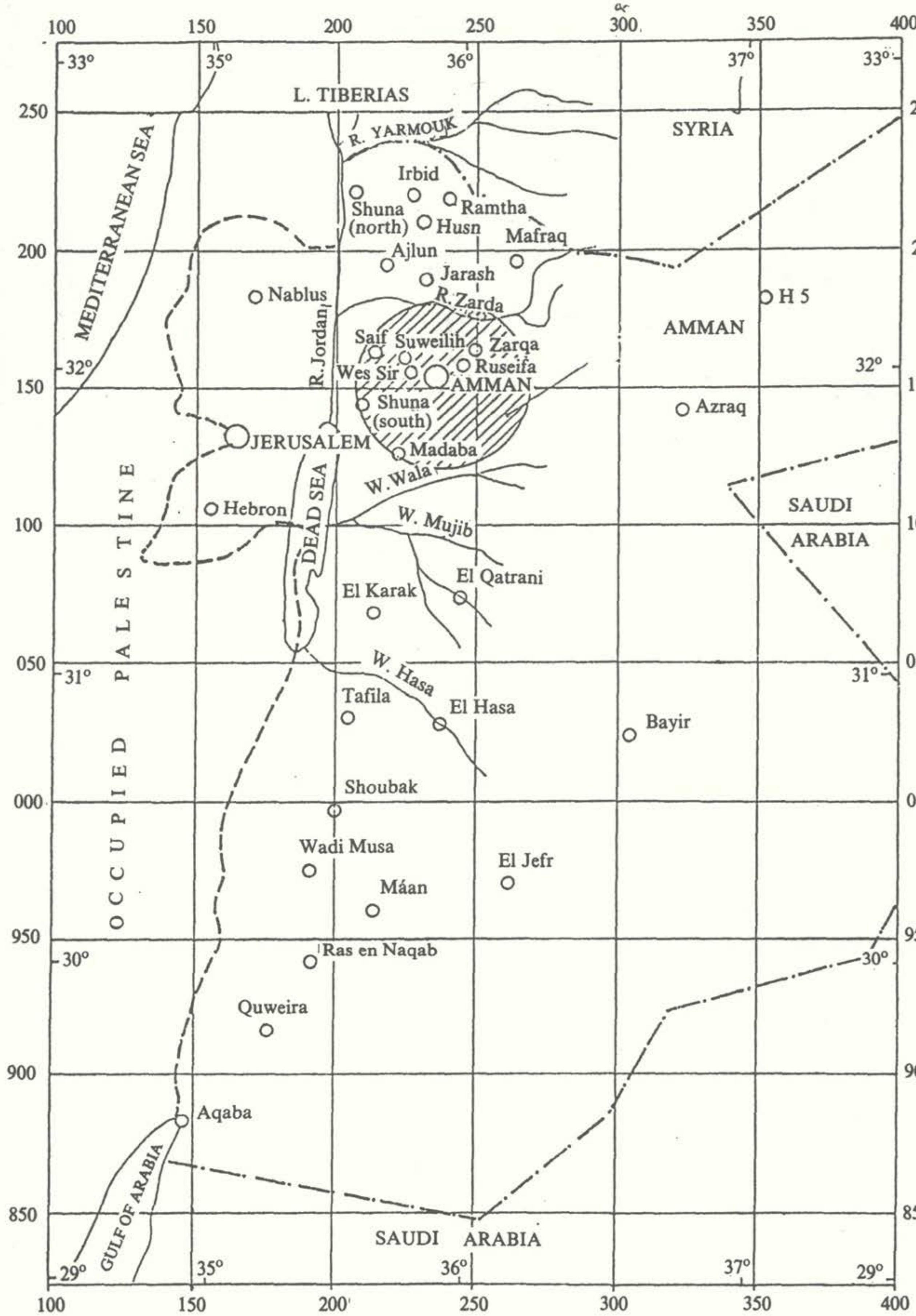

FIGURE 2: STUDY AREA LOCATION PLAN

Scale 1: 2,000,000

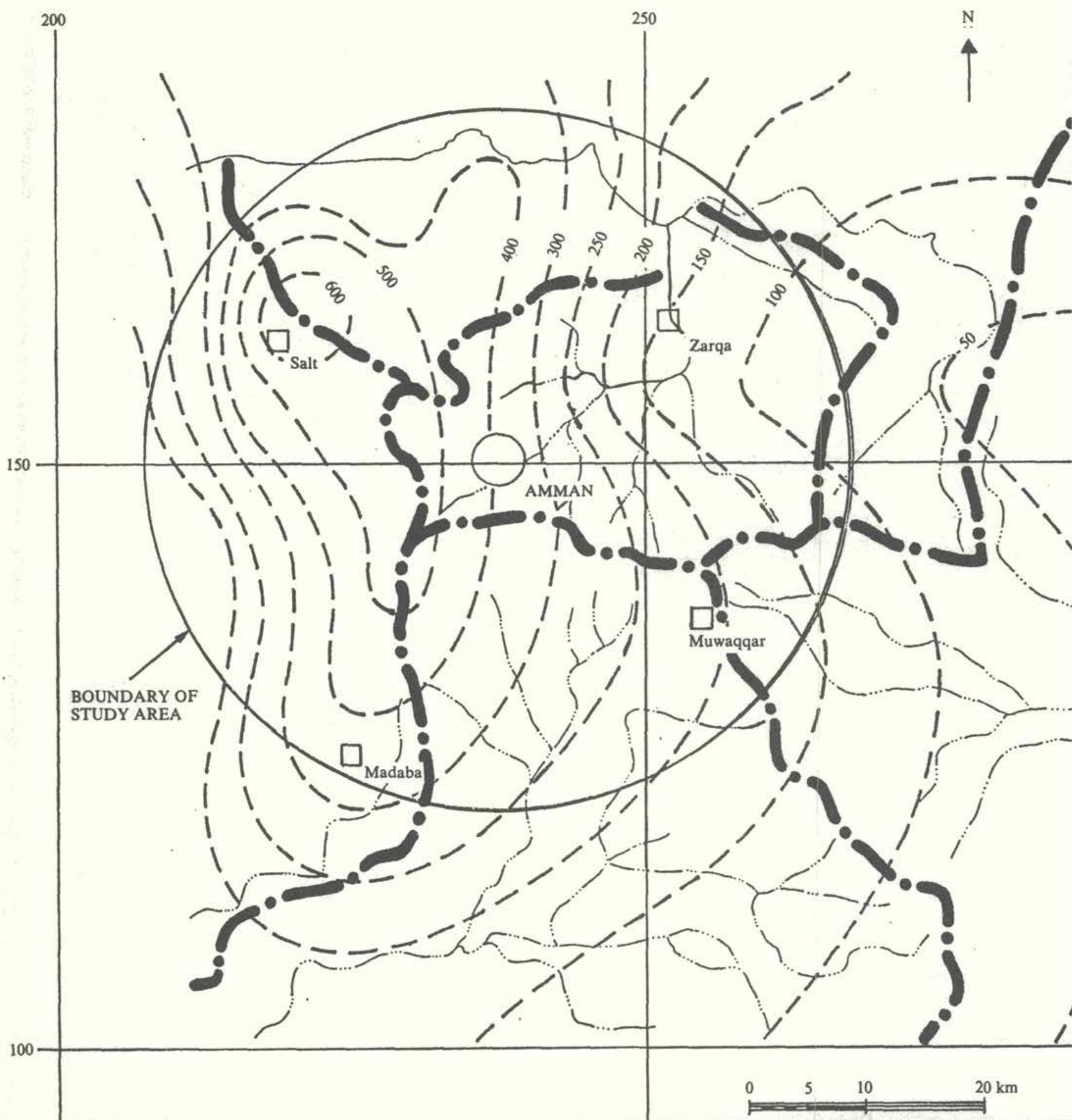

FIGURE 3: RAINFALL DISTRIBUTION IN GREATER AMMAN AREA AND THE SURROUNDING VICINITY (30 year average annual)

Isoheytal lines (mm)

Surface water catchment boundary

Wadi Perennial, Ephemeral

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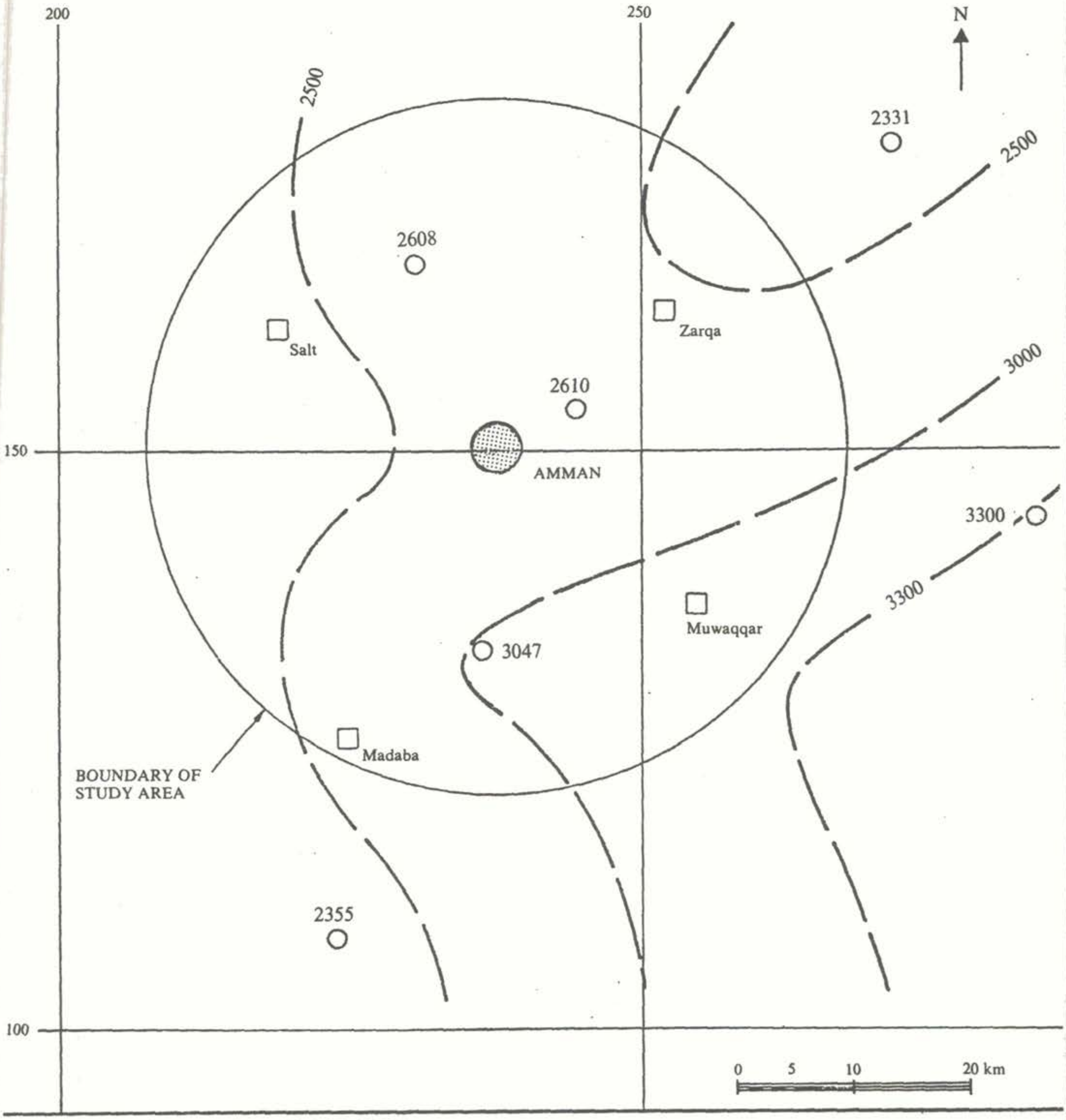

FIGURE 4: CLASS 'A' PAN EVAPORATION

3000 — Contour line of equal evaporation (mm)

3047 ○ Evaporation Station

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Hydrogeological setting

The regiona includes a number of ground water basins, sub-basins and parts of basins. The groundwater basin boundaries do not exactly coincide with the surface water catchment boundaries. This is due to the effect of the geological and hydrogeological characteristics of the area. The geological structures (faults, folds, flexures) greatly control the direction of groundwater flow and local accumulation of groundwater. On the other hand, the hydrogeological properties of the geological formations and the sequence of these formations, affect the groundwater occurrence, flow and conditions. A hydrogeological classification of the geological formations occurring in this area is given in Table 1. Some groundwater basins within the region have a high potential as water resources and are highly developed, for example the Amman-Zarqa, Baqa'a and Salt basins. A large number of wells tap the aquifers in these areas. Other areas such as Sahab-Muwaqqar are of poor groundwater potential and there is practically no development of this particular resource. A new well field has been recently completed in the Qastal area (20 km south of Amman) to supply Madaba and South Amman areas. The rift site areas between Salt and Madaba have a water surplus and supply the southern part of the Jordan Valley with irrigation water. The annual rainfall and recharge percentage for the different areas are given in Table 2.

The groundwater areas - Amman-Zarqa Basin

Groundwater in this area occurs in two important and high potential aquifers; a shallow water table aquifer in the alluvium and the B2 and A7 formations, referred to as the upper aquifer systems, and a deep artesian aquifer in the A4 limestone formation (see Table 1 for formation symbols). The two aquifers are separated by an aquitard, the A5/6 formation which acts as a leaky confining formation. Annual recharge to the lower and upper aquifers has been estimated as 5 and 20 million cubic metres (MC). Recharge takes place through direct infiltration of rainfall and run-off over the outcrop areas of these aquifers. In addition, the shallow aquifer receives about 28 MCM annually from cesspools, the sewage treatment plant effluent, leakage from the water distribution systems and from return irrigation water (VBB, 1976). This indicates a direct hydraulic connection between the ground surface and the upper aquifer. As a result, wastes tipped within the recharge area of this aquifer will become a potential source of contamination to the shallow aquifer. In fact, groundwater in both aquifers in this area has been affected by municipal and industrial waste pollution.

Salt-Madaba rift side area

This area can be sub-divided into two zones; the northern rift side zone between Salt and Wadi Hisban, which is characterised by a water surplus, and the southern zone which extends to, but does not include Wadi Zarqa Main. This zone is poorly developed and has a poor groundwater potential as indicated from the small number of low yielding springs occurring on the western slopes. The northern zone is characterised by a high annual rainfall and a high groundwater recharge rate. Groundwater in this area occurs in a number of aquifers which are tapped by a small number of wells. However, these aquifers are drained by a number of moderate to high yielding springs which contribute to the perennial streams. These aquifers also recharge the alluvial aquifer in the Jordan Valley. The groundwater in the Salt basin has been affected by pollution. The high rainfall over this area, and the high infiltration rates through the highly fractured rocks facilitate groundwater contamination from wastes tipped on the ground surface.

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Table 1

AQUIFER POTENTIAL OF LOCAL STRATIGRAPHIC UNITS

Group	Formation	Symbol	Rock Type	Thickness range (m)	Aquifer potential
	Alluvium	Qal	Soil, sand and gravel	?	Good to excellent
Jordan Valley	Lisan	JV3	Marl, clay and evaporites	300+	Poor
	Samra Neagene	JV1-2	Conglomerate with silicious cements and and and gravel	100-350	Fair
Belga	W. Shaila	B5	Limestone, chalky and marly with glauconite	350+	Poor
	Falij	B4	Chert and limestone	30-50	Good
	Muwaqqar	B3	Chalk, marly chalk and marl	300+	Poor
	Amman	B2	Chert, limestone with phosphate	30-120	Excellent
	Ruseifa	B1	Chalk, marl and marly limestone	0-75	Poor
Ajlun	Sadi Sir	A7	Limestone, dolomitic, some chert	65-100	Excellent
	Shueib	A5/6	Limestone, marly limestone	70	Fair to poor
	Hammar	A4	Dolomite, dol. limestone	60-120	Good to fair
	Fuheis	A3	Marl and marly limestone	80-120	Poor
	Na'ur	A1/2	Limestone, dol. limestone, marly limestone	250-350	Good
Kurnub	Subeihi	K2	Sand, shale, clay and sandy limestone	230-270	Fair to poor
	Aarda	K1	Sandstone, marl and shale	?	
Zarq	Huni	Z2	Limestone, marlstones, sandstone and shale	200-250	
	Main	Z1	Limestone, shale, sandstone and evaporites	?	Poor

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Table 2

RAINFALL AND RECHARGE PERCENTAGE (MacDonald, 1965)

	1959-1960		1960-1961		1961-1962		1962-1963		1963-1964	
	Rain-fall	Recharge as per cent of Rainfall	Rain-fall	Recharge as per cent of Rainfall	Rain-fall	Recharge as per cent of Rainfall	Rain-fall	Recharge as per cent of Rainfall	Rain-fall	Recharge as per cent of Rainfall
Salt Kafrein	178	Nil	417	18.4	322	8.9	186	Nil	525	24.9
Lower Zarga Valley (south)	152	Nil	392	17.9	332	4.9	228	Nil	469	17.2
Upper Zarga Valley	93	Nil	231	1.6	233	Nil	145	Nil	300	2.0
Madaba	134	Nil	325	3.1	325	2.7	117	Nil	475	19.2
Sahab-Mushata	79	Nil	248	2.9	223	Nil	109	Nil	312	7.1

Bagas Basin

This is a relatively highly developed groundwater basin with a limited potential. Sandstone forms the main aquifer which occurs under water table conditions. Groundwater recharge takes place from direct and indirect infiltration of rainfall over the aquifer outcrop area. So far the water quality is good; however, with increased urbanisation and industrial development in this area, groundwater pollution becomes possible unless protective measures are provided at an early stage.

Madaba-Muwaqqar area

This area includes two groundwater zones, the Qastal-Jiza and Sahab-Muwaqqar zones, Groundwater in both zones occurrs in the B2/A7 formations. However, the excessive depth to the aquifer in the Sahab-Muwaqqar area, in addition to the small quantity of groundwater flow in this area, results in the groundwater resources being economically unexploitable. In Aqastal-Jiza area some development is taking place and more is planned in the near future. The depth to water varies from 150m in Qastal to more than 200m in the Sahab-Muwaqqar area.

The B3 marly formation, which overlies the aquifer over much of the area, and the thick silt cover limit the amouunt of recharge. In addition, the relatively low annual rainfall in Sahab-Muwaqqar area makes the groundwater potential significantly low.

Geological/Hydrogeological Criteria for Site Selection

A number of criteria have been adopted for selection of safe waste disposal sites. These are respectively, geological, hydrological and hydrogeological, those related to the natural purification capacity of the rock and earth material and finally the physical, chemical and bacteriological characteristics of the wastes.

Geological criteria

The outcrop areas of marl and shale clay and thick soil covers are preferred rather than limestone formation outcrops. Fault zones and areas with intense fracturing and jointing should be avoided.

Hydrological criteria

Areas with high rainfall averages are not preferred. MacDonald, 1965, found that areas receiving less than 200mm of rainfall annually do not contribute any recharge to groundwater. An average annual rainfall of 150mm is a better and more conservative figure for the purpose of this study.

Therefore, sites west ofthe 150mm isohyet should be avoided unless other geological, hydrological and hydrogeological factors greatly favour a site. Infiltration rate and depth of rain water, or any other fluid, should be reasonably slow and shallow, respectively. Sites should be selected at sufficient distance from major streams particularly perennial streams. Catchment areas of such streams should be avoided as far as possible, unless the amount of run-off passing though the selected site is very small.

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Hydrogeological criteria

Site selection should avoid the following areas:

Recharge areas of the relatively shallow water table aquifers such as the upper aquifer in the Amman-Zarqa basin and in the Baq'a area.

Recharge areas of exploitable and potential aquifers and areas of groundwater abstraction and well fields.

The domain of local groundwater flow systems which usually have a short flow path and travel time of groundwater.

Groundwater discharge areas, where any infiltration of water or other fluids will very soon reappear as groundwater discharge without having any opportunity for natural purification.

On the other hand, the following conditions favour the selection of waste disposal sites:

The domain of regional groundwater flow systems away from their discharge and pumping areas. such flow systems would ensure natural purification before groundwater is discharged or pumped.

Outcrop areas of impermeable formations (aquicludes), or semi-permeable formations (aquitards), or areas of thick soil cover. Such areas do not contribute significant recharge to groundwater.

Areas where the first aquifer is deep, or separated from the ground surface by a relatively thick, impermeable formation.

Natural purification capacity of the rock material

Unindurated alluvium with a high percentage of fine clay, silt and sand and with sufficient thickness and extent, usually have a high natural purification capacity. Also soft, friable sandstone has a good purification capacity. On the other hand, fractured hard rocks hardly ever possess such capability. Clays and shales can purify contaminated water but at relatively slow rates. Limestone, marlstone, chert and well indurated sandstone falls into this category.

Waste characteristics

The waste characteristics are also important in selection of disposal sites because these will affect the quantity, rate, and quality of leachate to be produced. Liquid and semi-solid wastes are more hazardous than solid wastes. In addition, chemically contaminated wastes are much less susceptible to natural purification. The selection of sites for these types of wastes should be more conservative.

Proposed groundwater protection areas

Based on the above-mentioned criteria, groundwater areas which should be protected are identified and shown in Figure 5. Disposal of wastes in this area will sooner or later affect the groundwater resources. These wastes will remain a potential source of pollution in the long run, and aquifers, once polluted, will require years to become purified again because of the slow movement of groundwater.

Proposed new sites for waste disposal

Based on the previous discussion, sites which would provide maximum protection for water resources have been selected, and are shown in Fig.5.

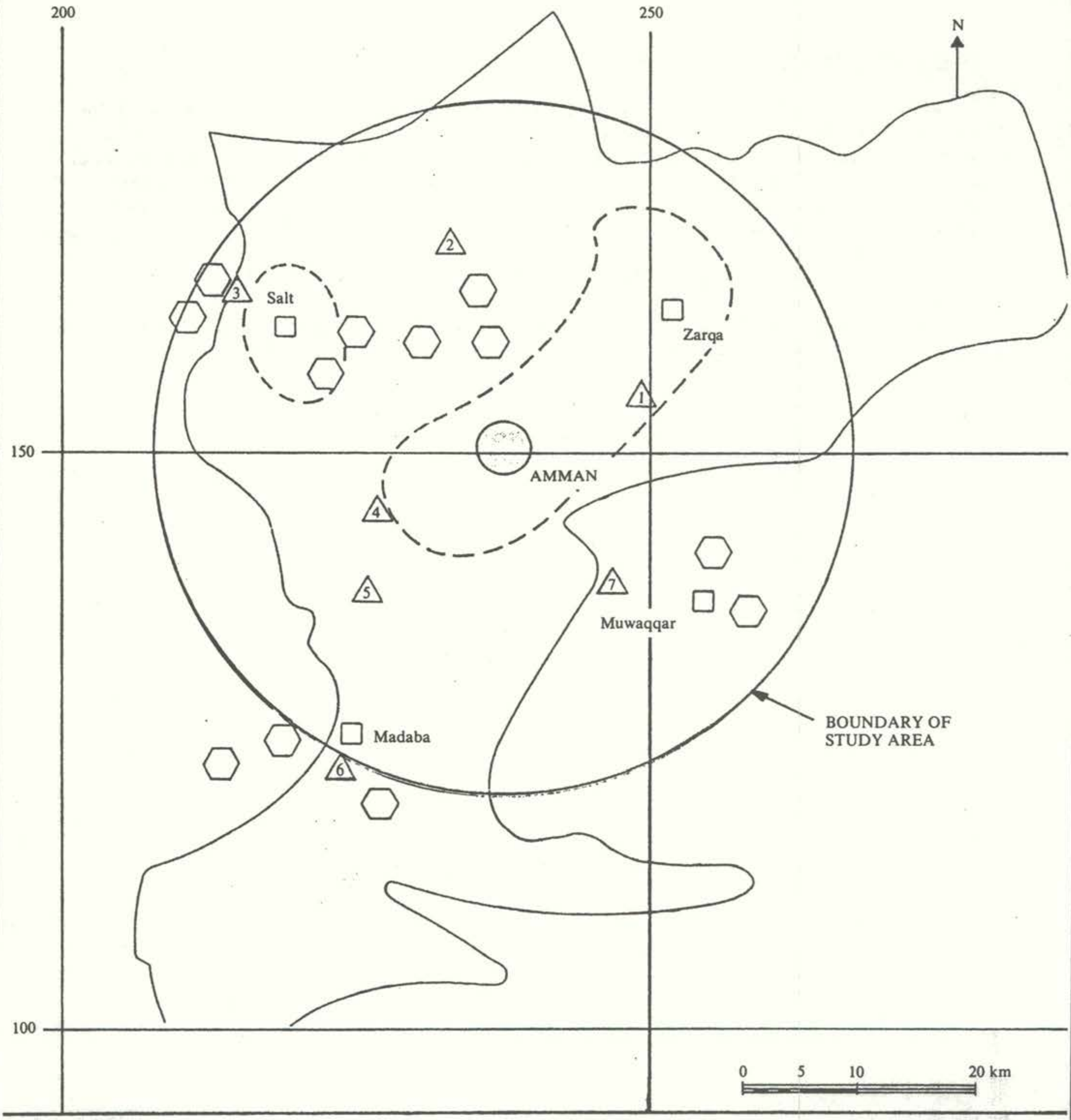
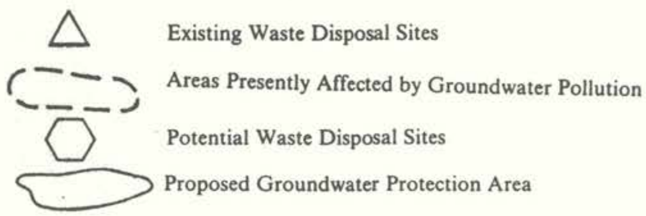


Fig. 5 EXISTING AND POTENTIAL DISPOSAL SITES WITH PROPOSED GROUNDWATER PROTECTION AREA



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Amman-Zarqa area

Three alternative sites were considered:

The Muwaqqar site is about 3km east of Muwaqqar. The following points are in favour of this location:

It is located in the recharge area of a regional groundwater system which flows towards Azraw in the eastern desert. The relatively long travel path and time will ensure natural purification takes place before groundwater reaches the points of use.

Very limited recharge takes place in the Sahab-Muwaqqar area because of the low annual rainfall, thick soil cover, and the outcrop of the B3 marl formation which overlies the B2/A7 aquifer.

No groundwater development exists in this area.

Surface water run-off is also limited in this flat and low rainfall area.

The depth to the aquifer is excessive and separated from the surface by thick impermeable material. No disadvantages, hydrologically speaking, are seen for this site and it is therefore recommended for the Amman-Zarqa area.

The Zumlet al Alya site is about 5km north of Muwaqqar and about 8km east of Sahab. In terms of hydrogeological conditions, this site is very similar to the Muwaqqar site, and is accordingly also recommended for the Amman-Zarqa area.

The Yajuz site is about 20 km northwest of Amman. It is located on top of the impermeable A3 marl formation. The A5/6 formation outcrop in this area is not recommended because of its semi-permeable nature, being an aquitartd, and its location between the two main aquifer systems in Amman-Zarqa area. This formtion proved to provide some hydraulic connection between the upper and lower aquifers. The location on top of the A3 formation is not highly recommended because of its limited extent in such a rough terrain, and because of the high rainfall and recharge rate in this area. Any run-off from the disposal site might flow on top of the A3 formation to enter the A4 aquifer. Aquifers recharged in this area are either highly exploited by wells, or furnish a good number of low to high yielding springs. Moreover, urban expansion is expected to reach this area in the near future, and hence, this site is the least preferred of the three potential sites identified in the Amman-Zarqa area.

Salt area: the site is about 6-7 km west of Salt. It can be located on top of the A3 formation if it is intended for a small quantity of solid wastes. The sandstone outcrop further west is a better alternative site for any quantity of waste since this potential aquifer is not exploitable in this area and the surroundings. Moreover, the sandstone is likely to have a good natural purification capacity.

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Suweileh area: The selected site is located 8km southwest of Suweileh on top of the sandstone outcrop. The points favouring this location are similar to those of the second alternative site of Salt, in addition to being a recharge area of a regional groundwater flow system. These advantages make this site most appropriate, hydrologically speaking, for such a high rainfall area.

Madaba area: two alternatives are given for this area:

A site 4-6km east of Madaba on top of the A3 outcrop where top soil is relatively thick. This site will be safe for solid waste disposal. There is, however, some uncertainty for using it for liquid or semi-liquid wastes unless a thick part of the A3 marl and a thick soil cover exist.

The second site is about six to 10km from Madaba. This will bring the site to the A3 or A5/6 outcrop. These formations will provide some protection against deep infiltration. Moreover, this site is located within the Dead Sea rift side catchment which is known to have a very poor groundwater potential and almost no development of water resources.

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AN APPROACH FOR COMPOST PRODUCTION FROM MUNICIPAL WASTE: KATHMANDU/PATAN, NEPAL

by S.B. Thapa
Director, Solid Waste Management Project

Teku, Nepal

Summary and suggestions

The physical and chemical characteristics of solid waste in the two cities of Kathmandu and Patan suggest that it is worthwhile to adopt composting as an alternative method of solid waste disposal. It will be worthwhile composting a greater quantity of the solid waste generated and the methods and technology used for composting should be objectively evaluated to extract maximum benefits.

Disposal by composting provides a hygienic method coupled with recovery of manure. It is felt that as far as possible pre-fermentation type composting with the cost effective mechanization should be practised in the Kingdom of Nepal.

A poor country like Nepal should apply a low technology, simple design, labour intensive and low capital cost scheme for the proposed full scale compost plant. The waste is suitable for the production of compost. The organic component will further increase when house-to-house collection is introduced. The different tests carried out at a rate of 20 tonnes per hectare by the Agricultural Science Division in Kumaltar have shown that the compost clearly leads to increased yields.

In the first stage, the proposed compost plant should definitively include preliminary sorting, screening and glass breaking.

In the initial full scale composting phase the compost windrows should be cone shaped and in the final composting phase they should be of the table type. During the first stage of construction a front end loader should be used to turn over the windrows, while in the final construction stage a turnover machine (turning and aerating machine) should be provided.

The cost of producing compost is one of the key factors in insuring success. Compost is a bulky and heavy material which involves the user in heavy operational costs which do not apply to mineral fertilisers. Delivery costs are important and the processing centre should be as central as possible to its market area. Municipal wastes have to be properly disposed of, and it should be accepted that part of the cost of producing compost is a direct garbage disposal element which should be borne by the user of the compost.

The objective of any compost project should be to produce good quality compost at the lowest possible cost. A marketing and delivery service contract for supply of compost to farmers should be considered. The local agencies should be encouraged to recycle non-compostible materials by supplying them with necessary technical help.

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The leachate produced by the compost plant should not create pollution in the surrounding area. This should be controlled through landscaping and other means. Most of the agricultural land of the Kathmandu Valley is becoming acidic. Research should be done on using agricultural lime in the compost.

For the fermentation of compost the use of drinking water should be given less priority where drinking water supply is inadequate for the two cities. Rather it would be better to use unfiltered water or sewer water. For protection against the prevailing winds, rains, etc. it is recommended that the windrows be covered with bamboo mats, etc.

It has been observed that unlike the European refuse, which can contain bulky wastes, Nepalese wastes consist of materials mostly of a size below 50mm. Shredding of waste is costly in terms of the high capital costs involved for a hammer mill or a pulveriser and in terms of high energy cost in running these units and is not essential for the proposed compost plants in Nepal.

An English economist, E.F. Schumacker warned us a decade ago: "Man has always made an enormous mistake in evaluating nature, he has always taken advantage of the natural resources by treating them as an unlimited source of richness without realising that nature must be considered as a fund from which one can draw only the yield, if one wants to keep its dimensions intact". Everybody is aware of the lack of equilibrium in the natural world caused by modern societies exploiting resources without taking care of raw material recycling. So, while on one hand a poor country like Nepal is facing waste disposal problems, especially in the urban areas, on the other hand, soils are being washed away every year through floods, landslides and erosion. Thus, fruitful soil, to remain so, must keep its biochemical characteristics and to do so it is necessary to restore the organic substances that have been removed. Therefore, the problem of Nepalese solid waste treatment should be considered in the context of the problem of soil structure in agricultural areas, where fertility is diminishing year by year. Humus, made of organic matter present in the soil, is too often burnt by the excessive use of chemical fertilisers; the ground becomes mineralised and, therefore no longer makes a favourable environment for cultivation. The use of compost in fact, once widespread, gives the first considerable example of recycling of organic matter, and its ecological significance is perhaps more important than the economical advantages derived from its use.

A poor country, like Nepal does not produce chemical fertilisers. The major sources of chemical fertilisers are commercial imports by bilateral and multilateral aid. It is time to start a campaign at national level to encourage production of organic manure so that the much needed nutrients can be replenished in the soil. This has become more important in the light of mounting bills for importing chemical fertilisers. In fact, organic manure (compost) is essential to increase the effectiveness of chemical fertilisers.

In view of the above, the Nepal Solid Waste Management Board is going to establish a full scale compost plant in the capital of the Kingdom of Nepal, through co-operation between the Federal Republic of Germany and the Government of Nepal.

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Where the scale of fully mechanised composting is concerned, the Nepalese Government should not underestimate their achievements with manual methods; they should seek to develop the mechanisation of the Nepalese system rather than adopt European methods designed for totally different wastes.

Values of composting of city wastes

The Kathmandu-Patan city wastes have a low calorific value, high moisture, high organic matter, and ash content, so that compost manufacturing is the only method which produces a useful product which is sure to enhance the agricultural output of our land. There are two important health aspects associated with disposal and utilisation of wastes. One is the high incidence of illness and death from faecal borne diseases which result from insanitary disposal and utilisation of waste. The other is improved nutrition, an important factor in the prevention of diseases, which can be obtained when the wastes are returned to agriculture to provide plant nutrients, i.e. compost (National asses)

Waste Analysis

The sample of general city waste was collected from the centre of Kathmandu and Patan. Then, the garbage was separated in different fraction as follows (see Table 1):

Straw, dung, kitchen waste, etc.
Paper, cardboards
Metals
Plastics
Woods
Stone, pottery fragments
Textiles
Glass
Bones, leather

To get an exact percentage of moisture content the compostable garbage was spread out and dehydrated in the appropriate equipment. Finally, it was dried by heating up to 100^{o}C and its total moisture content was found to be 30 to 50 per cent. The proportion of organic matter on average is 40 to 65 per cent, the water content is on average 35 per cent.

Pilot composting tests

The solid waste delivered to the site was dumped onto a platform where the non-compostable components and any valuable materials were sorted out. The workers were either standing or moving about in the solid waste heap all the time. Subsequently the waste suitable for composting was watered in a mixing bay for 24 hours in order to achieve a water content of 40 to 60 per cent. The triangular windrows have a base measurement of 2m to 3m, height of 1.8m, and the length of windrow depends on the amount of waste heaps and so on. After frequent turning over of the windrows the composted matter was then screened in ordinary wire mesh net by the workers. The number of screening stages are planned (see Fig.1). Finally, the composted materials was screened with sizes of 4, 10 and 20mm and square screen holes. The turning over of the windrows after a standing time of five days can be seen clearly at the dips in the temperature curves (see Fig.2). During the period of composting temperatres higher than 60^{o}C were measured at depth 1.5 metres on

PILOT COMPOST PLANT

TABLE 1. THE MOISTURE CONTENT IN CITY GARBAGE WARD NO. 25 HANUMAN DHOKA QUANTITY 0.50 CUBIC METRES

Particulars	Quantity		Moisture	
	Kg	Per cent	Kg	Per cent
Straw-dung, Vegetable				
Material	88.0	01.97	31.00	21.83
Stone, pottery, fragments	20.0	14.08	5.00	3.52
Paper, card board	10.0	7.04	4.00	2.81
Textile	19.5	13.73	9.50	0.68
Metals	1.0	0.70	0.50	0.35
Glass	0.5	0.36	-	-
Plastic	2.5	1.76	1.0	0.70
Woods	0.5	0.36	-	-
Total	142.00	100.00	51.00	35.89

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14 days at a depth of 1.0 metres on 6 days and at a depth of 0.3 metres on 24 days. At the end of the composting period the temperature level was at 60°C. The final screening with screen hole sizes 4, 10 and 20 mm produced the following results:

0 - 4 mm	100.0 kg	16 per cent
4 - 10 mm	201.5 kg	32 per cent
10 - 20 mm	181.4 kg	29 per cent
20 mm	145.6 kg	23 per cent
	628.5 kg	100 per cen

Chemical analyses of carbon, nitrogen, pH value, potash and phosphorus were prepared. The analyses were carried out by the Agriculture Science Division, Kumaltar, Nepal and Tractel Tirfor, India. The results in percntage of dry matter are as follows:

o	carbon:	16.8 per cent
o	nitrogen:	0.96 per cent
o	C/N:	17.6 per cent
o	pH value:	0.7 per cent
o	potash:	0.7 per cent
o	phosphorus:	0.6 per cent
o	ash:	72.0 per cent
o	organic substances	28.0 per cent

Plant tests were also carried out and evaluated in Kumaltar, Nepal.

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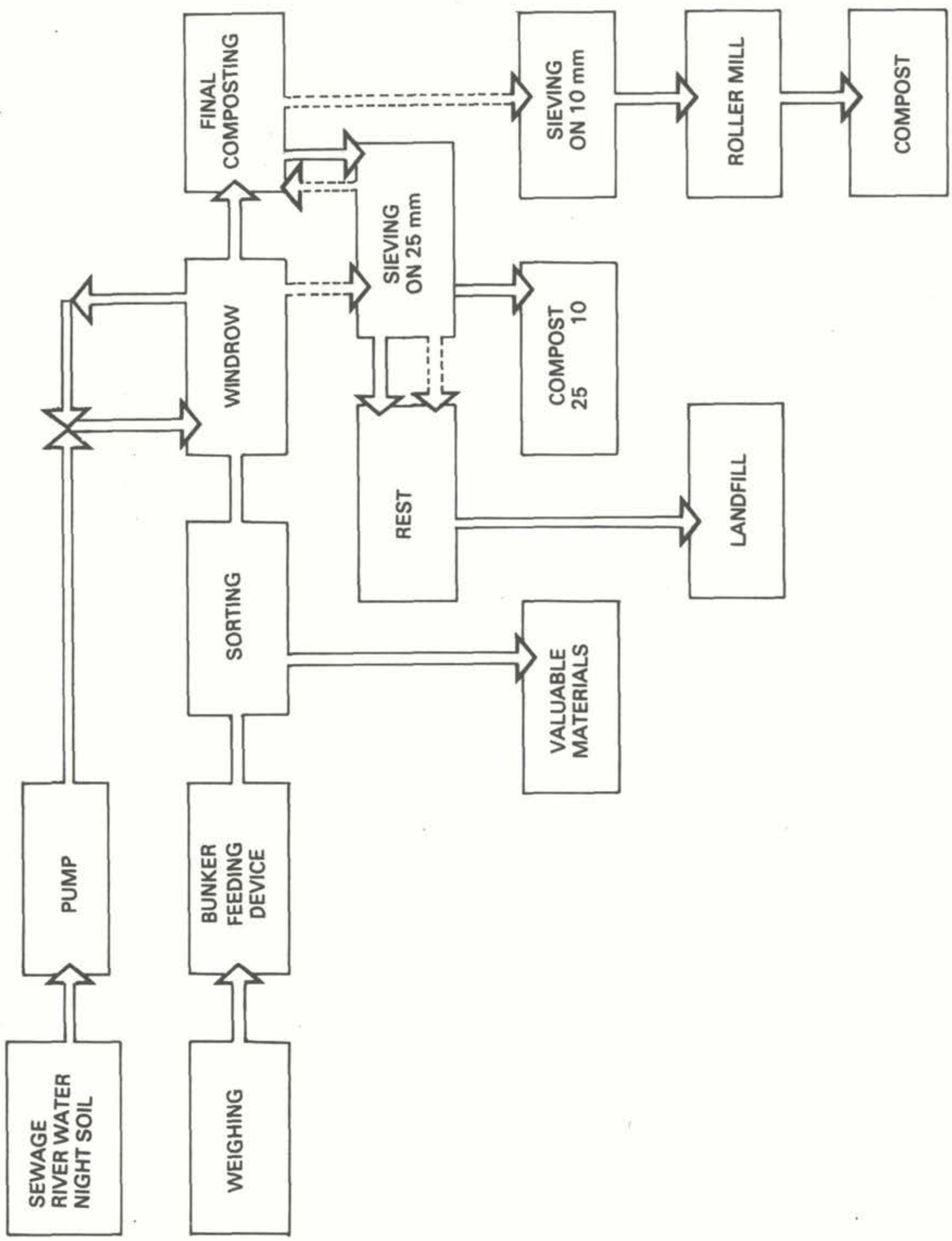
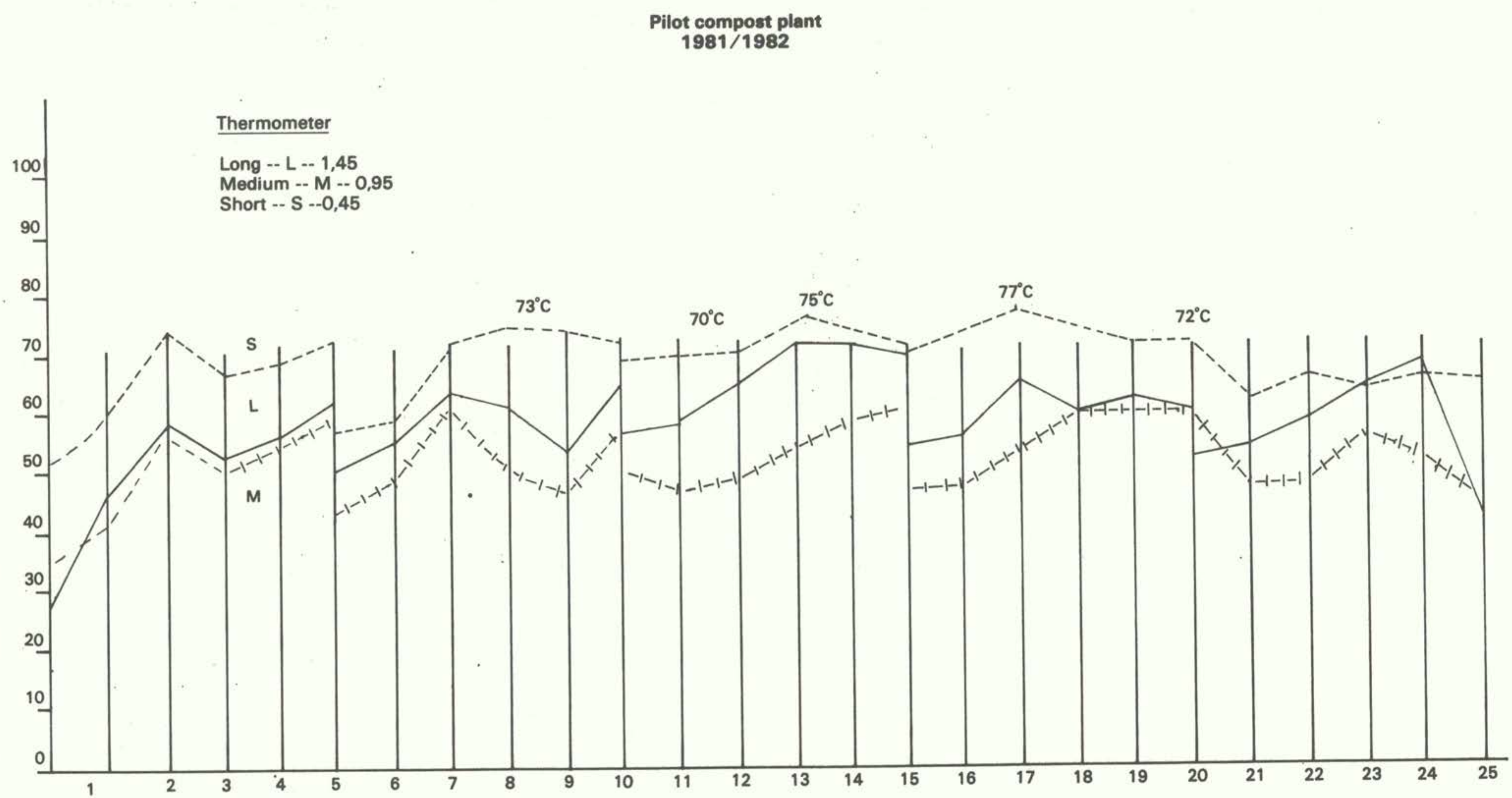


Fig. 3 Flow diagram of the future compost plant

Fig. 2 Temperatures in the windrow



Pot tests with Indian corn

Control	1.52 grams	100 per cent
Compost 100 per cent	2.65 grams	174 per cent
Compst 50 per cent	2.12 grams	139 per cent

Field test with Indian corn and chilli (20 tonnes per hectare)

Indian corn

Control	2533 kg/hectare	100 per cent
Compost	3568 kg/hectare	141 per cent
Chilli		
Control	3200 kg/hectare	100 per cent
Compost	5600 kg/hectare	175 per cent

No toxic effect of city waste compost was observed. It is clear from the experiments that though city waste compost increased the yield, to have better production balanced amounts of chemical fertiliser should be used with city waste compost. Undecomposed materials like sand, wood pieces, glass particles, etc. present in the compost should be removed. The quality of compost can be further increased by complete decomposition, which can be attained by maintaining proper pH, moisture, C/N ratio and time period.

2. IMPORTANCE OF COMPOST PLANT

2.1 Compost vs chemical fertiliser

The compost marketing survey confirmed that the production and use of compost in Nepal is a traditional process. More than 90 per cent of the farmers interviewed use chemical fertilisers and compost in parallel with one another. About 80 per cent of the compost was produced by the farmers themselves. The farmers questioned expressed the desire to buy about the same volume again. The volume of compost used each year is about 20 times that of chemical fertilisers. The demand for compost is quoted by the farmers as being 20 tonnes per hectare and this figure shows a minimum demand per annum. Compost rates of 20 tonnes per hectare each year are also usual in Europe and America. On the basis of the preceding figures, a compost demand of approximately 1,200,000 tonnes per annum is calculated for the agricultural areas of the Kathmandu Valley (approx. 60,000 hectares). This should be seen against the volume of compost which can be produced by the Solid Waste Management Board from the solid waste collected from the range approx. 20,000 to 42,000 tonnes per annum from 1984 to 1990.

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The demand quoted by the farmers must be influenced by this price structure (see Table 2), i.e. if compost prices were lower, more compost would be used and at the same time there would be a reduction in the use of chemical fertiliser. Due to these facts the establishment of a full scale compost plant is felt to be urgent.

2.2 New full scale composting plant and its process

Internationally it is found that the most successful compost plants are of moderate capacity and simple design. Large, sophisticated and heavily mechanised designs are proving to be unreliable or uneconomic for a poor country like Nepal.

In this regard, observations as well as studies have been done by experts. One of the most important guidelines was given by the evaluation team (evaluation report) on the aspect of a future compost plant which is in favour of a preliminary sorting out of valuable materials, screening, glass breaking, compost maturing and storage area and other standards prior to final composting.

After solid waste intake has been weighed (see Fig. 3) a sorting section is provided, the waste is dumped into an intermediate bunker, whereby the natural gap in the ground between the road and the plant site can be exploited to the full. By placing a ramp (see also the plan in the annex) it is possible to empty the containers directly into the bunkers. This ramp can also be used for transloading the containers into the lorries so that the Teku Site can serve as a transfer station at no additional cost.

The waste reaches the sorting belt via a feeding device. On the basis of present experience, plastic, metals, bones, paper and large glass bottles are sorted out. To what extent there is a market for textiles is still to be clarified. Since experience has so far shown that only broken glass is to be found in the city waste, it will be possible to sort out the glass in particles from the belt.

For the first construction stage of 42 tonnes a day, one sorting belt operating seven hours a day will be sufficient, six tonnes will pass along the belt each hour. The experience gained in other countries, in particular, has shown that women especially have a high work output in these jobs. The height of the belt should be designed such that the edge of the belt is at waist level for workers of average height. The width of the belt may not exceed 75 per cent of the arm's reach, otherwise the same number of staff must be posted again on the other side. It is planned that each sorter should have a simple handcart with a volume of 200 litres into which the materials sorted out can be thrown. The sorting personnel must in any case be equipped with rubber gloves.

It must be pointed out that as a result of these facilities, a group of approximately 40 people, who currently carry out this work at the present dumping site with the most primitive means, will lose their livelihood. However, for them this is the only possible way to survive. The project envisages that this group be engaged as a sorting team when the proposed full scale compost plant is commissioned.

The overflow from the sorting belt falls into one of the mobile containers. this is then driven by a tractor with a hydraulic trailor to the compost windrow area on a rotation system and the contents are dumped there.

TABLE 2. COMPILATION OF THE QUESTIONS AND RESULTS OF THE SURVEY ABOUT THE USAGE OF FERTILISERS (COMPOST/CHEMICAL FERTILISER)

Date: November 1980 to April 1981
Number of farmers interviewed:

Kathmandu	1,740
Patan	1,126
Bhaktapur	626
Total	3,492

Question	Result		Annex
Do you use fertiliser?	Yes	Almost 100%	6
What kind of fertiliser do you use?	Only chemical	6%	1
	Only compost	2%	1
	Both	92%	1
What yearly amounts of fertiliser do you have?	Chemical	355 kg	2
	compost	9100 kg	2
How much have you paid for fertiliser in the last 12 months?	Chemical	644 NRs	3
	Compost	167 NRs	3
Did you have problems with the delivery of chemical fertiliser?	Sometimes	50%	-
	Often	45%	6
Do you produce compost yourself?	Yes	94%	4
Which method do you use for composting?	In one covered pit	68%	4
	In several covered pits	5%	4
	Open in heaps	21%	4
What amount of compost do you produce yourself?	203 Bhari =	7,100 kg	5
What costs do you have for this?		361 NRs	5
What amount of compost would you buy extra?	174 Bhari =	6,090 kg	6
How much would you pay for it?	5NRs/Bhari =	140 NRs/t	6

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Question	Result		Annex
What distance would you accept for transporting the compost yourself?	approx. 1,300m		-
How much land do you own?	13,5 Ropani =	0,675 ha	7
What amount of fertiliser do you need per ropani ($500m^2$)	Chemical	39 kg	7
	Compost	1000 kg	7
Do you use nightsoil for fertilisation? How much in a year?	Yes	13%	8
	23 tins =	450 kg	9
How much have you paid for it?	3,67 NRs/tin =	200 NRs/t	9

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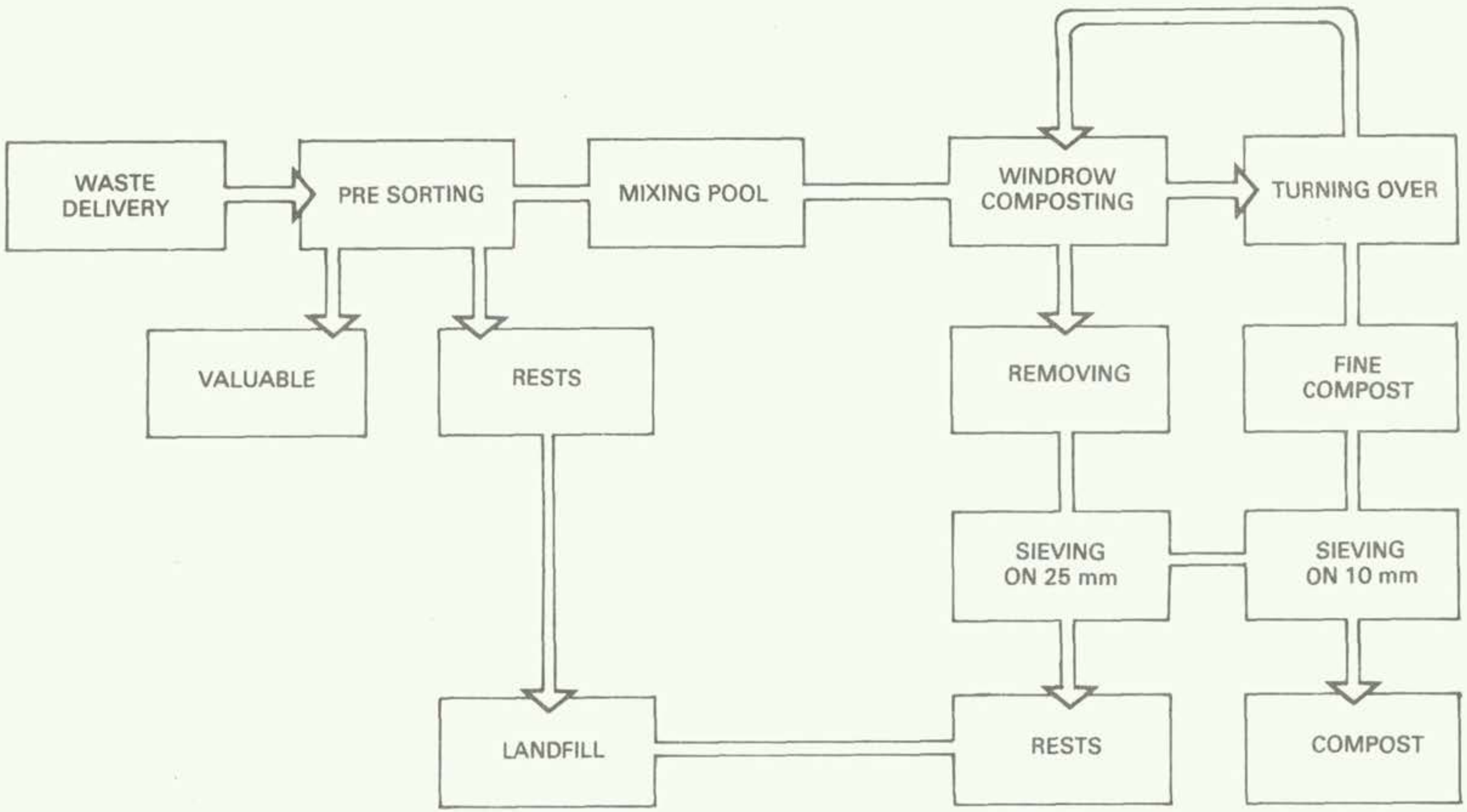
Fig. 1 Flow diagram of the pilot compost plant



As the windrow are built up, water is added to achieve the water content necessary for composting. It is planned as a first priority that this water should be taken from the main sewer from Kathmandu which runs along the compost site boundary. Only if this is not sufficient will water be drawn from other sources.

In the first construction phase the forming and turning over of the compost windrows should be by manual as well as front-end loader operations. The most important consideration in turning compost, apart from aeration, is to ensure that the material on the outside of the pile is turned into the centre, where it will be subjected to high temperatures.

The screening station should be provided between the initial windrows on the site. On the one hand there is a good possible location here from the point of view of site arrangement, while on the other hand this solution leaves open the question as to whether screening should take place prior to or after the final composting period. The screening station consists of a cylindrical screen which should be designed so that it has easily exchangeable screen plates and is covered in order to prevent dust emissions. To start with, two plates should be inserted with 10 adn 20mm, 10mm in the first third and 20mm in the last two-thirds. In this way two types of compost can be obtained. The elimination of broken glass is only possible with the aid of a wind or vibration device. Both processes must be excluded for this plant because the technology is too complicated and costly. It is therefore proposed to install a roller mill which will crust brittle materials and thus reduce the glass to such an extent that there will be no further risk of injury particularly after the product subsequently runs through the final composting phase. But in this regard, special attention should be taken to minimise glass particles.

The final composting period is fixed at 60 days with a maximum windrow height of 2 metres. The final composting area should be roofed over. All the window surfaces should be strengthened and the windrows should be provided with a drain. Intermediate transport should be carried out either by mobile manual operations or by means of a front-end-loader.

The extent to which a windrowing machine is desirable will be left to the experience gained in the first construcstion stage. The same applies for the milling of the solid waste at any point in the course of the various process.

2.3 Cost estimate

The current cost calculation can only be considered to be a very rough estimate of the costs since an exact calculation can only be made on the basis of detailed plans and after quotations have been called in. The costs are compiled in Tables 3 and 4, divided into construction measures and extension stages. Hence in the first stage the construction investment costs of NRs 2,192,730 must be reckoned with. The final construction stage with the use of a windrowing machine would require a further NRs 2,841,670.

2.4 Calculation for running costs

The probable running costs, depreciation and personnel costs in accordance with current cost and depreciation levels for the final construction stage are shown in the tables.

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The annual total is made up as follows:

Capital equipment-depreciation + maintenance	= NRs	996 000 p.a.
Capital equipment-operation	= NRs	531 100 p.a
Personnel costs	= NRs	592 750 p.a.
Construction mesasures - depreciation + maintenance	= NRs	302 064 p.a.
	NRs	2 422 814 p.a.

This results in compost production cost of 2,422,814/132t/d x 0.54 x 365 = 93 NRs/t saleable compost.

TABLE 3. CONSTRUCTION WORKS FOR THE COMPOSTING PLANT (COSTS IN NRs)

	First construction stage	Final construction stage
Water and electricity supply	150,000	-
Preparation of the area	100,000	200,000
Construction of the area	525,000	A. 1,306,200 B. 964,600
Streets, platforms	180,000	370,000
Consolidation of the river banks	200,000	210,000
Entrance building	100,000	---
Ramp	62,000	---
Water tank	70,000	130,000
Garages	80,000	---
Roofing of the final windrows	370,730	917,070
Drainage	30,000	50,000
Construction of the water inlet from Vishnumati	150,000	---
Buildings	145,000	---
Pumping station	10,000	---
Water inlet from the sewer	20,000	---
Total	2,192,730	A. 3,183,270 B. 2,841,670
Depreciation and maintenance (on average 6 per cent)	5,034,400 x 0.06 = 302,064 NRs	

TABLE 4. EQUIPMENT FOR THE COMPOSTING PLANT (COSTS IN NRs)

	Pieces	First construction stage	pieces	Final construction stage
Weighing facility	1	250,000	-	-
Sorting section (conveyor belts)	1	1,150,000	1	150,000
Pumps	2	125,000	2	125,000
Trailors	2	200,000	-	-
Containers	3	60,000	2	40,000
Sieving machine	1	150,000	1	450,000
Roller mill	1	600,000	-	-
Windrowing machine	-	-	1	600,000
Laboratory equipment		50,000	-	-
Front end loader	1	600,000	-	-
Handcarts (sorting)	6	10,800	10	18,000
Handcarts (transporting)	6	10,800	10	18,000
Circuits		40,000		60,000
Other small equipment		20,000		40,000
		3,266,600		1,501,000

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3.

3.1 Marketing and delivery

In full production a composting facility will produce compost each day in the year, but the pattern of local demand for agricultural use has three to four peak periods in the year. If the compost is stockpiled to await the peak demands, then it will be difficult if not impossible, to effect the necessary deliveries to users over a short period of time.

Marketing attempts should be made to encourage users to receive compost regularly on a contract basis, and stockpile it on the farm so that it is available as and when required. This may involve deferred payments to the producer, but it will enable the organisation of production and delivery to be spread uniformly throughout the year and can materially reduce the unnecessary loading and unloading of compost at the production site. The ideal arrangement would be to load delivery vehicles direct from the final screening plant.

From past experience with selling compost from the pilot compost plant, it was found generally that local farmers preferred direct delivery and a sale price to include this as they were not in position to undertake this task themselves. By a proper system of contract marketing these could be gainfully employed throughout the year.

3.2 Sales approach

A major problem of distribution is that many agricultural holdings have no road access suitable for large capacity trucks, and in many cases most commodities have to be manually conveyed. It is considered extremely important to facilitate marketing and distribution for the final compost to be bagged in 50 and 25kg sizes. The final compost should have a moisture content of about 25 per cent, the compost should have a final drop in temperature to not more than 30^{0}C and its carbon-nitrogen ration should be under 20.

4. Proposal for installing a 150 tonnes a day compost plant

The final compost discharged from the air separator would be collected in the garbage container and would be transported to the stock yard by a tractor. The composted materials unloaded on the stock yard would be dressed by the front-end loader to achieve the height of stock piling. The stockpile would have a capacity of accommodating about three months output of the plant. The compost would be despatched to the consumers from the stock yard.

The city refuse of the Kingdom of Nepal contains a high proportion of vegetable/putrescible matter which after simple treatment, i.e. composting, can be returned to the land as a compost for soil enrichment. Sanitary landfill methods and the practice of indiscriminative burning means that a large quantity of useful organic material is lost. The construction of a compost plant and the associated collection system to feed the compost plant will result in a tidier and cleaner city.

Although the nitrogen content of compost is low (1 per cent) compared with petrochemically based nitrogen fertiliser (6 per cent), the use of compost as a soil conditioner is economic as the raw material is a waste product. In a relatively poor country like Nepal the use of compost as a soil conditioner should appear attractive.

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The overall layout of the compost plant is to be sufficiently flexible to accommodate most configurations of land site that will be available and will be effectively screened to reduce environmental impact on the surrounding areas.

The composting process will be simple and will require a staffing level commensurate with the skills presently available or obtainable through local training and will help keep to a minimum the dependence of the Government on offshore assistance.

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THE POTENTIAL FOR COMPOSTING IN SOLID WASTE MANAGEMENT

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Federal Environment Agency
Federal Republic of Germany

In solid waste management the term composting is used for a combination of mechanical and biological processing designed to turn wastes into a useful product, called compost. Compost has some value as fertilizer but its main use is physical and biological soil improvement and erosion control. As shown in the simplified input-output scheme, Figure 1, only a portion of the waste is converted into compost. There are residual solid by-products to be disposed of and gaseous by-products emitted into the atmosphere.

The basic biological process used in composting is the aerobic decomposition of organic material through micro-organisms, which occurs naturally and unavoidably wherever moist bio-degradable materials are stock-piled, for instance in all landfills, but here only in the surface layers in the presence of air (oxygen). Below, in the absence of oxygen, anaerobic decomposition takes place, a process to be avoided in composting plants. So a landfill could be easily turned into something like a composting plant just by leaving an uncompacted layer of refuse on the surface of a section of the fill area for a certain period of time, for instance six months, digging it up again, and screening out what might be called "compost".

Although this may well be a reasonable approach, at least for starting composting, a proper plant goes beyond this and usually consists of three processes:

Mechanical pretreatment such as shredding, screening, mixing (e.g. admixing of sewage sludges), magnetic separation of ferrous metal etc.;

Composting process, i.e. controlling the process by providing for optimal air and moisture supply, preventing heat loss etc.;

Subsequent mechanical treatment such as screening, shredding, air classification (for separation of glass and other heavy, inert materials from the compost) and refinement of the end product, e.g. admixing of fertilizer, etc.

It is mostly in the second process that proprietary systems have been developed, while the design of the first process usually depends on local conditions and requirements with regard to waste composition, and the third on local requirements with regard to product quality.

Suitability of wastes for composting

When composting is to be taken into consideration in waste management, one should first determine what portion of the solid waste is suitable for this treatment and what could be achieved by composting in terms of waste volume reduction and production of useful materials.

Household waste components mainly suitable for composting are organic kitchen wastes (food wastes), organic garden wastes (except wood), and paper and cardboard.

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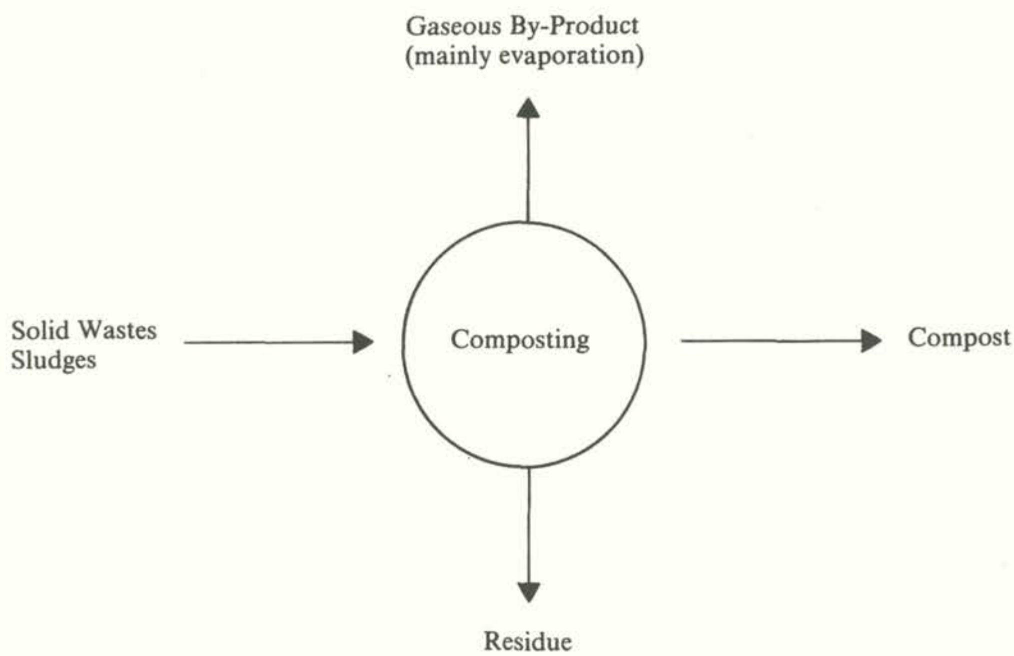

FIGURE 1: SIMPLIFIED INPUT-OUTPUT SCHEME

These components usually represent between 40 and 60 per cent by weight of European domestic wastes. Composting should in any case be excluded if the above mentioned components add up to less than 30 per cent of the waste mixture to be treated. Based on the usual 40 to 60 per cent of waste components suitable for composting the product/residue balances can vary within the following ranges:

Raw materials input =		100%	By weight
products:	matured, compost including non-separable ballast materials	30 to 50 per cent	"
	(ferrous metal	1 to 4 per cent)	"
solid residues:	e.g. glass ceramics, plastics, textiles, rubber etc. as far as separable	50 to 30 per cent	"
gaseous by-	H_2O (evaporated moisture), + CO_2	10 to 30 per cent	"

In cases where refuse of an especially high content of organic material such as vegetable matter and kitchen waste is to be handled, one might expect a higher compost output. However, due to the high water content of such materials, this would instead result in additional process losses (evaporation). If the composting residues are disposed of in landfill - the volume reduction achieved through composting would be 50 to 75 per cent based on the in place volume. Thus, there is still a substantial need for residue landfilling, if there is no additional materials recovery activity combined with the composting. However, residue landfill sites, if properly run, are more acceptable in terms of appearance and environmental impact, compared with normal landfill sites.

Besides household refuse, other types of waste suitable for disposal or utilisation through composting are: street sweepings, market wastes, sewage sludge, organic wastes from the food industry, wastes from the wood/paper industry (bark, saw dust, sludges) and manure from industrial livestock production. Most of these wastes should preferably be composted in mixtures with household refuse in which the moisture content should not exceed 45 to 60 per cent, depending on the system selected. In cases where one of the above mentioned wastes is the prevailing type, there may be special composting systems available, e.g. for sewage sludge.

A special advantage of composting which is particularly relevant, to sewage sludge disposal, is that of sanitisation. Pathogenic organisms are destroyed at the temperatures of 60 to 75°C generated by biological decomposition, if kept at that level for a sufficient period of time (of the order of weeks in the case of windrow systems), and through antibiotic substances produced by fungi participating in the biological process.

Compost uses and marketability

The second step in investigating the feasibility of composting is to determine the local market potential for solid waste compost. It should be made clear that solid waste compost is not a fertilizer to be compared, with conventional industrial fertilizers. It is rather a soil conditioner which adds to the water holding capacity of a soil, functions as a source of humus and various trace elements essential for vegetation, and contributes modestly, but not negligibly, to the fertilizer supply. An example of a typical compost composition is given in Table 1.

Some of the main areas of compost application in Europe are:

Landscaping, e.g. park and sports grounds development and maintenance, highway construction, etc.;

Special cultures, e.g. vineyards, mushroom growing, etc.;

Horticulture, agriculture, especially on intensively used land;

Forestry, tree nurseries;

Revegetation of waste land, e.g. landfills; erosion control, etc.;

Other uses: e.g. as filter material for biological filters for odour control.

In all cases where foodstuff is produced on compost-treated land, special attention has to be paid to the heavy metal (e.g. Cd, Pb) content of the compost, the soil and the produce. Although most of the metal compounds contributed by compost are not available to or are not taken up by plants, a routine test programme should be set up in parallel to compost application (see Preliminary Guidelines for Solid Waste Compost Application, Germany, 1977). One should realize in this context that most of the conventional industrial fertilizers also contain heavy metals, some in fairly high concentrations.

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TABLE 1: COMPOSITION OF COMPOST FROM SOLID WASTE

(Based on tests carried out on 36 samples taken from the Duisberg (Dano) Plant, Federal Republic of Germany, 1970-1973))

Criteria/Components		Average	Range
Particle size distribution (percentage)			
< 3.15 mm		52	41 - 67
3.15 - 7.1 mm		22	12 - 31
7.1 - 16 mm		17	5 - 32
> 16 mm		9	2 - 18
Dry matter	%	59.5	52.0 - 68.8
pH - Value (KCL)		7.9	7.5 - 6.6
Organic matter	%*	43.5	35.1 - 60.2
Degradable organic matter	%*	27.6	17.4 - 39.6
Total N	%*	0.65	0.22 - 1.2
Conductivity	%*	1.06	0.48 - 2.4
Total P as P_2O_5	%*	0.65	0.14 - 1.48
Total K as K_2O	%*	0.47	0.17 - 0.65
Total MgO	%*	0.61	0.35 - 1.08
Total $CaCO_3$	%*	3.98	2.85 - 5.46
Alkaline reacting constituents (CaO)	%*	7.0	3.8 - 13.2
Hot water soluble boron	ppm*	23.9	11.0 - 40.0
Active manganese	ppm*	66.0	39.9 - 98.0
Total copper	ppm*	200.0	100.0 - 326.0
Total zinc	ppm*	1039.0	460.0 - 1500.0
Total lead	ppm*	92.0	24.0 - 272.0
Total iron	ppm*	2.09	0.72 - 3.86
Total cadmium	ppm*	3.7	1.8 - 6.4

* = based on dry matter

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TABLE 2: INFORMATION AND DATA ON TOLERABLE TOTAL CONTENTS OF CERTAIN ELEMENTS IN CULTIVATED SOILS WITH REGARD TO THE HEALTH OF VEGETATION, LIVESTOCK AND MAN

	(mg/kg air-dried soil)		(proposal from Kicke - 1976)
Elements		Total content in mg/kg	
Name	Symbol	Normal Cultivated Soils	Tolerable in soils (proposal)
Arsenic	As	2 - 20	20
Beryllium	Be	1 - 5	10
Lead	Pb	0.1 - 20	100
Boron	B	5 - 30	25
Bromine	Br	1 - 10	10
Cadmium	Cd	0.1 - 1	5 (a)
Chrome	Cr	10 - 50	100
Fluorine	F	50 - 200	200
Cobalt	Co	1 - 10	50
Copper	Cu	5 - 20	100 (b)
Molybdenum	Mo	1 - 5	5
Nickel	Ni	10 - 50	50
Mercury	Hg	0.1 - 1	5 (a)
Salenium	Se	0.1 - 5	10
Vanadium	V	10 - 100	50
Zinc	Zn	10 - 50	300 (b)
Tin	Sn	1 - 20	50

a/ Here, only a few analyses exist so that these figures must be treated with some reservation.

b/ In hop and viniculture, where the application of Zn and Cu - containing plant protective agents has already enriched the soil with these elements, the responsible Agricultural Research Stations must check carefully the locational proportions.

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The advisable application rates for compost vary over wide ranges: 30 to 120 tons a hectare are typical rates in agriculture and horticulture, depending on type of soil and crop. This rate would be applied annually if land use is extremely intensive, otherwise every second or third year. For vineyards and for other special forms of cultivation, up to 300 tons a hectare are used every third year, and in landscaping or for reclamation of derelict land, up to 1,500 tons a hectare or more may be applied.

Prices obtainable for solid waste compost are usually modest, in Germany presently 5 to 25 DM a tonne, which is small in comparison to the cost of composting solid wastes. It should be realized that production and selling compost is part of an environmentally meaningful waste disposal system and not normally a commercial activity. So at the end of the second step of investigating the demand for compost, a well secured market based on low or even zero prices and proper compost usage should be valued more highly than maximum return potential under more risky conditions.

Selection of composting system

The third step to be taken, after investigations of the waste situation and the compost market have come to a sufficiently positive conclusion, would be an evaluation of the composting systems available, in order to prepare for the economic evaluations to follow. For purposes of general consideration, the large variety of systems and process design variations can be reduced to the following basic choices:

Composting in

Windrows, heaps:	reactors, cells:
- with/without artificial aeration (forced draught or suction)	"static systems" (material stationary) or
- with/without mechanical turning of windrows	"dynamic systems" (material being constantly or intermittently turned or stirred)
- on an open or roofed site	Both types usually combined with subsequent treatment on windrows for final maturing and/or storage purposes.

One somewhat unique system which does not fit into the above categorisation may be mentioned: the Brikollare System by IWKA, Karlsruhe, Germany, in which the composting process takes place in piles of bricks ("mini-bales") made out of a mixture of refuse and sewage sludge using brick manufacturing equipment. Following a high temperature (60^{o}C) decomposition phase, the bricks dry out and stabilise within two to four weeks. The final product is prepared by grinding the bricks. (See Appendix I).

The first basic choice between a windrow or reactor system cannot be made without getting involved in the important subject of site selection. Windrow systems require larger areas, i.e. towards the upper end of a range of 125 to 250 cubic metres a ton per day of refuse treated, which can be used as a rule of thumb. In addition, windrow systems are somewhat more critical with regard to odour problems which generally occur, but can be more easily controlled in the case of reactor type systems. Thus, in an area sensitive to odours and if land acquisition costs are high, a reactor system might be preferred, whereas in a more remote location where land costs or land availability do not represent a limiting factor, one would select a simpler windrow system for economic reasons.

The other choices include artificial aeration for windrow systems is usually recommended if the height of windrows is to exceed 2 metres, which may be recommendable where the available area for windrows is limited. Special mobile equipment is available for turning windrows. Frequent turning (e.g. once a week for a month and monthly thereafter for about 2 to 3 months) can replace artificial aeration and also provides for thorough mixing of the composting material.

In regions with high precipitation rates it is advisable to use covered windrow sites to enable control of the moisture content of the compost material, thereby also avoiding problems associated with potentially severe pollution through run-off from windrow sites. The choice between "static" and "dynamic" systems may seem difficult but is not really that important. A generally valid recommendation is to proceed towards composting with a simple and extremely flexible system, which can be further developed according to specific local requirements. About the only critical point with regard to the environmental impact of composting is the odour emissions, typical of biological processes. By maintaining aerobic conditions, the odours can be kept to a minimum. If additional effort is required, simple but effective compost filters can be used to treat odorous process air e.g. the exhaust from reactors. This is forced through perforated pipes (about 80 to 100 dm diameter) covered with a layer of gravel and 1.0 to 1.2 metres of compost which has to be kept moist. These odour filters have also been successfully used to treat odorous process air from other sources, e.g. sewage treatment plants and various industrial plants.

2.4 Economics

The economics of composting is quite a complex subject which cannot be dealt with properly without taking the specific local circumstances into account. As basis for rough estimatation, the following examples may be sufficient. They are based on German conditions and reflect 1978 cost levels. Land cost and external site development cost (e.g. access road, water supply, etc.) are excluded in all cases.

TABLE 3: INVESTMENT COSTS FOR COMPOSITION PLANTS

Annual Throughput	Investment Cost	
	DM per ton per day	Million DM
15000 - 20000 t	250 - 330	3.8 - 6.6
35000 - 40000 t	200 - 290	7.0 - 11.6
75000 - 80000 t	170 - 255	12.7 - 20.4
150000 t	150 - 230	22.5 - 34.5

The lowest costs are for simple windrow systems including at least mechanical equipment for shredding and screening, tractors for turning of heaps and some subsequent mechanical treatment. The higher costs apply to more sophisticated reactor-type systems. Extremely complex systems, as built in Germany and Switzerland for instance, could exceed the ranges given in Tables 3 and 4 substantially. On the other hand, very simple windrow systems, which may under favourable local conditions well serve the purpose of generating a usable compost, could cost less.

In general, the mechanical plus electrical equipment, inclusive of assembly, form 55 to 70 per cent of the investment cost, and construction, 30 to 45 per cent, including site development etc. The total cost for each ton of waste composted is given in Table 4, based on one-shift operation. This includes all operating effort, capital depreciation, etc. Very roughly, about half of the cost would be for operation and half for capital charges etc. Of the personnel required, about one third would have to be skilled workers, familiar with mechanical and electrical installations and at least one staff member should be experienced in agriculture to supervise and promote compost utilisation.

TABLE 4: TOTAL COST FOR COMPOSTING AND MANNING REQUIREMENTS

Annual Throughput	Total cost DM per ton of waste	Personnel required
15000 - 20000 t	55 - 85	6 - 9
35000 - 40000 t	45 - 70	9 - 13
75000 - 80000 t	35 - 60	13 - 19
150000 t	30 - 50	17 - 25

3. Outlook

The above discussed basic planning considerations:

- suitability of wastes;
- uses and marketability of compost;
- review of composting systems; and
- economic evaluation.

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In most cases the marketability of the compost is the main constraint and it is therefore recommendable to concentrate first on this aspect. Obviously, the task of establishing the possible uses and demands for compost is difficult in regions where refuse compost is an unknown product. A reasonable approach could be to start out with a small scale pilot project for instance at an existing landfill site in order to produce compost for testing and demonstration programmes.

It would be essential that all potential users and agriculture departments of governments and universities get involved in such programmes from the beginning. At the same time local experience in composting operations would be gained which would be extremely valuable in defining the scope and type of a full scale composting project to follow.

A particularly interesting area for future development seems to lie in combining composting with mechanical or manual sorting systems for materials recovery, with the sorted moist, organic fraction being suitable as a raw material for composting. Demonstration projects of this type are under way in a number of Western countries and Japan. In regions where present solid waste composition does not look attractive for materials recovery schemes, a composting plant can nevertheless be used to recover some recyclable materials besides producing compost without major additional efforts.

In practically all countries, solid waste composting still probably falls far short of its potential as a means of recovering a useful product from waste and contributing to the conservation of soil fertility, which will become increasingly important in the future. However, it is unlikely that composting will become an area of easy profitable business.

ENERGY RECOVERY FROM SOLID WASTES - INCINERATION AND OTHER THERMAL WASTE TREATMENT PROCESSES

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1. Introduction

Incineration has proved to be a particularly effective method of converting wastes into harmless products. The heat generated in this process represents a useful source of energy. The incineration of refuse began in England in 1876. This new disposal method spread to the USA in 1881. During this period, refuse incineration was primarily aimed at hygienically disposing of potential substrates for bacteria.

In Germany, the first large refuse incineration plant was erected in 1893 in Hamburg as a measure against epidemics. Further plants followed. A large proportion had to be closed down on account of various defects in their construction and insufficient profitability, upon which many had set great hopes. The rise in living standards after the Second World War brought a steady increase in generation of refuse more suited to incineration. In view of new environmental protection laws, many cities decided to solve their waste disposal problems by refuse incineration.

In the Federal Republic of Germany some 20 million inhabitants, corresponding to 32 per cent of total population, are served by 44 refuse incineration plants (1983). Almost all incinerators (corresponding to 98 per cent of refuse incinerated) are equipped with energy recovery devices.

- The increasing generation of waste;
- The increasing demand for energy; and
- The rising prices of energy;

make any kind of energy recovery from waste increasingly attractive. However, the contribution of energy from waste to overall energy supply should not be over-estimated: Figure 1 gives an idea of the potential of incineration of household waste compared to primary energy demand in the Federal Republic of Germany. The situation is different for the possible contribution of incineration to electrical energy production (Figure 2). Although these figures are of a theoretical nature they lead to the conclusion:

The contribution of household waste incineration to the overall energy demand is limited but not negligible.

There are five possibilities for recovery of energy from waste:

(a) Generation of methane gas from landfill sites by anaerobic digestion;
(b) Biological fermentation and methane production (mainly for agricultural wastes and livestock effluents);
(c) Refuse incineration with heat recovery;
(d) Pyrolysis;
(e) Production of waste derived fuel (wdf).

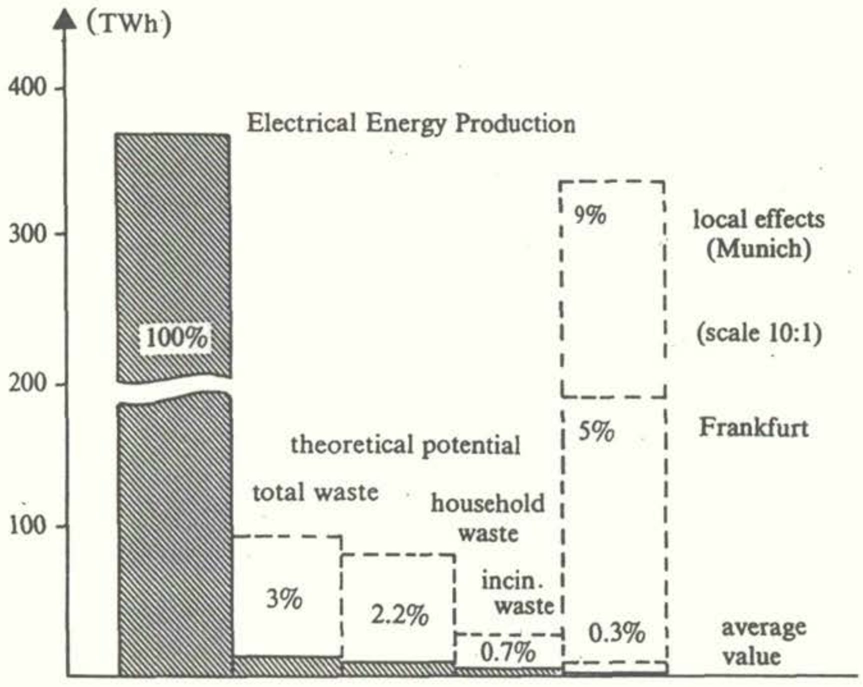

FIGURE 2:
POSSIBLE CONTRIBUTION OF INCINERATION TO ELECTRICAL ENERGY PRODUCTION

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Strecke

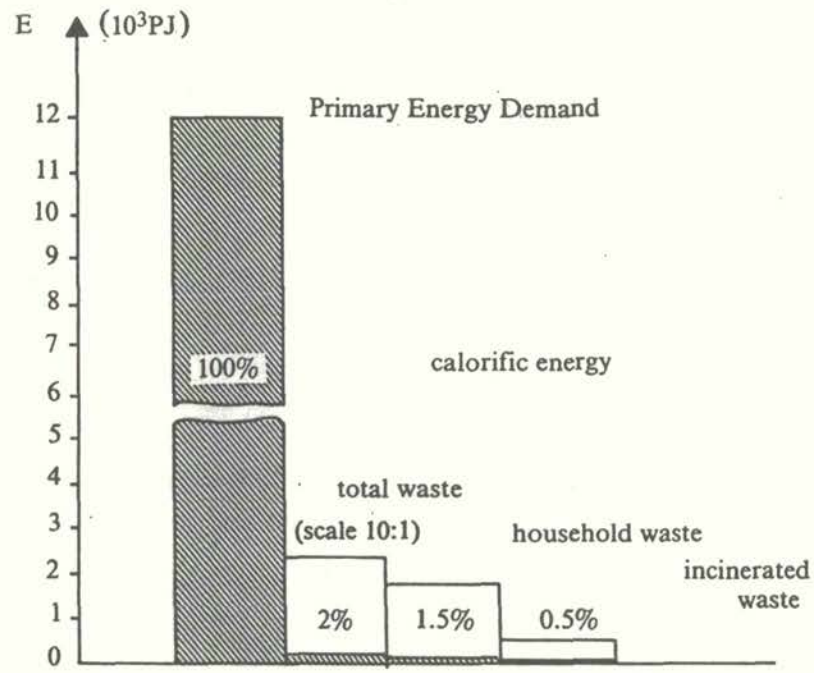

FIGURE 1:
POTENTIAL OF INCINERATION OF HOUSEHOLD WASTE COMPARED TO PRIMARY ENERGY DEMAND

III-003.81
Strecke

2. The basics of refuse incineration

Incineration serves as a method of treating wastes prior to disposal. Incineration in modern refuse incineration plants is an established and proven method of rapidly rendering wastes inert in a controlled manner. It also affords the possibility of using the heat generated as a welcome spin-off. The use of heat from incineration of household refuse is becoming of increasing interest economically, because the municipal refuse in many areas already attains a calorific value corresponding to that of brown coal.

2.1 Feedstock for incineration

Table 1 gives the calorific value of various fuels.

TABLE 1: CALORIFIC VALUE OF FUELS

Fuels	(kJ/kg)	(Kcal/kg)
Light oil	42 000	10 000
Fuel oil	41 000	9 800
Natural gas	32 000	7 700
Industrial coal	21 000 - 28 000	5 000 - 6 700
Town gas	15 000	3 600
Lignite	8 000 - 18 000	1 900 - 3 800
Peat (dry)	12 000 - 14 500	2 800 - 3 500

In comparison the calorific value of municipal refuse amounts to 6,300 to 10,500 kJ/kg (Table 2). However, whether it will increase to 12,500 kJ/kg as is frequently predicted, is uncertain. Refuse incineration plants being planned or under construction are already being designed for calorific values of this level.

TABLE 2: TYPES OF WASTES BURNED IN MUNICIPAL REFUSE INCINERATION PLANTS AND THEIR CALORIFIC VALUE

Waste Type	(kJ/kg)	(Kcal/kg)
Household refuse	6 300 - 10 500	1 500 - 2 500
Bulky refuse	10 500 - 16 800	2 500 - 4 000
Commercial and industrial refuse	7 600 - 12 600	1 800 - 3 000
Used oil	33 600 - 42 000	8 000 - 10 000
Sewage sludge (75% water content)	1 200	290
Residue from composting	6 300 - 10 500	1 500 - 2 500

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At this point one can draw a second conclusion:

Where domestic waste incinerations is planned, a long-term overview of future waste generation is essential - in terms of the amount, compositon, sources and calorific values of the wastes.

Comparison of the steam raising efficiency of modern refuse incinerators compared to other energy generating systems (Table 3) backs the conclusion that waste of this composition and calorific value is an interesting feedstock for incineration.

TABLE 3: STEAM-RAISING EFFICIENCY

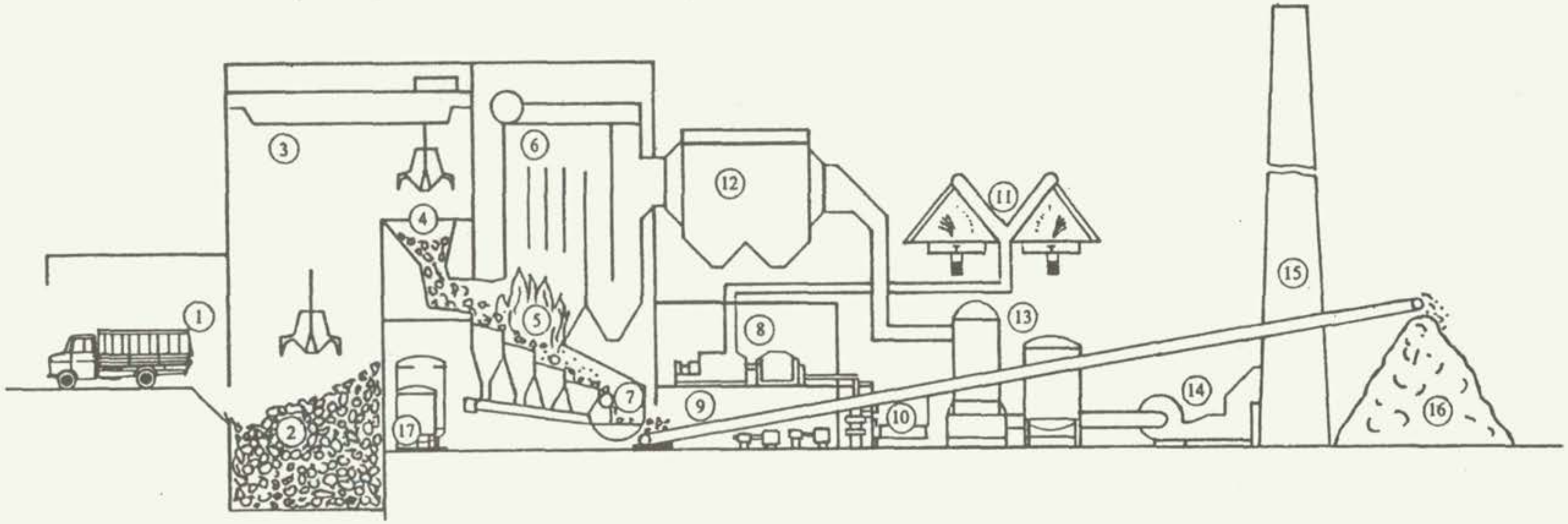
Fuel	Calorific value (kJ/jg)	Efficiency percentages
Industrial coal	21 000 - 28 000	78 - 82
Light oil	42 000	80 - 84
Fuel oil	41 000	80 - 82
Natural gas	32 000	86
Town gas	15 000	85
Lignite	8 000 - 18 000	76 - 80
Municipal waste	6 300 - 10 500	65 - 75

2.2 Some remarks on techniques

Figure 3 gives a sectorial view of a modern incinerator. The mode of operation of a refuse incineration plant with heat recovery is essentially the same for all plants. After passing over a weighbridge, waste collection vehicles discharge their loads into a storage bunker. From there the waste is conveyed with grab cranes into the charging hopper of the incinerator. It reaches the grate system via the feed mechanism where it is incinerated with air fed from the bunker. Combustion proceeds at a temperature range of 900 to 1,000°C. Cooling of the hot combustion gases takes place through heat exchange for the recovery of hot air, hot water or steam. Electrical energy is recovered through steam turbines while hot water or steam finds application in district heating. The cooled combustion gases have any particulate matter removed by filters and any noxious gases removed by wet or dry scrubbing systems. The cleaned gases are finally reheated prior to their discharge to the atmosphere via a stack. The slag is delivered via the slag quenching tank. The scrubbing effluents undergo a separate treatment depending on local requirements.

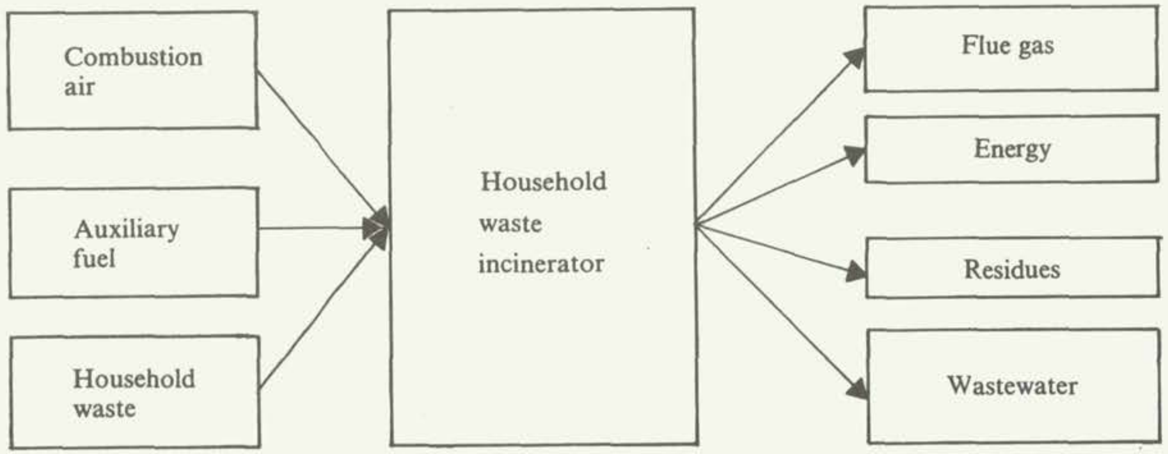
2.2.1 Solid incineration residues

Figure 4 gives an idea of the flow of material in the household waste incineration process. Whereas on the one side waste, auxiliary fuel (if necessary) and combustion air enter the process flue gases, energy (in form of hot air, hot water, steam or electricity) residues (in form of slag and filter ash) and wastewater (from the scrubbing system) leave the process.



1. Waste discharge
2. Storage bunkerg
3. Cranes
4. Hopperr
5. Grate
6. Boiler
7. Slag quenchin
8. Steam turbine
9. Turbine cella
10. Transformer
11. Air condenser
12. Electric filter
13. Flue gas scrubber
14. Suction blower
15. Stack
16. Slag dump

FIGURE 3: SECTORAL VIEW OF A MODERN REFUSE INCINERATOR



2.2.2 Solid incineration residues

The solid residues from incineration which arise as ash and slag, occur at the points in Table 4. In the Federal Republic of Germany, the residues from the incineration of municipal waste amount to around 2.5 million tonnes of which some 300,000 tonnes are scrap. The technical and economic conditions for separating ferrous scrap from incineration residues and for recovering the slag are found only in the larger plants. The recovery of ferrous scrap relies primarily on electro-magnetic separation.

TABLE 4: SOLID RESIDUES FROM INCINERATION

Residue	% by weight of refuse throughput, dry basis	Unit weight (kg/m^3)
Fall-through from grate		
Grate discard	25 - 35	1 200 - 2 000
Fly-ash from the boiler flues		
Fly-ash from flue gas cleaning	4 - 7	600 - 1 000
Dilute sludges from flue gas scrubbing, 95% water content	0.5 - 2.0	---

The ferrous scrap is accepted by the scrap dealer either in loose or compacted form and delivered to the steel works. The value of the scrap is subject particularly to seasonal and regional fluctuations. The separation of non-ferrous metal scrap from incinerator residues is still at the development stage. This valuable secondary raw material is currently landfilled together with the non-recoverable residues.

The slag arising in refuse incineration plants is tipped in the majority of cases. It is used to some extent for filling sand and gravel pits, where possible interference with ground water by the soluble salts in the slag and ashes must be taken into account. A further possibility for application is use of the slag in the construction of less frequented roads.

2.2.3 Gas and dust emissions

A substantial burden for the environment which can result from the incineration of refuse, is that created by the dust and noxious gases contained in the flue gases. Table 5 gives an overview of the concentration range of pollutants which have been determined by numerous emissions measurements at large municipal and industrial incineration plants.

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TABLE 5: MAXIMUM EMITTED POLLUTANTS

Solids ash and dust	2 000 to 15 000 (mg/m^3)
Noxious gases	
Cl^-	400 - 1 500 (mg/m^3)
F^-	2 - 20 (mg/m^3)
CO	< 0.1 Vol-%)
SO_2	400 - 1 000 (mg/m^3)
NO_x	100 - 400 (mg/m^3)

The type and quantity of the pollutants contained in the flue gases depends primarily on the composition of the wastes, the type of incineration system, the controlling of the flue gas in the furnace, and the incineration temperature.

To achieve a better compatibility of refuse incineration, limit values for dust and gas emissions were set by law in 1974 (Technical Instructions for Maintaining Air Purity - TA Luft 1974).

Because of these regulations about 50% of all waste incinerators in the Federal Republic of Germany in 1982 had equipment for reducing emissions of noxious gases, particularly gaseous compounds containing chlorine and fluorine. Because of earlier limitations on dust all incinerators are equipped with dust removal systems, mainly electrostatic precipitators. It is expected that by 1990 about 80 per cent of all incinerators will have some kind of scrubbing system available or under construction to reduce the content of noxious gases in the flue gas.

TABLE 6: GAS AND DUST EMISSION LIMITS

Kind of Pollutant	TA Luft 1974 (in mg/m^3 at 0°C and 1 013 bars, 11% O_2-content by volume)	Limits under Discussion
Dust	100	50
Gaseous compounds containing chlorine	100	100
Gaseous compounds containing fluorine	5	5
Carbon monoxide	1 000	1 000
Sulphur dioxide	--	200
Nitrogen oxides	--	-- (1)

(1) No limit values, but a limit of about 300 mg/m^3 NO_x can always be achieved by means of a reasonable plant operation.

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Although the present limits for harmful emissions are among the most stringent in Europe, lower limits are presently being discussed among experts. These unofficial values are given in Table 6, right column. The 1974 figures are related to the wet basis of the flue gases the new figures may be related to the dry basis which would mean another substantial cut back. Besides these special limits for incinerators of household waste there exist overall emission limits for carcenogenic substances and heavy metals. Details can be obtained from the quoted Technical Instructions.

The removal of dust is possible with cyclones, bag filters, electrostatic cleaning systems and wet scrubbers. Cyclones do not achieve a sufficient removal efficiency, particularly with fine particles. Bag filters demand extensive cooling of the flue gases and are very expensive. They may be applied more in the future in order to achieve the more stringent emission limits. Wet scrubbers afford the possibility of simultaneously eliminating the noxious gases, but they have not been applied because of the large unit throughputs of water and the high losses in pressure. Moreover, the particulate matter must then be separated from the scrubber effluent through a further process, and the resulting sludges dehydrated. A further problem is caused by the heavy metals found in high concentrations in particulate form, which would go into solution with wet scrubbing.

In the Federal Republic of Germany, electrostatic precipitators are commonly used due to the high removal efficiency required. Efficiencies from 98 to over 99 per cent are being achieved. In newly-erected plants in which the elimination of toxic gases is necessary, the separation of dry removal of dust by means of electrostatic filters and wet removal of noxious gases is quite common. Various types of scrubber have proved reliable for the absorption of the noxious gases HCl and HF from the flue gases. All of these make use of the solubility in water of the gases to be removed, but, in addition, the removal of SO_2 is necessary which requires the use of alkaline absorption agents on account of its poor solubility in water.

Dry removal processes based on the absorption of the toxic gases by means of suitable absorption agents (e.g. lime CaO) with subsequent dust removal have proven reliable in various experimental plants and are being added to existing or newly erected plants. From the point of view of water management its wider introduction will certainly be welcomed. The clarified water arising from the gas scrubbers must undergo further treatment before being discharged. Usually, neutralisation with lime milk $Ca(OH)_2$ or caustic soda NaOH is carried out and the solids separated in a settling basin. Depending on the neutralising agent, the salts $CaCl_2$ and CaF_2 or NaCl and NaF result.

If the condition of the receiving water does not permit discharge of saline effluents, then these must be treated. This is carried out by single or multiple stage evaporation for which the usable heat from refuse incineration can be applied. In some cases an additional special treatment is required to remove heavy metals from the effluents prior to their discharge into the receiving water.

This rather detailed discussion of the incineration process has made it clear that it is possible to incinerate household and similar waste without creating a new burden on the environment. But only through applying the most modern technology available. Waste incineration can be a highly sophisticated technology. It generates residues which have to be landfilled and gases which have to be cleaned before they are discharged into the atmosphere.

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Recoverable energy

The heat is generally used to produce steam, which may be converted into electrical energy by means of turbo generators. Assuming a calorific value of 8,400 kJ/kg (2,000 kcal/kg) for municipal waste and an average steam raising efficiency of 65 to 75 per cent, 1.9 to 2.4 tonnes of steam can be produced per tonne of waste. This steam can be used to generate electrical energy upto a maximum of 4.00 kWh, part of which is used to satisfy the incinerators' own requirements (30 to 80 kWh/t).

The composition of waste influences the steam-raising efficiency. An increasing proportion of ash and water in the waste reduces the efficiency, which increases if the cellulose content increases. Comparing the calorific value of municipal waste with that of fuels, and cross-checking at the same time with the heat-recovery efficiency attained with comparable average-capacity plants, incinerators are least efficient.

The use made of combustion heat depends mainly on local conditions. With domestic refuse incineration using conventional processes it is possible to recover the combustion heat in the form of steam in large- and medium-sized plants, and in the form of hot water (at high pressure or otherwise) in small plants. The steam can be used for electrical power with the conventional boiler turbine generally in large plants. Electricity is generated by means of high pressure (40 - 100 bars) and high temperature (400 - 500°C) steam. The steam can also be used for industrial use or for drying sewage sludge, generally in smaller plants but also in large plants. The steam is generally at a pressure between 15 and 20 bars and a temperature of between 200 and 250°C. This steam can be used to obtain low-pressure hot water (80 - 120°C) for district heating. It can be used for electrity and heat in combination.

Incineration of 1 tonne of waste with a calorific value of about 8 400 kJ/kg at a steam raising efficiency of 0.7 can produce about 2.2 t of steam which can be used to generate about 350 to 400 kWh of electricity. From a purely energetical viewpoint, 1 t of fuel oil.

2.4 Combinations of energy employment modalities

The multitude of possible circuits and combinations for using energy in waste incineration plants can be broken down basically into five types (Table 7).

In a refuse district heating plant, steam or hot water is produced at low pressure and fed into a district heating network or into the steam network of an industrial operation. As the heat demand of a district heating system is characterised by small daily fluctuations, but substantial seasonal fluctuations, refuse-fired heating plants are mostly operated in parallel with a conventional heating plant. Usually the base load is supplied by the refuse-fired part of the heating plant.

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TABLE 7: TYPES OF POSSIBLE CIRCUITS IN WASTE INCINERATION PLANTS

Type	Description
A	Refuse district heating plant
B	Refuse district heating plant with power production for in-plant use
C	Refuse condensing power plant
D	Refuse power plant with district heating capacity
E	Combined refuse and fossil fuel power plant with district heating capacity

Type B - A refuse district heating plant with power production for in-plant use, could be used prior to feeding into a district heating plant or a heat exchanger. The steam is passed through a back-pressure turbine to produce electricity which is at least sufficient to cover the needs of the plant.

Type C - In a refuse condensing power plant the high pressure steam produced is conveyed to condensing turbines with a high thermodynamic efficiency. The electrical energy produced is fed into the public grid.

Type D - A refuse power plant with district heating capacity is built in the same way as type C, but bleeder condensing turbines are employed. The bleeder condensing turbines allow seasonal changes in demand for heat of a district heating network to be extensively matched to periods of high demand for power; this enables an economically optimal operation to be achieved.

Type E - The combined refuse and fossil fuel power plant with district heating capacity. The construction resembles type D, but the refuse incineration is an integrated part of a coal-, oil-, or gas-fired power plant boiler. This type of construction has only been used in large power plants.

There exist various possibilities for energy use. The final decision depends mainly on local circumstances, such as the need for hot water, the presence of an electrical grid, the combination with an existing power or even sewage sludge treatment plant and others.

2.5 Planning of energy generation and utilization

If the responsible local authority plans to use the heat it is absolutely necessary to conclude contracts with potential customers for hot water or steam (large public buildings such as hospitals, schools, administrative buildings, swimming pools, greenhouses, sewage sludge treatment plants) as well as for electricity (e.g. the local electricity company).

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Plans for pipelines to distribute steam or electricity should be considered before the final decision is taken for or against energy recovery. To upgrade the calorific value of the feedstock, one should try to obtain commercial and industrial wastes which usually contain high proportions of paper from packing.

The best electricity supply and sales contract would be if all electricity generated could be sold to the customer (e.g. electricity board), at a price which did not depend on the amount or time of delivery. This is almost never the case. Because of the uncertainty of delivery and the inability to adapt to fluctuating energy demands only a rather low price can be realized. In case there is a need to buy electricity at a later time. Usually one has to pay up to ten times more for the energy than one obtains from selling it.

Incinerator plants may sell their output under vastly different market conditions. In one extreme case there are no sales at all, despite sizeable investments in boiler and condensing plant. Some incinerators have been installed in zones of future industrial expansion, but due to changes in the economic climate no users of steam or power were established within economic transport distances. As a result the expensive plant has to be operated and maintained to generate steam, then to dissipate its heat content, generating no revenues and inflating operating costs. In the other extreme the incinerator has a large captive market, to which it supplies its complete output throughout the year. The selling price for power may vary from the value of the fuel saved by the utility to the market value of electric power. Another favourable case is possible when all power generated can be consumed locally, e.g. in an adjacent sewage treatment plant, or when the incinerator and the local power plant are owned by the same public owner, which applies a uniform value for all power generated.

The possible use of the incinerator's output should be one of the decisive factors when selecting the appropriate waste treatment technology. Long-term contracts with the customers and the waste deliverers should be concluded before designing or constructing the plant.

2.6 Securing the energy supply and the waste treatment

To secure energy generation, even in case of a total break down of the plant, the incinerator should consist of more than one unit and should have a back up system, e.g. a boiler to burn light or heavy oil or natural gas. The incinerator should be equipped with separate burners to burn liquid fossil fuels. Usually the plant is operated 24 hours a day seven days a week to make the best use of the investment and to supply the energy. Therefore the bunker should be capable of storing enough waste for operation over weekends or holidays such as Christmas.

There are many areas for faults: slag cakes on the furnace walls, break down of the grate drive, corrosion and erosion of the boiler tubes, difficulties in the waste feeding system (e.g. crane, hopper) or slag and ash removal system and even the danger of fire in the bunker.

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These faults must be minimized, because every interruption of incineration causes severe difficulties: waste cannot be stored over a long period of time but requires treatment more or less upon delivery. In case of a break down the loss of revenues is negligible compared to other consequences: the storage of waste in the bunker, its unaerobic digestion, the necessary changes in organisation in order to deliver the waste at the next available landfill site.

The most essential preconditions for the continuous operation of an incinerator are the best available mechanical equipment and staff . Parts which are susceptible to repair or breakdown should be well designed. Areas of faults have to be inspected and maintained thoroughly. This requires a well trained, experienced and therefore well paid staff.

2.7 Economics of incineration

The costs of refuse collection and disposal are a major factor in the municipal budget. In absolute figures these costs are highly variable from one place to another, as are the levels of units costs (manpower, fuel, etc.), the frequency and quality of service and the environmental standards being enforced. In refuse disposal the cost factors are considered typical for Western Europe: controlled landfill 15-35 DM per tonne; composting 70-100 DM per tonne; incineration 60-100 DM per tonne.

Incineration is obviously expensive, though its cost normally remains below that of collection. Incineration is applied in densely populated areas, in which other methods of disposal are no longer practicable because of a lack of tipping sites and prohibitive transport distances.

2.7.1 Capital Costs

Several factors determine the overall investment costs:

- plant capacity expressed in tonnes per hour;
- method and extent of heat utilization;
- method and extent of flue gas cleaning;
- type and size of the devices for separating slag and, where appropriate, for drying and incinerating sewage sludge;
- method and extent of cooling and removal of surplus energy;
- number of units installed;
- amount of investment needed before any extension can be made.

Apart from these determining factors, there are certain subsidiary factors:

- the cost of land;
- type of land and its capacity for development;
- site services;
- requisite transport vehicles.

Investment in household waste incinerators drops with increasing throughput of the plant. The investment costs per ton of refuse burned per hour range from 2.0 to 4.5 million DM for incinerators with energy recovery. Table 8 gives the investment costs and their range for three different plants (1980 prices). Attention should be given to the fact that costs of flue gas cleaning comprise 7.5 to 11.5 per cent of total investment.

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TABLE 8: INVESTMENT COSTS OF HOUSEHOLD WASTE INCINERATORS

Installed capacity	Annual throughput	Investment costs: Construction and others		Machinery and electrical plant		Overall investment costs	
t/h	1,000 t/a	Mio DM	Mio DM / t/h	Mio DM	Mio DM / t/h	Mio DM	Mio DM / t/h
15	100	22-27	1.5-1.8	30- 41	2.0-2.7	52- 68	3.5-4.5
30	200	35-42	1.2.1.4	48- 67	1.6-2.2	83-109	2.8-3.6
60	400	54-66	0.9-1.1	75-106	1.2-1.8	129-172	2.1-2.9

Operating costs

The decisive factors affecting the operating costs of waste incineration plants are:

- financial charges, i.e. capital depreciation and interest on capital;
- repair and maintenance costs;
- staffing;
- revenue from electricity sales, heat and certain residues.

Other factors include costs arising from water and electicity consumption, purchase of chemicals, transport and storage of the residues. Since capital costs are high, financing may account for up to 80 per cent of total incineration costs. As a thumb role it is normally in the area of 50 per cent. It follows that the type of financing and the depreciation arrangements have a very significant effect on the total financial charges and generally play a more important part in the calculation of incineration costs than expenditure on staff, repairs, maintenance etc.

In the Federal Republic of Germany, the following basis of calculation is typical:

Interest on capital	impossible to generalize;
Depreciation period	25 years for the plant or 40 years for the building; 15 years for those parts of the plant subject to severe wear; 20 to 25 years for those parts of the plant subject to normal wear;
Repair and maintenance	2 per cent a year of the total capital cost or 1 per cent a year of the building investment; 1.5 to 2 per cent a year of the capital cost of electrical plant; 3 to 4 per cent a year of the capital cost of machinery;

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Staffing costs — average cost: DM 55,000 per person per year (1982 prices); staffing requirements: approximately 35 to 65 persons depending on the number and size of the incineration units, the method of operation and the size and number of auxiliary plant items.

Table 9 gives examples of operating costs of three plants in the Federal Republic of Germany.

TABLE 9: RANGE OF OPERATION COSTS OF THREE HOUSEHOLD WASTE INCINERATIONS WITH VARYING THROUGHPUT (1980 PRICES)

Installed capacity t/h	Annual throughput 1,000 t/a	Specific operation costs DM/t without	with revenues
15	100	110 - 140	77 - 112
30	200	82 - 103	45 - 79
60	400	62 - 79	22 - 59

Revenue from the incineration of municipal refuse accrues principally from the sale of energy as electricity, steam, hot water, or a combination of these. The sale of slag and scrap may also generate revenue even for incineration plants where there is no energy recovery. These sales have the further advantage of reducing residue disposal costs. Revenue from the sale of steam and residues can have a significant effect on the cost of disposal to be borne by national or local authorities. But since the recovery of energy requires much higher additional investment, a preliminary study must be carried out of the local conditions and the siting of any future incineration plant to optimize "energy" revenue.

Although there are some general guidelines, no hard and fast rules can be laid down for the method of heat recovery in view of the multiplicity of factors to be borne in mind, and local, regional, and national variations. Revenue from the sale of electricity to the grid can reach about 30 DM per tonne of refuse incinerated. Revenue from the sale of steam for industrial purposes or for district heating is generally twice as high as from the sale of electricity even at a recovery rate of 50 per cent. The profits from the sale of steam depend partly on the selling price laid down in the supply contract and partly on the utilization factor. Revenue from plants where there is a combined production of steam and electricity is generally higher than from plants generating steam alone but the incremental investment necessary is also higher. Revenue may exceed 50 DM per tonne of waste incinerated under favourable conditions.

In all cases it is very important from a revenue point of view that the plant is sited near the users. The evaluation of the energy from incineration is dependant on guaranteed steam supply (possibly with small fluctuations) and the various weights given to community services (electricity generation, district heating, waste disposal). Nevertheless, supply and disposal concepts should be well co-ordinated, so that energy production from waste incineration can be adequately assessed and in some cases a considerable reduction of disposal costs obtained.

Incineration costs are extremely sensitive to such factors as the amortization rate of equipment and buildings, interest rates on borrowed capital and unit rates of revenues. For this reason a bare statement of incineration cost is completely meaningless unless the basis for cost computation is explicitely stated.

3. Pyrolysis of Household Waste

Apart from the well developed and successful traditional method of waste incineration, increased work has been carried out since the middle of the 1970s on new thermal methods for waste treatment, above all pyrolysis.

Pyrolysis or de-gasification is a process which breaks down organic material at relatively high temperatures into molecules with a lower molecular weight. The process takes place in the absence of air. With pyrolytic conversion, there emerges a wide range of products with varying frequency. Their quantitative and qualitative composition is determined essentially by three factors. The composition of the input material, the heating conditions and the residence time during the pyrolytic process.

The term pyrolysis includes a great variety of methods which can be differentiated in the following simplified way:

- Type of reactor (shaft furnace, rotary kiln, fluidized bed);
- Temperature (high 1,200°C, medium 900 to 1,200°C, low 900°C);
- Heating (direct, indirect);
- Supply of oxygen;
- Pre-treatment of waste (from non crushed waste to dust form);
- Type of waste (domestic waste, industrial wastes such as used tyres, plastics etc., or a mixture of all these).

All kinds of different methods were imagined using the most varied combinations. A large number of these were tested and reached varying levels of development.

Reasons for development

Four expectations led to intensive research which was sponsored by public funds:

(a) The new methods should allow the construction of very simple plants for thermal treatment of waste which would, even with a small throughput (up to approximately 250 tonnes per day) run at a reasonable cost and would thus be suitable for waste disposal in small rural areas.

(b) The new methods should, apart from recovering energy, also enable an extremely extensive recovery of the valuable materials contained in wastes, for example in the form of synthesis gas, oil, coke and/or metals.

(c) The new methods should be flexible with regard to wastes of varying composition and quantity so that in a favourable case all the wastes occuring in a small catchment area (with a certain heating value) can be disposed of together.

(d) In addition, the new methods should cause as little environmental pollution as possible.

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3.3 Experiences in the Federal Republic of Germany

In the Federal Republic of Germany, developments from abroad have been taken up in several cases. In other cases German methods have been followed. The new methods have generally been judged very critically, because waste incineration as the conventional method was already able to look back on a high standard of technical development and on an extensive field of application.

After about ten years of intensive research and development the following methods have been proved successful to such an extent that pilot plants are under construction or commissioned.

The Kiener process: Pyrolysis of domestic waste and similar waste in an indirectly heated rotary kiln. The resulting gases are incinerated after dedusting, cracking in a gas transformer and scrubbing. Incineration takes place in a gas engine with a generator coupled on to it. A demonstration plant has been set up near Aalen with a capacity of about 70 tonnes per day with the financial assistance of the Federal Ministry for Research and Technology. Trial operations started in the spring of 1983.

There also exist two other pyrolysis processes mainly for the treatment of industrial waste such as waste tyres, plastics, plastic waste from car shredding, rubber waste and the like. One plant in Salzgitter (Odapyr process, 120 tonnes per day, rotary kiln, and another in Ebenhausen (D.R.P process, 25 tonnes per day, fluidized bed). Both techniques aim at producing oil (mainly the BTX-fraction) for market purposes and gas to cover their own needs.

3.4 Future assessment

When assessing future development, a difference should be made between methods of treating domestic waste whose primary aim is disposal, and those methods used above all for waste with a high heating value which serve to recover raw materials in the form of oil. A better assessment can be provided for domestic waste since it will occur in future at least in the same quantities and with a similar composition. Although increases in quantity and heating value are not taking place to the extent predicted, increased efforts to recover raw materials and a change in consumer behavior will not lead to failure. However, if domestic waste from a certain catchment area is treated according to a particular method A, this waste will no longer be available for other methods. This does not automatically remove the basis for other methods. Pyrolysis will, like other new developments in mechanical waste treatment supplement the range of existing waste treatment methods (landfilling, composting, incineration) and will offer flexible solutions to the increased demands placed on waste treatment.

The range of waste which can be treated is greater than for waste incineration. As only the pyrolysis gases, during their subsequent incineration, are subjected to high temperatures, the heavy metals remain almost exclusively in the solid residues, which is particularly interesting in the treatment of sewage sludge.

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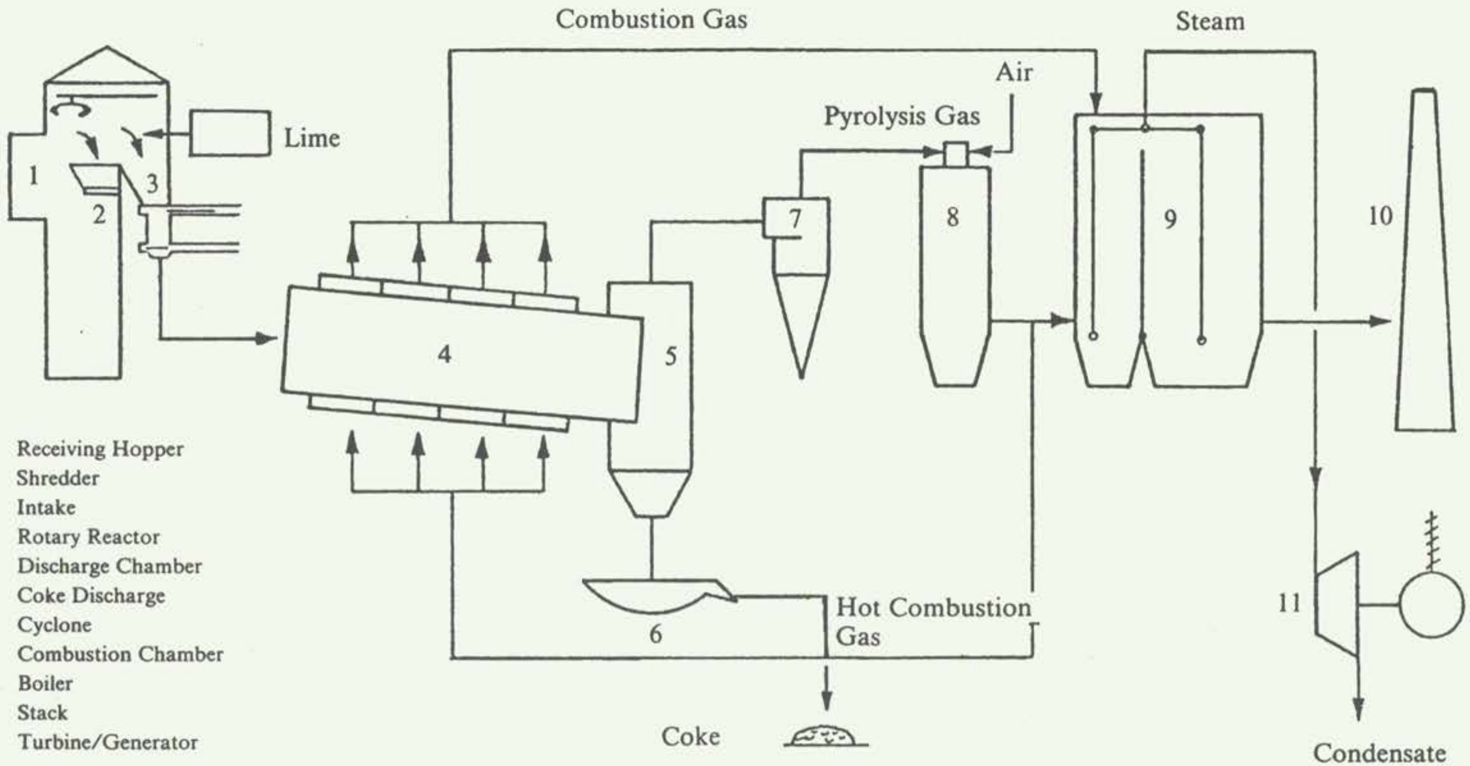
FIGURE 5: THE PYROCAL PROCESS



1 Receiving Hopper
2 Shredder
3 Intake
4 Rotary Reactor
5 Discharge Chamber
6 Coke Discharge
7 Cyclone
8 Combustion Chamber
9 Boiler
10 Stack
11 Turbine/Generator

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* All the information is taken from BKMI-information brochures.

The loading of basic materials in the reactor can simplify the process of cleaning flue gas decisively. Because of the low temperatures in the rotary kiln ($\leq$ 500°C), it does not have to be brick-lined so that, as a result of shorter start-up and close-down times, intermittent operation of the plant (e.g. five-day week, one to two shifts) becomes extremely interesting. If the pyrolysis gases are incinerated immediately, the hazardous organic compounds break down and sewage is not subject to the high level of organic pollution which affects many of the pyrolysis methods including gas washing. In this case, however, the demand to recover storable energy or raw materials in the form of gases or oil from domestic refuse must be given up.

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STATUS AND TRENDS IN MANAGEMENT OF INDUSTRIAL HAZARDOUS WASTE IN THE FEDERAL REPUBLIC OF GERMANY

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In the past, industrial waste has generally been accepted as an unavoidable consequence of industrial production and responsibility for it was left with industry. The consequences of improper disposal of individual kinds of waste as well as their dangerous properties were generally ignored and little was done to develop special disposal methods. It was only in the early 1960s, a period of rising concern about the state of the human environment, that even highly developed and industrialized countries took the first steps to investigate the scope of the problem and the means to solve it. In the last 15 years it has been recognized that compared with domestic wasts, hazardous wastes constitute relatively small quantities but which can only be disposed of in special facilities in an orderly fashion, without detriment to the environment.

The European Countries and the United States have undertaken intensive research to find ways of proper disposal of hazardous wastes. Great progress has been made in the last decade in the Federal Republic of Germany particularly with regard to organization of waste disposal and the development of safe disposal techniques. This paper draws attention to experiences in the legislative and administrative fields of hazardous waste management and gives practical examples of the collection, treatment, recycling and disposal of hazardous waste in the Federal Republic, as illustrated by the State of Bavaria, which has one of the world's most advanced hazardous waste disposal systems.

2. Legislation

The Federal Republic of Germany consists of 10 states including the three City States of Hamburg, Bremen and Berlin. Federal legislation was created in 1972 (Waste Disposal Act) to deal with the disposal of 'special wastes'. The responsibility for implementing and enforcing the Waste Disposal Act was delegated to the states each of which has a separate environment department. The Ministry of Interior retains federal responsibility for waste management, primarily in national and international environmental matters.

The Waste Disposal Act, which has been amended several times since 1972, covers:

Definitions of waste;
Facility siting;
Collection and transportation (i.e. manifest system - 38 categories).
Responsibility of generators for their wastes;
Management at facilities;
Export and import of wastes;
Licencing of waste management facilities;
Registration of generators, hauler and disposer
Fine and/or imprisonment of offenders.

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The Act has required industry to treat and/or dispose of their wastes in an environmentally acceptable manner. In response to this need, a number of private companies and quasi-public waste management agencies have been established.

Waste management systems used are:

- Regulated or limited monopoly systems;
- Municipal co-operatives;
- Private ventures;
- Closed-loop systems.

Figure 1 identifies the location of supraregional facilities of those companies involved in waste management. A number of large manufacturing firms in West Germany have established on-site facilities for the treatment and disposal of wastes which are not identified in Fig. 2.

In the Federal Republic a guideline "waste catalogue" has been in existence since 1975. It contains a wide variety of types of wastes (about 570). In 1977 a classification scheme was introduced to separate out hazardous or 'special wastes'. In the catalogue the list of 'special wastes' was designed to facilitate practical applications, for both the waste generators and the controlling authority. Thirty-eight different waste streams have so far been identified and their individual characteristics and origins defined in the statutory regulation. Examples include: Tannery sludge, asbestos dust, spent acids, pickling bath, pesticides wastes, halogenated organics, halogen-free organics, paint-sludges, hardening salts etc.

It is estimated that on the order of 3 to 4 millions tonnes of 'special wastes are generated each year. About 15 per cent are disposed of by incineration, 35 per cent treated by chemophysical treatment and 50 per cent disposed of in secure landfill-sites.

3. Surveillance and control

The central task in each hazardous waste disposal system is to ensure the safe transfer of hazardous waste from waste generator to waste transporter and to a disposal facility, where it may be properly treated. The control of waste transfer is perhaps the most difficult element to manage in the overall waste disposal control system, requiring skilled manpower and performance of a great number of individual checks.

Existing regulations allow for thorough control of the wastes from their source to their disposal on the base of a 'trip-ticket-system'. Producers of wastes that cannot be disposed of jointly with residential wastes (i.e. especially producers of hazardous wastes) can be obliged by the responsible authority to report on the type, amount and disposal of wastes generated at their plants. They may also be required to keep record books on wastes and to file reference documents which may be examined by the authorites.

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Fig. 1 Supraregional Special Waste Facilities in the Federal Republic of Germany

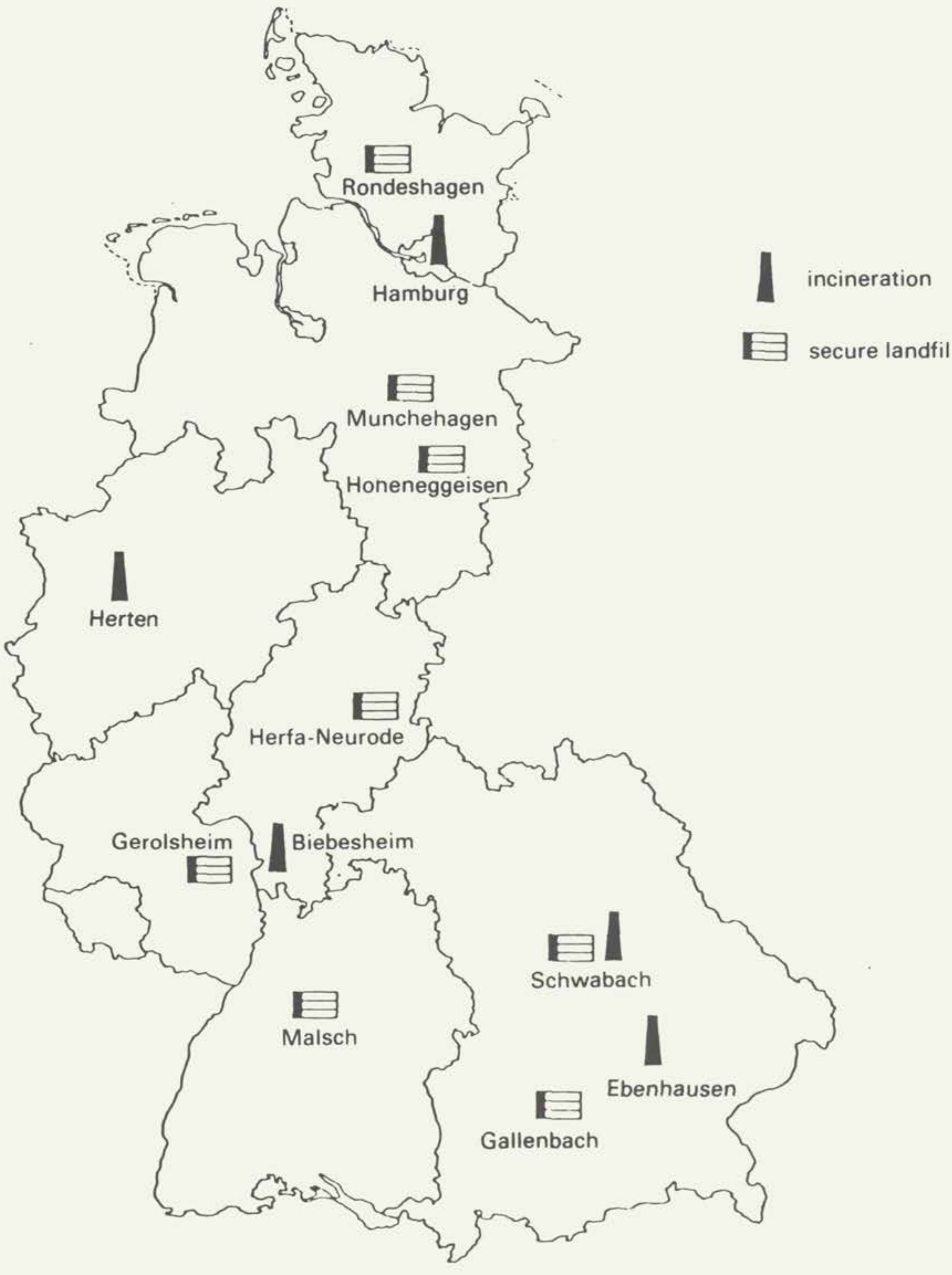
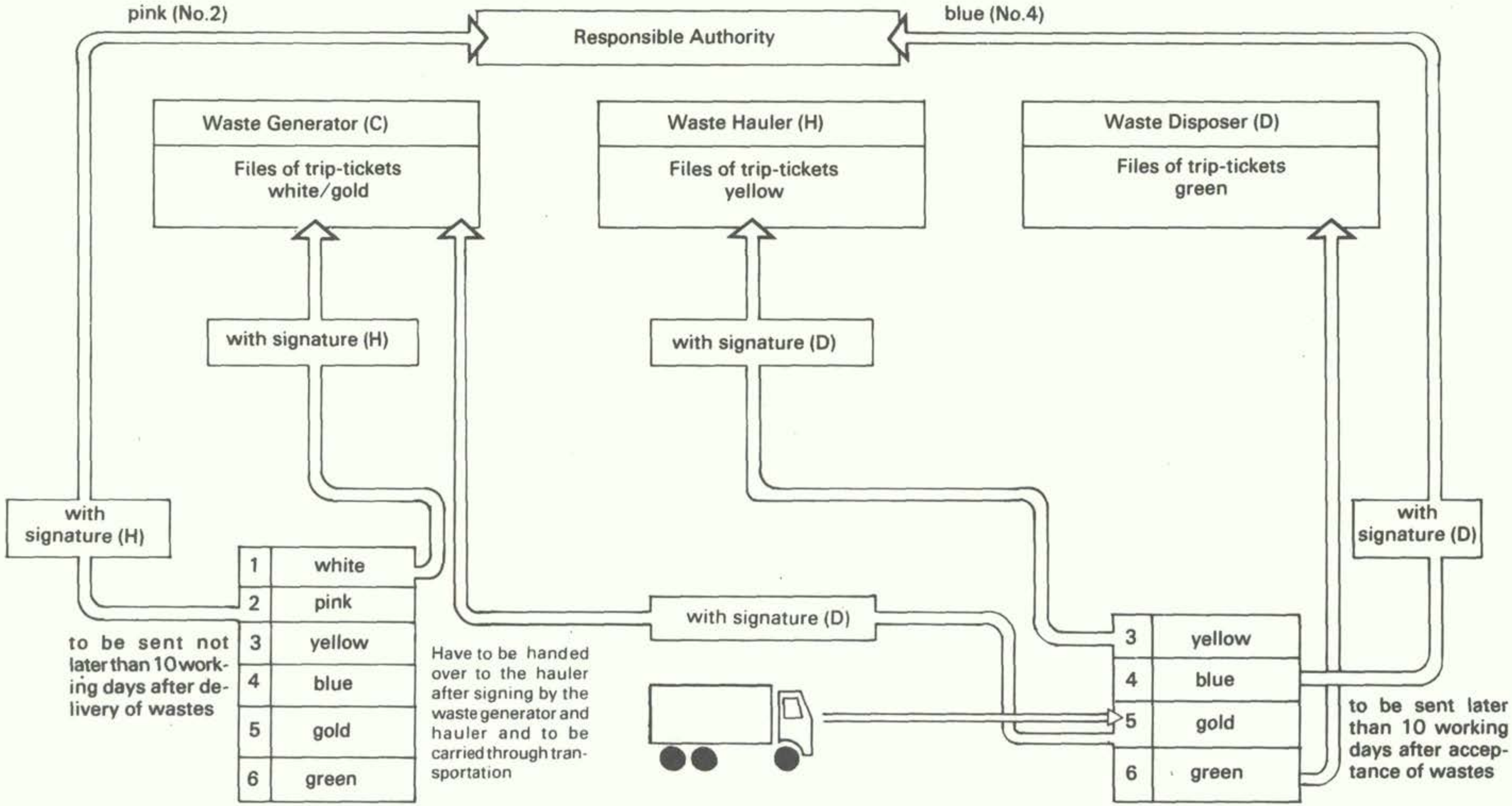


**Fig. 2 Trip Ticket System (Federal Republic of Germany)
Flow Chart**



A system of accompanying documents, the trip-ticket-system will enable the responsible authority to trace the path of notifiable wastes from their source to ultimate disposal. Copies of the notification forms enter the files of the authority as certificates of the orderly transport and disposal of the wastes. A flow chart of the trip-ticket-system is shown in Fig. 2.

The ordinance on plant waste management requires owners of landfill sites, incinerators and other waste disposal facilities, as well as industries generating wastes, to establish the position of "Works Supervisor for Waste" and appoint and register with state authorities the name of the supervisor responsible for directing the waste management operations of such facilities.

The Works Supervisor for Waste in the person responsible for the firm's waste management activities. This was done in an effort to decentralize the control of waste disposal activities and make the waste generating industries control themselves. Thus, the control is based on public authority and private or self responsibility. West German waste management legislation provides for fines or imprisonment of offenders depending on the nature of their crime. The highest fine appears to be DM 100,000 for each offence and common periods of imprisonment range from six months to ten years.

4. Licensing of waste disposal facilities

The complex licensing system of the Federal Republic's stationary waste handling, treatment, storage and disposal facilities is also intended to provide the necessary long-term care of landfill sites. All factors relevant to the expected operations of the facility must be explained in the application for a license, often which plan undergoes a comprehensive approval procedure. The license applicant must provide to the licensing authority a detailed waste management plan, including:

- Location, and capacity of the site;
- Possibility for expansion;
- Availability of the site (ownership of land, etc.);
- Wastes that can be disposed of;
- Geological conditions including hydrogeological situation;
- Assessment of the impact of landfill operations;
- Attenuation;
- Leachate migration, management and treatment;
- Extent and kind of construction work necessary;
- Technical and safety equipment;
- Access for transportation (road, railway, etc.);
- Proximity to similar facilities;
- Site characteristics for water management;
- Background level of air pollution;
- Climatology;
- Site conditions that could impose particular hazards;
- Contingency plans;
- Monitoring environmental protection and control devices;
- Particulars on financing of the facility (insurance, long-term care).

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The licensing procedure can be divided into the following steps: first, a draft of the disposal plan is submitted to the State auditing authority. The auditing authority then distributes the plan to relevant authorities for comments on their areas of expertise included in the plan. The plan is then sent to affected communities to be displayed publicly for one month. Thereafter during a period, of two weeks anyone can file objections with the auditing authority. An auditing session follows the expiration of the term for objections. Once the disposal plan is approved, the problem of long-term care (landfill site) is assumed to be resolved, since the approved disposal plan includes long-term plans for recultivation and reclamation. In addition the conditions of a licence can be modified by the supervising authority at any time or the license can be revoked.

5. Waste disposal plans

Most of the ten States of the Federal Republic have drawn up waste disposal plans along superregional lines with particular consideration given to hazardous wastes. In practice, this leads to the elaboration of separate plans for special-waste disposal. The plans indicate the form of management of disposal facilities and determine where and at which facilities special wastes are to be disposed of. In addition, regional collection and treatment facilities are indicated.

Such plans cover areas such as:

- Kinds and quantities of hazardous waste expected to be treated and disposed of in the area, including wastes dealt with directly by the disposal authority, wastes treated and disposed of by others and wastes imported or exported;
- Number, type and location of treatment/disposal facilities;
- Management of the waste disposal facilties (private, public, joint venture) (incineration, chemophysical treatment, landfill);
- Proposed methods of disposal and/or recycling;
- Identification and location of special facilities suitable for hazardous waste.

6. Technical Measures

In the selection and operation of waste management technologies, the German experience is that facilities must be flexible. Waste generation is dynamic and both the quantities and characteristics of waste received can change. Sophisticated continuous flow equipment and computerized process control originally designed as part of some facilities, were either never used or abandoned as impractical. Rotary kiln incinerators and secure landfills are fundamental to most of the facilities. Physical/chemical (off-site/on-site) treatment systems are also common. The major systems consist of local collection stations, one or more central treatment facilities and secure landfill sites.

6.1 Collection and transport

Collection stations for hazardous wastes are used to serve near by industries. They provide intermediate storage for small quantities of wastes and cut down on transportation costs by organizing bulk shipments. They also ensure a uniform pricing system so that more distant industries are not

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disadvantaged. The State of Bavaria where at present 10 regional collecting stations in operation offers a good example for a country-wide collecting system (see Figure 3). The system is run since 1970 by a non-profit company "Gesellschaft zur Beseitung von Sondermüll in Bayern mbH, (GSB) based joint venture of the State of Bavaria, municipal co-operatives and industrial companies.

The collection stations are designed or have been retrofitted, along uniform lines and generally contain the same equipment. Operations at the collection stations include pre-treatment of wastes such as volume reduction, oil/water separation, neutralization and sludge thickening. Each collection station is also equipped with weigh scales, a small laboratory, tanker, bunker storage and administrative facilities. A flow-chart of a collection station is given in Fig. 4.

Most collection stations are sited at or near existing municipal sewage treatment plants so that the liquid effluent produced at the collection stations can be treated at minimal cost. The principal method of waste transport is by tanker truck and tractor trailer. Most carriers required licences to transport wastes and waste collection transport is regulated by a manifest system.

Incineration

In general, industrial incinerators comprise a storage pit, fuel tanks, a furnace, mostly of the rotary kiln type, a heat-recovery boiler, an electrostatic precipitator, gas-emissions purification, possibly a scrubbing water treatment unit, an induced-draft fan, a reheating unit and a stack. Germany's largest incineration plant with a capacity of 25 million kcal at hour is integrated in GSB's central facility Ebenhausen/Bavaria, which comprises a laboratory, a chemical-physical treatment plant for organic and inorganic substances and waste water purification plants (see Fig. 5).

The incineration plant, able to process 70,000 tonnes a year of waste, has two parallel rotary kilns for solid and pasty wastes and a common burner-chamber with a set of eight burners for liquid wastes. The heat of the gas-emissions from the after-burners is utilized in a steam boiler where the gases are cooled from 1.000°C to about 270°C, gene rating up to 30 tons of steamer hour out of which 22 tonnes an hour are consumed in a 1,530 kw steam turbine while the remainder is condensed in an air condenser; this electric energy not only provides the incineration plant's entire power requirement but actually leaves an excess supply for the public grid. The steam from the turbine is utilized for heating the building and for process heat in the chemical-physical treatment plant.

Several solutions to the problem of reducing pollutant emission have been tried. At present these includes:

- Wet-process scrubbing and subsequent treatment of scrubbing water;
- Wet-process scrubbing with subsequent evaporation of scrubbing water and isolation of scrubbing water contents;
- Dry hot gas cleaning without a wet-process stage (Pilot-phase).

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Fig. 3 State of Bavaria -- West Germany
Special Waste Management System
Situation 1981

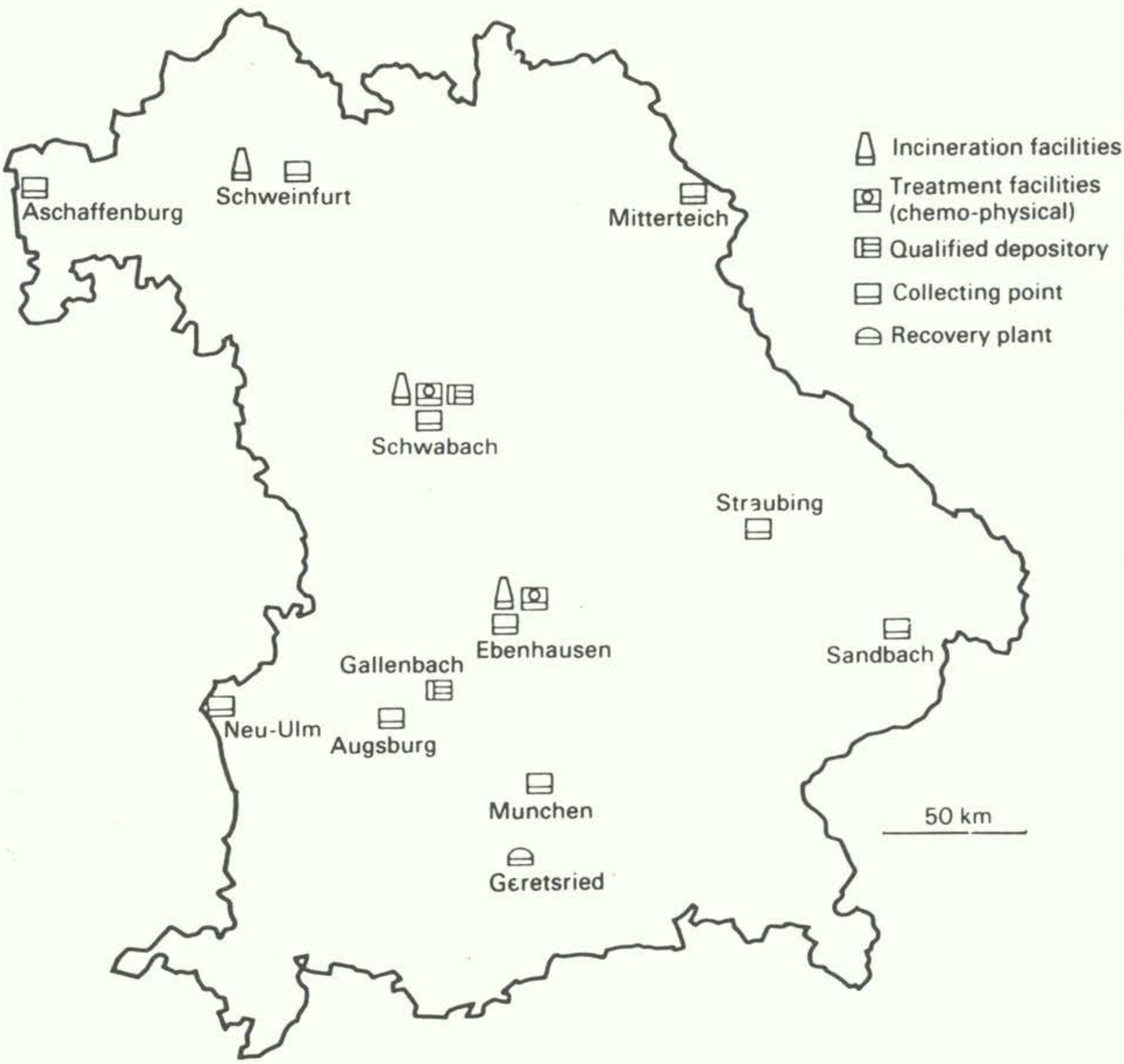

Fig. 4 Flow Chart: Collection Centre

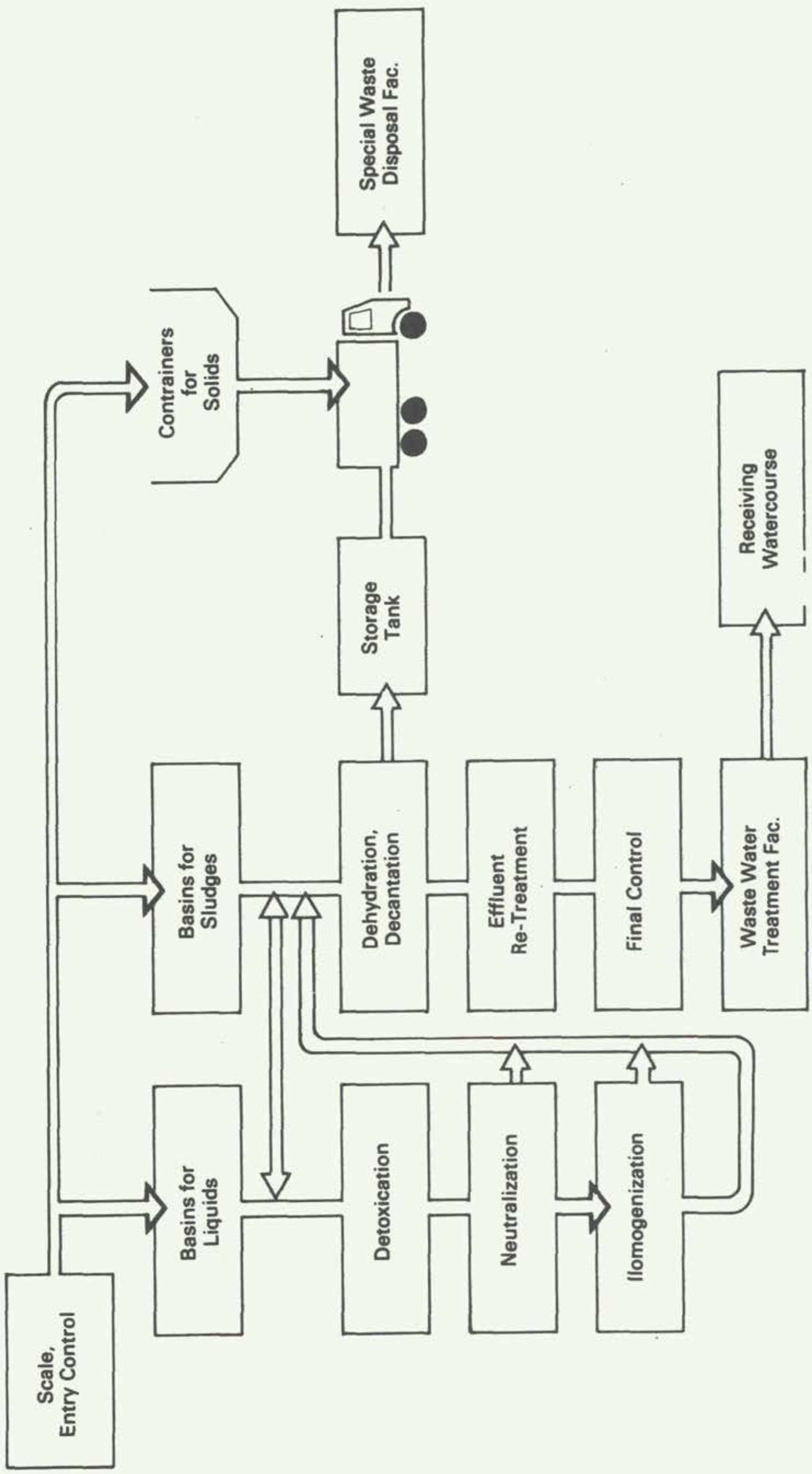

Fig. 5 Ebehnausen Central Treatment Plant
(incineration and chemo-physical treatment)

PLAN OF SITE

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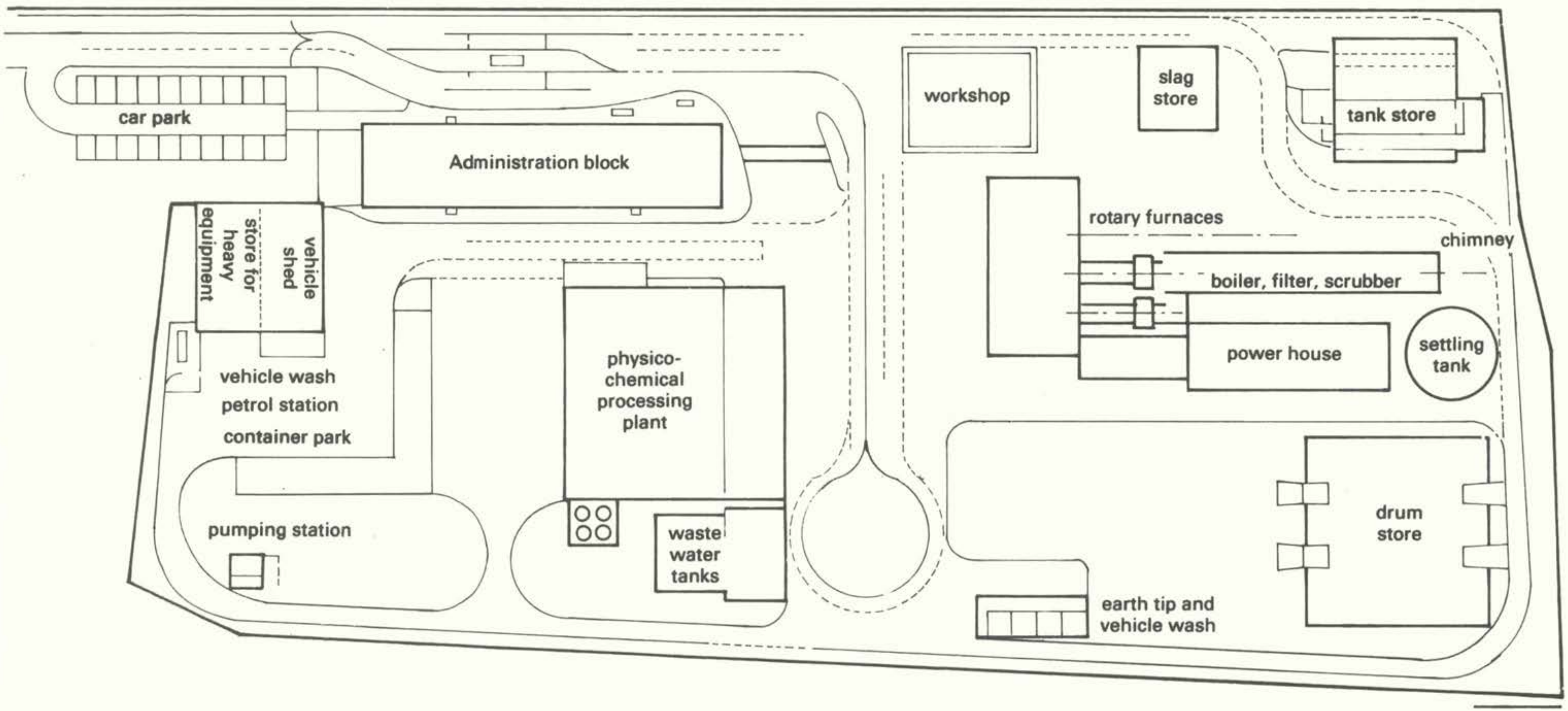

Gas-emissions purification of the Ebenhausen incinerator comprises an electrical precipitator for dust retention and a two-stage venture-type scrubber which removes HCL and HF almost completely while retention of SO_2 is 70 per cent. For airborne emissions and scrubbing water pollutants, this industrial incinerator has been reviewed several times. From simultaneously performed measurements of HCl, SO_2, HF and dust in raw gas and clean gas, the following fluctuation margins for routine operation can be derived:

Table 1

Pollutant	Raw gas mlg/m^3	Clean gas mg/m^3	limit (FRG) mg/m^3
HCl	1000-4000	22-90	100
SO_2	450-2100	40-300	400
HF	62-260	1-3	5
dust	100	0,9	50
CO	-	70	100

EMMISSION RATES OF THE EBENHAUSEN INCINERATOR

The high salt burden in waste water discharged by gas cleaning equipment has led to recent units being designed to evaporate water so as to obtain solid salts that can be tipped or reused. This process of treating waste water from incinerator gas scrubbers is now being tested in two different versions. One consists of spraying the thin sludge leaving the wet-process scrubber into the flow of hot waste gas downstream from the boiler to dry it, and to use a cyclone to obtain the solids content. This version is being tested in the plant operated by Hessische Industrieüll GmbH at Biebesheim (State of Hessen). In the other version the gas is scrubbed and waste water is evaporated using a two-stage evaporation crystalizer. This unit will be tested on the industrial incinerator line of Rohstoffrückgewinnungszentrum Ruh, Herten (State of Nordrheun-Westphalia).

Dry hot gas cleaning was tested in a pilot plant associated with the GSB incinerator at Ebenhausen. It seems possible to use a dry hot gas cleaning stage upstream from a wet-process scrubber in order to reduce the salt load of scrubbing waters.

6.3 Chemo-physical treatment

Liquids with inorganic and organic contaminants are treated in the following processes:

- Oxidation of cyanides and nitrates;
- Reduction of hexavalent chromium;
- Neutralization of acids and alkalis;
- Heavy metal precipitation;
- Solids/liquid separation;
- Dewatering of precipitates;
- Treatment of oily water mixtures;
- Waste water treatment;
- Treatment of flue-gas scrubber effluents;
- Treatment of leachate generated at the secure landfill site.

In the Ebenhausen plant, all liquid effluents are retained and sampled to ensure adequate quality prior to being discharged to the sewer. Storm water collected on-site is monitored and treated if necessary before release to the river. Inorganic sludges produced at the Ebenhausen physical/chemical plant are landfilled and organic and oily residues are incinerated. Discharge of effluents to the air and water from European waste management facilities is controlled by regulation, usually at the state level.

Secure landfill

In the Federal Republic the view has prevailed that special waste products with implications for the ecology should, after suitable preliminary treatment and subject to special safety measures such as the complete insulation of the deposited materials from the ground-water, be placed in secure landfill sites. However, the States have made varying degrees of progress in the practical implementation of this principle. In some States, also, solid and semi-solid special waste materials, mostly organic in character, which contain large amounts of halides and other injurious substances and which are therefore unsuitable for incineration either on land or at sea, are to an increasing extent being dumped in the salt mine, Herfa Neurode (Hessen).

A good example of a secure landfill is the Gallenbach landfill-site (Bavaria) which has been in operation since 1975 (see Fig. 6. This landfill site comprises the following installations:

- Operational building with amenity rooms of various types for personnel;
- Laboratory for sampling the substances delivered.
- Vehicle weigh bridge;
- Vehicle and instrument shop;
- Control systems (drainage, retaining basins) for holding and treating storm water and leachate.

The site is operated by the "area" method of landfilling on a 60 cm thick, pre-constructed clay pad with a reported permeability of 10^{-8}cm/second. summary data of Gallenbach is given in Table 2. Water-soluble solid wastes containing heavy metals are desposited in drums and covered with concrete to reduce contamination in the leachate. In addition to daily cover, a plastic membrane is intermittently placed over completed lifts to reduce infltration. A hand operated vibrator is also utilized to compact daily cover in an effort to reduce the volume of leachate generated. Leachate is collected by a series of under drains, located in the clay pad. Leachate is then channeled to a plastic lined (3 cm) detention pond from where it is trucked to the Ebenhausen plant for treatment. Approximately 10,000 tonnes per year of leachate is hauled 40 km to the Ebenhausen complex. Average leachate characteristics are identified in Table 3. The leachate is characterized by high organic (BOD, COD, TOC) and inorganic concentrations, in particular salt contents between 10 g/l and 40 g/l and ammonia between 30 mg/l and 500 mg/l.

From nearly 83,000 m^3 leachate, generated between 1976 and 1982, it was estimated that over 2,460 tonnes were produced as salt and about 2,750 kg heavy metal ions were diluted.

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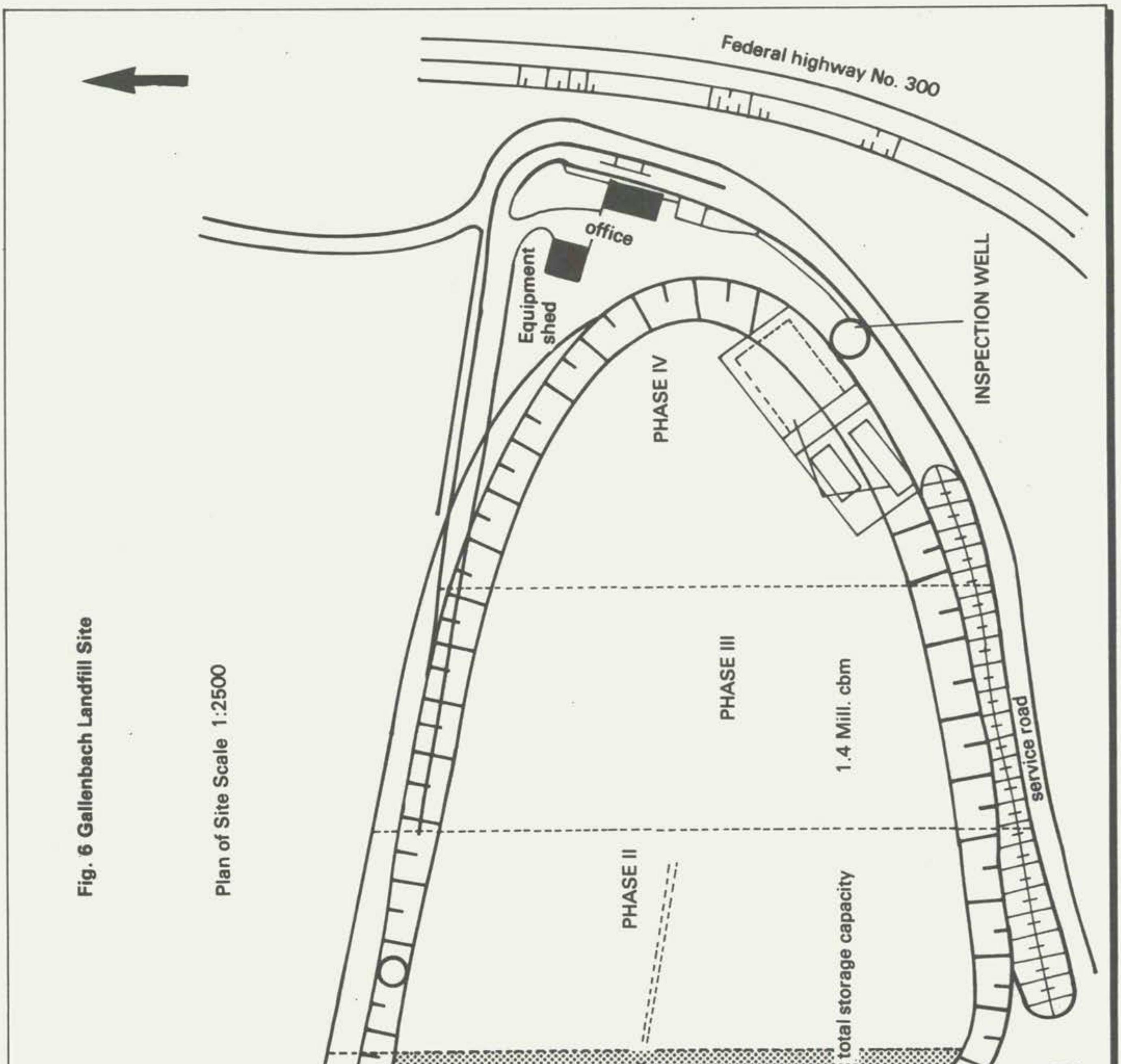

Fig. 6 Gallenbach Landfill Site

Plan of Site Scale 1:2500

Table 2

GALLENBACH SECURE LANDFILL SITE

SUMMARY DATA

Start-up Date	1975
Number of Personnel	5
Hours of Operation per Week	40
Total Capacity	1,400,000 m^3
Site Size	15 hectares
Tonnage per Year	70,000 tonnes (1981)
Leachate Collection	10,000 tonnes (1981)
On-Site Storage capacity:	
- Leachate	3250 m^3
- Storm Water	7500 m^3
Leachate Treatment	Trucked to Ebenhausen Physical/Chemical Facility
Distance to Leachate Treatment Facility	40 km
Tipping Fee (per tonne)	$35.00
Type of Soil	Clay and Loam
Depth of Water Table	
- Local	4 metres
- Regional	18 metres
Clay Pad Construction	
- Depth of Pads	60 cm
- Permeability	10^{-8} cm/sec.
- Depth of Sidewalls	60 cm
Final Cover	0.75 metres

Table 3

AVERAGE LEACHATE CHARACTERISTICS

Gallenbach)

PARAMETERS	1977	1978	1979	1980
PH	7.0	7.4	7.2	7.4
BOD	2720	3000	4000	4650
COD	3000	3500	9000	12000
TOC	1600	1900	4000	34000
Chromium (Cr)	0.4	0.7	0.5	0.2
Copper (Cu)	0.3	0.3	0.4	0.3
Nickel (Ni)	4.1	5.2	3.6	4.4
Zinc (Zn)	2.3	0.5	0.6	0.4
Cadmium (Cd)	0.2	0.1	0.2	0.2
Iron (Fe)	12	4	4	2.1
Tin (Sn)	2.3	8	4.4	3.4
Lead (Pb)	0.6	1.0	1.2	1.1
Phenol	2.1	7.3	1.0	1.0
Chloride	15000	26000	37000	40000
Sulphate	2100	3400	8300	3300

All units of measurement in mg/l

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Storm water is collected by a separate system and detained in ponds for sampling. Water which does not meet discharge standards is transported to a sewage treatment plant; otherwise, the water is discharged to a small stream adjacent to the site. The site is monitored by wells downstream of the site. The collecting systems for leachate and storm water are monitored by a mobile television camera.

7. Resource recovery

The most favourable economic conditions for the recycling of special wastes are found when high disposal costs and raw material prices coincide in time with low costs for the recycling and transport of waste products. Technological restrictions on the recycling of special waste materials are frequently imposed by a degree of purity of the waste insufficient for primary production purposes. Only exceptional cases have so far met with success in using such waste materials. The fact that the quantity of such waste which will become available is not reliably known is a further obstacle to more widespread recycling.

The majority of resource recovery activity in the Federal Republic is carried out by industry, rather than at a central treatment facility. Solvent recycling is practised at a few central facilities. The waste streams which have been reused or recovered are the high calorific value liquid wastes and dilute metal-containing waste streams. The surface finishing industry is recovering metal or producing metal hydroxide sludges for disposal rather than dilute aqueous streams.

8. Pricing and financing

The cost of disposing of hazardous waste fluctuates according to the nature of the waste and which of the many available disposal methods or treatment processes is applied.

In the Federal Republic, the charges for hazardous wastes that can be landfilled range from DM 50 to DM 150 a tonne, while the price per tonne for particularly hazardous waste requiring chemophysical or thermal treatment may reach several hundreds of German Marks.

Government financed and/or operated facilities are priced high enough to encourage industrial resource recovery but low enough to attract waste and prevent environmentally unacceptable disposal. In a number of agency operated systems and facilities, the pricing structure does not reflect the capital debts, expansion plans and sometimes operating costs in the early years of operation. These systems require financial support from the government (low-interest loans etc.) to remain competitive with private firms and offer reasonable prices to industry for waste management services. For example, hazardous waste disposal facilities in Bavaria required an investment of nearly DM 120 millions over the last 15 years. Financing is handled through subsidies, government loans and favourable interest terms (DM 75 million) and the company's own resources. Pricing is established on the basis of waste type and concentration as well as quantity. Wastes considered difficult to treat (i.e. high chlorine content) are usually priced to reflect the problem of disposal and treatment. Wastes hight in calorific value and suitable as a fuel substitute in the incineration process are priced at a lower unit disposal cost.

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MUNICIPAL REFUSE AND NIGHT SOIL COMPOSTING IN CHINA

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Municipal refuse in China consists of urban garbage, human and animal excrement. Urban garbage means city and suburban residential domestic wastes and solid wastes swept from the streets. Useful refuse is collected by commercial enterprises which convert it into saleable products. Kitchen and street garbage and night soil are collected by municipal environment hygiene organizations or by suburban farmers for composting.

The principal means of disposing of urban garbage is by composting. In China, since ancient time this has been an important means of utilization of garbage and night soil. There are two effective composting methods.

Composition and collection of urban garbage

Coal is the main energy source for municipal inhabitants in China, and, dust and slag make up 55 to 65 per cent of urban garbage. There is little organic matter, and waste paper constitutes only 1 to 4 per cent (most of it is purchased by waste purchasing company). As an example, investigation has revealed that Peking municipal refuse is composed of the following:

Organic matter: animal, 1.04 per cent; plant, 35.7 per cent; total 36.74 per cent

Inorganic matter: coal ash and slag,	28.81 per cent
broken bricks and crushed stones,	4.53 per cent
slag dust,	24.56 per cent
Total,	57.96 per cent
Refuse wastes: waste paper,	3.19 per cent
waste metal,	0.6 per cent
plastics,	0.24 per cent
glass,	0.45 per cent
waste material,	0.82 per cent.

The composition of municipal refuse in other cities is almost the same. Over a long period this refuse has been mixed with night soil and composted for use as crop fertilizer. Because there is a great deal of inorganics in the refuse its use was limited. The effects of such fertilizer was low and soil quality was destroyed. As a result, farmers now refuse to accept this kind of refuse.

In the search for a refuse treatment method suitable for China, a separate collection of organic and inorganic waste was tried in Peking, Nanjig and Guongzhou. It was successful in residential areas of Beijing and Shanghai. Two kinds of containers are put separately in residential areas for organic and inorganic refuse. This method is suitable in single-story houses, residential areas or buildings less than three stories, where no garbage disposal shafts have been erected.

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This method is suitable to most Chinese medium-sized and small cities and to some old residential area in big cities. Vegetable and fruit garbage should also be collected. By separating the collection of organic and inorganic garbage the inorganic component can be buried or used for land filling, while the organic garbage is composted or used as raw materials for producing biogas and fertilizer.

Composting: High-temperature composting method "Dragging out bamboo pole leaving hole for ventilation"

Nearly 1.3 million tons of municipal refuse is produced and 180 thousand tons of night soil are handled (the rest goes to sewage system) every year in Tientsin. The composting of this refuse is 67 per cent dust and slag and 26 per cent vegetable refuse, waste paper and street garbage. In 1959 a high temperature composting method was adapted in Tientsin. Since then the amount of fertilizer has increased and the environment has improved, with essentially no fly or odour pollution.

The method used in Tientsin for high temperature composting, as well it, is the "dragging bamboo pole out of composting pile leaving hole for ventilation" method. Sufficient air is provided through these holes so that temperature-addicted micro-organisms can be reproduced to effect good composting (Figure 1).

Municipal refuses are first carefully screened. Metals, broken containers and plastic wastes are removed. Three parts of refuse are mixed with one part of night soil. The moisture content of the mixture is kept at about 50 to 60 per cent. The mixture is laid on the composting field with a layer of 30 to 40 cm thick. Bamboo poles are placed 1 to 1.5 metres apart, (the diameter of bamboo pole is to be 10 to 15 cm in summer and 7 to 10 cm in winter). Then another layer of 30 to 40 cm height is laid, until the total height of the pile reaches two metres (see Figure 1). Then the surface of the pile is sealed with clay plaster with a thickness of 2 to 3 cm. Good sealing will prevent the loss of heat generated in the composting process. The bamboo supply oxygen into the mixture. The opening of the holes should be covered by gauze to keep flies from the pile. After 20 days of being composted, piles can be opened and the mixture is ready to be used as fertilizer. In winter, longer composting period (about 40 days) is needed.

The quality of the fertilizer and the speed of the composting depend mainly upon the activity of the micro-organisms. Many factors will affect the life and activity of micro-organisms such as the carbon nitrogen ratio C/N, the particle size of the mixture, the moisture content, pH value, potassium and phosphorus content etc. The most important factors are:

A. The Carbon-Nitrogen ratio (C/N)

Carbon elements supply the energy and nutrition for the micro-organisms; The extra carbon will be fixed in the form of humus. Nitrogen is also absorbed by the micro-organisms to synthesized all kinds of amino acid, organic bases, protein, nuclear acid etc. For the micro-organisms to

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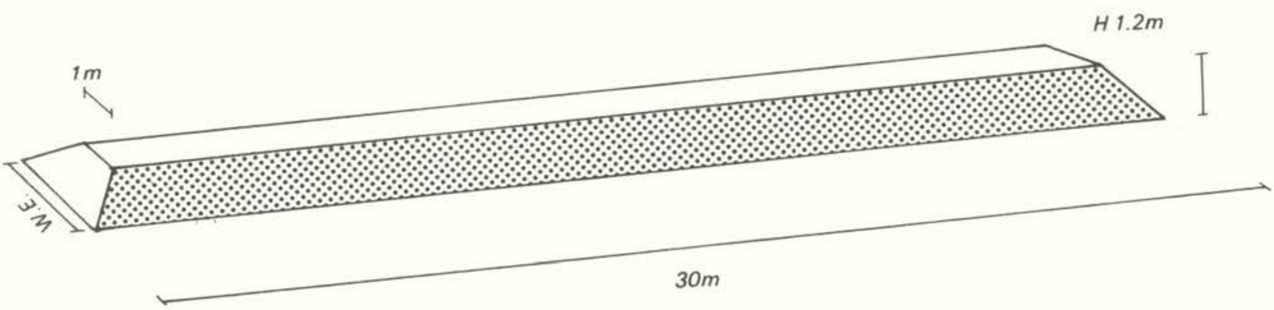

Fig. 1 Composting pile

High temperature composting method by dragging out bamboo pole leaving hole for ventilation

diameter of bamboo pole is 10 - 15 cm, spacing horizontally 100 - 150 m
vertically 30 - 40 cm

decompose 30 parts of carbon, oner part of nitrogen is needed. It is very easy for the micro-organisms to decompose the shorter chained carbohydrates such as starch but more difficult for them to decompose cellulose. The C/N ratio of night soil, grass, leaves and waste paper is 6:10, 25:45, 40:80, and 170 respectively. The C/N ratio for good composting should be adjusted according to the raw materials (garbages and refuses). The content of organic matters is controlled at about 30 per cent. If the organic content is too low in the refuse, animal excrement is added.

B. Moisture content

The cells of micro-organisms contain a large amount of water. Water is also the medium for all the biochemical reactions. When the micro-organisms absorb nutrition, supplies of outside water should be present. But if the moisture content in the pile is too high and the composting mixture is piled too densely, there will be problems of ventilation and oxygen supply. Due to lack of oxygen inside the pile, the decomposition rate will be very slow and the efficiency of composting will be lowered. In this situation, insufficient heat will be generated to raise the temperature inside the pile and thus pathogenic bacteria will not be exterminated. On the other hand, if the pile is too dry, heat will be accumulated rapidly and there will be loss of nitrogen in the form of ammonia through evaporation. In practice, moisture content should be controlled at about 50 to 60 per cent.

C. Ventilation and oxygen supply

To avoid anaerobic conditions sufficient air must be supplied to the pile, but an excess oxygen will cause loss of heat, moisture and ammonia. The amount of air to be supplied depends upon weather conditions and the degree of composting.

D. Sealing

Tightly sesaling the pile will keep heat and moisture in, reduce the loss of ammonia, avoid flies and prevent air pollution. The pile should be sealed by clay plaster. To avoid cracking, the clay plaster should be mixed with coal ash powder. The particle sizes of the composting mixture, and the pH value also affect the composting process. The stems of plants and grass should be cut into pieces less than 15 cm long. The diameter of particles should also be less 15 cm. Smaller diameters will increase the density of the pile and reduce the oxygen supply. Micro-organisms grow and reproduce very fast in weak acidic and weak basic environments. At beginning of the process, temperature rises slowly and pH value is about 5 to 6. When the pH value is higher than 7 temperature will rise rapidly. In summer and autumn, temperature inside the pile will reach 50°C after 3 to 5 days if all the factors are carefully controlled and adjusted. In winter, however, it takes 7 to 15 days for the temperature to reach 50°C. Such a high temperature should be kept for 20 days. The highest temperature inside the pile is about 65°C and 61°C in summer and winter respectively.

Composting results

According to the results obtained from research and farms practice, refuse and night soil mixture composting processes convert the nitrogen from organic form to an inorganic form which is directly absorbed by crops. Nitrogen presented in the mixture as ammonia increases by 60 per cent after composting. At the same time, night soil and refuse are converted into humus. This humus is beneficial to soil because it promoted the formation of grainy structures and greatly improves the quality of soil. A comparison of composted fertilizer and chemical fertilizer was done by the Chinese Academia of Agricultural Sciences and Beijing Research Institute of Environment and Hygiene. Results showed a reduction of content of nitrite ions, nitrate ions and putrid rate in vegetables to which composted fertilizer was applied.

In the composting process, the temperature inside the pile is at about 50°C and is stable for ten to 20 days. such high temperatures kill all pathogenic bacteria and scarabs. The bacteria causing black ear of wheat will die in ten minutes at 50°C. The death rate of roundworm is 95 to 100 per cent. The value of colon bacillus is 10^{-2}-10^{-1}.

Composting in high temperature fermentation pool

Fermentation pool composting has been successful in Hanchou. The compartment fermentation pool waa built in bricks and was 12 metres long, 3 metres wide and 2 metres high. Each compartment has the capacity to treat one day's refuse. There is a feed hole on the pool top with a moveable cement cover. There is a discharge opening in the front. At the bottom of the pool two cross ventiliation channels are dug out to 12 cm width and depth, which are covered by prefabricated concrete plate. Plastic tubes link up the channel with outside for good ventilation. The botton of the pool must be 30 cm higher than land level to prevent water accumulation. Before fermentation the broken bricks, stones and metals are removed from the refuse. The plastic tubes are held in the cross position of the channels and the pool gate is closed. Refuse is placed in the pool layer by layer. When it is full it is covered by plate and the moisture content is kept at 40 to 50 per cent. The day after filling the pool temperature measurement is done. When the temperature reaches the highest point and there is a decreasing tendency, the ventilation hole is blocked thus creating an anaerobic environment. Using this method, in 5 to 8 days the temperature may reach 50°C. During experiments and temperature of 50°C to 70°C was kept over 20 to 60 days. The roundworm death rate was 100 per cent. After 36 days composting the pile material is black brown colour with no foul smell, no fly, pH value is 7.5 to 7.6 and all waste is converted to humus.

In Peking high-temperature composting is under investigation in laboratories. The composting room is built of bricks. The top is covered with plastics amd solar energy is used to assist the fermentation process. The blower was used for forced ventilation. In winter biogas boiler steam was supplied to the composting. The whole composting process is finished in two weeks.

Biogas production

Another approach is to use night soil for biogas production. By the late 1970s, with the encouragement and support of the government, there was a remarkable development in the use of biogas in rural areas. Because of the lack of energy in rural area it is estimated that 400 to 500 million tons of firewood and straw are burnt every year in China's countryside. This primitive and backward form of direct combustion is a great waste of natural resources. Not only large quantities of stalks are destroyed by burning, which could be used otherwise as fodder and manure (more than 1 million tons large quantities of wood are consumed, causing serious soil erosion and an ecological imbalance. This situation makes a direct impact on the development of agriculture, forestry and animal husbandry. The government has attached importance to the utilization biogas.

Table 1

Test results of the cabbage quality

	Nitrate No_3-N PPm	Nitrite No_2-N PPm	Vitamin C mg/100 kg	Putrid rate after 10 days of storage
Without fertilizer	150	0.44	13	56.0 - 56.7
Composts	150	0.47	18	51.5 - 52.9
Chemical fertilizer	870	0.54	18	81.6 - 82.7
Chemical + composted	625	0.57	21	88.5 - 89.6

This method is simple and economical, but it needs large an area for piling and gives off a foul smell, therefore the composting pile must be located far from resedential areas.

In the past, when night soil was used as manure, the heat contained in it was not utilized. Stalks were usually burnt directly and only the residue left after burning could be used as fertilizer. By promoting the production of biogas, night soil and stalks may be used both as manure and fuel, thus enhancing the value of the natural resources. At the same time the thermal energy utilization in the combustion of biogas produced from stalks is increased by 30 to 40 per cent over that obtained in the direct combustion of stalks.

There are now 6.5 to 7 million family biogas digester of 8 to 10 m^3 each in the rural areas, benefiting about 30 million peasants. They use biogas to drive internal combustion engines, to pump water for irrigation, to process grain, to cut fodder as well as to dry agricultural products and to generate electricity (Figure 2).

Experience in China has revealed that biogas produced by anaerobic fermentation of organic matter is an ideal source of energy with the following characteristics:

1. There are abundant resources everywhere for producing biogas; animal manure, stalks, fallen leaves, weeds and organic wastes;

2. Digester construction is simple and can easily be mastered by the peasants. The building of a 10 m^3 digester from breaking the ground to producing gas takes only 20 days. The materials cost only 50 to 80 youn;

3. The sludge in the digester is a high-quality multi-element organic fertilizer and it increases crop yield by 10 per cent more than other fertilizer;

4. Biogas itself is a pollution free, hygienic energy resource. Its combustion is complete, smokeless and dustless and does not pollute. Furthermore, animal manure and organic waste that might otherwise spread disease, are collected, fed into the digester, sealed and fermented, thus improving enviromental hygiene.

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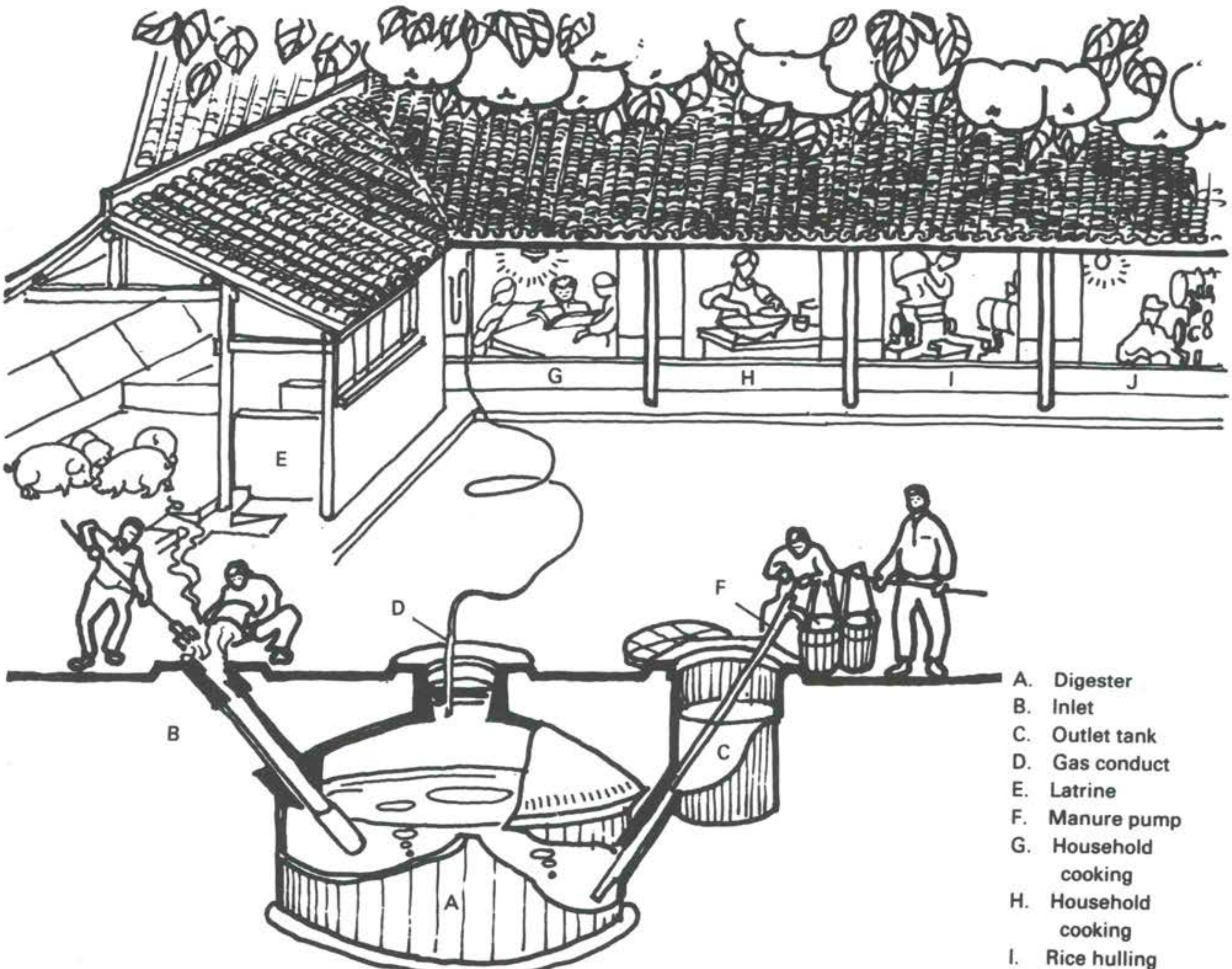
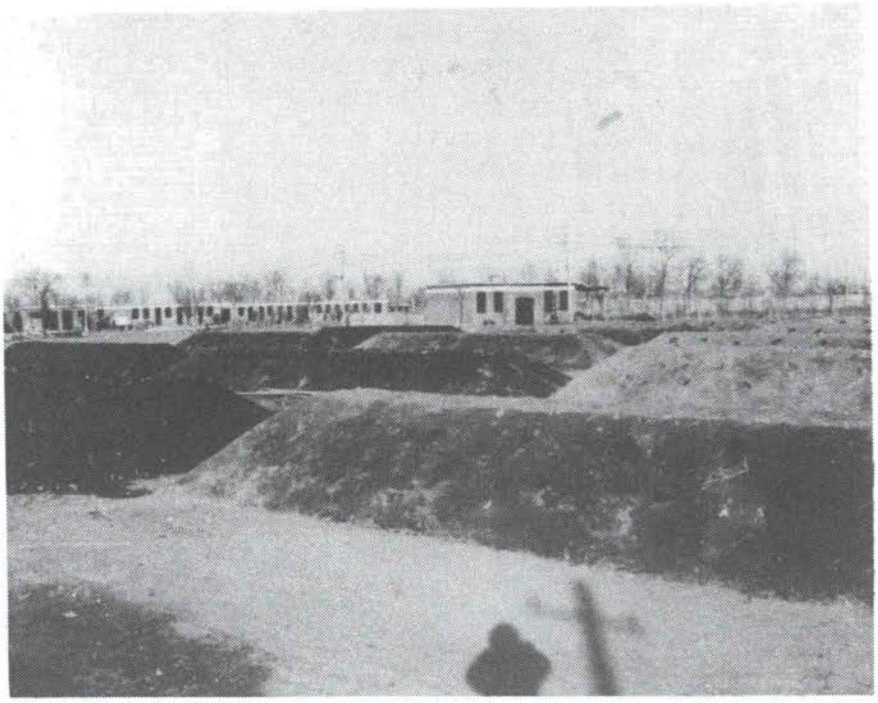
Fig. 2 Schematic View of a Digester and the Use of Biogas



MUNICIPAL REFUSE AND NIGHT SOIL COMPOSTING IN CHINA

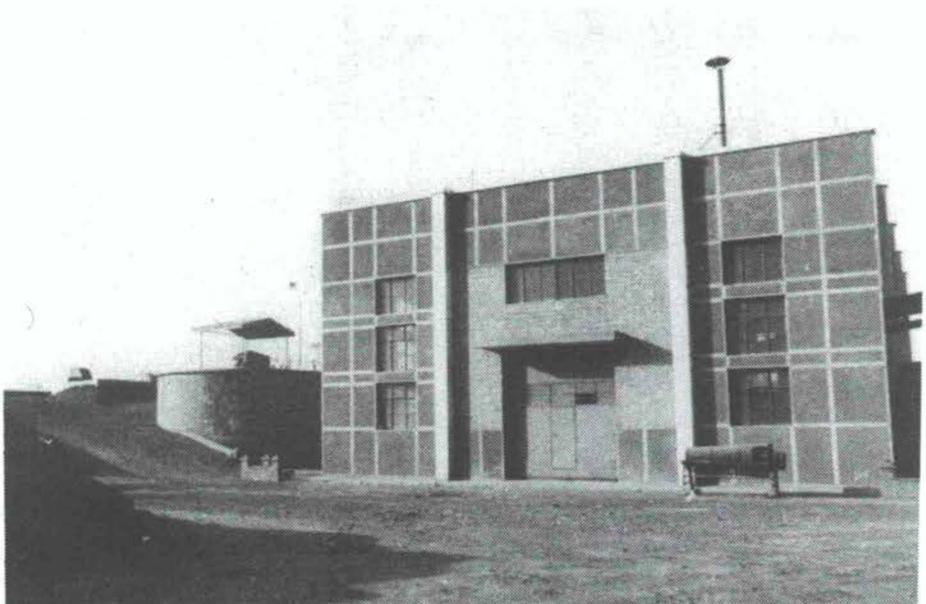
ILLUSTRATIONS



Composting pile (dragging bamboo pole out leaving holes for ventilation)

Composting pile with holes and the bamboo pole


Peasants are transporting composts


Refuse selecting plant is under construction

Peasants are making composting pile

Base layer with channel is made by refuse, into which the night soil is to be poured then mixed together for making composting pile

BIOGAS PRODUCTION FROM SOLID WASTES: THE STATUS AND PROSPECTS

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The use of solid wastes as either part or all of the feeding materials for anaerobic digestion has caught considerable attention during the recent development of biogas systems. This use would also reduce the quantity of waste destined to be landfilled. Anaerobic digestion of refuse to produce biogas is essentially the same process as the one for sewage sludge or animal manure. Even so, the physical and chemical characteristics of refuse, such as the predominantly cellulosic material, the likely imbalance of nutrients (e.g., high C:N ratios) and the contamination of undigestable materials (metals, plastics, bones, etc.) have a variety of implications. Another difference affecting the technology is the huge quantity of material involved, requiring large-scale (and hence most likely mechanical) operations.

Basically, the process can be divided into four different areas of operation, feed preparation, anaerobic digestion, gas upgrading and use, and effluent handling and disposal. This paper endeavours to review state of the art biogas production from solid wastes, and to assess its prospects with special reference to developing countries.

2. Feed Prepation: Waste separation and resource recovery

From the characteristics of refuse, it is evident that it needs some preparation prior to the anaerobic digestion process. Reducing the size of waste and removing inorganics greatly improve the performance of the digester. Screening of the shredded refuse is necessary to minimize the carry-over of these materials. Refuse preparation steps thus include size reduction, magnetic separation, screening and air classification. Particularly in studies in the United Kingdom, the sorting techniques used are aimed at separating as much paper as possible from putrescible material to enable maximum biogas production (Le Roux and Wakerley, 1978). Hence, the amount and composition of the organic material available for biogas production differs considerably from those which other investigators have used.

Physical and chemical treatment

The organic portion of municipal refuse in the West consists mostly of paper and other wood and fibre products. As such, it has a high content of cellulose, either free or in associated forms. The latter, especially lignocellulose complexes, may be less than 50 per cent available to anaerobic flora. In bioconversion systems, the net result is that 40 to 60 per cent of

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the organic material in refuse is not fermentable to methane and remains as a stable, refractory residue requiring subsequent and costly disposal. For this reason, considerable interest in the West has been paid to methods which render the refuse more accessible to anaerobic flora, thus offering a means for increasing the yield of methane production from refuse.

Various schemes have been investigated for increasing the digestibility of the refuse, all of which involve subjecting the waste to physical or chemical conditions conducive to the hydrolysis and partial breakdown of some of the resistant material. For example, they usually involve thermal treatment of material, applying pressure, and exposing the material to a strong acid and alkali. Pfeffer and Khan (1976), in their series of experiments on heat and caustic treatment of refuse, found that a pre-treatment temperature of 130^{o}C and a sodium hydroxide concentration of 3 g/100 g of dry solids resulted in the highest yield under the conditions tested. A high conversion efficiency is possible at much shorter retention times with pre-treatment than without pre-treatment. But with the probable increase in gas yield of 20 per cent for the best conditions tested, it is uncertain whether such a high dose of sodium hydroxide coupled with heat treatment is economically viable.

In a one-year study Gossett et al. (1975) used a simulation model to predict that with heat treatment of refuse at pH 13 and 200^{o}C for one hour, methane production could be increased 36 per cent, suspended solids for disposal could be reduced 31 per cent, and digester volume could be decreased 54 per cent. Although some important model assumptions need further testing, the model gives good insights into some of the implications of heat treatment. Working with a mixed water hyacinth-grass-refuse-sludge feed, Ghosh and Klass (1981) also found that the highest mesophilic (35^{o}C) methane yield was obtained with the feed pre-treated with 3 per cent weight caustic solution. An increase in mesophilic methane yield of up to 20 per cent may be expected.

In Japan, Ishida et al. (1979) chose a heat treatment regime of pH 9.8, temperature 60^{o}C and a duration of three hours. It is not clear whether these are optimum conditions and how they reached this choice.

Going further, Gosh and Klass (1981) suggested that post-treatment may be preferred to pre-treatment, because it only treats the recalcitrant residue remaining after the biodegradable material is gasified and not the total solids in the feed. Thus, the organic loading rate in the post-treatment process is substantially lower than that for a similar pre-treatment process. With the same purpose of economizing the treatment process rather than applying the phase separation concept Gossett et al. (1982) proposed a two-phase system, in which readily degradable organics would be fermented to biogas in the first-stage digester, and the effluent would be subjected to thermo-chemical treatment to make the remaining organics more degradable. The thermo-chemically treated effluent would then be fed to the second-stage digester for additional biogas production. The overall results in this scheme demonstrate that alkaline heat treatment can increase methane production by 80 per cent, and reduce the quantity of solids requiring final disposal by about 27 per cent.

The advantages of refuse thermal treatment have been suggested as (i) greater conversion of solids to gas; (ii) better separation of sludge solids after digestion; (iii) less costly ultimate disposal of solid residues; and (iv) better destruction of pathogens (on the basis of results in the literature). The last three merits are especially valuable in industrialized countries where the regulation with regard to environmental protection is strict. Whether pre-treatment to such a drastic degree is technologically viable in developing countries remains doubtful. The disadvantage common to all economic -technological settings would be the high volatile fatty acids content of the digested liquid which would increase the pollutants to be disposed by aerobic methods.

Nutrient enrichment

The chemical composition of domestic refuse is usually not ideal for biogas production. This is particularly true for the wastes generated in affluent societies where putrescible matter constitutes a small portion. In the United States, Pfeffer (1980) reported that the refuse from Ohio contained 0.68 per cent of N and practically no P was present. The C:N ratio was calculated to be 65. Similarly, the refuse from Indianapolis, has a total carbon content of 39.9 to 45.2 per and nitrogen gontent of 0.1 to 0.8 percent (in weight of toral solids). This results in the C:N ratio of about 94 (Ghosh and Klass, 1979). In a laboratory scale study, Aller (1979) found tht the refuse from Madrid, Spain offered no problem insofar as N is concerned, but it was deficient in P, and in fact this element was a limiting factor to the process. The implications of these deficiencies of nutrients are obvious: extra sources of nutrients should be added in order the enhance to process.

The deficiency/imbalance of nutrients in refuse does not seem to be universal. It is claimed (Le Roux and Wakerly, 1978) that no requirement for additional nitrogen or nutrient salts could be demonstrated with on sample refuse, and waste fractions from another sample of refuse also fermented without apparent difficulty. In this study, the paper portion from the refuse had been separated to an appreciable extent. Similarly, Alone et al. (1979) found that the refuse from Bombay contained 0.8 to 1.5 N and 0.6 to 1.2 per cent P. Apparently their laboratory-scale digester worked well without nutrient enrichment.

Quite interestingly, Pathe et al. (1982) found from their batch experiments that the optimum gas production was noticed between the C:N ratio range of 13 to 17. In another extreme, it was observed in the University of California studies that when wood (sawdust), straw, and newsprint served as the major part of the substrate, the C:N ratio could be as high as 50 without exerting any unduly adverse effects on digester performance (Klein, 1972). All of these results are contradictory to the common truth that anaerobic digestion works best in the C:N range of 20 to 30.

Although relevant data on anerobic digestion of refuse generated from developing countries are rather scanty, it could be expected that nutrient deficiency in refuse in developing countries (which has high percentages of putrescible matter) is at least not a serious problem. One possible method to enhance the methanogenesis of refuse would be to mix refuse with high-nitrogen wastes such as human excreta or animal manures.

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Feed Blending

The most sensible means to correct the deficiency of refuse is to mix it with nutrient-rich waste materials rather than adding chemicals. This is an ideal scheme if:

A. The waste to be added already contains anaerobic micro-organisms, to avoid the seeding step, shorten the start-up process, and later regularly supply the system with a continuous source of needed micro-organisms. Human excreta and animal manures (particularly cattle manure) are good candidates.

B. There is a need for treatment/disposal of a type of waste apart from refuse.

Various research works and a few application schemes have largely used sewage sludge as a blending ingredient, apparently due to the reason B rather than A. Digested sewage sludge can be effectively used as seed. Klein (1972) has found that a 1:1 mixture of refuse and sludge would digest.

A promising method which could enhance the efficiency of biogas production from refuse is to mix refuse with more digestible wastes such as animal manure. Alone et al. (1978) observed that the maximum gas production was obtained from a mixture containing 62.5 per cent of cow manure and 37.5 per cent of organic fraction of refuse. Laboratory studies using a 2:1 mixture of diary manure to refuse showed that the gas yield (m^3/kg Vs added) is nearly the same as for sole manure (Abeles et al., 1978). The extent to which refuse can be used in the blend depends on how much non-digestible matters are removed. Diaz and Trezek (1977) indicated that by selecting the proper refuse fraction, the digestion process can be carried out without the adition of nutrients or buffers.

In short, it is evident that no definite blending formula can be suggested. The data shown in Table 1 are meant as examples and should not be understood even as design guidelines. The charasteristics of refuse and of any other types of waste meterials differ greatly from place to place, and so only specific conditions dictate the blending ratio. Further research is warranted to explore the possibility of using other types of wastes besides sewage sludge. The study by Ghosh et al. (1979) and Ghosh and Klass (1981) on mixtures of water hyacinth, grass, sewage sludge and refuse is an interesting example, which demonstrates that such a digestion process could be continued almost indefinitely without external nutrient.

Size reduction

Refuse particle size has a very significant effect on gas production and yield. For example, gas yields from 10.1 and 5.1 mm median-size particles are only 15 per cent and 30 per cent of those obtained with fiberized refuse having a median size of 0.6 mm, but methane contents of digester gases remain unaffected by particle size (Ghosh and Klass, 1979). While Golueke (1977) claimed that the smaller the size the better the rate of the digestion, and the maximum permissible particle size is on the order of 1 to 3 cm with green vegetable matter and less than a millimetre or to with wood, Diaz et al. (1974) found that refuse material retained by a 7-mesh screen gave the highest VS fraction when compared with samples with mesh sizes of 4 and 17.

Table 1

PROCESS PERFORMANCE OF REFUSE DIGESTION - EXPERIMENTAL DATA*

	% TS	VS Loading kg/m^3d	HRT days	Digester Capacity, m^3%	Temperature °C	Gas Yield 1/kg VS	VS Destruction % CH_4	%	Reference
100% organic refuse	12	-	30	0.010	58	407 (CH_4) 1.61 m^3/m^3d	67	-	Aller (1979)
37.5% organic refuse 62.5% cow dung	7.2 ± 0.8	2.2	25	0.004	33	377 VS added	56-60	54.26	Alone et al. (1978)
80% newsprint 20% sludge	5	-	24	0.006	55	340 VS added	55	24	Cooney & Ackerman (1975)
90% refuse 10% sludge	2.5 2.5	- -	30 30	0.050 0.050	65 37	687 VS added 468 VS added	- -	- -	Cooney & Wise (1975)
80% 'light' refuse 20% sludge	-	1.6-3.2	12-21	0.400	35	212 (CH_4) VS added	-	50	Ghosh & Klass (1979)
6/11 refuse** 5/11 sludge	7.8%	9.4	8	0.007 + 0.021 (2-phase)	60	340 (CH_4) VS added	75	-	Ishida _et al_. (1979)

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Table 1 (contd.)

	% TS	VS Loading kg/m^{3}d	HRT days	Digester Capacity, m^3*	Temperature ^{o}C	Gas Yield 1/kg VS	VS Destruction % CH_4	%	Reference
6/11 refuse** 5/11 sludge	7.5	15	8	0.5 + 1.5 (2-phase)	60	340 (CH_4) VS	68	57	"
75% organic refuse 25% sludge	4	1.25	-	378.5	32.35	999 VS destroyed	62	38	James et al. (1980)
57.7% whole refuse 42.3%	-	1.46	30	1.514	37	437 VS added	>60	66.8	Klein (1972)
100% Putrescible fractions	9	-	21	0.003	30	480 VS added	65.70	-	Le Roux & Wakerley (1978)
50% refuse 50% sludge	3	-	30	0.015	60	459 VS added	-	-	Pfeffer (1974)
100% refuse**	3	-	10	0.015	60	279-308 VS added	53.7	-	Pfeffer & Khan (1976)
75% organic refuse	-	1.28	21	375	-	592 VS destroyed	72.5	7.5 (sic)	Swartzbaugh et al. (1977)

* Most original data have been converted to metric units.
** With thermo-chemical treatment. See section 3.2 for more details.

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Table 1 compiles relevant data from some experiments reported in the literature available. In most cases, the figures chosen indicate the best result obtained from the series of experiments - as far as the process output is concerned. The next sections will discuss the salient matters in the process.

Process operation and performance

Loading

Generally, a suitable loading for organic refuse (entire fraction) ranges from 0.05 to 4.86 kg/m^3-d (Golueke, 1977). The optimum level would depend on various factors, which will be discussed below.

Temperature

Conflicting opinions exist regarding the optimum temperature for anaerobic digestion. As pointed out by Cooney and Ackerman (1975), some investigators found no advantage in raising the temperature above 25^{o}C, one found that gas production at 32^{o}C was greater than at 57^{o}C, and these results contradict some classic works which indicate that gas production increase with increasing temperature up to 60^{o}C. Cooney and Ackerman (1975) suggested two explanations: (i) insufficient time was allowed to select an acclimatized population of organisms able to grow well at high temperatures; and (ii) because of the difficulty in measuring cell mass, only volumetric gas production was measured, and possible differences in cell population levels were not considered. Perhaps a third explanation should be added: different types of substrate may require different optimum temperatures.

Retention time

Contradictory opinions exist regarding the optimum retention time of refuse anaerobic digestion, apparently since this parameter is inter related with other factors, most important amoung them probably being temperature. An interesting finding by Cooney and Ackerman (1975) is that the methane content of the gas increases at short retention times. This increases results from more carbon dioxide being carried in the liquid effluent, and thus is a benefit of operation at short retention times.

Mixing

The study of results of mixing carried out by Ghosh and Klass (1979) with baffled cylindrical reactors showed that mild agitation at a mixing Reynold's number of about 600 was adequate to the slurry consisting of 80 parts of magnetically and air separated and fiberized refuse and 20 parts of sewage sludge (blending on the basis of weight of dry total solids). Little increase in digestion efficiency awas observed when the Reynold's number was doubled. In large-scale operations, mixing may need to be more extensive to prevent the formation of a thick scum layer. With the large amount of floatable material in refuse, it is likely that only an extensive mixing system, rather than simple gas mixing or slurry recirculation, would be effective in avoiding this problem (Klein, 1972).

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Phase separation

One of the bottlenecks in the anaerobic digestion process is considered to be due to the rate-limiting of the hydrolytic phase. There is nowadays a tendency to split digestion systems into two steps, in which the fermentation can be optimized separately. Two-phase operation can bring about a variety of benefits, as has been reviewed by Tam and Thanh (1982). But while the merits of phase separation have been widely accepted, the volume ratio of acid/Methane phases has still not been rationally studied. For instance, it is not known how Ishida et al. (1979) reached the volume ration of acid phase/methane phase at 1/3.

Studying a water hyacinth-grass-sludge-refuse blend, Ghosh and Klass (1981) suggest that it is desirable to operate the two-phase system at an even shorter retention time (only four days or less), and to couple this system to a cell mass recycling device (e.g., anaerobic settler) to prevent methane yield reductions and volatile acids accumulation associated with short retention time. It should be noted, however, that settling of relatively concentrated digested biomass-waste slurry with an anaerobic settler could be problematic and impractical

More discussion on two-phase anaerobic digestion can be found in the article by Ghosh and Klass (1978).

Destruction of volatile solids and gas production

Table 1 also gives some reported values on the destruction of volatile solids and gas production for various systems which are either fed by solid wastes or by mixtures of solid wastes with different types of materials. The results reported in the Table show that volatile solids destruction in anaerobic digestion of refuse is low, within the range of 40 to 60 per cent. This implies that inorganic and refractory elements are abundant in the refuse. This is especially severe if the refuse is not classified and sorted before feeding.

Gas production varies widely as shown in Table 1. This would be due to the different operating conditions. Generally, the extent of total and volatile solids destruction of the biodegradable fraction of refuse matches that accomplished in composting, namely, 20 to 40 per cent of the total solids and 30 to 60 per cent of the volatile solids (Golueke, 1977). Destruction of the cellulosic fraction can be as high as 80 per cent (Klein, 1972).

Kinetics

Using the data reported by Pfeffer (1974b), Chen and Hashimoto (1978) derived kinetic equations and determined kinetic constants. The rate of ultimately attainable methane production from refuse as the retention time reached infinity is shown to vary with temperatures, and is highest at 60°C and lowest at 35°C. Assuming that the ratio of COD/VS = 1.39 for raw refuse, the value at 35°C is close to the value reported by Gossett et al. (1975) for municipal refuse digested at the same temperature. The maximum specific growth rate is highest in the approximate temperature ranges of 40 to 42°C and of 60 to 65°C. This conforms to the generally accepted optimum temperatures for mesophilic and thermophilic micro-organisms, respectively. From the values found, the minimum solids retention time can be calculated, being about three days.

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The kinetics of refuse anaerobic digestion have been studied by Ghosh and Klass (1979). Based on these data, Ghosh and Klass suggested phase separation for the process, which is carried out in separate digesters at retention times of three and five days for acid phase and methane phase, respectively. Thus, the system can be operated at a total retention time of eight days, which is 50 per cent less than the 12-day retention time deemed optimum for standard high-rate digestion of refuse. This total retention agrees with the one suggested by Ishida et al. (1979).

Operating problems

The total solids destruction in anaerobic digestion of refuse is low (possibly in the range of 40 to 60 per cent) because of the large inorganic content of the refuse. This is worse if the refuse is not classified and sorted before feeding. Alone et al. (1978) in India obtained 45 to 54 per cent of VS destruction from the organic fraction of refuse digested in laboratory-scale digesters. Thus, it could be said that field-scale digesters operating with unsorted refuse would yield much lower solids destruction efficiencies.

However, a problem which could indicate difficulties in large-scale plants is that refuse contains a large proportion of floatable materials, which form a thick scum layer in the digester and remain largely undigested. Without an effective mixing device, stratification occurs easily in the digester due to the inherent characteristics of refuse.

Equipment problems may also be a result of the gitty cellulosic feed. Excessive wear on pump and scum-breaker has been experienced in a large-scale system (James et al., 1980), due to a build up of cellulosic material. Rope-like stringers wounds around the shaft and agitator arms, causing decreased mixing efficiency and excessive wear on the agitator drive mechanism. The operating life of this equipment is likely to be short in a full-scale, continuous operation plant.

The deficiency or imbalance of nutrients can cause far-reaching problems, whose seriousness could never be under-emphasized. The deficiency of nitrogen (protein or ammonia) reduces the amount of natural alkalinity that is processed. The ammonia produced by the deamination of the protein will form ammonium bicarbonate in this system. This buffers the system and maintains the near neutral pH. Klein (1972) reported that a decline in alkalinity to a dangerously low level in his pilot-scale digester was a recurrent problem. This was corrected by regular additions of sodium bicarbonate at a rate of 755 mg/l. Lime could have been used for the same purpose.

Energy analysis

Ojalvo and Keenan (1976-77) developed a model which described the energy balance of an anaerobic system producing biogas from refuse. In a comparative analysis, Hecklinger (1979) compared the relative value of refuse as a fuel for six processes, namely (1) raw refuse incineration; (2) mechanical processing to produce RDF for combustion; (3) thermo-chemical processing to produce liquid fuel; (4) pyrolysis in an oxygen-starved atmosphere to produce fuel gas; (5) pyrolysis with pure oxygen to produce fuel gas; and (6)

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methane (95 per cent pure) production. The conclusion was that raw refuse incineration is the most efficient means of utilizing the energy in refuse, depending on the calorific value of refuse. In the analysis, the use of energy in the residue was not considered.

Ultimate effluent disposal

The phyical characteristics of sludge from refuse digestion differ from those of digested agricultural wastes in that it may have larger particles and certainly a greater proportion of non-biodegradable debris than found in digested manure. The exception would be the Cal Resource Recovery system, because in that system all non-biodegradable materials are sorted and recovered (Diaz et al., 1974); Diaz and Trezek, 1977; Diaz et al., 1980).

If the principal motivation or objective of digesting the wastes is energy production, incineration might be the best approach for disposal of sludges from anaerobic digestion of refuse as a significant portion of the potential energy content of the refuse is to be found in the digested residue. This is true regardless of whether the residue is from a single exposure to the digestion process or from a second exposure following the special pre-treatment described earlier. However, incineration necessitates dewatering the sludge, a process that can be expensive in terms of money and energy. Added to the dewatering costs are those of preventing air pollution due to the incineration.

Ghosh and Klass (1979) suggested a conventional system comprised of digested sludge conditioning and flocculation; gravity thickening; vacuum or pressure filtration; activated sludge treatment and trickling filtration of filtrate and thickener overflow; disinfection of final effluent; and land application of filter cakes for reclamation or soil conditioning is proposed for the ultimate disposal of digester effluent. The cost of these processes would be substantial. Another technique applicable for ultimate disposal is extended aeration treatment with recirculation of the digested slurry; suspended solids and soluble COD removals up to 64 per cent and 94 per cent, respectively, at a detention time between three and five days are observed (Ghosh and Klass, 1979).

The most attractive method would be to use the effluent as a soil conditioner, either in liquid or dewatered form. Digested putrescible refuse retains most of the fertilizer value of the original material, but the metal content could cause problems. the analyses by Le Roux and Wakerley (1978) show that the metal content, with the exception of iron and aluminium, is not very different from that of typically digested sewage sludge.

The Status of large-scale application

The possibility of applying the anaerobic digestion process to solid wastes in the United States was first investigated in 1936 at the University of Illinois, according to Pfeffer (1978). A series of experiments was undertaken using a mixture of food wastes and sewage sludge as substrate. The results clearly showed that the refuse was amenable to anaerobic digestion.

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During the late 1940s and early 1950s, several sewage plants attempted full-scale digestion of refuse, but with varying success (Ross, 1954). The first reported successful large-scale application production from refuse was in 1952 at the sewage treatment plant in Richmond, Indiana, and was described by Ross (1954). The scheme was prompted by the fact that the sewage treatment plant had been overloaded and needed expansion and there was a call for an effective disposal of refuse generated in the area. Thus, various facilities of the plant were upgraded, and refuse was added to the newly-expanded sewage digestion tanks.

There was apparently a gap in further development of this technology in the USA during the 1950s and 1960s. The slow development of biogas production from refuse during this period in an industrialized country such as the United States may be misleading as regards the availability of this refuse recycling option. Several factors contributed to the lack of interest in this innovation for quite a while in the United States, namely (Pfeffer, 1978):

A. Extensive natural gas fields were being developed. The price of this high-quality fuel was very low and it waa available in large quantities. Therefore, the economic incentive for using biogas, a lower quality gas, was lacking.

B. The characteristics of refuse were changing. The quantity of food wastes was decreasing due to the development of the food processing industry, and hence the quantity of packaging was increasing. Household putrescible refuse was becoming a smaller percentage of the urban refuse stream, and paper, cans, bottles and plastics were assuming a much larger percentage.

The lack of suitable refuse feed and the very limited economic incentive for biogas production essentially eliminated all consideration for this process in the United States until the late 1960s. At that time, the Institute of Gas Technology (IGT) in Illinois, recognized the practical utility of a comprehensive solid and liquid waste management system capable of simultaneous waste disposal and energy recovery as methane. Substantial laboratory, small pilot and field work has been conducted on biogas production from refuse and sludge to maximize methane production and the recovery of recyclable materials. ITG has conducted a technology transfer programme to Brazil, which includes a 100-tonne a day pilot-demonstration plant in Sao Paolo. Independent studies by IGT and other groups have established the technical feasibility of the process, and indicate that a commercial system can be operated with a modest rate of return (Ghosh and Klass, 1979).

The process developed by IGT consists of a series of physical, chemical and biological unit operations for separation of raw refuse into organic and recyclable inorganic materials; blending of the organic fraction with primary sewage sludge; conversion of the blend to pipeline-quality or medium Btu gas and stabilized solid residue; and finally, treatment of the liquid effluent to discharge. The process is made up of five major sub-systems: refuse separation, refuse-sludge blending, anaerobic digestion, gas cleanup, and ultimate solid and liquid effluent disposal. After bench-scale work on digesting combined raw sewage and solid waste, the University of Arizona, had by 1976 completed scaled-up work for a 20,000-gallon (76-m^3) in-ground digester heated by solar energy. The cleaned methane was intended to be used for local needs, with the remaining carbon dioxide supporting a greenhouse and the residue serving as a soil conditioner (Hitte, 1976).

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The University of Illinois, has also had an extensive research program on refuse anaerobic digestion. As a result of its preliminary works, the full-scale RefCOM Demonstration Plant was built. The process flowsheet and material balance is shown in fig. 1 (Pfeffer, 1978). The processing line was designed to handle 100 tonnes of refuse on an "as received" basis during a two-shift operating day. As of 1979, after one year of operation, the system exhibited substantial shortcomings in many process areas, most of which were related to mechanical troubles as analyzed in detail by Geisser (1980), Walter (1980), Walter and Rines (1980), and Wright (1981). At the time of their writing the existing problems lay with the separation techniques employed in the classification system. In the form described, the plant could not perform at the level of throughput, or reliability necessary to meet the requirements of the experimental program.

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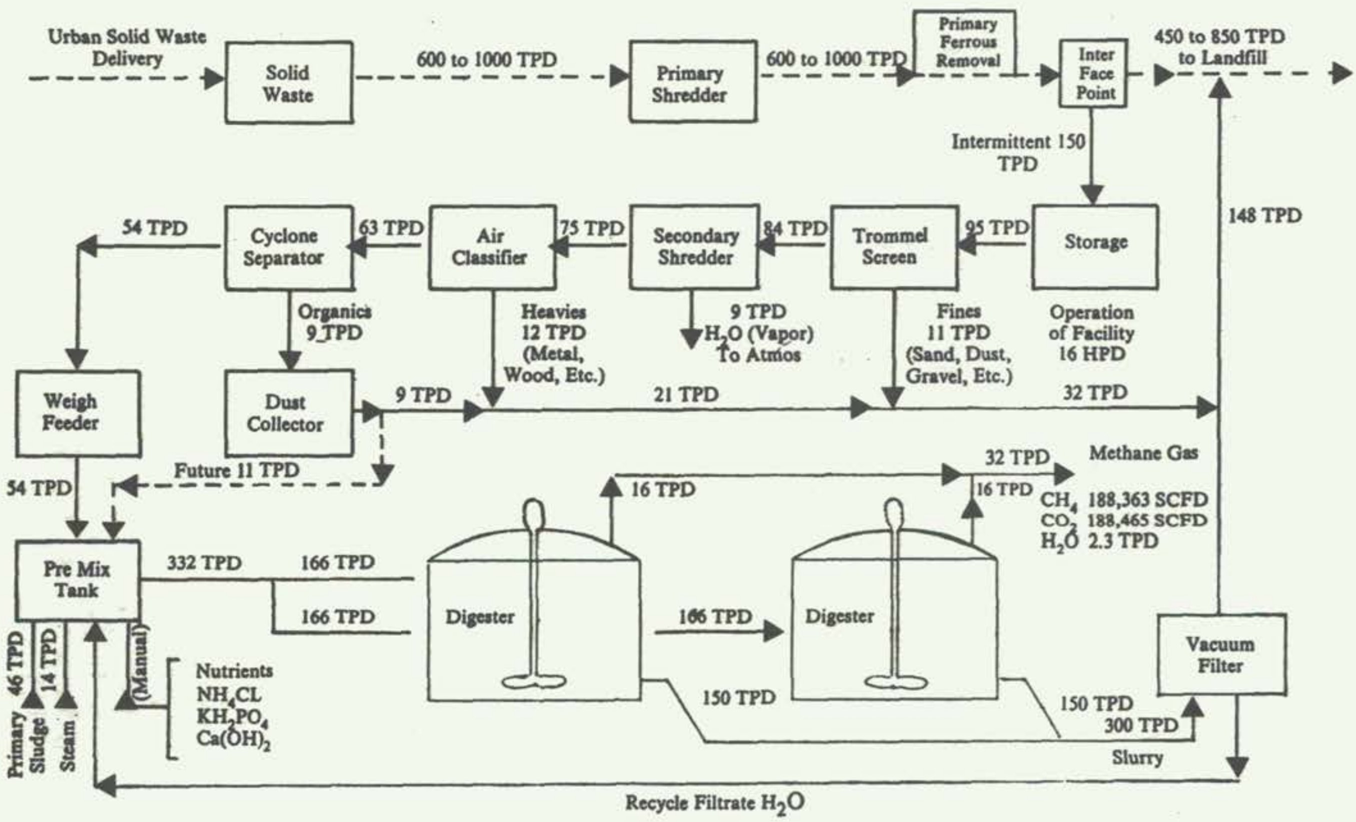
FIGURE 1. POMPANO BEACH REFUSE CONVERSION TO METHANE (REFCOM) FACILITY.



Economics

Economic evaluation of biogas production from refuse has been carried out by various investigators (Abeles et al., 1980; Aller, 1979; Ghosh and Klass, 1979; Hitte, 1976; Kispert et al.; 1976; Klein, 1972; Le Roux and Wakerly, 1978; Pfeffer, 1974a; Pfeffer, 1978; Ross, 1954; Swartzbough et al., 1977). Pfeffer (1974a) stated that methane can be produced by anaerobic digestion of organic refuse at a cost that would "permit the sale of the gas at a price that is competitive with the current energy costs."

Except in the case of Ross whose data are in any event somewhat scarce, the reported costs of digestion of refuse were based upon the results of small, pilot-scale experimental runs, or computer extrapolations of those results, and on experience with sewage sludge digestion. These data are closely relevant to the econo-technological settings of industrialized countries, and so of limited use for developing countries. These facts should be kept in mind when evaluating the various cost analyses.

Prospects for developing countries

Biogas production from refuse is basically a sound concept to be considered seriously, since:

A. It is ecologically meaningful. Instead of being burned or buried, the waste is used to produce energy and fertilizer - two commodities that constiture a major share of the import bills of developing countries.

B. The process can be incorporated in a wastewater treatment plant or resource recovery facility. Therefore, a whole plant does not need to be built, but an existing one can be expanded in size and scope.

C. Consequently, the incorporation into a resource management plan of a scheme producing biogas from refuse will encourage and broaden the applicability of resource recovery to its fullest extent, since the more valuable materials recovered, the more digestible is the residue. This residue, which is normally considered to be of "low value", now becomes more suitable as feed for digestion.

D. Compared with other solid waste management options, this option is the only one which can produce pipeline quality gas, and so marketing and distribution of the end-product is easy where such a gas utility exists. On the other hand, this option has a low gasification rate over a period of time, which may make its land use uncompetitive. Fortunately, land availability is seldom a constraint in developing countries.

E. Compared with composting, a commodity such as compost may behave according to the economic theory of "inferior goods". This theory states that, contrary to the law of supply and demand the demand for "inferior goods" decreases when the standards of living (and hence, the purchasing power) of the customer increases. This has been observed for the compost produced from large-scale refuse composting plants in some Asian countries, particularly Thailand. Most likely this theory does not apply to gas, and between the two options of refuse management, mamely biogas production and composting, in the future the former will be in a better competitive position.

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F. Developing in particular countries, are in a favorable situation since their refuse is largely made up of putrescible, readily digestable materials which are quite amenable to anaerobic digestion. In contrast, incineration and pyrolysis are not always feasible for those wastes consisting chiefly of vegetable matter and kitchen scraps.

Unfortunately, biogas production from refuse is still a relatively unproven technolgoy. Although it can make use of existing processes (such as shredding, waste separation, gas purification, etc.), some modifications of these processes are needed for preparing an appropriate feed material for biogas production. In fact, the failure of large-scale systems have mainly been due to unexpected problems in using existing equipment designs for refuse digestion. Likewise, although the experiences in designing and operating the existing sludge digestion tanks can be helpful, some problems have to be solved, among them scum formation, severe stratification, and quick sludge accumulation in the digester. Developing countries usually lack the necessary levels of technology and experience. In other words, if they wish to embark on a biogas from refuse program, they will probably have to start from scratch! This is especially true as far as the characteristics of refuse generated from a specific location are concerned. To put it in another way, technology transfer from North to South would be limited, due to inherent differences between the two.

It is undeniable that waste separation and thermo-chemical treatment of the feed material can offer various benefits, but for developing countries some questions have yet to be answered regarding the viability of these processes; for instance, whether the low level of technology, the lack of locally-produced equipment, and lack of skilled personnel can afford such a high-tech refuse management option.

There is an idea that refuse can be fed to the existing household-size or community medium-size digesters. For developing countries, the unsolved problems are:

1. How to educate the householders to separate the waste. This seems to be a simple matter, but many solid waste management programmes depending on waste separation at source, failed. In fact, waste separation at source carried out by householders has been successful only in industrialized countries (Japan, Europe, North America), where public awareness is high, and where there is not necessarily a great need for resource recovery.

2. S ple, low-cost equipment for the householder to shred, and if possible, thermo-chemically treat the waste before feeding it to the digester.

3. Modification of the existing facilities, such as those for more intensive mixing and more frequent de-sludging.

<u>Economic viability</u>

Biogas production from refuse is definitely not a low-cost option. Coupled with this are: (i) the huge amount of waste to be collected as soon and as regularly as possible, and then to be treated as properly as possible; and (ii) the complex process to be controlled as closely as possible. All of these obligations can be fulfilled better by mechanical systems, which require foreign currency to import, and probably foreign skill to install.

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Once all the resources are available to be invested in this venture, the next prerequisite is a secured market for the gas produced. In industrialized countries, the gas can be purified and injected into the existing public utility gas supply grids, which makes the task convenient and reduces the cost. Also in rural areas of these countries, small-scale biogas systems are usually marginally economical, and adding refuse to a manure digester can effectively increase the size of the system to where it could be profitable for the farmer. In developing countries, this may not be the case, and their large-scale installations may find it very hard to secure an outlet for the gas produced. The authors have seen that several sewage treatment plants in Malaysia and Thailand with sludge digestion facilities which have to burn off their gas, simply because the gas cannot be marketed. This marketing problem is compounded by the fact that the characteristics of refuse change seasonally, and so does the gas quantity and quality. A gas supply system depending solely on methane from biogas can not accept such a high fluctuation.

Markets for bottled liquified natural gas for cooking exist and are flourishing in developing countries. Unfortunately, it is not feasible to compress and bottle methane to distribute it widely. There is a possibility of using the gas for generating electricity through dual fuel generators. When the gas supply is short, the generator can be switched to conventional fuels. Unless there is a careful feasibility assessment for such a large-scale scheme, its viability cannot be ascertained. A promising method could be using biogas to run various engines in a wastewater treatment plant or refuse processing plant, in reducing external energy needs.

Operation and maintenance

Even if the technology is proved and economically viable, operation and maintenance is still a problem. Biogas production from animal manures is much simpler than biogas generation from refuse. Yet many small-scale biogas schemes in developing countries such as China (Smil 1982a, 1982b), Korea (Park et al., 1979), and Thailand (Sermpol et al., 1979) have not been up to expectations. The technology may be correct, the economic situation may be favorable, but still things do not work as expected, due to various social or human factors (Tam and Thanh, 1982).

Various refuse incineration and composting plants in developing countries have likewise been operated and maintained badly, with very disappointing results. Mechanical breakdowns during long periods of waiting imported spare parts, coupled with mis-management all have become a "fact of life" in these facilities. In such a situation, the chances for a successful large-scale plant producing biogas from refuse seem uncertain.

Conclusion

This review indicates that the viability of biogas production from refuse, is still in doubt particularly in developing countries. Much research and development would be needed to devise an efficient, reliable and affordable processing line. On implementing this concept, it might be wise not to look at it as a profitable venture, but as a means of waste disposal for environmental protection. However, this may not be readily accepted by local authorities, who have to shoulder more burdens while suffering increased financial liability.

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The authors do not suggest that this technology be ignored completely. It is in any case vitally important that feasibility evaluation be carried out on a case-by-case basis, taking into consideration all specific local conditions. Most instances will require that this technology - as other technologies - be adapted wisely rather than adopted blindly.

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LOW-WASTE TECHNOLOGY : SUMMARY

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Waste management, particularly hazardous waste management, calls for a policy in which the life history of wastes must be followed rigorously from "cradle to grave". Among the residues from various human activities, and especially from industrial production, some can be re-utilized or recycled for financial savings, to save resources or for environmental enhancement. The cost of waste treatment and of its final disposal, including landfilling, dumping at sea, incineration or underground disposal can be so punitive that preventive techniques through which the quantity of wastes produced per unit of human activity is reduced, have an edge over corrective approaches. Dr. Joe Ling of 3M has coined the name of 3P for this stategy: "Pollution Prevention Pays ".

Low-waste technologies cover internal waste control measures which can be characterized at three levels:

A. Improving the management of production units: This does not call for radical technological change, but for an analysis of the points where the waste appears and for improvement of water, energy, raw materials and finished products management. It calls for separation of process streams which are unnecessarily mixed, limitation of losses, etc.

B. Process modifications: This relates to the introduction of clean technologies, without modifying the basic nature of the process, for example through residue recycling or closed-circle operations.

C. Low-waste processes per-se: In such "clean" processes, there has been a radical conceptual change that ensures that no waste is created (for example, replacing sulphuric acid treatment of steel wire by a mechanical process). European governments have set up processes to gather monographs on low- and non-waste technologies in a Compendium. In each monograph, comparative data on resource use, investment and operating costs and environmental impact of the traditional technology and of the low-waste technology are provided.

By reducing the amount of waste, waste treatment and disposal costs to comply with legal standards are also reduced. But in addition, very often, a cleaner technology, producing less waste, will permit gains in productivity.

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A CASE STUDY FOR UPGRADING WASTE MANAGEMENT SERVICES IN CAIRO

by M.S. Neamatalla, L. Oldham, and R. Assaad

At the beginning of the 1980's, the Governorate of Cairo was in the position of having to govern a city which had rapidly outstripped its capacity for delivery of urban services. The population of Greater Cairo, around 4 million in 1986, grew to 5 million by 1976, and passed 7 million by 1980. Indications suggested that this rate of growth would produce a metropolitan population of about 16 million by the year 2000. By 1980, large areas of the city, especially on its peripheries, were already lacking basic urban services such as sewerage, piped water, adequate public transportation, roads and footpaths, street cleaning services and regular solid waste collection.

As part of its efforts to remedy these deficiencies in urban service delivery, the Cairo Governorate has embarked on an integrated programme to upgrade solid waste management services. The programme includes basic studies of the current waste management system in the city, as well as pilot programmes to test alternative waste management practices and technologies. These studies and programmes have now placed the Cairo Governorate in a position to make long-term policy decisions and organize new frameworks for improved solid waste management in the city.

The current waste collection system

Basic studies of the private and public sector components of the Cairo waste management system have revealed that the current system is essentially sound in conception. However, it suffers from a number of constraints which have led to lowered service levels in recent times.

The current household waste collection system is entirely in private hands and partially financed by the recovery of waste materials. The Administrators of the system, the wahis, gain access rights to the wastes through contracts with building owners. The wahis subsequently allocate the refuse to individual garbage collectors, or zabbaleen, for haulage by means of donkey carts to one of six settlements the zabbaleen inhabit on the outskirts of the city. The waste is then sorted. The organic components are used for animal breeding and the recyclable materials are returned to the industrial stream via a network of specialized dealers.

The zabbaleen and the wahis share the labour involved in bringing the wastes to the donkey cart. The wahi receives the entire household fee in return for his labour and supervisory functions. The zabba, on the other hand, derives his income from recovery of the resource value of the waste.

This paper represents the views of its authors and does not necessarily represent the views of the Cairo Governorate or the various international funding agencies which have partially financed this work.

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This system served Cairo very well for many years, providing economical and effective waste collection services and achieving full cost recovery. However, it has not kept pace with the explosive growth of the city, so that today a significant portion of Cairo's households are severely underserviced. The reasons for the inability to keep pace are manifold. First, the income of the zabbaleen from the sale of recycled materials has not increased sufficiently in recent years to attract the necessary additional labour. Second, access to capital by service providers is limited and has, therefore, curtailed their ability to upgrade waste collection technology. Third, the fragmented nature ofthe zabbaleen work force has constrained their internal capacity to respond effectively as a group to changes in Cairo's waste management needs and demand patterns.

The municipal sanitation system, which is only responsible for street cleaning, has been adversely affected by the recent inability of the private sector systems to provide comprehensive household service. This deficiency has produced a situation in which large quantities of household waste are thrown onto the streets because many householders simply have no other alternative. The accumulation of waste in the streets is overtaxing the municipal system which is often forced to undertake manor clean-up efforts, thus undermining its capacity to fulfill its usual street cleaning function. The removal of household wastes from street surfaces is a needlessly expensive task. Therefore, the studies and system designs have concentrated on developing mechanisms to strengthen the capacity of the private sector system to trap wastes at the source rather than removing them after they are thrown onto city streets.

Preliminary findings of waste quantity studies indicate that approximately 3,000 tons of solid waste are generated daily in Cairo. The current private sector service providers remove approximately 1,800 tons; the municipality collects 1,200 tons, part of which is removed by irregular clean-up campaigns, mostly undertaken in low income areas.

Waste composition studies conducted in Cairo have shown that there is a direct association between the income level of the household and the resource recovery value of its waste. Wastes generated from low income areas generally have little or no value to the zabbaleen, limiting their incentive to service these areas. The low resource value of the wastes, coupled with the rapidly expanding demand for service in high and middle income areas have caused a gradual shift of service delivery away from many low income areas in Cairo.

Composting of municipal solid waste

A market structure survey was carried out to determine the demand for compost and other recyclable materials recovered in a composting plant. The survey revealed the presence of an active recycling industry in Cairo which spans dealers and factories specialized in the reprocessing of plastics, paper, bone, glass, textiles, ferrous and non-ferrous metals. The demand for compost was also found to be quite high, especially from land reclamation projects which utilize compost to improve the water retention capacity and the nutrient content of poor, sandy soils.

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As a result of this finding, the Governorate of Cairo carried out several studies aimed at examining the merits of composting as an alternative for processing street waste. The waste stream was sorted and analyzed in terms of compostibility, size distribution and materials recovery. The resulting data provided strong evidence for the technical feasibility of aerobic windrow composting as a potential method for recovery of the resource value of Cairo's street waste. The quality of the resulting compost proved to be well above government specifications for organic fertilizers.

Pilot programmes

As a complement to the basic studies described above, the Cairo Governorate has undertaken a number of pilot projects to test the viability of mechanisms designed to alleviate the problems of the current waste management system. The pilot programmes include projects aiming at: (i) extending waste collection services to previously unserviced low income areas; (ii) creating an institutional structure among the current service providers capable of assuming responsibility for solid waste management projects; (iii) designing and implementing a mechanized waste collection system in the central business district of Cairo to serve as a prototype for other high and middle income areas in the city; and (iv) evaluating the performance of an intermediate technology composting facility for the processing of Cairo's street waste.

Route extension in low income areas

The basic studies have demonstrated that the existing household waste collection system does not offer sufficient incentives to the current service providers to collect waste from low income areas. The pilot programme for extension of waste collection services to these areas consisted of developing a mechanism for direct monetary remuneration to the waste haulers in substitution for the low value of the waste. In addition, the use of a low cost donkey cart system has made it possible to achieve full cost recovery from service recipients in the low income areas. The resources of low income communities are too limited to make a capital-intensive system of waste collection a real option for the time being and, in any event, street widths and surface conditions often rule out the use of motorized vehicles.

To ensure continuity in delivery of service to low-income areas, a waste collectors' organization was created to manage and implement route extension programmes to unserviced and partially serviced areas in Cairo. These route extension programmes have expanded to cover no less than three low income communities with a total population of over 100,000. The costs of the system are at an average low of LE 0.25 per household and are fully borne by the beneficiaries of the service with no cost to the Governorate.

Institution building among the current service providers

The basic studies revealed that there was no form of organization among the service providers, allowing them to respond, as a group, to changes in demand patterns. A major programme of institutional development was launched with the aim of creating a community organization among the zabbaleen. This organization was created to permit the mobilization of the refuse collectors as an integrated group in order to capitalize on their experience and skills

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in the Governorate's waste management upgrading programme. Intensive efforts were made to develop the business skills and organizational ability of the community organization to the point where it was able to assume responsibility for the route extension programme in the low income areas.

The zabbaleen community organization has subsequently initiated a pilot programme to mechanize waste collection in the central business district. The organization is now also able to respond to many of the zabbaleen community's internal needs. For instance, it is operating a system for the regular removal and disposal of unwanted materials remaining after the sorting of the wastes at the zabbaleen settlement. Thus, the development of the zabbaleen community organization made it possible to capitalize on an experienced labour pool which had previously been a fragmented group of individual workers.

Mechanization of waste collection services in the central business district

At the request of the Cairo Governorate, the zabbaleen community organization undertook to institute mechanized waste collection services in the central business district on a trial basis. The purpose of the programme was to test collection methodology and level of technology on a limited scale to minimize the risks invariably involved in instituting any new system which carries with it a substantial level of investment.

This programme was instituted on a phased basis during the summer of 1983. The results were encouraging. The zabbaleen demonstrated that they are capable of adapting to the new technology and can provide mechanized solid waste collection service at a cost substantially lower than would otherwise be the case. It is thus possible for the Governorate to capitalize on the long experience of the zabbaleen when modernizing solid waste collection service in the city, which will save on both the cost of implementation and the trauma to the system which would be implicit in a complete shift of personnel.

The Shoubra pilot composting programme

The results of the experiments with composting of municipal wastes revealed that an intermediate technology windrow composting facility was suitable to the needs of the Cairo Governorate and that substantial savings could be realized by eliminating front end size reduction as superflous given the size distribution profiles of Cairo wastes. Construction had begun at Shoubra on an 160 ton a day intermediate technology pilot composting plant to reprocess street wastes collected by the municipal sanitation force. The plant was due to be completed and operational by May 1984.

Policies and programmes

The basic studies and pilot programmes indicate several reasons why any solid waste management system for Cairo should utilize the existing resources and skills of the current service providers. Detailed cost analyses have shown that the cost of systems relying on the current waste management labour force are substantially lower than comparable systems using labour recruited from outside the trade. This is mainly due to the ability of the current work force to benefit from the resource recovery value of the waste by returning waste components to the industrial stream. Moreover, the use of an experienced and trained labour force which has been engaged in the waste management industry in Cairo for more than 70 years reduces the risks of service disruption which are especially great at the initial stages of an upgrading programme.

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The current service providers have the advantage of being familiar with the areas they presently service in terms of access routes, building configurations, waste handling techniques and with human factors such as the trust of service recipients, building owners and doormen.

The creation of a representative organization among current service providers has made it easier to have access to this large existing labour pool, preferably through contractual arrangements. These arrangements can substantially increase productivity and reduce overhead costs. Furthermore, the basic studies show that the recovery of the cost of Cairo's waste management system from service recipients should be based on the principle of differential charging. Higher income residents receiving the benefit of a mechanized programme should pay the full costs of this service in order not to unnecessarily burden residents of lower income areas with the added costs associated with mechanization.

The Governorate is, therefore, embarking on a programme to mechanize services in high and middle income areas with special emphasis on areas such as the central business district wehre donkey carts pose a serious problem for traffic flow. The Governorate is also encouraging low cost collection systems to partially serviced low income areas according to the format successfuly implemented in the pilot programme. The overriding idea is to secure the attainment of high levels of service together with full cost recovery by providing city residents with the level of technology they can afford and which is most appropriate for their conditions.

The extension of mechanized service to high and middle income areas requires financial resources which outstrip the means of the current service providers. For this reason, the Governorate has established the baseline conditions and organizational framework to mobilize private sector investment in upgrading waste collection technologies in these areas. Private sector waste management companies continue to rely on the current waste collection labour force by enhancing their three most important functions: door to door collection of wastes, loading onto collection vehicles, and waste utilization through sorting and reprocessing. Subcontracting arrangements between the waste management firms and the representative bodies of the current service providers would provide the necessary incentives to achieve high labour productivity and would reduce the need for direct supervision functions on the part of the firms involved.

Basic investigations of composting as a waste utilization technique for Cairo's solid waste show that there are suffient grounds to consider the composting of street wastes collected by the municipal sanitation force. These wastes are presently being disposed of in open dump sites with serious consequences for the environment and public health. Close monitoring of the operation of the pilot composting plant at Shoubra will determine whether or not to embark on a larger programme for composting street wastes in Cairo.

In upgrading the collection and utilization of Cairo's solid wastes, the Governorate is exercising extreme caution to ensure the current system is not upset but rather enhanced to the point where it can respond to the service delivery needs of both high and low-income communities in Cairo.

REGULATORY AND ORGANIZATIONAL ASPECTS OF SOLID WASTES MANAGEMENT

Bert A. Szelinski

1. Introduction

Waste management is a complex matter. Although the technical aspects are of prime importance there are also a number of non-technical questions that have to be addressed to give a complete picture of the issue. Waste management differs substantially from "normal" industrial activities, particularly because waste generally has a negative value. If society did not organize waste disposal it would basically follow economic principles. Waste would therefore be disposed of at the lowest possible costs. In many places this still seems to be the principle for waste disposal.

Proper waste management is costly but mismanagement can also be costly. Clean-up costs for improper dumping of hazardous waste can add up to millions of dollars. The health risks connected with pollution caused by dumping of wastes are high For instance, in many case improper waste disposal has led to pollution of ground water tables used for the production of drinking water. For all these reasons waste management cannot follow simple market principles.

The role of legislation is basically to provide a framework for organizational decisions. Legislation has to assure that:

- Public responsibility for waste management is established;
- That management decisions can be made at the appropriate level of government;
- That duties, necessary to make the system work can be enforced; and
- That control can be executed.

It is very difficult to establish generally acceptable principles on administrative and legislative questions. The self-evident: the need for and the enforcement of administrative and legislative patterns for waste management depends on the situation of the country in question. Considerations such as the constitution of the state, whether it is an unitarian state or a federation, its distribution of administrative powers, i.e. centralization or devolution of administrative functions, have a strong influence both on the extent to which legislation is possible and on the form in which legislation can be enacted, implemented and enforced. The economic constitution of a state may equally have a strong influence on legislation.

A clear distinction must be made between disposal of municipal waste as compared to other types of waste, in particular to industrial or hazardous waste. Whereas the legal and administrative needs for organizing municipal waste disposal are already clearly established, this is not the case with regard to industrial waste disposal. These issues should therefore be considered separately. It might be useful to note the most important differences between municipal and hazardous waste disposal before giving recommendations on organizational issues, as what applies to one group does not necessarily apply to the other.

- Municipal refuse is generated everywhere where people live. This is not the case with industrial waste and particularly not with hazardous waste. The organization of municipal waste disposal is a necessity for every community on the local level. Industrial waste disposal can only be done on a regional, supraregional or even national level.

- To avoid unnecessary, long distance transportation of municipal waste, facilities for the disposal of such waste should be within a reasonably close distance from the municipality. This can be achieved in most cases.

- Industrial waste disposal needs special precautions, technically and with regard to control, to assure proper disposal. To be cost-effective, facilities will need large "catchment areas".

- Hazardous waste, when generated in large quantities, needs specially designed disposal facilities. To establish suitable facilities will generally be beyond the financial and technical capacities of local authorities.

2. Administration and legislation

The term "administration" covers both the private and the public sector. It is not limited to state, regional or local authorities. In cases where responsibility for waste disposal is left to the waste generator, he will have to carry part of the administrative burden.

Other than the term administration, the term "legislation" refers to central and local governments as well as legislative bodies, only, i.e. to the public sector. However, the term "legislation" should not be understood too narrowly. The scope and nature of legislation required for waste management depend strongly on the individual state's constitutional and administrative requirements.

There might be states which do not need any legislation in the strict sense of the word. There must be, however, some binding principles. Some states may require laws, others might operate under statutory or even administrative regulations.

Many aspects of waste management would be hampered rather than improved by binding laws. This is particularly true for the technical sector of waste disposal. It has, therefore, to be borne in mind that these areas can often be better regulated by the use of guidelines.

All these instruments will be regarded as "legislation" in this paper. Where appropriate, indications will be given as to the legal quality of regulations required.

3. Basic legal requirements

There are a number of basic legal requirements which have to be provided when establishing a waste management scheme.

A law has to regulate

1. What is to be regulated as waste;
2. Who is responsible for waste disposal;
3. Where can waste be disposed of; and
4. How shall disposal take place?

These matters should be regulated on a national basis, i.e. by national laws and/or regulations. There are other matters which should be addressed on the regional or rather local level, such as frequency of collection, usage of containers etc.

3.1 Definition of wastes

At first glance, a definition of waste may seem superfluous, as waste is a commonly understood term. There are situations, however, where a definition of the term "waste" can be helpful. It is clear that material which its owner wants to remove through waste disposal should be regarded as waste without considering its value. This does not necessarily mean that it has to be disposed of. This principle only means that the decision to regard material as waste should in the first instance be a decision of its owner. There are cases where material is not handed over for waste disposal but may be a public nuisance or even danger. If someone collects empty tins in his backyard, and if this material attracts rats and insects, there should be a way to dispose of it even if the owner objects. The same should be true for abandoned cars left alongside streets or on public land or in the extreme, for hazardous material leaching away in the backyard of a factory.

In such cases, it might be useful to have regulations that allow for the disposal of such materials even against the will of the owner. An objective definition of the term waste can be dispensible if the law grants sufficient power to the authorities to remove items from their owners on the grounds that the items have no value and are, by their condition, a clear public nuisance.

3.2 Designation of responsibility

The most important issue to be regulated is that of responsibility for waste disposal. With regard to municipal refuse, responsibility should lie with the city administration or other comparable public institutions. It is important to mention that responsibility for waste disposal does not necessarily mean that the public institutions have to provide the service themselves. In certain cases it may be technically and economically favourable to use a third party, for example a private enterprise particularly for the collection and transport of waste. Joint ventures of different local authorities should be encouraged, especially when these authorities aim at operating a common disposal site or facility. Private investments for waste disposal facilities may be difficult to get unless there is compulsory use of the service.

The "waste disposal authorities" should have the power to issue bylaws regulating details of the local waste disposal scheme, such as the use, size, and type of containers, fees for the service and its frequency. They should be in a position to decide which waste can be accepted for municipal waste disposal.

As mentioned before, the duty of the local authorities should be limited to municipal waste disposal, including the waste of small shops and enterprises, market-generated waste, etc. Additionally, industrial waste can be accepted, provided it does not impose greater risks during transportation and disposal than household waste.

Waste disposal covers three different phases:

- Collection;
- Transportation;
- Treatment and/or disposal (in the narrow sense of the word).

With regard to municipal refuse, the responsible authorities should be required to cover all three phases. If industrial waste of certain types and quantities can be accepted for treatment and disposal, this does not imply that the local authorities should also take care of collection and transportation. This should be done by the respective industrial enterprises or by special transportation firms, as it often requires special equipment.

Whereas the designation of responsibility for municipal waste is quite easy (as there is generally only one organization that would be acceptable for this task), the same does not apply for industrial or hazardous waste.

There are different ways to organize hazardous waste disposal.

- The responsibility can remain with industry, which will then have to organize its own disposal scheme or use "third parties", i.e. private enterprises for disposal;
- It can be designated to a particular public authority, who can then share the responsibility through the use of joint ventures between industry and public bodies.

Which of these options will best suit a given situation cannot be predicted in general terms. It is therefore advisable, to refrain from promoting one particular pattern of organization through legislation without investigating the suitable options in the given situation.

The advantages and weaknesses of the different organizational options for hazardous waste management can be summarized as follows:

<u>Advantages</u>

- The participation of public corporations can ensure directly the adequate utilization of certain facilities, direct influence can be used to assure the observation of certain disposal standards;

- The government's duty to eliminate dangers to the general public can be met directly and effectively if the govenment participates in hazardous waste disposal enterprises or if it establishes facilities itself. By means of strong governmental involvement, the creation of a comprehensive hazardous waste disposal system becomes feasible. Such a comprehensive system will not arise from market forces.

Problems

- Strong government influence will result in a reduction of private investment and would be regarded as a takeover of responsibilty. This would inevitably result in a lack of participation and co-operation of industry. Waste generation and waste disposal would be in separate hands. This could lead to a loss of co-ordination and co-operation. In the case of industry-owned facilities, adjustment of waste disposal to the production process and the technical know-how of the operators, however, can be an additional advantage.

- The willingness of waste-generating industries to develop and utilize waste reduction techniques might be diminished, if all responsibilities were taken over by public corporations.

The establishment of a disposal scheme for industrial waste requires thorough planning. The need for, and scope of, such a scheme depends on the types and distribution of industries and the quantities and kinds of wastes generated. Co-disposal of industrial waste together with municipal refuse can be an viable option unless particular hazards of industrial wastes or other factors prohibit the use of this method.

In cases of low industrial density or monoculture it may be advisable to leave responsibility for industrial waste disposal with industries but provide tight control by governmental authorities with regard to disposal operations.

The waste disposal aspect should in any case be considered in the planning phase for industrial settlements. Industrial developments should be allowed only where provision is made for adequate waste disposal.

To summarize the findings on the designation of responsibility, it can be concluded that:

1. The responsibility for municipal waste disposal should lie with the appropriate local authorities;

2. Co-operative efforts of local authorities should be encouraged, particularly on the treatment and disposal side;

3. Municipal refuse disposal schemes should consider including waste from small shops and businesses in their service. Industrial and hazardous waste should generally be excluded from this service, unless it can be proved that co-disposal is acceptable in environmental terms.

4. Means to ensure co-operation of industry should be exhausted to make use of industrial know-how and financial contributions from industry;

5. Wherever possible, the establishment of industry owned facilitities should be encouraged. Government control of such facilities, however, should be provided (cf. below 5);

6. The distribution of responsibility for organizing waste disposal should be regulated in national law.

3.3 The licensing and planning of facilities

Waste should only be disposed of in facilities licensed for this purpose. This principle should be subject to national law, which has to provide regulations for licensing and planning for such facilities. The law should include a provision requiring that all types of waste disposal facilities need a license prior to construction and operation. Licensing should therefore cover:

- Landfills;
- Incineration plants;
- Recycling facilities (if not covered by other legislation on the production of goods including provisions necessary for environmental protection);
- Chemical, physical and biological treatment plants;
- Transload and storage facilities.

Special considerations should be given to the storage of industrial waste, as storage often slides into ultimate disposal, which may result in high cleanup and removal costs.

Licensing of industry-owned disposal facilities may not be necessary if there is a comprehensive licensing scheme for industrial facilities as a whole, which also covers the waste disposal aspect. It can be generally noted that licensing of waste disposal activities should be looked at in the same way as licensing of potentially hazardous industrial activities.

To ensure that given standards are met, it can be helpful to distribute responsibilities for planning and licensing of facilities to different government authorities. Facility planning can be done on the local level, provided the necessary technical know-how is available. Licenses should be issued by a different, preferably a higher administration to guarantee control of local authorities, the harmonization of planning decisions and the consideration of overall planning requirements. Licensing by non-local authorities may also help to avoid local pressures which might otherwise influence administrative decisions.

The licensing procedure should be regulated by law. The technical side of site selection, equipment of facilities, safety precautions etc. needs only be regulated in a very general form, stating the basic principles. To ensure uniform practice, guidelines or administrative regulations on these issues can be helpful. They should be binding for planning and licensing authorities. It should be emphasized that licensing of facilities particularly of landfills can only be done on a case to case basis, as local conditions and lcoal needs tend to differ very much. This should be considered when drafting guidance documents. It is essential to make the system flexible enough to allow it to work under different conditions. The most important factors that have to be considered for planning and licensing of waste disposal facilities - particularly landfills - can be summarized as follows:

- Location of facility, geological conditions;
- Size of the site;
- Capacity of the site;

- Possibility of expansion;
- Availability of the site (ownership etc.);
- Waste that can be disposed of (municipal refuse, industrial waste, hazardous waste);
- Extent and kind of construction work necessary;
- Technical and safety equipment;
- Access to transportation (road, railways, canals);
- Proximity to similar facilities;
- Proximity to possible users (important to both municipal refuse and industrial waste disposal facilities);
- Site characteristics with regard to water management;
- Background level of air pollution (incinerator plants);
- Climatology;
- Site conditions that could impose particular hazards;
- Contingency plans;
- Monitoring and control devices;
- Particulars on financing of the facility (where appropriate, including insurance and long term care).

This long list of determining factors for planning and licensing of a facility, shows that it would not be reasonable to include provisions on site selection and particulars of the licensing of a facility in laws and regulations. These should only regulate the basic principles. Guidance documents, however, can be extremely helpful.

The list given above is by no means exhaustive. There are many more factors to be consider when licensing a facility. For instance landfill disposal sites will require a fairly comprehensive study of local, particularly hydrogeological conditions. The following subject areas should, therefore, be particularly carefully examined when a licence for a landfill site is applied for:

- Geological conditions including hydrogeological situations to avoid groundwater or surface water pollution;
- Assessment of the impact of landfill operations particularly of attenuation, leachate migration, and leachate management;
- Climatoloy;
- Proximity of settlements and water supply facilities;
- Environmental impact control (control boreholes or wells).

Legislation in the field of planning and licensing of facilities should take account of the fact that the controlling authorities will need broad competences to insure proper construction and maintenance of facilities. To this end the following principles should be regulated by law:

- Principle of licensing of facilities;
- Purpose of the licensing procedure, stating the matters that have to be considered in broad terms;
- Right of access to the facility by control authorities;
- Right to issue or alter conditions of the license even after start of operations.

Facilities should only be licensed for the disposal of <u>certain</u> waste which are acceptable in terms of technical equipment and safety precautions. The answer as to <u>how</u> waste and particularly how certain types of waste have to be disposed of cannot be given in a general way. A commonly accepted state of

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the art does not yet exist with regard to waste disposal techniques. It can be said that, for some industrial waste, incineration is a safer method of disposal than landfilling. However, using highly developed technology is very costly, and facilities might not be available. Still, the waste is generated. This calls for compromise. In trying to find the right compromise between exonomic needs and the protection of the environment, it should at least minimize the risks of large scale environmental damages. Therefore, hazardous waste should - when disposed of in landfills - be transferred to sites where there are favourable site conditions, particularly with regard to climatology and ground water protection.

On the other hand, it has to be said that an environmentally neutral form for waste disposal does not exists. The aim should be to reduce the residual risk as much as possible. This principle should find an appropriate expression in legislation.

Whenever the structure of local government and the distribution of competences allow, a regional, and, for industrial waste, even supraregional planning for site selection purposes should be aimed at. Waste disposal plans should at least give guidance to the local authorities on suitable sites for waste disposal facilities.

It has to be mentioned, however, that the development of a comprehensive waste management system cannot start from scratch. Existing facilities have to be considered for intermediate use and will have to be the basis of any future disposal scheme.

4. Other aspects of legislation

In some countries, waste legislation is already a highly sophisticated and specialized area. It is always very tempting to make good use of others experiences. This will not work in the field of waste management legislation. Legislation as such and particularly environmental legislation should aim at the feasible. Legislation only makes sense, when enforceable. Waste legislation should therefore, in the first place, be directed towards people that are actively involved in waste management, such as operators of waste disposal facilities, regional and local governments as opposed to the public in general. To cover this aspect, I should at least mention some areas which are the subject of legislation in some countries which already have a comprehensive waste management system. In these countries, laws and regulations do exist on i.a.:

- Waste management planning (planning principles, aims of planning, procedural questions);
- Waste management principles, (priority of waste generation avoidance and material and energy recovery as against "simple" disposal);
- Control procedures, including such as licensing transportation, import and export of waste;
- Special legislation for certain types of waste like:
- Waste oils and lubricants,
- Hazardous waste (including definitions, hazardous waste lists, special requirements for disposal, special control procedures like waybill or trip-ticket procedures),
- Sludges (regulations on agricultural use of waste water treatment sludges etc.).

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When introducing waste legislation, it should be kept in mind that the transmission of problems into other media should be avoided as far as possible. If the disposal of waste on land is regulated but there is no regulation on incineration of waste, incineration would be used and may cause severe air pollution problems. Imposing regulations on the disposal of sewage sludges, where there is no obligation for waste water purification, can lead to unpurified discharge of waste water to avoid costly disposal of sludge. Waste management legislation should be developed within the framework of general legislation and of environmental legislation in particular. Rather than developing a whole set of new legislation it is advisable to use existing patterns to also cover the waste aspect. Existing laws and regulations on hazardous industrial activities can, for example, also cover the hazardous waste aspect. Public cleansing laws can be extended to also regulate municipal waste management. Such a co-ordinated approach can reduce problems of enforcement and make the establishment of new administrations superfluous, as existing authorities can be used to take care of the new legislation. Waste legislation should - in so far as it is possible for legislation - take into account the social, cultural and economic background and should give due regard to the problems of public acceptance that have to be faced.

5. Special control issues

There are two control issues that need special mentioning particularly with regard to developing countries, i.e. waste stream control and import of waste.

Many of the industrialized countries have already established specialized legislation on waste stream control including so called trip-ticket-procedures for potentially hazardous wastes to insure that wastes reach their ultimate destination. These control procedures are rather costly and personnel consuming. However, they have to be introduced if there is a free, open market for hazardous waste disposal enterprises and a large number of waste transports. To make best use of control capacity it can be recommended to concentrate control on the waste generators and on disposal facilities and reduce the use of "third parties" as much as possible. Records on wastes generation and waste disposal should be obligatory. These records should be subject to inspection by the control authorities. Wherever an "open market" for disposal firms is aimed at, these firms will be a weak point in the system with regard to control and should be subject to specific control measures.

Rising standards and rising prices for waste disposal in industrialized countries have led to increasing "transborder trade" with wastes, even to developing countries. This issue is worked on by a number of international organizations including i.a. UNEP and OECD.

As disposal costs on the basis of comparable standards generally will be very much the same, transborder movements of wastes tend to be directed to low price/low standard countries. Long distance transportation is no longer a limiting factor when disposal prices differ by some 100 per cent. There have been waste exports to developing countries where no adequate disposal system existed. The danger for pollution in the receiving country cannot be overestimated in such cases.

Unless internationally agreed principles are developed with regard to transborder movements of wastes, countries that have not yet established a disposal system and adequate control procedures should not allow waste importation. To insure control of waste imports, the customs authorities should be informed of the problems connected with waste imports and should be put in a position to refuse waste transports at the border unless they are properly declared and the import is sanctioned by an appropriate government authority.

6. Administrative aspects of waste management

Waste management legislation would be useless without an administration to enforce the law. Additionally, trained personnel are needed to organize and execute waste management operations and enforce legislation. Both these aspects call for trained, specialized administrators with insight into the problems of waste management. The right distribution of administrative powers is of prime importance for the established of a comprehensive waste disposal system. The same is true for the establishment of information lines.

Waste management cannot be ordered by central government. It has to consider local needs and options. Therefore, central (government) authorities should only be responsible for the enactment of relevant legislation. Regional, as opposed to local, authorities should be responsible for waste disposal planning. Local authorities however should at least be heard in the planning process. It can be advisable to base planning procedures on proposals made by local authorities.

The prime responsibility of local authorities should lie in the field of municipal waste collection, transportation, and operation of facilities. Co-operation of different local authorities should, where appropriate, be encouraged to reduce costs and promote capable centralized facilities.

Cost is a very important aspect of waste management. Financing should therefore be considered with regard to all stages of administrative action. Organizing waste management will require public funds not only for investments for car parks and facilities but also for current operations unless the public is prepared to pay fees for the service to cover the expenses. Where fees are not imposed on waste disposal, the costs must be born out of public funds or from the budget of the municipality. Costs may very well be a limiting factor in establishing a "streamlined" modern waste management system. However, it has to be emphasized that technical investments can pay off in the long run, provided that costs and benefits are evaluated before investments are made.

Finally, it should be mentioned that a system will not work properly without control. Control will be necessary not only for industrial enterprises and private waste disposal companies but also to ensure proper operation of communal disposal facilities. Experience shows that control cannot effectively be exercised within the same administrative bodies that are responsible for providing the disposal service.

The establishment of a centralized advisory agency for technical matters of waste management can be a strong incentive for the establishment of a comprehensive waste disposal system. Such an agency need not necessarily have executive powers but should provide the necessary technical information and advise local authorities.

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WHEN DECIDING TO DRAFT WASTE LEGISLATION THE FOLLOWING QUESTIONS HAVE TO BE ANSWERED:

1. WHAT IS THE ACTUAL STATE OF LEGISLATION, i.e. are there:
   - PLANNING PERMITS?
   - WATER PROTECTION LEGISLATION
   - LICENSING OF INDUSTRIAL ENTERPRISES (ACTIVITIES)?
   - LABOUR SAFETY, TRANSPORTATION OF DANGEROUS GOODS REGULATIONS?
   - PUBLIC HEALTH LAWS? .... etc.

   IT IS ALWAYS BETTER TO BASE NEW LEGISLATION ON EXISTING PRINCIPLES, THAN TO INTRODUCE NEW ONES!
   AVOID DUPLICATION AND, WHAT IS WORSE, CONTRADICTION!

2. GOALS (DO YOU NEED LEGISLATION AT ALL?)
   - WHAT IS THE CURRENT PRACTICE?
   - WHAT IS AIMED AT?
   - IS IT NECESSARY TO ENACT LEGISLATION TO ACHIEVE AN IDENTIFIED GOAL?

   OFTEN OFFERING A SERVICE IS MUCH MORE EFFECTIVE THAN ISSUING A LAW! THIS IS PARTICULARLY VALID IN CASES WHERE THE DUTIES IMPOSED CANNOT BE FULFILLED FOR LACK OF PRACTICAL MEANS.

3. COVERAGE, TYPE OF LEGISLATION
   - WHICH WASTES DO YOU WANT TO COVER?
   - ARE THERE EXISTING LEGAL INSTRUMENTS COVERING SOME KINDS OF WASTES ALREADY? - WASTE DEFINITION! -
   - WHAT KIND OF LEGAL INSTRUMENT DO YOU NEED (CONSTITUTION!) LAW, REGULATION, ADMINISTRATIVE ORDER?
   - WOULD A GUIDELINE BE MORE PRACTICAL THAN LEGISLATION?
   - WHAT SHOULD BE THE GEOGRAPHIC (ADMINISTRATIVE) COVERAGE? LOCAL vs. REGIONAL vs. NATIONAL PROBLEM?
   - WHO SHOULD BE ADDRESSED? EVERYBODY? WASTE GENERATORS, ONLY? AUTHORITIES, ONLY?

4. BASIC QUESTIONS
   - IS THERE A POWER TO LEGISLATE? IN GENERAL, IN THE WANTED FORM?
   - IS IT POSSIBLE TO ENACT GENERAL ENVIRONMENTAL LEGISLATION?
   - ARE THERE MEANS TO ABOLISH SCATTERED LEGISLATION?

<u>BASIC REQUIREMENTS FOR WASTE LEGISLATION</u>
WASTE LEGISLATION SHOULD AT LEAST ADDRESS THE FOLLOWING SUBJECTS:

<u>WHAT</u> IS REGARDED AS WASTE (WASTE DEFINITION)

EXCLUSION OF SOME TYPES?
BORDERLINE TO OTHER SUBECTS? LIQUID WASTES vs. WASTE-WATER?
THINK OF LOOPHOLES!

<u>WHO</u> SHALL BE RESPONSIBLE FOR DISPOSAL COMPRISING:

COLLECTION
TRANSPORTATION
STORAGE
TREATMENT
DISPOSAL ON LAND

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THERE MIGHT BE DIFFERENT ANSWERS TO THE DIFFERENT STAGES!
PROBLEM: INDUSTRIAL WASTES

WHERE AND HOW TO DISPOSE OF A GIVEN WASTE/WHAT METHOD SHOULD BE USED!

LICENSING OF DISPOSAL ACTIVITIES, COVERING ALL PHASES
EXECUTION OF CONTROL
DESIGNATION OF RESPONSIBILITY

NECESSARY POWERS

PLANNING COMPETENCE
- expropriation of land needed?

CONTROL COMPETENCE
- inspection of facilities (right of entry)?
- inspection of waste generating enterprises?

ENFORCEMENT
- penalties
- closure of facilities
- disposal at waste generator's cost
- disposal against waste generator's will (definition of the term: waste)

FINANCIAL POWERS - BUDGET
SCIENTIFIC KNOW-HOW (specialists)

OBSTACLES

Scattered (unknown) legislation

LOBBIES (either industrial or local groups) might call for decision making in their favour. This might call for decision making on a higher level of government.

LACK OF FUNDS
The authority in charge of organizing waste disposal must have sufficient funds not only for investments but also for current expenditure (repaid, maintenance)

FEES for the service might not be enforceable

LACK OF KNOW-HOW: can be overcome by use of (either internal or external) experts.

CO-OPERATION IS THE MAGIC WORD BUT MIGHT NOT BE FEASIBLE.

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ORGANIZATIONAL PATTERNS

	Responsible for:
CENTRAL GOVERNMENT (too far away?)	"OVERALL" LEGISLATION "OVERALL" PLANNING (CONTROL?) (LICENSING OF FACILITIES?)
Government Agency -------------	Scientific Advice?
	FINANCING (BUDGET) SUPERVISION OF LOCAL/REGIONAL GOVERNMENT.
REGIONS (SPECIALIZED BODIES) ?	REGIONAL PLANNING LICENSING OF FACILITIES DISTRIBUTION OF MONEY (INVESTMENTS). CONTROL OF WASTE DISPOSAL FACILITIES? MANAGEMENT OF REGIONAL FACILITIES FOR HAZARDOUS WASTE DISPOSAL. (TRANSPORTATION, HW COLLECTION CENTRES).
LOCAL GOVERNMENTS (MUNICIPALITIES, COUNTIES etc) (probably too close to some of the problems)	BUDGET LOCAL LEGISLATION (BYLAWS) MANAGEMENT OF LOCAL FACILITIES COLLECTION, TRANSPORT OF MUNICIPAL WASTE (CONTROL OF WASTE GENERATING INDUSTRY?)
MUNICIPAL WASTE DISPOSAL	SHOULD be the responsibility of government authorities, they can, however, use third parties for the service but should remain resposible.
INDUSTRIAL AND HAZARDOUS WASTE DISPOSAL	SHOULD NOT PER SE be made a public resposibility. Ideally governments should be able to limit themselves to legislation and control. Facilities should be run on a supraregional or national level. Transport distances should be levelled by appropriate measures (fees, collection points). Industry-owned facilities should be aimed at. Planning should be influenced by government. Control and licensing are indispensible government duties. STATES should only step in where private initiative proves insufficient. Industry should have to pay for the service.

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THE LICENSING OF NEW INDUSTRIAL FACILITIES IS OF PRIME IMPORTANCE FOR ENVIRONMENTAL PROTECTION IN GENERAL.

A license should only be granted when there is evidence that proper waste disposal is provided for.

PRIORITY should be given to waste avoidance and internal or external recycling as opposed to waste disposal.

GOVERNING POLITICAL PRINCIPLES

PRIORITY to waste avoidance (reduction at source) and recycling (reuse, material recovery, energy recovery)

over "simple" disposal

MEANS: interlocking systems of industrial production.
Problems should not be shifted to other media:

WASTE - WATER
WATER - WASTE
WASTE - AIR
AIR - WASTE/

PRINCIPLE: Solutions should fit in an OVERALL CONCEPT!

RESPONSIBILITY OF THE "POLLUTER"

either: find a solution or pay for the service

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WASTE DISPOSAL LEGISLATION

Type of legal instrument	Issued by	Addressing	Regulating
LAW	Central Government Parliament	Everybody	PRINCIPAL MATTERS, ONLY RESPONSIBILITIES NO technical details i.e.: DEFINITIONS, LICENSING, CONTROL, RESPONSIBILITIES, PENALTIES
REGULATION (ADMINISTRATIVE ORDERS)	Central Government Individual Ministry sometimes: Regional Authority	Everybody	MORE TECHNICAL MATTERS, PROCEDURES, MATTERS, THAT HAVE TO BE UPDATED REGULARLY
BYLAWS	Regional Authority Local Authority Municipal Regions		LOCAL PECULIARITIES, CHARGES, FREQUENCY OF SERVICES, CONTAINERS, EXCLUSION OF WASTES FROM THE SERVICE, (approval of higher administrative levels might be necessary)
GUIDELINES (FLEXIBLE, NOT BINDING FOR EVERYBODY)	Central Government (Agencies)	WHO MIGHT BE CONCERNED ADMINISTRATIONS	STRICTLY TECHNICAL MATTERS, i.e. how to design a landfill, what to do with hospital waste etc.

COSTING AND COST RECOVERY FOR WASTE DISPOSAL AND RECYCLING

By Charles G. Gunnerson
and
David C. Jones

1. Introduction

There is increasing recognition in both developing and industrial countries of the need for technical and economic efficiency in allocation and utilization of resources. A large body of World Bank Research has been directed to this end, including that on Appropriate Technology for Water Supply and Waste Disposal (Bank Research Project 671-46). The latter revealed a need for further research and development in integrated systems for recovery and utilization of household and community wastes.

In 1981, a three year global research and development project on integrated resource recovery (GLO/80/004) was undertaken by the World Bank as executing agency for the United Nations Development Programme. Project goals were to achieve environmental, employment, energy, economic, financial and health benefits through sustainable resource recovery and utilization projects and programmes in developing countries. Liquid and solid waste from municipal, industrial and agricultural sources and their recycling are within the scope of the project. Sustainability in solid waste management systems depends upon a number of important policy, technical and economic interrelationships. These interrelationships, some of which are discussed below, are particularly important in integrated multipurpose systems.

2. Solid Waste Management Objectives and Technologies

Materials become wastes when their owner will give them away or pay to have them hauled away. The essential decision in solid waste management is whether to dispose of the wastes or retain the remaining values in them. This decision is being made at all levels, household, municipal and industrial. In any event, people carry more materials into their communities than they carry out and the residue has to be dealt with. The goal of solid waste management and recycling is to conserve resources including the community space which the wastes would otherwise pollute. Solid waste management is not cheap; some developing country cities spend over 30 per cent of their budgets on refuse collection and disposal.

2.1 Environmental Objectives and Constraints

Urban space is limited, expensive and easily polluted. The conventional approach is to collect wastes which would otherwise cause a myriad of small dispersed environmental problems and combine them into a single large concentrated environmental problem. Centralized sewage and garbage disposal systems are both designed to get the wastes off the streets; they reduce the area but not the mass of pollution problems.

Annual capital recovery costs are typically two to four times the operation and maintenance costs. Total financial costs for sanitation or sewerage are from about 1.2 to nine times the cost of water supply, depending on the water service level. The higher values reflect the hydraulic costs of collection and treatment; note that the costs of treatment and collection problems are not from getting solids out of the water but from getting water out of the solids. 2/ While this ratio is reversed for solid materials and products because of the much higher costs of supply, the total costs for solid waste disposal are characteristically higher than those for sewage disposal. These costs are determined by the particular service levels and technologies selected.

2.2 Technology Options

The solid waste management and recycling technologies listed below are illustrative rather than exhaustive. Each is appropriate under proper site-specific conditions. Waste quantities and characteristics which contribute to this specificity are listed in Tables 1 through 4.

2.2.1 Storage, Collection and Transport

On site or neighbourhood storage requirements are determined by collection frequency (see Sec. 5.1). Unless affordable initial storage is available, domestic and commercial trash will be trown (1) onto street surfaces for eventual crisis type collection, (2) into low-lyiing swamp or drainage areas unsuitable for building (see Sec. 2.2.2) or (3) over walls onto neighbours' property. In higher income areas, household storage in disposable plastic bags or reusable containers is feasible. In lower income areas, manually emptied covered concrete depots or bins (Freetown, Abidjan), truck-borne roll-on or lift-on boxes or farm tractor drawn trailers which are periodically replaced with empty ones are approprite (Kathmandu). 3/

Open or covered body trucks are generally preferred to compaction vehicles for refuse collection and transport in developing countries because the initial density of wastes is often already as high (see Table 1) as the 400 kg/m^3 density that the compactors are designed to produce. The higher densities of developing countries are due to inclusion of great sweepings and, especially during rainy seasons, higher moisture content.

Vacuum trucks are used for emptying and transporting nightsoil from household vaults, settled and stabilized solids from septic tanks and other sludges. Solids concentrations greater than about 10 per cent cannot ordinarily be pumped. The tendency of nightsoil solids to form a thick, visous (thixotropic) mass within about two weeks requires either collection frequencies of about ten days or fluidization by stirring or adding water or previously pumped sludge with lower solids concentrations. Long-handled shovels are generally used for heavier sludges.

2/ This is completely analagous to separating, say, glass from a much larger volume of municipal refuse.

3/ Reorganisation of Solid Waste Management in the Kathmandu Valley-Technical Concept for Solid Waste Management in the Cities of Kathmandu and Patan. Solid Waste Management Project, Nepal Solid Waste Management Board, Nepal and German Agency for Technical Co-operation Ltd., Germany. (April,1983).

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Table 1

GENERALIZED QUANTITIES AND CHARACTERISTICS OF URBAN REFUSE

(after Cointreau 6/

	Quantity kg/cap/day	Density kg/m^3	Percent Moisture
Industrialized countries	0.7 to 1.8	100 to 150	20 to 40
Middle income countries	0.5 to 0.9	200 to 400	40 to 60
Low income countries	0.3 to 0.6	250 to 500	40 to 80

6/ Cointreau, Sandra J. Environmental Management of Urban Solid Wastes in Developing Countries - A Project Guide. The World Bank, Urban Development Department. Urban Development Technical Paper Number 5. Washington, D.C. (June 1982).

Table 2

COMPOSITION OF URBAN REFUSE (in percentage by weight)

(after Cointreau 6/

Brooklyn, N.Y. (62) London, England (63) Rome, Italy (64)

Singapore (65) Hong Kong (66) Medellin, Colombia (67)

Lagos, Nigeria (68) Kano, Nigeria (69) Manila, Philippines (70)

Jakarta, Indonesia (71) Lahore, Pakistan (72) Karachi, Pakistan (73)

Lucknow, India (74) Calcutta, India (75)

Type of Materials	Industrialized			Middle Income						Low Income				
Paper	35	37	18	43	32	22	14	17	17	2	4	< 1	2	3
Glass, ceramics	9	8	4	1	10	2	3	2	5	< 1	3	< 1	6	8
Metals	13	8	3	3	2	1	4	5	2	4	4	< 1	3	1
Plastics	10	2	4	6	6	5	-	4	4	3	2	-	4	1
Leather, rubber	-	-	-	-	-	-	-	-	2	-	76	< 1	-	-
Textiles	4	2	-	9	10	4	-	7	4	1	5	1	3	4
Wood, bones, straw	4	-	-	-	-	-	-	-	6	4	2	1	< 1	5
Non-food total	74	57	29	63	60	34	21	35	40	15	27	4	18	22
Vegetative, putrescible	22	28	50	5	9	56	60	43	43	82	49	56	80	36
Miscellaneous inerts	4	15	21	32	31	10	19	22	17	3	24	40	2	42
Compostable total	26	38	71	37	40	66	79	65	60	85	73	96	82	78
TOTAL	100	100	100	100	100	100	100	100	100	100	100	100	100	100

Note: The above values have been rounded to the nearest whole number, unless the amount was less than 1.0.

6/ Cointreau, Sandra J. Environmental Management of Urban Solid Wastes in Developing Countries - A Project Guide. The World Bank, Urban Development Department. Urban Development Technical Paper Number 5. Washington, D.C. (June 1982).

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Table 3

QUANTITIES OF ADULT HUMAN FECES

(after Feachem et al 7/)

	Urban		Rural	
	Avg kg/d	Range	Avg kg/d	Range
U.K. general	.12	.40 to .25	-	-
vegetation	.22	.07 to .49	-	-
USA	.14	-	-	-
Peru	-	-	.32	.06 to .65
Kenya	-	-	.52	-
Uganda	.18	.05 to .35	.47	.18 to .98
India	.31	.02 to 1.5	-	-
Malaysia	.16	.04 to .30	.45	.26 to .58

7/ Feachem, Richard G., David J. Bradley, Hemda Garelick and D. Duncan Mara. Appropriate Technology for Water Supply and Sanitation - Health Aspects of Excreta and Sullage Management: A State-of-the-Art Review. The World Bank. (June 1981).

Table 4

COMPOSITION OF ADULT HUMAN FECES AND URINE

(after Feachem at al 7/)

Item	Feces	Urine
Quantity (wed) per person daily	100 to 400 g	1.0 to 1.31 kg
Quantity (dry solids) per person daily	30 to 60 g	50 to 70 g
Moisture content	70 to 85%	93 to 96%
Approximate composition (per cent dry weight)		
Organic matter	88 to 97	65 to 85
Nitrogen	5.0 to 7.0	15 to 19
Phosphorus (as P_2O_5)	3.0 to 5.4	2.5 to 5.0
Potassium (as K_2O)	1.0 to 2.5	3.0 to 4.5
Carbon	44 to 55	11 to 17
Calcium	4.5	2.5 to 6.0

7/ Feachem, Richard G., David J. Bradley, Hemda Garelick and D. Duncan Mara. Appropriate Technology for Water Supply and Sanitation - Health Aspects of Excreta and Sullage Management: A State-of-the-Art Review. The World Bank. (June 1981).

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Collection and transport costs usually dominate solid waste management costs. Operation and maintenance efficiencies are determined by labour wages and benefits, the ratio of collection time to haulage time, truck or trailer capacity, availability of imposed spare parts and skilled mechanics, average downtime for equipment, and costs of fuel and tires. Compaction vehicles are particularly vulnerable to breakdown. Hand-drawn cart and mechanized vehicle designs and capacities are fixed by street widths and grades and by the sizes of areas served.

In all cases, the short operating lives of vehicles require complete cost recovery so that equipment can be retired and replaced aftter about five to eight years. Meanwhile, an additional 10 to 15 per cent of investment costs is required each year for equipment maintenance.

2.2.2 Conventional Disposal

Solid waste disposal costs in developing countries vary from essentially zero for littering or unofficial dumping into small low-lying area drainage channels to \$20 to \$60/ton for landfills with daily cover and leachate control to \$150 to \$200/ton for incineration. Investment costs for each piece of landfill equipment range from about \$40,000 to \$160,000; 10 to 15 per cent of that is required annually for maintenance, and average life is five to ten years. Some of these costs can be applied toward resource recovery systems engineered into the disposal technology (Sec. 2.2.3).

2.2.3 Resource Recovery Technologies

The Resource Recovery Project (UNDP/GLO/8)/004) 4/ is completing state of the art reviews of a number of technologies including wastewater irrigation, anaerobic digestion (including landfill gas), inorganic materials recovery, re-manufacturing and advanced technologies for materials recycling. These reviews are co-ordinated with a number of site-specific surveys of existing waste management and recycling systems in which potential improvements in productivity are identified.

Some research and development programmes currently underway include wastewater irrigation in Cyprus, land reclamation with small engineered landfills in Bangkok, wastewater aquaculture in Lima, nonferrous metals and plastics recycling in Shanghai, compost and materials marketing in Kathmandu, landfill gas in Recife, and thermophilic digestion in India and China.

4/ Base funding for the three year global Resource Recovery Project is about US\$2 million. This has been generally sufficient for the state of the art studies and for limited site investigations, project identification and project preparation activities. Cost-sharing with national, bilateral, or other multinational sources is required for demonstration or investment project preparation and execution. Although the Project assists with the drafting of project documents, their submission to a development agency is on the initiative of the host country. Some agencies providing funding are IBRD, PAHO, BMZ, GTZ, CIDA, DDC, GOI and UNDP.

Technologies listed above are applicable to wastes from one or more sources (residential, commercial, institutional, industrial, agricultural) and cann deliver one or more products (energy, materials, water, land, fertilizer) as well as environmental and economic benefits. Meanwhile, interim findings of the Resource Recovery Project confirm that single sector approaches to waste recycling such as energy, compost or materials recovery, continue to receive more government and donor support than integrated multipurpose systems.

A constraint to development of multipurpose resource recovery systems is the sectorial separation of costs and benefits. Often the utility (refuse disposal agency) pays most of the accounting costs while other sectors (agriculture, industry) receive most of the benefits of recycling.

Both state of the art and site-specific projects are essentially pre-investment studies whose benefits to governments include: (1) identification of policy options in materials, energy, health, urbanization and waste management; (2) increased productivity of land and people; (3) minimum costs of staged construction for rural, urban and environmental sanitation; (4) technical co-operation with other developing countries; and (5) support for stewardship of resources and the environment with benefits increasing in the future.

2.2.4 Technology Interrelationships and Constraints

Many waste collection and transport technologies and service levels are interrelated with resource recovery infrastructures and operations. Some of the linkages and tradeoffs are listed below:

(1) Daily collection is required for recovery of edible garbage for direct feeding to animals or for processing into pelletized animal feed while twice weekly collection is sufficient for fly and odour control;

(2) Competition for recyclable wastes occurs at all levels (households, hawkers, collection crews, scavengers, municipal workers). Compaction trucks reduce recycling efficiencies of crews and scavengers but would not affect heat recovery from incinerators;

(3) Collection and transport efficiencies and tidiness can be increased in commercial areas by use of compaction trucks, but recycling efficiences are reduced. An extreme proposal to eliminate the untidiness of scavenging at a major municipal dump was to shred the refuse to the point where manual picking and sorting would be impossible (shredding to this size would cost some $50 to $100/ton);

(4) Baling refuse can extend landfill space but can cause overloaded trucks and provide dump scavengers with wire or metal banding for the taking;

(5) Energy recovered as digester biogas is not available in slurry used as animal or fish food supplement. However, energy can be added to dewatered slurry by sprouting maize in it which is then fed (roots, substrate and sprouts) to animals. 5/ Alternatively, about 30 per cent of the gas can provide thermophilic (55-60°C) temperatures which increase gas generation rates (and decrease needed reactor volumes) and provide a sterile, easily handled slurry.

These and other tradeoffs lie at the roots of many constraints to recycling. Advantages of municipal scale operations may sometimes be possible in market economies, but they attract attention and suggestions that revenues be used to lower taxes. In other words, people resent others making money from what they have discarded as worthless. Other constraints include the previously mentioned sectoral separation of costs and benefits; development agency preference for complete elimination of health risks by conventional industrial technologies for a few (to provide an "example") rather than reduction of health effects among the many; and reluctance of local government and development agency officials to recognize and improve productivity of informal sector resource recovery systems and institutions.

In spite of the constraints, there are examples of integrated systems for resource recovery. These range from household and community biogas systems throughout much of Asia, which provide energy, environmental, fertilizer and health benefits, to the production of garbage bags from recycled plastic in Rome refuse.

3. Cost Control and Recovery

The questions of cost control and cost recovery for solid waste removal, disposal and recycling are complex. The more obvious disciplines of cost accounting and economics must necessarily be tempered by those of engineering, physical, environmental, social and political sciences. Much has been demonstrated and discussed regarding cost effective or revenue earning elements within solid waste management systems. Rarely, to date, has it been demonstrated that a potential exists for making the solid waste management process commercially profitable in its entirety. Thus, as a starting hypothesis, it is reasonable to assert that solid waste management represents a net cost to a community, which it seeks to minimize by efficiency of operation, enhancement of revenues from collection and disposal services, improvements in productivity of recycling practices already in place and the introduction of appropriate technologies for additional recycling.

5/ An Integrated Approach to the Thermophilic Anaerobic Digestion of Manure, Crop Waste and Night-Soil for an Integrated REsource Recovery Waste REcycling Project in a Village. Research & Development Institute, Kibbutz Industries Association. Tel-Aviv. (November 1982).

3.1 Financial and Economic Background

A useful starting point in looking at the financial and economic aspects of the solid waste service is the acknowledgement that, to a household or firm, solid waste represents an asset of negative value. This is in spite of the fact that much of the original value can sometimes be returned by appropriate methodology. The household or firm may be prepared to pay a price to have the solid waste removed from its own premises as an alternative to the nuisance of keeping it. However, the household or firm will not necessarily be prepared to pay the full cost of its removal, transportation and disposal because its perceptions of satisfaction will almost certainly be different from those of the local community. The charge (if any) which the household or firm is willing to pay will depend upon what is socially acceptable or legally enforceable. For example, in many communities, in developing and industrial countries alike, examples abound of liquid, solid, pathogenic, toxic and other wastes being dumped into streets, drains, unused ground, waterways and countryside as well as being allowed to accumulate on the users' own property. A particularly prevalent problem in developing countries is the clogging of drains with garbage. This is clear evidence of the gap, which can be measured in monetary terms, between the perceived benefits to waste dumpers and those of the community at large. The solutions which present themselves are those already commonly in use, described below.

If costs of waste management systems are recovered mainly by the levy of local taxes, households and firms are encouraged to maximize their use of the service. They are also forced to pay for it, whether they use it or not. On top of this, charges can be levied, usually upon industrial and commercial eenterprises, as additional contributions towards extra costs incurred in the collection and disposal of especially heavy or offensive loads. These direct charges, like property taxes, tend to be arbitrary because of the difficulty of measuring the quantity and quality of wastes. Furthermore, these additional waste services are likely to be used and paid for directly only to the extent that there are no viable (legal, cost effective and socially acceptable) alternatives.

3.1.1 Taxes

It is, perhaps, futile to argue the merits and demerits of particular tax systems relative to solid waste services. In general, it is unusual and unnecessary to earmark particular local taxes to specific services. Even when this is done for legal or administrative reasons, it has little economic merit. However, two important local taxes should be looked at briefly from a philosophical or psychological point of view: property taxes and sales taxes.

Because solid wastes originate on properties, it is reasonable to perceive at least three important relationships to the provision of service. First, in the absence of massive exemptions, tax on each property at least ensures that each occupying household or firm makes a contribution to local services, including solid waste disposal. Second, there is likely to be at least a rough relationship between the size and value of a property and its capacity to generate solid wastes. Indeed, uncollected wastes are highly likely to affect the property values, albeit belatedly. Third, the system is likely to be consistent with social equity concerns in that low value properties may well house large families with a high garbage producing potential.

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Sales taxes focus attention on the fact that solid wastes ordinarily originate as purchases. This is especially so in those consumer societies where packaging represents a major portion of the bulk of commodities purchased in stores. Thus, municipal sales tax collects the cost of disposal as part of the original purchase, in a manner somewhat analogous to the levy of sewerage surcharges on water usage.

3.2 Commercial Opportunities - Costs and Benefits

Within this generalized framework of overall solid waste management it is appropriate to consider the commercial opportunities which have been found useful or which could be exploited in the management of solid wastes.

Sometimes wastes have no value to households or firms because they are unable or unwilling to convert these to marketable commodities. A good example would be unserviceable cars and machinery. A scrap merchant, however, may be well prepared to pay for such items in order to remanufacture them or sell the parts. This provides for removal of limited categories of solid wastes and recycling on a commercial basis. The used car "graveyards" sometimes created occupy valuable land space, presumably allowed for in the cost of the operation. However, the eyesore usually created might be regarded as an environmental cost to the community, perhaps also reflected in the depleted value of adjoining property.

A most unsatisfactory situation may arise when households or firms (especially industries creating objectionable wastes) contract to have their wastes removed commercially. The original household or firm may be completely indifferent to its obligation to dispose of the wastes in an environmentally or socially acceptable fashion, concerned instead only with profit maximization. In such cases the households and firms are merely paying the contractor to creat a public nuisance elsewhere or even to break the law-either being social costs.

Collection of solid wastes by enterpreneurs or commercial firms, with charges levied directly upon households and firms, can be done profitably only when the community is well motivated or has regulated environmental standards and is willing and able to pay to have wastes disposed of in an acceptable fashion. This situation is not necessarily confined to affluent neighbourhoods. Even slum areas may be prepared to pay to keep the area clean on the basis of community participation in low cost arrangements. The motivation, in this case, is lack of space for garbage, peer pressure and the promise of better services as a reward for civic responsibility. It may also be that low cost efforts result in readily perceived improvements to a largely deprived community. Some communities encourage commercial waste collection by providing free or subsidized disposal facilities. In these circumstances, the household or firm pays the additional costs, via local taxes, to maintain the disposal facilities.

A commercial collection firm has an option of establishing facilities to enhance profits through the sale of recycled wastes. It will adopt this practice only if its marginal revenues from sales exceed the marginal costs of recycling. A high proportion of recycling costs are for sorting. Least cost sorting depends upon the socio-economic situation of the community. In a consumer oriented "throw-away" society with relatively high labour costs, hand sorting of wastes is likely to be difficult and expensive to encourage unless special motivation exists, such as "paper drives" for charity. By contrast, where labour costs are relatively low and there is material scarcity, manual sorting may be easier to encourage. One example of this is an informal but effective system of small scale enterprises in Cairo. A hereditary guild of garbage collectors (Zabaleen) are commissioned by middlemen (Moalem) to collect garbage which has sufficient value to sort and recycle. However, they are highly selective and generally only take garbage which has commercial potential. This usually comes from middle or upper class households, leaving the poor with no service. Another, more disciplined, example comes from Shanghai, China, where households and commercial establishments are paid according to posted schedules for recyclable materials brought to municipal redemption centers.

3.3 Public Services - Private Contracting

Shifting from commercial services provided directly to households and firms, we now consider those provided to solid waste management authorities. In this case, the authorities employ private contractors to perform all or part of the services otherwise provided directly. For example, an authority might contract out the collection services, disposal operations and/or recycling operations. There are several advantages claimed. For example, a commercially oriented firm, working for a fee, may be more economically efficient than direct labour operations, especially where the latter are highly unionized. Also, there may be much lower administrative overhead costs when the work is contracted out. Sometimes the claimed benefits may be only temporary or illusory. It may well be possible, through good management and incentives, to bring about significant efficiencies within the solid waste authority itself. Furthermore, it must be recognized that solid waste handling equipment is usually highly specialized. An authority which divests itself of owenership of such equipment to the private sector in the interest of "privatization" may well find itself at a later stage being held to ransom, as it were, by a private sector monopolist who then owns all the available equipment.

When contracts are let for collection or disposal management, there will be a net cost to the authority, as in any other normal contractual relationship. For recycling, the situation may be different. This is because recycling is normally an alternative to other forms of disposal. Alternative disposal systems are likely to require land (e.g., for tipping or dumping) and/or equipment (e.g., incinerators). Thus, even if a recycling contract has a gross cost to the authority there may be a net economic cost saving against the alternatives. Furthermore, the recycling, by itself, may be a profitable commercial operation. Thus in seeking competitive bids, the authority may be able to seek a net income to itself rather than a net loss.

3.4 Financial Management

Sound financial management of solid waste systems demands good financial analysis supported by cost accounting. Because the service is not usually fully revenue earning, investment decisions normally should be made on the basis of the "least cost feasible solution." Given that the primary purpose of solid waste management is still that of household and community sanitation, alternatives should be compared on the basis of estimated net present values, including costs of land, equipment, operations and maintenance as well as offsetting revenues from recycling. The social and environmental costs, to the extent not given monetary values, will need to be judged in terms of "minimum acceptable standards." This may done either by discarding from analysis a priori all schemes not meeting such standards or else by judging ex poste estimated incremental costs (net of monetary benefits) against expected environmental or social impacts (or improvements). These perceived, if unquantifiable, benefits must not be absolute standareds for which the solid waste entity is merely presented a bill. They must be judged in terms of affordability to the public authority, users and taxpayers with particular reference to the marginal impact on limited available overall local resources.

The efficient running of a service, once established, requires that cost controls be exercised using appropriate accounting standards for estimating, budgeting and recording. The use of well prepared accounting information will greatly assist in short term management decisions, particularly as regards optimization of the use of labour and equipment. Unfortunately, many municipal accounting systems do not produce the information necessary to facilitate good financial management or else produce it tardily and poorly presented. Furthermore, the cash accounting or fund accounting systems commonly in use often give inadequate emphasis to the costs of using expensive equipment - a significant shortcoming. There is much scope for improvement in these matters. Of particular concern is the necessity to generate adequate cash flows from taxes and charges to ensure that the relatively short-lived equipment used in solid waste management will be promptly and regularly replaced. Undue reliance upon external debt or other forms of aid or even upon government grants to sustain these operations is a recipe for disaster. We must look instead to careful management of likely available local resources.

This suggests a warning to those engaged in the development and sale of sophisticated equipment for the management of solid wastes, including recycling. Such equipment may often require operation and maintenance skills unlikely to be available in many developing countries. Furthermore, such countries may well lack the material and financial resources to ensure that the equipment is adequately repaired, much less replaced. Thus, an overagressive supplier may well have much more to lose in terms of a long term business reputation than it may gain in short term profits. There is enough "modern" solid waste equipment lying idle or underutilized in developing countries to attest to this concern.

Examples of financial information required for successful long term management are listed in Table 5. Not all of this information will be available from a cost-accounting system. Some will be used to supplement the costing system, depending upon which decisions are at issue. For example, capital investment decisions will require different analysis from operating decisions. Frequently, physical statistics will be as useful as financial information.

Table 5

EXAMPLES OF FINANCIAL INFORMATION FOR SOLID WASTE MANAGEMENT

A. Financial Information Likely to be Available from the Accounting System of the Solid Waste Management Unit or its Parent Entity.

1. Capital expenditures on land, disposal and recycling plant, vehicles, equipment, transfer stations and operational and administrative premises.

2. Recurrent cash expenditures on labour, power and water, rent, vehicle hire, contractual services, supplies, interest and debt repayment.

3. Capital receipts from fixed asset disposals, loans (including terms), grants and land sales.

4. Recurrent receipts from taxes (collectibles and collected), charges to households and firms (for collection, use of tip, etc.), fines for unauthorized dumping and sales of recycled products.

5. Imputed or assessed costs for use of inventory, depreciation, labour overheads, administrative overheads, pooled plant expenses and provision for debt amortization.

B. Financial Information Unlikely to Be Available from Accounting System and the Solid Waste Unit or its Parent Entity.

1. Replacement costs of vehicles, plant and other short lived assets.

2. Opportunity costs and disposal values of land for initial purchases and for final disposal on closure of controlled tips.

3. Discount rates for DCF calculations.

C. Supplementary Physical Statistics.

1. Working lives of fixed assets and depletion lives of controlled tips.

2. Inventory of equipment giving sizes, load capacities and limits of working with restricted access.

3. Collection and disposal statistics, including tons collected and disposed of and route mileages for collections and haulage to tips.

4. Labour hours, including productive and unproductive.

5. Outshedding times of vehicles and information on repairs and maintenance, including down time.

6. Comparative operating statistics (and reliability) of different types of vehicles and plant.

7. Numbers of premises served by type and locality.

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Table 5 (contd.)

D. Monitoring Indicators.

1. Costs per load, per ton, per mile, per ton-mile, per household/firm, per labour unit, per vehicle type, etc.

2. Tax and user charge recovery rates in relation to sums collectible.

3. User charges (by type of premises, waste product or locality) in relation to imputed costs of service.

4. Timewise comparison of cost components.

5. Revenues from recycling sales relative to costs recycling.

6. Vehicle running times to dumps relative to collection times.

The recording, assessment and presentation of financial information requires a sophisticated blend of art and science, as with engineering. However, as with engineering data, financial information has its limitations and can be bungled in the hands of the unskilled. Unfortunately, necessary financial skills are often in short supply in developing countries. There is thus a danger that overly sophisticated engineering will be combined with crude financial data to produce sub-optimal decisions.

The information presented in Table 5 is merely a list, therefore, and not a system. It needs to be in the hands of a seasoned financial specialist who knows what to select and to discard for any particular purpose.

4. <u>Technology Selection</u>

Selection of waste management and recycling technologies which can be replicated within or among developing countries is based on service levels, manpower and equipment availability and efficiencies and costs.

4.1 <u>Service Levels</u>

Conventional engineering masterplans and feasibility studies lead by staged implementation of uniform minimum service levels throughout a city or other project area. However, minimum cost solutions are those in which capacity most closely matches demand. Demand in solid waste collection and disposal varies according to population densities, income levels and seasons, which are reflected in waste quantities and characteristics. Demand in waste recycling systems varies both seasonally and in response to longer term economic trends. Demand changes can be accomodated by variable service levels in collection frequency, convenience, storage at household, depot or terminal locations, manpower and equipment utilization and in equipment maintenance and service life. All of these are interactive, and all are affected by operational constraints including access (street widths and grades), traffic congestion, noise and costs of fuel, tires and maintenance.

4.2 <u>Technology Options</u>

Generic listings of waste storage, collection, transport, disposal and waste recycling technologies are presented in Tables 6 and 7. The lists are representative rather than exhaustive. Item 1.5 on Table 7, "Alchemy and hypertechnology," is included to provide for capital intensive adaptation of aerospace technologies, special enzymes, advanced numerical modelling and control systems, and other schemes for which marginal benefits have not been shown to exceed marginal costs.

5.3 <u>Summary</u>

Research, development, demonstration and investment projects in municipal waste disposal and recycling are of increasing importance in both developing and industrial countries. Current UNDP supported research and development in integrated resource recovery being executed by the World Bank reveals that single purpose systems for recovery of energy, water, compost, metals, etc., continue to receive more government and development agency support than integrated cross-sectoral systems. There are exceptions. For example, in a part of Cairo, integrated entrepreneurial systems for domestic refuse recycling are in place. In Shanghai, municipal integration of supply and

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recovery of resources from industrial, commercial, residential and governmental scrap is in effect. Major on-going research and development includes demonstration project preparation in Cyprus, advanced biogas technologies in India, plastics and nonferrous metals recovery in China and waste fed aquaculture in Peru.

Technologies and costs for solid waste collection and disposal both constrain and are constrained by resource recovery objectives and practices. Identification and assessment of information needed for complete costing and cost recovery for both the utility and the economy is essential. A vital first step in the establishment of efficiency of waste disposal systems must be based upon cost minimization or benefit maximization from an economic and social viewpoint. This necessitates financial and economic analysis which will challenge and, if necessary, override accounting conventions, budgetary procedures and single enterprise financial objectives when these prove inappropriate to an integrated approach.

Table 6

A GENERIC CLASSIFICATION OF SOLID WASTE MANAGEMENT TECHNOLOGIES

1.	Storage	
1.1	On-site	- disposable containers
		- reusable containers
		- roll-on or lift on containers
		- piles or open bins
1.2	Collection	
2.1	On-site	- tossed onto nearest street
		- open or covered bins
		- open trailers
		- roll-on or lift-on containers
2.	Collection	
2.1	On-site	- door-to-door pickup
		- brooms, shovels and carts
		- front-end loaders
		- mechanized street sweepers
3.	Transport	- hand or animal drawn carts
		- farm tractor drawn trailer, open or covered
		- trucks, open or covered
		- compaction trucks (solid wastes)

		- vacuum trucks (liquids or sludges
4.	Transfer Stations	
		- gravity transfer of solid wastes
		- pumped transfer of sludges
5.	Transfer Vehicles	
		- large tractor-trailer combinations
		- barges (requires unloading or second transfer station)
6.	Disposal	- littering or dumping into small depressions or channels
		- engineered, rapid filling of small depressions or channels
		- open (usually burning) dumps
		- landfills with daily cover
		- incineration with quenched ash disposal into dumps or landfills

Table 7

A GENERIC CLASSIFICATION OF RESOURCE RECOVERY TECHNOLOGIES

1.	Inorganic Material Recovery
1.1	Reuse, repair, remanufacturing
1.2	Manual sorting and classification (with or without picking belt and magnetic pulley)
1.3	Mechanical preparation, sorting and classification
1.3.1	Shears
1.3.2	Shredding and grinding
1.3.3	Trommels and screens
1.3.4	Magnetic separation
1.3.5	Eddy-current separation
1.3.6	Air classification
1.3.7	Liquid classification (float/sink, hydroscopic/hydrophilic, heavy media, etc.)
1.4	Processing
1.4.1	Ferrous metals - cold refabrication, foundry electric furnace
1.4.2	Nonferrous metals - cold refabrication, chemical separation and purification, ingots or industrial grade chemicals) realloying
1.4.3	Thermoplastic polymers - heat and pressure reforming
1.4.4	Thermosetting polymers - pyrolysis/cracking back to monomer and reconstiting
1.5	Alchemy and hypertechnology
2.	Organic Materials Recovery
2.1	Composting
2.1.1	Aerobic (batch or continuous; windrow, enclosed bins or reactors)
2.1.2	Anaerobic digestion
2.2	Anaerobic digestion
2.2.1	Ambient, mesophilic (35°C), thermophilic (55°C)
2.2.2	Low (4-12%) solids in feed
2.2.3	High (18-24%) solids in feed
2.2.4	Landfills (controlled moisture)
2.3	Hydrolysis and fermentation
3.	Energy Recovery
3.1	Direct combustion
3.1.1	Dung, crop offal, etc., for cooking and heating
3.1.2	Heat recovery from incinerators
3.2	Biogas (see 2.2)
3.3	Energy equivalents in recovered inorganic materials
4.	Protein, Humus and Fertilizer Reclamation
4.1	Direct refeeding
4.2	Indirect refeeding
4.3	Agriculture and aquaculture (see 5.)
5.	Wastewater Reclamation
5.1	Sewage farms
5.2	Effluent irrigation
5.3	Aquaculture (ponds for effluent maturation, fish, prawns, algae, etc.)
6.	Land Reclamation
6.1	Small, neighbourhood scale for early completion
6.2	Large metropolitan

Several factors create additional difficulties. It is seldom easy to levy direct charges upon users or beneficiaries of the service; benefits (and even some costs) are difficult to quantify. Surrogates for taxes must often be substituted, limiting both the effect and the analysis of market forces.

SOCIAL AND CULTURAL ASPECTS OF WASTE MANAGEMENT

by Jon Vogler

SUMMARY

A great deal of attention is paid to the technical, commercial and environmental aspects of waste management but social and cultural considerations often determine whether attempts to introduce or change systems or plant are successful. These are not defined here but are illustrated by real examples from waste management projects in both developing and industrialized countries. The interdependence of social and cultural aspects with economic, commercial and environmental matters is stressed in relation to garbage generation, collection, of knowledge about it is discussed. In conclusion a set of rules is derived for taking account of social and cultural aspects in waste management.

INTRODUCTION

"There's nowt so queer as folk" - Traditional Yorkshire Proverb

Earlier parts of this conference have included lectures on all aspects of waste management: on how to analyse garbage, quantify it, collect it, store it, dispose of it or recycle it. Delegates have heard what technology is available, what markets exist, what dangers arise, what costs are incurred and what laws are commonly applied. They could therefore be pardoned for expecting to be able to return to their municipalities and, over the coming years, apply this knowledge to achieve far better and more efficient service to their citizens.

Were they to do so they would undoubtedly encounter problems and difficulties on a scale that would make plant breakdowns, financial crises or polluting emissions appear trivial. For no matter how well planned and financed the systems, or how well chosen or engineered the equipment, the overriding difficulty of introducing any kind of technical or organisational change lies with the people involved.

Superficially they may appear disorganised, careless, lazy or just to have priorities in their lives that differ from those of the local waste managers. Experience and research over many years have shown that the reality is different: that the problems usually occur because the changes have been planned without taking account of the social structures and the cultural background of those concerned.

These expressions need to be understood but, instead of defining words like "social" and "culture" I propose to demonstrate their meanings by descriptions of real life situations. I hold no magical powers of sociological understanding. My own qualification for giving this talk is that I have made my full share of mistakes in this regard. For some years I ran a project that recycled, to industry, part of the household waste of the city of Huddersfield, England. The project depended for its success on the co-operation of householders as much as on the efficiency of our own staff and

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I learned the hard way how to achieve this and how to lose it. Since that time I have travelled widely, to study how waste is managed in other, particularly developing, countries and now operate a small consultancy known as INTERWASTE which attempts to make this experience available to those on the "sharp end": the waste managers with the actual responsibility of keeping towns and cities clean.

For convenience we may split the waste management operation into four stages: Generation, Collection, Disposal and Recycling. Let us examine each in turn.

Generation

It is not only waste managers who accept garbage as a normal feature of their lives. Many communities originate in the countryside where garbage collection was not practiced because it was unnecessary. When they migrate to the cities, often to peripheral slums, so recently formed that garbage collection, has not yet been established, disposal into the street or onto wasteland is the accepted practice. To these people such ideas as that "one should not drop litter", for example, must seem like nonsense. When they move to a more prosperous suburb, or the area is upgraded or the municipality commences a garbage collection service, officials often complain that the people are dirty, stupid or primitive because this former behaviour persists. In fact they are behaving absolutely normally and it is the officials who are being unrealistic in expecting behaviour to alter overnight. Experience shows that communities often take many years or even generations to achieve this kind of change.

G.M. Trevelyan writes of seventeenth century Britain (Ref. 1) "Far overhead the windows opened, five, six or ten storeys in the air, and the close stools of Edinburgh discharged the collected filth of the last twenty-four hours into the street ... The ordure thus sent down lay in the broad High Street... making the night air horrible, until early in the morning it was perfunctorily cleared away by the City Guard. Only on a Sabbath (Sunday) morning it might not be touched but lay there all day long, filling Scotland's capital with the savour of a mistaken piety." Edinburgh today is a clean and pollution free city and the residents are proud that it should be so but this took two hundred years to achieve. Other city authorities must also be reconciled to the long time-scales required for changes in human behaviour.

Refuse Analysis

This technique, now widely used as a preliminary to waste management planning, is of course a reflector of social as well as economic behaviour. Indeed the two can often not be separated; today's culture or custom is often only the remnant of yesterday's economic constraint. For example the garbage of Cairo increases dramatically in moisture content during the water-melon season. No such phenomenon occurs in Paris. The people of Cairo do not necessarily eat more water melons per annum than do the people of Paris but the economics of Parisian life permit importation and storage of melons and their consumption all the year round.

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Early plans for a resource recovery plant in Doncaster, England, assume that the garbage from all the surrounding villages would be included. Engineers were suprised to find that refuse analysis yielded a very low paper fraction. The explanation was that these are mining villages and, by long tradition, mineworkers are entitled to free coal for domestic use. While the rest of Britain used gas-fired central heating the miners' homes still have open coal fires, on which waste paper is normally burnt, rather than placed in the garbage. The plan had to be changed to handle only the refuse from the city, with its full riches of cellulose fibre. Analysis, followed by social investigation, saved an expensive mistake!

Collectors

Even though the behaviour of communities may puzzle them, most waste managers understand the behaviour of collectors from long experience of controlling such labour. Often the collector's culture is the same as the manager's and he or she intuitively takes it into account. I am told that no Indian waste manager would encounter problems of caste when recruiting staff or allotting tasks. He has been brought up to be sensitive to the situation, even though such considerations may have been officially outlawed, while an expatriate might commit terrible errors! Where managers are not familiar with the community with which they are working they may be in for surprises however, particularly when attempting to introduce change.

This is a strong argument for using local and not expatriate consultants wherever possible.

Sometimes even local managers lose control of the behaviour of their labour. In at least one Latin American capital the "sindicatos" (labour unions) effectively control garbage collection and street sweeping. In addition to the householder paying local taxes to the municipality, from whom the employee receives a wage for these tasks, there is a complex system of "propinas" (payments): from householder to sweeper or collector to ensure the work is done properly and from collector and sweeper to the "lider" of the sindicato to retain a favourable district or route which yields a full crop of recyclables, for sale. The employee thus receives a three part remuneration of which the supervisor controls only one part. Although not always so open, similar situations exist in many cities.

In Britain certain municipalities that had, for years, operated a work-study based bonus incentive scheme were troubled by inflated wage earnings in a time of national financial restraint and moved to "task" schemes. The feature of these is that, once the team has completed their task for the day, they are free to go home. Managers were amazed when operators completed routes half way through the morning. They had not understood that, for the men, free time (to go fishing or work in the garden), was a greater incentive than extra money, (which had to be partly surrendered to the tax man - or the wife!)

A further example of social behaviour which is economically motivated is the practice of garbage collectors in South East Asian capitals and elsewhere, of sorting the garbage in the road, behind the vehicle. Recyclables are extracted for sale to warehouses that line the last few kilometres of the road to the disposal site. Such practices can play havoc with vehicle routing and timetabling and increase by as much as 50 per cent the number of vehicles

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required to service a given population. The normal procedure is to "buy out" the right to do this by an increase in wage that is till cheaper overall than the cost of low vehicle utilisation. In such cases it is essential to enforce the agreement rigorously thereafter, otherwise the collectors end up by reverting to their former practices while still keeping the wage increase.

Junk Vehicles

Such economically motivated scavenging is not always a problem to the waste manager. Sometimes it can be used constructively. Take the problem that must plague many delegates here: junk vehicles. They are large and costly to collect whole, yet the destruction technology preferred in the "North" (flattening, baling, shearing or fragmentising) is too ponderous to be truly mobile and often too expensive and complex for Third World cities to maintain. The result is that the vehicles remain in the streets, a threat to health, an eyesore and a serious challenge to the professional pride of the waste manager.

I approached this problem a few years back by utilising the heavy incidence of unemployment in such cities and the high prices available for reusable waste materials in countries with a foreign exchange problem. Development of simple techniqpues of cutting up cars where they lie, using nothing more complicated than a hammer and special chisel, made it possible to generate sufficient income (from sale of materials and secondhand parts) to cover the labour costs involved: in short a nil-cost system for junk vehicle disposal with no additions to the municipal labour force. The technique is fully explained in a recently published book Jobs from Junks (Ref.2).

Disposal

The lectures of the past few days have shown that the selection of waste disposal process is more than a matter of mere technical considerations: geography, cost, environmental impact have all to be taken into account. So of course, have social matters which are often interwoven with them. For example one city in South East Asia commissioned four huge compost plants which had the greatest difficulty in selling their production. The plants made no provision for front-end sorting of recyclables with the result that the hammermilled product contained a high proportion of glass splinters. These might seem of little significance to the European plant manufacturer, in whose country farmers sow their crops almost entirely by tractor. Asian farmers however, who spend days on end up to their ankles in water in flooded paddy fields, pushing in rice seedlings with their fingers, will never accept soil additives that contain lethal splinters. Whether their objections should be described as social or economic or environmental may not be clear; what was beyond dispute was their unwillingness to buy the product.

This project further illustrates early considerations of garbage generation. In the elapsed time between plant design and operation, significant changes in the shopping habits of the local housewives had taken place. They started to purchase far greater quantities of packaged foods which resulted in a great increase in the amount of polythene film scrap in the garbage. This material does not biodegrade in the composting process but remains, ugly and obtrusive, in the finished product, making it even less acceptable to the customer. Careful preliminary study of social trends in the city could have predicted this and incorporated suitable screening plant in the design at an early stage.

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Resistance to Disposal Sites

Even apparently straight forward and, in some cases, ages-old disposal techniques have, in the last decade, come into conflict with social preferences on a massive scale, particularly in some of the industrialised countries. It is to be expected that, with the ease of international mobility and communication, these trends will be encountered in the Third World in due course.

Take simple landfilling for example. Although the quality of environmental control of landfill sites has enormously improved over the past forty years, communities in Britain, Holland or the U.S., which formerly accepted "the dump" as a necessary feature of the urban environment, now strenuously resist proposals for local landfill siting. Nor are these the actions of a few cranks; often their resistance is upheld by powerful Government Ministries.

Formerly only the rich could afford environmental awareness. along one lovely seafront of North Africa, where millions of people bathe in the Mediterranean waters, myriads of outfall pipes spew untreated city sewage close to the beaches. Those with local knowledge are careful to swim only on the beaches near the former Royal palaces, where no outfalls were ever permitted! (In fact a major scheme to dump the sewage much further out at sea is in progress, while in Penzance, England untreated sea disposal continued near bathing beaches in 1983).

In the industrialised countries a succession of scandals about waste disposal sites causing serious or hazardous pollution, have been trumpeted by the press during the past few years. Reactions to Love Canal, Lekkerkirk and Pitsea, coupled with greatly heightened environmental awareness, have now made the common people, as well as the rich, both choosy and powerful in their objections. In developing countries this movement is at an earlier stage but few can doubt that it will follow.

It should be remembered that environmental standards: of emissions, noise, conservation, visual impact, living and traffic densities etc. are matters of social as well as technical and medical concern. If residents see an incinerator chimney belching black smoke their first, and possibly strongest, reaction is to the possibility that it will dirty their washing. Its effect on the incidence of respiratory diseases, or the fact that it breaks environmental laws, may never cross their minds. Nonetheless the social preferences of the people are being codified in such laws and the waste manager, no less than any industrialist or transport operator, disregards them at his peril. The massive failure of resource recovery plants in the U.S.A. (in 1982 of 55 plants constructed, only 17 were fully operational - Ref. 3) is primarily associated with failure to meet environmental standards.

As well as community reactions to disposal plants, the social norms of employees have to be considered at the initial planning stage. Thirty years ago it was common for municipal incinerators in Britain to have a front-end picking belt, from which men and women selected recyclables and any items that were evidently non-combustible. In 1983 few such facilities remained; the practice of picking is regarded as "socially unacceptable". They had been intended to be replaced by resource recovery plants but these appear to be both technically and economically doomed none has so far thought of applying modern engineering techniques to the problem (Ref. 4) and the resources are allowed to go to waste.

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In many parts of the Third World, massive unemployment, high costs of investment in "modern sector" industry and good markets for recycled wastes that substitute for imported raw materials, make people more realistic and less choosy. Garbage picking is a common formal, as well as informal, occupation.

In Monterrey, Mexico, for example, when a new garbage composting plant was commissioned and the landfill closed, picking jobs on the front end sorting line of the new plant were offered first to the former scavengers from the dump. Although not always perfect employees, my observations were that they picked industriously and intelligently, working as people do who are psychologically attuned to their occupation. The City made a good profit from the plant, despite difficulties in selling the compost and the volume of material recovered represents significant foreign exchange saving. If social changes alter the refuse analysis, there will be no need to alter plant; just to vary the pickers' tasks. For the workers: better and more regular earnings, washing facilities and toilets, a roof over their heads in rainy weather and participation in the state social security scheme undoubtedly represented an enormous improvement in working conditions. This is a far-sighted and excellent project, socially, technically and commercially competent. It should be widely copied elsewhere instead of money being wasted on expensive, technological white elephants that try to eliminate labour. It effectively combines the functions of disposal and recycling and fittingly leads on to the topic of:

Recycling

The two main areas of interest lie in the marketing of recycled materials and in the activities of scavengers.

Marketing of Recycled Materials

The essence of the problem is that some goods that contain recycled materials are of lower quality than those made only from primary raw materials. Often the customer is happy to accept this in return for a significant reduction in the cost but some communities have standards below which they will not drop. For example a firm in Nairobi, Kenya has made significant manufacturing economies by using recycled paper for toilet paper manufacture and the same practice is applied in Mexico. Yet in at least one Caribbean island people have become accustomed to U.S. standards of quality and, even for this humble function, recycled products are rejected in favour of more expensive brands manufactured from primary pulp. The waste manager who contemplates recycling must take account of these social preferences as much as technical, economic and financial factors.

Scavengers

Scavangers (Ref. 5) are extremely numerous in almost all developing countries; (and in some so-called developed ones as well). One estimate quotes 1 to 2 per cent of the population (Ref. 6). They operate in different ways: some precede the refuse collection teams from house to house. Others pick from litter bins in streets and parks. Huge numbers work on the refuse dumps, in appalling, insanitary conditions, mobbing each refuse vehicle as it discharges to try and seize the most valuable material. They pick bottles, ferrous and non-ferrous metals, cartons, paper, wood and a variety of reusable objects. They work with considerable energy but vaguely and inefficiently and with little awareness of the health risks they incur and indeed create for others. They are often in a state of barely suppressed conflict with the officials who are in charge of the dump, who find them a nuisance, an obstruction and an offence. Their condition of health, dress, nutrition, education and organisation is often pitiable. Some, with their families often totalling hundreds or even thousands of people, live, among vermin and their own excreta as well as the refuse, around the dump in shanty housing that lacks electricity, safe water or sanitation, and is often only accessible through a morass of wastes. They often keep animals, especially pigs, which feed directly off the dump without restriction and constitute a serious public health hazard. Some burn charcoal, using primitive and inefficient earth kilns, charged with scrap wood from the tip.

Almost all scavengers are confronted with similar problems, the world over. The most significant are:

1. Poverty. Although they often have cash in their pockets from the day's sale, most scavengers earn far below the accepted minimum for subsistence.

2. Ignorance. Scavengers often have few contacts with the world outside the dump, especially if they live on it. They know little of the rules of health, hygiene, reading or writing and less of business or social behaviour.

3. Illiteracy is often common to whole communities of scavengers.

4. Health. Scavengers live and work in dangerously substandard conditions, take few health precautions, are isolated from medical services and poorly nourished. Accurate health statistics are virtually non-existent but I have have heard verbal statements that expectation of life may be less than half the national average and infant mortality rates are horrific.

5. Housing rarely exists. Most scavengers live in a shanty built from waste materials from the dump.

6. Lack of services: such as medical, social or educational care or public works such as drinking water, sanitation or electricity.

7. Employment of children is one of the worst features because it keeps the children out of school and, by depriving them of education, robs them of the only chance to break out of the lifestyle. The practice therefore continues, generation after generation.

8. Inability to organise, so that it is very difficult to provide help.

9. Exploitation by Buyers. Because they are ignorant, scavengers are ruthlessly exploited by those who buy their materials.

10. Lack of concern by the public and the authorities, so that nothing is done to help improve conditions and any development of the country passes them by.

Little experience exists, anywhere in the world, of successfully helping scavengers break out of the trap in which they are caught. There is a need for a co-ordinated programme as follows:

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1. There is a lack of hard data about scavengers: who they are, where they come from and what happens to them. Are they new rural immigrants, using this as a jumping-off point to a new life in the city or are they the city's failures, making one final desperate attemtpt at self sufficiency before they slip below the barest subsistence level? The answers to these questions will no doubt vary from place to place but they are nonetheless important.

2. How harmful are they? In terms of dump and collection operations most waste managers will answer "Very!". However, public health considerations may be far more important. I know of one dump where vaccine ampoules are scavenged and fetch a far better price than other glass. Who can be sure these, bursting with pathogens, are not getting back into the vaccine factory?

3. How useful is the economic contribution they make: marginal or highly significant? If it saves substantial foreign exchange, what investment does it justify in improved conditions or more systematic activity?

4. What successes have been achieved in scavenger community development? There are none reported, with the qualified exception of Metro Manila (Ref. 7).

5. Finally, what code of practice might be adopted by municipal authorities to guard against the dangers and disadvantages of scavenging while preserving the economic benefits and avoiding persecution of individuals whose state is already pathetic. The writer has for some time been seeking finance for a project aimed at tackling these matters. He has made some proposals to the I.L.O. but has so far, had no response.

Conclusions

From the foregoing the following simple ground rules emerge for taking account of social and cultural matters in waste management.

1. Where changes are planned, some of the managers involved should be local people, in touch with local customs and communities.

2. Where this local contact and understanding is limited or does not exist, it is important to carry out sociological surveys of communities affected by new planning.

3. Project design should aim for flexibility and should adapt systems and technology to the needs of people rather than attempting the reverse. Where it is hoped that patterns of behaviour will change, with education, publicity or motivation, extremely long time-scales should be anticipated.

4. Communities should be consulted and, if possible, involved in system design at an early stage. Systems should be tested out on a pilot basis and evaluated by the communities concerned as well as by officals, before full scale operation is attempted.

5. Rigid technology and systems "packages" are rarely appropriate to waste management. All communities differ and systems need to be individually tailored to take account of this.

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6. Scavenging can have benefits as well as drawbacks. Like most other aspects of waste it justifies careful sociological study before action is attempted.

7. The penalties of ignoring these rules is that waste management systems cost more to operate, do a worse job or even fail to work at all. You have been warned!

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REVIEW OF SELECTED SOLID WASTE MANAGEMENT PROJECTS IN DEVELOPING COUNTRIES - SYNOPSIS AND CASE STUDY*

By Bernhard H. Metzger

INTRODUCTION

Modern human settlements do not allow for natural waste disposal and recycling and, thus, impair hygienic living conditions and health. The impact of growing urban populations and their associated masses of wastes can lead to profound degradation and damage of the physical environment - the very foundation of human activity. Increasing imbalances between economic production cycles and ecologic reproduction cycles, the depletion of natural resources and the amassing of waste severely strain both the physical and the socio-economic environment.

The magnitude of these phenomena around the globe is assuming dramatic dimensions. The situation is most pronounced and marked where population growth and density are highest, natural resources scarce and economic strengths insufficient. This scenario can be found in many Third World countries and particularly in their rapidly growing cities. Today one out of four people in the Third World live in cities. This is close to one billion people. By the year 2000 almost half of a projected population of nearly 5 billion people will be living in a Third World urban environment. The prospects for future urban life are gloomy, if not frightening (1, 2).

Public awareness

Waste management seems to be lowest on the priority list of many national development plans and urban development programs. The control of human waste carries little prestigious value as compared to more high profile projects. Frequently it even has a stigma attached. The subject almost seems to be regarded as taboo.

The seriousness of the problem has been recognized, however, on an international level. Solution strategies and policies have been developed and are being tested around the world. Various UN organizations have taken action, the UN conferences "Water" and "Habitat" have addressed the problem. The 1981 -1990 IDWSSD has set specific targets and priorities. The 3. ITC in Berlin 1982 which attracted 1400 participants from 42 countries evidenced a rising awareness of dangers caused by inadequate waste management concepts (3). Much more consciousness raising is needed, however, to attract the attention of decision makers and urban population if the aforementioned gloomy scenario is to be averted.

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* Views in this paper are those of the author. They do not necessarily reflect the policies or viewpoints of the German Agency for Technical Cooperation, Ltd. (GTZ)

Concepts

The German Federal Government in July 1980 committed itself in the "Development Policy Guidelines" to giving top priority to the satisfaction of basic human needs. The German Agency for Technical Cooperation, Ltd. (GTZ) has since increased its global activities in the field of urban waste management.

In close cooperation with other agencies, an integrated residues management and waste disposal policy has been developed which is based on (a) public health, (b) socio-economic, and (c) environmental considerations. A comprehensive management concept thus derived aims at:

- protection of public health
  through proper and adequate waste management;
- improvement of economics of waste management
  through waste reduction and resource recycling (4);
- Protection and preservation of the environment
  through eliminating hazards associated with transportation and disposal.

When applying the above concept to a specific case some careful tailoring, planning and on the spot testing is required. But the general validity remains unchanged. Planning and design criteria must be observed, constraints must be taken into account and assumptions about the unknown must be made. Essential prerequisites for a viable, effective and affordable waste management system are:

(a) Comprehensive waste management legislation allowing for:
    (a) strong and competent authorities
    (b) stringent control of waste disposal practices
    (c) proper cost allocation;

(b) Sound organizational and technical concepts (5) including:
    (a) efficient management and administration
    (b) cost efficient and locally sustainable operations
    (c) manpower training and development
    (d) attractive personnel policy;

(c) Sound finances through:
    (a) minimizing O&M costs
    (b) levying and collecting fees
    (c) revenues from resource recycling
    (d) subsidy provisions;

(d) Public awareness and participation through:
    (a) public relations work
    (b) efficient waste collection services
    (c) demonstration of benefits;

(e) Robust infrastructure through:
    (a) indigenous and appropriate technologies
    (b) proper maintenance of plants/equipment
    (c) adequate logistics and supply.

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Technical assistance

Technical assistance by national and international organizations is frequently requested and provided at various stages of conceptual planning, implementation and operation of urban waste management schemes. Cooperation between local authorities and foreign aid agencies, governmental or non-profit, is usually carried out upon the conclusion of specific project agreements, which specify the terms of contract.

Technical assistance generally consists of the provision of short term or long term advisory services, the transfer of appropriate technologies and concepts, the training of national managerial and technical experts and personnel, and to a limited extent, the contribution of equipment and supplies.

It is indispensable, however, that technical assistance be provided only over a limited period of time sufficient to realize the joint objectives of strengthening the potential for self-help and self-reliance.

TABLE 1. DATA ON CURRENT GTZ-SUPPORTED WASTE MANAGEMENT PROJECTS, 1983

A Synopsis of Current GTZ - Supported Waste Management Project

		Project Location					
City		Tahoua	Juba	Lima	Accra	Kathmandu/ Patan	Bhaktapur
Country		Niger	Sudan	Peru	Ghana	Nepal	Nepal
Start of Project		1979	1983	1980	1982	1976	1982
Exec. Agency		DU/Marie	PEWC	ESMLL	ACC	SWMB	SWMB
Stage of	Planning	X	X	X	X	X	X
Project	Implement.	X		X		X	(X)
Project	Solid	X	X	X	X	X	X
Component	Liquid		X		X		(X)
	Compost				X	X	X
	Recycl.					X	X
	Sanit.		X		X	X	(X)
Population		32,000	130,000	4,304,000	1,280,000	309,000	51,000
Waste t/y		7,200	?	1,351,000	170,000	43,800	5,600
Personnel (total)		60	?	3,300	2,000	920	120
Personnel/Pop.	(Solid Waste)	1.9/1000	?	0.8/1000	1.4/1000	2.6/100	1.7/1000

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A CASE STUDY: SOLID WASTE MANAGEMENT IN THE KATHMANDU VALLEY

1. Chronology

The Kathmandu Valley, which includes the cities of Kathmandu (220,000 pop,), Patan (80,000 pop.) and Bhaktapur (50,000 pop.), is inhabited by some 50 per cent of Nepal's urban population, which in 1980 was only 5.8 per cent of the total population of some 14 million. The population is growing rapidly (2.5 - 3.0 per cent annually). Tourism, business and industry account for a bustling and crowded atmosphere.

In 1970 WHO (6) appraised the solid waste situation in the Valley and found that it needed urgent remedial action. Kathmandu particularly appeared to be suffocating in its own waste. In 1976 the GTZ commissioned a study on the reorganization of solid waste management in Kathmandu Valley (7). On the basis of that and reports on specific aspects of the subject, His Majesty's Government of Nepal (HMG) and the German Federal Government signed an agreement on technical co-operation regarding the reorganization of solid waste management in the Kathmandu Valley. The "Solid Waste Management Board" (SWMB) was established the same year. In October 1980 phase I of implementation (3 years) was started. A German advisory team of three was dispatched to assist SWMB. In November of 1983 Phase II will be started completing the implementation in Kathmandu/Patan, commencing activities in Bhaktapur and establishing a compost plant. Various sanitation facilities (public toilets, "hygiene centers", slaughtering areas) will be created as well. Recovery and recycling of reusable materials (glass, metals, plastics, paper, wood, etc.) will be introduced. Hence, by the end of Phase II (1986) the complete integrated residues management concept will be implemented encompassing the components HEALTH, SOCIO-ECONOMICS and ENVIRONMENT (Table 2).

2. Legislation and Institution

In 1979 the authority, "SWMB", was established. Among others all member cities were represented on the board as well as the Ministry of Works and Transport, the Ministry of Finance and SWMB's Project Director. According to the then existing legislation (Board Establishment Order, 1980; Town Panchayat Act, 1962) SWMB was charged with the execution of Phase I of the Project, i.e. implementation of a new solid waste management concept. The overall responsibility for waste disposal, however, remained for the time being with the Town Panchayats.

Prior to the beginning of Phase II this arrangement will be changed by modifying the Board Establishment Order (1983). The Town Panchayats agreed to relinquish all responsibilities to SWMB. This new legislation which will be in effect in late 1983 grants SWMB the comprehensive power necessary for the operation and maintenance of an efficient solid waste management service in member cities. SWMB will exercise a stringent control of waste disposal practices. Penalties may be imposed for violations of the pertinent rules and regulations. SWMB is authorised to levy and raise service fees as well as to manage its own funds. Now as before, the member cities are on the Board governing SWMB's operation.

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3. Organizational and Technical Concept - Implementation

3.1 Organization and Management

The proposed organizational structure for Phase II is shown in Fig. 1. The administration of SWMB is headed by the Project Director who controls six divisions and reports to the Board. Within the operations division, there are sections responsible for the various member cities (Kathmandu and Patan have joint operations). An assistant director is head of the division of Administration and Finance. A commercial accounting system to be introduced in early 1984 will be audited internally. At the same time the government accounting system will be retained, to be audited by the General Auditor (Ministry of Finance). This organizational structure was chosen to reflect the administrative and managerial capabilities necessary for full-scale operation of an integrated waste management service in three and possibly more cities in the future.

3.2 Operations

Collection/Transport/Disposal:

In a combination of kerbside (high population density, shops, etc. - daily service) and communal collection (low population density, outskirts, etc. - 300 collection points - service every other day) as well as street cleansing, the total waste generated in Kathmandu/Patan - 120 tons daily - will be gathered in some 82 central containers (6 m^3) distributed over the city areas (8). Daily (47 containers) or every other day (35 containers), respectively, the full containers are exchanged for empty ones. At full scale ten tractor/hydraulic trailer units will be carrying out this task, shipping the waste to the central composting plant. There, salvageable materials (glass, plastics, paper, metals, wood, bones, etc.) will be separated (altogether ca. 10 per cent of total). Raw compost material will be fed into the compost plant, where daily about 16 per cent of the total waste will remain as residual matter to be disposed of in the sanitary landfill. Two dump truck/trailer units (12 m^3 ea) will be operating between compost plant and landfill (distance 14 km). Until the compost plant is fully operational, all of the waste will have to be disposed of in the controlled sanitary landfill which has a fill volume of some 600,000 m^3.

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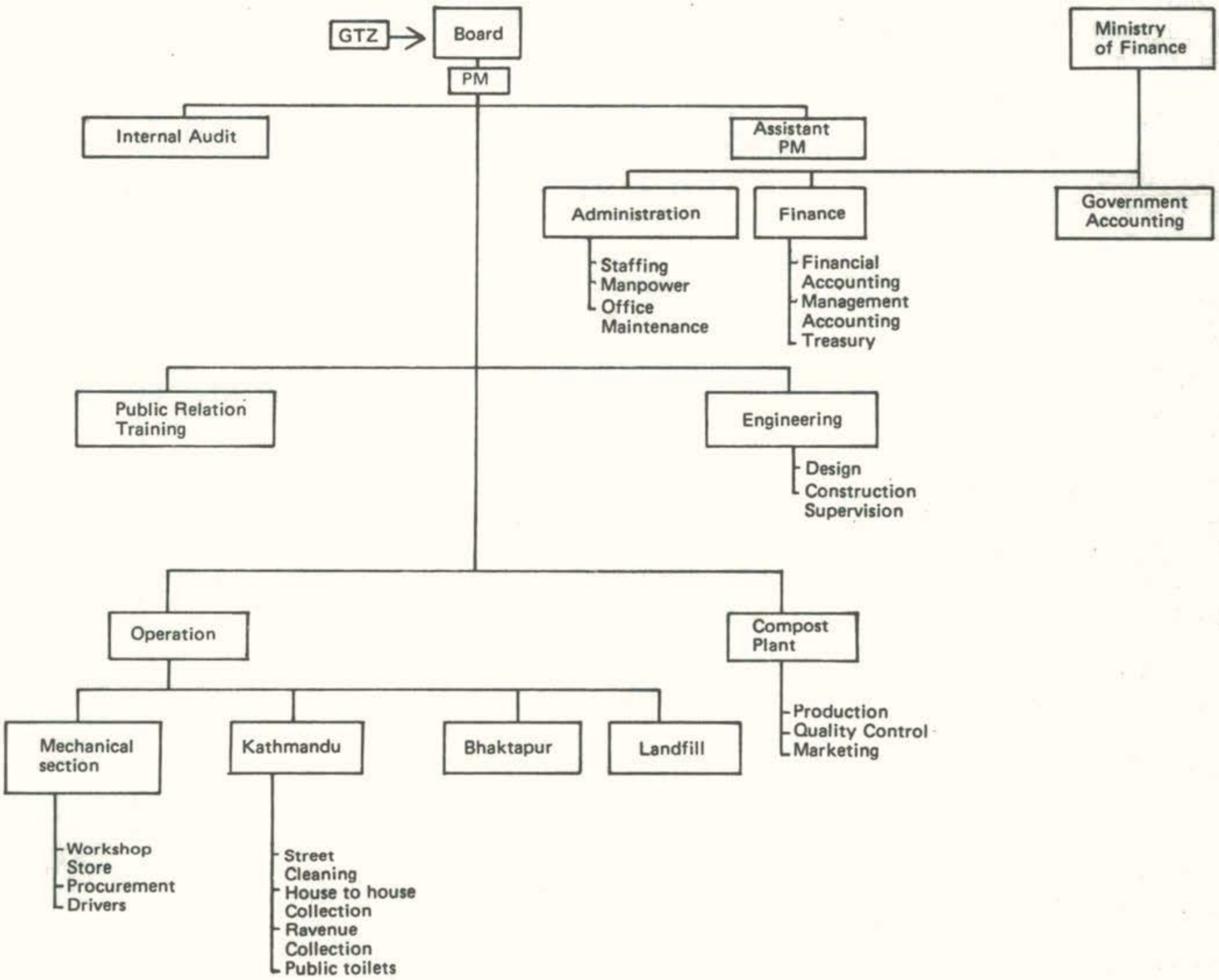
Table 2

PROJECTED DATA ON SOLID WASTE MANAGEMENT AND RESOURCES RECYCLING IN KATHMANDU/PATAN, 1984/85, (1US$ = 13 NRs)

Population in Service area	309,000		
Growth rate (%.y)	3		
Population served	278,100		90%
Population density/km^2	10,000		
No. of households	48,000		
Av. Persons/household	5.7		
Waste generated t/d	111.0		
Waste kg pcd	0.4		
Density kg/m^3	440		
Street Length km	190.0		
Waste collected t/d	120.0		
Waste collected t/y	43,800		(100%)
Raw compost matrial t/y	39,420		(90%)
Compost produced t/y	23,600		(54%)
Salvageable materials t/y	4,380		(10%)
Waste disposed t/y	7,008		(16%)
Staff, collection	815	(2.6/1000)	
Staff, composting	75		
Staff, recycling	30		
Staff, total	920	(3.0/1000)	
Worker's wage $/y	500.00	(13 months)	
Household's fee $/y	3.70	(7.4/1000)	

Fig. 1 Proposed Organisation Structure



Composting

Seven months of pilot composting (N.N.) yielded the following average chemical data:

N = 0.6 %, P = 0.7 %, K = 2.3 %, CN = pH = 7.4.

Composting:

Seven months of pilot composting (9) yielded the following chemical data:

N = 0.6%, P = 0.7%, K = 2.3%, CN = 19, pH = 7.4.

Process temperatures were in excess of 60°C, aerobic conditions were maintained throughout the process. The digestion period was determined to be 24 days (windrows turned over 4 times). Water content was 30 per cent, organic content was also 30 per cent. Particle size was less than 20 mm. Storage and maturing period was estimated to be about 60 days, final specific weight was 0.7 t/m^3.

Growth tests in the field indicate that the application of the compost will result in a substantial increase in yield (40-75 per cent vs untreated soil at application rate of 2 kg/m^2). Other experiments provided evidence that the application rate may be proportional to the increase in yield.

In the Kathmandu Valley more than 60,000 ha are cultivated for agriculture and horticulture. The projected capacity of the compost plant of 74 t/d (27,000 t/y) could supply some 2.3 per cent of that land with refuse derived compost at an application rate of 2 kg/m^2. Hence, sufficient compost is believed to exist within a radius of less than 10 km from the compost plant. A large proportion of potential customers (farmers) will be able to haul the compost themselves.

The projected plant will require capital investment of aprox. US$ 11,500/t capacity. The operating costs are estimated at US$ 7.5/t (including depreciation). A retail price is assumed at US$ 11.54/t, the equivalent value of the nutrient content N/P/K. Competitive products (night soil, animal manure, private compost, etc.) sell currently at US$ 15 - 90/t.

A detailed study was prepared to substantiate the above and develop a market strategy. Compost production was planned to begin in late 1984.

Salvaging and Recycling:

Up to 10 per cent of the daily collected waste consists of potentially salvageable and commercially marketable materials. Assuming that 60 per cent of that potential can be tapped by means of systematic separation some US$ 140,000/y of net profit could be derived from the sale of glass, paper, metals, plastics and wood (Table 3, (10)). Due to the central composting, the necessary logistics and premises for the salvaging of the materials are provided already. The exploitation of this valuable resource can thus be facilitated at little additional cost (Table 3, 5). The commercial windfall for the waste operator SWMB as well as the economic benefits are significant. Moreover, due to central composting total annual savings in terms of transportation and disposal costs amount to some US$ 85,000 or US$ 3.6/t, respectively, if related to the annual production of compost - this being 50 per cent cost/t (Table 3).

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Table 3

PROJECTED DATA ON ECONOMICS OF RESOURCE RECYCLING IN KATHMANDU/PATAN, 1984/85, PRICE 1983

Resource	Production t/y Potential	Exploitable	Unit costs/prices $/t costs	Prices	Profit in $/y, '000
Compost	23,600	23,600	7.25	11.54	101.20
Glass	548	329	17.54	60.00	13.97
Paper	548	329	17.54	60.00	13.97
Metals	365	219	17.54	220.00	44.34
Plastics	730	438	17.54	170.00	66.76
Wood	183	110	17.54	60.00	4.67
					244.91

Urban sanitation facilities

Ten "Hygiene Centers" will be evenly distributed over the city areas of Kathmandu and Patan. They will be attached to service yards (for waste collection operations) and will consist of public toilets and shower facilities. Advice on hygiene matters will also be offered. Public relations activities will be centered around these facilities. In addition, approximately ten public toilets will be built and operated throughout the cities and particularly along the Vishnumati River. There, facilities for hygienic slaughtering and vegetable cleansing will be set up.

Continuous maintenance will be provided by SWMB attendants. Operations and maintenance costs will be financed through user fees. All waste products and residual matters will be managed by SWMB.

Manpower training and development:

Regular training for supervisors, drivers, technicians, mechanics and workers is conducted and will be intensified by SWMB personnel, local and foreign advisors. Seminars will be carried out for managerial personnel and supervisors. Training modules will be developed. More than 500 man-months of training at universities, technical colleges and other institutions will be provided in connection with this project - in Nepal, in other Asian countries, and in the FRG.

3.3 Public Relations

Promotional activities and dialogue with the population are seen as an essential instrument for securing the success of any comprehensive waste management operation. In Kathmandu/Patan the news media (radio, newspapers, cinema) have, in the past, been enlisted for public relations work. Co-operation with schools in the context of general hygiene education, permits the furtherance of the common goal of cleansing the urban environment. Public meetings and hearings are held in the process of planning waste management in the cities. Posters placed throughout the cities and especially the establishment of the "hygiene centers" are and will be instrumental in maintaining a dialogue with the population - elucidating and illustrating the interrelationship between proper waste disposal and the physical well-being of the people. Self-help groups are being supported when conducting cleansing campaigns in their neighbourhoods.

4. Final Evaluation

Based on the projected integrated solid waste management system outlined above (see data Tables 2, 3) the total annual costs were calculated at US$ 0.94 million (US$ 3.40 pca) for the year 1984/85 (Table 5, O & M of sanitation facilities not included). In this it is assumed that the compost plant is operating at 87 per cent capacity (i.e. processing total waste) to permit an estimate of SWMB's financial status at full-scale operation. It is planned, however, that in a start-up period compost production will be operating at reduced capacity (40 per cent, break even production).

A breakdown of costs according to cost centers reveals that collection/transport/disposal accounts for nearly two thirds of total costs. Savings may be achieved in the future by reducing the collection frequency upon alteration of people's habits of discarding household wastes. A projected 815 workers (2.6/1000) will be required. This is roughly the same number as was formerly employed by the Nagar Panchayats. The unit cost per ton of waste (without composting and salvaging) is estimated at US$ 16.6/t.

A fee system ("Polluter Pays Principle") is currently being implemented. At full operation it will have to include all waste generating groups, whereby the economically strong shall subsidize the low income groups in order to yield sufficient revenues to sustain the operation. According to the proposed fee system (Table 4, 70 per cent collection efficiency assumed) an average household will be charged US$ 3.7/y (33 per cent of total cost incurred) which is the equivalent of some 0.74 per cent of a SWMB worker's (sweeper) annual income.

Table 4

PROJECTED DATA ON PROPOSED FEE FYSTEM, 1984/85

		Fees $/m		
Waste generating groups	No of units	Full cost recovery	Proposed	total, $/y (70% efficiency)
NP Kathmandu	1	-	61.538	61,538
NP Patan	1	-	15.585	15,385
Foreign Community (Households)	300	2.31	7.69 (342%)	19,345
Luxury Hotels	7	55.38	110.77 (200%)	6,531
Tourist Hotels	32	13.85	27.69 (200%)	7,444
Industrial/Public	3,000	3.23	4.00 (124%)	144,324
Commercial/Retail	7,800	.85	.77 (90%)	50,400
Dom. Households	48,000	.92	.31 (33%)	126,129
				431,078

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Table 5

PROJECTED ANNUAL DATA ON COST AND FINANCING OF INTEGRATED SOLID WASTE MANAGEMENT IN KATHMANDU/PATAN, (1984/85)

Center		$/year, constant prices of 1983 Costs	Revenues	% of Total
1.1	Administration/ Workshop	130,768		12.2
1.2	Depreciation	15,385		1.6
2.1	Collection/Transport/ Disposal	469,000		50.0
2.2	Depreciation	127,231		13.6
3.1	Compost Production	98,077		10.4
3.2	Depreciation	73,077		7.8
4.1	Resource Recycling	21,154		2.3
4.2	Depreciation	3,646		0.4
5.	Compost Sale		272,308	29.0
6.	Resource Sale		168,692	18.0
7.	Fees		431,078	45.9
8.	Government Subsidy		66,460	7.1
	Total	938,538	938,538	100.0

Hence, of total costs fees will cover 46 per cent and revenues from recycled products 47 per cent (at cost of 21 per cent only). The balance (US$ 66,460 or 7.1 per cent) will have to be financed through a governmental subsidy. Future savings on costs (increased efficiency and possible revenues from fees for the use of sanitation facilities would reduce that subsidy. Current governmental subsidies for Kathmandu/Patan are believed to be higher than the aforementioned amount. Current expenses of the Nagar Panchayats will also be lowered in the future. Current expenses of the households and other groups will be shifted somewhat from the informal sector (private, domestic sweepers) to the public sector by buying superior services of urban cleansing and sanitation.

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CONCLUSION

An integrated residues management and waste disposal policy translatable into concrete management concepts was defined in the introduction of this paper. Its emphasis was placed on public health, socio-economic and environmental considerations. It was pointed out that the salient features of a viable, effective and locally sustainable waste management system are a comprehensive legislation, a sound organizational and technical concept, sound finances, public awareness and participation, and a robust infrastructure.

A synopsis of current GTZ supported waste management projects which were conceived around the aforementioned integrated approach was given. Their various stages of planning and implementation and their differing geographic, socio-cultural and socio-economic settings will in the future provide valuable comparative information and experiences. They will reveal more about mechanics and the constraints governing the induced change of an urban population's habits of dealing with their waste.

The case study presented is based upon the project that is furthest evolved so far, in that a large-scale field test of the concept has been successfully completed and implementation is well underway. If the projections made come true, a decisive contribution will be made towards the improvement of public health in the cities of Kathmandu and Patan. This will be achieved at reasonable and locally sustainable costs, since almost 50 per cent can be recovered through resources recycling. The other half of the annual cost will be financed by the waste generators themselves who are at the same time the main beneficiaries of the public service provided. To a large extent government and municipalities will be relieved of their financial burdens. The responsibility for waste management is delegated to a competent and financially independent semi-autonomous authority or public utility.

The Solid Waste Management Project is of a pilot nature as an integrated package of measures contributing to the improvement of hygiene in an entire region. It is expected to have significant implications for future projects of this type in other developing countries.

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THE ROLE OF RESEARCH IN SOLID WASTE TECHNOLOGY FOR DEVELOPING COUNTRIES

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Federal Ministry of Research and Technology

Low-pollution, low-cost waste management is a goal which is equally attractive for both developing countries and industrialized countries.

Past experience has shown that neglecting anticipatory measures in environmental protection, leads to considerable consequences and costs, which are often very difficult to eliminate.

Let me only mention here the field of old dumps of hazardous waste or oil which entail considerable hazards for ground water or for surface waters and thus also for man.

After many unhappy experiences in this field, which most industrialized nations have undergone particularly in the phase of their development, it is now generally accepted that waste management and planning, begun in time, can help save considerable costs.

It would be useful if these experiences became generally known and accepted in all developing countries, so that they can avail themselves of this experience and recognize and avoid undesirable developments.

I would now like to outline a few elements, facts and other background information relevant to waste management.

To begin with, the symposium here in Karlsruhe and the visits programme have made it clear that there is a large number of techniques and methods for waste management. For example, landfill techniques, waste sorting techniques, separation at source, incineration, composting, biogas plants, pyrolysis etc.

Each of these processes has its merits in waste management. To ask for the best waste treatment and disposal system is almost tantamount to asking for the "philosopher's stone", and it is certainly useless to ask the question in this form because answering it would render an undifferentiated and therefore erroneous picture.

However, once the prerequisites and requirements of waste management planning have become clear, it is easier to find an answer to the question.

This clarifification includes in particular:

Sound data on waste data arisings and waste composition and identification of the areas from which waste must be collected including transport routes.

We know that these data vary considerably from country to country and even from region to region.

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The composition of municipal waste differs from that of rural areas, e.g. the waste generated here in Karlsruhe has a much higher calorific value, and specific waste arisings are greater, than that in rural areas.

The waste arising in the Italian capital of Rome must for example be collected twice weekly for hygienic reasons because average temperatures there are considerably higher than in the Federal Republic. In more temperate regions this is not necessary.

If such differences exist even in Europe, the prerequisites and requirements of waste management in developing countries are likely to differ even more from those in the Federal Repbulic.

Thus, the decision to build a centralized waste treatment and disposal facility, as a rule, increases transpost costs, but decreases the specific investment costs of a waste treatment and disposal facility (costs per ton of waste), irrespective of the waste technology applied.

In terms of the long term costs of waste management and disposal in densely populated areas, it may be more cost-effective to build several decentralized waste treatment facilities, instead of one central plant. Even availability and the assurance of waste treatment and disposal are as a rule improved.

It therefore seems important to compare and contrast decentralized and centralized solutions in the framework of a cost-benefit analysis.

It is also important to assess the waste arisings to be expected in the future because they are related to the demographic trend and to living conditions as well as to the degree of industrialization.

To get these fundamentals clear - which may differ from one country to another and from one region to another - is a first prerequisite for any further technically sound planning and solid political decisions.

Corresponding studies and analyses, which should be regarded as research and development, can make very valuable contributions and pay in the long term.

<u>Development of alternative waste treatment and disposal techniques, fixing of priorities</u>

It seems helpful in this connection to look back at the historical development of waste management.

The first waste incineration plant was erected in Hamburg, Germany, just before the end of the 19th century.

The first plant was built for the sole reason that epidemics were to be controlled. In the 17th century it was quite current practice to simply dump waste in the street or throw it away at the nearest available site. Vermin and rat infestation and its consequences became intolerable for the population.

I am saying this because it seems essential to me that it was hygienic demands which, in the first instance, determined the technology of waste management.

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The following questions and demands were raised very much later:

- saving landfill volume by waste-volume reduction (e.g. incineration)

- utilization of the energy and raw materials content of wastes

- Treatment and utilization of sludges

These goals continue to largely determine the development of waste treatment and disposal facilities in this country.

Currently, approximately 30 million tons of household refuse and similar wastes are generated in the Federal Republic of Germany. About 65 per cent of these wastes are dumped in landfills, about 1/3 is incinerated and the off-heat generated, mostly used in district heating networks and/or for electricity generation, while less than 3 per cent are composted.

On the one hand this shows that landfills are the "backbone" of waste management, and we are trying to make sparing use of the scarce landfill sites available in this country.

There is also an economic reason for taking care that landfills have the longest possible life, because once these landfills are filled, new ones can only be planned in out-of-town areas. This increases transport costs considerably, which account for the major share of overall waste treatment and disposal costs.

By building thermal waste treatment facilities - the residual cinders and non-usable residues must be dumped - it is possible to increase the life of a landfill site by a factor of 5 or 6 and that of raw material recycling facilities by a factor of 2 or 3.

In other countries, the need to reduce landfill volumes may be less great than in the Federal Republic of Germany. However, the following development goals are certainly generally and widely applicable.

They include:

- production of low-pollutant composts from waste and sewage sludges

- production and utilization of gases from waste containment sites

- production of biogas from sludges and wastes

- recycling of raw materials from wastes into the production cycle

- avoidance of damage to the environment by lining waste disposal facilities, by treating landfill leachates and by closing the cycle as well as by protecting groundwater.

In addition, I would like to point out that pyrolysis systems for household refuse and hazardous waste are being developed in the field of low-temperature techniques (500 - 800°C).

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We expect that these developments, which are not yet state-of-the-art, will be highly compatible with the environment and broadly applicable to various types of waste. In the case of the pyrolysis of hazardous waste, including used tyres, shredder residues from old cars etc., there is in addition a possibility of recovering oil and chemical raw materials (aromatic substances).

At any rate, the treatment and disposal of hazardous waste from industry should be separated from that of household refuse. In this way utilization potentials are increased and the danger of damaging the environment by hazardous waste is reduced.

Recycling raw materials and energy contents into economic cycles always presupposes a market for these products.

Let me give you an example:

Currently, only 3 per cent of wastes arising in the Federal Republic are composted and only 70 per cent of this compost can be sold in the market. This is done mostly in wine-growing areas on stony slopes where there is a demand for humus and compost. Roughly 30 per cent of the composts thus generated must be dumped in landfills. In other European countries, e.g. Sweden and Italy, there is a much greater need for waste composts owing to the stony soils these countries have.

Organizational measures and technical systems must be complementary

Waste separation at source is an effective means of sorting out raw materials such as paper, glass and metals from the waste arisings and of reducing the arisings as such. Such measures and their success are determined on the one hand by the market value of the secondary raw materials, and on the other hand by the different sizes of containers made available to the population, and motivation on the part of the public.

We have for example, found that large-volume waste containers (240 litres) per household jeopardize the success of separation at source since many people give up separate collection for the sake of convenience and because of the large volume available in large containers.

In addition there is the possibility of converting the organic components of waste into high-quality composts by means of separation at source.

The approach followed by the county of Aurich in the Federal Republic, which makes available only very small waste collection containers to its citizens but provides them at the same time with sufficient containers for valuable materials such as glass, paper etc. proved that a far above-average recycling of valuable materials from waste is possible and that at the same time high-quality composts can be produced from the remaining organic waste components.

These successes can also be further encouraged by waste collection rates which act as an incentive to separation at source.

However, separation of paper and plastics at source in combination with a refuse incineration plant may constitute a contradiction since the calorific value of the remaining waste is lowered considerably.

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At any rate, however, recycling of raw materials from waste into the production cycle helps to reduce landfill volumes. In addition the production of economic commodities from primary raw materials is usually less compatible with the environment and more energy-intensive than production from secondary raw materials.

<u>The need for an adaptation of waste treatment and disposal technologies to the demands of the developing countries</u>

Most waste treatment and disposal technologies were developed with a view to the specific needs of the industrialized countries. It is necessary to adapt them to the needs of the developing countries since they have different priorities and refuse composition is frequently very different there.

For this reason an active dialogue would be desirable and useful in order to speed up the relevant research and development activities.

In conclusion let me express the hope that your stay in the Federal Republic of Germany has brought you some interesting ideas and suggestions, not only in the field of waste management problems.

5. SUMMARY OF DISCUSSIONS ON THE LECTURES

(reported by ERL)

Tuesday, 4 October

Collection and Transport of Solid Waste - Dr. Knoch, VPS Private Refuse Disposal Contractors Association, Cologne.

Dr. Knoch explained trends and present techniques used by contractors in Germany. The paper covered collection, disposal, transfer and future trends.

Q. Mr. Jones, World Bank; stated that during visits to installations he had seen extremely large and heavy vehicles carrying small loads. He estimated that two thirds of the fuel being used was purely for transporting the vehicle, thus only one third of the fuel was used for the vehicle's pay-load.

A. Dr. Knoch explained that it was found that by using large and fully automatic equipment the machine costs offset labour costs.

Q. Mr. Kyong Ho Kim, Korea; asked who is responsible for the cleaning of containers deposited in dwellings and transfer points?

A. The collection authority or company is responsible for ensuring containers are kept in a hygienic condition.

Q. Mr. Hunter, Jamaica; asked if the statistics referred to were the findings of his company in his area, or the whole of Germany? also, what collection and storage regulations applied in Germany?

A. Dr. Knoch answered that the statistics given were for the whole of Germany but these could also be applied to many other European countries. Graphs at the back of his paper were from the findings of his company. He would explain the legal requirements applying to storage and collection outside of the meeting, but there were stringent regulations applying to these areas.

Cairo Waste Management Problems - Dr. M. Neamatalla, Consultant to the Government, Environmental Quality International, Inc.

Dr. Neamatalla described the present collection and disposal systems in Cairo and a programme for improving existing services.

Q. Mr. Hugo Garcia-Perez, Mexico; asked what percentage of the total collection and disposal cost was paid by the Municipality?

A. Dr. Neamatalla said this was a difficult question as he had not carried out an in-depth analysis of costs, but as a guideline he would suggest that the Municipality only had to bear the cost of transportation.

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Materials Recovery and Recyling in Brazil - Prof. Luiz Edmundo Costa Leite, President of COMLURB, Public Corporation for Solid Waste Management.

Prof. Leite described the recovery and compost recycling operations in Brazil.

Q. Mr. Hunter, Jamaica; asked why the price of compost varied so much from area to area?

A. The price per tonne was determined by the soil conditions that existed in certain areas.

Q. Mr. Gómez Palomo, W.U., Guatemala; had a full cost evaluation been carried out on direct landfill and had they considered biogas technology, and if so, how did it compare?

A. Compost: $10.00 per tonne; landfill: $3.00 per tonne; $7.00 per tonne for transport. Biogas technology was considered but would only be used when a user was available nearby for example next to a factory.

Q. Mr. Ibrahim Ageel, Saudi Arabia; were there any problems in changing from manual sorting to mechanical sorting?

A. No.

Q. Ms. Marta Pilon de Pacheco, Guatemala; explained that in her country they had to import many tonnes of chemical fertilisers, mainly for coffee plantations. Could the type of compost being produced in Brazil be used instead of chemical fertilisers?

A. Prof. Leite considered that the compost would be suitable.

Q. Dr. Neamatalla, Egypt; asked what was the residence time in the Dano drum?

A. 2-3 days and 60 days in windrows.

Q. Mr. Ghulam S. Siddiqui, Pakistan; are the composting plants economically viable (financially self-supporting) or are they subsidised by the Government?

A. No subsidy is required.

Q. Mr. F. Botafogo Goncalves, Brazil; asked how much the City of Cairo would have to pay if the present system was not used?

A. Approximately six times as much, say 30-50 million dollars more.

Q. Mr. Nono Aboejoewono, Indonesia; as the waste from higher income areas would be more attractive than that from the lower income areas, collection from the lower income areas must be very infrequent. How does the Municipality cope with this situation?

A. Dr. Neamatalla explained this was a problem, but the Government was not injecting monies for collecting waste in the lower income areas.

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Q. Dr. Septimus W. George, Sierra Leone; asked how the speaker could recommend collection of wastes by animals and not mechanical means?

A. Animals are cheaper and the lower income groups could not bear the cost of mechanised collection.

Q. Mr. Marco B. Breakenridge, Jamaica; Cairo problems seemed similar to Jamaica; what were they planning for the future?

A. A composting plant of a pilot nature was already being built and was due to be commissioned in five months time.

Q. M. Betts, ERL, United Kingdom; asked who arranged the main 'clean-up' programme?

A. The Municipality organised the 'clean up', but it was paid for by the collectors. With regard to the composting plant, it was estimated that 150 tonnes per day of compost would be produced.

Q. Dr. Klaus Komorowski, Federal Republic of Germany; concerning the fee charged by collectors, what percentage was paid by the lower income group?

A. The higher income group pays about three times more. The lower income groups pay only 25 piasters per household per month, which equals the price of a packet of cigarettes and it is interesting that 85 per cent of the people have responded to this levy.

Materials Recovery and Recycling - German and European Trends - Dr. Eckhard Willing, Federal German Environment Agency.

Dr. Willing highlighted the current trends in recycling and the latest technologies.

Q. Mr. Hunter, Jamaica; what was Dr. Willing's opinion of Waste-Derived Fuel?

A. It depended on the incoming waste, for example if the waste was high in organic matter and therefore wet, it would not be viable. If the waste was high in paper and other combustible materials it could then be viable.

Q. Mr. Sajjad Hussain, Pakistan; who defines the quality of recycled materials?

A. Unlike in the USA, our waste recycling is determined by current market conditions.

Landfill Technology - Dr. Werner Bidlingmaier, Stuttgart University.

Dr. W. Bidlingmaier explained the selection parameters for landfill sites and operational methods, and the advantages found by closing smaller sites and using large central sites.

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Q. Dr. Septimus W. George, Sierra Leone; what safety measures are required for gas collection?

A. Explosions are caused mainly by the oxygen in the gas. Therefore, each system must have an oxygen analyser.

Q. Mr. Ghulam S. Siddiqui, Pakistan; could information be given regarding rainfall on landfill sites?

A. In Germany they have, on average, 800 mm of rain a year. 25 per cent of this will become leachate.

Q. Mr. E.G. Hunter, Jamaica; what is your opinion of landfill in a coastal environment?

A. (Prof. Georg Goosman) this practice is not recommended.

Planning of Landfill Operations in Amman, Jordan - M. Betts, United Kingdom and Dr. Omar Joudeh, Jordan.

The paper described the problems of site selection for sanitary landfill operations in the Amman area of Jordan.

Q. Mr. Claude Della Paolera, Argentina; how big is the area of Amman?

A. The population of the study area is about 1.8 million, approximately 60 per cent of the total population of Jordan.

Q. Mr. Shashi Thapa, Nepal; how deep are the layers deposited on the landfill site and was cover being used?

A. Each layer is approximately 1 metre deep and covered with 50 cm of material. One of the reasons for recommending the site was because of the availability of suitable covering material.

Q. Mr. Marco Breakenridge, Jamaica; how did you ensure that water was not polluted?

A. Hydrogeological surveys provided information that any waste deposited at the selected sites would not effect ground water.

Q. Dr. Neamatalla; what causes fire on landfill sites?

A. There are many possible reasons for fires, varying from broken glass causing a magnifying effect with the sun, to spontaneous combustion.

An Approach for Compost Production from Municipal Waste (Patan/Kathmandu), - Mr. S.B. Thapa, Project Manager, Solid Waste Management Board, Kathmandu.

Mr. Thapa explained that in Patan and Kathmandu, soils are being washed away every year by floods, landslides and erosion. Therefore, for retention of the soil's biochemical characteristics and restoration of its organic matter, many tonnes of chemical fertilisers have to be used. Under these circumstances a decision was made to install a pilot composting plant.

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Q. Dr. W.U. Gómez Palomo, Guatemala; why not, as there was plenty of wood type products in the waste, use biogas technology?

A. The main requirement in the particular area was soil enrichment, and thus composting was selected.

Q. Ms. Marta P. de Pacheco, Guatemala; it was stated there were no toxic substances found. Did you expect to find some?

A. Yes there was a possibility and you should always carry out a test to study the possibility of toxic materials, etc.

Q. Dr. Neamatalla, Egypt, it was mentioned you adopted the DANO drum; what is meant by this?

A. Mr. Thapa explained that it was a DANO-type drum and not the DANO system. For example, the drum was far shorter than a recognised type and the residence time was a lot less.

Q. Mr. Hunter, Jamaica, it was stated that funds were acquired from the German Government, but also the plant is not economical. Why do it?

A. The first stage is only a pilot stage, the next stage for 150 tonnes/day will be economical.

Energy Recovery from Solid Wastes Incineration and Other Thermal Waste Treatment Processes - by Christian Nels, Federal German Environment Agency.

There were no questions on this presentation.

Wednesay, 5 October

Status and Trends in the Management of Industrial Hazardous Waste in the Federal Republic of Germany - by Franz Defregger, Bavarian State Ministry for Land Development and Environment.

Mr. Defregger explained that Germany is producing on the order of 3-4 million tonnes of 'special wastes' per year. Of this, 15 per cent is treated by incineration, 35 per cent by chemico-physical treatment and 50 per cent disposed of in secure landfill sites. He then expanded on licencing and transportation regulations in the FRG.

Q. Mr. Hugo Garcia-Perez, Mexico; asked if Mr. Defregger could define types of hazardous wastes and also provide him with a list of difficult types?

A. Mr. Defregger agreed to provide a list of difficult wastes which would also assist in definitionns.

Q. Mr. Fernando Botafogo Goncalves, Brazil; would it be more beneficial to treat wastes at a transfer point rather than at final deposit?

A. There would be no difference.

Q. Mr. Hunter, Jamaica; asked why nuclear wastes and hospital wastes were not mentioned?

A. Mr. Defregger explained that these wastes were encompassed within different legislation.

Q. Mr. César Fernando Arias, Argentina; who made the monies available for the resent system, i.e. Government or contractor?

A. The monies were made available from Central Government as the small Municipalities were unable to afford the initial outlay.

Q. Mr. Nono Aboejoewono, Indonesia; was hospital waste considered hazardous?

A. No, only if high in mercury content.

Q. Dr. Septimus W. George, Sierra Leone; were there any problems from taking toxic waste from the USA?

A. No, but if wastes were dumped indiscriminately at sea, then this could be a problem for them.

Q. Mr. Sarkis Garabedian, Syria; asked why in Syria the BOD measurement was much higher than that quoted in Germany?

A. Mr. Defregger stated he was referring to leachate characteristics, the main problem being chlorides, which should have separate treatment.

Biogas Production from Solid Wastes: The status and prospects by Eddie K.S. Hum, D.M. Tam, N.C. Thanh and Municipal Refuse Night-Soil Composting in China by Liu Xishu and Shi Qing

Questions on these two presentations were taken together.

Q. Mr. Hunter, Jamaica; can the composting system be used in Jamaica?

A. It is suitable for China because of the right soil element, but she did not have knowledge of Jamaica's problems.

Q. Mr. Chwee Hock Lim, Singapore; how much does the process cost?

A. Farmers assist in the process and are rewarded by receiving a percentage of the produced compost.

Q. Mr. Theodore Mogol, Philippines; how is night soil collected?

A. From the city's main storage tanks, by tanker.

Q. Mr. Adewale Aderibigbe, Nigeria; asked about health hazards.

A. It had been found there were no adverse effects from odours, but if skin contact were made this could be a problem.

Q. Mr. Doo Ho Rhee, Korea; is biogas used in China and, if so, how is the process temperature achieved in Northern China?

A. Biogas is used extensively in China. In the Northern provinces (as in the South), tanks are located under ground.

Q. Mr. Hugo Garcia-Perez, Mexico; could some costs be provided?

A. They vary from site to site, but are of a very minimal nature.

Q. Mr. Theodore Mogol, Philippines; what size tank is required for one family, say?

A. Average household is 5 persons, and a tank of 8-10 m^3 would suffice.

<u>Low Waste Technology</u> - Mr. D. Larré, Director, UNEP Industry and Environment Office, Paris.

Q. Mr. Fernando Botafogo Goncalves, Brazil; asked if some information and guidance could be given on hazardous waste?

A. Mr. Larré said that hazardous wastes were created mainly by mismanagement. The first stage was to ensure efficient management within organisations.

Q. Mr. Hunter, Jamaica; could legal areas and rules be defined?

A. Consultations take place with Government and industrial representatives to define and agree the areas.

Q. Dr. Neamatalla, Egypt; what help could be given to assist with legislation in developing countries?

A. The problem is staff. UNEP has a staff of only 200 but would try to assist in this field, if requested.

<u>Regulatory and Organisational Aspects of Solid Wastes Management</u> - by Mr. S.A. Szelinski, Federal German Environment Agency.

Q. Mr. Hunter, Jamaica; in his opinion, should governments supply plants?

A. Yes, but with financial support from industry.

Q. Mr. Marco B. Breakenridge, Jamaica; what is meant by government control?

A. A body of laws drawn up by government, that are legally binding and enforceable.

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Costing and Cost Recovery for Waste Disposal and Recycling - by Charles G. Gunnerson and David C. Jones, World Bank.

Messrs. Gunnerson and Jones emphasised the important financial implications of a waste management. It was shown what financial information should be obtained before various collection, transfer, treatment and recycling projects should be undertaken.

There were no specific questions on this paper.

Sociological and Cultural Aspects of Waste Management - by J. Vogler

Mr. Vogler presented a pictorial summary and commentary on employment creation and recycling using basic techniques.

There were no specific questions on this paper.

Friday, 7 October

Two other papers were presented:

The Role of Research in Solid Waste Technology for Developing Countries by K. Komorowski, BMDFT, and

Review of Selected Solid Wastes Management Projects in Developing Countries by B.H. Metzger, GTZ

Questions were not invited on these papers.

5. REVIEW OF CASE STUDY WORKSHOP
(reported by ERL)

Case Study Workshop

General

Part IV of the Symposium consisted of a Case Study Workshop, for which ERL had prepared Case Study Materials. The Case Study Workshop was concerned with the planning of solid waste management for a region within a fictitious developing country, 'The Puedam Region'.

The study was divided into five 'sub-case studies', on the following lines:

(i) Analysis and Forecasting of Solid Waste Composition and Quantities;

(ii) Refuse Storage and Collection;

(iii) Transport and Landfill Operations;

(iv) Incineration and Composting;

(v) Hazardous Wastes.

Accordingly, participants were organised into five working groups, having previously ascertained which participants had a strong preference for working on a particular aspect of the Case Study.

In this respect, it is worth mentioning that the subjects of Transport and Landfill Operations, and Hazardous Wastes, were the most popular subjects among the participants.

The Workshop represented something of a challenge for the various working groups, in-as-much as each 'sub-case study' required the participants to:

- Review and consider a substantial amount of background information and specific data;
- Appreciate what was required and identify the possible alternatives;
- Analyse the relevant information and reach some conclusions;
- Present and justify their results and conclusions.

Moreover, the time available to the working groups was limited, even though the Seminar Programme was later rearranged in order to give them a little more time.

Each working group received general guidance and occasional assistance from a group convenor. In our view, the continuous presence of a convenor contributed considerably to the smooth running of the Workshop and helped the participants to benefit more from the Case Study.

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Results of the Workshop

Below, is a brief summary of our impressions of the proceedings of the Case Studies, and the results from each of the Working Groups:

(i) Analysis and Forecasting of Solid Waste Composition and Quantities

This was the smallest of the Working Groups, which probably was an advantage given that this part of the Case Study involved rather more statistical analysis and computation than the others. The amount of data analysis and calculation required had been of some concern to ERL, during the preparation of this sub-case study. In the event, this did not seem to create undue difficulties for the Working Group. It was also evident from discussions during the working sessions, that the group examined several alternative approaches to generating the estimates and forecasts of waste arisings, and considered the best way of presenting the data.

The results presented by this group were, with one or two minor differences, virtually idential to the solution prepared by ERL.

(ii) Refuse Storage and Collection

This group was asked to estimate the requirements for collection vehicles, storage containers and manpower, in order to provide a refuse collection system for the City of Puedam. It appeared to us that the group had some initial difficulty in relating the different factors which affect collection system performance, to the ultimate requirements for equipment and manpower. However, having eventually grasped the key factors and relationships, the group proceeded to prepare a full schedule of plant and manpower requirements for refuse collection in the City, without any problems. Several very good questions were also raised by members of the group, which generated some interesting discussions and views.

One very good point which was made, concerned the collection system for the city centre. The group had concluded that this was the only district of the city where the use of a compression-type collection vehicle might be worthwhile but, quite rightly, pointed out that having just one vehicle of this type in the collection fleet did not make much sense, because of the management problems this would create in terms of reserve vehicles and maintenance.

(iii) Transport and Landfill Operations

This sub-case study contained two distinct elements:

- Review and selection of potential future landfill sites, taking into account environmental, operational and economic factors;

- Assessment of the requirements and costs for transporting wastes.

The study was structured in such a way that, of the existing and potential landfill sites, only two sites were really suitable for the long-term disposal of wastes - one fairly close to the City of Puedam, and the other much further away.

The site close to the city required substantial investment in measures to protect ground surface waters, but had the advantage of relatively low costs of transportation. Conversely, the more distant site did not require a great deal of investment to develop as a sanitary landfill operation, but involved high costs of transportation.

The group was able to narrow down the choice of potentially suitable landfill sites fairly readily, and then proceeded to calculate the associated transport costs. Their figures showed that the site close to the city was the cheapest option overall, but, interestingly, the group recommended using the more distant site on the grounds that the risks of polluting potable water supplies at the closer site were too great even with the proposed protective measures.

In other words, the group preferred a 'higher cost-minimal pollution risk' strategy.

(iv) Incineration and Composting

This Working Group elected to divide into two sub-groups, one dealing with refuse incineration and the other with refuse composting. A particular feature of this sub-case study was the need to undertake a quite detailed economic analysis of the plant alternatives, as well as an assessment of their technical suitability and performance.

The two sub-groups were able to determine the number and sizes of plant to be considered in detail, without much difficulty, but the detailed economic analysis did prove a little difficult for some participants, especially those unfamiliar with the subject. Nevertheless, with assistance from the convenor, the group managed to complete the economic analysis and prepare a comparison of the costs of alternative plant options.

The group concluded that incineration involved much higher costs than other alternatives, even with the revenue produced from selling the energy recovered. Reservations were also expressed about the suitability of Puedam's waste for incineration, and the desirability of installing such a technically-sophisticated system of waste treatment.

With respect to composting, the group felt that, while this was technically feasible, much depended on the eventual market for the compost. Some participants also suggested that a simpler and cheaper system of composting might be more appropriate to Puedam's circumstances.

Overall, the group appeared to conclude that neither incineration nor composting were particularly attractive options for treating and recovering Puedam's refuse.

(v) Hazardous Wastes

This part of the Case Study was perhaps the most complex in a technical sense, and the least straightforward in terms of being able to arrive at a definite set of conclusions and recommendations. This was reflected in the discussions of the Working Group, which focussed in turn on the many technical, environmental, administrative and legal issues of hazardous waste management without arriving at many firm conclusions.

The group was asked to consider arrangements for managing and controlling the wastes generated by the Puedam Industrial Area, an industrial complex founded largely on oil refining and petro-chemicals production. The first essential step in the exercise was to assess the limited information available regarding the nature and quantities of wastes. In practice, this requires quite specialised expertise, and so the group was provided with quite a lot of assistance in this regard. After much discussion, the various wastes were then classified according to their physical/chemical characteristics and their potential requirements in terms of waste storage, handling, pre-treatment and disposal.

Having arrived at a broad classification of the wastes, the group considered the possible options for future handling and disposal, the need for specialised pre-treatment of certain difficult wastes, and a possible framework for planning, regulating and financing hazardous waste management.

The main conclusions reached by this group were:

- There is insufficient information available to prepare a comprehensive waste management plan for the Puedam Industrial Area. Therefore, a survey should be carried out to collect additional data;

- In the short-to-medium term, disposal in landfill in conjunction with municipal solid wastes would seem to be the only practical choice;

- In the longer term, cetain wastes (notably those containing heavy metals) should be chemically pre-treated;

- Some wastes should, for environmental reasons, be incinerated rather than landfilled, but the high costs of incineration are likely to provoke resistance by the industries concerned;

- The Puedam Industrial Area Development Authority (PIADA) should be given overall responsibility for planning and control of waste disposal throughout the Puedam Region;

- Comprehensive regulations should be introduced, but not before the means to ensure their enforcement are available. In this respect, the group felt that a lack of qualified personnel is likely to be a major constraint for the Authority.

<u>Concluding Remarks</u>

Judging from the many comments received, the Case Study Workshop was much appreciated and enjoyed by the participants. In our opinion, such workshops are an excellent way of focussing attention on specific issues and aspects of solid waste management, and provoking discussion and the exchange of ideas.

This particular Case Study was quite demanding of the participants but, in general, they responded with enthusiasm and commendable pragmatism. All of the Working Groups managed to complete most of what was required, even though time was limited.

However, it was a pity that so little time was allocated to presenting and discussing the results of the Case Study in open forum. This is a point to be borne in mind for any future workshops of this kind.

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7. TECHNICAL VISITS TOUR GUIDE
- PLANT DESCRIPTIONS -

Prepared by: Federal Environment Agency, BERLIN

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INTRODUCTORY REMARKS

The selection of plants and sites to be visited during the international symposium on Solid Waste Management was one of the more difficult parts of the programme preparation.

A compromise had to be found between a number of incompatible postulates, taking into account various constraints such as available time, location of plants, etc.

The main approach used was to present a realistic picture rather than selecting show-pieces only.

As a result, a mixture of old and new plants, sophisticated and simpler examples of technology were visited. It was repeatedly stressed during the programme that none of the various technological solutions presented would be transferable to other countries without modification, if at all.

The brief plant descriptions of this "Tour Guide" were intended to inform participants of some basic facts in advance of the actual visits and to help to overcome the obvious problem of limited time available at most of the sites.

The idea was that the technical visits would provoke discussion. It was considered essential that all information, impressions and immediate conclusions resulting from this part of the programme would become subject to evaluative questioning, supplementation and where necessary rectification throughout the subsequent seminar and workshop parts of the symposium.

We wish to express our gratitude to the plant operators and manufacturers who have been extremely co-operative in providing us with information and for their hospitality during the tour.

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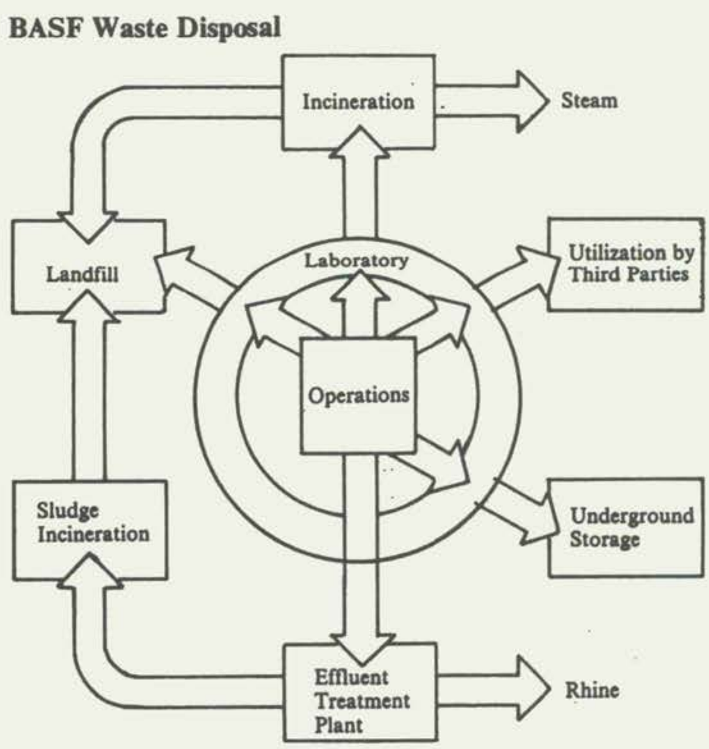
LUDWIGSHAFEN
BASF

Covering an area of 6 km^2 the BASF facilities in Ludwigshafen, Federal Republic of Germany, constitute the largest chemical production complex in Europe. It contains some 1,600 buildings, including 300 plants, and employs currently about 50,000 people. More than 6,000 different products with a total volume of 6 million tonnes are manufactured annually. The utilities thus consumed are 5,100 million kilowatt hours of electricity, 16 million tonnes of steam and 1,000 million m^3 of water.

Inevitably associated with the production sector is a complex waste management operation.

The BASF Waste Disposal Department (270 employees) is responsible for the operation of the waste water treatment and sludge incineration plants, the incinerators for liquids, viscous and solid production residues and the "Flotzgruen" landfill located on an island in the Rhine. As shown in the general BASF waste disposal scheme below, residue utilization by third parties and underground storage of hazardous materials are also parts of the overall system.



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Effluent Treatment Plant

Process: chemical-mechanical-biological. 180 million cubic metres per year of BASF effluent requiring treatment; 20 million cubic metres per year of municipal sewage from Ludwigshafen, Frankenthal, and Bobenheim-Roxheim. 7.6 cubic metres per second hydraulic flow in dry weather. 4 coarse sludge removal basins for mechanical clarification, each 29 metres in diameter. 5 activated sludge treatment basins for biological treatment, each 122 x 116 x 4.25 metres. 110 aerators, driven by 15,000 kilowatts of power. Separation of sludge and cleaned water: 10 basins (57 metres in diameter).

Sludge thickening and dewatering: 5 round basins (52 metres in diameter); 7 filter presses each providing 1080 square metres of filter surface; pressure plates measure 2 x 2 metres.

Sludge incineration:

2 fluidized bed furnaces, each incinerating 20 tonnes of filter cake per hour.

Waste gas cleaning: 3 electrostatic precipitators.

Residue Control

About 1,000 different types of residues, approximately 100 new types each year. Utilizing all possible means for recycling. Laboratory determines environmentally most compatible and economical method for disposal. Registration of all residues.

Flotzgruen Landfill

21 million cubic metres of landfill on an 80 hectare site. 600,000 tonnes per year: Rubble, excavation fill, refuse, production wastes and dewatered sludge, sludge ash.

Transported 40 kilometres up the Rhine on push barges.

Herfa-Neurode Underground Waste Disposal

About 2,500 tonnes of solid wastes generated annually by chemical production can neither be deposited on Flotzgruen nor incinerated. These facilities are available for such so-called critical wastes. This "landfill" is included in the "Refuse Removal Plan 2 - Critical Wastes" of the Federal State of Hessen. It does not solely serve BASF but also accepts problematic wastes of different origins from all States in the Federal Republic.

The Herfa-Neurode storage facility is located in a large mine of the Wintershall Potassium Salt Works. The mine (exhausted decades ago) is part of a massive stable salt formation measuring 300 metres in thickness and located at a depth of 800 metres. Only solid wastes which must be delivered in tightly sealed drums can be stored here. They are assigned to separate chambers according to type of material.

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Residue Incineration

6 rotary kilns and 1 converted grate furnace, all equipped for heat utilization.

370 GJ/h (Gigajoules per hour) heat generated. 1 tonne residue = 5 tonnes of steam.

80,000 tonnes of liquid, viscous and solid residues in 1980. 100,000 tonnes of liquid residues for energy production in the power plants.

To achieve complete combustion of the flue gas from the various rotary kilns it is passed through a secondary combustion chamber operation at 1,200°C and subjected to a special combustion process.

Thereafter, the heat is transferred to a waste heat boiler generating steam.

Cooled now to 350°C, the flue gas out of the first five furnaces passes an electrostatic precipitator for dust removal. The waste gas out of the sixth furnace is scrubbed with water to remove remaining dust and hydrocloric acid.

The slag from each of the six incinerators is disposed of by landfilling. The fly ash collected by the electrostatic precipitator is mixed with lime prior to disposal. After the removal of solids the effluent from the flue gas scrubbing is fed into the effluent treatment plant.

Over the past 10 years, the investment for residue incineration has amounted to 55 million DM. The operating costs are virtually 20 million DM per year, but 2/3 are covered by the exploitation of the heat generated by the waste incineration installation.

All the information is taken out of brochures presented by BASF.

HEIDELBERG

Refuse Composting Plant

The composting plant is operated by the City of Heidelberg. It went into operation in 1973.

The plant handles some 50,000 t/y of household and commercial wastes and sewage sludge in combined operation with a residue incinerator.

The daily throughput is about 200 tonnes, the population served, about 170,000.

The composting process (main contractor: Hazemag, Münster) used in Heidelberg is one of the more sophisticated ones.

One reason for not choosing a simpler windrow system, as for instance in Wiesloch, was the limited space. The available site had an area of only 2.3 ha. The entire compost plant is housed in one complex building of 68 x 78.5 metres. For storing the produced compost, the plant was provided with a clear area of 14,000 m^2 with a storage capacity of about 16,000 m^3.

The refuse trucks are weighed on entering the plant and then are directed to a dumping spot in the entrance hall of the bunker. This hall is completely closed off except for two large doors, so that no dust reaches the outside.

From the bunker the refuse is fed into the processing line by grab crane. The front-end processing is by special rasp-type grinders (also known as "grater"), a purpose-designed piece of equipment providing for selective grinding, i.e. soft components suitable for composting pass through the screen bottom (30 mm), whereas the grindable components are removed from above the screen bottom.

Bulky wastes are pre-treated in a high-speed impact pulverizer before being fed into the rasp-type grinders.

The residue discharged from the grinder is returned to the bunker and then burned in the incinerator. The ground refuse and dewatered sludge are mixed and conveyed to an intermediate storage bunker. Necessary to balance out the different working hours between the sewage purification (approx. 8 hrs.) and composting (about 16 hrs.). By a special conveyor system the refuse-sludge-mixture is transported to the four fermentation silos. The material is moved by slow turning agitators with plough-shares through the 10-deck silo from top to bottom, lasting 24 hours.

The fermentation of the refuse is a biological process whereby temperatures of up to 65°C are reached. From the bottom floor of each tower the raw compost is drawn off and transported to two compost screens.

The screens have a mesh size of only 5 mm. In this way, all irritating particles, above all glass splinters, small metal particles, wood and pieces of plastic are removed as residue.

/...

The screened material, called fresh compost, has a water content of about 40 per cent. Having passed through a 24 hour fermentation process only, biological decomposition is not yet complete.

This material could be used as it is for certain agricultural or other applications where "maturity" is not a requirement, however, if stored in heaps or in containers for any length of time fermentation would continue immediately.

Normally fresh compost is placed in windrows for further decomposition called "maturing".

In Heidelberg, as a special feature, another way of stabilizing the fresh compost is provided for, i.e. stabilization by drying by means of hot combustion gases from the residue incinerator. The drying prevents further fermentation and facilitates storage in high heaps. When moistened again decomposition continues.

Residue Incinerator

The composting plant is also equipped with a residue incinerator, to dispose of:

Bulky wastes	2 000 t/a
Commercial wastes	4 500 t/a
Residues from composting process	7 500 t/a
Total	14,000 t/a

Technical Data

Thermal throughput capacity	max. 12.5 Gcal/h
Mechanical throughput capacity	max. 5 t/h
Grate surface	22.4 m^2
System manufacturer	Lambion

The incinerator is equipped with energy recovery facilities. The only energy utilization is for compost drying.

Sludge Treatment

An important task of the Heidelberg composting plant is to dispose of the sludge from the sewage treatment plant located adjacent to it.

The liquid sludge is pumped to the composting plant at a water content of 92 per cent, stored in thickening tanks and treated by chemical conditioning flocculation and dewatering in filterpresses before it is admixed to the refuse, then having a water content of about 60 per cent.

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Material Balance

(Composting and Incinerator)

Input Materials:

Household waste	200 tonnes per day
Dewatered sludge (60 per cent content)	40 tonnes per day
Bulky refuse	4 tonnes per day
Commercial industrial wastes	18 tonnes per day
Total input	262 tonnes per day = 100%

Gaseous and Vaporous Outputs:

Flue gas (stack	41 tonnes per day
Exhaust air - composting	42 tonnes per day
Exhaust air - compost drier	52 tonnes per day
	135 tonnes per day = 52%

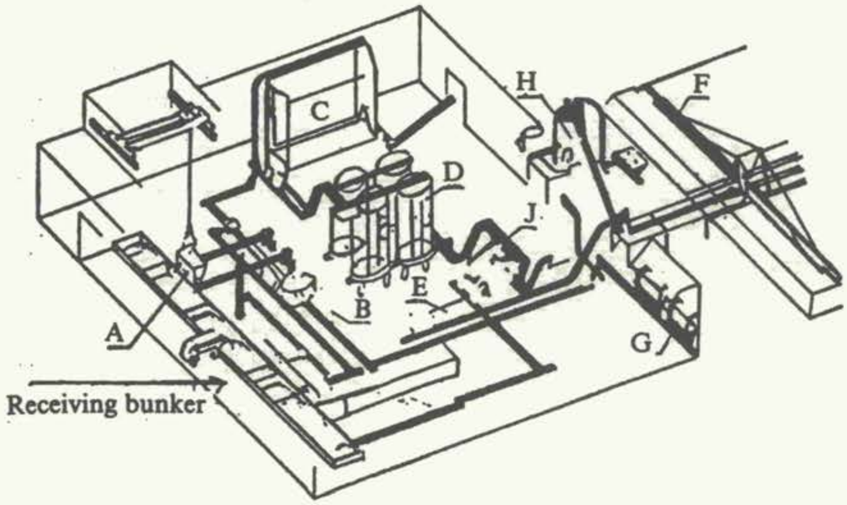
Solid Residues Output:

Slag	11 tonnes per day
Screen residue (30% water content)	40 tonnes per day
	51 tonnes per day = 19%

Recovered Materials Output:

Compost (12% water content)	66 tonnes per day
Ferrous scrap	10 tonnes per day
	76 tonnes per day
Total Output	262 tonnes per day = 100%

HEIDELBERG PLANT PROCESS SCHEME



A Dosage bunker
B Rasp-type grinder
C Intermediate storage
D Fermentation silos
E Compost drier
F Compost discharge conveyor system
G Filterpress (sludge treatment)
H Compost storage silo
I Compost screening

WIESLOCH

Refuse Composting Plant

The plant is operated by the Rhein-Neckar-County as one of a number of waste disposal facilities. It serves a population of about 130,000 (ie. about 28 per cent of the total population of the county of 465,000), accepting, however, only household wastes suitable for composting whereas bulky and other unsuitable wastes from the served area are directed to other facilities.

The plant was commissioned in 1973 but the sections for compost screening and air classification were added later.

<u>Basic Data</u>:

Theoretical throughput per year:	18,000 t
Average hourly throughput:	6.0 t
Actual Input in 1982:	17,832 t

Composition of Input:

Paper	18 %
cardboard	6 %
plastics	6.5 %
metal	4.7 %
textiles	1.7 %
wood, leather, rubber	2.1 %
glass	11.2 %
other inorganic material	1.9 %
other organic material	46.8 %

Compost output:	1,200 t/a
Residues (including scrap)	6,887 t/a
System:	Windrow composting "Voith-Müllex*)

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* The company Voith, Heidenheim, having been involved as a main contractor, is no longer active in the field of composting. Similar systems are, however, offered nowadays by a number of other companies.

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Staff	1 manager 7 workers
Installed power	183 KW
Consumed energy	311.100 kWh/a
Investment costs (total)	4,715,545.53 DM
Operating costs per year	1,121,739.23 DM
Capital costs	327,525.10 DM/a
Specific costs per ton of refuse handled	81.28 DM

Proceeds: air-classified compost 20, - DM/t

compost, screened only 20. - DM/t

<u>Process Description</u>:

The front-end processing is the same as in the Heidelberg plant visited before, i.e. grinding in a rasp-type grinder. The further processing, however, is much simpler, consisting of 2-stage windrow fermentation over a period of about 2 months:

- Primary fermentation aided by forced aeration through perforated air channels built into the surface of the site, simultaneously collecting the leachate;

- And secondary fermentation in heaps - about 4 months - supported by turning by means of mobile mechanical turning equipment as frequently as is necessary to prevent anaerobic decomposition;

- The windrows for primary fermentation are built up by a special stationary conveyor system (similar to that seen in Heidelberg) whereas the heaps for secondary fermentation are formed using a shovel loader.

After a total fermentation period of about 6 months the material is screened and - as an optional final processing step - treated in a special air classifier (see scheme below) for further removal of objectionable heavy particles and better end product quality.

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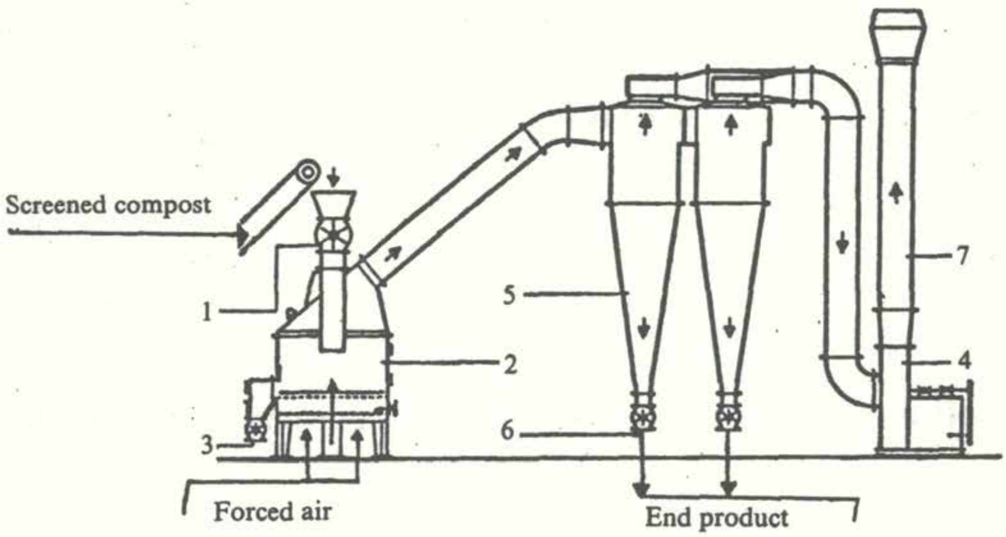
SCHEME OF AIR CLASSIFIER

Type: Suspension Classifier
System: Babcock Group



1. Intake
2. Suspension classifier
3. Heavy/coarse particles discharge
4. Suction fan
5. Cyclones
6. Fine/light particles discharge
7. Exhaust stack

PFORZHEIM

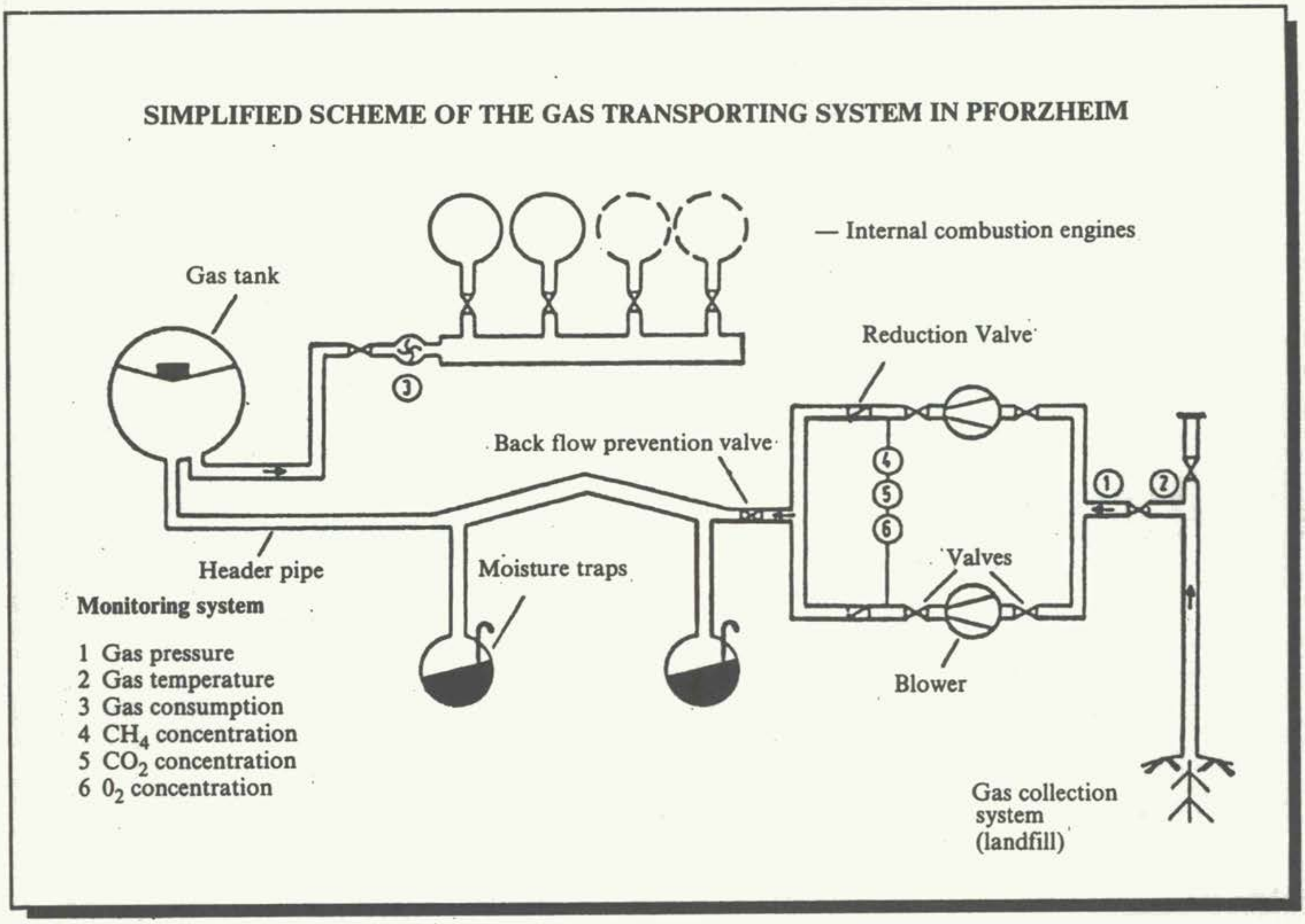
Landfill Gas Recovery System

The landfill gas utilization plant in Pforzheim, as the first of its kind in the Federal Republic of Germany was erected with financial support of BMFT. The project is linked to extensive measuring and testing programmes of the Technical University of Karlsruhe.

The landfill in Pforzheim was commissioned in the year 1972. Within an area of 10 ha (24.6 acres) approximately 3 million m^3 of waste shall be disposed of serving approximately 190,000 inhabitants of the region.

Since the beginning of 1981, landfill gas which had until then been burnt off is being converted into electricity in internal combustion engines (co-generation). The electricity reproduced is fed into the public network via a trànsformer station on the site of the landfill.

Simplified Scheme of the Gas Transporting System in Pforzheim



Process Description

The landfill gas is gathered from the header pipe of the leachate drainage system. The layer of refuse covering has at the present time a thickness of about 9 m. In order to obtain an optimal collection of gas a further horizontal drainage system was laid on top. From the central collection point the gas is transported by means of electrically-driven radial blowers via a 418 m long plastic pipe, into a gas tank with a capacity of 50 m^3, which provides 25 mbar internal pressure, the necessary precompression for the internal combustion engines. The polyethylene gas pipes having a diameter o f 150 mm have the condensing water removed at the ends by means of moisture trap s.

Technical Data:

Volume	3,000,000 3,920,000
Extraction rate	133 m^3/hr 78.3 cfm0
Heating value	21,400 kj/m^3 575 Btu/scf
Extraction system and well casing	horizontal drain system. 100 mm perforated plastic pipe
Gas engine	2 MWM, Type G 232

Costs

Investment costs for header system radial blowers, and internal combustion engine	approx. 1 million DM
Operating costs	approx.30.000 DM annually

GUNZBURG

Municipal Waste Pyroloysis Demonstration Plant

Refuse pyrolysis has not yet been introduced into waste management practice in the Federal Republic of Germany. The Burgau plant is one of two plants using this new technology presently in trial operation in Germany. The plant is owned and will be operated by the County of Günzburg. It was financially supported by the State of Bavaria and the Federal Ministry for Research and Technology (BMFT). The process (Pyrocal Process) was developed by BKMI, German Babcock Group, München.

Basic Data:

Throughput:	2 x 3 t/h = 6 t/h (design capacity)
Annual throughput:	30 000 t/a household waste
	5 000 t/a sewage sludge
	35 000 t/a total
Population served:	approx. 100 000
Energy generation	2.2 MW (electric)
Volume Reduction:	80 - 85 %

Costs:

Construction of plant	36 million DM
additional costs e.g. for connection to the water supply, electricity and sewage system, a separate dumping area for carbonization coke etc.	3.2 million DM

Operating costs (exclusive of capital costs) are expected to not exceed 60 DM per tonne of collected waste (based on 1979 figures).

Process Description

The BKMI-Process is based on the carbonization principle - i.e. degasification with the exclusion of air.* At temperatures of 500°C (932°F) organic components of the refuse, such as paper, plastics, kitchen waste etc., are converted into low-temperature carbonization gases. In the case of typical domestic waste, these gases consist of steam due to moisture content of the refuse, methane, higher-boiling hydro-carbons, carbon monoxide, hydrogen, and carbon dioxide.

The low-temperature carbonizer is an indirectly-heated rotary kiln. It is surrounded on the outside by stationary heating chambers which heat up the kiln through the flow of combustion gases from the combustion chamber. An outside energy supply, such as natural gas, fuel oil, or another energy medium, is required only for start-up operation.

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The rotary kiln discharge leads into a stationary chamber. Via an airtight system, the solid low-temperature carbonization coke residues are transported out of the discharge housing. Via the same unit, the low-temperature carbonization gases flow into the subsequent plant units. The incoming waste is dried in the first section of the rotary kiln and degasified at temperatures increasing slowly up to maximum 400°C (752°F). The low-temperature carbonization gases are all combustible.

The residue left over is low-temperature carbonization coke consisting of inorganic waste components (ash, glass, metal) at 80-90 per cent and of pure inert carbon at 10-20 per cent. This residue has absorbing properties which means that any noxious matters and particularly substances that are soluble in water, are bound to the low-temperature carbonization coke, valuable materials - particularly metals - are separated. The rest which is hardly more than 10-20 per cent of the original waste volume, can be dumped.

Noxious matters in the gaseous state are bound by admixture of alkali additives, such as lime: fluorides and sulphur compounds in the form of salts insoluble in water and hydrogen chloride in the form of calcium chloride.

From the rotary kiln discharge housing the low-temperature carbonization gas flows into a cyclone battery where the dust is removed. The gas is then mixed with the odorous air from the storage building and burnt in the combustion chamber. A combustion temperature of more than 1200°C (2192°F) and a combustion period of more than 1 sec. guarantee that both the low-temperature carbonization gases and the odors are burnt completely. Carbon dioxide, steam, and a small amount of HCl are the only components of the combustion gas generated.

The ammonia produced by the carbonization process is converted into molecular nitrogen by means of a special type of burner mounted in the combustion chamber.

Some of the hot gas (1200°C/2192°F) is returned to the heat low-temperature carbonizer.

The remaining combustion gas flows into a waste heat boiler where it is used to generate steam. Electricity is generated via the turbine/generator. Part of the electricity is used to operate the plant itself, the remaining energy is supplied to the public mains.

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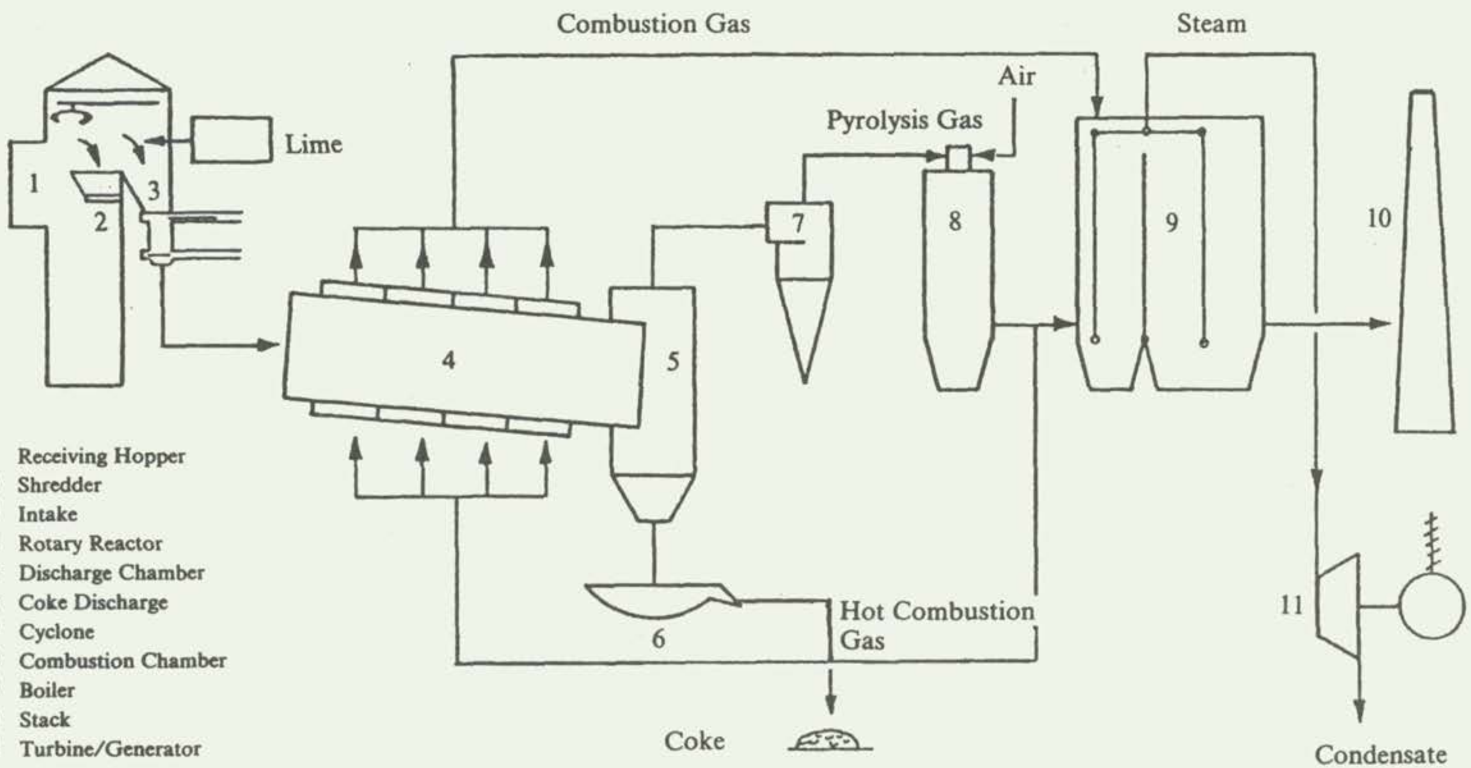
FIGURE 5: THE PYROCAL PROCESS



1 Receiving Hopper
2 Shredder
3 Intake
4 Rotary Reactor
5 Discharge Chamber
6 Coke Discharge
7 Cyclone
8 Combustion Chamber
9 Boiler
10 Stack
11 Turbine/Generator

- All the information is taken from BKMI-information brochures.

GEISELBULLACH

Small Scale Incineration Plant (combined refuse - sludge burning)

The plant is operated by GFA, "Gemeinnützige Gesellschaft zur Beseitigung und Verwertung von Abfällen in den Landkreisen Dachau und Fürstenfeldbruck GmbH", an association of the counties of Dachau und Fürstenfeldbruck.

It was first commisioned in 1970, enlarged in 1972 (2nd incinerator) and another expansion was planned for 1984.

Basic Data:

Incinerators:	1)	2 t/h	(theoretical throughput)
	2)	6 t/h	(theoretical throughput)

System:	German Babcock Group
Grate system:	Contra motion revolving grate
Input:	Household and commercial waste, dried sewage sludge
Output:	Steam used for sludge drying slag partially used as low-grade construction material, ferrous scrap
Annual throughput:	55 000 t
Population served:	175 000

The combined refuse - sewage sludge treatment plant in Geiselbullach was not conceived primarily to generate energy and to dispose of sewage sludge but to produce pasteurized and dried sewage sludge for agricultural utilization or to burn it as an alternative.

When it was planned the possibilities for generating electricity or energy for district heating were not given, thus the recovered energy was entirely destined for the treatment and drying of sewage sludge.

The principle sludge treatment scheme is as follows (simplified): Wet, digested sewage sludge (water content approx. 95 per cent) is first pasteurized by use of steam from refuse incineration. In a second step the water content is reduced to about 50 per cent in a steam-heated thin-layer-evaporator and finally dried in a combined milling-drying process (using hot incinerator flue gases) down to about 20 per cent water content.

This dried end product could be used as fertilizer but is presently burnt in the incinerator.

/...

Mechanically dewatered sludges also delivered to the plant are diverted directly into the milling-drying stage.

The Geiselbullach plant has been used for a number of research and development projects. Some of the numerous installations are no longer or only temporarily, in operation.

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EBENHAUSEN

Waste Rubber/Plastics Pyrolysis
Demonstration Plant

This plant is not intended for general waste treatment but for converting special high calorific value wastes such as used tires, waste rubber and plastics into saleble products i.e. mainly liquid hydrocarbons.

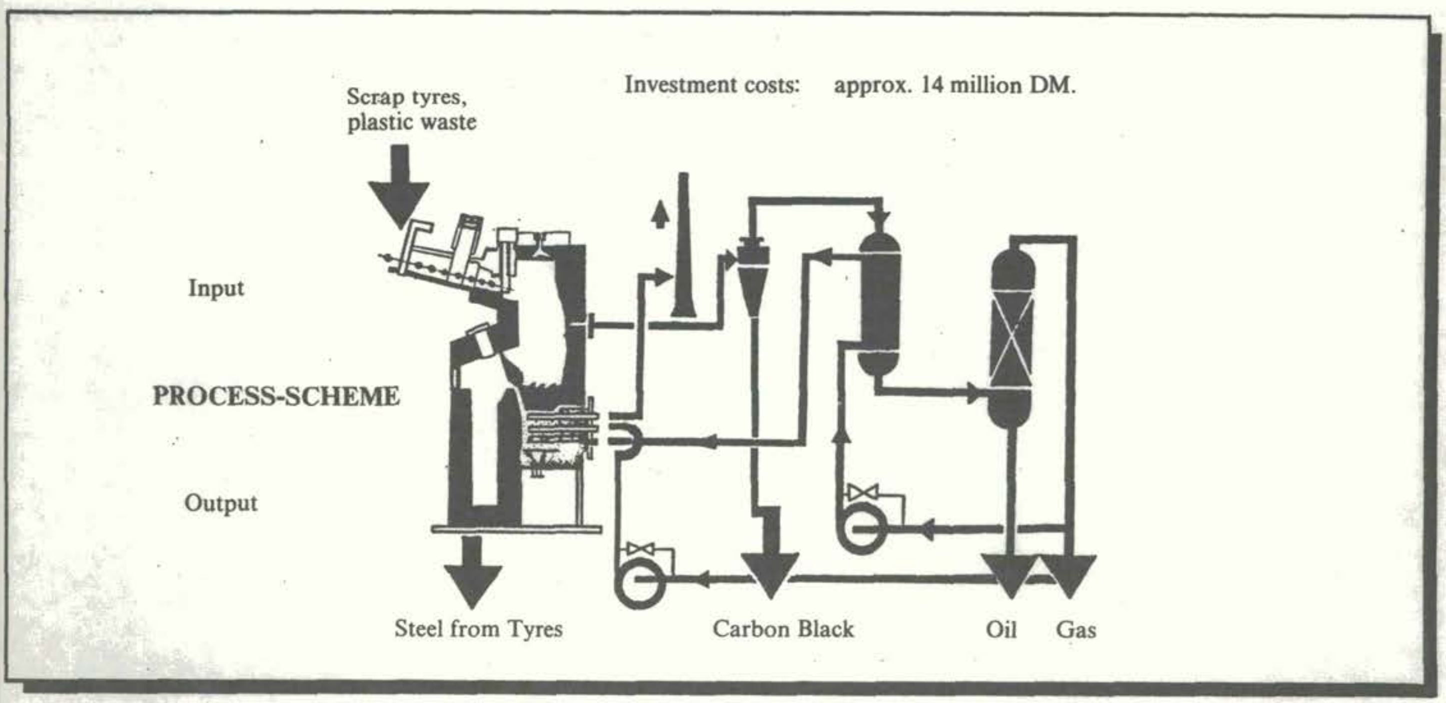
The Ebenhausen demonstration plant, the first of its kind in the Federal Republic of Germany, is owned and operated by Bayerische Reifen- und Kunststoff-Pyrolyse GmbH, associated with Deutsche Reifen- und Kunststoff Pyrolyse GmbH, (DRP), Hamburg.

The project was financially supported by the Federal Ministry for Research and Technology (BMFT). The DRP-Process, i.e. Fluidized bed pyrolysis, is based on developments initiated by the University of Hamburg (Prof. H.J. Sinn/prof. W. Kaminsky).

The plant went into trial operation only a few months ago.

Basic Information

Hourly throughput:	2 x 0.6 t/h
Annual throughput:	6000 - 8000 t
Input:	Used tires, waste, rubber/plastics, scrap cables
Output:	Oils, gas, carbon black, steel from tire reinforcement, non-ferrous metals from scrap cables.
Process:	Fluidized bed pyrolysis, operating at temperatures between 500 and 850^{o}C depending on type of products required.



Process Description:

The fluidized bed is generated by blowing gas (fluidizing gas) into a bed of fine solids - e.g. sand - and behaves like a liquid. Parts with a lower density than the fluidized bed swim on it like a cork on water.

This fluidized bed is maintained at a temperature where rubber/plastics decompose. If pyrolyzable substances are fed into the fluidized bed, the decomposition products are discharged with the gas flow and can be collected by condensation. The use of gaseous pyrolysis products as carrier gas leads to the prevention of oxidation processes. The recycling of plastic wastes by pyrolytic degradation in a fluidized bed means decomposing them thermally and largely residue free in the absence of oxygen into products that can be utilized as fuels or chemical raw materials. Up to 50 per cent of the feed material can be recovered as liquid corresponding to a mixture of light naphta, plastic wastes can furthermore yield 50-60 weight - per cent of gas, mainly consisting of methane, ethane, ethylene and propene. Less than half of the gas showing a calorific value of about 50 x 10^{0} J/Nm^3 is sufficient for energy autarchic heating of the plant.

The burning of the pyrolysis gases in steel radiant tubes produces lower emissions of carbon monoxide and nitrogen oxide than in normal furnaces. Other emissions do not arise in closed process conduction. Depending on the feed material, between 1 and 5 per cent by weight of carbon black (soot) contaminated with sand is produced as solid residue contraining practically all fillers and heavy materials of the feed.

The liquids produced in the course of the plastics pyrolysis can be processed into organic chemicals according to the normal petrochemical processes. A comparative feedstock value assessment shows that the chemical processing of these highly aromatic pyrolysis oils leads to a higher feed-stock value than the application for heating purposes or preliminary fuel production. Also the fine soot produced in the course of the pyrolysis of used tires can possibly be reused.

Reliable information on actual plant performance based on continuous full scale operation was to be available in 1984.

SCHWABACH

Hazardous Waste Treatment and Disposal Facilities

The Schwabach treatment and disposal facilities are owned and operated by the:

Zweckverband Son dermüllplätze
Mitterlfranken (SMM),

an association of municipalities of the Mitterlfranken district, State of Bavaria.

The region served by the Schwabach facilities has a total area of 21,000 km^2 comprising also parts of the State of Baden-Württemberg with a total of approximately 400 industrial companies using the SMM waste disposal services.

Description of the Disposal Plant*

(a) Special wastes tip:

The special wastes tip has been created from an exhausted clay pit. As a precaution the pit was equipped with sealing layers of clay before tipping commenced.

The leachate is treated in a chemico-physical plant.

The tip area is 61,000 m^2; the volume ca. 1.1 million m^3.

(b) Waste water treatment plant:

The waste water treatment plant treats liquids and slurries, containing oil. The maximum annual capacity is about 48,000 tonnes.

The de-emulsification plant consists mainly of:

- receiving and storage basins with a capacity of about 1,100 m^3;
- 5 reactors with a total volume of 150 m^3;
- 1 decanter with a flocculation station;
- 1 oil-water separator.

In the reactors liquids containing oil can be neutralized, oxidized or reduced, depending on the additional pollutants which they contain.

(c) Chemico-physical treatment plant:

This plant treats metal hydroxide slurries, acids and alkaline solutions, as well, as chemically complex solutions. The maximum throughput is 36,000 tonnes per annum.

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* From: Hans-Georg Rückel, Director, SMM. "German experiences with the disposal of special wastes."

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The plant consists mainly of:

- receiving and pre-detoxification basin, volume 300 m^3;
- chamber filter press, filter surface 100 m^3;
- 3 reactors, total volume 125 m^3;
- two-stage exhaust wet air scrubber.

Methods of treatment:

- neutralization;
- oxidation;
- reduction;
- filtration.

(d) Special wastes incinerator:

The special wastes incinerator is used to dispose of solid, semi-solid and liquid organic special. The maximum capacity of the incinerator is about 18,000 tons per annum, assuming a mean thermal value of the wastes of about 16,000 KJ/kg.

This plant consists mainly of:

- 1 cylindrical rotary furnace,	diameter	2.4 m
	length	8.5 m
- 1 secondary combustion chamber with 3 flues		
- 4 liquid fuel burners, maximum operating temperature		1,400° C
- Flue gas dust collector: electrostatic filter		
- height of chimney stack		65 m
- storage capacity for solid and liquid wastes		1,200 m^3.

Storage of Residual Wastes

The residual wastes of the waste water treatment plant (e.g. oil and oil slurries) are disposed of in the special wastes incinerator.

The residues from the chemico-physical plant (filter cakes) are deposited in the special wastes tip.

Slag and filtration dust from the special wastes incinerator are also deposited in the special wastes tip.

The special wastes disposal unit at Schwabach can handle any type of special wastes with the exception of hardening salts containing cyanide; these salts are collected and finally deposited in the underground tip at Herfa-Neurode.

Throughput of the Different Types of Wastes and Prices

In 1980 the special wastes disposal unit at Schwabach received:

(a) Special wastes to be tipped: 101,000 tonnes; price per tonne 45. - DM.

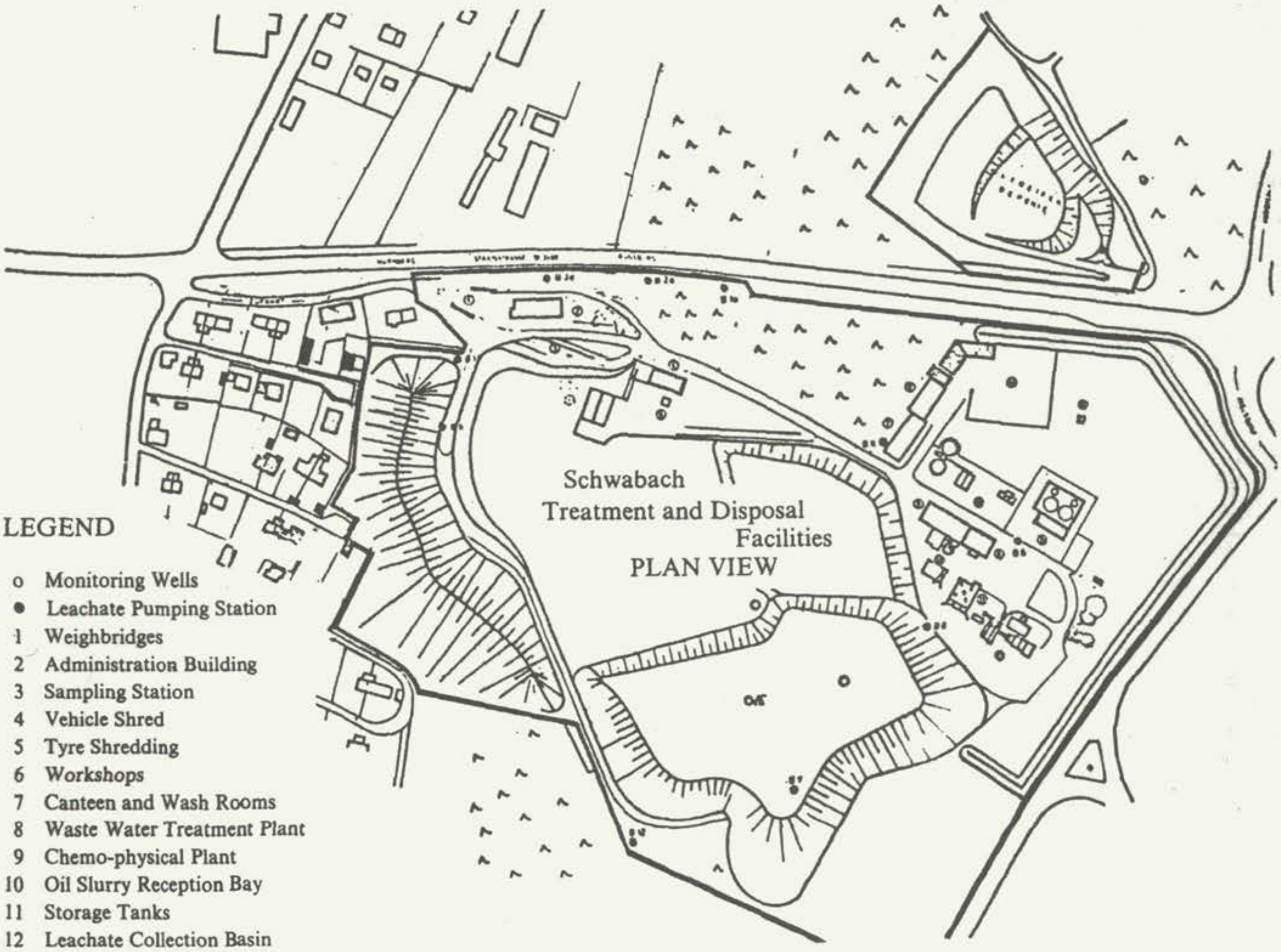
(b) Special wastes to be chemically or mechanically treated: ca. 46,000 tonnes; average price 90. - DM/tonne.

(c) Special wastes to be thermally treated: 12,000 tonnes; price 210. - DM/tonne.

(d) Old tyres and rubber wastes: 1,200 tons; price 100. - DM/tonne.

Proportion of Operating Costs Recovered Via Prices

The prices charged fully cover all costs of the special wastes disposal plant at Schwabach (including depreciation and interest payments on capital).



LEGEND

- o Monitoring Wells
- • Leachate Pumping Station
- 1 Weighbridges
- 2 Administration Building
- 3 Sampling Station
- 4 Vehicle Shred
- 5 Tyre Shredding
- 6 Workshops
- 7 Canteen and Wash Rooms
- 8 Waste Water Treatment Plant
- 9 Chemo-physical Plant
- 10 Oil Slurry Reception Bay
- 11 Storage Tanks
- 12 Leachate Collection Basin
- 13 Incinerator
- 14 Storage Area
- 15 Meteorological Station
- 16 Landfill

* Plus extra charges for additional treatment like detoxification, neutralization, laboratory services, etc., where required.

SCHWANDORF

Combined Heat and Power Incineration Plant/VAW Nabwerk

The Combined Heat and Power Incineration Plant Schwandorf can be considered a unique project in a number of aspects:

It is a joint venture between an association of municipalities delivering solid wastes and sewage sludge to the plant and an industrial partner, the VAW aluminium works utilizing the energy recovered from the wastes.

The siting of the plant was determined by the location of the energy demand. The plant does not serve a large city or metropolitan area, as is the case with all other large scale refuse incinerators in Germany, but a large, not too densely populated rural area with many small and medium size towns and industrial centres.

The transport problem - the distance between some of the participating municipalities and the Schwandorf plant is more than 100 km - was solved by installing 8 road/rail transfer stations and utilizing the existing rail-road system.

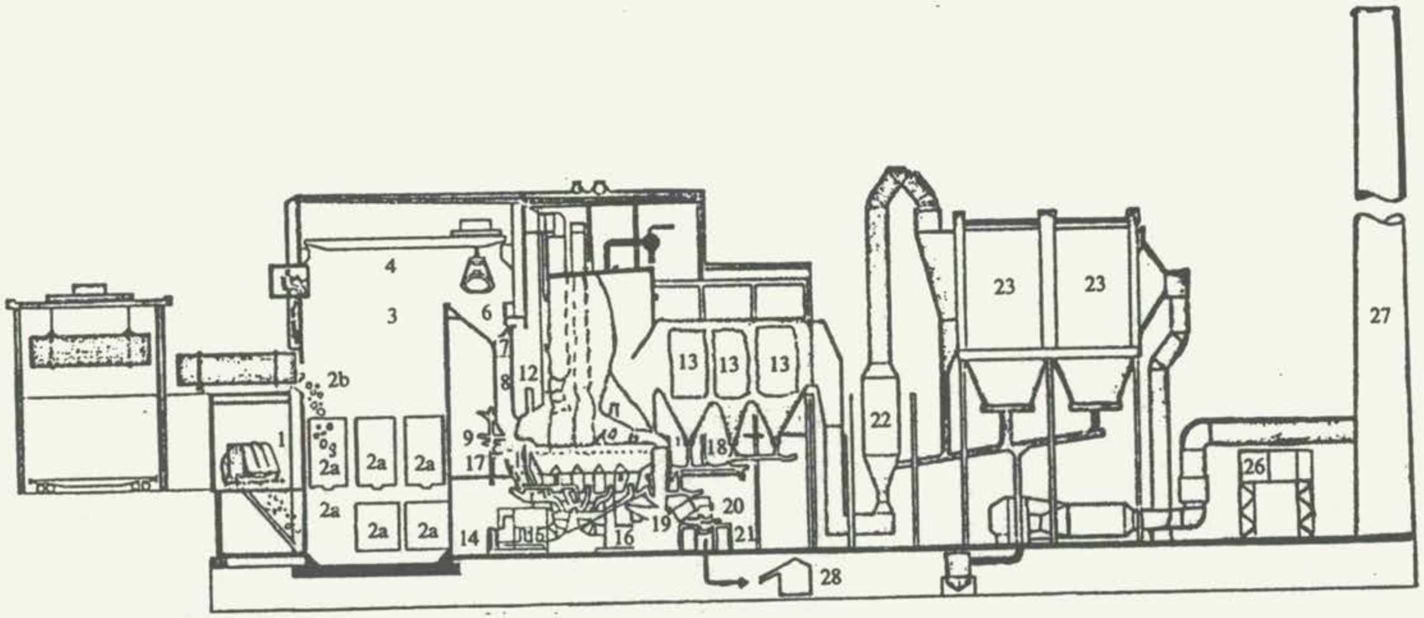
The plant is operated by VAW Nabwerk, the aluminium works at Schwandorf in co-operation with Zweckverband Müllheizwerk Schwandorf, an association of 13 cities and counties which operates the transport system.

A total area of about 11,800 km^2 with a population of 1.25 million is served by the plant. The project received considerable financial support from the State of Bavaria. In August 1983 the plant was commissioned.

Basic Data:

Annual throughput	(- approximately -)
- refuse	355 000 t
- sewage sludge	35 000 t
	390 000 t
Calorific value (average)	8 400 kJ/kg (=2 000 kcal/kg)

PROCESS SCHEME



Process Description

In the central unloading station the incoming wastes are tipped into a storage bunker (3) with a volume of 10,000 m^3. This storage volume is necessary to facilitate continuous operation of the plant during weekends and holidays.

The waste is then conveyed by a grab crane (4) into the charging hopper (6-8). It reaches the grate (10) in the combustion chamber (11) via the hyraulically regulated feed system (9).

There the waste is initially ignited by oil burners and is incinerated at a temperature of 800 to 1,000°C without auxiliary fuel.

The air necessary for combustion is introduced by blowers (14 and 16) and if necessary warmed up by air preheaters (15).

The grate can be put into different forms of motion (17) to provide for the most favourable stocking effect. The co-combustion of a certain quantity of sewage sludge is possible. At the end of the grate the combustion residues in the form of slag and scrap are discharged together with fly-ash from the boiler into the slag quenching tank (19) and then transported via a conveyor belt (20, 21) to the slag bunker (28).

The hot combustion gases pass through the boiler zone, heating the water in the pipes, generating steam with a temperature of 410°C at a pressure of 72 bar/abs.

Through the heat exchange in the boiler the combustion gases are cooled down to 220°C and are then processed in the flue gas purification system (22). By adding lime as an absorbent, noxious components such as HCl, HF and SO_2 are eliminated sufficiently to meet required emission standards. The dust is removed by an electrostatic precipitator and then the flue gases are discharged into the atmosphere via a 120 m high stack (27).

In the monitoring station (26) the composition of the flue gases is continuously controlled and registered.

The high pressure steam is partly used as processing heat in the chemical production branch of VAW, and partly conveyed to two condensing turbines generating electricity.

The generated energy covers both the energy demand of the incineration plant and the VAW-Nabwerk aluminium works.

The described concept of combined heat and electric power utilization results in an overall efficiency of about 50 per cent (effective utilization of 50 per cent of the energy content of the input material) as compared to an efficiency of about 20 per cent in the case of electric power generation only.

In the Schwandorf plant, the energy recovered from waste is replacing some 110,000 t of Czechoslovakian brown coal annually, formerly used by VAW Nabwerk, which is equivalent to approximately 58,000 t of fuel oil.

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<u>Transport System</u>

At the 8 transfer stations the collection vehicles unload into a bunker from where the refuse is fed into special cylindrical containers via grab cranes and hydraulicaly operated presses.

The containers are forwarded to Schwandorf by rail, but can also be transported by road vehicles.

One of these transfer stations will be visited, i.e. the Amberg transfer station handling some 35,000 t of refuse per year.

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BERLIN

Alba Recycling Center

Alba GmbH & Co. KG is a private company operating nation-wide in the fields of waste collection and recycling of waste paper, glass, plastics, metals etc.

While in Berlin (population 1,9 million) the normal refuse collection from households is carried out by a large municipal organization, "Berliner Stadtreinigung", (BSR), Alba specializes in commercial and industrial waste collection and in separate collection of recoverable materials from households and commercial sources, having at present the following equipment in use for their Berlin operations:

5000	containers for waste paper and plastics
4000	containers for waste glass
12	Special vehicles serving residential areas
12	Special vehicles serving commercial and industrial sources

Total investment: approximately 10 million DM.

The containers are placed to serve industrial and commercial companies, at central points of the city for public use or in residential areas, replacing a certain portion of the normally used refuse containers to receive recoverable materials separated by the householders.

Differently coloured containers are used for the separate collection of glass and of paper.

The Recycling Center, Alba's central facility in Berlin for storing, sorting and processing recovered materials was opened in 1978. The main activities are:

Recovery of Paper and Board

The paper and cardboard is sorted, shredded and baled. The centre is equipped with two sorting lines and baling presses, having a total capacity of 200 tonnes per day, and with shredding and cutting machines. In 1982 approximately 30,000 t of waste paper and board were handled.

Recycling of glass

In 1982 approximately 17,000 t of waste glass were collected and processed. A waste glass processing plant, installed in 1977 (System Hazemag, Münster) is operated by Alba, producing pulverized cullet to be shipped by water to the nearest glass works over a distance of some 300 km, since there is no glass industry in Berlin.

In different process steps (see scheme below), magnetic and non-magnetic contaminants are separated from the cullet to meet the strict specifications of the container glass industry with respect to the purity of the raw material.

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Recovery of plastics

The main types of plastics collected from industrial and commercial sources are: high-pressure-polyethylene, low-pressure-polyethylene, polystyrol, polyamid, polyvinyle chloride. In 1982 about 2,000 t were recovered. As far as possible the waste plastics are sorted and granulated to be reused as raw material for the plstics processing industry.

Residual mixtures of unclassifiable plastics not suitable for industrial purposes are used for the manufacture of plastic products such as boxes, flower pots, etc. by means of "Remaker" injection moulding machines.

Recovery of metals and other materials

In 1982 about 35,000 t of ferrous and non-ferrous metals were collected, sorted and shipped to users.

In addition, approximately 10,000 t/y of other materials are being recovered, such as waste wood, slag, textiles etc.

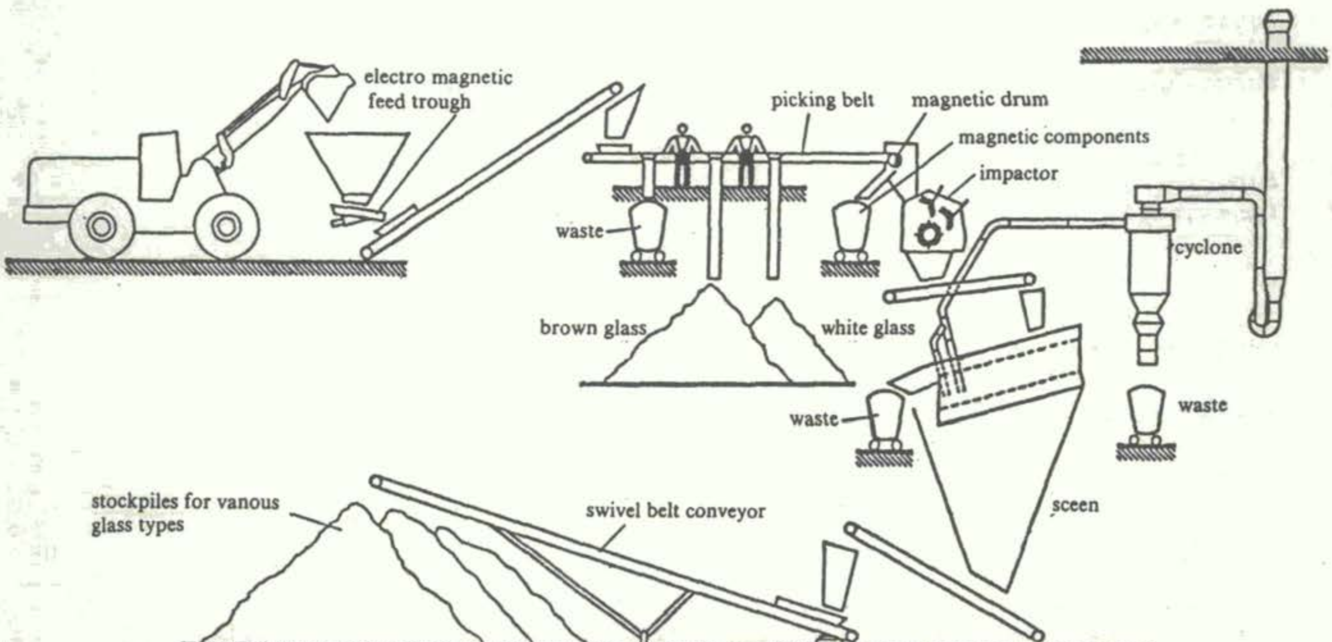
Research and development activities

Presently, in Berlin, there is an additional potential of about 700,000 t of waste paper and board from commercial and household wastes which cannot be exploited because of lack of demand from the paper industry. This quantity could be used for energy recovery. In co-operation with the Technical University of Berlin (Prof. Thomé-Kozmiensky), a survey of the possiblities of energy utilization of pelletized or briquetted waste paper is being carried out.

The extended separate collection of plastics, textile wastes and metals from domestic and other sources and the processing of mixed plastics waste for existing and possibly new uses, is the subject of another research project planned to be carried out with the assistance of BMFT/UBA.

SCHEME

Waste glass processing



NEUSS

Materials Recovery Plant

In 1975 the City of Neuss made use of the possibility provided by the 1972 Waste Disposal Act, to delegate all tasks related to the operation of a sanitary landfill to a private enterprise.

On behalf of the City of Neuss the M. Trienekens Company designed a full scale plant for materials recovery from household and commercial wastes. The plant was financially supported by BMFT (subsidy: 5.05 million DM) in co-operation with UBA. With a total of 13,5 million DM of investment costs, the present plant was erected covering an area of 5,500 m^3. It was commissioned in October 1981 being the first of its kind in the Federal Republic of Germany.

Basic Data:

Throughput per hour:	approx. 40 tonnes of household waste approx. 6.5 tonnes of commercial wastes
Annual throughput (one-shift-operation):	approx. 90,000 t/y household waste approx. 13,000 t/y commercial waste approx. 93.000 t/y Total

Landfill site:

Total disposal capacity:	approx. 84 hectares 7 million m^3
Projected life time:	20 years

Process scheme

The commercial waste consists mainly of packaging materials. Paper and board recovery is achieved by manual sorting along a conveyor belt. The different types of salable paper and cardboard are then baled for transport.

Household waste processing is shown in the scheme at the end.

The main process steps are:

screening
manual sorting
shredding
magnetic separation
air classification

The non-recoverable material (fines from screens and heavy fraction from air classifier) consisting mainly of moist organic components is composed in a subsequent tunnel reactor after having passed another magnetic separator and a special shredder.

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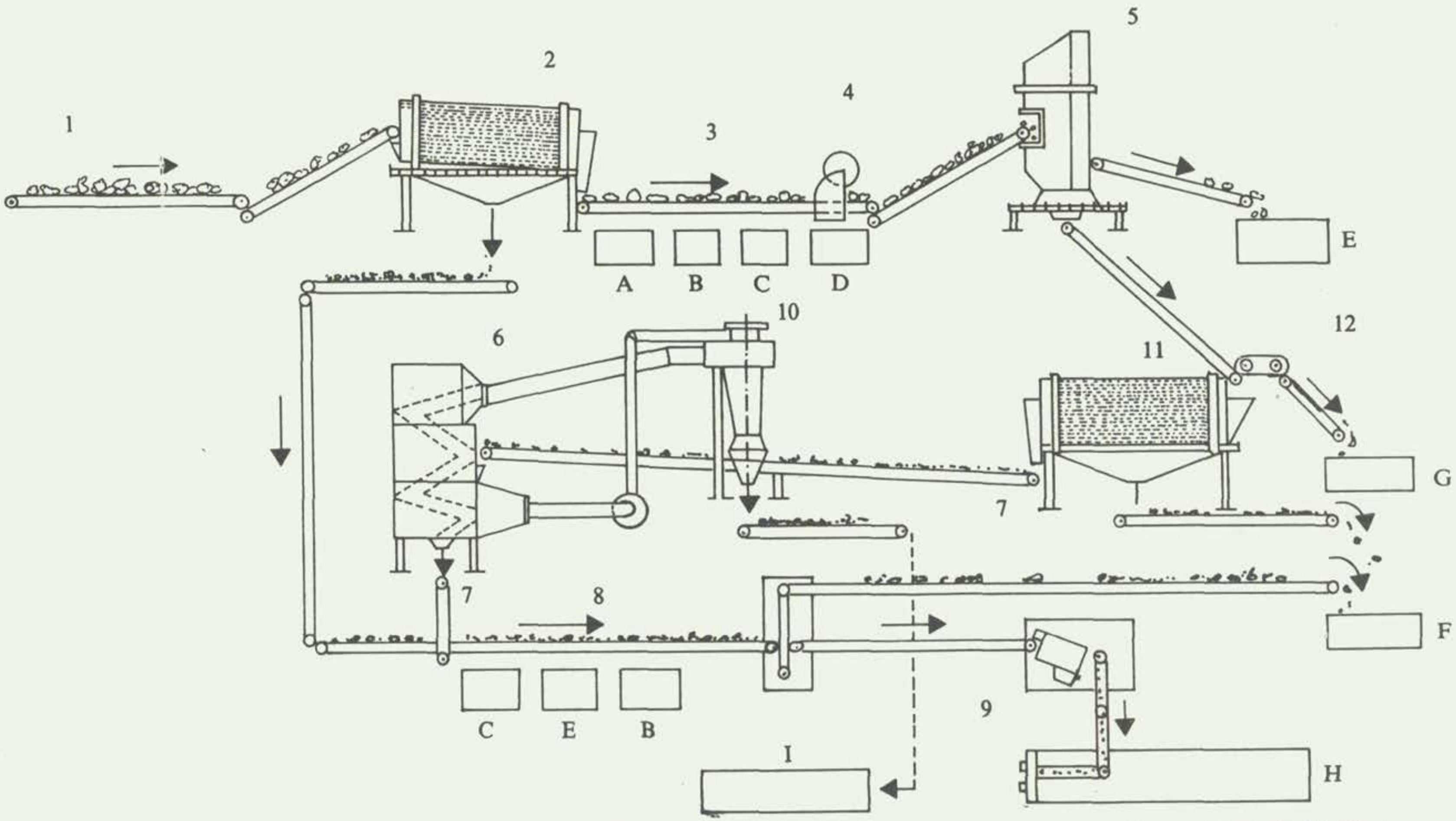
The composting process heat from the tunnel reactor is partially recovered and utilized for evaporation of leachate from the landfill and for heating the building.

The product from the composting unit is a low-wide compost and so far only used as cover material in landfill operations.

Research and development activities towards further optimization of plant operation and alternative product utilization such as refuse derived fuel (RDF) are presently being carried out by Trienekens and UTG, an associated engineering firm.

Annual materials output:

Paper (from household- and commercial waste)	approx. 18,000 tons
Ferrous scrap	approx. 5,000 tons
Other metals	approx. 200 tons
Plastics (from commercial waste)	approx. 600 tons
Compost	approx. 35,000 tons
Population served:	approx. 213,000
Total staff for plant operation	18
Operating costs:	45 - 50 DM per tonne of waste



MATERIALS RECOVERY SCHEME (Household Waste Processing)
DEMONSTRATION PLANT OF THE CITY OF NUEUSS, GERMANY

Legend

1 Input: Household Waste
2 Trommel Screen
3 Handsorting
4 Plastics Separator
5 Hammer Mill
6 Air Classifier
7 Heavy Fraction Output
8 Handsorting
9 Special Shredder
10 Cyclone
11 Trommel Screen
12 Magnetic-Separator

Products/Residues

A Bulky Items
B Glass
C Paper, Board
D Plastics
E Non-Ferrous Metal
F Rejects
G Ferrous Metal
H Composting-Comp.
I Light Fraction

DUSSELDORF

Paper and Textile Waste Recycling at J. Schulte Söhne Paper-Mill

Paper and textile recycling is an essential part of the production of the Schulte Söhne Paper-Mill, founded in 1886 and in the possession of the family for four generations.

It is located near the Dusseldorf City Center, so special attention has to be paid to preventing environmental problems, e.g. air- and noise pollution. This is remarkably well achieved in this case.

In 1982 approximately 44,000 tonnes of paper and cardboard were produced on two paper machines. Each paper machine is operated by three men per shift, three shifts a day. The total personnel employed is about 140. The material feed consists of 45,000 tonnes of waste paper and 6,000 tonnes of rags per year. Virgin fibres are not processed. The end products are packaging papers, cardboard and roofing paper.

Utilizing waste paper as a source of raw material requires additional efforts in processing technology as compared to using virgin fibres. The waste paper has to be dissolved in a pulper. The fibrous suspension is then cleaned by means of special screens and centrifuges separating contaminants and any foreign components from the pulp before being finally converted into new products on the paper machine. For this final process step it does not make any difference whether recycled or virgin fibres are used. The extra effort in pre-processing referred to above, is compensated by the lower price of secondary fibres as compared to virgin raw materials.

The J. Schulte Söhne Paper-Mill was included in the programme as an exemplary representative of a total of some 180 paper-mills in the Federal Republic of Germany using waste paper as a raw material source. The existence of such paper-mills is the most important and irrevocably necessary prerequisite for paper and board recycling.

With regard to textile recycling the situation is different in so far as there are various options available for reuse. The utilization of recycled textile fibre for the production of roofing paper is only practiced in a small number of German paper-mills.

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BOCHUM

In the City of Bochum several types of waste management facilities will be visited:

1. Vehicle Maintenance Facilities
2. Municipal Recycling Depots
3. Mobile Sorting Plant.

GENERAL

The Bochum municipal waste disposal organization serves a population of 435,000, living in an area of 145 km^2. The services provided are manifold, e.g. waste collection and landfill disposal, recycling wastes, and the cleansing of the 963.1 km of streets of the City of Bochum.

The City's annual budget for the waste disposal organization is 22 million DM, employing 184 people.

4,4 million DM are assigned for maintenance of vehicles.

The city's annual waste arisings, disposed of by landfilling are:

150.000 t =	750,000 m^3	household waste
35.000 t =	45,000 m^3	street sweepings
50.000 t =	200,000 m^3	commercial waste
35.000 t =	45,000 m^3	industrial wastes suitable for co-disposal with household wastes
	300,000 m^3	demolition wastes
	35,000 m^3	sewage sludge

Vehicle Maintenance Facilities:

The vehicle maintenance facilities service a total number of 420 municipal vehicles, only a few of which are operated by the waste disposal organization, these are:

11 special trucks for container exchange
43 refuse collection vehicles
4 collection vehicles for bulky wastes
3 vehicles collecting materials from the recycling depots
6 lorries
4 steel wheel compactors (landfill)
2 tractor-type compactors (landfill)
3 tank trucks

Municipal Recycling Depots

In order to promote recycling activities, the City of Bochum installed nine recycling depots in 1980, also called Recycling Centres where the public can deliver, - free of charge -, recoverable materials such as:

- waste paper
- glass
- tyres
- waste plastics
- metals

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as well as special types of wastes arising from households in small quantities, which might fall under the category of hazardous wastes and could cause environmental problems at the disposal facilities if collected within the routine service, i.e.:

- batteries
- waste oil
- residual herbicides and pesticides
- other residual household chemicals
- or pharmaceuticals, and the like.

These depots consist of a relatively small area, of approximately 1,000 - 1,500 m^2, where a number of containers are placed for the various types of materials. They are operated by a gate man in each of two shifts, i.e. from 6.30 hrs to 21.30 hrs. In case any problem arises related to classification of wastes, the gateman can call a mobile expert for technical assistance. Each depot serves an area of about a 1.5 km radius with a population of 40-50,000. The depots have been well accepted by the public.

Mobile Sorting Plant

This installation was developed by Mannesmann Veba-Umweltschutz (MVU) under contract with Kommunalverband Ruhr (KVR), an association of municipalities of the Ruhr region, and received financial assistance from BMFT/UBA.

The main purpose of this pilot project is to facilitate trial operations for materials recovery from household and commercial waste at landfill sites.

The advantage of a mobile plant for such trials to prepare for a decision on a possible permanent installation is obvious. It is anticipated that this mobile plant may be used in a number of different places where the feasibility of resource recovery through mechanical sorting is to be studied. In Bochum this mobile plant will to be tested for about 12 months.

The mobile waste sorting plant (see scheme below) consists of a trommel screen with special equipment for bag-opening, a simple air classification device for separating the light fraction made up of plastics, textiles, paper, and cardboard. This light fraction can be baled and transported to any waste incinerator or industrial heat and power center or shredded and densified to refuse-derived-fuel (RdF) briquettes.

The heavy fraction and the undersize material from the trommel screen consisting of kitchen and garden wastes, glass, fines and other components has to be disposed of at the landfill site or could be used as a composting raw material.

Hourly throughput:	10-15 t
Input material:	Household waste
Output material:	light fraction for RdF fine material for composting ferrous scrap

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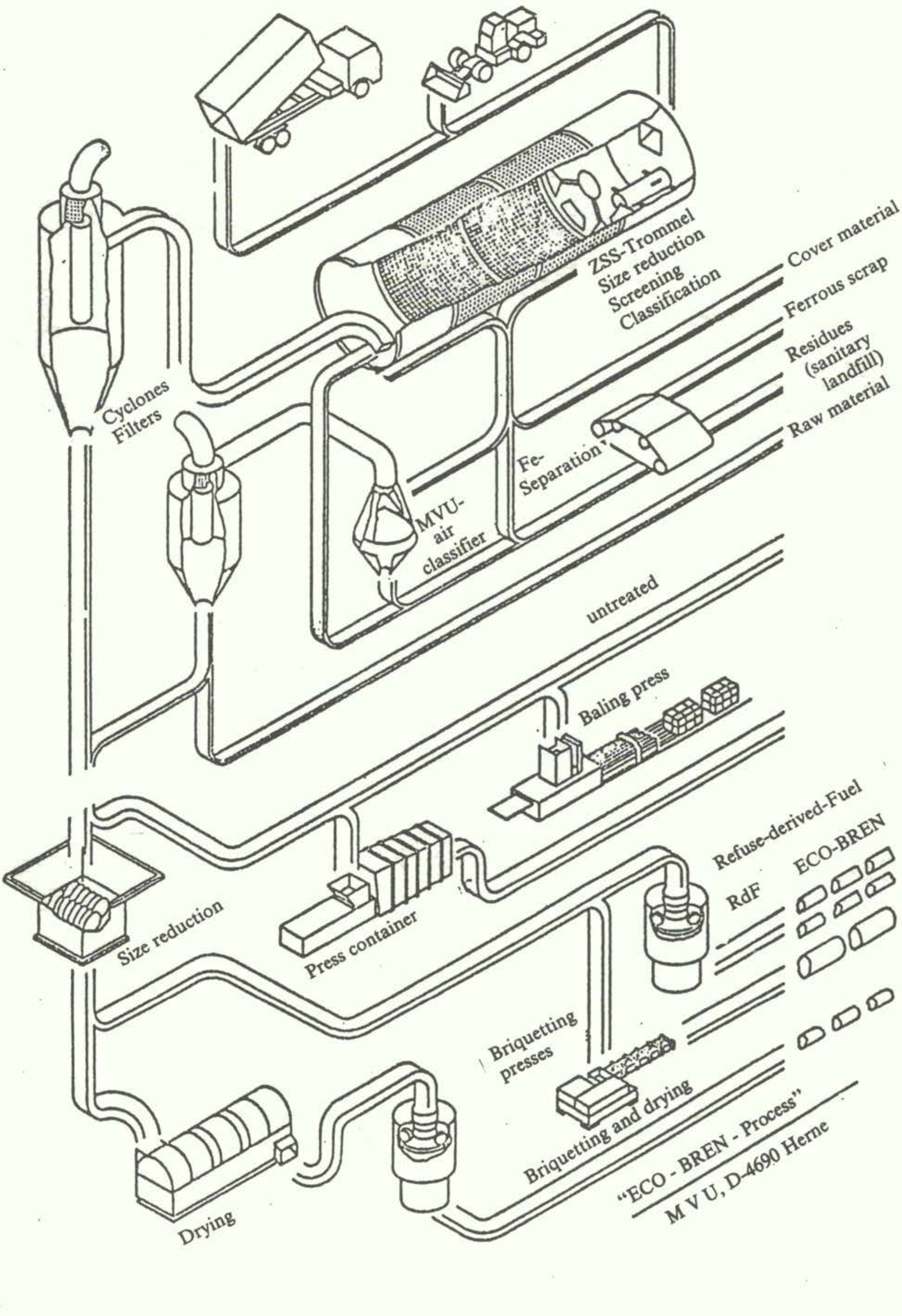
PROCESS OF MOBILE SORTING PLANT



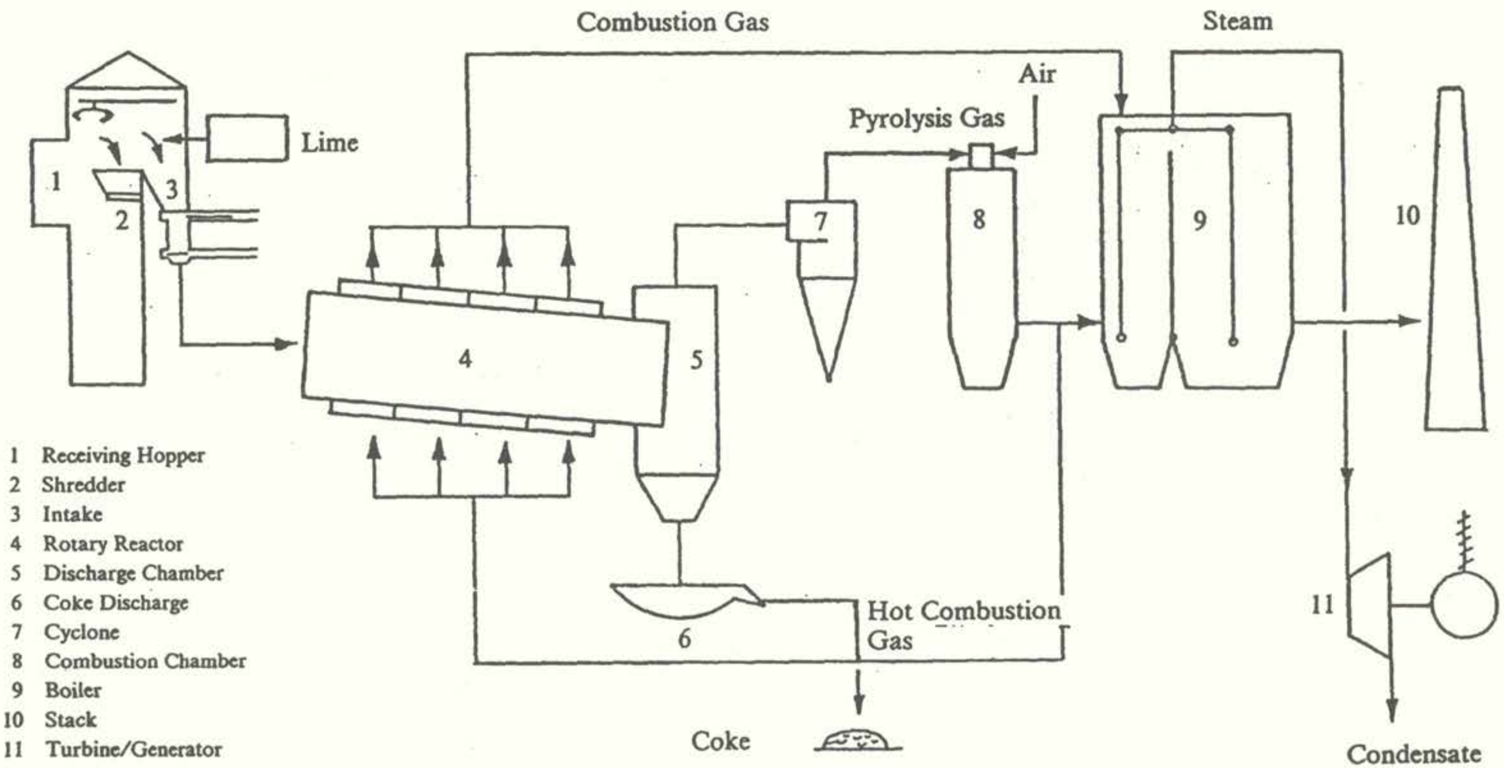
From the rotary kiln discharge housing, the low-temperature carbonization gas flows into a cyclone battery where the dust is removed. The gas is then mixed with the odorous air from the storage building and burnt in the combustion chamber. A combustion temperature of more than 1200°C (2192°F) and a combustion period of more than 1 sec. guarantee that both the low-temperature carbonization gases and the odors are burnt completely. Carbon dioxide, steam, and a small amount of HCl, are the only components of the combustion gas generated.

The ammonia produced by the carbonization process is converted into molecular nitrogen by means of a special type of burner mounted in the combustion chamber.

Some of the hot gas (1200°C/2192°F) is returned to the heat low-temperature carbonizer.

The remaining combustion gas flows into a waste heat boiler where it is used to generate steam. The turbine/generator, in turn, generates electricity. Part of the electricity is used to operate the plant itself, the remaining energy is supplied to the public mains.

FIGURE 5: THE PYROCAL PROCESS



1 Receiving Hopper
2 Shredder
3 Intake
4 Rotary Reactor
5 Discharge Chamber
6 Coke Discharge
7 Cyclone
8 Combustion Chamber
9 Boiler
10 Stack
11 Turbine/Generator

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* All the information is taken from BKMI-information brochures.