EP

United Nations
Environment
Programme

UNEP(DEC)/MED WG.264/Inf.11
5 May 2005

ENGLISH

MEDITERRANEAN ACTION PLAN

Meeting of the MED POL National Coordinators

Barcelona, Spain, 24 - 27 May 2005

GUIDANCE FOR TREATED WASTEWATER USE IN IRRIGATION

In cooperation with

WHO

UNEP
Athens, 2005

EXECUTIVE SUMMARY

The problem of water shortage in the Mediterranean region is well documented. Most countries in the Mediterranean area are arid or semi-arid. The region is characterized by a severe water imbalance, particularly in the summer months, due to low rainfall, which is mostly seasonal and with erratic distribution. Moreover, due to rapid development, which affords the agricultural sector top priority, conventional water resources have been seriously depleted. This is particularly acute in southern Mediterranean countries where the scarcity in some countries reaches crisis levels and poses heavy constraints on economical development.

To meet this increasing demand, groundwater, the main source of water in many countries, is being extracted well beyond the renewal rate of the resource. In some cases, governments are tapping into fossil groundwater and, where feasible, have initiated sea-water desalination projects. Therefore, as the demand for water increases wastewater treatment and use has progressively become an important tool in integrated water resources management, and it is integrated into the holistic water resources management of many countries.

The use of treated wastewater can provide many benefits, including the stimulation of economic growth through provision of a guaranteed supply of defined quality. Treated wastewater can also make a significant contribution to sustainability by reducing pressure on our existing water supplies and transferring nutrients to beneficial uses, rather than discharge to our waterways.

However, wastewater is unique in composition, often associated with environmental and health hazards, and its acceptability to replace more conventional or other non-conventional water sources for irrigation is highly dependent upon whether the health risk and environmental impact are within acceptable levels. Therefore, the formulation of guidelines for the use of treated wastewater is of prime importance to countries in the Mediterranean region.

The guidelines are intended to be a key reference and guide for the use of treated wastewater in Mediterranean countries. They are also designed to support the regulatory requirements prescribed by the national regulatory authorities. It provides guidance for conveying treated wastewater to intended customers, based on levels of treatment, intended use and operational practises

The guidelines rely upon qualified professionals who are responsible and accountable in their areas of practise. It also outlines the expectations of qualified professionals. These include the expectation to follow the precautionary principle while exercising responsibilities in projects that involve the use of treated wastewater under the guidance of both national regulations and this guide. Compliance with national regulations and understanding of the guidelines should ensure the safe use of treated wastewater.

The overall objective of this guide is to maximize the use of treated wastewater through minimizing and managing any hazard associated with its production, storage, transport and use.

Table of Contents

Page No.

1. BACKGROUND

The problem of water shortage in the Mediterranean region is well documented. Most countries in the Mediterranean area are arid or semi-arid. The region is characterized by a severe water imbalance, particularly in the summer months due to low rainfall, which is mostly seasonal and with erratic distribution. Moreover, due to the rapid development, which affords the agricultural sector top priority, conventional water resources have been seriously depleted. This is particularly acute in southern Mediterranean countries and the Middle East region where the scarcity in some countries reaches crisis levels and poses heavy constraints on economical development.

To meet this increasing demand, groundwater, the main source of water in many countries, is being extracted well beyond the renewal rate of the resource in parts of the region. In some cases, governments are tapping into fossil groundwater and, where feasible, have initiated seawater desalination projects.

Water conservation is the answer to the problem and certainly water reuse is an important component of water conservation strategies.

Incentives to use treated wastewater include:

- treatment and disposal cost savings by turning a waste into a resource that can provide economic or social benefits;
- attractiveness of treated wastewater in terms of reliability of supply (quantity and quality) versus the variability associated with other traditional water sources;
- capacity to supplement potentially limited or costly traditional primary water sources;
- minimization of the diversion of water from watercourses, groundwater, etc.;
- reduction (ultimate aim is for avoidance) of discharges to surface waters, unless there are sufficient environmental benefits to justify the continuing discharge; and
- nutrient recovery as fertilizers and crop production during the dry season.

However, wastewater is unique in composition, often associated with environmental and health risks, and its acceptability to replace more conventional or other non-conventional water sources for irrigation is highly dependent upon whether the health risks and environmental impact are within acceptable levels. Therefore, the formulation of guidelines for the use of treated wastewater for irrigation is of prime importance for countries of the Mediterranean region.

2. PURPOSE OF THIS DOCUMENT

This document is intended to be a key reference and guide for the use of treated wastewater in Mediterranean countries. It is designed to support the regulatory requirements prescribed by the national regulatory authorities. It provides guidance for conveying treated wastewater to intended customers, based on level of treatment, intended use and operational practises

The guidelines rely upon qualified professionals, responsible and accountable in their areas of practise. It also outlines the expectations of qualified professionals. These include the expectation to follow the precautionary principle while exercising responsibilities in projects that involve the use of treated wastewater under guidance of both the national regulations and this guide. Compliance with the national regulations and understanding of the guidelines should ensure the safe use of treated wastewater.

2.1. Objectives

The overall objective of this document is to maximize the use of treated wastewater through minimizing and managing any hazard associated with its use.

Specific objectives

- encourage the sustainable and safe use of treated wastewater;
- help users and suppliers to effectively develop, implement, assess, and report on local water management activities;
- establish the obligations of suppliers and users of wastewater; and
- suggest best practise environment measures (based on available experience) for treatment, water quality, site selection, application, site management, monitoring and reporting in order to meet the performance objectives.

3. ROLES AND RESPONSIBILITIES

End-users and providers of treated wastewater, technology suppliers, qualified professionals, and regulatory agencies all play important roles and have certain responsibilities to ensure that the use of treated wastewater is practised safely. It is important that suppliers and users of treated wastewater understand and meet the obligations set by the national guidelines and this guide.

3.1 End-users

Informed end-users can play an important role in the successful use of treated wastewater. They can identify concerns regarding specific uses of treated wastewater and report them to local agencies. They can also contribute to the formation of local policies by forming water users associations. Local Governments are encouraged to undertake wastewater management planning, which includes public consultation.

3.2 Suppliers and surveyors of treated wastewater

The use of treated wastewater is based on the assumption that its providers are prepared to exercise responsibility and accountability in protecting human health and the environment. Suppliers of treated wastewater have a responsibility to ensure that the wastewater is of a quality suitable for its intended purpose.

Suppliers of treated wastewater must prepare an operating plan that covers operational and maintenance details for the treatment facility and associated backup options for surplus wastewater. A copy of the operating plan must be kept at the facility for inspection by the regulatory authorities. A hydro-geological assessment conducted by a qualified professional should address the on-site and off-site environmental impact of wastewater irrigation, including soil stability and erosion. The report must include recommendations as to the number and locations of groundwater sampling wells, including at least one background sampling well.

Suppliers have a responsibility to keep a register of all irrigation schemes to which they supply treated wastewater. This register should include information about end-use site addresses, the quality and quantity of supply, and end uses of the wastewater. Each year, the supplier must provide the legal authorities with summary details of wastewater supply and end use.

Suppliers must obtain the services of appropriately qualified professionals, as required. When employing qualified professionals, they should use an appropriate selection process based on quality of service, not on price alone. The services of a qualified professional typically amounts to a small portion of the lifecycle costs of a project and should also help to ensure the success of the undertaking.

3.3 Technology suppliers

Technology suppliers are expected to provide wastewater treatment technologies that can meet wastewater use standards and these guidelines. These include the construction, operation, and maintenance of treatment systems and associated services.

3.4 Regulatory agencies

The responsibilities of Ministries of Environment and/or Environmental Protection Agencies, involve setting of clear environment protection standards and developing and implementing policies, procedures, and guidelines for compliance with these standards. They should also promote awareness of national guidelines and this guide, to assist stakeholders in understanding their role and responsibilities. The regulatory authorities are also responsible for measuring compliance with the laws and regulations and for appropriate enforcement action.

Environmental Protection Agencies (EPAs) should consult with local health authorities on issues relating to the use of treated wastewater. It is the responsibility of local health authorities, in consultation with Ministry of Health officials, to advise EPA and providers of wastewater so that standards are set and practises conducted to protect human health.

Moreover, the EPA should consult with the Ministries of Agriculture, Food and Fisheries on issues relating to the use of treated wastewater for agricultural land and aquaculture.

3.5 Community liaison

Treated wastewater suppliers and users should establish pathways and procedures for continual and open liaison with the community. The extent of liaison should reflect the site circumstances (for example, proximity to sensitive land uses or level of community interest). Key effective community liaison measures are:

- education of likely affected parties (such as neighbours and wastewater users);
- free exchange of information; and
- a reliable system of response to complaints.

It is important that the suppliers and/or users maintain records of all complaints and rectification actions. Complaint records should include the name and address of complainant, as well as the date and time of the incident.

3.6 Community planning

Liquid waste management plans, based on a comprehensive evaluation of all aspects of municipal liquid wastes and extensive public participation, can be used to integrate cost-effective solutions to address various local liquid waste issues. These include:

- meeting water conservation goals;
- developing strategies to minimize wastewater generation and maximize the use of treated wastewater; and

- protecting human health and the environment.

3.7 Local governments

Local governments must cooperate with provincial agencies in the implementation of the municipal wastewater regulations and this guide. In addition, they should also coordinate programmes involving wastewater management, whenever possible.

Approved liquid waste management plans give local governments more control over municipal liquid waste discharges within their communities, including projects for the use of treated wastewater

3.8 Agreements

A formal agreement should be developed between the supplier and users of wastewater. Suggested issues that may be addressed in the wastewater use agreement include:

- definition of roles and responsibilities to meet the objectives of the guidance;
- responsibility for conveyance works;
- ownership of the facilities;
- cost of wastewater;
- contract duration (term and conditions for termination);
- wastewater characteristics (source, quality, quantity, pressure, flow variations);
- reliability of supply;
- commencement of use;
- intended uses;
- responsibility for operation, maintenance, monitoring and auditing processes; and
- liabilities (including risk allocation and insurance).

4. IDENTIFYING RISK EXPOSURE POTENTIAL

Risk management is now recognized as an integral part of good management practise and is an appropriate tool to use in assessing and managing the risk from wastewater use. Risk management provides a series of steps which, when taken in sequence, support better decision-making by allowing greater insight into risks and their impacts. In general, a risk-based approach supports the concept of continuous improvement.

The major emphasis for risk management of water reuse schemes is the maximization of water quality whilst, at the same, time minimizing the risks to the environment, health, agriculture and food safety**.** Water authorities should develop wastewater use management strategies (including trade waste management), the primary objective being the production of high quality wastewater with low levels of pathogens and chemical contaminants. High quality wastewater will facilitate a wider range of end-use opportunities.

Depending on wastewater quality, restrictions on end-uses are needed to control the exposure routes from residual pathogens and chemical contaminants to humans, crops and/or livestock. It is, therefore, important that suppliers and users of wastewater work together to identify and assess the potential exposure routes associated with their use schemes. Potential exposure routes and/or risks fall into the following categories:

- environmental;
- human and live stock health;

- crop (food) safety; and
- legal liability.

The risks posed vary depending upon the location (for example, relative to houses or watercourses), land capability (such as soil types, slopes, salinity, depth to water table, etc.), size of the scheme (volume of wastewater used), application techniques and the end-use (such as irrigation of golf courses or growing food crops). For the use of wastewater, details of risk identification and assessment should be provided in any Environmental Improvement Plan (EIP), thus providing an effective mechanism for third party review.

4.1 Environmental risk

Wastewater use schemes should meet the following environmental protection objectives:

- protect the beneficial uses of groundwater and surface waters;
- avoid structural changes to the soil or contamination (for example, soil salinity or that which may reduce the productivity of the land);
- avoid contamination of the air environment by the production of offensive odours, spray drift and aerosols; and
- protect flora and fauna.

To evaluate whether these objectives can be met, the following risks need to be assessed:

Soils:

Impacts on soils from excessive nutrients, salts, organic and inorganic contaminants that may be present in wastewater including:

- deterioration of soil structure and loss of soil permeability from wastewater containing elevated salt levels (typically total dissolved solids (TDS) greater than 500 mg/L, and high proportion of sodium relative to other cations);
- loss (erosion) of saline or nutrient-rich (especially phosphorus) soils;
- waterlogging effects of over-irrigation, poor drainage and high water tables; and
- impact on soil biota and risks of disease transmission to native flora and fauna from inappropriate management of wastewater and/or inappropriate crop management practises.

Groundwater:

Impacts on the beneficial uses of groundwater, particularly from salts, nitrogen (nitrate) and pathogens that may be present in wastewater.

Surface waters:

Impact on beneficial uses of surface waters from contaminated run-off containing nutrients, salts, metals and pathogens from wastewater and health risks associated with the exposure to microbiological and chemical contaminants present in the wastewaters.

Air:

Risk of air pollution problems from aerosols generated by the spray application of wastewater or odours from inadequate treatment.

4.2 Human and livestock exposure routes

Impacts of wastewater use must not pose an unacceptable risk to humans (general public and on-site workers), livestock health and associated food products (such as milk and meat) or any other living environment such as flora and fauna. The presence of helminths in untreated sewage is a key risk to be managed with the use of wastewater for cattle grazing. Without adequate treatment and management, helminths in sewage applied to grazing land have the potential to establish cycles of infection between humans and animals (such as *Taenia* or tapeworms in humans and pigs, and *Cysticercosis* or “beef measles” in cattle). Consumption of contaminated and uncooked meat by humans can complete infection cycles from animals back to humans.

To manage human and livestock health risks, treatment processes should ensure appropriate levels of pathogen and chemical contaminant removal before use.

Pathogens

Appropriate restrictions should be placed on both human and livestock exposure to treated wastewater based upon the reductions in pathogen levels achieved by the treatment process. The helminth reduction processes (that is a minimum of 25 days pondage detention or an approved method of filtration) are required for any reuse scheme involving cattle grazing. Dairy animals must be prohibited from grazing for six days after irrigation ceases. Other cattle must be prohibited from grazing for three days after irrigation ceases.

In general, as the extent of treatment increases and the level of human or stock exposure decreases, potential health risks also decrease. The receiving land (particularly agricultural land) should not be utilized as an extension of the treatment process for pathogen control, or chemical contamination dispersal and dilution. These circumstances would be considered as disposal and, therefore, be subject to works approval and licensing.

Pathogens in wastewater that need to be considered for health risk assessment include:

- helminths - intestinal nematodes such as *Taenia* which causes tape worm in humans and “Cysticercosis” in cattle and pigs, and *Ascaris* that causes roundworms in humans;
- bacteria (such as those causing cholera, typhoid, and shigellosis);
- protozoa (causing amoebiasis, giardiasis); and
- viruses (such as those causing viral gastroenteritis or infectious hepatitis).

The degree of risk from each of the above pathogen groups depends upon the quality of wastewater and its use. Potential impacts from the use of wastewater due to pathogen re-growth and disease transmission need to be assessed and appropriately controlled. This is particularly relevant where contamination via “vectors”, such as birds (that could be attracted to wastewater ponds) is concerned. If not controlled, pathogens have the potential to be transmitted to humans or stock by: (a) direct routes (that is through skin contact, ingestion or inhalation) or (b) indirect contact (that is consumption of contaminated food or feed).

Wastewater schemes that require particular attention for health risk assessment include:

- irrigation of readily accessible public areas with potential for direct exposure to treated wastewater (for example, via spray drift);
- consumption of crops that has come into direct contact with wastewater and is not cooked or processed prior to eating; and
- discharging wastewater to surface waters that are used for fishing, or water contact sports.

Algae

Algae that flourish in secondary treatment lagoons and winter storages may pose a risk to the adequate treatment and distribution of wastewater during bloom events. Blue-green algae may also pose a hazard to human and stock health through the production of toxins if the site is not appropriately managed. Generally, algae applied to pasture via wastewater will not affect stock health provided the appropriate withholding periods are implemented and stock are grazed on dry land. There is, however, a greater risk to stock health associated with drinking treated wastewater containing blue-green algae. On-site workers who come into direct contact with wastewater containing high numbers of blue-green algae may also be at risk of developing skin and eye irritations or gastric upsets.

Chemicals

Given the fact that municipal wastewater originates mostly from domestic sources, the health risk posed by chemical contaminants is expected to be less than that posed by pathogens. However, trade effluents should comply with the allowable limits before discharge into public sewer.

Industries generating trade effluent, which does not meet permissible limits, should install, operate and maintain a treatment plant to treat the effluent to the allowable limits before discharge.

Diluting trade effluent with potable water, rainwater or industrial water to comply with the allowable limits before discharge is not permitted.

4.3 Crop risks

Water reuse schemes must not adversely affect the quality of farm products or otherwise result in any unacceptable microbial or chemical contamination of crops.

While all water sources contain some salts, treated wastewater contains higher levels of salts than the fresh water supply. There is also a higher proportion of sodium in relation to other dissolved cations. For control of sodicity and salinity in treated wastewater, the following have to be considered:

- selecting crops properly;
- ensuring adequate salt and specific ion tolerance of the crops to be irrigated;
- ensuring satisfactory levels of salinity, sodicity, and specific ion concentrations in soil seed-bed during germination;
- ensuring sufficient irrigation to allow for some leaching; and
- ensuring sufficient drainage to dispose of leaching water.

Exposure routes need to be carefully managed to prevent contamination of crops via:

- direct routes (for example, contact between crops and pathogens/contaminants in wastewater and/or receiving soils); or

- indirect routes (for example, chemical bioaccumulation in animal meat/fat or microbiological contamination of milk via exposure of cow teats and udders to pasture irrigated with treated wastewater).

The acceptance of treated wastewater use in food production may be influenced through education programmes or similar means. However, situations may exist where the use of treated wastewater is potentially unacceptable to consumers.

4.4 Legal liability

Treatment plant owners, operators and wastewater end-users may be liable under laws regulating use of a product (including wastewater) that causes harm.

Wastewater suppliers and end-users should be familiar with the regulations, policies, guidance, standards, guidelines and other documents relevant to the use of treated wastewater. Suppliers should ensure that the legal risks associated with water reuse schemes are minimized. Such risk minimization could include:

- the implementation of procedures and systems (such as an environmental management system) which are specifically designed to prevent environmental and public health problems; and

- demonstrating that they are environmentally responsible regarding wastewater supply and use (that is, complying with guidelines and other relevant guidance and standards).

5. WATER QUALITY

Treated wastewater can be classified into two different water quality standards, herein referred to as category I and category II. The intention is to identify two different qualities of treated wastewater for various uses. The two categories of wastewater quality are founded on the basic principle of protecting public health.

Category I: Unrestricted public access

Category I wastewater is of such a high quality that national regulations and guidance allow public contact with it. The term Category I applies here to treated wastewater meeting the unrestricted public access category requirements of the recommended guidelines for water reuse in the Mediterranean (Appendix 2).

Category I water may be applied to: food crops eaten raw, landscaping areas such as playgrounds, golf courses, cemeteries, residential lawns, greenhouses, and silviculture operations.

Category II: Restricted public access

Category II treated wastewater requirements are at a level more stringent than most discharge effluent standards, though the resulting quality still requires that the public be restricted from contact with it, including access to land irrigated with the treated wastewater. The term Category II applies here to treated wastewater that meets the restricted public access category requirements of the recommended guidelines for water reuse in the Mediterranean (Appendix 2).

Category II wastewater uses are limited to activities where:

- the public will not likely come into contact with the treated wastewater;
- sufficient time has elapsed since treatment or use prior to public contact; and
- in the case of agricultural products, a commercial process has been applied to make the product safe for distribution such as agricultural crops that are processed or to vegetation such as pasture, fodder, nurseries, and silviculture operations. Landscapes may not be irrigated with this water. Orchards and vineyards irrigated with a drip irrigation system that does not contact the plant or crop may use this water. In general, Category II can be classified into more classes according to its use.

Uses of treated wastewater that differ from those two categories must be approved in writing after consultation with the health authorities.

6. DETERMINING ACCEPTABLE USE FOR TREATED WASTEWATER

Once the class of the treated wastewater is known, its range of potentially acceptable end-uses can be identified. Table 1, Appendix 1 provides a generic overview of acceptable end-use categories thus enabling rapid identification of the scheme type that the treated wastewater is suited to. Ultimately, however, the acceptability of a reuse scheme also depends on its ability to comply with the management controls necessary for the proposed use.

All uses of treated wastewater require some site management to ensure appropriate management of the risks. The stringency of the specific controls depends on the treated wastewater quality and also on the human or stock exposure potential associated with each use (Table 2, Appendix 1). When investigating potential reuse schemes for a treatment plant, it may be more appropriate to determine the local opportunities for treated wastewater use.

6.1 Agricultural reuse

A provider of treated wastewater must prepare an operating plan that covers operational and maintenance details for the wastewater treatment facility and associated backup options for surplus treated water. A copy of the operating plan must be kept at the facility for inspection by regulatory authorities.

A hydro-geological assessment conducted by a qualified professional should address the on-site and off-site environmental impact of treated wastewater for irrigation, including soil stability and erosion. The report must include recommendations as to the number and locations of groundwater sampling wells, including at least one background sampling well.

6.2 Urban reuse

Urban water reuse is a term generally applied to the use of reclaimed water for the beneficial irrigation of areas that are intended to be accessible to the public, such as golf courses, residential and commercial landscaping, parks, athletic fields, roadway medians, etc. Expanded uses for reclaimed water may also include fire protection, aesthetic purposes (landscape impoundments and fountains), industrial uses and some agricultural irrigation. Reclaimed water is domestic wastewater, or a combination of domestic and industrial wastewater, that has been treated to stringent effluent limitations such that the reclaimed water is suitable for use in areas of unrestricted public access. Since most areas where reclaimed water is to be used are designated for public access, protection of public health is the primary concern.

6.3 Specific design suggestions

Wastewater treatment and distribution systems must be designed by qualified professionals. The irrigation system itself should be designed by a professional engineer with experience in irrigation system design, or by a certified irrigation designer (CID). Plans of modifications and/or extensions to existing works must be signed and sealed by a qualified professional.

The general philosophy is that the irrigation system must be designed and operated to maximize the beneficial use of treated wastewater and to minimize the need for effluent disposal to water courses or the ground. This prevents excessive irrigation and subsequent negative impacts on irrigated lands and lands down-gradient from them.

Soil: soil profile and hydraulic conductivity should be determined for irrigation areas. Soil types least suitable for irrigation include highly permeable (high sand and/or gravel content), or those with a low infiltration rate (heavy clay soils). While these soil types make a site less suitable, wastewater can still be applied providing associated risks are managed.

Slope: sites with a slope of less than 10% are preferred for irrigation, as this reduces the risk of run-off and erosion. The greater the slope the more restraints on the design of the irrigation system and the more site management controls that are required.

Groundwater: a hydro-geological assessment of the proposed irrigation scheme should be undertaken. This will determine possible impacts on the groundwater, particularly for schemes that pose a significant risk. The assessment should consider the effect of the plant/crop production system and the effects of climate and reclaimed water on groundwater quality. Where an assessment indicates that irrigation is likely to result in surface water logging, root zone salinity and/or groundwater contamination, advice should be sought from a suitably experienced agronomist to determine whether these risks can be managed adequately through site-specific controls.

7. WASTEWATER TREATMENT, STORAGE AND DISTRIBUTION

In planning for wastewater use schemes, there are two major issues that must be considered prior to developing such a system:

The first of these is the issue of treated wastewater disposal when irrigation users cannot take additional water without harming their “cover crop”. This situation usually arises during wet weather periods. Since the wastewater will continue to come to the treatment facility, one or more of the following options must be considered:

- sufficient storage can be established to handle the flows until irrigation can be resumed. This can be onsite or at the user’s location; and/or

- additional land can be set aside that can be irrigated without causing harm to the “cover crop”.

The second issue that must be considered is the pollutants (e.g., heavy metals) which may be present in the treated wastewater and what effect(s) they may have on the crops that will be irrigated.

7.1 Treatment technology

There is a vast array of treatment technologies that can be applied for wastewater treatment and use. Different approaches are required, depending on the overall reuse strategy and the type of treatment under consideration. Generally speaking, treatment technologies can be grouped into either on–site (decentralized) treatment or treatment at a central plant.

The processes applied at central facilities range from relatively low technology systems (usually in the form of waste stabilization ponds where land is available at a reasonable cost) to more advanced treatment systems. It should be noted that a combination of more than one process may be needed to attain the desired wastewater quality, as is commonly recognized in water reuse guidelines and regulations.

In general, secondary treatment is the minimum standard of treatment needed for most agricultural wastewater use schemes. Secondary treatment is typically regarded as either:

(a) low-rate stabilization process such as stabilization lagoons. Aerated lagoons and facultative lagoons are designed to achieve median concentrations for BOD of 20 mg/L and SS of 55 up to 150 mg/L. This level of actual performance may be difficult for lagoon based systems to achieve over summer due to algal productivity. Therefore, in times of algal blooms, it is appropriate to also monitor filtered BOD to establish a correlation between the BOD levels for the treatment process under normal conditions with BOD levels due to algal growth (for low rate processes, SS is used as a design criteria and is not used for ongoing confirmation of process efficiency);

(b) primary sedimentation (or an equivalent process for removal of solids), followed by organic matter and solids reduction via biological/mechanical treatment (for example, bio-filtration, trickling filter, intermittently decanted extended aeration, or activated sludge plants) processes to achieve median BOD of 20 milligrams per litre and SS of 30 milligrams per litre;

(c) natural systems that utilize soil as a treatment and disposal medium, including land application, constructed wetlands, and subsurface infiltration**;** and

(d) tertiary or other advanced treatments that produce very low pathogen levels are required for schemes having high exposure potential to humans, livestock and crops.

7.2 Treatment measures for specific pollutants

Pathogens

The presence of helminths in untreated sewage is a key risk to be managed with the use of treated wastewater for cattle grazing. Without adequate treatment and management, helminths in sewage applied to grazing land have the potential to establish cycles of infection between humans and animals (such as *Taenia* or tapeworms in humans and pigs, and *Cysticercosis* or “beef measles” in cattle). Consumption of contaminated and uncooked meat by humans can complete infection cycles from animals back to humans. The helminth reduction processes (that is a minimum of 25 days pondage detention or an approved method of filtration) are required for any reuse scheme involving cattle grazing.

If the treated wastewater does not undergo the prescribed helminth treatment, a waiting period of at least two years may be required before cattle would be allowed to return to infected land for grazing, or before fodder could be grown as stock feed for these animals. In warmer/drier areas, these long withholding periods may be shorter (for example, three summer months and reseeding to pasture). However, specific advice and approval must be sought from the health authorities on the appropriate “decontamination” practises for the land. If fodder or crops are grown using treated wastewater, after harvest they should be dried before packaging.

If fodder is to be sold, growers should ensure that it is to be fed to livestock appropriate to the class of treated wastewater used for irrigation. This assurance could be through selling the fodder only to defined users, or if the fodder is for a broader market, labelling with the relevant prohibitions should be considered.

Conventional primary and secondary treatment processes, including disinfection via chlorination or UV, may not ensure adequate removal of helminths such as intestinal nematodes. The specified treatment measures to reduce helminth numbers are:

- at least 25 days detention in treatment lagoons (this may include either primary, secondary or maturation lagoons provided the helminth settling process is not disturbed by processes such as mixing, aeration or any other process), or a storage facility where all wastewater must be redetained for at least one week from the time of the last discharge into the storage facility); or

- an approved method of filtration, such as sand or membrane filtration. The requirement for helminth control is a key component for the livestock to prevent livestock diseases, including helminth infections in cattle (“beef measles” or *Cysticercus bovis*).

Chemicals

Some organic chemicals (atrazine, chlorophenols) and heavy metals (Cd, Cr, Ni) present in treated wastewater, may adversely affect soils and the safety levels of crops, particularly if wastewater contains industrial waste inputs.

Suppliers should periodically undertake investigations for the presence of toxicants, such as heavy metals and organic chemicals, in treated wastewater. Such toxicant investigations should occur when a modification to a treatment plant process commences operation, or when significant changes occur within the sewerage catchment (such as new or modified trade and/or industrial waste connections). Investigations should also be undertaken periodically according to the size of the treatment facility and potential risks of the associated reclaimed water schemes.

Algae

Algal blooms can affect the treatment reliability of treated wastewater supplies. For systems subject to algal blooms, a blue-green algal emergency response plan should be developed. The emergency response plan should entail:

- allowance for alternative supply systems;
- measures to allow the screening or filtering of reclaimed water before supply or application;
- suitable mechanisms to clean and flush the distribution system;
- a blue-green algal monitoring programme; and

- threshold blue-green algal cell numbers that trigger actions, such as cessation of supply for stock drinking.

7.3 Treatment systems requirements and reliability

7.3.1 Treatment systems design requirements

Wastewater treatment plants should be designed and managed to consistently provide treated wastewater of the desired quality and quantity. This requires the inclusion of multiple process units. The ability to isolate and bypass all process units must be included in the design. The system must be capable of treating peak flows with the largest unit out of service. Spare parts must be available so that repairs can be completed and the system placed back into operation within a maximum of three days, or emergency storage provided. An inventory of critical spare parts must be maintained at the facility. For those facilities which have no alternative method for disposal, multiple process units for critical units are required. In addition to providing multiple treatment units, for systems which have widely varying flows, equalization tanks may be needed. Alternative reliability methods may be considered on a case-by case basis (i.e., separate land application system (LAS) spray-field, additional reject storage, etc.).

Biological oxidation

All reuse facilities should employ a biological oxidation process (or equivalent), after the pre-treatment, to reduce the biochemical oxygen demanding materials. Multiple oxidation basins are recommended. Stand-by aeration equipment is required so that the aeration requirement can be met with the largest unit out of service. All aeration equipment must be accessible for ease of repair.

Clarification

Multiple units will be required. The units must be designed so that loading rates (solids, hydraulic, and weir) are clearly within acceptable ranges.

Coagulation

Addition of chemical coagulants generally increases the effectiveness of pathogen removal. Chemical feed facilities for coagulant, coagulant aids such as lime, poly-electrolytes, etc., must be provided unless manufacturer's information, pilot testing, or other rational is provided to waive this requirement.

Chemical feed systems may remain idle if, after start-up of the system the NTU level can be maintained without chemical addition. Such chemical feed facilities must be operated (exercised) at a minimum of twice per month so that the complete chemical feed system is operational, should it ever be needed.

Filtration

Filtration is an important component of a wastewater treatment/reuse scheme. By removing solids and turbidity prior to disinfection, filtration serves to increase the ability of the disinfection process to inactivate or remove pathogenic organisms. Filtration also serves as the primary barrier for the removal of protozoan pathogens (Cryptosporidium, Giardia, and others). Therefore, filtration should be provided for turbidity control. The maximum (peak) filtration rate should not exceed the manufacturer's documented performance. Loading rates must be considered based on manufacturer's information, pilot testing, and actual records from operating treatment units.

Disinfection

Disinfection is required to achieve a faecal coliform level not exceeding the permissible limit. If a faecal coliform test yields results in excess of the set count, the cause must be determined and appropriate actions taken within the operation/maintenance scheme to prevent future occurrences. Provisions must be made for automatic diversion due to any failure of any component of the disinfection system. All disinfection systems must include provisions for continuous disinfection. Items which should be considered include:

- automatic switch-over feed system;
- stand-by disinfection source; and
- uninterruptible power source.

It is recommended that all disinfection systems provide a detectable disinfectant residual at the point of delivery. The design should consider multiple points of disinfection (before and after storage, prior to long transport lines, critical points within the distribution system, etc.), or have provisions to redirect the flow to an alternate permitted site.

Specific measures

A turbidity meter must be required on the filter effluent followed by an automatic diversion valve. The automatic diversion valve should automatically divert treated wastewater which does not meet the requirement away from the reuse storage facilities to the reject pond. Once diversion has begun, it must continue until the requirement is met and the operator manually overrides the reject diversion.

Power supply

Sufficient resources must be available to provide uninterrupted service to the reclaimed water treatment system. Options available to accomplish this are:

- onsite generator as a stand- by power source; or
- uninterruptible power supply; or
- separate feed lines from different sub-stations.

Automatic switch-over is required to initiate the reserve power source.

The switch-over must disconnect the primary power source during stand-by operation.

Alarms

Alarms must be installed to provide warnings of:

- loss of normal power supply;
- failure of pumping systems;
- failure of disinfection system; and
- a telemetry system must be provided that will immediately notify the operator of any alarm warnings.

7.3.2 Treatment reliability

Reliability is the ability of a component or system to perform its designated function without failure, and is critical in maintaining continuous operation of any high quality operation.

Generally, a higher quality of treated wastewater requires a greater importance placed on treatment reliability measures. The following measures should be considered to improve treatment reliability:

- design, operate and maintain plants in accordance with the appropriate guidance;
- ensure that the level of treatment of the treated wastewater satisfies the treatment and water quality objectives;
- treated wastewater used for the irrigation of pasture or fodder grazed by stock is either retained for at least 25 days in detention lagoons or filtered by an approved method (such as sand filtration);
- reclaimed water is monitored for the presence of potential contaminants to ensure compliance with guideline numbers listed in WHO & FAO Guidelines (Appendix 2);
- transport of treated wastewater is undertaken in accordance with best practise;
- treated wastewater should not be supplemented with other water sources to improve the quality of inadequately treated wastewater;
- an emergency blue-green algal management plan is prepared for schemes at risk from algal bloom impacts;
- ensure that above-ground and buried facilities and water hose tap outlets in areas of public access are distinctively colour-coded (deep purple) and/or marked with the words: WARNING: TREATED WASTEWATER - NOT FOR DRINKING;
- for dual potable and reclaimed water distribution systems, develop an audit or educational programme for identification of household cross connections;
- where there are cross connections with potable (or other critical) water supply systems, operate the treated wastewater system at a lower pressure than the potable system, or install back flow prevention devices complying with AS 2845.1 1995 Water Supply -Back Flow Prevention Devices;
- implement a field test and maintenance programme of back-flow prevention devices;
- implement an inspection programme for non-potable supply systems to residential areas in accordance with the National Plumbing and Drainage Code of practise;
- ensure that environmentally acceptable provisions are made for the cleaning and disinfection of the distribution pipe work to control biological solids and bacterial re-growth;
- develop contingency plans for potential non-compliant and emergency events;
- provide back-up power supply systems for essential plant elements, such as the disinfection system and individual treatment units;
- implement alarm systems, automatic controls and on-line monitoring to detect process malfunctions.
- provide emergency storage facilities for overflows or inadequately treated wastewater;
- document (in EIP) and implement effective inspection and maintenance programmes to detect process malfunctions and optimize treatment efficiency;
- minimize the concentrations of potential contaminants entering the sewer through a trade waste management programme (for example, factories having waste management plans or cleaner production programmes);

- adoption of QA systems;
- duplicate and/or provide standby facilities for power, treatment units, pumps and disinfection systems;
- implement flexible modes of operation;
- employ appropriately trained and experienced operators;
- implement effective inspection, maintenance and monitoring programme;
- formulation of contingency plans, such as diversions for noncompliant events and emergencies (for example, unacceptable treated wastewater quality, treatment plant and disinfection system failures, transfer pipeline bursts, illegal waste discharges, overflows or spills); and
- provision for emergency storage.

7.3.3 Validation of treatment train

The treatment process should undergo validation. Results consistent with the compliance values should be produced for a minimum of three months before supply is commenced. During the validation period the treated wastewater should be discharged to sewer.

8. STORAGE

Treated wastewater must meet the required quality before it is transported to the designated user(s) or reuse storage pond. If, for any reason, the quality limits are not met, the wastewater must be rejected. An off-line system for storage of reject water must be provided for all dedicated reuse facilities relying on irrigation as the only means of effluent disposal. Minimum, capacity of this storage must be equal to three days of average daily design flow of the treatment facility. Provisions for returning this reject water to the facility for further treatment, or for sending the reject water to a separate disposal site, should be incorporated into the design. In all cases, the reject water stream must be isolated from the reuse stream.

It is anticipated that storage will be provided at the plant site or by the designated users. Unlike land treatment systems utilizing dedicated irrigation sites, the determination of storage capacity will depend on the actual needs of the designated users. Storage requirements vary significantly with how the treated wastewater is utilized. Storage of treated wastewater will make it available for delivery when needed. Therefore, ponds must be constructed to minimize leakage. Covered storage should be considered to retard algal growth. In general, the storage of treated wastewater improves its characteristics in several ways, the most important of which is bacteriological decay.

The ability to store treated wastewater is required for:

- irrigation purposes - when the method of application is not continuous. Storage is required during the non-growing season;
- normal balancing (seasonal) storage - when wastewater production exceeds water usage (particularly for the winter non-irrigation season); and
- emergency storage - for times when wastewater usage is unexpectedly interrupted, or the wastewater does not meet the quality standards that have been set.

Irrigation purposes

For irrigation, the storage facility must be large enough to contain the average daily treated wastewater flow occurring outside the normal irrigation season. The normal irrigation season is defined as the time when irrigation is required because of a climatic moisture deficit during the growing season. It is estimated from the length of the normal growing season, climatic trends, the annual climatic moisture deficit, and knowledge of irrigation periods in the different countries.

Wet climates

The storage facility may have to provide an allowance for cumulative volumes of treated wastewater because of reduced irrigation in wet weather. If the average seasonal irrigation requirements are used to determine the irrigation area, then this is not necessary. If the land base area is not sufficient to accommodate the average seasonal irrigation requirement, then a cumulative capacity of five years of wet weather for a five-year return period should be added to storage.

Restricted public access

For restricted public access the number of irrigation days may be reduced due to the grazing of animals or harvesting of crops. If the irrigated site is large enough to allow for the rotation of irrigation applications to accommodate the requirements for restricted public access, there will not be additional implications for storage. If not, the reduced number of irrigation days must be subtracted from the normal irrigation period.

Emergency storage

If emergency disposal is not available, emergency storage must be available throughout the year. Storage volume should be enough to retain 75% of the normal treated wastewater production for a period of at least 20 days. Emergency storage capacity must be available in addition to normal seasonal storage but may be combined with seasonal storage in seasonal storage basins.

Storage for treatment

In non-irrigation applications, 60 days storage capacity should be available for quality reasons. For irrigation, a 60-day storage period is required for the restricted public access category. For parks, school grounds, and golf courses, the national legal authorities might impose additional requirements.

General considerations

- using multiple storage reservoirs is encouraged;
- the flow to and from storage needs to be designed to minimize short-circuiting; and
- artificial aeration in deep storage basins to minimize stratification and odours and to prevent oxygen depletion should be considered.

9. TRANSPORT OF TREATED WASTEWATER

If reclaimed water is to be tanked, procedures must ensure that this does not result in spillage, odours or the contamination of the water being transported. Suggested best practise measures include:

- ensuring that the full quantity of water supplied to the transporters is delivered to the reuse site;
- transporting treated wastewater in a watertight and enclosed tanker;
- ensuring that the tanker or pipeline is not contaminated with other sources of waste that will in turn contaminate the treated wastewater and cause public health, crop contamination or environmental problems on the reuse site; and
- ensuring that treated wastewater is not transported in tankers used for transporting potable water for human drinking.

9.1 Distribution reliability

To improve distribution reliability, distribution systems (including all pipe work, fittings and drainage of the treated wastewater) should be designed in accordance with National Plumbing and Drainage Standards:

- to ensure the separation and prevention of cross connection between treated wastewater and potable water systems; and
- to allow the disinfection or slug dosing of distribution pipe work with disinfectant or algaecide to control biological solids and bacterial re-growth. (The discharge of treated wastewater drained or scoured from these procedures should, where practicable, be to land or back to the treatment and/or storage facilities).

10. CROP IRRIGATION

10.1 Irrigation systems

Agricultural irrigation may use a variety of types of irrigation systems, including sprinklers, drip or trickle, and subsurface drip.

Sprinkler irrigation

Sprinkler systems use a spray pattern to distribute water to the crop. Sprinkler irrigation systems that can apply treated wastewater to agricultural crops include centre pivot, hand line, wheel move, solid set over tree and under tree, micro-sprinklers, and travelling and stationary guns. The type of system selected depends on the crop to be grown, field shape, topography, and system management. Category I treated wastewater may be applied by sprinkler irrigation systems to forage, fibre, nursery, food crops that are commercially processed and to crops that are eaten raw, provided that the water does not contact the fruit or vegetable directly.

The irrigation system must be designed and operated so that the application rate matches the crop water requirement throughout the growing season. An allowance for some leaching must also be incorporated to ensure that salt build-up in the soil does not occur. Correct selection of sprinkler spacing, nozzles, and operating pressure is necessary.

Some limitations to the use of sprinkler systems are the purchase, replacement costs, and field space for the equipment. Uncultivated tracks must be maintained for travelling systems. Field operations must manoeuvre around solid set systems. Another limitation of sprinkler systems is spray drift. Setbacks must be included in the field layout to minimize spray drift onto roads and dwellings.

Drip/trickle irrigation

Drip/trickle irrigation systems use emitters to apply water directly to the plant rooting area. Water is applied at a low flow rate but in an amount sufficient to replenish the crop water requirements frequency, usually daily. Spray emitters that apply water only to the plant rooting area can be considered a trickle system.

Drip and trickle systems can be used for sweet corn, berry, and fruit crops. Vegetable crops must be irrigated with a sub-surface drip irrigation system. Root crops may not be irrigated with wastewater if they are likely to be eaten raw. Processed vegetables should be thoroughly washed and cooked

Extra precautions should be taken with sweet corn. Water that accumulates inside the husks may not have an opportunity to drain away and maybe shielded from the disinfecting effects of sunlight. There is greater potential for bacteria to grow under these conditions.

Subsurface drip irrigation (SDI)

These drip systems are buried below the soil surface. This method of installation increases the volume of soil wetted by an emitter, improves crop yield and quality, reduces disease transfer, and reduces weed growth. The design, maintenance, and installation of SDI systems are different from surface systems.

Problems associated with using treated wastewater through a drip system depend on the level of treatment. The worst case situation is when the wastewater receives only primary treatment. This condition exists where private homes discharge the wastewater from septic tanks through a subsurface drip irrigation system instead of a leach line. Experience has shown that with proper filtration and an automated flushing system for the filter, the drip system with regular maintenance can apply wastewater to lawns without problems. However, the drip tubing has to be designed specifically for wastewater (Lesikar, 2000).

Combined systems

Some operations may wish to combine irrigation system types. Some of the wastewater may be reused for the landscaping around buildings through a drip irrigation system. Turf and field crop areas may be irrigated with sprinklers. The areas close to roads may rely on surface irrigation to minimize spray drift

Zone operation

Irrigation systems are often designed to operate in zones across the field area. Zone operation has several advantages. Pumping capacity can be lower, which results in energy savings. Zone operation also allows wastewater and air to infiltrate the soil.

Control valves

Control valves are needed throughout the system to accommodate field management and system maintenance. While it is tempting to consider the use of automatic valves, extensive use is not recommended. Operators need to attend to irrigation operations to monitor weather conditions, check for system clogging, and observe ponding and possible runoff. Automatic valves not only give the illusion that the system is completely automatic;

they can make it difficult for the operator to make necessary adjustments. Consider valves that are manual on with an automatic shut-off. In this way the operator can check field conditions prior to irrigation. If automatic valves are used, they should be controlled from a central location and be easy to override with manual control.

10.2 Site selection

Irrigation sites fall into three categories:

- Unrestricted access sites - parks, golf courses, lawns, highway medians, and playing fields; and
- Restricted access sites - fenced or isolated woodlands or meadows.

Although site characteristics make some areas more suitable for irrigation than others, provisions can be made to allow irrigation in areas that are less than ideal. The characteristics of an ideal site, as well as strategies for overcoming site limitation are presented in Table 1.

When selecting a site for irrigation, cost trade-offs must be kept in mind. Land cost is an obvious factor to consider. Cost to transport the wastewater to the site may present some important trade-offs. Pumping treated wastewater to an upland site is more costly than gravity flow to a lowland site. The cost of a stream crossing to reach a possible site may outweigh the higher land costs nearby. Restricted access and remote sites have lower treatment requirements, resulting in lower treatment costs.

Table 1

Site characteristics for a wastewater use site.

Site characteristic	Ideal	Provisions if not ideal
Soil permeability.	Greater than 0.5cm/hour.	More than 0.01 km^2 are needed for irrigation.
Slope.	Less than 15% for cultivated fields.	Runoff control measures (consult with Natural Resources Conservation Service).
	Less than 20% for turf or pasture.	
	Less than 40% for timber.	
Surface water.	Not applied to wetlands, streams, or waterways.	
Floodplains.	More than 10-year flood return period.	Storage or alternate application site during flood event.
Depth to groundwater.	0.30m to soil mottling or other evidence of groundwater.	Storage or alternate management strategy during high groundwater periods. Drainage systems may also be an option.
Depth to bedrock.		
Agricultural and restricted access.	More than 0.60m.	If site is filled, fill material must be in place for at least four years before re-evaluation for suitability.
Unrestricted access.	More than 0.30m.	

10.3 Requirement

Land area needs are determined by calculating a water and nutrient balance for a site. A water balance is a design tool that balances the water losses from the site through evapo-transpiration, drainage, and rainfall runoff with the water inputs from rainfall and wastewater irrigation. Estimates of the total land area needed to assimilate hydraulic loads are presented in Figures 1 and 2 and can be consulted as a quick check to determine project feasibility.

All plants use nitrogen (N) to sustain themselves and grow. To encourage plant growth, farmers apply manure or fertilizer to supply necessary amounts of nitrogen. The amount of nitrogen needed to reach a desired crop yield varies with the crop grown.

A nitrogen balance for the irrigation site should be developed to insure that groundwater contamination will not result. The objective is to keep nitrate levels below 10 mg/L in the groundwater beneath the site.

Nitrogen applied - nitrogen used by crop = nitrogen available for leaching.
Water applied + precipitation - water evaporated = water available for dilution.

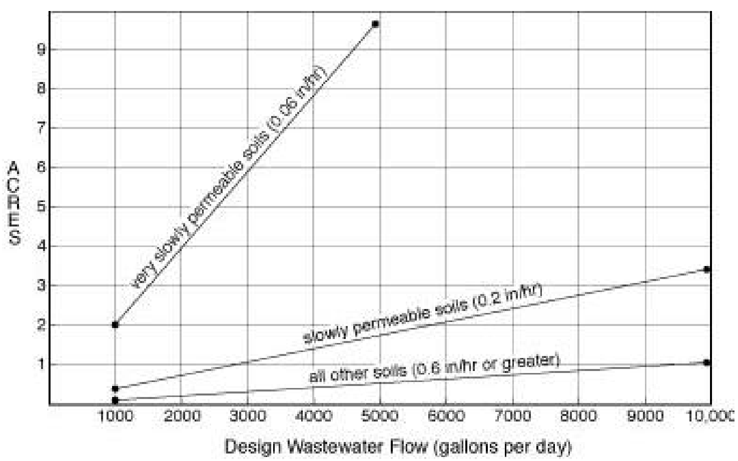

Figure 1. Minimum acreage needed for very small irrigation systems.

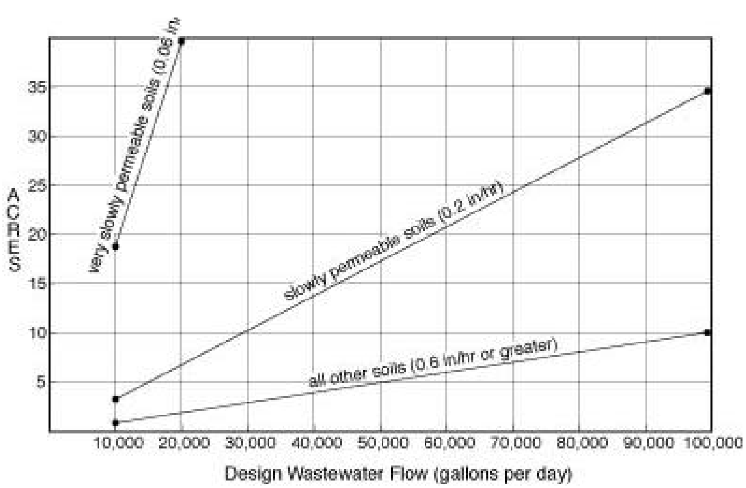

Figure 2. Minimum area needed for small to medium-sized irrigation systems.

All of the nitrate and ammonia in the wastewater is available for plant uptake and any excess can leach into groundwater. Organic nitrogen in the wastewater becomes a part of the soil organic matter and is mineralized at a rate of less than 5% per year.

- Nitrogen available for leaching (kg/0,01km^2) = (Inorganic N content of wastewater (mg/L) x annual wastewater application(cm) x 0.226) + N fertilizer (kg/0,01km^2) - N crop needs (kg/0,01km^2).
- Water available for dilution (cm) = Wastewater applied (cm) + annual precipitation (cm) - annual evaporation (cm).
- Nitrate content of water leaching from site (mg/L) = [available N (kg/0,01km^2)/ dilution water (cm) x 4.42

This calculation is a conservative approach in that the nitrate leaching from the site can be further diluted in the groundwater. It also does not take into account denitrification losses. Consider working with a hydrogeologist to conduct a more comprehensive analysis if designing a large system, applying high nitrogen content wastewater, or working in problem areas with elevated groundwater nitrate levels.

Accordingly, annual application of 38.7 acre -inches of treated wastewater per year will not pose a problem in elevating the nitrate levels in the infiltration water above 10 mg/L. Fertilizer and /or manure application to the site may need to be adjusted and agreed upon to account for nitrogen applied through reused wastewater.

10.4 Irrigation scheduling

Irrigation scheduling encompasses timing and quantity determination. It is important for scheme sustainability that the loading rates of water, nutrients and salts are balanced with the site's ability to safely convert, absorb, use or store the nutrients and salts over the long term (nominally 100 years). This can be achieved by modelling a water balance and irrigation schedule for the site. Alternate water balance modelling methodologies may be used to undertake water balance calculations, provided they have been peer reviewed by appropriate educational and/or research institutions (with recognized expertise in agricultural engineering and science) and are accepted as being technically sound. Climate, irrigation area, and crop water and nutrient requirements will determine how much treated wastewater is needed in a typical year.

Seasonal conditions, weather, and both soil physical characteristics and moisture levels will determine how much of the annual amount can be applied per day. An irrigation scheme should be designed to supply treated wastewater to the crop at a level determined by that crop's requirements. This may be achieved by designing the system to meet irrigation needs in an average year, yet allows for the supply rate to be cut back during wet years. Alternatively, the system may be designed to cater for calculated wastewater flows up to and including 90th percentile wet years.

The maximum hydraulic loading rate and the crop factor for a specified volume of wastewater determine the minimum possible irrigation area in terms of water use. However, a larger area than the one calculated will generally be required to cope with variable factors, such as lower water uptake due to young or ageing crops. Directly monitoring soil moisture levels is the preferred method for determining actual water application rates throughout the irrigation season.

Alternatively, pan evaporation readings and the appropriate crop factor, or meteorological data and standard evapotranspiration models can be used.

During the irrigation season, the crop's capacity to take water needs to be monitored regularly (weekly to bi-weekly) to determine when watering should occur.

11. MONITORING

Monitoring approaches for irrigation systems are different than for systems that discharge into streams. The objective of an irrigation site monitoring programme is to provide for early detection of problems. In most cases, simple adjustments can be made to the operation to avoid polluting ground or surface water. As a minimum, monitoring should occur at four spots in the system: 1) the treatment plant effluent; 2) storage; 3) irrigation system; and 4) soil (and in some cases the vegetation and groundwater). The frequency of monitoring depends on public access to the irrigation site and the system size (Table 2).

Table 2

Water quality monitoring requirements.
Guidelines, Municipal Water Reuse for the Mediterranean Region (2003).

Water Category	Sampling frequency/Number of samples per year		
	Quality criteria		
	Microbiological		Physical
	Intestinal nematode (No. eggs per litre)	**FC or *E. coli* [a] (cfu/100 mL)**	**SS [b] (mg/L)**
Category I			
a) Residential reuse: private garden watering, toilet flushing, and vehicle washing.	Fortnightly	Twice weekly	Weekly
b) Urban reuse: irrigation of areas with free admittance (greenbelts, parks, golf courses, sport fields), street cleaning, fire-fighting, fountains, and other recreational places.			
c) Landscape and recreational impoundments: ponds, water bodies and streams for recreational purposes, where incidental contact is allowed (except for bathing purposes).			
Category II			
a) Irrigation of vegetables (surface or sprinkler irrigated), green fodder and pasture for direct grazing, sprinkler-irrigated fruit trees.	Fortnightly [c]	Weekly	Weekly (where affordable also check BOD for efficiency o treatment reasons).
b) Landscape impoundments: ponds, water bodies and ornamental streams, where public contact with water is not allowed.			
c) Industrial reuse (except for food industry).	-		

Category III			
Irrigation of cereals and oleaginous seeds, fibre and seed crops, dry fodder, green fodder without direct grazing, crops for canning industry, industrial crops, fruit trees (except sprinkler-irrigated), plant nurseries, ornamental nurseries, trees, green areas with no access to the public.	Monthly[c]	Monthly	Monthly
Category IV			
a) Irrigation of vegetables (except tuber, roots, etc.) with surface and subsurface trickle systems (except micro-sprinklers) using practises (such as plastic mulching, support, etc.), guaranteeing absence of contact between reclaimed water and edible part of vegetables.			
b) Irrigation of crops in Category III with trickle irrigation systems (such as drip, bubbler, micro-sprinkler and subsurface).	-	-	-
c) Irrigation with surface trickle irrigation systems of greenbelts and green areas with no access to the public. d) Irrigation of parks, golf courses, sport fields with sub-surface irrigation systems.			

[a] FC or *E. coli* (cfu/100mL): faecal coliforms or *Escherichia coli* (cfu: colony forming unit/100 mL).
[b] SS: Suspended solids. When affordable, continuous recording of NTU should be preferred.
[c] Routine effluent quality monitoring not required if the wastewater is treated in WSP or WSTR designed to achieve these egg numbers.

Treatment plant effluent

The treatment plant effluent should be monitored to ensure that minimum treatment levels are achieved before it is discharged to the storage facility. The effluent should be monitored for BOD_5 and total coliform bacteria. Treatment systems using chlorine for disinfection may choose to monitor chlorine residual as an early warning for problems in the disinfection system. Total metal analysis is necessary for treatment plants receiving industrial wastewater. The wastewater flow must be monitored.

Storage system

The storage system requires only limited monitoring. A weekly record of storage volume will help in managing the system to avoid future problems. A simple, easy to read staff gauge with cross-arms is an excellent way to measure liquid levels. Red markings at the top of the gauge give an easy indication that water levels are too high.

Irrigation system

For the irrigation system, precipitation and water applied by the system need to be monitored. Simple rain gauges placed in and near the application site can capture both precipitation and irrigation water.

Soil

The soil within the irrigation site is one of the integrators of all the material being applied. One benchmark site per 0.1 km^2 has to be identified. A soil sample before irrigation begins and each year at the beginning of the application season must be collected. For systems over 567,000 L per day, samples should be collected twice a year.

By testing a sample of soil from the same spot each year, any possible accumulations of metals can be monitored. This will act as an early warning for possible surface or ground water contamination. If levels begin to get high, simple adjustments can be made in irrigation scheduling to avoid problems, (see Limits for heavy metals concentrations in soil, Appendix 2).

Vegetation

The vegetation is a biological integrator of all of the material being applied. Both information on yield and plant tissue nutrient levels can act as an early warning system for problems. Plant tissue samples can also be analyzed. Plant tissue tests can reveal nutrient imbalances and the need to add soil amendments such as lime, potassium, or phosphorus.

Groundwater

Groundwater should be monitored up-gradient and down-gradient of large irrigation systems. Monitoring wells should be sampled at the beginning and end of the irrigation season for indicators of wastewater contamination.

Monitoring programmes

Monitoring programmes for systems greater than 1892 m^3, need to be developed individually to meet local conditions and wastewater characteristics.

While much of the monitoring occurs during the irrigation period, some monitoring must continue year-round. Records of wastewater flow and storage volumes, for example, need to be recorded throughout the year. Depending on the pre-treatment system used, the effluent may also need to be monitored throughout the year.

Treated wastewater monitoring programme should cover:

- flow-monitoring. The volume of treated wastewater flowing to the reuse scheme should be monitored and recorded;
- parameters to be monitored. Monitoring of the water quality parameters recommended by the FAO and WHO should be carried out;
- sampling locations. Sampling locations should be identified; and
- frequency of sampling. Frequency of sampling should be specified.

Samples should be collected at the point of entry of treated wastewater to the distribution system. Appropriately trained personnel should collect all samples. A laboratory accredited for the specified tests by an independent body acceptable to national health authorities (such as the National Association of Testing Authorities (NATA) or equivalent) should carry out all analyses. On-line monitoring equipment should be calibrated weekly (or as per manufacturer's instructions). Test results should be kept for a period of at least two years and made available to the public upon request.

11.1 Monitoring requirements for health and environment protection

There are three monitoring requirements of particular interest to the medical health and environmental officers:

- initial requirements;
- on-going requirements; and
- outbreak of contingency monitoring.

Providers of treated wastewater are responsible to expeditiously notify both the environmental and the medical health officers in the event of a breakdown in the treatment process that could affect the quality of the treated wastewater.

Initial monitoring requirements

Initial monitoring requirements are intended to show that the treated wastewater quality is equal to or better than its intended use (restricted or unrestricted public access).

Ongoing monitoring requirements

Ongoing monitoring requirements are intended to assure that the quality of treated wastewater is equal to or better than that required for its intended use. When wastewater does not meet the quality requirements, remedial action must be implemented and initial monitoring requirements reinstated.

Outbreak or contingency monitoring requirements

Outbreak monitoring requirements would be instituted in the event of an outbreak of disease as required by the medical health officer. Contingency monitoring may be required by the medical health officer if, in her or his opinion, there is a need to monitor beyond the requirements given by ongoing monitoring

In addition to water monitoring, irrigated land must be monitored to prevent soil saturation, surface erosion, and instability in the irrigated areas and down-gradient of the irrigated lands.

12. MINIMIZING PUBLIC HEALTH CONCERNS

12.1 Labelling, signs and fencing

Avoiding direct contact between people and disease-causing organisms in wastewater is the goal in reducing health concerns. Several approaches can be used to avoid direct contact. Reliable disinfection to reduce the number of bacteria and other pathogens is one approach. In addition to testing for faecal coliform bacteria, quick tests for chlorine residual can increase confidence in the disinfection system. Restricting irrigation to times of the day or year when people are not present is another way to avoid direct contact. Irrigation only at night or when a facility is closed can be incorporated into the management plan. Establishing buffer areas between the irrigation site and the edge of the field is another approach to avoid contact. Fencing o r signs may be needed to help define the buffer area.

Buffer area

Table 3 lists the faecal coliform limits and buffer area requirements for each category of reuse. Most domestic wastewater contains low levels of metals.

Table 3

Faecal coliform limits (MPN/100 ml--30 day average) for wastewater reuse.

Public access buffer area	Unrestricted access sites	Restricted access sites	Agricultural sites
None	23 night application	23	23
25 m	-	23	23
30 m	-	200	1000
60 m	-	1000	No disinfection necessary.
90 m	-	-	No disinfection necessary.
Additional buffer areas need to be observed for fixed features, such as:			
Private water well	30 m		
Community water well	90 m		
Sink hole	30 m		
Drainage way	15 m		
Surface water	15 m		
Road right-of-way	30 m without windbreak using spray irrigation.		
	3 m with windbreak or with flood irrigation.		
Property line	15 m		

Labelling

Labelling and signs are needed to advise workers and the general public that wastewater is being used and that certain precautions are necessary. Fencing is required to control access when Category II wastewater is used in irrigation.

Warning signs

A suitable sign must be erected at the main entrance to the wastewater storage reservoir, evaporation basins, and infiltration site. It must bear emergency contact phone numbers. Golf score cards must indicate that treated wastewater is used for irrigation on golf course lands.

Fencing

A chain-link security fence at least 1,8m high, or functional, equivalent is required around treated wastewater storage reservoirs to prevent public access. Also, a suitable fence must be erected and maintained around all areas irrigated with Category II reclaimed water.

12.2 Crop management

Crop management must also be considered when developing an irrigation plan. Irrigation may need to be suspended to allow time for planting, cultivation, mowing, and harvest. While it is difficult to predict exactly what day agricultural operations will occur, the irrigation plan must include time allowances for "down time."

12.3 Crop variety

Incorporating a variety of crops into a wastewater reuse system can help minimize conflicts between the need to manage a crop and the need to disperse wastewater over the site. Combining plots with turf, woodlot, and a variety of agricultural crops is strongly recommended because it gives an operator maximum flexibility. Develop a simple field map with acreage, crop, and any irrigation restrictions.

12.4 Human exposure control

The objective of this approach is to prevent the population groups at risk from coming into direct contact with pathogens in the wastewater or to prevent any contact with the pathogens leading to disease. Four groups are at risk in agricultural use of marginal quality water:

- agricultural workers and their families;
- crop handlers;
- consumers of crops, meat and milk; and
- those living near the areas irrigated with treated wastewater.

Different methods of exposure control might be applied for each group.

Control measures aimed at protecting agricultural field workers and crop handlers include the provision (and insistence on the wearing) of protective clothing, the maintenance of high levels of hygiene and immunization against (or chemotherapeutic control) selected infections.

Risks to consumers can be reduced through cooking the agricultural products before consumption and by high standards of food hygiene, which should be emphasized in the health education associated with irrigation schemes.

Local residents should be kept fully informed on the use of treated wastewater in agriculture so that they, and their children, can avoid these areas.

Special care must always be taken to ensure that agricultural workers or the public do not use irrigation water for drinking or domestic purposes by accident or for lack of an alternative.

13. RECORDS AND REPORTING

Those using or disposing wastewater are required to monitor and submit reports on the effects of the water to the authorized officer. Depending upon the size of the operation, there might be a requirement to submit data according to wastewater treatment requirements. An annual report is also required.

Maintenance of records

An assessment of any area to be irrigated must be performed by a suitably qualified professional, using best current climate and soils data to substantiate that the land is capable of accepting treated wastewater for irrigation. This assessment must include any suggested restrictions or recommendations that the qualified professional deems necessary, including any further assessments.

Soils assessment must be submitted to the environmental agency for review, prior to the initial commencement of irrigation on the site in question. Further review and ongoing soils assessments are to be conducted in accordance with the qualified professional's recommendations. Required information should appear in the annual report.

Assessment of new uses of treated wastewater

An assessment of any new use of treated wastewater must be performed by a suitably qualified professional who can substantiate that the produced wastewater is suitable for the proposed use. This assessment must include any suggested restrictions or recommendations that the qualified professional considers necessary, including any further assessments.

This assessment must be submitted to the authorized persons for review prior to the initial commencement of the new use. Further review and ongoing assessments are to be conducted in accordance with the qualified professional's recommendations.

Annual performance report

In addition to regularly submitted data, providers of treated wastewater must submit a yearly report that includes a summary of the results of all sampling and monitoring programmes. Data interpretation and trend analyses should be provided where appropriate. The overview or executive summary should contain a table of the specific occasions, if any, when the operation was not in compliance with the national standards. The report must confirm that each of the users of the wastewater was informed as to the requirements for use of wastewater prior to the irrigation season that year.

It is strongly recommended that a special handout be provided to each user. A copy of the handout should be included as one of the appendices in the annual report.

The report must also contain an appendix wherein the substance of all complaints received during the year are listed, with remedial action taken and appropriate comments.

The report is due within 60 days of the end of the calendar year for that year's monitoring. Raw data, suitably tabulated, are to be attached as appendices to the report.

The report is to be in a format suitable for review by the public and government agencies, in electronic and printed format satisfactory to the legal authorities

14. COMMUNICATIONS

The approval of this guide means that regulators, providers and end-users of wastewater need to communicate effectively with the general public. A communication plan is essential for positive relations with the public.

In such case, any departure from accepted practises is potentially subject to public resistance. Businesses that want to introduce treated wastewater as a substitute for current water sources might encounter this. Therefore, communications planning that anticipates potential resistance from the public should accompany the introduction of treated wastewater usage.

Any part considering using treated wastewater and any regulator encouraging its use should develop a complete communication plan. The plan should begin with either a review of an existing communication strategy or preparation of a new one. The plan should identify end-users and other affected parties, what opposition might arise from them, and whose support is needed to gain public acceptance for the intended use.

The communications plan should address these considerations:

- what do we know about the customers who will be affected by the introduction of treated wastewater usage? Can we identify them specifically?
- What communication have we had so far with this group?
- What information do we have on this group's perception and understanding of treated wastewater issues? How have we reacted, to date, to their level of understanding?
- How can we alleviate the potential for negative reactions to the proposed use of treated wastewater?
- How can public acceptance be fostered proactively, before potentially negative reactions can take hold?
- Is the timing appropriate? Are we at the front end of the issue or following already formed public perception?

Once the information has been gathered, an action plan has to be established to address concerns that could arise. The plan should build on what has been learned elsewhere. Identify the key steps taken to raise an appropriate level of community understanding and acceptance of the use of treated wastewater. How were public perceptions monitored? What steps could counter misconceptions effectively? What role did education play in gaining acceptance elsewhere?

Awareness of the benefits of using treated wastewater and of the safety measures associated with its use are critical in dispelling public concern. Information on benefits and safety measures should be ready prior to queries from the public or the media.

Because public acceptance is critical to the ongoing use of treated wastewater, it warrants attention and effort. The engineering aspects of using treated wastewater may indeed be simple compared to managing public opinion, but with a good communications plan, resistance can be avoided and the safe and beneficial use of treated wastewater can proliferate.

14.1 Elements of a communications plan

Strategic communication is a necessity in water reuse projects and must be an integral part of the overall planning process. Proactive communications enable proponents of treated wastewater usage to manage various challenges successfully that could otherwise become significant public relations issues.

The following approaches are fundamental to successful strategic communication:

- start public education early;
- establish an adequate communications budget;
- identify target audiences, including all groups and any specific interests;
- ensure on-going public education and outreach;
- know your opposition;
- create a simple, clear message;
- frame the issues with care; and
- develop a wide array of communication tools.

Depending on their own communications capabilities, proponents should consider taking advice from an experienced communications consultant to meet their specific needs.

15. EMERGENCY RESPONSE PLAN

Providers of treated wastewater must prepare and maintain an up-to-date emergency response plan documenting procedures to be followed in emergencies.

15.1 Plan contents

The emergency response plan should identify:

- diversion to contingency procedures;
- shut-down procedures, including identification of safety issues and safety precautions for responding personnel;
- communication networks to be used;
- notification procedures including contact names and telephone numbers for local government, local environmental and local medical health officials;
- appropriate corrective or abatement measures including stopping the distribution of any unfit wastewater or containing or redirecting unfit wastewater to approved disposal facilities;
- measures to mitigate any damage that might have been caused; and
- environmental or health risks Media relations plan.

The provider of treated wastewater must:

- appoint one person and at least one alternate to act as an Emergency Response Coordinator with authority to act in accordance with the emergency response plan; and
- provide a copy of the emergency response plan to the Emergency Response Coordinator and each alternate, local government, Ministries of Agriculture, Food and Fisheries, and local medical health officials.

15.2 Potential emergency situations

Providers of treated wastewater should identify potential emergency situations and design their emergency response plans accordingly. The plan should provide for an escalating approach to address:

- relatively minor situations (e.g., dealing with complaints regarding a broken irrigation line that allows wastewater to drain into a neighbouring swimming pool, or the spray from an irrigation system drifting over a neighbour's backyard garden);
- more urgent situations (e.g., a treatment system problem that allows inadequately treated wastewater into distribution system); and
- critical situations (e.g., a treatment system problem that allows inadequately treated water to be sprayed onto an agricultural food crop).

Providers of reclaimed water must consult with local government, Ministries of Agriculture, Food and Fisheries, and local medical health officials to determine appropriate responses to emergency situations. Relatively minor situations might not be health hazards and might be appropriately addressed as mere nuisances. Critical situations constitute potential health hazards and might require an immediate public health warning or food recall. Urgent situations might require remedial measures such as cleaning distribution lines, additional monitoring, and end-user or public notification.

APPENDIX 1

GLOSSARY OF TERMS

Term	Definitions
activated sludge	A sludge made by continuous recirculation of solids from a secondary sedimentation tank to an aeration tank, thus acquiring many useful aerobic bacteria.
aquatic ecosystems	Any watery environment from small to large, from pond to in which plants and animals interact with the ocean, chemical and physical features of the environment
BOD	Biochemical oxygen demand a measure of the amount of oxygen used in the biochemical oxidation of organic matter. The BOD test is typically conducted over a period of five days under specified conditions and may then also be referenced as BOD5.
chlorination	The application of chlorine or chlorine compounds to water, usually for the purpose of pathogen reduction. In some circumstances, chlorination may also provide chemical oxidation and odour control.
coagulation	The addition of a chemical to a colloidal dispersion resulting in particle destabilization by a reduction of the forces tending to keep the particles apart.
controlled access	The limitation of public or livestock access to a site for defined periods of time so as to minimize the likelihood of direct physical contact with reclaimed water and, where required, to ensure adequate reductions in pathogen levels.
crop factor	A factor relating crop water use, to pan evaporation or potential evaporation over the same time.
CID	Certified irrigation designer
disinfection	A process that destroys, inactivates or removes micro-organisms
dry weather flow (DWF)	The flow carried by a wastewater system during dry weather. It consists of flows generated by properties connected to a wastewater system, excluding the effects of inflow and infiltration.
effluent	Treated wastewater flowing out of a treatment plant or treatment process.

environmental values	Particular values or uses of the environment that are important for a healthy ecosystem or for public benefit, welfare, safety or health, and that require protection from the effects of pollution, waste discharges and deposits. Several environmental values may be designated for a specific water body.
epidemiology	Study of exposure factors of disease in human populations.
E.coli	*Escherichia coli*. A bacterium found in the gut of warm blooded animals that indicates faecal contamination.
EIP	Environment improvement plan. A plan covering the use of treated wastewater that manages identified risks and thereby ensures protection of the environment and human health.
ensiling	Process for preservation of animal fodder crops by storage in silos, pits or trenches with exclusion of air.
EPAs	Environmental Protection Agencies.
filter	A device or structure for removing solid or colloidal material.
flocculation	The formation of settleable particles from destabilized colloidal-sized particles.
groundwater inflow	Water stored underground in rock crevices and in the pores of geological materials that make up the earth's crust.
LAS	Land application systems.
MAFF	Ministries of Agriculture, Food and Fisheries.
NTU	Nephlometric Turbidity Unit - unit of measure of the turbidity of water due to suspended, colloidal and particulate matter.
pollution	The introduction of unwanted material into waters, air or soil, usually as result of human activities.
property sewer (or connection)	A portion of the gravity sewerage system that links the property to the reticulation/collection sewer.
pathogens	Organisms capable of causing disease. In untreated sewage, the key potential pathogens are bacteria, viruses, protozoans and helminths.
primary treatment	Treatment involving sedimentation (sometimes preceded by screening and grit removal) to remove gross and settleable solids. The remaining settled solids, referred to as sludge, are removed and treated separately.
reclaimed water	Water which has been derived from wastewater systems and treated to a standard which is satisfactory for its intended use.

risk	The probability of injury, disease, or death under specific circumstances. In quantitative terms, risk is expressed in values ranging form zero (representing the certainty that harm will not occur) to one (representing the certainty that harm will occur).
risk assessment/ analysis	The use of the factual base to define the potential health effects of exposure of individuals or populations or ecosystems to hazardous materials and situations. It may contain some or all of the following four steps: (a) hazard identification; a qualitative and cursory determination of whether a threat to human beings or the environment exists, (b) dose-response assessment; analysis of what degree of harm results from differing "doses" of the threat (exposure duration and, intensity) (c) exposure assessment; measurement or prediction of duration and intensity of exposure, and (d) risk characterization; prediction of occurrence of expected adverse effects (usually probabilistic).
risk characterization	The description of the nature and often the magnitude of human risk, including attendant uncertainty.
risk communication	The exchange of information about risk.
risk management .	The decision-making process that uses the results of risk assessment to produce a decision about environmental action. Risk management includes consideration of technical, social, economic, and political information.
reclaimed water	Water that has been derived from sewerage systems or industry processes and treated to a standard that is appropriate for its intended use.
sewer	Pipes for conveying wastewater.
SDI	Sub-surface drip irrigation.
secondary treatment	Generally, a level of treatment that removes 85% of BOD and suspended solids via biological or chemical treatment processes. Secondary treated reclaimed water usually has a BOD of < 20 mg/L and suspended solids of < 30 mg/L, but this may increase to > 100 mg/L due to algal solids in lagoon systems.
SS	Suspended solids.
sodium adsorption ratio (SAR)	An expression of the relative concentrations of sodium ions in reclaimed water to calcium and magnesium ions, indicating a potential sodium or alkali hazard to the soil.
storage lagoon	A lagoon used to store treated reclaimed water prior to application, either to maintain adequate supplies, or to assist meeting the SEPP (*Waters of Victoria*) requirement for on-site retention of all wastes up to a 90th percentile wet year.

supplier A person or organization that supplies reclaimed water for use.

trade waste The liquid waste generated from any industry, business, trade, or manufacturing process. It does not include domestic wastewater.

tertiary treatment The treatment of treated wastewater beyond the secondary biological stage. This normally implies the removal of a high percentage of suspended solids and/or nutrients, followed by disinfection. It may include processes such as coagulation, flocculation and filtration.

treatment lagoon Any large pond or holding used to contain reclaimed water while treatment processes including sedimentation and biological oxidation o ccur. Stabilization and maturation lagoons are examples of treatment lagoons.

90th percentile When expressed as a limit, ninety percent of the samples taken over a specified period must not exceed the prescribed value, that is, the 90^{th} percentile of the available data's statistical distribution.

uncontrolled access Members of the public have unrestricted access to areas where reclaimed water is in use.

user A person or organization that uses reclaimed water.

wastewater The liquid, including dissolved and suspended matter (including inflow and infiltration) discharging from a wastewater system to the environment.

wastewater overflow An overflow from a wastewater system.

water quality objective A numerical concentration limit or narrative statementthat has been established to support and protect the designated uses of water at a specified site. It is based on scientific criteria or water quality guidelines but may be modified by other inputs such as social or political constraints.

wastewater pumping station A facility that may be above ground or underground, with pumps and wells, that provides the hydraulic lift for pressurized wastewater flows in rising mains.

wet weather flow (WWF) The flow carried by a wastewater system during wet weather. It consists of sanitary flow and the flows resulting from inflow/infiltration from liquids by physically trapping the particles and removing them.

APPENDIX 1

Table 1

Classes of treated wastewater and the associated acceptable uses (typically subject to site controls).
Guidelines for Environmental Management, Use of Reclaimed Water, EPA Victoria, June 2003.

Treated wastewater class	Agricultural Uses					Urban (non-potable) and industrial uses	
	Raw human food crops exposed to treated wastewater	Dairy cattle grazing/fodder, livestock drinking (not pigs)	Cooked/processed human food crops, or selected crops not directly exposed to treated wastewater	Grazing/fodder for Cattle, sheep, horses, goats, etc	Non-food crops woodlots, turf, flowers	Residential, unrestricted public access, open industrial systems	Restricted public access, closed industrial systems
A	v	v	v	v	v	v	v
B	X	v	v	v	v	X	v
C	X	X	v	v	v	X	v
D	X	X	X	X	v	X	X

Notes to Table 1

1. Dairy cattle grazing with Class C treated wastewater is also allowed subject to a five-day withholding period after irrigation.

v - Treated wastewater of this quality is generally acceptable for the corresponding uses. However, management controls may apply.

X - Treated wastewater of this quality will generally not be acceptable under these guidelines for the corresponding uses.

Table 2

Acceptable Agricultural Uses - Livestock Access and Food Safety Controls for Specific Irrigation Methods.

Reuse category	**Minimum water Class**	**Irrigation method**	**Key management controls for use, e.g., withholding period**
Raw human food crops exposed to treated wastewater			
Crops grown close to the ground and consumed raw (e.g., celery, cabbage).	Class A	Unrestricted	
Root crops consumed raw (e.g., carrots, onions, radish).	Class A	Unrestricted	
Human food crops cooked (>70?C/for 2 minutes) or processed before human consumption, or consumed raw but with edible parts not exposed to treated wastewater			
Crops grown over one meter above the ground and eaten raw (e.g., apples, pears, apricots, table grapes, olives).	Class A Class C	Unrestricted Flood, furrow, drip, sub-surface.	 Dropped produce not to be harvested.
Crops which are skinned, peeled or shelled before consumption (e.g., lemons, limes, nuts, watermelons, rockmelons).	Class A Class C	Unrestricted Flood, furrow, drip, sub-surface.	 Produce should not be wet from treated wastewater irrigation when harvested. Dropped produce not to be harvested.
Crops to be cooked (>70?C for two minutes) or processed before sale to consumers* (e.g., wheat, wine grapes).	Class C	Unrestricted	Produce should not be wet from treated wastewater irrigation when harvested.
Non food crops			
Crops not for consumption (e.g., woodlots, turf growing, flowers).	Class D	Unrestricted	Restrict public access to application area. Harvested products not to be wet form treated wastewater when sold.

APPENDIX 2

RELEVANT GUIDELINES
GUIDELINES FOR INTERPRETATION OF WATER QUALITY FOR IRRIGATION

Source: FAO (1985)

Potential irrigation problem		Units	Degree of restriction on use		
			None	Slight to moderate	Severe
Salinity					
Ec_w[1]		dS/m	< 0.7	0.7 - 3.0	> 3.0
or					
TDS		mg/L	< 450	450 - 2000	> 2000
Infiltration					
SAR[2] = 0 - 3 and EC			> 0.7	0.7 - 0.2	> 0.2
	3 -6		> 1.2	1.2 - 0.3	>0.3
	6-12		> 1.9	1.9 - 0.5	> 0.5
	12-20		> 2.9	2.9 - 1.3	> 1.3
	20-40		> 5.0	5.0 - 2.9	> 2.9
Specific ion toxicity					
Sodium (Na)					
	Surface irrigation	SAR	< 3	3 - 9	> 9
	Sprinkler irrigation	me/l	< 3	> 3	
Chloride (Cl)					
	Surface irrigation	me/l	< 4	4 - 10	> 10
	Sprinkler irrigation	me/l	< 3	> 3	
Boron (B)		mg/L	< 0.7	0.7 - 3.0	> 3.0
Trace Elements (see Table 5)					
Miscellaneous effects					
Nitrogen (NO_3-N)[3]		mg/L	< 5	5 - 30	> 30
Bicarbonate (HCO_3)		me/l	< 1.5	1.5 - 8.5	> 8.5
pH		Normal range 6.5-8			

[1] EC_w means electrical conductivity in deci-Siemens per metre at 25°C.
[2] SAR means sodium adsorption ratio.
[3] NO_3-N means nitrate nitrogen reported in terms of elemental nitrogen.

Threshold Levels of Trace Elements for Crop Production.
Source: Adopted from National Academy of Sciences (1972) and Pratt (1972)
Ayres & Westcot (1985).

	Element	Recommended maximum concentration (mg/L)	Remarks
Al	(aluminium)	5.0	Can cause non-productivity in acid soils (pH < 5.5), but more alkaline soils at pH > 7.0 will precipitate the ion and eliminate any toxicity.
As	(arsenic)	0.10	Toxicity to plants varies widely, ranging from 12 mg/L for Sudan grass to less than 0.05 mg/L for rice.
Be	(beryllium)	0.10	Toxicity to plants varies widely, ranging from 5 mg/L for kale to 0.5 mg/L for bush beans.
Cd	(cadmium)	0.01	Toxic to beans, beets and turnips at concentrations as low as 0.1 mg/L in nutrient solutions. Conservative limits recommended due to its potential for accumulation in plants and soils to concentrations that may be harmful to humans.
Co	(cobalt)	0.05	Toxic to tomato plants at 0.1 mg/L in nutrient solution. Tends to be inactivated by neutral and alkaline soils.
Cr	(chromium)	0.10	Not generally recognized as an essential growth element. Conservative limits recommended due to lack of knowledge on its toxicity to plants.
Cu	(copper)	0.20	Toxic to a number of plants at 0.1 to 1.0 mg/L in nutrient solutions.
F	(fluoride)	1.0	Inactivated by neutral and alkaline soils.
Fe	(iron)	5.0	Not toxic to plants in aerated soils, but can contribute to soil acidification and loss of availability of essential phosphorus and molybdenum. Overhead sprinkling may result in unsightly deposits on plants, equipment and buildings.
Li	(lithium)	2.5	Tolerated by most crops up to 5 mg/L; mobile in soil. Toxic to citrus at low concentrations (<0.075 mg/L). Acts similarly to boron.
Mn	(manganese)	0.20	Toxic to a number of crops from a few-tenths to a few mg/L, but usually only in acid soils.
Mo	(molybdenum)	0.01	Not toxic to plants at normal concentrations in soil and water. Can be toxic to livestock if forage is grown in soils with high concentrations of available molybdenum.
Ni	(nickel)	0.20	Toxic to a number of plants at 0.5 mg/L to 1.0 mg/L; reduced toxicity at neutral or alkaline pH.

	Element	Recommended maximum concentration (mg/L)	Remarks
Pd	(lead)	5.0	Can inhibit plant cell growth at very high concentrations.
Se	(selenium)	0.02	Toxic to plants at concentrations as low as 0.025 mg/L and toxic to livestock if forage is grown in soils with relatively high levels of added selenium. As essential element to animals but in very low concentrations.
Sn	(tin)		
Ti	(titanium)	-	Effectively excluded by plants; specific tolerance unknown.
W	(tungsten)		
V	(vanadium)	0.10	Toxic to many plants at relatively low concentrations.
Zn	(zinc)	2.0	Toxic to many plants at widely varying concentrations; reduced toxicity at pH > 6.0 and in fine textured or organic soils.

The maximum concentration is based on a water application rate which is consistent with good irrigation practises (10 000 m^3 per 10 000 m^2 per year). If the water application rate greatly exceeds this, the maximum concentrations should be adjusted downward accordingly. No adjustment should be made for application rates less than 10 000 m^3 per hectare per year. The values given are for water used on a continuous basis at one site.

Recommended guidelines for water reuse in the Mediterranean region.

Water Category	Quality criteria: Microbiological – Intestinal nematode[a] (No. eggs per litre, arithmetic mean)	Quality criteria: Microbiological – FC or *E. coli*[b] (cfu/100 mL, geometric mean)	Quality criteria: Physical-chemical – SS [c] (mg/L)	Wastewater treatment expected to meet the criteria
Category I				
a) Residential reuse: private garden watering, toilet flushing, and vehicle washing. b) Urban reuse: irrigation of areas with free admittance (greenbelts, parks, golf courses, sport fields), street cleaning, fire-fighting, fountains, and other recreational places. c) Landscape and recreational impoundments: ponds, water bodies and streams for recreational purposes, where incidental contact is allowed (except for bathing purposes).	≤ 0.1 [h]	≤ 200 [d]	≤ 10	Secondary treatment + filtration + disinfection.
Category II				
a) Irrigation of vegetables (surface or sprinkler irrigated), green fodder and pasture for direct grazing, sprinkler-irrigated fruit trees b) Landscape impoundments: ponds, water bodies and ornamental streams, where public contact with water is not allowed.	≤ 0.1 [h]	≤ 1000 [d]	≤ 20 ≤ 150 [f]	Secondary treatment or equivalent [g] + filtration + disinfection, or Secondary treatment or equivalent [g] + either storage or well-designed series of maturation ponds or infiltration percolation.
c) Industrial reuse (except for food, beverage and pharmaceutical industry).	-			
Category III				
Irrigation of cereals and oleaginous seeds, fibre and seed crops, dry fodder, green fodder without direct grazing, crops for canning industry, industrial crops, fruit trees (except sprinkler-irrigated)[e], plant nurseries, ornamental nurseries, trees, green areas with no access to the public.	≤ 1	<10-5	≤ 35 ≤ 150 [f]	Secondary treatment or equivalent [g] + a few days storage, or Oxidation pond systems.

Water Category	Quality criteria			Wastewater treatment expected to meet the criteria
	Microbiological		Physical-chemical	
	Intestinal nematode[a] (No. eggs per liter, arithmetic mean)	FC or *E. coli*[b] (cfu/100 mL, geometric mean)	SS [c] (mg/L)	
Category IV				
a) Irrigation of vegetables (except tuber, roots, etc.) with surface and subsurface trickle systems (except micro-sprinklers) using practises (such as plastic mulching, support, etc.), guaranteeing absence of contact between reclaimed water and edible part of vegetables. b) Irrigation of crops in Category III with trickle irrigation systems (such as drip, bubbler, micro-sprinkler and subsurface).	None required	None required	Pre-treatment as required by the irrigation technology, but not less than primary sedimentation.	
c) Irrigation with surface trickle irrigation systems of greenbelts and green areas with no access to the public.				
d) Irrigation of parks, golf courses, sport fields with sub-surface irrigation systems.				

[a] *Ascaris and Trichuris* species and hookworms; the guideline limit is also intended to protect against risks from parasitic protozoa.
[b] FC or *E. coli* (cfu/100mL): faecal coliforms or *Escherichia coli* (cfu: colony forming unit/100 mL). This indicator should be monitored preferably weekly but at least monthly.
[c] SS: Suspended solids.
[d] Values must be conformed at the 80% of the samples per month, minimum number of samples is five.
[e] In the case of fruit trees, irrigation should stop two weeks before fruit is picked, and no fruit should be picked off the ground. Sprinkler irrigation should not be used.
[f] Stabilization ponds.
[g] Such as advanced primary treatment (APT) (Jimenez *et al.*, 1999 and 2001).
[h] The nematode guideline of 0 < 0.1 nematode egg /L, is a design criteria, which once verified does not require routing monitoring.

Limit values for concentrations of heavy metals in soil in EU Directive and some European countries (mg/kg DW).
Source: IAWQ (1996)

Elements	**EU Directive 86/278**	**Greece**	**UK**	**Germany**	**Finland**	**Belgium**	**France**	**Italy**	**Sweden**	**The Netherlands**
Cadmium (Cd)	1-3	1-3	3	1-1.5	0.5	1-3	2	1.5	0.4	0.8
Chromium (Cr)	-	-	400	100	200	100-150	150	-	30	100
Copper (Cu)	50-140	50-140	80-200	60	100	50-140	100	100	40	36
Mercury (Hg)	1-1.5	1-1.5	1-1.5	1	0.2	1-1.5	1	1	0.3	35
Nickel (Ni)	30-75	30-75	50-100	50	30	30-70	50	75	75	0.3
Lead (Pb)	50-300	50-300	300	100	60	50-100	100	100	40	85
Zinc (Zn)	150-300	150-300	200-450	150-200	150	150-300	300	300	75	140
Arsenic (As)	-	-	50	-	-	-	-	-	-	29
Fluorine (F)	-	-	500	-	-	-	-	-	-	-
Molybdenum (Mo)	-	-	4	-	-	-	-	-	-	-
Selinium (Se)	-	-	4	-	-	-	-	-	-	-

DW “Dry weight“

Water Quality International Guidelines for Irrigation

Parameter	Unit	Canada All Soils 1999	USA Sandy Soils 1973	Taiwan All Soils 1978	Hungary All Soils 1991	Peoples Republic of China Rice Paddy Undated	 Dry land Undated	 Vegetable Undated	Saudi Arabia All Soils Undated	Tunisia All Soils Undated	FAO 1992	Egypt Law 48/1982 Article "65"	Egypt Decree No.44/2000
pH				6.0-9.0	6.5-8.5	5.5-8.5	5.5-8.5	5.5-8.5	6-8.4	6.5-8.5		7-8.5	
TDS	mg/L	500-3500				1000-2000	1000-2000	1000-2000					2000
E.C.	umho/cm 25 °C			750						700			
S. S	mg/L			100		150	200	100	10	30			20
Chloride	mg/L	100-700[a]		175		250		250	280	2000			300
Sulfate	mg/L			200									
T. K. N	mg/L			1		12	30	30					
BOD	mg/L					80	150	80	10			10	20
COD	mg/L					200	300	150		90		6	40
Temperature	°C			35		35	35	35					
Al	mg/L	5	5	5	5				5		5		
As	mg/L	0.1	0.1	1	0.2	0.05	0.1	0.05	0.1	0.1	0.1	0.05	0.1
Ba	mg/L				4								
Be	mg/L	0.1	0.1	0.5	0.1				0.1				
B	mg/L	0.5-6.0[b]	0.75	0.75	0.7	10.0 - 30.0	7.0 - 3.0	1.0 - 3.0	0.5	3			3
Cd	mg/L	0.005	0.01	0.01	0.02	0.005	0.005	0.005	0.01	0.01	0.01	0.01	0.01
Cr (Total)	mg/L	0.01	0.1	0.1	5	0.1	0.1	0.1	0.1	0.1	0.1	0.01	0.1
Co	mg/L	0.05	0.05	0.05	0.05				0.05	0.1	0.05	1	0.05

Cu	mgl	0.2-1.0	0.2	0.2	2	1	1	1	0.4	0.5	0.2		0.2
F (Total)	mg/L	1			1	2.0-3.0	2.0 - 3.0	2.0 - 3.0	2	3	1	0.5	
Fe	mg/L	5			0.1				5	5	5	1	5
Pb	mg/L	0.2	5	0.1	1	0.1	0.1	0.1	0.1	1			5
Li	mg/L	2.5	2.5	2.5	2.5				0.07		2.5		
Mn	mg/L	0.2	0.2	2	5				0.2	0.5	0.2	1.5	0.2
Hg	mg/L			0.005	0.01	0.001	0.001	0.001	0.001	0.001			
Mo	mg/L	0.01 - 0.05[c]	1.01	0.01					0.1		0.01		0.01
Ni	mg/L	0.2	0.2	0.5	1				0.02	0.2	0.2		0.2
Se	mg/L	0.02-0.05[d]	0.02	0.02		0.02	0.02	0.02	0.02	0.05	0.02		
Ag	mg/L				0.1								
V	mg/L	0.1	0.1	10	5						0.1		
Zn	mg/	1.0 - 5.0[e]	2	2	5	2	2	2	4	5	2	1	2
CN(Total)	mg/L				10	0.5	0.5	0.5	0.05			0.1	
Surfact (ABS)	mg/L			5	50	5	3	5				0.5	
Oil and Grease	mg/L			5	8							1	5
Benzene	mg/L				2.5	2.5	2.5	2.5					
Tar	mg/L				30								
Petroleum	mg/L				0.5	1	0.5	0.5					
Methanol	mg/L				0.1								
Trichloroacetylaldehyde	mg/L					1	0.5	0.5					
Propionaldehyde	mg/L					0.5	0.5	0.5					
Phenol	mg/L								2			0.02	
Atrazine	mg/L	0.01											

Hydrocarbons												1.5	
Coliforms fecal	cfu/100	100/100											
Coliform total	cfu/100	1000/100											

(a) Chloride guideline = 100-175 mg/L for almonds, apricots and plums
= 178-355 mg/L for grapes, peppers, potatoes and tomatoes
= 355-710 mg/L for alfalfa, barley, corn and cucumbers
> 710 mg/L for cotton, sorghum, sugar beets and sunflowers
= 180-600 mg/L for stone fruit (peaches, plums, etc.)
= 710-900 mg/L for grapes

(b) Boron guidelines = 0.5 mg/L for blackberries
= 0.5 – 1.0 mg/L for grapes, onions, garlic, sweet potatoes, sunflowers, wheat and barley
= 1.0 – 2.0 mg/L for red peppers, potatoes and cucumbers
= 2.0 – 4.0 mg/L for lettuce and cabbage
= 4.0 – 6.0 mg/L for sugar beets
= 6.0 mg/L for asparagus

(c)Molybdenum guideline= 0.05 mg/L for short-term use on acidic soils

(d) Selenium guideline = 0.02 mg/L for continuous use
= 0.05 mg/L for intermittent use

(e) Zinc guideline = 1.0 mg/L when soil pH < 6.5
= 5.0 mg/L when soil pH > 6.5

APPENDIX 3

REFERENCES

Appropriate Technology Consortium (ATC). (2000). Online. Available: http://www.gal-soc.org/atc.html

Asano, T., & Mills, R.A. (1990, January). Planning and analysis for water reuse projects. *Journal American Water Works Association*, 38-47

The Consortium of Institutes for Decentralized Wastewater Treatment (CIDWT). (2000). Online. Available: http://www.dal.ca/~cwrs/cdwt/

Draft Code of Practice for Wastewater Overflow Management for Public Consultation, October 2003,EPA

Gerba, C.P., Wallis, C., & Melnick, J.L. (1975). Fate of wastewater bacteria and viruses in soil. *J. Irrig. Drainage Div.*, ASCE 101 (IR3), 157-174

Lesikar, B. (1999, August). *On-site wastewater treatment systems: Subsurface drip distribution* (Publication No. L-5237). Online. Texas Agricultural Extension Service. Available:
http://agpublications.tamu.edu/pubs/eengine/l5237.pdf

Middle East Wastewater Use Clearinghouse. (2000). Online. Available: http://weather.nmsu.edu/hydrology/wastewater/

National Small Flows Clearinghouse (NSFC). (2000). Online. Available: http://www.estd.wvu.edu/nsfc/NSFC_homepage.html

Oron, G., Campos, C., Gillerman, L., & Salgot M. (1999). Wastewater treatment, renovation and reuse for agricultural irrigation in small communities. *Ag. Water Management, 38*, 223-224.

World Health Organization. (1989). *Health guidelines for the use of wastewater in agriculture and aquaculture* (MAP Technical Reports Series No. 778, pp. 1-74).

Zachariou Dodou, M. Strategies to minimize health risk in Cyprus. Standards for reclaimed waters used for irrigation. Water Development Department, Nicosia, September 2000.

Web sites (Glossary):
http://glossary.eea.eu.int/EEAGlossary
http://www.wef.org/publicinfo/newsroom/wastewater_glossary.jhtml