Sustainable wastewater treatment with soil filters

Centre for applied ecology Schattweid

SWISS AGENCY FOR DEVELOPMENT AND COOPERATION
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Swiss Centre for Development Cooperation in Technology and Management

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Authors	Philippe Wyss, Centre for Applied Ecology, Schattweid Brigitta Züst, Centre for Applied Ecology, Schattweid For economic, social and institutional aspects: Dominique Guenat, Swiss College of Agriculture Gil Ducommun, Swiss College of Agriculture

Layout	Catherine Ndiaye-Dia, SKAT
Comments, inquiries	Please address them to Centre for Applied Ecology Schattweid CH-6114 Steinhuserberg, Switzerland Tel: +41 41 490 17 93 Fax: +41 41 490 49 75 e-mail: zentrum@schattweid.ch
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Title page: Soil filters for different situations.

A) In the garden of a private home.
B) In a farm (where weekend courses take place)
C) At an airport
D) At a cheese factory

Summary

Wastewater treatment is an "end of pipe" measure. On-site management of wastes is desirable and necessary, but in many situations there is no substitute for a wastewater treatment plant. Wastewater treatment methods using little or no energy and large land areas are particularly suitable for rural areas and regions with dispersed settlement. One treatment method of this type is soil filtration. Soil filters can be suitable and sustainable solutions to wastewater problems.

The brochure is intended to assist decision-makers. It is not a design manual. The construction and operational principles of soil filters are described. Their economic, institutional, legal and socio-cultural aspects are also outlined. The brochure also includes a short comparison of soil filters with other extensive treatment methods, and a list of questions to consider when faced with the need to select a wastewater treatment system.

Key words: extensive wastewater treatment; soil filters.

*Terms indicated with * are defined in the glossary.*

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1 Options for wastewater treatment

1.1 Introduction

Preserve drinking water and treat wastewater

All over the world the preoccupation with the worrying lack of safe drinking water is increasing. An important way of preserving drinking water consists in not polluting it. Another approach is to pollute as little as absolutely necessary. A third important way of preserving drinking water is to install sanitation and treat the wastewater.

History of wastewater treatment and significance of extensive systems

Given time and favourable conditions, natural processes can reduce the polluting effects of wastewater on rivers, lakes and underground water. In past centuries, because of this self purification of water and low population densities, it was often possible to avoid the spread of waterborne diseases by simple habits, such as collecting water upstream of any local wastewater discharges. Nevertheless, constructive measures were also taken, such as digging latrine pits, constructing storage tanks, and installing pipes to take wastewater away.

However, by the end of the 19th century, with continuous increases of populations, the clamour to find the best way to get rid of human and domestic wastes from urban areas could not be ignored. Eventually the advocates of water-borne sewerage were the most persuasive, bringing in a period of wastefulness – large quantities of good drinking water were used for flushing the wastes, and organic matter in the wastewater (that could have enriched the soil) was discarded. The proven efficiency of on-site excreta management was disregarded. This wasteful approach still persists in many parts of the world, and is regarded by many as the most desirable and sophisticated system.

It was not long before Europe began to realise that evacuating wastewater was no longer sufficient. The pollution potential of the wastewater had to be reduced. The construction of treatment facilities took root in the first quarter of the twentieth century – a perfect example of the "end of pipe"* philosophy.

In the 1960s, when the costs for intensive* treatment could not be ignored, the interest in extensive* treatment increased. Different systems were designed, research was conducted and experience gained. Today, extensive wastewater treatment methods are well established and efficient. They are a real alternative to intensive treatment, particularly for smaller communities.

* Terms are defined in the Glossary

Wastewater, domestic and communal*, can be both a hazard and a resource. Ways to deal with it include prevention, treatment and use. In the authors' opinion all three ways, or combinations thereof, are equally important. However, there are situations where one or another is more appropriate.

Present and future wastewater policy

In the future, management at the source will gain in importance and allow recycling of nutrients. The implementation of no-mix or source separation strategies* will assist effective wastewater treatment and facilitate the recycling of carbon, nitrogen and phosphorous. The present wastewater policy particularly in industrialised countries and in urban centres involves allowing the mixing of excreta* and grey water (grey water is domestic wastewater from washing and food preparation without urine and faeces) and then treat this mixture. However, it is becoming more and more evident that this "mixing everything" strategy allows neither sustainable nor affordable wastewater treatment. Intensive research efforts are being devoted to finding strategies to treat urine alone, faeces alone, grey water alone, urine and faeces together or faeces and grey water together (see Table 6). In a rural context, such strategies may be easier to realise than in an urban context, but promising ideas also exist for urban areas.

The way in which wastewater treatment strategies are evolving will gradually become clear. It is evident that "end of pipe" treatment approaches cannot yet be abandoned because the changes in strategy are taking place very slowly. Therefore the interest in cheap and reliable wastewater treatment is considerable, and will remain so. A range of techniques is available and it is important to select the most appropriate alternative for each given geographic, economic, socio-cultural and environmental situation.

Major treatment methods

Different wastewater treatment techniques have very different requirements for energy and land (see Section 1.7). The greater the land area that is used for the treatment process, the smaller the energy requirement, and vice versa. In densely populated areas wastewater treatment techniques requiring a high energy input are generally more appropriate.

Extensive and intensive wastewater treatment

Wastewater treatment functioning with little or no energy may be called "extensive" by analogy to extensive agriculture or extensive aquaculture. In all these cases "extensive" implies the use of large areas of land (in agriculture) or water (in aquaculture). On the other hand, little land or water is necessary for "intensive" alternatives, but there is an intensive use of energy (directly or indirectly).

Rationale and scope of this brochure

Wastewater treatment is necessary now and into the future. It is more common to treat wastewater using intensive methods in densely populated areas than in sparsely populated ones. Consequently, planning engineers are more familiar with these techniques but lack information regarding alternatives that consume little energy, such as waste stabilisation ponds, soil filters, irrigation, infiltration and aquaculture. This brochure aims to fill this gap, particularly with regard to soil filters.

Soil filters

The main topic of this publication is soil filters. They are considered to be a reliable, energy-efficient (or even energy-independent), cheap and sustainable wastewater treatment method. Soil filters, like other low-cost, low-energy treatment options, require more land than energy-intensive systems. Generally, soil filters are applicable in rural or periurban areas, serving populations of up to 1000 (although much larger ones exist).

This brochure is for decision makers but not for design engineers

This brochure aims to assist decision-makers to decide whether soil filters are an appropriate solution for their wastewater problems; it is not a design manual for engineers. It lists the pros and cons of soil filters and compares them with other extensive treatment methods (see Section 2.6). Like most engineering systems, wastewater treatment plants are most sustainable when they are adapted to the individual situation. This publication addresses the technical, economic, institutional and socio-cultural aspects which should be considered when deciding on the most appropriate way of treating wastewater in a particular context. And it must never be forgotten that the most carefully selected system is useless if it is not carefully maintained.

What types of wastewater can be treated by soil filters?

Soil filters can treat domestic, communal and industrial wastewaters. However, this brochure is not concerned with industrial wastewaters and wastewaters polluted with significant amounts of toxic substances (such as pesticides, fungicides and heavy metals, mainly from agriculture and industries), and organic wastes which biodegrade very slowly. Mainly domestic and communal wastewaters are considered here because they are biodegradable* (and so amenable to common treatment methods) and widespread.

1.2 Chapter contents

Review of contents

This chapter gives an introduction with some general background information on wastewater treatment and explains the differences between extensive and intensive treatment. Chapter 2 gives an overview of the most important extensive wastewater treatment methods. Chapters 3 and 4 are devoted to soil filters - chapter 3 to basic information on the different types of soil filters and on the processes that operate in soil filters, and chapter 4 to steps towards sustainable application of this technology. Chapter 5 suggests questions to ask when looking for a solution to a wastewater problem and refers to the corresponding passages in the text. Further information, addresses, and a list of relevant literature complete the brochure.

Explanation of technical terms and abbreviations

The use of some technical terms is unavoidable. To help the reader understand terms that may be unfamiliar, a short list of definitions has been prepared. Words marked with an asterisk * the first time that they appear in a chapter, and abbreviations, are defined in the glossary at the end of this brochure.

1.3 Types of wastewater and their characteristics

Wastewater can be characterised in many different ways. A useful criterion in the present context is its origin – whether it is domestic, communal (which may include some wastewaters from trades), agricultural, or industrial. The type of toilet system used determines whether domestic wastewater comes with or without excreta (either urine or faeces or both together).

Another important method for characterising wastewater is according to its constituents: whether they are biodegradable or not, toxic or not, or a combination of both.

Wastewater – waste or resource?

Wastewater can be seen as a friend or an enemy. It can be considered as waste which is hazardous if it is not dealt with in an appropriate way. It can endanger human health directly and indirectly by polluting watercourses and reservoirs. However, it can just as well be considered to be a valuable resource, a liquid fertiliser (see Sections 2.2, 2.4 and 4.4).

1.4 Wastewater prevention

Wastewater prevention measures

Wastewater prevention means taking action to reduce the volume of wastewater that is discharged to the drains.

Wastewater prevention measures - or measures to prevent different components mixing at the source - can considerably reduce the amount of wastewater and consequently the costs of treatment. One of the following methods may be used:

- Keeping urine separate from faeces and grey water, by means of specially designed toilets. This has the advantage of reducing the nitrogen in the main wastewater flow. (Nitrogen is associated with rapid algal growth in lakes – eutrophication – and is undesirable in drinking water. Nitrogen is also an important plant nutrient and so separated urine could be used as fertiliser.) This might become one of the major options in the future but at present it is not yet widely practised.

- Keeping all three components – urine, faeces and water – separated from each other. This is necessary for successful use of dry or composting toilets. At present composting toilets are in use in Central America, Scandinavia and a number of other areas. This system has the big advantage that it does not require water for flushing and so does not produce large amounts of wastewater. Grey water can be dealt with separately.

- Not mixing black water or sanitary sewage (which is a mixture of urine, faeces and toilet flushing water) with grey water. In most current systems these components are mixed. For individual houses, black water can be discharged to a septic tank. However, such an approach for communities would call for not only a functioning sewerage system but also a functioning wastewater treatment plant which removes nitrogen and phosphorus – a costly procedure.

- Aiming for a general reduction of the quantity of wastewater by water saving equipment and changes in habits (such as dual flush cisterns that allow a smaller flushing volume to be selected, cisterns and toilets that use less water, and the use of grey water or treated wastewater for flushing toilets).

These wastewater reduction and "no-mix" strategies should be key components of the wastewater management approach of the future.

1.5 Treatment goals

Goals of wastewater treatment

The goals of treating wastewater are:

- to reduce health risks by reducing the numbers of pathogenic* organisms in the water;
- to reduce surface and groundwater pollution; (Groundwater often serves as a drinking water reservoir.)
- to simplify the treatment of drinking water by reducing the amount of impurities that need to be removed;
- to reduce visual pollution and bad smells;
- to render the effluent fit for reuse.

Wastewater treatment reduces organic compounds and suspended solids

Most of these goals can be achieved by reducing the content of organic compounds and suspended solids. This, however, does not make the water bacteriologically safe for drinking. Considerable additional treatment would be necessary to obtain drinking water complying with the WHO** standards. But treated wastewater* is safe to be released into the environment or reused in agriculture, for example. (See Section 4.4.)

Define needs of wastewater producers and users

The choice of wastewater treatment process depends on the context, the nature of the wastewater and the needs of the user of the treated wastewater. It is therefore important to understand these factors. They include the need to protect water bodies, and clear communication of instructions for reusing the wastewater in agriculture or aquaculture. These factors determine whether partial or full treatment is required.

1.6 Treatment processes

Basic processes in wastewater treatment

Wastewater treatment techniques depend on three types of processes: - physical, biological (including microbiological) and chemical. They can operate in conjunction or separately (Figure 1).

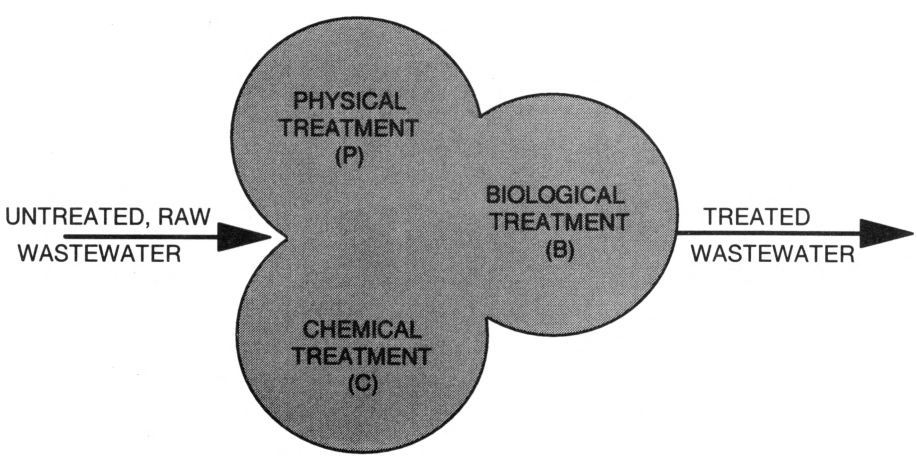

Fig. 1 The basic processes involved in wastewater treatment

** see Directory of Organisations

Basically, these three types of process can occur in three different contexts, which can be called natural, extensive and intensive wastewater treatment. (So far, no standardised terminology has been established, so terms like „low technology", „with low energy input" or "land intensive" may be used instead of "extensive", and „high technology" or „energy intensive" or "land saving" may be used to describe intensive processes.)

Natural wastewater treatment is self-purification

The most extensive wastewater treatment is natural self-purification. Nature just needs enough space and time, the necessary energy being supplied by the sun. Natural treatment or self purification is efficient: There is a German proverb concerning natural purification in flowing water: "Fliesst das Wasser über sieben Stein, ist es wieder rein" (If the water flows over seven stones it will again be clean.) Muslims believe that flowing water is safe to drink. Whilst there is truth in this concept, the proverb must not be taken literally – natural purification takes time. If more wastewater is produced than Nature can deal with, measures must be taken to prevent harm to man and the environment.

Extensive wastewater treatment

In extensive wastewater treatment, natural processes are accelerated. The necessary area is less than what would be needed for self-purification, but it is still considerable. Some types of extensive treatment plant require no artificial energy input, others require a small input. Extensive treatment methods include soil filters (constructed wetlands* ; see Chapter 3), aquaculture systems (see Section 2.2), ponds (see Section 2.3) and irrigation and infiltration (see Sections 2.4 and 4.4).

Intensive wastewater treatment

Larger quantities of wastewater can be treated in a still smaller area and in a shorter time in a highly mechanised treatment plant. Such treatment plants often need a continuous input of chemicals, and have continuously moving parts that need to be controlled, serviced and replaced. Construction and operation consume considerable amounts of energy. Intensive treatment methods include activated sludge, biofilters (trickling or percolating filters), rapid sand filtration (with or without coagulation and flocculation*) and several other processes.

Intensive wastewater treatment was introduced mainly because of its small land requirement - an important advantage in urban agglomerations. However, its shortcomings have long been apparent in both developing and industrialised countries. In many developing countries, plants which were constructed amidst great enthusiasm were soon left to slumber in hopeless inactivity – for many different reasons, such as:

Intensive treatment is often not sustainable

- they often needed chemicals which were not obtainable or were too expensive;
- electricity supplies were not reliable;
- spare parts were not available or not affordable;
- there was a lack of qualified technicians for maintenance and repairs of these highly complex installations;
- the funds ran out before completion of some of the plants;
- the sewerage system (for supplying the wastewater) could not be built for lack of money;
- the sewerage system was blocked or leaking.

Such experiences have been repeated again and again.

There have also been unfortunate failures in industrialised countries, where

- the maintenance and renewal of installations built in rather sparsely inhabited regions cannot be financed from local resources, and
- the mixing – in large central plants – of chemically contaminated industrial wastewater with domestic wastewater containing no problematic chemicals has imposed difficulties for the treatment of the solid residues – the sludge. Since the sludge is contaminated with chemicals it cannot be used to fertilise agricultural fields but must be incinerated at high cost – a practice that is not sustainable.

A wastewater treatment plant that does not function at all or not in a sustainable way, represents a health hazard, a considerable loss of investment, and a political and social nuisance.

1.7 Extensive versus intensive wastewater treatment

The choice of the treatment system: factors to be considered

When it comes to choosing between extensive and intensive systems the following aspects should be considered:

- the density of population,
- the daily volume of wastewater to be treated,
- the availability of land and its price,
- the availability of energy, its price and the reliability of the supply,
- the availability of trained operators, and
- the required quality of the treated wastewater at the outlet of the plant and whether biological treatment alone would be able to achieve this quality or whether additional chemical treatment would also be necessary.

The impact on four main factors of natural, extensive and intensive wastewater treatment are shown in Figure 2.

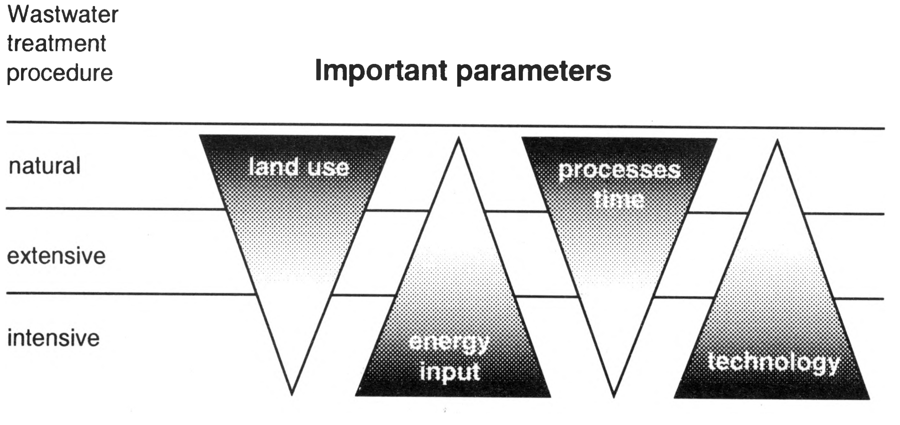

Fig. 2 The influence of the choice of wastewater treatment method on four basic parameters

Intensive systems are preferred where land is scarce, the price of energy is low, access to technology is easy and the quantity of wastewater to be treated is large. Conversely, extensive systems are preferred where land is abundant, the price of energy is high or its supply not dependable, and where the quantity of wastewater to be treated is comparatively low (see Table 1).

Table 1 Comparison of data for extensive and intensive wastewater treatment systems

Parameters	Extensive systems	Intensive systems
Net treatment area (note 1)	2 to 20 m^2 per person (depending on climate)	< 0.1m^2 per person (depending on climate)
Energy requirement	Little or none	10-15 kWh/day (note 2)
Investment costs	Low to high (depending on costs of labour and land price)	low to high (depending on technical equipment, labour costs and land price)
Running costs	Low	High

Notes
1. The figures are estimates and apply to treatment plants for communities of up to 500 persons. They indicate the net area (that is the area required for the actual pretreatment and treatment processes, but not the additional space that would be needed for stores, access routes, perimeter fencing etc.).
2. The energy need for intensive methods is approximately constant for plants treating wastewater from 100 to 500 people

Dependence on external factors

It is also important to evaluate the reliability of the supply of chemicals, spare parts, energy and skilled operators. If the reliability of supply is considered high, this aspect does not represent a disadvantage for intensive methods. If problems are experienced in the supply of any of these requirements, extensive treatment will be more effective over the plant's lifetime of say 20 years. The impacts of external factors outside the control and influence of the responsible bodies (such as security, embargoes, budget cuts) should also be considered.

Community involvement

Most people find extensive systems easier to understand than intensive ones. Therefore it can be expected that interest, a feeling of ownership, and a sense of responsibility among users will all be higher with extensive systems.

Extensive versus intensive = plants versus motors

Apart from material and technical aspects, the choice between extensive and intensive wastewater treatment can – in simple terms – be seen as a choice between dealing with plants and Nature on the one hand, or dealing with motors and screwdrivers on the other. The choice of one or other method influences the requirements for skills and qualifications of personnel at all levels. It is important that decision-makers, planners and engineers beware of walking into the trap of equating a prestigious and sophisticated solution with a sustainable solution.

1.8 Economic considerations

The costs of wastewater treatment systems include the costs for planning, land acquisition, construction, operation and maintenance. The effluent standard (or the degree of purification required) can have a significant influence on the costs.

The requirement for land is typically 5 to 100 times higher for extensive treatment than for intensive methods (see Table 1).

Costs of land

Although no general statements are possible regarding the costs of land, with a good knowledge of the local situation costs can be estimated.

Costs of construction

For the same wastewater treatment capacity, construction costs for intensive systems are higher than for extensive ones because intensive systems require major concrete construction and use sophisticated – and often imported – technology (Boller, 1997).

Operating costs

Operating costs include regular expenses such as salaries (including supervision and overheads), electricity if needed, cleaning of pipes, cutting and disposal of vegetation, and solids removal from pretreatment facilities. These will usually also be higher in intensive treatment than in extensive because of both the large amount of energy required and the salaries of the highly qualified personnel. Even if it is difficult to predict the evolution of the price of energy in the coming 10 to 15 years, it is a fact that intensive systems are sensitive to any significant rise in the price of energy.

Maintenance costs

Maintenance costs of extensive wastewater treatment systems include repairs to broken pumps, pipes and fences, rebuilding and protection of eroded slopes, and replanting where vegetation has died or been eaten.

Intensive systems can be maintained with less labour input per person equivalent*, but they require highly trained personnel. Furthermore, the purchase of spare parts for the machinery may have a big impact on maintenance costs, especially if the parts must be imported.

1.9 Centralised versus decentralised wastewater treatment

Centralised versus decentralised treatment

Extensive wastewater treatment can be applied in either a centralised or a decentralised manner. The same applies to intensive treatment. This is illustrated in Figure 3. For the same arrangement of houses or other sources of wastewater, the figure shows wastewater being collected for treatment in three different ways. Between the two extremes there is a range of possibilities.

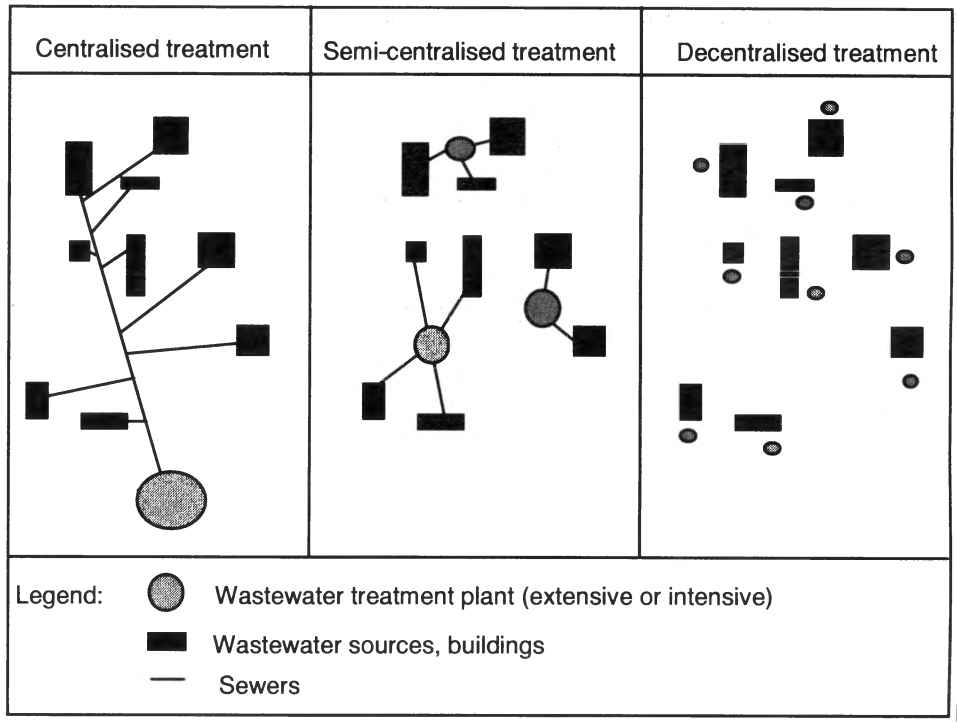

Fig. 3 Centralised, semi-centralised and decentralised wastewater treatment

Centralised versus decentralised = uniformity versus diversity

The decision regarding the extent to which wastewater treatment should be decentralised depends on a number of criteria and system features (see Table 2). Each decentralised unit can be adapted to suit specific local conditions, especially wastewater composition and quality requirements for the effluent. (For example, if there is an area which has some factories producing chemical wastes that prevent reuse of the wastewater, with a decentralised system wastewater that is purely domestic in origin could be treated and used for irrigation, without pollution by industrial wastes. Another example would be if a particular part of the area needed effluent of a particular standard, wastewater from that area might be given a degree of treatment that would be uneconomical for the whole wastewater flow.)

Table 2 Overview of major factors of centralised versus decentralised wastewater management

Parameter	**Centralised**	**Decentralised**
Size	Few larger treatment plants	Many smaller treatment plants
Sewers*	Systems of long sewers with the possible need of pumping in flat areas.	Sewers are short and pumping can often be avoided.
Movement of water	It is taken away from the local area.	It remains in the locality.
Drainage area	Total drainage area forms a single system.	Many individual drainage areas which can be treated individually.
Construction of treatment plant	The one centralised plant must be constructed at one time.	Stepwise construction – individual treatment plants can be constructed one at a time.
Construction costs	Relatively high for sewers due to large sewers and deep trenches. Lower cost for treatment plant.	Relatively low for sewerage as no or few sewers are necessary and trenches are shallow and sewers small. The total cost of all the treatment plants may be more.
Maintenance costs	Relatively high for sewerage because sewers are large and deep.	Relatively low as no or few sewers necessary and sewers are small and shallow.
Operating costs	Per capita relatively low	Per capita relatively high.
Financial reserves	Large reserves needed.	Small reserves sufficient.
User's interest, responsibility	Low due to centralised management and distance.	High if involvement is encouraged and ownership possible.

<u>Note</u> For institutional settings and responsibilities see Table 15

Users' concern and ownership

The concern and involvement of the users is likely to be higher for decentralised systems than for centralised ones. Centralised systems are characterised by a large number of users, most of whom have not been involved in the planning, construction or management of the plant. Moreover, the plants are generally a considerable distance away from the wastewater producers and are therefore rarely in their thoughts. Residents served by the system are therefore usually not very interested nor do they feel responsible for the plant. As long as the organisation responsible for a centralised plant fulfils its technical and public relations duties satisfactorily, this is fine. However, if it neglects its duties, the impact is large.

On the other hand, users of decentralised systems live close to the plant and when a new decentralised system is under consideration, potential users should be involved in the project from the planning phase onwards. They should contribute actively to the implementation of the system (for example, by supplying local resources and manpower) because this fosters a sense of ownership and raises the feeling of responsibility for the management and maintenance of the system – costs included. Supervision of maintenance may be less effective, but the smaller the plant, the smaller the damage stemming from neglected maintenance.

Costs

No general statement can be made regarding the relative costs of centralised and decentralised systems. Nevertheless, decentralised wastewater treatment plants are generally smaller, and their construction tends to be simpler, which influences the costs of construction, operation and maintenance per person served. Experience shows that the reliability of smaller treatment systems is generally better, and so this is an argument in favour of decentralised systems (Boller, 1997).

1.10 Ecological factors

Respect of ecology favours sustainability: Important factors

Choices of technology for wastewater treatment have ecological consequences, which in turn have an influence on sustainability (see Section 4.1). Wastewater, and the techniques used to treat it, have an impact on

- human health,
- water and nutrient cycles*,
- energy demands,
- supply of chemicals and spare parts,
- the number and types of animal and plant species, (biodiversity*), and
- the involvement of the beneficiaries (that is, the community served by the system).

Table 3 lists and comments on the ecological relevance of these factors.

Table 3 List of factors to be considered when planning wastewater treatment, and the impact of these factors on health and the environment

Factors	Health and environmental impacts and comments
Human health	The risk to human health from treated wastewater should be negligible or very slight.
Water cycle*	The local water balance (between use and replenishment) should be maintained to safeguard supplies of drinking water from groundwater. The supply of irrigation water for agriculture may be vital.
Energy	Low energy consumption is preferred because energy generation causes pollution and involves high costs. Energy costs are likely to increase in future (see also Figure 2 and Table 1).
Nutrients	The local nutrient cycle* should be safeguarded for garden, agricultural and forestry production. (This means that nutrients taken from the soil should be returned to the soil.)
Biodiversity	Treated wastewater should have minimal impact on wild animals and indigenous plant life.
Operational standards	Standards should be high so that all wastewater is treated. (See below.)
Sense of responsibility	It should be generated by involving and informing users so that better treatment results are obtained.

Water and nutrient cycles

In natural wastewater treatment the water and nutrient cycles are largely undisturbed (remaining closed cycles) as long as the capacity for self-purification is not exceeded. But these natural cycles become more and more disrupted, as construction and higher energy inputs are required for wastewater treatment. In intensive wastewater treatment, both water and nutrients contained in the wastewater are transported further away from their origin, and are thus less and less likely to replenish the local ground water, or enrich the local soils with nutrients. Nutrients may even be incinerated. As a consequence fertiliser and soil conditioners may have to be imported. These effects may be negligible in small decentralised plants but be quite significant in larger, centralised facilities.

"Robustness" of extensive treatment

Inherent in extensive wastewater treatment is a "robustness*" which contrasts with the higher vulnerability or sensitivity of intensive systems. Biological factors contribute largely to this "robustness". In natural, extensive and intensive wastewater treatment, basically the same types of bacteria are involved. However, in extensive systems, bacteria have more diverse living areas, more ecological niches*, resulting in a more diverse and richer bacterial flora than in intensive plants. Moreover, bacteria in extensive systems are mostly attached to soil, media* or vegetation (fixed film attached growth).

Diverse and numerous bacteria species, long retention time

The large volume in extensive systems (such as ponds) also enhances robustness since fluctuations in flowrates* and composition are attenuated by the large volume of water present. Without these phenomena, surges of stormwater might flush the bacteria away and stop the plant from functioning for days or weeks until a new bacteria population became established, as happens in intensive systems. In extensive systems slow-growing bacteria have a much better chance to develop than in intensive ones. This and the longer residence time allow better breakdown of organic substances that degrade slowly, in comparison with intensive plants.

Inertia

Another aspect of robustness is inertia: influences exerted on the system rarely show a quick effect. This is positive when an accident happens, but it is tiresome when trying to trace the cause of a problem. During the relatively long time of retention (or residence) several parameters influence the operation of the treatment plant simultaneously, and it is often not obvious which parameter causes which effect.

2 Extensive wastewater treatment

2.1 Introduction

Suitability of extensive wastewater treatment methods

In sparsely inhabited regions, in smaller towns or in periurban areas of larger cities, extensive wastewater treatment techniques have many advantages. Nevertheless a careful evaluation of their suitability in each specific context is needed (see Section 4.1). The most common extensive treatment systems are shown in Table 4.

Table 4 The main extensive wastewater treatment systems

System	Main features and components	Application	Remarks	Examples
Soil filters (constructed wetlands*)	Soil-based system ■ planted or unplanted ■ aerobic or anaerobic ■ at surface or below surface	Tropical, arid temperate or continental climates. In areas of relatively high population density (as they have the lowest land requirement of the extensive systems) See Table 5.	Provide full treatment. Treated water is suitable for different uses: e.g. ■ irrigation (consider hygienic regulations) ■ cleaning (of equipment) ■ watering animals	Australia Britain Denmark Estonia Germany Poland Switzerland Thailand
Aquaculture systems	Aquatic system. Usually combined with ponds	Tropical climates. Some experimental plants in temperate climates. Considerable experience and management skills necessary	Provide full treatment or polishing. Production of vegetables, fodder and/or proteins (fish)	China India (Calcutta) Thailand Vietnam
Wastewater pond systems	Aquatic system. Aerobic and/or anaerobic	Tropical or temperate climate where sufficient land is available	Provide full treatment or polishing. Polishing ponds* can serve as fish ponds, vegetable ponds and/or for recreational purposes (landscaping but not swimming)	Colombia France Germany India Israel Jordan Kenya Peru USA
Irrigation and infiltration. Requires careful supervision when using untreated wastewater	Land system	Agricultural regions, especially where water is scarce. Low capital cost (very little infrastructure is necessary). Permeability of ground must be suitable	Fertilising with treated wastewater. Irrigation with untreated wastewater not recommended for health reasons. Prejudice against produce.	Argentina Australia India Israel Jordan Mexico Morocco Peru Saudi Arabia Tunisia, USA

Extensive and intensive methods combined

Extensive and intensive wastewater treatment methods can be combined, as discussed in Section 3.10.

2.2 Aquaculture systems

Goals: Production and wastewater treatment

Aquaculture systems have a long tradition in China and many other countries in Southeast Asia. Their main purposes are the production of biomass* and wastewater treatment. Biomass production includes fish farming and the cultivation of aquatic vegetables for man; algae, Lemna, and other plants as food for fish or fodder for domestic animals. The types of aquatic plants that are selected should be suited to high nutrient contents and to the local conditions. Water hyacinth (Eichhornia), duckweed (Lemnaceae) and others can be harvested and used as fodder. Some aquatic plants (e.g. water hyacinth) cannot survive in freezing temperatures and so should not be used in temperate and continental climates.

Lifetimes

In tropical climates, aquaculture produces crops all year round whilst in temperate climates heating is required during the winter. Aquaculture needs experienced and skilled management since there are many highly interconnected parameters and processes to be considered (see Figure 4). No general statement can be made about the lifetimes of aquaculture systems since they are dependent on the climate and on many other factors.

Expected effluent quality

A well planned, designed and maintained aquaculture system can produce a good quality of effluent, with a BOD_5* in the order of 30 mg/litre or less and a suspended solids concentration of less than 30 mg/litre.

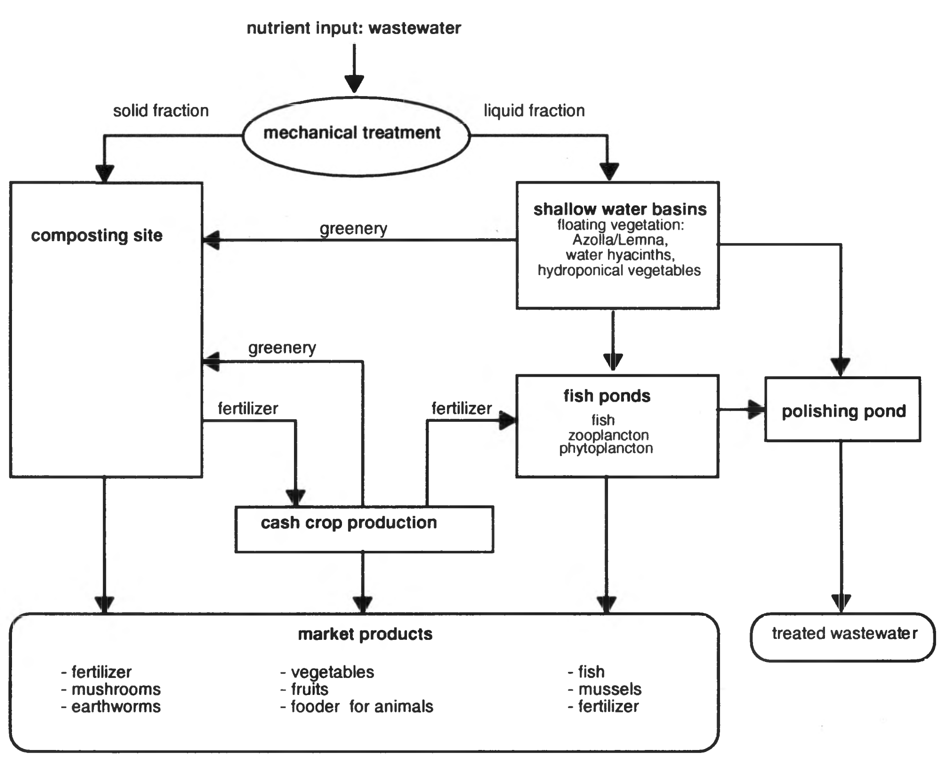

Fig. 4 *Example of flow chart for an aquaculture system*

2.3 Pond systems

Ponds for wastewater treatment are widely used and many publications are available on this topic (see the Bibliography).

Different pond types

Waste stabilisation ponds are a reliable, cheap, robust and effective method of treating wastewater. In terms of the microbiological activity there are aerobic*, anaerobic and mixed aerobic-anaerobic ("facultative") ponds. The first ponds in the series are mainly designed for BOD removal, and maturation (polishing*) ponds are used for pathogen* removal. Wastewater ponds are used alone or in combination with other wastewater treatment systems. (Figure 7 shows a settling* pond.) Due to their size they are quite robust (i.e. insensitive to variations in quantity and quality of the incoming wastewater; see Table 5).

Area requirement

Ponds function all year round

Most ponds are relatively shallow and have large surface areas. The area requirement per person for full pond treatment with three or more ponds in series lies between 2 and 20 square metres, depending on the minimum ambient temperature. In temperate and tropical climates ponds function all year round. In continental climates, however, only pretreatment (in particular sedimentation*) takes place all year round. Biological treatment depends on the local climatic and microclimatic conditions, since anaerobic treatment does not take place below 15 °C, and there is no significant aerobic activity below about 2-3 °C (see Figure 9).

Smells, mosquitoes, wildlife

Depending on the weather conditions, ponds, particularly anaerobic ones, can produce unpleasant odours. During the warm season, they may become mosquito breeding sites (but mosquito populations can be controlled with proper maintenance). In polluted water Culex mosquitoes are found, in good quality water Anopheles mosquitoes. Mosquito breeding can be reduced by removing vegetation that is growing in polishing ponds* and by breaking up any floating scum so that it sinks (because this deprives the female mosquitoes of their egg-laying sites). In certain regions, wild animals may come to the ponds to drink, damaging the side slopes as they do so. Because of this, and erosion caused by heavy rainfall, measures should be taken to protect the banks against erosion and damage.

2.4 Irrigation

Limited to growing season

Wastewater irrigation has been used since ancient times. It brings not only water to the crops but also nutrients. The vegetation and the soil provide treatment. Daily wastewater application should be 3 - 5 litres of wastewater per square metre less the expected precipitation. Irrigation should be limited to the growing season. In temperate and continental climates wastewater storage, usually in 3 - 5 m deep ponds, will normally be necessary for winter periods. Storage ponds provide a degree of pretreatment. Wastewater may be treated in different ways before it is used for irrigation. Pretreated wastewater and treated wastewater from soil filters, from aquaculture systems or from ponds can all be used for irrigation.

2.5 Soil filters (constructed wetlands)

Definition

Soil filters are basins in the ground of appropriate size and shape, as shown in Figure 5. Generally they are made watertight (with clay, plastic sheeting or concrete) and filled with an appropriate filter medium. (See Section 3.6.) The water circulates through the medium from an inlet to an outlet structure (Section 3.7) and becomes clean on its way through the filter.

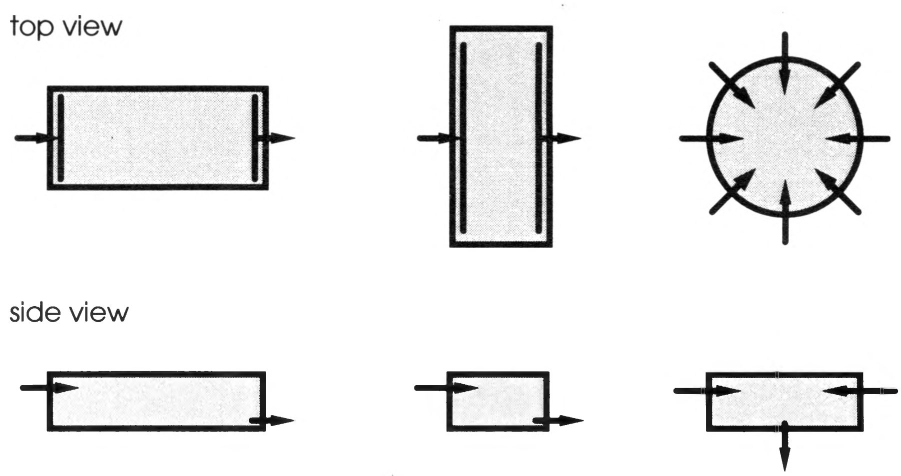

Fig. 5 Different layouts for soil filters (vegetation not shown)

Terminology

The term "soil filter" designates several types of wastewater treatment plants. Mostly, they support vegetation, but some soil filters have no vegetation and yet also function.

Synonyms

The soil filters with vegetation are called

- planted soil filters
- planted sand filters
- sand plant filters
- constructed wetlands
- root zone systems
- reed beds
- green wastewater treatment plants.

Soil filters without vegetation – whether at the surface or below it – are called

- sand filters.

The basic features of soil filters pertain to the type of media, the size and shape of the filter, inlet and outlet zones, direction of the water flow, frequency of feeding the wastewater to the filter, hydraulic and organic loadings*, whether the filter supports vegetation, and, if so, what type of vegetation is growing there. (See Table 11.)

Suitability of wastewater for treatment

It is stated in Section 1.1 that soil filters are used to treat many different types of wastewater, but in the context of this brochure only the biodegradable wastewaters are considered. Domestic and communal* wastewaters are normally biodegradable*. Wastewaters from food processing factories are biodegradable, but due to their high concentrations and often unbalanced nutrient content, they need special attention.

Sand filters can also be used as polishing filters for partially treated wastewater (see Section 2.4).

Soil filters are tolerant to changing concentrations and quantities of wastewater (see Table 5). Retention times vary from hours to days.

No smells, no mosquitoes

No smells originate from soil filters and there is no danger of mosquito breeding as the water circulates below the surface.

Life time

The lifetime of well-maintained soil filters can be between 20 and 50 years.

2.6 Comparison of extensive treatment methods

An attempt to compare the different extensive treatment methods can only be qualitative as there are many variables for each method and many different climatic, and other influences. However, Table 5 shows some qualitative differences.

Table 5 Soil filters compared to other extensive treatment methods

All systems are considered to be of similar size, e.g. for the same number of users and at comparable treatment efficiency. The comparisons are qualitative and refer exclusively to the four systems compared. Shaded frames indicate treatment methods which clearly differ from others regarding a particular parameter

Parameter	Soil filters	Ponds	Aquaculture	Irrigation
Sensitivity to variations in quality and quantity of incoming wastewater	low to medium	negligible to low	low to high	low to medium
Energy demand for operation	zero to low	zero to low	zero to medium	zero to high
Land requirement	little	medium	medium to high	high
Health risks	negligible to low	medium to high (1)	medium to high (1,2)	low to high (2)
Impact of site conditions on operation (See Section 4.2 and Table 12)	high	medium	high	medium
Importance of containing the wastewater	medium	medium to high	medium to high	Not required
Suitability in different climatic conditions	high	low to medium	low to medium	low to medium
Probability of malfunction	low	very low	medium	very low
Maintenance effort required	medium	low	high	very variable
Technical sophistication	high	medium	medium to high	very low to low
Construction costs	high	medium to high	medium to high	low
Maintenance costs	medium	low	medium to high	low to medium

Notes – Health risks (1) Drowning and mosquitoes (2) Contaminated crops

3 Treating wastewater with soil filters

3.1 Introduction

Soil filters function either as the complete treatment process or in combination with other systems. During the passage of the wastewater through a soil filter (and more generally through most wastewater treatment plants) physical, biological and chemical processes take place (see Figure 1). A basic understanding of these processes is necessary for planning a treatment plant that will provide the conditions that will allow these processes to operate most effectively.

3.2 Physical pre-treatment (primary* treatment)

For soil filters physical pre-treatment is essential for operational reasons – mainly to prevent the clogging of pipes and filter media. There are several possible pretreatment methods for the different constituents of the wastewater.

Screens, grit chambers, sand traps

Screens separate large objects from the wastewater. In grit chambers and sand traps the velocity of the wastewater is reduced so that finer particles settle to the bottom and are retained. The lower the velocity, the smaller the size of particle that settles.

Grease traps

Grease traps are necessary for wastewaters containing considerable amounts of fatty or oily substances. Wastewaters from restaurants, slaughterhouses, fish processing factories and car servicing stations are likely to contain significant amounts of oils or fats. Home-made soaps also add grease to the wastewater.

Suspended solids are removed by sedimentation

Suspended solids can be separated from wastewater by sedimentation in septic tanks, sedimentation tanks (Figure 6), settling ditches and settling ponds (Figure 7). If biological processes occur in these installations, they are generally anaerobic*. The residence time of the water in the tank should be at least two hours and the water should flow no faster than a few millimetres per second. When dimensioning a sedimentation tank it is important to include room for the settled material. The frequency at which the sludge should be removed from the tank or pond depends on the size and the usage of the installation. The accumulated solids may need to be removed from some settling ponds or sedimentation tanks only once every two to three years, but in others sludge removal may be needed as often as two to three times per year, or even more frequently. To avoid health risks, the sludge must be treated appropriately (for example, by composting it).

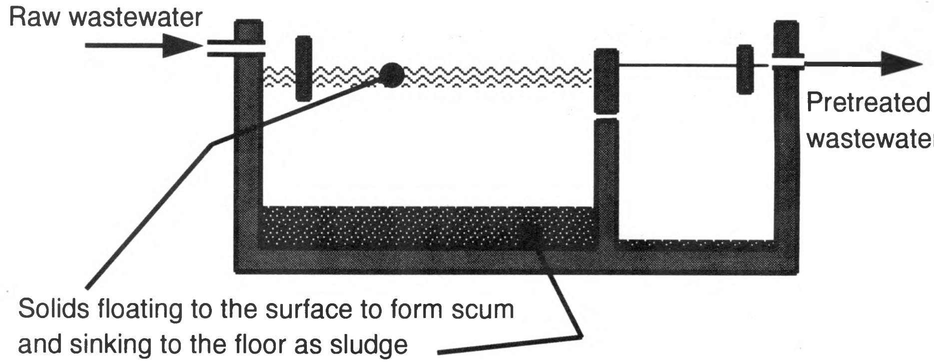

Fig. 6 Pretreatment using a sedimentation tank

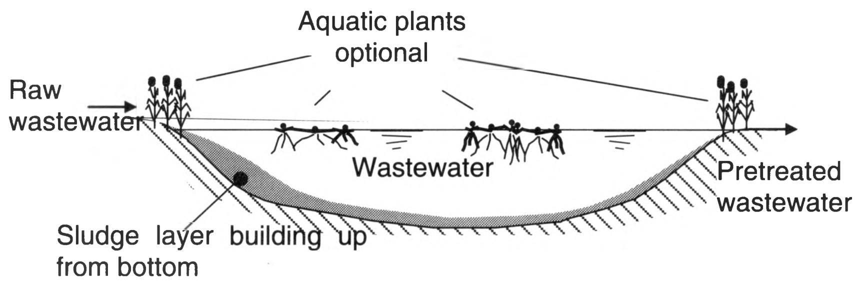

Fig. 7 Pretreatment using a settling pond (longitudinal section)

When using soil filters, pre-treatment in settling ponds (Figure 7) is only recommended when :

- there is sufficient space available (but soil filters may have been chosen because the available area was restricted – Table 5);
- there would be no danger from mosquito breeding in the planned pond (but soil filters may have been chosen because of the risk of mosquito breeding – Section 2.3);
- the preferred treatment process in the soil filters is anaerobic (because wastewater from ponds would have a low oxygen content which would not favour aerobic* treatment in the soil filters).

Filter out suspended solids

Suspended solids can be retained by filtration through a "mineralisator"* or filter sacks as shown in Figure 8. This allows an aerobic storage with virtually no smell. At regular intervals (generally one to several weeks) a layer of chopped straw, reed or similar material is spread over the settled sludge in the mineralisator. (In filter sacks this step can sometimes be omitted.)

When a container or filter sack is full, it is left to drain and another one is filled. The contents of the containers or filter sacks should be composted, taking care that the temperature rises sufficiently to kill pathogenic* organisms in the material.

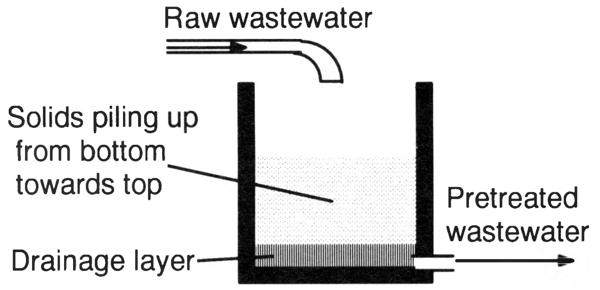

Fig. 8 *Pretreatment with mineralisator*

Comparison of sedimentation and filtration

Pre-treatment by filtration is more labour-intensive than by sedimentation but filtration has the advantage that it is easier to obtain a hygienically safe fertiliser using the solids removed in a filter.

Finally, it must be stressed that the decisive factor for good pretreatment is not so much the issue of which process is chosen, but much more the way in which it is maintained. It should be monitored carefully and the solids or sludge should be removed in time.

Maintenance of pretreatment systems is discussed in Section 4.3.

3.3 Biological treatment

Reducing the amount of organic compounds

The major goal of biological wastewater treatment is to reduce the concentration of organic compounds in the wastewater as much as possible.

The organic material can be decomposed to form mainly carbon dioxide CO_2 (a gas) and H_2O (water). If untreated wastewater is discharged into surface water or groundwater, the decomposition of the organic compounds takes dissolved oxygen from the receiving water. (The amount of oxygen used in this decomposition is measured in the BOD_5* test to indicate the amount of organic matter in the water.). If the amounts of phosphorus and nitrogen in the wastewater are not reduced, discharge of the wastewater into lakes and rivers causes rapid and problematic growth of algae (mainly due to phosphorous). Large inflows of wastewater can cause fish to die (because the oxygen is used up) and wastewater can also pollute the groundwater.

Bacteria in biological treatment

In biological treatment, bacteria feed on dissolved and particulate organic materials (i.e. fats, proteins, and carbohydrates) in the wastewater. Some of this organic material is used to provide energy for the bacteria, and some is incorporated into the growing number of bacteria cells. Bacteria that can use wastewater in this way occur naturally; they include many species with quite different - even contradictory – requirements (for example, some need oxygen (aerobic) and others flourish where there is no oxygen (anaerobic). The better the living conditions for the bacteria, the more efficient is the treatment. Good living conditions include optimal temperatures (between 1° and 35°C; see Figure 9), a balanced nutrient supply, the absence of harmful substances in the wastewater (such as pesticides, fungicides, and heavy metals) and sufficient time for development (see also Section 1.10). In planted soil filters the variety of bacteria is higher than in sand filters (which support no vegetation). Figure 9 lists factors that should be considered when deciding whether anaerobic or aerobic treatment is preferable.

Aerobic decomposition

In aerobic conditions, many bacteria types take part in decomposition. Aerobic bacteria can adapt fairly well to certain poisons, they are tolerant of temperature variations and the processes are faster than in anaerobic conditions. They have a better removal efficiency and this results in lower effluent* concentrations.

Anaerobic decomposition

Anaerobic treatment is basically a two-stage process which occurs in the absence of oxygen. The processes are sensitive to temperature and to the presence of poisonous substances. They may cause unpleasant odours but they produce biogas (which can be used as a fuel when produced in bioreactors but cannot be collected from anaerobic ponds or soil filters.) Anaerobic decomposition is often used as a pretreatment for highly polluted wastewaters such as industrial wastewaters.

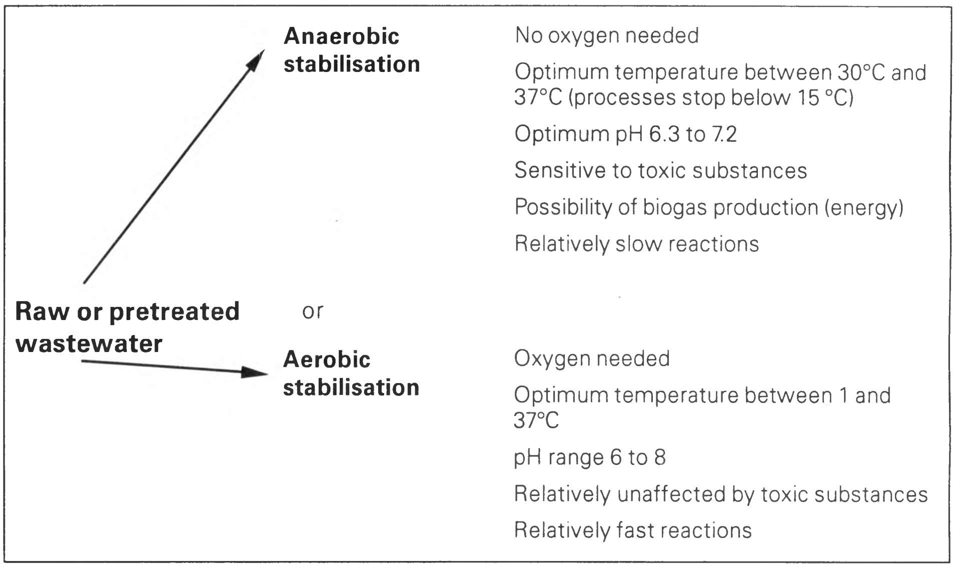

Fig. 9 Basic features of aerobic and anaerobic wastewater treatment

3.4 Chemical treatment

In chemical treatment some of the substances in the wastewater react with other substances. In extensive* wastewater treatment no chemicals are added so only the substances naturally present react together. It is possible to induce reactions by adding chemicals, but in the vast majority of cases this is not necessary. Phosphates, for example, can be precipitated by adding a chemical. Such chemical involves extra costs and inputs. A costly dosing device must be installed to control the addition of the chemical, a regular supply of the chemical is needed, precipitated sludges must be disposed of, and maintenance and control are essential. Therefore induced chemical treatment is normally not recommended for extensive treatment plants.

3.5 Horizontal and vertical soil filters

Horizontal and vertical systems

Wastewater circulates through soil filters either horizontally or vertically (or sometimes diagonally). Horizontal-flow systems need rather more area but are easier to build, whilst vertical-flow systems need rather less area but are more sophisticated (Figure 10). Their depths (d) range between 50 cm and one metre.

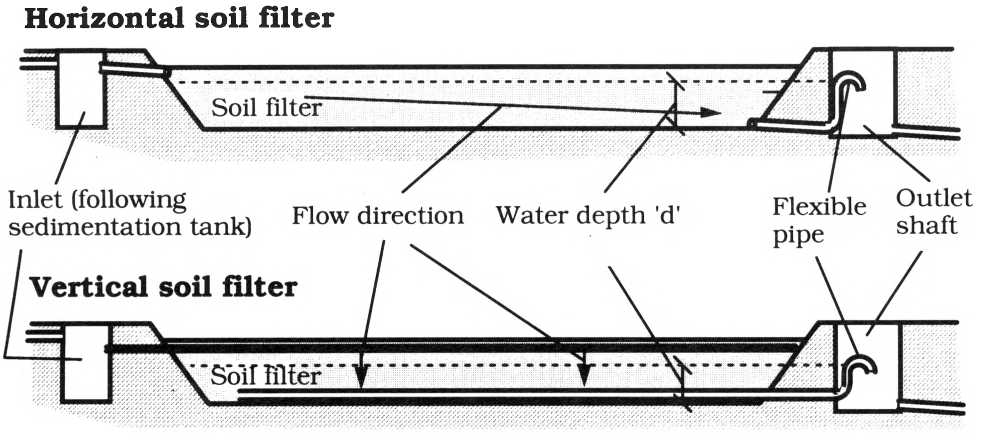

Fig. 10 Longitudinal sections through horizontal and vertical soil filters (vegetation not shown)

3.6 Media

Fine medium
→ high purification
→ high clogging risk

One of the most important parts of a soil filter is the media. As a general rule the finer the media the better the purification efficiency. However, it is equally true that the finer the media the less the hydraulic conductivity and thus the higher the probability of clogging or blocking of the filter by the accumulated deposits. It is therefore a test of the designer's skill and experience to find the best media for each situation. Gravel (4 - 50 mm) and sand (0.1 - 4 mm) are generally used to fill filter beds. The sand should be washed to remove clay or loam and so reduce the risk of clogging. Local soil (sandy loam, loamy sand, or sand) may be used for pretreated wastewater e.g. for polishing filters. Broken tiles, leca* or other porous media can be used instead of gravel. If a source of readily available carbon is needed for the micro-organisms, it may be possible to provide this carbon by choosing a media that also provides the needed carbon. (This extra carbon for the bacteria may be needed to balance the other nutrients in the water.). Such might be the case in a polishing filter in which the easily degradable carbon in the wastewater has already been depleted. Straw, compost, wood chips or similar materials are suitable to meet this particular need. Contradictory opinions exist as to whether the addition of pieces of iron helps to improve the removal of phosphate.

Filters may be filled with only one media or with layers of different media, as shown in Figure 11.

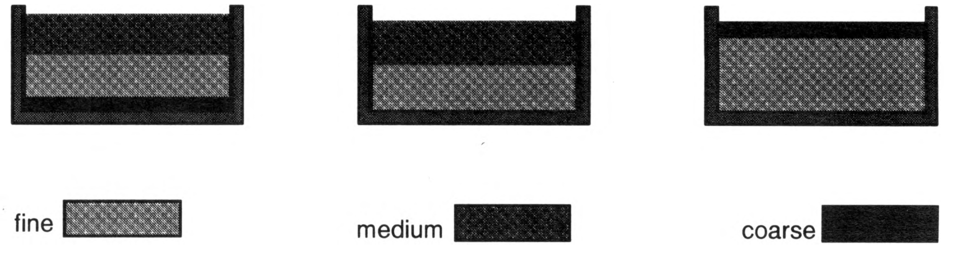

Fig. 11 *Cross sections through vertical soil filters showing three filling options.*

Chemical and physical characteristics of media

The chemical composition of the media (e.g. whether the rocks are of calcareous or basaltic origin) and the size and shape of the grains (whether they are broken and angular or rounded, and their grain size) are all important properties. If a choice is available, media with a calcareous component are preferred (since they provide a buffering* effect). Plants clearly prefer rounded grains to sharp, angular shapes. It is important to keep a sample of the media in its original state to allow monitoring of any deterioration of the material.

3.7 Inlet and outlet zones

The inlet zones of soil filters (Figure 12) are particularly prone to clogging because nutrient-rich wastewater causes intensive bacterial growth. Particularly in horizontal filters it is strongly recommended that the inlet should be filled with a coarse material (such as gravel or broken tiles, as shown in Photograph 1), because fine media would quickly become clogged.

In vertical filters the inlet pipes (which are like drainage pipes, having holes or slots at close intervals) can either be placed onto the filter surface or slightly below it, as shown in Photo 1). Pipes laid on the surface can be checked more easily but they are more vulnerable to damage and the water in them is more likely to get frozen in a cold climate.

Pipes within the medium are better protected but it is more difficult to verify whether their outlet holes are functioning or blocked.

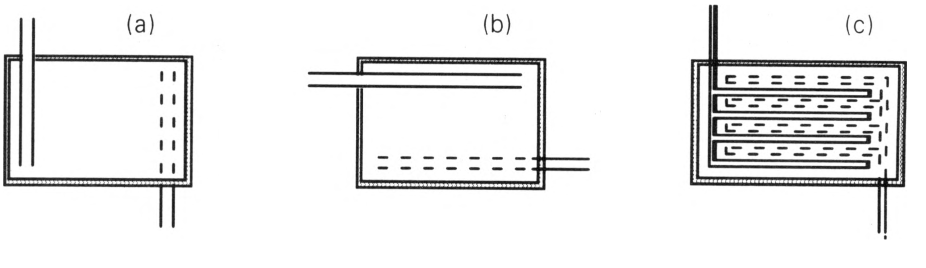

Fig. 12 *Inlet and outlet options for soil filters: views from above.*
(a) and (b) horizontal or diagonal flow, (c) vertical flow.
Solid lines indicate inlet pipes at the tops of the filters, broken lines show outlets, at the bottom.

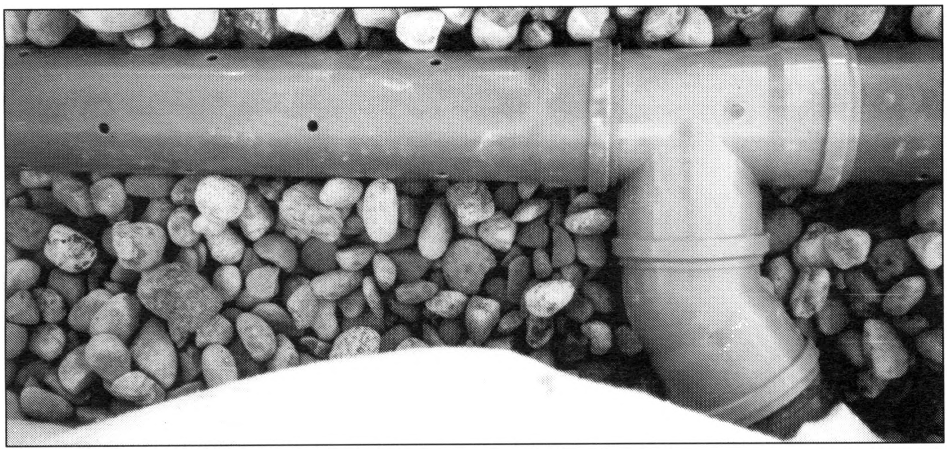

Photo 1 *Inlet zone of a soil filter.*
The photograph shows the inlet pipe of a horizontal filter being laid in coarse material.

For both types of filter, easy access for cleaning and maintenance must be ensured. Coarse material should be placed around the collecting pipes in the outlet zone to prevent fine material accumulating around the pipes because this reduces the risk of the media near the outlet becoming clogged.

The outlet zone discharges into an outlet control chamber (Figure 13). The depth of water in the filter can be adjusted by means of a flexible pipe in this chamber – this pipe can be raised or lowered and fixed in any chosen position. In newly planted filters the water level must temporarily be kept just below the surface to allow the roots of the plants to reach the water.

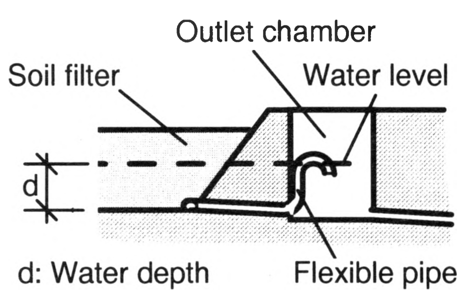

Fig. 13 *Regulation in the outlet control chamber of the water table in soil filters.*

3.8 Options for feeding wastewater to filters

Continuous, intermittent, periodical

Wastewater can be fed to the soil filters in a continuous or intermittent manner. If the wastewater is fed continuously the flow varies according to the rate at which the wastewater reaches the plant unless there is a pond upstream that absorbs the fluctuations. Intermittent flow can result from periods of pumping or be achieved by a mechanical device, such as buckets that tilt when they are full or siphons that discharge when the water level in a tank reaches a certain depth. (Problems can arise when siphons are used with wastewater.). If two or more filter beds are available, they are normally fed alternately, each one receiving all the flow for a period which may be as little as a day or as long as a month, or even up to one year. During periods when there is an unusually high input of wastewater, the filters may be fed together, in parallel.

There is an important difference between horizontal and vertical filters in terms of the way they are fed with wastewater. Horizontal filters are normally fed continuously. Even if the flow is alternated between two or more beds, the wastewater may be allowed to flow continuously to one bed for days, weeks or even months. On the other hand, wastewater is fed to vertical filters in short bursts lasting for about one minute, on about six occasions each day. Each burst fills up the bed, driving out the stale air in the bed so that it can be replaced by fresh air when the water level gradually falls. This intermittent feeding also uses the filter area more efficiently, thereby reducing the required area. An additional advantage is that each surge flushes the holes in the pipes, dislodging bacterial growths. The price for these advantages of vertical filters is the need for extra equipment to provide the pulses of flow and to ensure even distribution of the water over the filter area.

3.9 Hydraulic and organic loading

Hydraulic loading

Data on hydraulic loadings* of soil filters show considerable variations in operating practice. Rates vary from 40 mm/d to 1000 mm/d (which is 40 litres/m^2.day to 1000 litres/m^2.day). This range is so wide because of large variations in media* and qualities of wastewater. Hydraulic loading is not the most decisive factor for dimensioning a soil filter, but it must be taken into consideration. Higher hydraulic loadings mean shorter residence times and therefore less effective purification (See Section 3.11).

Organic loading

Organic loading of the wastewater relates to the amount of excreta* and grey water* produced per person expressed in three different ways: BOD_5, COD* or TOC* (Table 6). Table 6 shows the considerable differences in organic loading, depending, in particular, on the presence or absence of excreta and urine in the wastewater. The organic loading has a direct influence on the required size of soil filters (see below) and consequently on the costs.

Table 6 Pollutant loads of domestic wastewater, shown as grams per person equivalent each day.
All values show wide variations; but for a specific wastewater source the relative loads for the four types of wastewater differ little from the data in this table. (Based on data from VSA, 1995 and Larsen and Gujer, 1996)

	Domestic wastewater (flush toilets)		**"No-mix* strategy" wastewater**	
Type of wastewater / Parameter	Raw wastewater	Settled wastewater	Raw wastewater without urine	Raw grey water
Suspended solids	90	50	90	8
Organic material	BOD_5 75 TOC 50 COD 150	BOD_5 50 TOC 35 COD 105	TOC 44	TOC 15
Nitrogen	14	12	2	0.2
Total phosphate	2.2	1.9	0.95	0.7 (1)

Note (1) Depends on the phosphate content of detergents

3.10 Net treatment area and overall size

Size depends on local conditions

The size of soil filters depends on several parameters such as the local climate, the quantity and nature of the wastewater, the required effluent quality and the desired lifetime of the filter. The areas required for the treatment process can be estimated by taking into account the design organic loading rate, the organic biodegradable load* produced per person (i.e. the person equivalent*) and the population to be served. In industrialised countries (with water distribution systems which encourage wasteful water consumption), the per capita wastewater production lies between 80 and 170 litres per day, corresponding to 50 g BOD_5 per day after sedimentation (Table 6). To provide a rough indication of the areas required, Table 7 presents the net area required per person for treating domestic wastewater in soil filters in temperate and tropical climates. Not surprisingly, recommendations on sizing vary greatly (ATV-A 262 1998; Boutin et al., 1998; Cooper, 1990; Cooper et al. 1996; Reed, 1990; VSA, 1995).

Combinations of extensive systems are possible. (Examples are: ponds and soil filters, soil filters and irrigation, aquaculture and soil filters). If the availability of land is restricted, a combination of extensive and intensive treatment should be considered.

Table 7 Net treatment area per person for wastewater (including excreta and grey water) in vertical and horizontal soil filters in different climates. Areas in square metres per person equivalent.

Necessary area in different climates

Wastewater treatment system	Temperate, continental climate	Tropical climate
Vertical soil filters	4 - 8	1 - 3
Horizontal soil filters	4 - 10	1 - 5

In particularly cold climatic conditions the required area may be larger, and in tropical conditions the requirement is at the low end of the ranges. For settled grey water the net treatment area can be reduced considerably (as only small amounts of nutrients are to be removed – Table 6). In this case the grey water can be infiltrated into the ground after passing though a small bed of gravel or other media where bacteria can provide the small amount of biological treatment that is necessary.

Land is needed not only for the filter itself (the "net treatment area") but also for manholes, inspection chambers, access and passage ways, fencing, storage etc. – adding, with the net treatment area, up to the total required area. This has to be calculated for each individual treatment plant. For small plants the total area is approximately 150 per cent of the net treatment area, and for large ones it is 130 per cent.

3.11 Soil filters in different climates

Seasonal variations

In climates with marked seasonal variations, a planted soil filter changes considerably in appearance during the year because of the development of the vegetation. Photographs 2 (a to d) show a soil filter in a temperate climate in each of the four seasons.

Photo 2 Planted soil filter in a temperate climate during the four seasons. a) Early spring, b) Early summer, c) Autumn, d) Winter

Dry climates

In dry climates, soil filters should be protected from drying out. If the filter does not receive sufficient wastewater, the vegetation may dry and wilt, and certain types of media might form cracks. However, the most important consequence could be the effects on the community of bacteria and other organisms that are needed to treat the wastewater. One method of protecting soil filters is to place them underground, another one is not to plant them but to cover them with wooden boards, mats or other material.

Wet climates

In regions with high precipitation rates (above 3000 mm per year) or rainy seasons (e.g. monsoon rains), filters may need to be covered with a roof. If significant quantities of rain enter the filters, the residence time of the wastewater in the filter is so much reduced that treatment efficiency suffers. (See Sections 3.9 and 3.13.). Another treatment system might be more suitable in climates with high rainfall.

Roofing over or other protective measures may be necessary when

$$\frac{\text{annual precipitation in mm}}{\text{duration of rainy season in days}} \times \frac{\text{surface of soil filter in m}^2}{\text{wastewater flow in litres per day}} \geq 2$$

Continental climates

In continental climates soil filters need to be protected from deep frosts by an insulating layer (of reeds, straw, wood chippings or snow). Aerobic soil filters are better suited to such climates than anaerobic soil filters (See Table 4).

Soil filters function all year round

Soil filters typically function throughout the year in all climates, provided that wastewater flows regularly to the filter bed. This means feeding the filter at least once a day in dry climates and once a week in temperate climates.

3.12 Vegetation on soil filters

Vegetation

It is widely believed that the vegetation plays an important role in extensive wastewater treatment. In some ways this is true, but not with regard to removing nutrients from the wastewater. Bacteria and their predators are mainly responsible for removing nutrients. Plants* nevertheless fulfil numerous functions:

The many functions of plants

- Through their fine roots aquatic plants bring oxygen in small quantities into the soil and water.
- Through their fine roots they also excrete substances which create micro-regions with particular living conditions that suit some types of bacteria. In this way they encourage bacteria diversity and, as a consequence, the robustness* of the treatment process.
- They can lose water by transpiration through their leaves (particularly when humidity is low) and so considerably reduce the amount of effluent. This results in an increase in the concentration of the remaining nutrients since the organic load does not change.

- Plants act as temperature buffers, insulating the filter in winter and shading it from the sun in summer.
- Their roots can prevent compaction of the media and secure percolation through the media.
- Some species – such as Phragmites (reeds), Thypha (bulrushes) and Salix (willow) – can be harvested and used as roofing, insulating, construction or heating materials.

Plants used in wastewater treatment must satisfy three requirements:

- They must be able to thrive in waterlogged soil
- where the water has a high nutrient content, and
- they must be adapted to the local climate.

3.13 Treatment efficiencies

The required quality standards for effluents are defined by central or local authorities. Both absolute and relative values can be found. The relative standards are related to the local environmental situation. As an example, the discharge limits of the European Union are indicated in Table 8.

Table 8 Required discharge limits for treated domestic wastewaters in the European Union (21 May 1991)

Parameter	Size of plant (2)	Concentration mg per litre	Minimum reduction per cent (3)
BOD_5		25	70 - 90
COD		125	75
Suspended solids	large small	35 60	90
Total phosphorus (1)	large small	1 2	80
Total nitrogen (1)	large small	10 15	70 - 80

Notes:
(1) In sensitive areas where there is a danger of eutrophication.
(2) Large treatment plants – more than 10 000 PE;
smaller treatment plants 2 000 to 10 000 PE.
(3) The load at inlet is considered to be 100%.

Expected performance

For a well planned, designed and maintained soil filter, the BOD_5 of the effluent would be expected to be of the order of 20 mg/litre, the suspended solids less than 20 mg/litre, and total phosphorous 1-10 mg/litre. Thus, soil filters can meet European Union limits (Table 8) except for the phosphorus concentration – the biological phosphorus retention may not be sufficient to achieve the required standards. However, it is important to consider also the flowrate* of the effluent in relation to that of the receiving waters* which are to be protected, and the significance of the supply of phosphorous from other sources (such as domestic and wild animals).

Good reduction of pathogenic bacteria

The objectives of wastewater treatment may be different in different situations. Conventional treatment in temperate, industrialised countries has focused on the need to reduce the concentrations of suspended solids and BOD_5 so that oxygen levels in rivers and lakes do not drop too far. More recently, concerns have focussed on preventing eutrophication and discharges of toxic chemicals. Pathogenic organisms may not be a great concern because people do not bathe in the rivers or use wastewater for irrigation, and all drinking water supplies are treated. However, in many situations in warmer climates there is much greater contact with river water and possibly treated* wastewater, and so the transmission of disease by wastewater is of much greater concern. In such situations the reduction in numbers of pathogenic organisms becomes very important.

Properly functioning soil filters are known to be very effective in reducing bacterial contamination – significantly better than intensive wastewater treatment plants due to the relatively long residence times within extensive systems (Mitterer, 1995). Generally, the E. coli* content of water at the outlets of soil filter plants is acceptable according to the standards for bathing waters (which in Switzerland is 1000 CFU*/100ml).

4 Planning and running sustainable soil filters

4.1 Introduction

What is sustainability?

In many parts of the world there are wastewater treatment plants that are not functioning, or performing very poorly. The technical theory used in their design may have been adequate, and they may have been built according to the designs, but they are not working. Often the problem is that they were not designed with a good knowledge of the local conditions – actual flowrates and compositions may have proved to be very different from the design assumptions. Often insufficient attention is given to institutional and financial matters, so that the skills and revenue are not available to keep the plant running. Sustainable treatment plants are systems that will keep operating effectively for their design lifetime – twenty years or more.

Parameters of sustainability

The following parameters contribute to the sustainability of soil filters:

- the use of appropriate technology,
- the management of human and local resources,
- consideration of socio-cultural and institutional processes,
- ecological factors (see Section 1.10),
- the quality of construction, and
- maintenance.

Special knowledge and considerable experience is needed for design – on the one hand for dimensioning, and on the other, for selecting appropriate materials (e.g. media). Therefore, specialists should be consulted during the design process to ensure that the soil filter plant functions well and is sustainable.

The selection of the type of wastewater treatment plant is a complex process. Some steps must be taken one after the other whilst other stages occur simultaneously. A thorough feasibility study must be undertaken before the design, implementation, and operation and maintenance phases. (See Table 9 and Figure 14.)

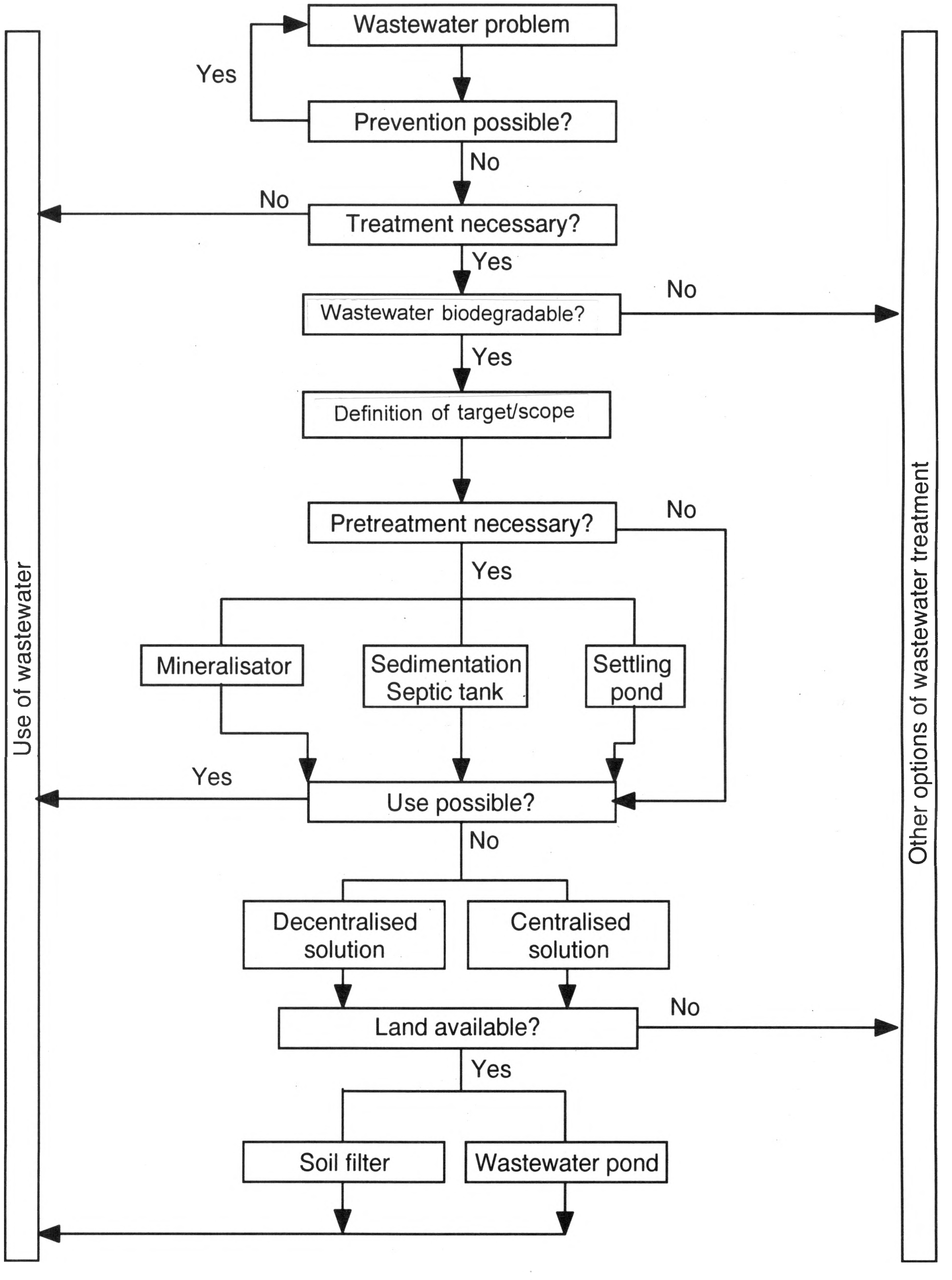

Fig. 14 Flowchart for selection of extensive wastewater treatment systems (strategic and technical considerations)

Figure 14 recommends a selection procedure for deciding on the suitability of extensive wastewater treatment. It is limited to strategic and technical questions. Sections 4.5 to 4.8 discuss economic, institutional, legal and socio-cultural aspects, which are equally important.

Table 9 Main steps for planning and implementation of a wastewater treatment project

Feasibility study ▪ Quantity and nature of wastewater (see Section 1.3 and Table 10). ▪ Land availability ▪ Institutional and legal data (see Sections 4.6 and 4.7) ▪ Socio-cultural considerations (see Section 4.8) ▪ Wastewater treatment system (see Table 1 and Table 5) ▪ Preliminary design ▪ Cost estimate
Design phase ▪ Dimensioning of the wastewater treatment plant and auxiliary structures ▪ Construction design ▪ Cost calculation (Table 13) ▪ Financing plan for implementation, and the operation and maintenance phase ▪ Socio-cultural and institutional aspects ▪ Concept of the operation and maintenance phase
Implementation phase ▪ Construction of the wastewater treatment plant and auxiliary structures ▪ Implementation of the socio-cultural and institutional proposals ▪ Preparation of the operation and maintenance phase
Operation and maintenance phase ▪ Running of the wastewater treatment plant and auxiliary facilities ▪ Maintenance of the wastewater treatment plant and auxiliary facilities ▪ Ensure smooth operation of socio-cultural and institutional arrangements

4.2 Technical aspects

Origin of wastewater

In some situations wastewater is already causing problems. Elsewhere a problem related to wastewater is foreseen (for example, where large numbers of buildings are being constructed, or a refugee camp is being prepared). In both cases the following questions should be answered (See also Section 1.4).

Prevention possible?

1) Is wastewater prevention possible? (Instead of collecting wastewater in a sewerage system, consider the options of dry toilets, urine separating toilets, different production or handling processes and on site treatment. See also Table 6). In many cases reduction of wastewater may be feasible, but rarely complete prevention.

Treatment necessary?

2) Is treatment necessary? Can the wastewater be used untreated, without health risks, over a long period? What are the treatment requirements? What is the expected performance of different treatment methods? (For soil filters see Section 3.13.)

3) Is the wastewater suitable for treatment? (See Sections 1.1 and 3.3, and Table 10.)

Table 10 shows the characteristics of wastewater and its sources that should be considered when planning treatment.

Table 10 The impact of wastewater parameters on treatment

Parameters to be considered	**Conditions favouring treatment**	**Conditions requiring special care**	**Conditions that may exclude certain options**
Composition of wastewater	Domestic or communal wastewater*, with or without urine and faeces	Small quantities of toxic substances (in wastewaters from hospitals, businesses and industry); extreme temperatures (cooling water, melting snow); changes of composition.	Constituents toxic to bacteria or their predators
Distances between sources	One building or short sewers*; no stormwater influx	Long sewers, so that there is more chance of stormwater influx, infiltration or illegal connections	Buildings too far apart so that several treatment plants are necessary
Wastewater flow	Uniform flow and composition	Irregular flow (e.g. from restaurants or schools)	Extreme fluctuations in flow

Table 11 lists the parameters of a soil filter treatment plant that should be defined at the design stage. The role that each parameter plays has been discussed in Chapter 3.

Table 11 Design parameters for soil filters

Parameters	**Comments**
Pretreatment	Screening, sedimentation* or preliminary filtration
Biological treatment	Aerobic, anaerobic or combined
Shape	Circular, rectangular, regular or irregular, shaped to suit location (see Figure 5).
Location	On surface or below surface
Volume	Depth 50 to 100 cm; area (see Table 7)
Water influx	Continuous or intermittent; alternating between beds; on surface or subsurface; exclusion of stormwater
Direction of flow	Vertical, horizontal or diagonal
Size	(See Section 3.10 and Table 7.)
Media (bacteria support)	Sand, gravel, soil, roots in planted filters (see Section 3.6.)
Hydraulic retention time	Can be hours or days

Influence of physical site characteristics

Site characteristics are shown in Table 12. Close proximity of the future treatment site to the wastewater source is desirable. Soil based systems are strongly influenced by soil characteristics (since the soil may possibly be suitable as media), topography and the depth of the water table. Aquatic systems (ponds) depend mainly on the containment of water in the treatment unit and therefore are less dependent on the physical characteristics of the potential site.

Table 12 Site characteristics relevant to the planning and construction of soil filters

Parameters to be considered	Conditions favouring treatment	Conditions requiring special care	Conditions that may exclude certain options
Climate - precipitation - temperature - evaporation Microclimate*	Temperate, tropical Mild, protected from cold winds	Continental, arid, very high rainfall (Section 3.11) Particularly cold, hot or windy	Arctic
Wastewater See Table 10			
Treated wastewater - use - infiltration - receiving water	 Irrigation, washing equipment Flowrate of treated wastewater less than one tenth of flowrate of receiving water	 Children's playgrounds Ground frozen in winter Flowrate of treated wastewater more than one tenth of flowrate of receiving water	 Need for drinking water quality Impermeable soils, land unstable and prone to slides Receiving water seasonal, drying up for part of the year
Infiltration site	Good infiltration Large depth between outlet and water table	Slow infiltration; groundwater protection area Water table close to outlet	Unstable soil prone to land-slides Karstic* regions
Topography - slope - depth to bedrock - depth to groundwater - drinking water protection area - areas exposed to natural hazards	 Less than 5% Greater than 1.5 m Greater than 1.5 m Clearly not affecting protection area Not threatened by natural hazards	 5 to 20 % 1 to 1.5 m 1 to 1.5 m Close to perimeter of protection area Earthquakes and other natural hazards	 Greater than 20% Less than 1 m Less than 1 m Within protection area Regular flooding, avalanches, sandstorms or landslides
Type of soil - hydraulic properties	Clay loams or sandy loams as media Impermeable soil as base for ponds or sand filters	Impermeable soils as media (addition of sand or humus) Gravel as media (with possible addition of loams or sand) For ponds and soil filters permeable soils need membranes or sealing.	rock
Permeability* of soil for use as filter media	$10^{5} < K_f < 10^{6}$ cm/s	$10^{-8} < K_f < 10^{5}$ cm/s	$K_f < 10^{-8}$ cm/s
Land use	Relatively flat land not in demand for agriculture or urban development	Scarcity of productive land. Consider installing treatment facility underground	Densely built-up areas; land earmarked for urban develop-ment or intensive agriculture.
Local resources (Human resources See 4.6 and 4.7)	Local availability of sand and gravel Local availability of suitable pipes and material to seal ground	Local material of unsuitable quality	No material available within reasonable distance
Access to site	Safe access	Access difficult or interrupted for short periods	Access impossible for long periods each year
Electricity – availability and reliability	Electricity not required	Irregular, uncertain supply	

Access

Access should be possible at all times including the rainy season and winter. The type of access should be appropriate to the equipment used for construction of the treatment plant – a consolidated road when using heavy machines, a dirt road for light vehicles, or a footpath when exclusively labour-intensive methods are used.

Slope

Gravity flow from the wastewater source to the treatment site is desirable and suitable for horizontal soil filters. For vertical soil filters a system to generate intermittent flow is necessary. All such systems, except pumps, require a drop, which necessitates a bigger difference in elevation between the sources and the treatment plant than is needed for a horizontal filter. Construction of soil filters is more economical if the natural slopes at the site do not exceed 3 to 4 per cent. If necessary, higher slopes can be accommodated, but the construction costs are greater. Unstable ground should be avoided.

Soil characteristics

Clay loams, sandy loams and sand are welcome because they can be used as constituents for soil filter media. For infiltration of untreated or treated wastewater, the permeability coefficient (K_f*) of the soil should be greater than 10^5 cm/s. An impermeable soil for the floor and sides of soil filters should have a permeability coefficient less than 10^{-8} cm/s.

Site selection

To select a site a stepwise approach is recommended. The three main steps are:

1) Selection of the most promising sites based on available information on potential sites. The screening criteria should be defined, taking into account the quantity and quality of wastewater and use of treated wastewater.
2) Each site should be roughly surveyed to help in ranking the most promising ones for more detailed investigations.
3) Detailed site investigations should be carried out for the most promising sites.

Local knowledge and materials

Soil filters can generally be constructed with local skills, techniques and materials. The main work consists of excavation and fill and can be carried out either by machines or using labour-intensive methods. Both during the construction phase and thereafter, erosion protection is important and should be provided.

Pipes for directing the water to, within and from the plant can generally be obtained locally. It may be possible to use open channels instead of pipes. If pumps and other mechanical devices are needed, it is important to choose types which can be serviced by local personnel.

4.3 Operation and maintenance

Maintenance to ensure sustainability

Maintenance is in many respects the most important part of the whole wastewater treatment project. Careful evaluation of needs and the local situation, planning, design and construction are essential but they can all be wasted if maintenance is ignored.

Moreover, maintenance, however, is a continuing, long-term duty which influences the function and lifetime of any wastewater treatment plant (Figure 15). If maintenance is neglected, a soil filter can become damaged (meaning that the media become clogged), and in the worst case even permanently damaged. Experience has shown again and again that the most frequent reason for malfunction of a treatment plant is neglected maintenance.

Operator and supervisor

Not only should an operator be appointed to carry out the routine tasks, but also a supervisor. The duties of both should be clearly defined in job descriptions and with checklists. A logbook must be kept in which jobs carried out, observations, and special occurrences (such as major changes in wastewater composition or weather) are recorded.

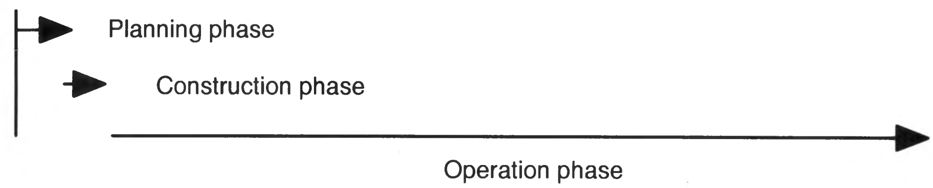

Fig. 15 *The relative durations of the planning, construction and operation phases for a wastewater treatment plant.*

Once a plant is built and in operation

Plant owners are strongly encouraged to keep the operational records, such as logbooks, in a safe place, and to exchange their experiences (good or bad) in order to further develop knowledge about soil filters. Such exchange of information can benefit the operation of individual plants and the design and operation of future plants, including providing a better understanding of the impact of climate and the methods of using treated wastewater. Documentation centres are seen as an important means of managing and disseminating such information. They could function at different levels, such as regional and international, or according to climatic zones. The new means of electronic communication are expected to facilitate such projects: the World Bank has launched a start-up kit to help water utility managers improve operational performance through comparison of results, and they are looking for partners. (Anyone interested in participating in this programme should contact the World Bank Water Help Desk – see Chapter 6.)

Maintenance of pretreatment facilities

All pretreatment facilities need to be desludged regularly. (See also Section 3.2.). The quantities of sludge collecting in sedimentation tanks can vary considerably, depending on the living habits of the local users. Therefore, regular observation is important. A stick lowered into a sedimentation tank can indicate the depth of the accumulated sludge and scum layers. If together they amount to between a third and a half of the total depth of the tank or pond, the solids must be removed; otherwise the danger of clogging increases rapidly.

Maintenance of soil filters

Maintenance duties for soil filters include checking whether pipes are free from blockages, and cleaning the pipes once every one to three years, depending on the bacteria growth in the pipes. Other tasks are repairs to the fencing and cutting vegetation. Soil filters should be fenced in to prevent animals and children from playing and walking on the filter and thus compacting it. The vegetation does not need to be harvested during the first vegetation period, nor possibly up to three years after planting, depending mainly on climatic conditions. Thereafter, it can be managed in different ways: The vegetation may be harvested or left. (See photographs 2a and 2c.). If it is to be harvested, the intervals at which it is to be cut must be decided, and also the season when the harvesting takes place (for example spring, late summer or late autumn).

Quality of treated wastewater

A cheap and efficient method of monitoring the treated wastewater is visual and olfactory inspection - the water should be clear and should not smell. (The appearance of the treated wastewater should be monitored by looking at a sample in a glass container, preferably of a large size.). It may be necessary to arrange for a chemical analysis of the treated wastewater to be undertaken at regular intervals, to check compliance with local pollution control regulations.

4.4 Using sludge and treated wastewater

Use of sludge

Both, sludge and treated wastewater can be used to the benefit of horticulture, agriculture and forestry. Provided that the handling methods are hygienically acceptable and that the needs of the crops and trees are respected, such use should be encouraged and increased. (The term "sludge" is used here, but suitable solids from scum layers or separated in other ways (such as in a mineralisator) should also be used according to the suggestions in this Section.)

The sludge can be composted and/or spread on the land. Health risks can be minimised by correct composting, by correct methods of utilisation, by the wearing of suitable shoes and by growing suitable crops (vegetables that are eaten raw should be avoided). It is also important to ensure a balanced fertiliser regime. Experts recommend that no more than one cubic metre of material such as sludge (which contains phosphorous, potassium, micronutrients, but hardly any nitrogen) be spread on 100 square metres of agricultural land.

Treated wastewater from a well designed and operated treatment plant is fit for infiltration, for various use as described below or for discharge to rivers, lakes or the sea (see Section 3.13).

Estimate the quantity of wastewater

The quantity of the effluent from a soil filter is dependent on the local microclimate and the types of vegetation (if any) growing on the filter. In warm and dry regions most, if not all, of the treated wastewater may be lost to the atmosphere as a result of transpiration by the plants, and so there might be no water at the outlet except after heavy rain. In temperate climates on some hot summer days, there might be no water leaving the soil filter in the middle of the day, but during the rest of the day effluent would flow from the plant.

Use of treated wastewater

An ecologically and economically sound solution is to use the treated wastewater for watering animals, for the washing of equipment and for other purposes. In gardens, agriculture and forestry it is suitable for irrigation if the salt concentration (increased by evaporative water losses) is not too high (see also Section 2.4). Water from treatment plants should nevertheless not be used to irrigate lettuce and vegetables shortly before consumption, even if the effluent complies with local quality standards*.

Infiltration of treated wastewater

Under appropriate climatic and soil conditions, treated wastewater can be infiltrated, to help replenish groundwater resources. Infiltration is an ecologically desirable solution because it completes the water and nutrient cycles*. The ground should have a good permeability and infiltrating water must not cause landslides nor saturate the upper layers of soil, making the ground surface waterlogged. The infiltration site must not be in the vicinity of a borehole for drinking water nor in a groundwater protection area. Water resources regulations should be consulted, or the advice of specialists sought, to determine the suitability of infiltration before construction of the plant.

Discharge of effluent to surface water

If there is no local need for the treated wastewater, it can be discharged into a river or stream. The flowrate in the receiving stream or river should be at least ten times the flowrate of the treated wastewater. If the recipient water is stationary, such as a lake or reservoir, the phosphorous in the treated wastewater must be controlled carefully as it can be the decisive factor in eutrophication.

4.5 Economic aspects

Cost estimation

Following the steps of planning and implementation (see also Table 9), the costs of the project can be estimated. A distinction should be made between costs in local currency and costs in foreign currency. When preparing an estimate for an extensive wastewater treatment plant in a specific location, Table 13 can be used as a checklist.

Table 13 Approximate total costs of a soil filter project

a) Costs for design and construction

Step	Item	Quantity and Unit	Unit price (2)	Total per item local currency	Total per item foreign currency
Survey / data collection	Consultant (local)	p.d (1)			
	Consultant (expatriate)	p.d			
Feasibility study	Consultant (local)	p.d			
	Consultant (expatriate)	p.d			
Design	Consultant (local)	p.d			
	Consultant (expatriate)	p.d			
Construction	Land purchase	m^2			
	Material and equipment (local)	l.s. (3)			
	Material and equipment (imported)	l.s.			
	Earthworks (by hand)	m^3			
	Earthworks (by machine)	m^3			
	Pipes – supply, laying and testing	m			
	Impervious lining	m^2			
	Filter media	m^3			
	Access roads	m			
	Fencing	m			
Total Investment Costs	In local currency				
	in foreign currency				

b) Annual costs

Operations	Supervisor	p.d			
	Transport, fuel, electricity	l.s.			
Maintenance	Fencing	p.d			
	Sludge removal	p.d			
	Cutting vegetation	p.d			
	Pipes – inspection and cleaning	p.d			
	Material and equipment (local)	l.s.			
	Material and equipment (imported)	l.s.			
Total Annual Costs	In local currency				
	in foreign currency				

Notes
1. p.d: person-day or man-day
2. Prices quoted in local currency for local expenditures, in US$ for expatriates and imports.
3. l.s.: lump sum

Financing

On the basis of the estimated project costs, and considering the financial capacity of a local community desiring such a wastewater treatment system, the needs for external funding can easily be assessed. The key principle should be that recurrent costs for operation and maintenance are entirely covered locally to avoid dependence on external support. External funds may be used as a contribution to the capital investment, which includes planning, appraisal, financial feasibility and design studies.

External funding

Covering operating and maintenance costs

There are various ways in which money can be collected from the water consumers to cover the operation and maintenance costs of the treatment system. Common methods are to add a surcharge to payments made for water, or to collect fees from members of an association. Another way of generating revenue is to sell irrigation water, a possibility that should at least be considered in each specific context.

Productive activities

The possibility of combining the treatment of wastewater with profitable productive activities makes wastewater treatment more economically attractive. These activities may include the production of water hyacinths on a settling pond as fodder for livestock, fish farming in polishing ponds*, and growing trees for firewood on soil filters or around the ponds.

Assessment of economic feasibility

Productive activities defined in this sense include only those directly linked with the wastewater treatment plant itself, and not for instance crops irrigated with treated wastewater. Productive activities attached to wastewater treatment units should be properly planned and implemented. Both technical and economic feasibility should be carefully assessed. A prerequisite is the existence of a market for the proposed produce at a price that covers production costs and generates a profit. For assessment of costs and income a list similar to Table 14 may be helpful. For each economic activity detailed production costs should be assessed.

Table 14 Productive activities linked to a wastewater treatment plant

Activity	Unit selling price	Volume of sales	Production costs	Net income from sales
water hyacinth				
fish farming				
firewood production (fuelwood)				
sale of irrigation water				
other				
TOTAL				
Profit				

4.6 Institutional aspects

In industrialised countries, wastewater treatment is generally a public service financed by fees for water supply or wastewater treatment. Charges are often based on the "polluter pays" system. The situation is quite different in most other countries (with the possible exception of large urban centres) where central government usually has other priorities and no resources to tackle the problem. This explains why the main target groups for the implementation of low-cost, extensive wastewater treatment systems are various types of local institutions such as community associations, private enterprises, co-operatives and local authorities (rather than central government).

Target groups

Sense of ownership among users

A strong sense of ownership among users is supposed to be the best guarantee for sustained operation and maintenance of a wastewater plant.

Community involvement starting at planning stage

The critical importance of community involvement from the very beginning of a wastewater treatment project has already been emphasised. (See Sections 1.7 and 1.9.). Some other elements may also contribute to fostering the interest of communities, among them the possibility of linking wastewater treatment with some kind of profitable activities. In very favourable – but rather exceptional – situations, the costs of operation and maintenance can be entirely covered by income from related economic activities.

Key actors: polluters, victims of pollution, water users, political authorities

Four main groups of persons concerned with wastewater treatment can be identified:

- the polluters (people associated with the sources of wastewater);
- the people suffering from polluted water (such as people living beside a river, downstream of a wastewater outlet, or people whose water source is polluted);
- the users or potential users of treated wastewater (such as potential industrial users, farmers seeking irrigation water), and
- political authorities who are supposed to control the problem (such as pollution control agencies and water resources authorities).

All key actors should be involved

Obviously, these groups can overlap to a large extent. Some of the polluters may also be suffering from polluted water, and users or potential users of treated water may themselves add to the pollution. Similarly, individual local government representatives necessarily belong to one or more of the three other groups. To be successful, a project requires the involvement of representatives of all four of these groups in project planning to ensure that their various interests are taken into account.

Wastewater treatment concerns ALL members of community

Some associations are of concern to only a section of the population – for example a vegetable producers' association. Others are potentially of concern to everyone. Associations dealing with wastewater treatment are clearly one of the second type: everyone in the target community should be concerned since they all need water and produce wastewater.

Identify the most suitable partner for implementation – through key informants

The most suitable partner for project implementation might be a new association for wastewater treatment, an existing community association, or a local authority (in the case of a wastewater project initiated from outside). The partner can be identified by interviewing key informants in the project area and by conducting various types of surveys. Key informants are persons with a detailed knowledge of the situation of a region, such as the head of village, a traditional chief, the president of an association, or an agricultural extension officer.

4.7 Legal aspects

Prevailing legislation

The prevailing legislation of the country should be reviewed with the following questions in mind:

- Have standards been defined for the discharge and reuse of treated wastewater?
- Are there regulations about the forms of organisation and how their activities may be financed?
- How well are laws and regulations enforced?
  What measures and means are available for enforcing laws and water quality standards?
  (It is important to get realistic answers to these questions.)
- Is the legal framework open to the option of extensive wastewater treatment systems or is it prejudiced in favour of conventional intensive methods?
- If the legislation favours intensive systems, is there still a possibility of promoting extensive wastewater treatment?

Answers to these questions should be taken into consideration during the planning and implementation process. (See Table 9.)

4.8 Socio-cultural aspects

Cultural, social and political aspects must be considered when planning a wastewater treatment system (see Table 15). The following list suggests some of the of socio-cultural questions which should be asked:

Attitude towards wastewater

- What type of wastewater is produced? What attitude do people have towards wastewater? Is wastewater reused or thrown away? How and where is wastewater discharged? Are there any gender issues related to wastewater management? Is there an awareness of the links between dirty water and health?

Attitude towards urine and faeces

- What are the beliefs and attitude of the people towards human faeces and urine? Can faeces and urine be utilised, and what for? Are there religious rules about faeces and urine? Is there a taboo about using faeces and sludge?
- Who deals with wastewater containing faeces? Is it an activity only for a specific social stratum of the population?
- Who decides about the utilisation of untreated wastewater in the family, in the village?
- Which people should be involved in planning a wastewater treatment system?
- Does wastewater have an economic value? Is it sold for cash or bartered? To whom would the treated wastewater belong, if it were to be used for cattle watering or irrigation?

Depending on the answers to such questions – i.e. on the attitude towards wastewater and human faeces in the particular society or context – the type of wastewater treatment system will have to be adapted to suit local practices and beliefs. Though there is no ready-made recipe for the integration of socio-cultural aspects, their importance should not be underestimated. The challenge is to identify solutions that fit into the set of values, beliefs and traditions of a society. Ideally, such problems should be addressed jointly by local authorities, traditional chiefs, religious leaders and other influential people of the area in a participatory process.

5 Subject index and review of issues

5.1 Introduction

When searching for a solution for a wastewater treatment problem, numerous aspects must be considered. Table 15 lists the major aspects as a summary of this brochure. This table can therefore serve as a starting point in an evaluation process as well as a quick checklist at different stages during the process.

Table 15 Technical, economic, institutional, legal and socio-cultural aspects that should be considered during the planning of an extensive wastewater treatment plant, in particular a soil filter.

Aspect to consider	Favourable conditions	Factors requiring consideration	Factors demanding special attention
Technical (see also Table 9)	– Technical assistance available – Trained local technicians available	– Transfer of skills for plant operation – Public education – Organisation of maintenance	– Wastewater treatment is not considered as an important issue – Difficulty in obtaining spare parts
Economic	– Incentives for environmental upgrading – Existence of a market for produce from related economic activities – External finance available	– Identification of markets for produce of related activities	– Exorbitant taxes – High recurrent costs – Lack of external financial support
Institutional	– Active associations of stakeholders – Supportive local government – Existence of supportive agency – Enabling policy environment – Relevant experience available in the country	– Developing sense of ownership and commitment to maintenance – Developing sense of responsibility	– Heterogeneous community – Lack of social organisation – Weak or unconcerned local government – No relevant experience within the country
Legal	– Conducive legal framework	– Effluent quality standards	– Laws favouring conventional wastewater management methods
Socio-cultural	– Local people consider wastewater to be an important issue – The various stakeholders share a common interest – Strong social organisation – Interest of women – Support of local leader	– Defining clearly responsibilities and tasks	– Diverse interests, conflicts – No tradition or experience of working together – Local leaders not supportive

The following pages contain lists of topics covered in this brochure and the section, table or figure where the particular topic is discussed or illustrated. The topics are classified under four themes:

5.2 Background, basic issues
5.3 Strategic aspects
5.4 Technical issues
5.5 Socio-cultural, economic, legal and institutional aspects

5.2 Background, basic issues

Topics	Sub-topics	Reference
Environment	Water cycle*	Sec 1.10, Table 3
	Nutrient cycle*	Sec 1.10, Table 3
	Ecological factors	Sec 1.10
Human health	Impacts of untreated wastewater	Sec 1.5 and 3.13, Table 3
Wastewater	Origin of wastewater to be treated	Sec 1.1, Table 10
	Characteristics of wastewater to be treated	Tables 6 and 10
	Constituents of wastewater to be treated	Sec 3.9, Table 6
Wastewater treatment	Optimum living conditions for bacteria	Sec. 3.3 and 3.12
	Extensive* treatment or intensive* treatment	Sec 1.6 and 1.7, Figure 2
	Aerobic* or anaerobic treatment	Sec 3.3, Figure 9
	Treatment processes	Sec. 1.6 and 3.3

5.3 Strategic aspects

Topics	Sub-topics	Reference
Local needs	Preferences of decision-makers regarding sustainability and prestige	Sec. 1.7 and 4.1
	Defining the needs of wastewater producers and users	Sec 1.5, Table 9
On-site measures	What can be done on-site? – separation, treatment, disposal	Sec. 1.4, 1.5 and 4.2
Planning	Need for specialists	Sec 4.1
	Availability of material, spare parts, and chemicals	Sec 1.7
	Availability of land	Sec. 1.7, 3.10;Tables 9, 12
	Feasibility study	Table 9
Special requirements	Requirements of different types of extensive treatment methods	Table 5
	Requirements for outside expertise	Sec 1.7
Type of wastewater treatment	Is the wastewater suitable for treatment?	Sec 1.1; Table 10
	Choice of extensive or intensive treatment	Sec. 1.7 and 2.1
	Extensive treatment alone or in combination with intensive methods	Sec 3.10
	Centralised or decentralised treatment	Sec 1.9
Wastewater treatment	Is prevention possible?	Sec 1.4
	Is wastewater treatment necessary?	Sec. 1.3 and 1.5
	Defining the context and needs of wastewater producers, users, and the environment	Sec. 1.5 and 1.10
	Expected quality of treated* wastewater	Sec. 1.7 and 1.8

5.4 Technical issues

Topics	Sub-topics	Reference
Local situation	The community – population, population density, proximity to other communities	Sec 1.7; Table 10
	Characteristics of the possible sites for the plant – select	Sec 4.2; Table 12
	Distance from the source to the treatment plant the most suitable.	Table 12
Planning	Consideration of toxic substances	Sec 1.1; Table 10
	Availability of energy and the reliability of the supply	Sec 1.7; Table 1
	The need for a grease trap and other pretreatment stages	Sec 3.2
	Planning the maintenance	Sec 4.3; Table 9
Wastewater	General – wide range of aspects	Table 15
	Daily flow of wastewater? constant or changing?	Sec 1.7; Tables 5 and 10
	Is the nature and concentration stable or changing	Sec 2.5; Table 10
	Domestic, communal*	Sec. 1.1 and 2.5
	Biodegradability*	Sec. 1.1 and 3.3
Wastewater treatment plant	General considerations	Table 15
	Soil characteristics	Sec. 3.6 and 4.2; Table 12
	Types of vegetation	Sec 3.12
	Pond or soil filter	Sec. 2.3 and 2.5; Table 5
	Design parameters	Table 11
	Choice of flow direction – horizontal or vertical	Sec 3.5
	Filter media* (chemical composition, grain shape)	Sec 3.6
	Method of feeding wastewater – continuous, intermittent, alternating	Sec 3.8
	Operating period – all year or seasonal?	Chap. 2; Sec 3.11; Table 5
	Retention time	Sec. 1.10 and 2.5; Table 11
	Protection of treatment plant	Sec. 3.11 and 4.3
	Lifetime of treatment plant	Sec. 2.5 and 4.3
	Odour	Sec 2.5
	Mosquito breeding	Sec 2.5
Construction	Protection against erosion	Sec. 2.3 and 4.2
	Locally available material (pipes, lining materials, pumps etc.)	Sec. 1.7, 4.1 and 4.2
Operation	Quantity of treated wastewater	Sec 4.4
	Quality of treated wastewater	Sec 3.13; Table 8
	Uses of treated wastewater	Sec 4.4
	Uses of separated solids (sludge)	Sec 4.4
Maintenance	Requirements for operator and supervisor	Sec 4.3
	Duties, and importance of not neglecting maintenance	Sec. 1.9 and 4.3; Figure 15

5.5 Socio-cultural, economic, institutional and legal aspects

Topics	Sub-topics	Reference
Socio-cultural	General	Table 15
	Persons concerned (stakeholders) – polluters, users, authorities	Sec 4.6
	Key informants (people with particular local knowledge)	Sec 4.6
	Attitude of population to wastewater	Sec 4.8
	Is wastewater being used?	Sec. 4.4 and 4.8
	How do women manage wastewater?	Sec 4.8
	Is there an awareness of the link between dirty water and disease?	Sec 4.8
	Wastewater and human health	Sec. 1.5 and 3.13
	The concern and involvement of users	Sec. 1.7, 1.9 and 4.6; Table 2
	The availability of land and its price	Sec. 1.7 and 1.8; Tables 9 and 12
	The local availability of trained builders and operators	Sec 1.7 and 4.3
	Maintenance – can servicing be done locally?	Sec 1.7 and 4.3
	Supervising the operator	Sec 4.3
Economic	Costs of planning	Sec 1.8; Table 13
	Costs of land	Sec 1.8; Table 13
	Construction costs	Sec. 3.9 and 3.10; Table 13
	Operation costs	Sec 4.5; Table 13
	Maintenance costs	Table 13
	Need for external funding	Sec 4.5
	Local currency component of construction costs	Table 13
	Foreign currency component of construction costs	Table 13
	Can recurrent costs be covered by local revenues?	Sec 4.5; Table 13
	Are related productive activities possible? (Products, markets, required investments)	Sec 3.12 and 4.5
Institutional	General	Table 15
	Forms of organisations: private companies, associations, co-operatives, local utilities and authorities	Sec 4.6
	Mechanisms for revenue generation	Sec 4.6
Legal	General	Table 15
	Is the legal framework favourable to extensive wastewater treatment?	Sec 4.7
	Existing statutory water and effluent quality standards	Sec 4.7; Table 8
	Forms of organisations	Sec. 4.6 and 4.7
	Arrangements for financing	Sec. 4.6 and 4.7

6 Directory of organisations

Agricultural University of Norway, Centre for Soil and Environmental Research, N-1432 ÅS:
Organises courses on "Sustainability of wastewater treatment systems in temperate and cold climates".
Tel. +47-6494-7560;
Fax +47-6494-7440;
e-mail SEVU@adm.nlh.no

Center for Applied Ecology, Schattweid, CH-6114 Steinhuserberg, Switzerland;
Tel. +41-41-490 17 93;
Fax +41-41-490 40 75;
e-mail zentrum@schattweid.ch

gtz, Deutsche Gesellschaft für technische Zusammenarbeit, Postfach 5180, D-65726 Eschborn, Germany.
Tel. +49-6196 79 0;
Fax +49-6196 79 1115;
e-mail postmaster@gtz.de

INFOTERRA-the Global Information Exchange Network. UNEP, PO Box 30552, Nairobi, Kenya.
Tel. +254-2-623511/621234;
Fax +254-2-623943;
e-mail infotinf@unep.org

SANDEC, Water and Sanitation in Developing Countries at EAWAG (Swiss Federal Institute for Environmental Science and Technology), CH-8600 Dübendorf, Switzerland
Tel. +41-1-823 50 20;
Fax +41-1-823 53 99;
e-mail strauss@eawag.ch

SDC, Swiss Agency for Development and Co-operation, Water and Infrastructure Division, CH-3003 Bern, Switzerland;
Tel. +41-31-325 92 52;
Fax +41-31-323 26 10;
e-mail Armon.hartmann@admin.ch

SKAT, Swiss Centre for Development Cooperation in Technology and Management, Vadianstrasse 42, CH-9000 St.Gallen. Switzerland
Tel. +41-71-228 54 54;
Fax +41-71-228 54 55;
e-mail info@skat.ch

Swiss College of Agriculture, Länggasse 85, CH-3052 Zollikofen, Switzerland
Tel. +41-31-910 21 11;
Fax +41-31-910 22 96;
e-mail office@shl.bfh.ch

UNEP, United Nations Environment Programme, Tour Mirabeau, 39-43 Quai André Citroen, F-75739 Paris Cedex 15, France
Tel. +33-1-44-37 14 41;
Fax +33-1-44-37 14 74;
e-mail unepie@unep.fr

Water Solidarity Program, c/o GRET (Groupe de recherches et d'échanges technologiques), 211-213 Rue Lafayette, F-75010 Paris, France
Tel. +33-1-40 05 61 30;
Fax +33-1-40 05 61 10

WEDC (Water, Engineering and Development Centre): Sharing applied research information between researchers working in the water and sanitation sector throughout the world through informal, low-cost and decentralised networking links. Loughborough University, Leicestershire, LE11 3TU United Kingdom.

WHO, World Health Organisation, CH 1211 Geneva 27, Switzerland
Tel. +41-22-791 37 54;
Fax +41-22-791 41 23;
e-mail lapensee@who.ch

World Bank, Water and Sanitation Division, 1818 H Street NW, Washington D.C. 20433, USA. Water Help Desk
e-mail whelpdesk@worldbank.org

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9 Glossary

9.1 Abbreviations

BOD_5: Biological oxygen demand in 5 days, measured as mgO_2/litre. More precisely, it is the weight of oxygen that is consumed by micro-organisms in a one litre sample of the water in five days. The BOD_5 is an indication of the concentration of biodegradable organic material in wastewater. The higher the value, the more polluted the water.

CFU: Colony forming units – a measure for the number of bacteria in a water sample.

COD: Chemical oxygen demand. Determined by a chemical procedure, to give a measure of the concentration of organic matter in a sample. In domestic wastewater the COD value is often approximately twice the BOD_5.

K_f: Permeability coefficient. This is a measure of the ease with which water can pass through soil.

PE Person equivalent (See word list below.)

pH This is an indication of whether the sample is acid, neutral or alkali. A pH value of 7.0 indicates that the sample is neutral. (Absolutely pure water has a pH of 7.0.) Lower values indicate acidity, higher values alkalinity.

SS Suspended solids. This is the weight of tiny particles that are suspended (or floating throughout the depth) in one litre of the water.

TOC: Total organic carbon, which is an another indication of the degree of pollution of wastewater.

9.2 Definitions

Asterisks (*) are used to indicate which words are defined in this list. Asterisks are used the first time that any word listed here occurs in any chapter.

aerobic

This refers to the presence of air (or more particularly dissolved oxygen) in the water so that bacteria that use oxygen can operate. **Anaerobic** means that there is no (or very little) dissolved oxygen in the water, and in such conditions bacteria that do not need dissolved oxygen operate by taking the oxygen they need from organic materials in the water. **Facultative** bacteria can operate in either aerobic or anaerobic conditions, and facultative ponds are partly anaerobic (in the lower layers) and partly aerobic.

biodegradable

One of the most important processes in most methods for treating wastewater is the breaking down of organic matter into simpler compounds that do not cause pollution. This is accomplished by bacteria that feed on (or metabolise) the organic chemicals in the water. A substance is termed biodegradable if it can be broken down in this way. Faeces are biodegradable but most plastics, although they are organic, are not biodegradable.

biodiversity

This refers to the number of different species that are found living naturally in a particular setting. A wide range of flora and fauna – biodiversity – suggests that the ecosystem under consideration is in a natural state. One of the effects of man-made pollution is often to reduce the number of different species that live in the affected area.

biomass

Animal or vegetable growth for a specific purpose. The purpose might be to provide food or fuel, or to provide an enlarged capability for treating wastewater.

buffering

In this context, buffering refers to a reduction of the impact of an added chemical. For example, if acid is added to water, the pH of the water will be reduced. The pH is reduced to a smaller extent if the water is buffered.

coagulation and flocculation

A complex physical and chemical process by which turbid or cloudy water is made clear. It is widely used in the treatment of surface water for drinking water supplies. Tiny suspended particles are joined together to form flocs which can be separated from the water by sedimentation or filtration.

communal wastewater

This is wastewater that is predominantly of domestic origin.

discharge

See "flowrate".

E. coli

E. coli are a species of bacteria that are found in the human digestive system, though they can also come from non-human sources. Because they are found in faeces, they are used as "indicator bacteria" to indicate the possibility that there might be other, more harmful bacteria (also found in human faeces) in the water. If no E. coli are found, it is presumed that there are no other pathogenic bacteria in the water. **Faecal coliforms** are bacteria of the E. coli group that are associated with faeces, and the presence of this type of bacteria suggests more strongly that the water has recently been contaminated by faeces.

effluent

see "**treated wastewater**".

"**end of pipe**"

This refers to the application of treatment or disposal systems after wastes have been collected, mixed together and transported for some distance. (The opposite is referred to as *on-site disposal* or *at-source treatment*, in which case treatment or disposal is carried out close to the point of origin of the wastes, without the mixing of different wastes. The opposite to "end of pipe" might be thought of as *beginning of pipe*, but usually with on-site disposal, no subsequent pipe is involved.)

eutrophication

This is a situation where the concentration of plant nutrients (nitrate and phosphate) are so high that algae multiply very rapidly (or bloom), causing serious water quality problems (colour, turbidity, taste, odours, high BOD).

excreta

Waste matter (faeces and urine) expelled from the human body.

extensive wastewater treatment

A method for treating wastewater that requires little or no artificial energy input and a large land area.

faecal coliforms

See "E. coli".

flowrate

The volume of water that passes a certain point (in a pipe, channel, river etc) in unit time. Common units are litres per minute or cubic metres per second. The letter "Q" is commonly used to refer to this measurement.

grey water

Domestic wastewater without water and excreta from toilets (i.e. without urine and faeces)

intensive wastewater treatment

A method for treating wastewater which requires a large artificial energy input and a relatively small land area.

karstic

This refers to underground calcarious rock in which cracks have been enlarged by flowing water which has dissolved the material in or around the crack. These enlarged cracks or fissures allow water to flow down quickly to the groundwater with very little treatment (in comparison with water that flows slowly though fine, granular material which provides very effective filtration.) If polluted water infiltrates into karstic rock it may cause serious pollution of the groundwater below.

leca

Light Expanded Clay Aggregate – a porous mineral material, which may be natural or artificially made. Because of its porosity it has a very large surface area. It is commonly available in the form of small spheres.

loading

In general the term "loading" refers to how much wastewater can be treated by one square metre of the plan area of a treatment unit (such as a pond or tank) in one day or one hour. "**Hydraulic loading**" is a guide to the volume of water that can be treated by one square metre, and "**organic loading**" refers to the amount of organic material, or BOD, that can be treated by one square metre, in each case in a particular time. These loading rates are used to decide how large the treatment unit should be.

media

This refers to the sand, gravel, rock or soil that fills a filter and removes pollutants from the water that flows through. (Strictly speaking, the word should often be used in its singular form – "medium" – but in practice the plural form is always used, even if there is only one material in the filter.) **Porous media** refers to collections of pieces of a material that allow water to pass though the gaps between the individual pieces. (The material itself may not be porous, but the hardness of the material and the shape of the pieces ensure that there are always gaps between the pieces.)

microclimate

This refers to the temperature, moisture, airflow, radiation etc. conditions in a restricted space that may be only a few centimetres or metres across. The local microclimate can differ considerably from the general climate.

mineralisator

A method of providing pretreatment to wastewater; described in Section 3.2

niche

An ecological niche refers both to a type of location where the conditions are such that a particular organism can thrive, and to the relationship between an organism and its environment. If there are large numbers of various kinds of ecological niches, it can be expected that there will be a wide variety of organisms.

"no-mix" strategy (Also known as source separation.)

Keeping urine, faeces and grey water separate. Sometimes urine is kept separate from the other two, and sometimes grey water is kept separate from faeces and urine.

nutrient cycle

For sustainability, the minerals and other components taken from the soil by plants as they grow (the nutrients) should be returned to the soil either as fertiliser, as recycled wastewater, or as composted solid waste. The movement of essential minerals and organic matter from the soil, through preparation for consumption, consumption, into wastewater and solid waste streams, and back to the soil, is called the nutrient cycle.

pathogenic

Pathogenic organisms are those which can cause disease. Some bacteria, for example, are not associated with any disease, and so are not pathogenic.

permeability

A measure of the ease with which water passes into and through soil. (See also K_f.)

person equivalent (PE)

The average amount of wastewater produced by one person per day. This may refer to the weight of organic matter (the organic load) or the volume. Both the organic load and (even more so) the volume of water differ greatly between persons of different cultures, but also between persons of the same culture.

plant

The reader is warned about a possible confusion here, since both meanings of this word (as a noun) can be relevant. In this brochure, unless the context makes the meaning clear, it will be used to refer to a planned facility that is designed, constructed and operated to modify the characteristics of wastewater that flows through it. When flora is referred to, the terms "vegetation" or "green plant" will be used.

polishing ponds

The last ponds in a series of wastewater treatment ponds. The earlier ponds are designed to remove solid particles and reduce the strength of the wastewater, and the polishing ponds are used to ensure that the water leaving the pond system is of a very high quality. (Also known as maturation ponds.)

primary treatment

A term used by wastewater engineers to refer to the first major stage of conventional wastewater treatment. Primary treatment involves the physical separation of suspended organic material as scum and sludge in sedimentation tanks or mineralisators. "Secondary treatment" in this context refers to biological processes that reduce the concentration of (mainly dissolved) biodegradable organics.

receiving waters

The running water (river, creek, or stream) or standing water (pond or lake) that receives treated wastewater.

retention time

This is a theoretical estimate of the time that water stays in a soil filter, tank or pond when it is flowing into and out of it at a constant rate. It is equal to the volume of water in the tank divided by the flowrate, or the time that it would take for the tank to be filled if it were initially empty. In practice some of the water stays in the tank for less time, and other parts of the water stay for a longer time. It is also known as the residence time.

robustness

Natural purification processes can be disrupted. For example bacteria can be poisoned by toxic chemicals in the wastewater. Suspended material can be stirred up by high flows. A treatment process is said to be *robust* if it can withstand changes in wastewater composition, flowrate, temperature etc so that it is not made ineffective by these changes. The opposite is *sensitive*.

sedimentation

Sedimentation is the removal of suspended particles from flowing water by reducing the velocity and turbulence of the water so that the particles move to the bottom by the action of gravity. Small suspended particles fall very slowly, so it is often necessary to keep the water in a sedimentation tank for two hours or more to obtain the desired removal of suspended particles. (See also SS.)

settling

the same meaning as sedimentation

sewer

A pipe to which drains from houses are connected. Its purpose is to carry sewage (wastewater) away.

self-purification

When waste materials pollute a body of water, there are natural processes (such as sedimentation, decomposition by bacteria and disinfection by sunlight) that reduce the pollution. These processes acting together are called self-purification.

stabilisation

Stable compounds do not change with time, but stay in the same form, so they do not use oxygen when in water. Most organics in wastewater are biodegradable, i.e. they are not stable. If organic compounds in wastewater are stabilised, it means that they are converted into stable compounds, which do not pollute the water by using its dissolved oxygen.

standards as in **effluent standards**

Effluent or discharge standards are quantitative criteria that must be met by the treated wastewater. It is common for effluent standards to include the maximum BOD and the maximum concentration of suspended solids that are acceptable. If the measured values are higher than these maxima, the effluent should not be discharged into the environment.

treated wastewater

Wastewater which has passed through a wastewater treatment plant. Even though it is normally quite clean it is still wastewater in a technical sense. Also known as "effluent".

water cycle

This term refers to the abstraction of water from surface or underground sources, consumption and use, discharge as wastewater, treatment, and return to the surface or underground water bodies. Water sources are also replenished by rainfall and streamflow. For sustainability, the rate of abstraction of water must not exceed the rate at which the sources are replenished, and the quality of the sources must not deteriorate as a result of returning wastewater.

wetland system

This term is used in two different ways: some authors consider it as an aquatic system (with water standing above the soil), and others as a soil-based system (with water logged soils). Both types occur both naturally and as man-made (engineered) systems, and can be used for treating wastewater. Here, the term is used for soil-based, engineered systems. Systems of this type that involve a considerable degree of engineering construction are known as ***constructed wetlands.***

Sustainable wastewater treatment with soil filters

Wastewater treatment is an "end of pipe" measure. On-site management of wastes is desirable and necessary, but in many situations there is no substitute for a wastewater treatment plant. Wastewater treatment methods using little or no energy and large land areas are particularly suitable for rural areas and regions with dispersed settlement. One treatment method of this type is soil filtration. Soil filters can be suitable and sustainable solutions to wastewater problems.

The brochure is intended to assist decision-makers. It is not a design manual. The construction and operational principles of soil filters are described. Their economic, institutional, legal and socio-cultural aspects are also outlined. The brochure also includes a short comparison of soil filters with other extensive treatment methods, and a list of questions to consider when faced with the need to select a wastewater treatment system.

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