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# Appropriate technology for the treatment of wastewaters for small rural communities

Report on a WHO meeting

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## INTRODUCTION

The meeting was organized by the WHO Regional Office for Europe in cooperation with the French Government, and was hosted by the National Centre for Agricultural Mechanization, Rural Engineering, Water and Forestry Management (CEMAGREF). It was convened as part of WHO's strategy for the International Drinking Water Supply and Sanitation Decade in pursuance of resolution EUR/RC31/R9 of the thirty-first session of the Regional Committee for Europe, whereby the Member States recommended the improvement and development of water supplies and sanitation in rural areas. This strategy, described in document EHE 82/29, assigns first priority among the development tasks to appropriate technologies for the treatment of wastes for the presently underserved communities in rural and periurban areas.

The group was composed of 21 participants from 11 countries of the WHO European Region (see Annex 5) and chaired by Mr D. Ballay of the French Ministry of Agriculture. The discussions were conducted in English and French, with simultaneous interpretation into each language.

The group set out first to identify possibilities, limitations and conditions with regard to the application of appropriate technology for wastewater treatment for small rural communities. It also considered the quality control requirements that should be met in the treatment of effluents, especially from the health standpoint. Finally, it examined problems in the operation of treatment plants and the training of the staff who have the main responsibility for ensuring that they function efficiently and without interruption.

Before proceeding to the technical part of the discussions, the group heard a number of reports by participants describing the different types of sanitation system encountered in the Region (see Annex 1).

In all countries of the Region, sanitation systems are designed mainly for waste treatment for urban communities, and include installations for:

- collection of wastes through a sewer network and their conveyance to a treatment site;

- treatment of the wastes in a large plant permanently manned by a team of specialists;
- discharge of the treatment effluents, usually into a river.

Systems of this kind offer a satisfactory service and a high level of convenience to consumers in urban areas.

In many countries similar systems have been developed for small rural communities. However, simply transferring an urban system to a rural area involves a number of difficulties; in particular:

- the cost of the sanitation service per consumer is much higher, as economies of scale are not possible;
- the treatment techniques are not suited to the educational level of the operators, and the plants rarely function with optimum efficiency.

The problem of sanitation in rural areas therefore calls for *appropriate technologies* which should be developed in the light of the following considerations:

- the drawback of the small size of rural communities can be compensated by making optimum use of the natural potential: available land area, use of the soil and subsoil, agricultural reuse of wastewater or sludge;
- the range of sanitation options may be increased by using a combination of individual sanitation and sewer systems;
- in some cases it may be worth while to use new technologies from the developing countries for sanitation in rural areas.

## CONVENTIONAL SANITATION SYSTEMS

Such systems collect wastewater through a sewer network. It is then treated either by a conventional method (activated sludge, trickling filters, etc.) or an extensive or specifically rural method (natural lagooning, land treatment).

The different waste treatment methods are described below (see also the comparative table in Annex 3).

## **Standard methods**

Such methods are simplified versions of those used in urban areas. In a conventional plant, wastewater is treated in several stages:

- physical pretreatment;
- primary settlement;
- biological treatment;
- secondary treatment;
- treatment of sludge collected from settlement tanks.

By combining different types of equipment, a large number of treatment techniques may be used. The decision to use one or the other to deal with a particular sanitation problem must be made on a case-by-case basis, taking into account the local conditions including:

- characteristics of the effluent: nature, concentration, fluctuations in flow and load;
- degree of treatment required, depending on the waste discharge environment;
- the possibility of ensuring efficient operation of the system (in this respect consideration must also be given to the operational capacity and organization of the basic health services);
- the suitability of the site: climatic conditions, nature of the terrain and available land area, sociocultural characteristics;
- capital costs.

Annex 2 describes the waste treatment methods most commonly used in rural areas, with details of their applications and the factors governing their adoption and use.

The following guidelines are applicable to treatment systems for rural areas.

### *Pretreatment*

Even in small plants, the pretreatment unit should include at least a bar screen. The design of this device does not pose any particular problem. It is, however, important to ensure that it is reliable, i.e.:

- that it is designed with operational requirements in mind (ease of cleaning, inclusion of a screening trough and refuse storage container in the system);

- that the bars in the screen are not too fine: a net spacing of 30–70 mm between the bars is preferable in most cases;
- that there is provision for shortcircuiting the system to prevent any overflow of effluent in the case of a temporary breakdown of the pretreatment process.

### *Settlement*

The settlement process produces sludge that must then be treated. For this reason, at least where primary settlement is concerned, it is often worth while to combine this process with digestion (two-storey tanks — Imhoff or other).

In cases where the secondary settlement is not carried out in a combined tank, consideration must be given:

- either to recirculation of the sludge to the top of the primary settlement tank;
- or to separate treatment (on the spot, or in a central unit).

Different combinations of primary or secondary settlement tanks and settlement-digestion tanks are possible, and the choice will depend on the nature of the site (gradient, presence of groundwater) and the cost of the operation (unless the equipment is standardized, two-storey tanks have the disadvantage of high cost).

### *Biological treatment*

Three types of system have been found particularly suitable for wastewater treatment for small communities: trickling filters, biodiscs and modified processes, and the extended-aeration active-sludge method. The use of such systems should, however, meet the following criteria.

*Low- or medium-rate trickling filters.* This system is particularly suitable for wastewater treatment for very small communities. Its main disadvantage is its high cost, but this can be offset by using rural construction techniques to which it lends itself quite well.

At the top of the unit there should be an integral system for periodic flushing (siphon, tipping system) which ensures satisfactory dispersion of the effluent over the filter. The smaller the community, the more important this is. Recirculation of the effluent avoids drying of the filter and ensures more reliable treatment. It should be borne in mind, however, that recirculation requires the installation of a pump and the supply of power to



the treatment site (the other parts of the system operate without power since they are gravity-fed). The organic load on the installation can vary from 0.1 to 0.4 kg BOD<sub>5</sub>/m<sup>3</sup> of material/day, depending on the level of treatment of the effluent and the degree of stabilization required for the sludge.

*Biodiscs and modified processes.* One of the main advantages of these systems is their modular design, which makes it easier to adjust them to increases in the number of users. They provide high quality treatment for an organic load of 7–15 g of BOD<sub>5</sub>/m<sup>2</sup> of disc/day.

*Extended-aeration active-sludge method.* This process is very suitable for wastewater treatment for small communities — particularly the sequential systems in which secondary settlement takes place in one part of the aeration tank (Pasveer and similar). The treatment produces only a small quantity of sludge and also overcomes the constraints of primary settlement. At the same time it has a high energy cost compared with the other systems and its use calls for greater technical skill. Loading rates are between 0.05 and 0.1 kg of BOD/kg of volatile solids/day, depending on the degree of sludge stabilization that is required. It should be noted that the loading rate decided upon will greatly affect the cost of construction of the system.

It can be said in general, with regard to each of the treatment methods presented above, that the low-rate options seem best suited to the conditions in small rural communities.

### *Sludge disposal*

Sludge treatment and removal are the operations that pose the greatest difficulty in small treatment plants, and preference should always be given to methods that reduce the number of such operations to a minimum, particularly the extended-aeration active-sludge method.

Drying beds are frequently used prior to agricultural irrigation or dumping of dried sludge. The possibilities for using this technique and the sizing of the beds depend largely on the local climatic conditions. The current norms range from 1 m<sup>2</sup>/2 users in the United Kingdom to 1 m<sup>2</sup>/25 users in Italy.

Application of liquid sludge to agricultural land is an increasingly common technique. It requires installations for:

- temporary storage, in the case of sludge that is satisfactorily stabilized and applied to crops at little risk from the epidemiological standpoint (cereals, vines, etc.);

- storage to enable stabilization and disinfection in cases where the sludge is applied to grazing land or vulnerable crops.

A third possibility that may be envisaged is that of transferring the sludge to a central unit where inexpensive digestion (possibly including biogas production) or composting treatments may be carried out.

### *Conclusion*

Conventional systems have been widely used in many European countries for wastewater treatment for small rural communities. They are still suitable in many cases; before recommending them, however, it is essential to ensure that the technical resources needed to operate them are available.

At the same time the high cost of setting up such facilities is an obstacle to their use. The cost may be lowered by using standard model designs, or standardized components. In that case, however, a preliminary check must be made on the quality and efficiency of the proposed equipment, and this will be the responsibility of the technical services of the relevant authorities in each country.

### **Natural lagooning**

Natural lagooning is a biological wastewater treatment process carried out in tanks where a constant level of water is maintained (oxidation pond). In the tanks, the pollutant loads are transformed concurrently with stabilization of the resulting sludge, through the action of microorganisms that are generated in this environment (especially bacteria and algae). This technique has become increasingly popular for wastewater treatment in developing countries and in small rural communities in Europe because of its:

- efficiency in destroying pathogens;
- simple operation;
- appropriateness for the rural environment.

### *Design*

In Europe lagooning is carried out using many different techniques. Within this diversity, however, it is possible to identify three main principles:

- natural lagooning is suitable for direct treatment of raw effluents (a bar screen for pretreatment may be installed upstream of the tanks);

- it is essential to divide the total area of the installation into at least three tanks so as to produce effluent of adequate quality from both the physicochemical and the bacteriological standpoints;
- the lagoons should be sufficiently watertight to maintain the desired water level, taking into account both inflow (effluent, rain-water) and losses (rate of discharge, evaporation, infiltration).

With regard to the dimensions of the tanks, two types of system should be considered: aerobic-anaerobic and fully aerobic.

*Aerobic-anaerobic systems* (Fig. 1) consist of a series of three to five lagoons, arranged as follows:

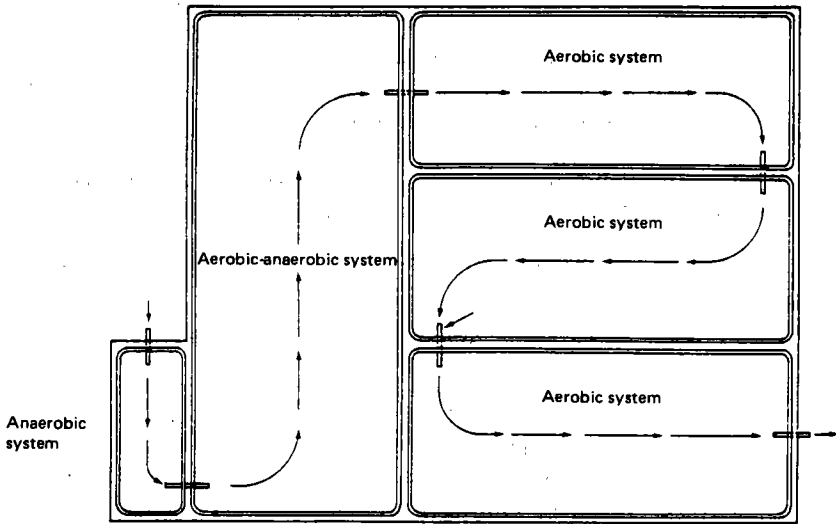
- a first anaerobic lagoon:  
depth: 2 to 4 m,  
theoretical retention time: 1 to 5 days;
- an aerobic-anaerobic lagoon:  
depth: 1 to 1.5 m,  
theoretical retention time: 5 to 30 days;
- one to three aerobic lagoons:  
depth: 1 to 1.5 m,  
theoretical retention time: 5 to 10 days.

*Fully aerobic systems* (Fig. 2) are designed to produce aerobic conditions in a first, large lagoon (50% of the total water surface in the installation) as well as more diversified biocenoses in the remaining lagoons. For this purpose it is sometimes considered useful to establish aquatic root plants in the lagoons (macrophyte as opposed to microphyte lagoons).

The dimensions of the lagoons will depend on the nature of the effluent to be treated and the local climatic conditions. By way of illustration, the following dimensions have been found appropriate for temperate climatic conditions in France:

- first (microphyte) lagoon:  
depth: 1 to 1.4 m,  
organic load: 100 kg BOD/ha of water surface, i.e. about 5 m<sup>2</sup> per user,  
theoretical retention time: 30 days;
- second and third lagoons:  
surface area of each: 2.5 m<sup>2</sup> per user.

Fig. 1. Aerobic-anaerobic lagoon system



Source: **Kalbermatten, J.M. et al.** *A Planner's Guide*. Appropriate Technology for Water Supply and Sanitation, Vol. 2. Washington, DC, World Bank, 1980.

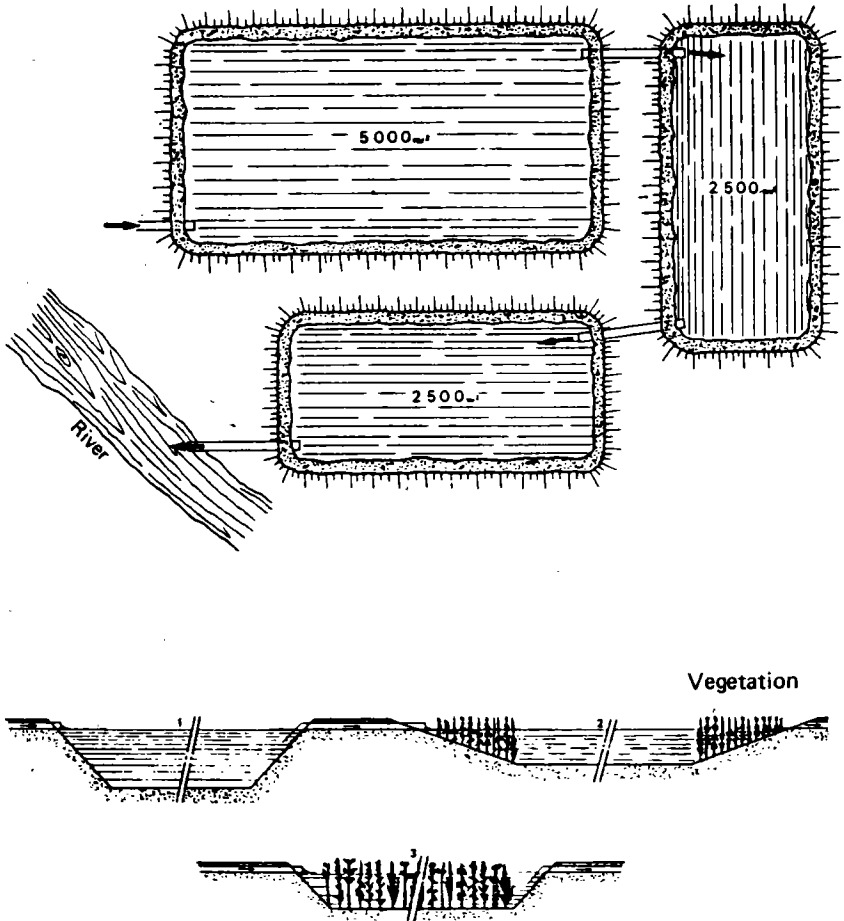
The installations consist either of microphyte lagoons averaging 1 m in depth or macrophyte lagoons averaging 0.3 m in depth, with dense growth of aquatic plants (*Scirpus*, *Phragmites*, *Typha*, etc.) or mixed lagoons combining the characteristics of the other two types.

The norms on the dimensions of the two types of system are given as an example; other techniques require different dimensions.

The choice between one system or another may be based on the following considerations:

- anaerobic systems are especially suitable for treating concentrated effluents ( $BOD_5 > 500$  mg/l);
- aerobic-anaerobic systems require less land than fully aerobic ones;
- maintenance of anaerobic systems involves more frequent cleansing, and the lagoons may produce offensive odours;
- macrophyte lagoons should not be used in areas where they may give rise to breeding of mosquitos that would constitute a nuisance for the population or be vectors of diseases.

Fig. 2. Natural lagoon system — overhead and cross-sectional views



1. Microphyte lagoon
2. Mixed lagoon
3. Macrophyte lagoon

Source: *Lagunage naturel et lagunage aéré, procédés d'épuration des petites collectivités*. Paris, CTGREF et Agence de Bassin Loire-Bretagne, 1979.

### *Construction*

Preliminary geotechnical and geological studies are needed to determine whether the site is suitable for lagooning. If the soil is not sufficiently impermeable to keep water in the lagoons, or if there is a danger of contamination of groundwater that is being or could be used for water supply, the lagoons should be made watertight.

The most economical approach is to use local materials (clay), when there is a nearby source of supply. Other sealing techniques generally entail excessively high capital costs, which may mean that the lagooning option is abandoned. Embankment materials should be laid so as to achieve a satisfactory degree of stability and watertightness. Earth compaction is essential. The gradient of the embankment should be sufficiently low to prevent the sides falling away. Adequate protection against lapping of the water is also indispensable (planting of grass, enrockment, etc.).

### *Applications*

Apart from the requirements mentioned above concerning the selection of a site (nature and area of land needed), the main obstacle to the expansion of natural lagooning is the fact that the process is sensitive to variations in temperature: in cold climates or harsh winters, the biological activity may fall to zero. However, even in these circumstances, the technique can be used to treat seasonal effluents (tourist areas). Also, the loss of efficiency in winter may be compensated by a greater dilution in the recipient water. At the same time, because of the improved efficiency during warm weather, it is possible, to a limited but nevertheless appreciable extent, to treat the wastes of a temporarily increased population in a tourist area without enlarging the lagoon system correspondingly.

Natural lagooning is also an effective technique for microbial disinfection. The results are particularly satisfactory in shallow lagoon systems. It therefore appears to be the most suitable technique for disinfection of effluents of small communities in cases where this is necessary (discharge of sewage near bathing or shellfish growing areas, epidemiological situation). Furthermore, because they are of satisfactory bacteriological quality, effluents from lagooning are more suitable for agricultural reuse (irrigation) than those produced by other methods. Some precautions must, however, be taken: there should be limitations with regard to the choice of crops, and the mode and duration of application.

### *Maintenance*

Lagoons should be managed like other wastewater treatment facilities. Access to them should be restricted to maintenance staff and they should preferably be fenced off.

The most important maintenance requirements involve keeping the access roads in good order, controlling vegetation on the embankments especially to prevent mosquito breeding, servicing the pretreatment units and, if necessary, periodically removing floating vegetation (which may be reused, particularly as fertilizer). Regular desludging should be carried out to prevent silting, at intervals which will depend on the design and mode of operation of the facility. The desludging procedure and the arrangements for disposal of the sludge should be specified at the design stage of the project.

### *Conclusion*

Because it is suited to rural conditions, lagooning should always be considered at the outset as an option for waste treatment for a small rural community. The method may prove inapplicable under the local conditions but it should not be ruled out without very good reason. It is also important to ensure that the community realizes that such systems, although designed for rural use, do require regular maintenance.

### **Land treatment**

Land treatment involves using the purification and infiltration potential of existing or redeveloped land for sanitation purposes. However, it is not only a form of treatment but in most cases also a method of disposal (infiltration). A number of land treatment techniques are suitable for small communities:

- irrigation through drainage trenches (surface irrigation);
- subsurface irrigation into existing or reconstituted soil (sand filters).

These techniques are modified versions of individual sanitation methods, and will be described in the next chapter.

### *Design*

The wastewater is infiltrated into a network of open trenches. Primary treatment is not essential from the technical standpoint since the trenches are readily accessible should silting occur. Only a bar screen seems absolutely indispensable. In practice, however, the technique is normally used for secondary treatment. In this case primary treatment in a settlement-digestion tank is recommended, since septic tanks are not suitable (problem of odour). The technique may also be used to supplement treatment in a conventional plant or lagooning.

No general rule can be laid down with regard to dimensions, which should be worked out on a case-by-case basis, bearing the following points in mind:

- silting is very easy to correct (by desludging or marking out the trenches again);
- methods for sizing subsurface irrigation systems (see next chapter) furnish unduly high values for this purpose.

In practice, maintenance is required only for the pretreatment and possibly the primary treatment units. In the effluent discharge area itself all that is needed is to cut the vegetation in the trenches and desludge them from time to time.

### *Applications*

Surface irrigation is suitable for remote rural communities which cannot meet high investment and operating costs. It is a secondary treatment technique particularly suited to sites without outlets and to communities of variable size (tourist areas). Thus it is efficient in rural conditions and should be considered whenever it seems feasible, having regard to:

- the geological and soil characteristics of the site;
- the degree of protection of the groundwater;
- the proximity of sources of drinking-water.

### **Modified processes**

#### *Peat beds*

Attention is again being paid to the use of peat beds for treating the wastes of small communities. Further research is needed to determine the effectiveness and suitability of this process in rural areas. Its use may be considered, bearing in mind the following points:

(a) the wastewater must undergo primary treatment upstream of peat beds (a settlement-digestion tank is suitable for this purpose);

(b) continuous use of peat beds results in rapid silting, i.e.

- formation of a more or less impermeable scum on the surface,
- silting in the beds themselves,

and hence the following precautions should be taken:

- a number of parallel beds should be established so that some can be taken out of service periodically for desilting,



- the surface of the beds must receive regular attention (scarification),
- the peat must be changed at appropriate intervals;

(c) variations in the humus content of peat (i.e. whether it is light and only slightly decomposed or dark and at a more advanced stage of decomposition) affect its capacity for infiltration and purification, and hence full account must be taken of the type used when sizing the beds.

### *Macrophyte techniques*

Studies have been carried out in several European countries on the possibilities for using the purification potential of certain aquatic root plants. The systems proposed include:

- macrophyte lagoons (see Fig. 2);
- macrophyte trenches: trenches planted with *Scirpus* or *Phragmites*, which were developed in the Netherlands for secondary treatment of wastes of small seasonal communities (camping sites);
- macrophyte tanks: drained watertight tanks planted with *Scirpus*, *Phragmites* or irises and installed on a filtering substratum, which were developed in the Federal Republic of Germany for main or secondary treatment of wastes of small communities or for independent systems; different designs allow for combinations of tanks in series or in parallel.

These systems provide an adequate level of treatment. The only maintenance involved consists of attention to the aquatic plants. Fuller details of research on such methods would, however, be necessary to show how they should be applied in small rural communities.

## ON-SITE WASTE DISPOSAL

On-site waste disposal systems are in common use and they remain an important means of sanitation for small rural communities. Systems with septic tanks are by far the most frequent option. Technical aspects of their correct use were discussed by the group in some detail. After treatment in a septic tank, the effluent is usually discharged into the soil. Thus the satisfactory operation of these systems depends to a large extent on the design and size of the infiltration units.

Other techniques suitable for rural areas were also studied. They have more limited applications than septic tanks in Europe but may be

appropriate in certain cases. Mention may be made in particular of techniques for localities without a piped water supply, on which considerable research has been done in a number of developing countries in recent years.

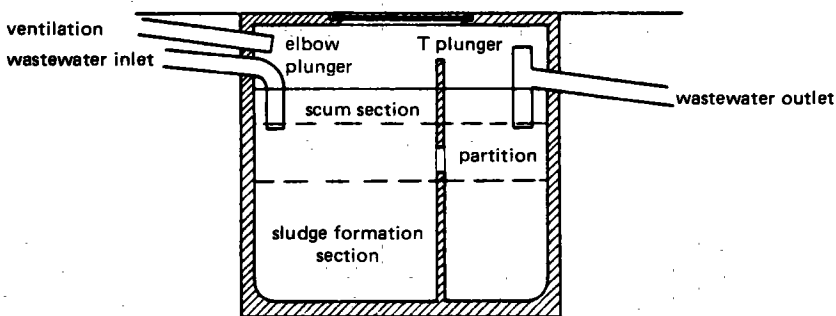
### Septic tanks and infiltration

This technique seems particularly suitable for treatment of the wastes of single households, institutions and small communities which have a water supply system. The associated treatment and effluent disposal system will depend on the nature of the soil and the requirement to protect the local groundwater and drinking-water sources: whenever it is feasible, drain-fields are the most simple and least expensive option.

#### Design

Septic tanks are built with watertight materials and normally comprise two compartments (see Fig. 3).

Fig. 3. Design of a septic tank



Source: *L'assainissement individuel - principes et techniques actuelles*. Paris, Ministère de l'Environnement et de Cadre de Vie et Agence de Bassin Loire-Bretagne, 1980.

Both sullage and faecal wastewater are conveyed to the septic tank. In the first compartment the solid fraction settles to form a sludge layer which undergoes anaerobic digestion. Further sedimentation as well as sedimentation of sludge that has been resuspended by peak flows takes place in the second compartment, which is generally half the size of the first.

The effectiveness of the treatment depends on the local climate (and especially temperature). BOD may be reduced by 30–50% and total suspended solids (TSS) by 50–70%. Generally speaking, however, the physico-chemical quality of the effluent is such that it cannot be discharged directly into surface water or an aquifer (cesspool, fissured subsoil).

Most, if not all European countries have codes of practice for the sizing of septic tanks. There is considerable variation in their design recommendations which may, at least partially, be explained by the different climatic and sociocultural conditions in each country. In any case, however, it is accepted that the required size depends on the following factors:

- the influent wastewater flow;
- the retention time required for effective solids settlement;
- the sludge accumulation rate;
- the frequency of desludging.

The influent wastewater flow depends on water consumption, and measures to reduce it (e.g. replacing conventional flush toilets by water-saving designs) allow a more economical sizing of the installation. The required retention time for effective solids settlement depends on the number of users; for instance, for tanks serving a single household it is usually taken as the equivalent of one day (i.e. a tank having a capacity of three days when empty). The sludge accumulation rate varies considerably, depending on climatic conditions, and ranges from 30 litres/person/year in southern Europe to 70 litres/person/year in the north.

The frequency of desludging depends on the rate of solids accumulation and the cost of emptying. According to the practice in different European countries, the recommended frequency of desludging varies from twice a year to once every four years, although yearly or twice-yearly intervals are usually advised. When the local conditions do not allow regular emptying, additional sludge storage capacity within the tank may be required.

### *Subsurface irrigation systems*

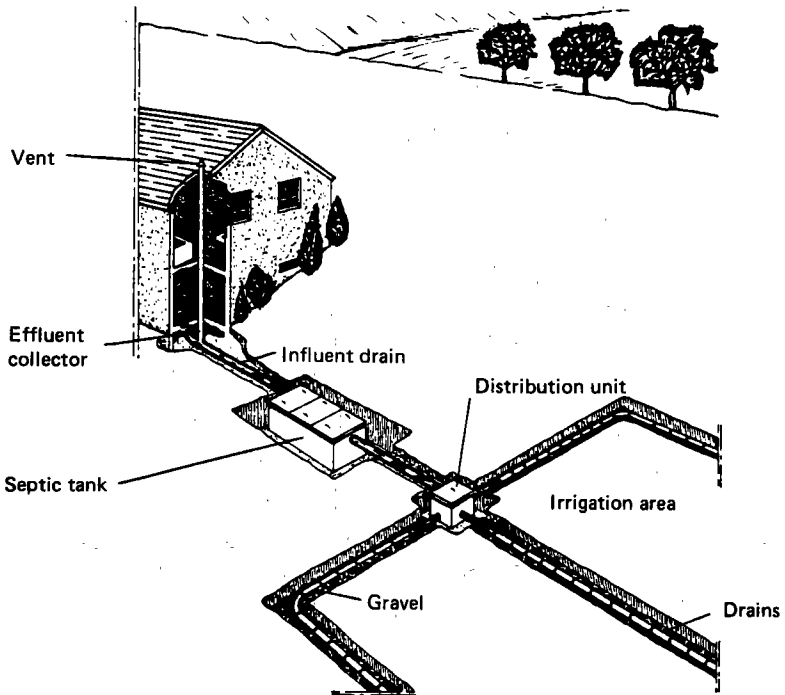
Such systems involve the infiltration of wastewater into the soil through drains embedded in a filtering stratum.

Infiltration of wastewater into the soil is the best means of completing purification that has started in a septic tank, while allowing for very safe disposal of the effluent.

The basic system is shown in Fig. 4. It could also include as additional options:

- a prefilter upstream of the distribution unit, serving as a precaution against silting of the drains since it is an indicator of the functioning of the septic tank:
- a flushing cistern to ensure better distribution of the wastewater in the treatment units.

Fig. 4. Shallow subsurface irrigation system

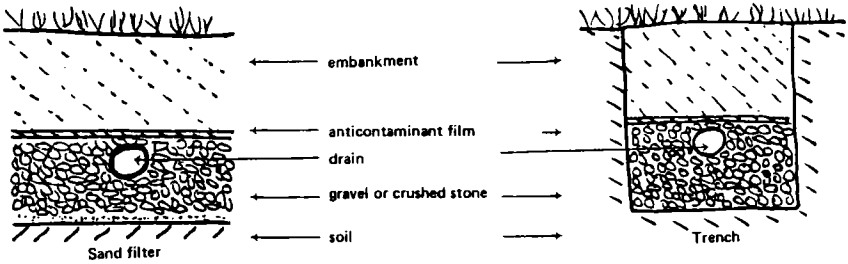


Source: *L'assainissement individuel - principes et techniques actuelles*. Paris, Ministère de l'Environnement et du Cadre de Vie et Agence de Bassin Loire-Bretagne, 1980.

A subsurface treatment system may consist of a series of narrow (0.5 to 1 m) leaching trenches or one or more sand filters.

The choice between trenches or filters will depend on the nature of the soil and the land immediately surrounding the system (see Fig. 5).

Fig. 5. Subsurface irrigation



Source: *L'épandage des eaux usées domestiques*. Etude préalable de l'aptitude des sols et règles de dimensionnement des installations. Paris, CTGRF, Etude No. 50, 1980.

*Trenches* are more suitable when the terrain is not very permeable and is difficult to work on. They allow some storage of the effluent, the walls play a useful role in the infiltration process, and there is no need to move any equipment over the infiltration area.

*Sand filters* are more compact and are particularly suitable when the soil is permeable, and when the site does not present any topographical problems or difficulties due to the presence of impermeable strata (risk of resurgence of the wastewater).

To use these techniques, the local soil must have the necessary properties for infiltration and purification of the wastewater.

The soil must be sufficiently permeable to avoid the risk of stagnation or resurgence of wastewater and it must also be capable of purifying the septic tank effluent. The relative importance of the last requirement depends on the risk posed to any groundwater in the vicinity of the system.

Permeability is conventionally assessed by means of clean water percolation tests.

Using this empirical method it is possible:

- to assess the suitability of the soil;
- to work out the size of installation required, in terms of the admissible water pressure or the required surface area per person served.

The validity of this approach may be questioned since in place of knowledge of the actual conditions governing the infiltration of wastewater (which has a silting effect), the size of the installation is determined empirically and statistically from the results of a measurement using clean water.

Experience has, however, shown that the method can be considered reliable, with certain provisos as outlined below.

1. Measurement of permeability must always be combined with soil studies showing:

- the thickness of the soil stratum;
- the nature of the subsoil: impermeable rock, fissured rock;
- the presence of permanent or temporary groundwater (it is essential to carry out this investigation (presence of mottling) if the measurements are made when the water level is low).

These studies are a minimum requirement for assessing the suitability of the soil in cases where the available means do not allow the performance of permeability tests.

Furthermore, only a design specialist with considerable local experience would be able to make grain-size measurements of the soil in place of permeability studies, since there is no direct relationship between grain size and permeability except in extreme cases (sand, compact clay).

A method that combines a measurement of permeability with soil studies in order to determine the feasibility and appropriate size of proposed irrigation systems is now coming into general use in France.

2. The measurement of permeability is concerned only with the hydraulic aspect of infiltration of the wastewater and not the purification capacity of the soil. It may therefore also be necessary to consider the thickness and grain size of the soil, the possible presence of fissures which would allow rapid subsurface movement of the wastewater, and constraints associated with the risk to the groundwater.

The suitability of soil for an irrigation system is often assessed by means of studies relating to a given group of users: collective system, housing estate, institution.

Assessments are rarely undertaken, even in the minimum form proposed (soil studies), for a single household.

In some cases the preparation of maps showing the suitability of the soil for individual sanitation (on the basis of soil maps or studies) may be a worthwhile approach and provide a very useful planning tool.

### *Alternatives to subsurface irrigation*

Certain more costly techniques may be used as alternatives to land treatment when the environment does not lend itself to the use of the methods described above, particularly:

- when unprotected groundwater is located near the surface;
- when the soil stratum is not sufficiently thick.

*Drained sand filters* (Fig. 6) are used when the soil is too impermeable or when groundwater at risk is located near the surface (0.5–1 m). They should be used only in cases where the effluent can be discharged into the surface environment. It is preferable to use regularly sized grains of 0.35 to 1.7 mm. A preliminary study will enable correct sizing of the filter.

*Undrained sand filters* (Fig. 7) are a variant of the system described above and can be used when the land is not suitable for irrigation (soil stratum not sufficiently thick) but does allow infiltration of effluents after treatment (fissured substratum).

*Raised sand filters* (Fig. 8) consist of a mound of sand placed on the natural terrain after levelling. The height of the mound should be about 1 m. This system may be appropriate if there is an aquifer close to the surface (depth of 0.5 to 1 m) and if the effluent cannot be discharged into the environment.

To use this technique the soil must be sufficiently permeable, and equipment to raise the effluent is necessary in many cases.

### *Conclusion*

Combined septic tank/irrigation systems are being adopted increasingly for both individual sanitation and sewerage (for up to 1000 people in some European countries). They should be used in accordance with the following guidelines:

*Maintenance and operation.* Land treatment facilities are inexpensive to run and very easy to maintain. However, to ensure that they function satisfactorily, desludging of the septic tanks must be carried out at the appropriate intervals (problem of possible silting of the drains).

Fig. 6. Drained sand filter for a single household

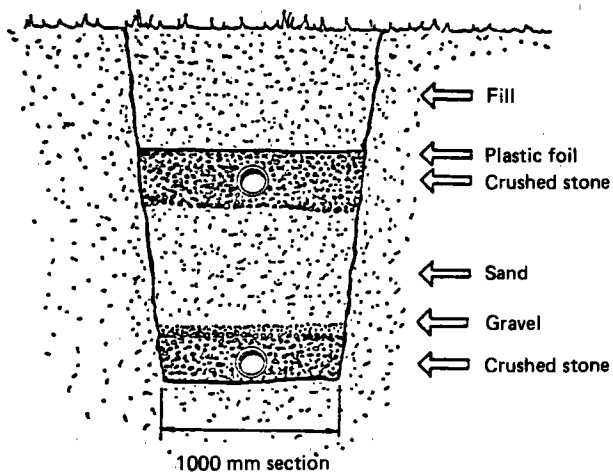
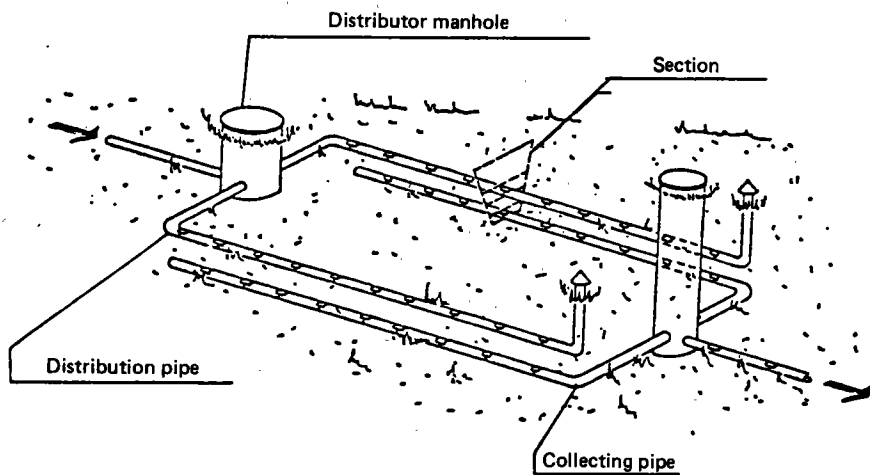
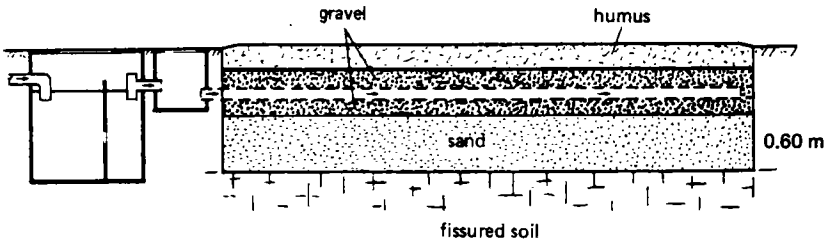


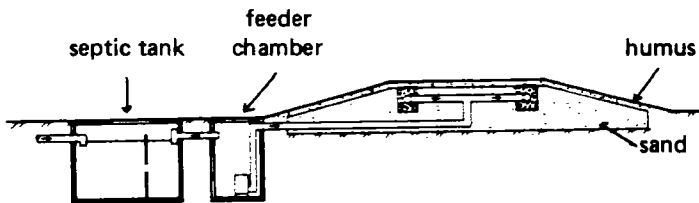


Fig. 7. Undrained sand filter



Source: *L'assainissement individuel - principes et techniques actuelles*. Paris, Ministère de l'Environnement et du Cadre de Vie et Agence de Bassin Loire-Bretagne, 1980.

Fig. 8. Raised sand filter



Source: *L'assainissement individuel - principes et techniques actuelles*. Paris, Ministère de l'Environnement et du Cadre de Vie et Agence de Bassin Loire-Bretagne, 1980.

**Quality of the effluent.** Precise monitoring of the quality is possible only in the case of systems where the discharge of the effluent is localized (drained sand filters). All irrigation systems, when correctly operated, provide satisfactory treatment from the physicochemical and bacteriological standpoint. The treatment facilities must, however, be located at some distance from drinking-water sources. A protective zone should be established in accordance with the hydrogeological characteristics of the site and the depth of the catchment.

## Other methods

This section describes techniques which may be an alternative to the combined septic tank/irrigation system, some of which receive only part of the wastewater (sullage or faecal water), while others are suitable for sites that do not have a water supply.

### *Cesspools*

In situations where none of the effluent can be discharged, the wastewater may be stored on site in cesspools, for subsequent removal to a treatment plant by a vacuum tanker at regular intervals. The following guidelines should be observed when using this system:

- it is important to ensure that the walls of the cesspool are watertight;
- an optimum balance can be reached between the capacity of the cesspool and the frequency of emptying, taking into account the local costs of construction and emptying.

Cesspools are nevertheless a costly sanitation option that should be considered only as a last resort. The cost may be lowered by:

- restricting water consumption;
- wherever possible, providing separate facilities for on-site disposal of sullage, and using the cesspool for faecal water only.

### *Composting toilets*

These units consist either of a single compartment (continuous composting) or a double compartment, one part of which is used alternately. Both types are waterless toilets receiving only excreta and they require organic household wastes to obtain a suitable carbon-nitrogen balance and reduce the moisture content to around 60%, for more efficient composting.

Composting toilets have the advantage of producing no liquid effluent and are therefore suitable for use in areas where the discharge of effluent, even after treatment, might be a major hazard (possibility of groundwater pollution, fragile aquatic ecosystems). They have, however, the following disadvantages:

- shortcircuiting may occur in continuous day-to-day use, and the compost may be contaminated by untreated excreta;
- sociocultural factors may militate against the reuse of excreta.

Compared with other methods, composting toilets require a high degree of user care and maintenance. It is therefore recommended that they be adopted as a rural sanitation option only after careful evaluation of all the factors involved.

### *Biogas units*

As biogas yields from human excrement are relatively low, such units can be considered only for treating animal excrement, to which human wastes may be added (on-site treatment of effluents of a farm, for instance). However, even in these circumstances the technique may not be effective in cold climates or cold weather. Moreover, the sludge may still contain viable pathogens infective to both man and animals (*Taenia*, for instance) and precautions must be taken if it is to be reused.

### *Ventilated improved pit latrines (Fig. 9)*

Screened pit latrines may be used in more remote areas without a piped water supply. In their simplest form they consist of a pit, a cover slab and a superstructure. Ventilation corrects two of the principal disadvantages associated with traditional pit latrines, namely fly and odour nuisance.

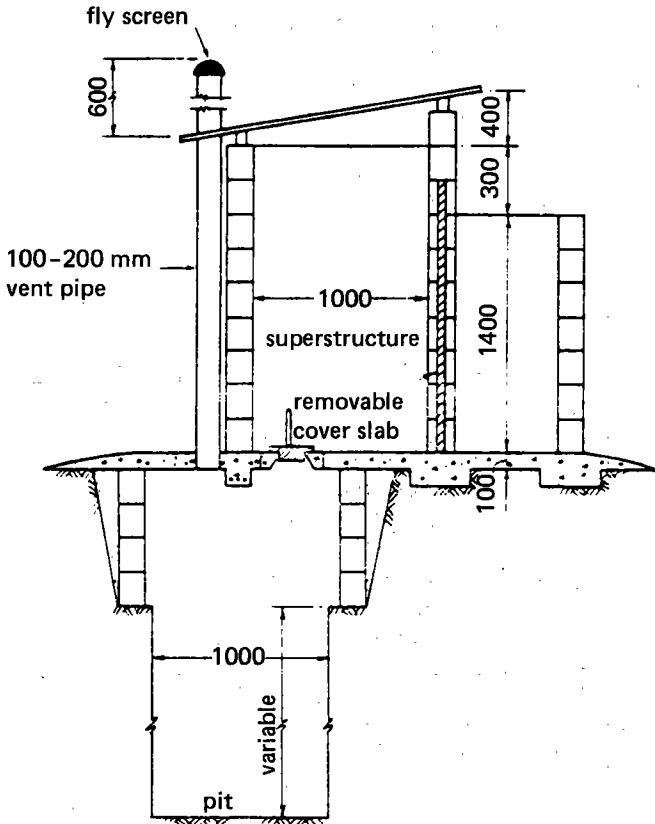
Ventilation is provided by a large diameter (100–200 mm) external vertical vent topped by a fly screen. Air is drawn from the storage pit and through the hole in the cover slab, thereby leaving the superstructure odour-free. The circulation of air is effective at wind speeds down to 0.5 m/s.

The vent pipe also has a major role in controlling flies, which are attracted to the pit where they lay eggs. After hatching, the adult insects, due to their phototropic nature, fly up the vent pipe, are trapped by the screen, and eventually fall down and die in the pit. In a three-month controlled trial in Zimbabwe, about 14 000 flies were caught from an unventilated latrine, compared with only about 150 from a ventilated but otherwise identical latrine.

The latrine may have a single pit, in which case it is dismantled and moved to another site when the pit is full, or twin pits, which are used and emptied alternately each year. After a year of storage, the sludge does not present any major health hazard and may be applied to soil. The pit size is determined by:

- the sludge accumulation rate (60 to 100 litres/person/year, according to climatic conditions (mean temperature));
- the household size;
- the desired pit life (1–2 years in the case of twin pit latrines, and 5–10 years for the single pit version).

Fig. 9. Ventilated improved pit latrine (cross section):  
dimensions in mm



Source: **Kalbermatten, J.M. et al.** *A planner's guide: appropriate technology for water supply and sanitation*, Vol. 2. Washington, DC, World Bank, 1980.

Groundwater pollution may pose a health risk if the household obtains its water from an on-site well located too close to the pit latrine. The required distance between the well and the latrine depends on the local hydrogeology and soil conditions. Finally, it is not recommended to use pit latrines in karst/limestone areas.

### *Disposal of sullage*

In the case of sanitation systems which are not designed to treat sullage, such as pit latrines, a separate facility is required for its treatment or disposal.

Sullage contains a much lower concentration of pathogens than faecal water, although its organic load may be relatively high. Depending on the risk to adjacent groundwater, the sullage may be disposed of through a soakage pit or by subsurface irrigation. In determining the size of the system, account should be taken of the fact that sullage has a lower silting effect.

Before irrigation or discharge into a soakage pit, the sullage should undergo at least 12 or so hours of primary settlement, and it may also be channelled to the last compartment of a modified three-compartment septic tank.

### *Small-bore sewers*

Small-bore sewers operate in the same way as conventional sewers in that the effluent is conveyed to a central treatment unit. In this case, however, the effluent is collected after treatment in a septic tank and consequently the cost of the sewers will be lower; in particular:

- they may be laid at a very shallow gradient, since the lower proportion of suspended solids in the wastewater means that it is unnecessary to design the system to achieve self-cleansing velocities;
- they can be smaller in diameter.

The effluent remains septic and may be further treated by anaerobic lagooning.

When setting up a sewer system of this nature, it is important to arrange for desludging of septic tanks at the correct intervals.

## QUALITY CONTROL

### **Protection of the waste discharge environment**

Protection of the waste discharge environment (watercourse, lake, aquifer, marine environment) is a key requirement of sanitation systems in some

areas. A number of countries have laid down effluent discharge standards which, depending on the legislation, relate to the type or size of treatment plant, or to the required quality of the waste discharge environment. The quality of the discharged effluent is measured in terms of its content of oxidizable organic matter (BOD<sub>5</sub> and COD tests) and of suspended solids. In the case of discharge environments that are at greater risk (certain watercourses, aquifers used for water supplies, lakes), account must also be taken of the content of fertilizing minerals in the effluent (nitrogen and phosphorous compounds). Assessment of the potential impact of an effluent on a particular environment does, however, require a knowledge of its quality and quantity in terms of pollutants, in relation to the absorption capacity of the environment.

All the various sanitation options are not equally effective or reliable (see Annexes 2 and 3) and the degree of treatment to be achieved is a major factor in the choice of a method. An increase in water pressure in a facility during periods of rainfall (separate unit or drainage system) is one of the most common causes of a temporary lowering of final effluent quality. In such cases it is necessary to install an overflow for discharge of the excess effluent into the environment, so as to ensure efficient operation of the treatment plant. To achieve greater reliability in the quality of the final effluent, it is necessary to:

- use treatment systems that are less sensitive to increases in water pressure (lagooning);
- build extra capacity into the system (e.g. to handle three times the dry weather load in the United Kingdom);
- incorporate settlement/storage units in the system (e.g. to handle up to ten times the dry weather load in the Federal Republic of Germany).

### Health considerations

The principle public health hazard associated with wastewater is that due to the substantial microbial content of faecal water and to a lesser extent sullage. The toxic risk cannot be wholly discounted but generally relates only to flows of nitrogen into adjacent groundwater, which may increase its nitrate concentration.

The microbiological risk may be assessed in terms of:

- (a) the *seriousness of the risk*, which depends on:
- the nature of the microorganisms present in the wastewater: hepatitis viruses, *Shigella*, *Salmonella*, *Vibrio cholerae*, *Entamoeba dysenteriae*, or *Giardia*, which may cause severe infections in humans;

- the concept of the “minimum infective dose” according to which, all things being equal, a low concentration of cysts of parasites or viruses is more likely to cause an epidemic than the same low concentration of *Salmonella* or *Escherichia coli*;
- the survival and reproductive capacity of microorganisms, especially in foodstuffs (this is an important factor in the case of on-site sanitation systems, since the effluent is discharged close to areas where household activities are carried out);

(b) the *frequency of the risk*, in that the risk associated with effluents is not the same in areas affected by certain endemic or epidemic diseases, and in sedentary, remote communities sheltered from the usual outbreaks.

Annex 4 gives a list of excreted infections. The pathogens are classified according to their potential virulence.

The health aspects of the transmission of diseases — especially diarrhoea and dysentery — in relation to the bacteriological quality of water have been studied by a WHO workshop.<sup>a</sup>

Risks of infection also arise both within treatment facilities (hence the need for protection of operators) and outside them, and are associated with:

- possible wastewater contamination of aquifers used for human water supplies;
- agricultural reuse of sludge which may contain highly persistent parasites (e.g. *Taenia*) that can infect animals and then man.

### *Disinfection*

At present techniques are available for *bacterial disinfection*, but as yet very little is known about their effectiveness against viruses. Moreover, they are never totally effective even against bacteria and it is always wise to bear in mind that all the microorganisms present in wastewater may reappear, at lower concentrations, in treated effluent.

Improvement of the bacteriological quality of final effluent, assessed in terms of a reduction of microbial indicators of contamination, may be advisable in some cases, particularly:

- when the final effluent is discharged into bathing or shellfish growing areas or into groundwater used for human water supplies;

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<sup>a</sup> *Surveillance and control of acute diarrhoeal diseases*: report on a WHO meeting. Copenhagen, WHO Regional Office for Europe, 1981 (EURO Reports and Studies, No. 44).

- when the final effluent is reused in agriculture;
- in certain epidemiological situations (endemic diseases, epidemics).

In the case of on-site sanitation or systems for small rural communities, adequate bacterial disinfection may be achieved using the following techniques:

- land treatment, provided the system is correctly planned on the basis of appropriate soil and hydrogeological studies; or
- natural lagooning, particularly where shallow lagoon systems are used.

*Chemical disinfection* techniques (chlorination) are difficult to use, costly and not fully effective. They should be used in treatment systems for small communities only in very special circumstances, after ascertaining their operational feasibility (supplies of reagents, training of operators). Generally speaking it is more common to use chemical disinfection units in drinking-water treatment systems.

### **Reuse of wastewater and sludge in agriculture**

If the proper precautions are taken, recycling of "by-products" of the treatment is of value economically and contributes to environmental protection. The recovery of the wastes does, however, entail a potential public health risk associated with the contamination of soil, agricultural crops or groundwater.

To minimize the risk in effluent reuse schemes, account must be taken at the outset of certain factors such as the nature of the terrain, the chemical composition and bacteriological quality of the wastewater and sludge, the proposed crop and the mode of application. The preliminary study of the terrain, with a view to protecting any adjacent groundwater, may be carried out using the methods developed for assessing the suitability of soil for irrigation systems (see page 11).

Any wastewater reused in agriculture must have a sufficiently low concentration of organic matter and suspended solids (silting of irrigation systems or soil) and of dissolved salts (toxicity for crops, damage to the structure of certain types of soil). Similarly, it should not contain toxic concentrations of organic or metallic micropollutants. Measurement of the nitrogen or phosphorous content may be of value for monitoring the fertilization effect. The optimum application rate may also be determined by measuring the nitrogen content of the sludge. The heavy metal content must also be monitored.

Natural lagooning, which produces a satisfactory level of bacterial disinfection, may be considered a suitable treatment technique for wastewater



that is to be reused in agriculture. However, the technique is not reliable in removing viruses and resistant forms of parasites. At a later stage attention will have to be given to the question of the duration of microbial resistance in soil and on plants (*Ascaris* eggs can survive for over a year in soil, and *Salmonella* for up to six months on plants). The survival times in sludge must also be borne in mind when it is applied to crops.

The risks of bacterial contamination can be greatly reduced by an appropriate choice of the type of crop to irrigate (plants not directly consumed by man or animals) and the form of irrigation (sprinkling on parts of the plant that are not consumed). Industrial crops (cotton, flax, sugar beet, trees for timber) are less subject to bacterial contamination than food crops and, among the latter, cereals and fruit trees are less vulnerable than vegetables or pasture. As far as the mode of irrigation is concerned, gravity irrigation is far preferable to sprinkling.

In any case systems for agricultural reuse of the by-products of treatment should be established within a regulatory framework, and there should be provision for monitoring and information of users.

## OPERATION AND SUPERVISION OF WASTE TREATMENT FACILITIES

Whatever technique is used, proper maintenance is necessary for the efficient operation of a treatment facility. Bearing in mind the particular conditions in rural areas, the group recommended the use of systems that are as simple to operate as possible. Nevertheless, an essential minimum of maintenance must be carried out. In many European countries the situation is not altogether satisfactory at present and, to improve it, efforts must be made at a number of levels:

- design of systems;
- operation of facilities;
- assistance to operators;
- motivation of policy-makers.

These efforts should preferably take the form of national initiatives whose nature will depend on the political and economic systems of the country concerned.

### **Design of systems**

At the design stage of a system, the technical services must make an objective long-term assessment of the motivation of the community, its

resources in manpower and funds, the qualifications and training potential of the staff, and the capacity of the environment to absorb the by-products of the treatment process. They must also ensure that the system which has been designed taking these factors into account is acceptable to the authorities: failing this there is a risk that it will fall into gradual and irreversible disuse.

Furthermore, even a specifically rural system may be difficult to operate if it has not been designed so as to:

- allow satisfactory access to the different installations and the regulatory equipment;
- function with the use of simple procedures and readily available local supplies of consumable materials;
- ensure the physical safety of the operators (railings, emergency switch for electrical and mechanical installations, etc.);
- enable the operators to work in suitably hygienic conditions (water outlet for washing, handling of wastes).

Particular attention should be paid to these aspects when standard model designs or systems using standardized components are being considered. In this case arrangements must be made for prior testing and harmonization.

It is becoming increasingly difficult to monitor the operation of on-site sanitation systems. Users should where possible be consulted about the maintenance requirements at the design stage. If there is a sufficiently large number of on-site treatment systems in a particular locality, it may be worth while to organize a communal system for operations such as emptying of septic tanks.

### **Operation of facilities**

Routine maintenance of treatment facilities calls for staff who have received middle-level technical training, and who are motivated and available; thus there is a need to enhance the prestige of this work. Routine operation consists mainly of supervision, regulation, maintenance and cleaning of the installations, including minor repairs and the removal of wastes (screenings, sludge). A log book is useful for recording these operations as well as observations about the running of the plant.

Supervision and regulation involve the performance of simple tests to monitor the operation of the system and determine whether certain procedures are necessary (drawing off excess sludge, regulation of flow, etc.); the operators should therefore be given specialized training in wastewater treatment generally and in the operation of the particular system used. Both

organized courses and training visits are suitable for this purpose. In any case simple, practical handbooks should be distributed. As far as possible, the staff should be available at all times and be assigned permanently to the same plant.

Since the maintenance of small facilities does not require full-time staff it is possible, where local conditions allow (associations of communities, operation of public services by a corporation, etc.), for the same operator to supervise several plants in the same area, thereby improving his experience and technical expertise.

Action on the present recommendations should ensure the necessary motivation of operators, particularly in cases where the local sociocultural attitudes attach little prestige to any work connected with waste disposal. It is recommended that operators should live in the area concerned as it is felt that they are in the best position to know about the functioning of the system and the local practices: it is therefore easier for them to understand variations in the effluent, to take action if the system breaks down, to develop waste disposal methods, etc. In this way they will also be able to function as health workers in the community.

The operation of a treatment plant, however simple, may nevertheless require high-level professional support from time to time. The establishment of technical services that can meet the needs of a large area is recommended for this purpose. Where the local conditions permit, specialists from nearby urban treatment plants may be asked to perform this function.

### **Assistance to operators**

The technical service should:

- provide training for operators;
- come to the assistance of operators at their request in cases of difficulty;
- perform in-depth operational assessments when necessary;
- collect and analyse data on the performance of treatment plants in order to improve skills and training;
- supply information to administrators responsible for capital investment policy.

The technical expertise required for this purpose includes a thorough knowledge of chemistry, biology, hydraulics and electromechanics.

The service should have a flexible form of organization enabling it to provide on-site assistance (measurement and sampling equipment that is easy to transport and suitable for different purposes, etc.) while the

operators should be given the necessary testing materials, training and information. If it is to be acceptable to the local authorities, the service should always seek to function in an advisory rather than a supervisory capacity.

The establishment of a service of this kind presupposes that the countries will first set up the necessary training facilities (universities, specialized schools) or will use the programmes in other countries. In developing such training systems it may be advisable to use the resources of institutions in other fields (local authority staff training centres in some countries, associations of technicians).

### **Motivation of policy-makers**

Renewal of the materials and equipment used in treatment plants, as well as improvements in the light of experience and technological advances are essential for continuous and efficient operation of a treatment plant. It is important to make policy-makers aware of this need so that they will be prepared, in so far as economic conditions and priorities allow, to authorize the required investments.

## **CONCLUSIONS AND RECOMMENDATIONS ON TECHNICAL ASPECTS**

### **Choice of a sanitation system**

1. The use of a combination of on-site sanitation and sewer systems, taking into account the characteristics of the environment, the pattern of housing and future development prospects, is a promising approach to the provision of wastewater treatment for small rural communities and the achievement of the goals of the International Drinking Water Supply and Sanitation Decade in Europe.
2. At the design stage of a sanitation system, account must be taken of the form of water supply and water consumption. Reducing the amounts of water used for the disposal of faecal matter facilitates and reduces the cost of its treatment. Similarly, consideration may be given to treating faecal water and sullage separately.
3. On-site sanitation plays and will continue to play an important role, especially in the form of combined septic tank/subsurface irrigation systems. However, many existing on-site sanitation systems are not altogether

satisfactory. Research programmes should be established to improve and refine the design and sizing of such systems. New technologies have emerged in the developing countries and it seems worth while to consider and even promote their use in Europe in certain situations (ventilated improved pit latrines).

4. Since natural lagooning involves the most simple operating procedures and provides adequate microbial disinfection, especially in shallow lagoon systems, it should always be considered as an option for small communities; it may be rejected because of local conditions such as climate, topography, soil composition, available land, etc., but the reasons should be compelling.

5. In view of recent developments in land treatment and infiltration techniques, consideration should be given to using them for secondary treatment. Wherever possible, subject to appropriate sizing of the installation, their use depends on:

- the geological and soil characteristics of the site;
- the degree of protection of the groundwater;
- the proximity of sources of drinking-water (account must be taken of the depth of the catchment as well as the distance between the treatment plant and the point of draw-off of the water).

6. If after studying the different possibilities it is decided to use a conventional treatment technique, it is preferable to opt for a standard model design, or one with standardized components, whose quality and efficiency have been determined in advance. This assumes that the authorities will arrange to monitor the performance of small plants and make the results widely known — whether satisfactory or unsatisfactory.

### **Operation of waste treatment facilities**

7. The efficiency of waste treatment plants for small rural communities is often dependent on operational factors. It is therefore important to consider the operating conditions when choosing a treatment system. In the past, operational constraints have been disregarded in the design of plants; in the future it is essential that they be taken into account from the outset.

8. Operators of small treatment plants in rural areas generally work part time. They must therefore have access to professional support when needed. This can be provided either by specialists from nearby larger treatment plants or by an organized technical service for a given geographical area containing a large number of plants. It is also important to

consult these technical services when organizing training courses for staff of small treatment plants.

9. Sludge handling and removal are probably the operations that pose the greatest difficulty for small plants. The form of management must be planned from the outset and the necessary technical arrangements made.

### **Disinfection**

10. Disinfection of waste effluents may be advisable in some cases, particularly:

- in certain epidemiological situations (endemic diseases, epidemics);
- when the effluent is discharged into bathing or shellfish culture areas;
- when the final effluent is discharged into groundwater (need for protection);
- when the final effluent is reused.

In such cases it is preferable to use systems with lagoons.

11. Chemical disinfection of effluents from small treatment plants can only rarely be justified. Chlorination should be regarded as part of the drinking-water treatment process and not as a means of reducing the numbers of pathogens in the environment. Moreover, chemical disinfection is still an expensive and difficult process, which generates undesirable by-products in the environment.

12. It should be borne in mind that it is almost impossible to achieve total disinfection of effluents: in particular, there is no guarantee that certain viruses and parasites will be destroyed, whatever the technique used (lagooning or chemical disinfection).

### **Training in the design of systems**

13. The most effective and economical systems of sanitation for small communities are generally those that make optimum use of the natural features of the site. An analysis of the socioeconomic, soil, geological and hydrological characteristics of the area is therefore an essential step in the design of a system, and sanitarians should receive special training for this purpose.

## RECOMMENDATIONS FOR ACTION AT THE INTERNATIONAL LEVEL

1. WHO should establish a collaborating centre for rural sanitation.
2. A working group should be convened to discuss basic and further training for operators, as there is a need to bring the training into line with practice.
3. The correct functioning of an individual sanitation system involves the regular performance of operations such as desludging of septic tanks. WHO could collate the different experience of the organization and financing of such operations.
4. WHO should promote reciprocal exchanges of information on rural sanitation technology between the developed and the developing countries.
5. WHO should encourage Member States to develop infrastructure and organize systems that will show what results can be expected in the operation, supervision and evaluation of the effectiveness of small waste treatment plants in rural areas.
6. Numerous studies should be undertaken on the hygienic aspects of the reuse of waste effluents in agriculture.
7. WHO should support studies on the health effects of the dispersion of pathogens in the environment.

## EXISTING SANITATION SYSTEMS FOR SMALL RURAL COMMUNITIES IN EUROPE

Participants described a variety of sanitation systems that have been adopted for small rural communities, and this information is summarized in the first part of the Annex; the second part describes a number of features of sanitation systems that are common to the different countries.

### **Situation in different European countries**

#### *Czechoslovakia*

Some 27% of the population live in communities of less than 2000 people, which may be rural or industrial, and 58% are served by a sewer system (mainly in towns).

Priority is now being given to the construction of treatment plants for communities of 100 to 5000 people. For this purpose standardized treatment units (using biodiscs) have been proposed in order to reduce the costs of research and development and of production. The installation of these facilities is supervised by the responsible technical services. Most of the treatment plants are operated by a public agency under the Ministry of Water and Forests.

#### *France*

The rural sector comprises a settled population of 20 million and a seasonal population of 9 million (second homes, camping sites, etc.), 40% of whom are served by wastewater collection and treatment systems. The aim is to achieve a coverage of 70% in 15 years. Individual systems should serve 30% of the rural population.

A separate authorization is required for the discharge of all waste effluent, and it must comply with minimum quality standards depending on the nature of the discharge environment. The regulations provide for six levels of treatment for oxidizable matter, and several for nitrogen and phosphorous compounds. The smaller plants generally use activated sludge or extended-aeration active-sludge techniques. At the same time there has been a considerable increase in lagoon treatment.

District services provide technical support and supervision of the treatment plants, supervise their operation, and carry out four inspections



per year. Many individual sanitation systems are not wholly satisfactory, and steps are now being taken to specify operating conditions for them (Ministry of Agriculture, Ministry of the Environment).

### *Germany, Federal Republic of*

About 25% of the population live in communities of less than 10 000 people, and 3% in communities of less than 1000. At present 71% of the population are served by a sewer system and 51% have a piped, treated water supply. Current development is directed to increasing the number of treatment facilities and improving the quality of effluents.

The present standards call for effluent qualities of varying levels, depending on the size of the facility. Professional associations of sanitarians (ATV) assist in the design and operation of facilities in the following ways:

- by publishing handbooks on the design of plants to serve different numbers of users;
- by training operators and providing technical support (within a given region close cooperation is maintained between the staff of large treatment plants and those of small facilities).

Making allowance for stormwater is one of the problems encountered in setting quality standards for watercourses. In place of stormwater overflows, which used to be widespread, the present tendency is to install storage facilities (with a capacity of up to ten times the dry weather flow).

### *Hungary*

In Hungary 34% of the population are served by a sewer system, including only 3.3% in rural areas. A great many dwellings have individual sanitation systems, generally consisting of septic tanks or pit latrines. This situation is not wholly satisfactory, for the following reasons:

- checking of such a large number of facilities, which is a responsibility of the Housing Board, is impossible;
- the hydrogeological conditions in a large part of the country are highly unsuitable for subsurface irrigation (groundwater near the surface, impermeable soil) and the present situation is leading to a significant level of pollution of the groundwater.

The present tendency is to install:

- sewer systems and treatment units for villages;
- more carefully supervised individual sanitation systems (combined septic tanks/irrigation).

The most common treatment systems are trickling filters for low population densities, and oxidation ditches. The latter system has proved particularly reliable under the local operating conditions. Activated sludge systems pose greater operational problems in rural areas. Lagoon treatment has been tried out, but the system does not seem well suited to the local climatic conditions.

### *Portugal*

The population is 57% rural, with 2.3% not living in communities. In 1980, 40% of people were served by a sewer system and 10% by a system incorporating a treatment facility. At present it is mainly the urban population that is served by such systems, i.e. those living in towns of more than 2000 people. In rural areas only 28% of the population have a piped water supply.

Consequently the sanitation problem in rural areas is very different from that in towns and in certain respects the situation is similar to that in the developing countries. The current targets give priority to water supplies and sanitation for large towns. In urban areas a coverage rate of 80% has been set within the framework of the International Drinking Water Supply and Sanitation Decade.

From the technical standpoint the tendency is to install sewer systems — except for single households — and to use simple operating methods. A study is currently being made of the use of lagoons and oxidation ditches, and it is planned to develop land treatment. Major problems include technical training of operators and arrangements for technical operation of systems.

### *United Kingdom*

Some 95% of the population are served by sewer systems, and the remaining 5% by individual systems or private facilities (camping sites, etc.).

Out of the 7800 existing sanitation systems in the country:

- 4000 serve up to 500 people;
- 1000 serve 500 to 1000 people;
- 1500 serve 1000 to 5000 people;
- 1300 serve more than 5000 people.

Considerable progress in wastewater treatment, monitoring of the operation of facilities by river inspectors, and efforts to improve coordination between the setting up and operation of systems on the part of the river basin authorities, have resulted in a definite improvement in the quality of surface waters. These advances have been achieved within the

framework of a Code of Practice that was introduced in 1974 and is now being updated. The Code lays down technical criteria for the design and operation of treatment plants.

### **Common features of sanitation systems in different countries**

Because of the variety of situations encountered, it is not possible to give a very precise definition of a “small rural community”. However, for statistical purposes it has generally been agreed to adopt an upper population limit of 2000. Such communities also have the following features:

- a lower level of facilities in relation to urban areas, both for sanitation and for water supply systems;
- a variable, but never negligible, proportion of single households;
- in many cases, polluting agricultural processing activities or, in some, small-scale industrial activities;
- limited technical and financial resources and organizational capacity.

The extent of coverage of the needs for water supplies and sanitation varies considerably from country to country. However, the sanitation programmes depend on the water supply programmes which in any case always have priority. Finally, where sanitation is concerned, problems in the running of small facilities are always recognized as being a priority, and they relate both to technical training of staff and to operational and supervisory arrangements.

## STANDARD METHODS OF WASTE TREATMENT FOR SMALL COMMUNITIES

### PRETREATMENT UNITS

#### Features

Pretreatment of domestic wastewater is carried out using techniques for physical separation of bulky objects, scum and undesirable materials.

It is essential to install pretreatment units upstream of treatment plants to protect the equipment (valves, pumps, pipes, etc.) against stoppages and unnecessary wear.

For communities with a small treatment plant that does not require a full-time operator, only the following forms of pretreatment should be envisaged:

- manual screening;
- grit removal;
- flotation.

#### Bar screen

##### *First screen*

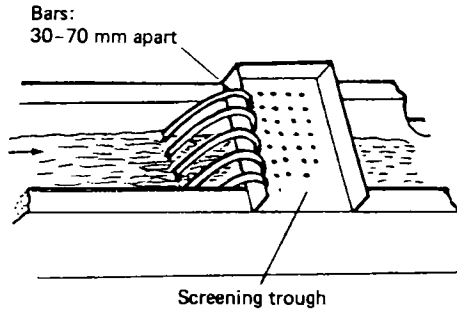
The purpose of this screen is to prevent rapid clogging of the main screen by bulky objects. The spacing of the bars should be 50–100 mm. This device is optional for small plants.

##### *Main screen*

The bars are generally installed at an angle of 60° or 80° from the horizontal. In the case of small communities, a coarse bar screen is preferable (net spacing of 30–70 mm between the bars). If there is a stormwater overflow, the bar screen should be arranged so as not to hinder its operation.

A device for by-passing the pretreatment unit is useful to ensure a continuous flow of wastewater to the treatment plant in the case of accidental clogging of the bar screen and thereby avoid the discharge of raw effluent into the environment. It is essential to include a screening trough and refuse storage container in the system.

Fig. 1. Manually operated bar screen

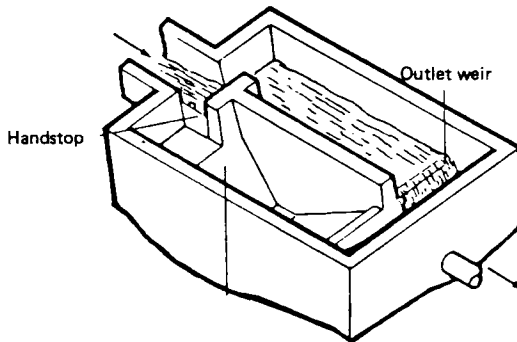


Source: *The operation and maintenance of small sewage works*. National Water Council, Occasional Technical Paper No. 4. Standing Technical Committee on Waste Water Treatment, London, 1980.

### Grit removal

When it is necessary to include a grit chamber in the system, it may take the form of a small, easy to clean unit to collect grit and stones. In many cases extra capacity may have to be built into the system to enable it to cope effectively with large fluctuations in the wastewater flows, which increases the operating cost.

Fig. 2. Grit chamber



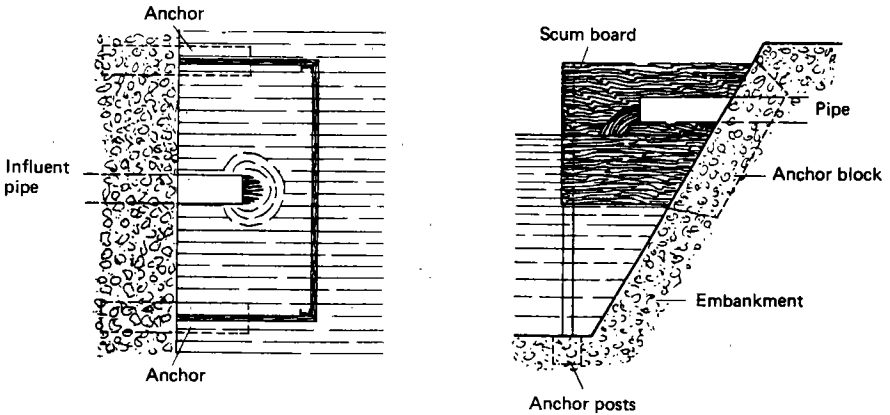
Source: *The operation and maintenance of small sewage works*. National Water Council, Occasional Technical Paper No. 4. Standing Technical Committee on Waste Water Treatment, London, 1980.

It is preferable to dispense with such units in treatment plants for very small communities.

### Flotation

When a flotation system is necessary it may consist of a simple scum board installed near the wastewater inlet. The device shown below by way of illustration may be located upstream of a lagoon.

Fig. 3. Simple grease trap



Source: *Lagunage naturel et lagunage aéré, procédés d'épuration des petites collectivités*. Paris, CTGREF et Agence de Bassin Loire-Bretagne, 1979.

## PRIMARY SETTLEMENT

### Features

For small plants (average flow up to  $20 \text{ m}^3/\text{h}$ ; population under 1000–2000), the type of settlement tank normally used is a vertical circulation unit, either cylindro-conical or in the form of a hopper (Dortmund type), with sides at a sharp angle from the horizontal ( $60^\circ$ ).

Settlement and digestion of the sludge that forms may be carried out:

- in a single two-storey unit (Imhoff settlement-digestion tank);

- in two separate units in the case of larger systems (primary settlement tank and unheated digestion unit).

The effluent moves rapidly through the settlement tank and therefore remains “raw” as compared with that flowing from a septic tank.

Fig. 4. Two-storey tank

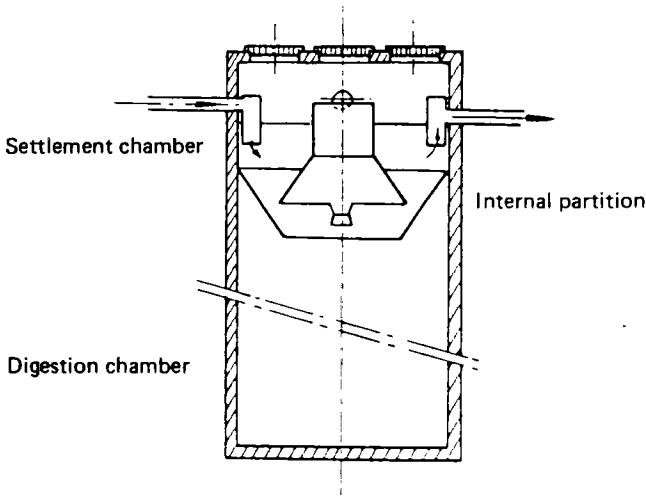
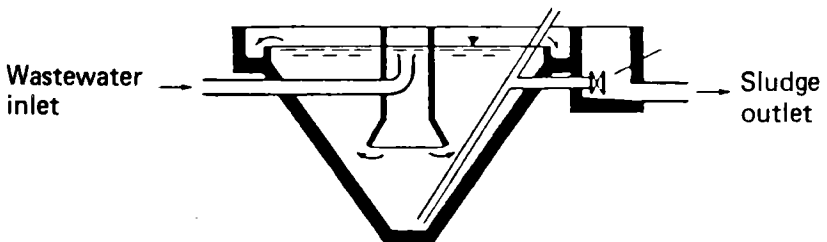


Fig. 5. Settlement tank



Source: *L'assainissement individuel - principes et techniques actuelles*. Paris, Ministère de l'Environnement et du Cadre de Vie et Agence de Bassin Loire-Bretagne, 1980.

## Description — dimensions

*Primary settlement unit:* a unit with a scum retention device:

- retention time:  $\geq 1$  hour at peak flow;
- upward rate of flow:  $\leq 1.5$  m/h at peak flow.

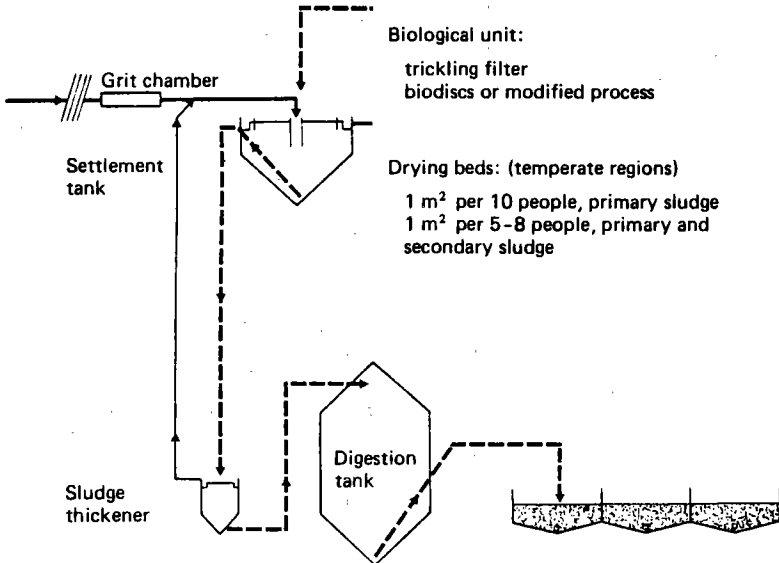
*Digestion unit:* useful digestion capacity  $\geq 120$  litres per person served.

The dimensions depend to a great extent on the climatic and operating conditions (intervals at which the sludge is drawn off).

The digestion unit may be somewhat smaller in the case of a two-storey tank, in which contact between the sludge and raw effluent allows a sufficient temperature to be maintained.

In the case of medium- and high-rate systems with separate settlement and digestion units installed upstream, the useful digestion capacity

Fig. 6. Separate settlement and digestion system



Source: *Etude comparative des procédés d'épuration applicables aux effluents des petites et moyennes collectivités*. Paris, Centre technique du Génie rural des Eaux et des Forêts et Agence du Bassin Loire-Bretagne, 1976.



required will be above or equal to 150 litres per person served. The raw primary (and secondary) sludge collected from the bottom of the settlement unit is pumped to the digestion unit after thickening.

### **Efficiency — maintenance**

The efficiency of these systems is in theory comparable to that of septic tanks (removal of 30% of BOD<sub>5</sub> and 50% of TSS) but in practice tends to be lower because of the less satisfactory hydraulic conditions in small systems.

Regular maintenance involves:

- removing the scum and scraping the sides of the tank;
- breaking up the floating sludge and drawing off the digested sediment.

### **Applications**

Primary settlement units:

- are suitable for processing wastewater prior to aerobic treatment (trickling filters, biodiscs);
- can be used in conjunction with surface irrigation;
- are not very effective prior to lagooning or subsurface irrigation.

Number of users: between 100 and 1000.

## **TRICKLING FILTERS — LOW- OR MEDIUM-RATE**

### **Features**

Trickling filters operate by having the previously settled wastewater flow over a bed composed of coarse filler material.

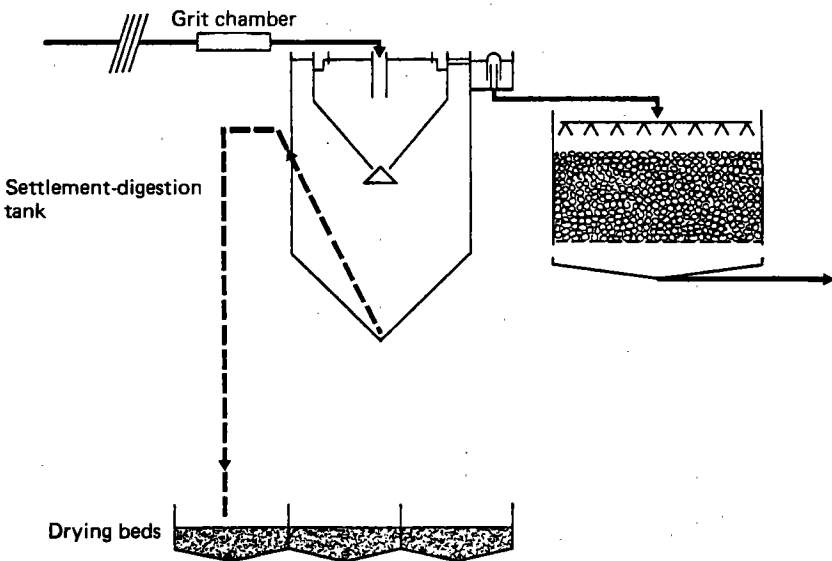
The material allows the growth of microorganisms which form a slime through which the liquor and oxygen pass. Types of material suitable for the purpose include pozzolan and crushed stones of regular size.

The flow of wastewater is discontinuous and aeration is carried out by natural ventilation.

## Description — dimensions

- Pretreatment unit: primary settlement tank.
- Trickling filters:
  - depth of filler:  $> 1.5$  m of material of 40–80 mm;
  - distribution by sprinkler;
  - loading rate: 0.1 to 0.4 kg BOD<sub>5</sub>/m<sup>3</sup> of material per day.
- Secondary settlement tank (optional).
- Drying beds.

Fig. 7. Settlement-digestion tank and trickling filter without secondary settlement tank



Source: *Etude comparative des procédés d'épuration applicables aux effluents des petites et moyennes collectivités*. Paris, Centre technique du Génie rural des Eaux et des Forêts et Agence du Bassin Loire-Bretagne, 1976.

In gravity-fed systems, a flush tank fitted with a self-closing syphon is installed at the outlet of the primary settlement tank to ensure an adequate rate of flow to the sprinkler. It is advisable to use simple flush devices which are not easily affected by stoppages.

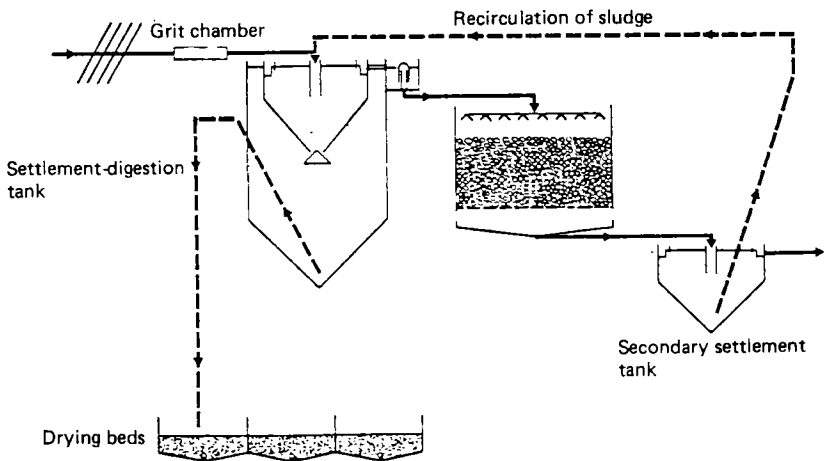
### *Alternative designs*

A modular trickling filter which can be constructed by a local builder:

- series-flow system;
- parallel-flow system.

Depending on the size of the community and degree of treatment required, the trickling filter system may include a secondary settlement tank.

Fig. 8. Settlement-digestion tank, trickling filter and secondary settlement tank



*Source: Etude comparative des procédés d'épuration applicables aux effluents des petites et moyennes collectivités. Paris, Centre technique du Génie rural des Eaux et des Forêts et Agence du Bassin Loire-Bretagne, 1976.*

## **Efficiency — maintenance**

Efficiency of treatment:

- BOD<sub>5</sub>: 30–40 mg/l;
- TTS: 30 mg/l (100 mg/l or more without settlement);
- partial nitrification of effluent.

The system is simple to operate and uses either no or very little electricity.

## **Applications**

- Suitable for small communities, makes use of natural gradient of the land.
- Not suitable for use in a cold climate or if there are sharp variations in the water pressure.

Number of users: communities of 100 to 600 people:

- trickling filter without secondary settlement tank: 100–400 users.
- trickling filter with secondary settlement tank: over 500 users.

The lower limit depends on economic considerations.

## **BIODISCS AND MODIFIED PROCESSES**

### **Features**

The equipment consists of large-bore discs or contactors mounted horizontally. This assembly, which is half submerged, rotates around the central axis. A surface film varying in thickness from 1 to 4 mm then forms on the discs.

Rotation of the discs allows both oxygenation and contact with the wastewater.

### **Description — dimensions**

- Pretreatment units.
- Biodiscs rotating slowly in a basin of the same shape:
  - at least two storeys separated by a spillway and protected by a building;

- useful surface of the discs sufficient to ensure that the specific loading rate is between 7 and 15 g BOD<sub>5</sub>/m<sup>2</sup> of disc per day;
  - secondary sludge recirculated upstream of the installation by a pump or self-closing valve;
  - pumping of the raw primary and secondary sludge collected from the bottom of the settlement tank to the digestion tank after thickening.
- Secondary settlement tank (or clarifier).
  - Drying beds.

### *Alternative designs*

Primary and secondary settlement units consisting of earth lagoons:

- primary lagoon: depth 1.5–3 m, capacity equivalent to four times the daily flow of effluent to be treated;
- secondary lagoon: unit with a sludge collector upstream, and a capacity equivalent to one day's retention.

In modified processes, the contactors are lined with special materials.

### **Efficiency — maintenance**

Efficiency of treatment:

- BOD<sub>5</sub>: 30–40 mg/l;
- TTS: 30 mg/l.

Maintenance involves operations similar to those applicable to conventional treatment plants. Particular care must be taken with the electro-mechanical equipment. It is important to avoid lengthy interruptions of service that may cause an imbalance of the system (contactors out of true) in the case of axial-drive units.

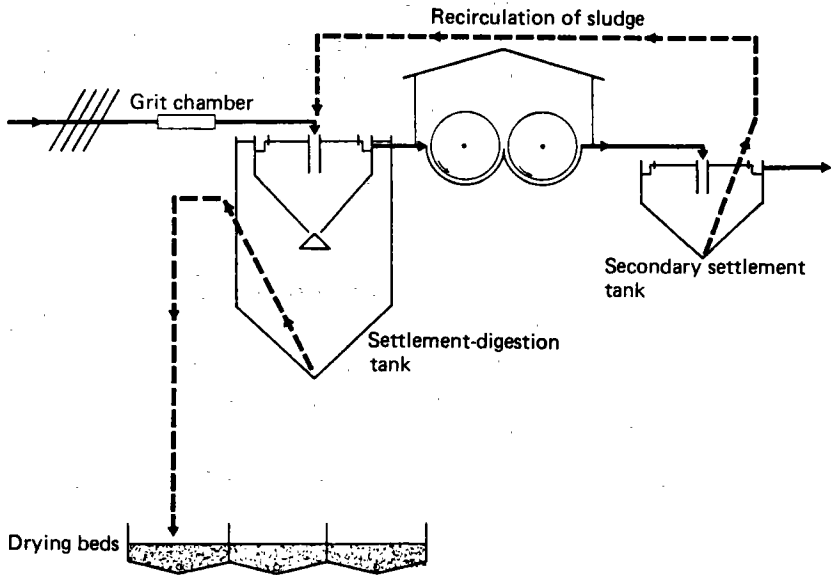
### **Applications**

Biodiscs and modified processes:

- are suitable for small communities;
- fit into the surroundings of dwellings and take up little space;
- entail high investment costs and require the installation of prefabricated modular units for systems serving less than 1500 people.

Number of users: communities of a few hundred people or more.

Fig. 9. Settlement-digestion tank, biodiscs



Source: *Etude comparative des procédés d'épuration applicables aux effluents des petites et moyennes collectivités*. Paris, Centre technique du Génie rural des Eaux et des Forêts et Agence du Bassin Loire-Bretagne, 1976.

## EXTENDED-AERATION ACTIVE-SLUDGE TECHNIQUE

### Features

This treatment process is based on the activity of a bacterial culture that is dispersed and maintained in a condition of aerobiosis in the system. The mixture of wastewater and biological floc is agitated and aerated. The activated sludge is subsequently separated from the treated wastewater in a secondary settlement tank (clarifier). Part of the thickened sludge is then recirculated to the aeration tank, and the excess removed from the system.

### **Description — dimensions**

- Pretreatment unit: bar screen, grit chamber, possibly a grease trap.
- Aeration tank:
  - loading rates: 0.35 kg BOD<sub>5</sub>/m<sup>3</sup>/day;  
0.1 kg BOD<sub>5</sub>/kg volatile solids/day.
- Secondary settlement tank:
  - retention time: 2 h at peak flow;
  - recirculation of sludge by pumping, at a rate of up to 100% of the average flow.
- Possible collection of excess sludge removed from the system in a thickener (20 litres per user), followed by dehydration.
- Drying beds.

### *Alternative designs*

For small communities, compact systems are used. They are constructed with prefabricated components; and aeration and settlement may be carried out in a single (package) unit. Generally speaking, the system should be of large capacity so as to handle peak flows and organic loads, and this requirement is not readily compatible with space saving. If possible the aeration and settlement compartments should be quite separate and the sludge should be circulated by pumping.

### **Efficiency — maintenance**

Efficiency of treatment:

- BOD<sub>5</sub>: 15–40 mg/l;
- TTS: 20–30 mg/l.

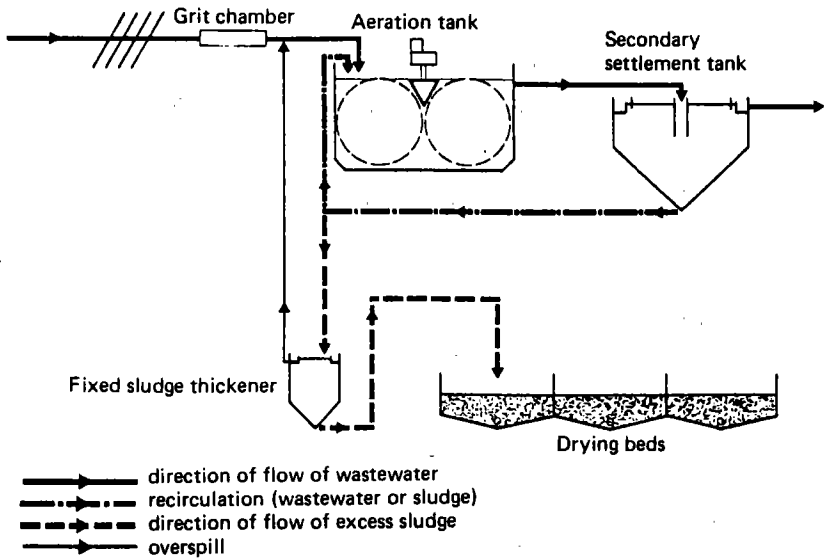
Nitrification of the effluent: it is possible to achieve a higher level of nitrification by adopting lower loading rates than the customary ones (0.1–0.2 BOD<sub>5</sub>/m<sup>3</sup>/day). Energy consumption is around 100 Wh/user/day.

Regular maintenance is required, amounting to 3–5 hours a week at two-day intervals.

### **Applications**

These systems are suitable for intensive treatment of wastewater but they call for regular attention.

Fig. 10. Extended aeration with recirculation by pumping



Source: *Etude comparative des procédés d'épuration applicables aux effluents des petites et moyennes collectivités*. Paris, Centre technique du Génie rural des Eaux et des Forêts et Agence du Bassin Loire-Bretagne, 1976.

Number of users: communities of over 1000 population equivalent. Monobloc units may be used for smaller communities (100–500 people). Precautions must be taken with regard to foreseeable losses of sludge.

## AERATED LAGOONING

### Features

The oxygen required for the biological treatment is provided by an artificial aeration device which both oxygenates and agitates the wastewater.



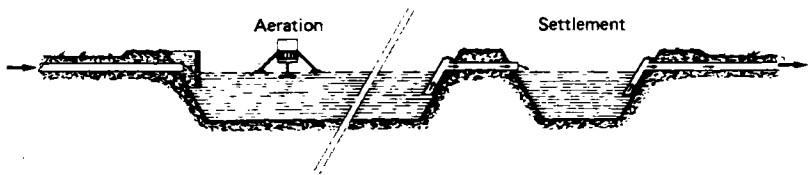
## Description — dimensions

- Bar screen.
- Aeration tank: floor surface and sides made of compacted earth, without additional waterproofing.
- Protection of sides against lapping water (by a plastic film, stone packing, etc.) and the floor surface immediately below the aerators (concrete slab, for instance).
- One or several tanks arranged in a series:
  - depth: 2.5–3 m;
  - effluent retention time: 20 days;
  - surface aerator (floating rotors, for instance);
  - installed power capacity: 4–5 W/m<sup>3</sup> of tank (domestic wastewater).

By using several rotors it is possible to limit the effects of a possible breakdown and to make more efficient use of energy for agitating the effluent.

- Settlement tank:
  - same features;
  - effluent retention time: 5 days (two identical tanks arranged in parallel).

Fig. 11. Aerated lagoon (cross section)



Source: *L'assainissement individuel - principes et techniques actuelles*. Paris, Ministère de l'Environnement et du Cadre de Vie et Agence de Bassin Loire-Bretagne, 1980.

**Efficiency — maintenance**

— Aerated lagooning with settlement:

— BOD<sub>5</sub>: 30–40 mg/l;

— TTS: 30–50 mg/l.

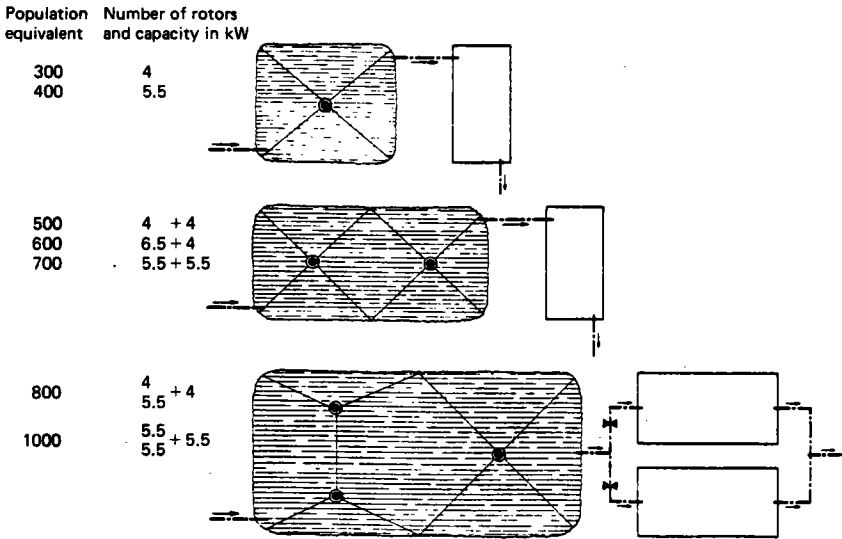
— Aerated lagooning without settlement:

— BOD<sub>5</sub>: 40 mg/l (with filtered water);

— TTS: 50–100 mg/l.

— Reduction in the number of indicator microbes for faecal contamination.

Fig. 12. Aerated lagooning: layout of aeration rotors



Source: *Lagunage naturel et lagunage aéré, procédés d'épuration des petites collectivités*. Paris, CTGREF et Agence de Bassin Loire-Bretagne, 1979.

Maintenance of the system involves:

- regular attention to the electromechanical equipment (supervision and regulation of daily operating times of the aerators);
- periodic removal of sludge which accumulates at the bottom of the settlement tank (variable: 1–5 years), either in liquid form (irrigation onto adjoining land), or in solid form after drying out the tank.

The energy requirement for aeration is about 2 kWh per kg of BOD<sub>5</sub> removed, or about 100 Wh/person/day.

### **Applications**

Lagoon systems:

- are suitable for treating mixtures of domestic wastewater and agricultural or agro-industrial effluents (in which case a higher installed energy capacity is required);
- are little affected by septic effluents;
- are suitable for treating diluted effluents;
- are able to deal with fluctuations in load;
- are not unduly affected by errors of regulation and routine operation;
- do not take up much space and therefore blend into the environment;
- use a great deal of energy.

Number of users: from a few hundred to about 3000.



*Annex 3*

COMPARISON OF SANITATION TECHNOLOGY OPTIONS  
FOR SMALL COMMUNITIES

	Degree of treatment of domestic effluent		Nature and frequency of maintenance operations	Manpower requirements		Capital cost	
	BOD mg/l	TTS mg/l		skilled	unskilled	< 1000 population	> 1000 population
Trickling filters	30-50	30-100	Drawing off sludge every 6 months; removal of screenings 3 times a week	medium	high	high	very high
Biodiscs	30-50	30-50	Drawing off sludge every 6 months; removal of screenings 3 times a week	medium	low	high	very high
Extended aeration	15-30	10-40	Regulation of system 2-5 times a year; desludging every 15 days, attention to pretreatment units every 2 days	high	low	high	high
Aerated lagooning	30-50	20-100	Regulation of system twice a year, desludging every 2-3 years; attention to pretreatment units twice a week	medium	high	low	low
Natural lagooning							
— fully aerobic	30	50-+100	Maintenance of surroundings with either system; desludging every 5-10 years; removal of screenings 1-2 times a week	low	medium	low	medium
— aerobic-anaerobic	30	?	Desludging every 2-5 years, removal of screenings 1-2 times a week	low	medium	low	medium
Settlement-digestion tank surface irrigation	?	?	Drawing off sludge every 4-6 months; removal of screenings and frothing 2-3 times a week; clearance of vegetation 1-2 times a year	low	medium	medium	medium
Septic tank surface irrigation	?	?	Desludging every 2 years (every year in the case of seasonal use); clearance of vegetation	low	medium	medium	high
Peat beds (for the record only; details not available)							
Macrophyte systems			Attention to pretreatment units twice a week in an alternate feed system, changing the containers every 1-3 days; possibly, clearing out the macrophytes 1-2 times a year	low	high	medium	high

Energy cost of operation (Wh/user/day)	Suitability for coping with fluctuations in load		Suitability for treating sewage together with agro-industrial wastewater	Possibility of siting the system near dwellings (free from nuisances)
	water pressure	organic load		
20: 15-20% of the operating cost	poor	average	poor	average
40: 20-30% of the operating cost	good	average	average	good
80-100: 25-40% of the operating cost	poor (very poor in combined systems)	good (poor in combined systems)	good	good
70	very good	very good	very good	limited
nil	very good	very good	good	average
nil	very good	very good	very good	limited
nil	average	good	average	limited
nil	average	good	very poor	very good
nil	good	very good	average	good

## Annex 4

### ENVIRONMENTAL CLASSIFICATION OF EXCRETED INFECTIONS

Category	Epidemiological feature	Infection	Dominant transmission focus	Major control measure
I	Nonlatent, low infective dose	Enterobiasis Enteroviral infections Hymenolepiasis Amoebiasis Giardiasis Balantidiasis	Personal Domestic	Domestic water supply Health education Improved housing Provision of toilets
II	Nonlatent, medium or high infective dose, moderately persistent and able to multiply	Typhoid Salmonellosis Shigellosis Cholera Path. <i>Escherichia coli</i> Yersiniosis <i>Campylobacter</i> infection	Personal Domestic Water Crop	Domestic water supply Health education Improved housing Provision of toilets Treatment prior to discharge or reuse
III	Latent and persistent with no intermediate host	Ascariasis Trichuriasis Hookworm	Yard Field Crop	Provision of toilets Treatment of excreta prior to land application
IV	Latent and persistent with cow or pig intermediate host	Taeniasis	Yard Field Fodder	Provision of toilets Treatment of excreta prior to land application Cooking, meat inspection
V	Latent and persistent with aquatic intermediate host(s)	Clonorchiasis Diphyllobothriasis Fascioliasis Fasciolopsiasis Gastrodiscoidiasis Heterophyiasis Metagonimiasis Paragonimiasis Schistosomiasis	Water	Provision of toilets Treatment of excreta prior to discharge Control of animal reservoirs Cooking
VI	Excreta-related insect vectors	Bancroftian filariasis (transmitted by <i>Culex pipiens</i> ), <sup>a</sup> and all the infections listed in I-V for which flies and cockroaches can be vectors	Various faecally contaminated sites in which insects breed	Identification and elimination of suitable breeding sites

<sup>a</sup> *Culex pipiens* is a complex of mosquito species and subspecies. The principal tropical species, and the vector of filariasis in those tropical areas where the infection is transmitted by *Culex*, is *Culex quinquefasciatus* (previously also known as *Culex pipiens fatigans*, *C. p. quinquefasciatus*, or *C. fatigans*).

Source. Kalbermatten, J.M. et al. *Appropriate technology for water supply and sanitation: technical and economic options*, Vol 1a. Washington, DC, World Bank, 1980.



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