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SEPTIC TANKS AND SMALL SEWAGE-TREATMENT PLANTS

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by

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SUMMARY

This report offers guidance to those responsible for the provision and maintenance of septic tanks and small sewage-treatment plants.

The selection of suitable treatment plant for particular conditions is discussed, and the available plant are listed with their potential advantages and disadvantages. Some typical costings are also given.

Treatment plants employing septic tanks are the most common, and their design and operation are considered in some detail. The effluent from septic tanks is often given further treatment on a percolating filter, so a section of the report is devoted to the design and operation of such plant. To obtain an even better effluent, tertiary treatment can, in addition, be employed, and systems particularly suited to small works in rural areas are described.

Several manufacturers now supply 'package' treatment plant expressly designed for small communities. Modified forms of the activated-sludge process (extended aeration, contact stabilisation), extended filtration, rotary biological contactors, and oxidation ditches are among the methods of treatment adopted, and the merits and drawbacks of each are discussed.

Finally, procedures for the commissioning of new plant are outlined, and methods of uprating and improving old works are suggested.

CONTENTS

1. INTRODUCTION

The Water Research Centre and the Regional Water Authorities receive many enquiries relating to the selection and operation of small sewage-treatment plants. Some of the underlying problems are discussed in this report and guidance is offered to those responsible for provision and maintenance of such plants.

There is no clear dividing line between small sewage-treatment plants and conventional plants, since many of the same basic physical and biochemical processes are used in both types. There are differences, however, in the design of the two categories of plant, in their ownership, and in those having responsibility for plant operation and maintenance. Control of many small plants has been assumed by the Regional Water Authorities in recent years, but many remain privately operated. The extension of rural sewerage has made some small plants redundant but many established plants, in a range of types and sizes, are still in use and, owing to the rising cost of rural sewerage, some are being upgraded to meet future requirements. Also new small treatment plants are being built to serve groups of dwellings in areas where the cost of connection of the dwellings to public sewers would be prohibitive.

In a few cases, sewage is not discharged to a sewer or treated on site but is stored in cesspools. These are watertight storage tanks of capacity sufficient to contain all domestic waste waters for periods between collection by tanker for treatment off the site. Such systems, that demand no quality control and produce no effluent discharge, have obvious advantages, but these are only obtained at a relatively high cost because of the expense of the regular emptying service. Some economy can be made by adopting water-saving measures in the home, but these measures are often onerous. It is important for users to recognise that a cesspool is simply a storage tank, not designed to bring about treatment of sewage. Many users confuse cesspools and septic tanks, leading to wrongly-based enquiries.

A septic tank is a plant which has provision for storage of sludge but not of liquid; effluent is discharged irregularly and provision must be made for its treatment and final disposal. Such a tank may bring about some treatment of the liquid in ideal circumstances.

Small sewage-treatment plants exist in sizes ranging from those serving single houses, to those serving communities such as villages, service camps, and hospitals. Such communities have a relatively constant population, but there are establishments, such as schools and factories, that are occupied part-time, and hotels and caravan sites or camping sites that have wide seasonal variations in population. These too may have small sewage-treatment plants and, because of the intermittent nature of the sewage flow, treatment of the sewage will present special problems.

Many users and potential users of small plants have sought advice from the WRC. During 1976, 70 enquiries were received. These have been classified in Table 1 according to the type of plant used. The majority of the enquiries were from private individuals, usually concerned with the smallest types of plant, though some were from builders or architects and a few from agents of equipment manufacturers and the Regional Water Authorities.

More than half the enquiries related to the care of established plant of several types, the commonest of which were systems incorporating septic tanks. It is evident that many users of such plants are not familiar with the care and maintenance requirements. Many enquiries and problems could be avoided if all owners of small treatment plants were fully informed of the nature of the pipework to and away from their plants, and of the regular maintenance needed.

Table 1. Enquiries in 1976 relating to small sewage-treatment plants

Type of plant	Number of enquiries	Percentage of total
Septic tank	47	67
Conventional small works	14	20
Package treatment plants	8	11
Non-gravity sewerage	1	1

The advice of the Centre has also been sought on aspects of the design and testing of a number of proprietary plants that companies have sought to introduce to the UK. None of the new plants in this category has offered any facility that has not been available from British manufacturers for some years.

2. THE SELECTION OF A SMALL SEWAGE-TREATMENT PLANT

The objectives of all schemes for sewage treatment must include that of maintaining a high standard of hygiene at the site. A plant must be able to deal effectively with the peak flow of sewage and peak organic load, and produce a final effluent of adequate quality for the means of disposal selected. A plant which discharges effluent to a watercourse usually needs to achieve a higher standard than one which discharges effluent to subsoil drains in isolated areas, where the dangers of water pollution are not great.

In most average domestic situations in the UK, the volume and strength of the sewage discharged can be predicted with some confidence. Water consumption and other factors tend to be different in other countries; thus imported treatment plant is not necessarily suitable for use in the UK without modification, and vice versa.

At the time of the Jeger Report in 1970[(1)] the average daily domestic consumption of water per person was estimated to be about 140 l in England and Wales. Of this, about 120 l would be dischared to sewers, though some variations from this figure can be found. There is some evidence that there may have been a slight increase in water consumption since that time, though the drought of 1976 stimulated measures that may have reversed the trend in some places. Measurements made by the Central Water Planning Unit in 1975 indicate no substantial change from the estimate in the Jeger report. There is extensive use in some areas in Scotland of a 13.6-l (3-gal) flushing cistern rather than the 9-l (2-gal) cistern commonly used in England and Wales; this can increase the volume of sewage by about 30 l/person day. Where dual-flush or controlled-flush cisterns are used, a reduction of up to 30 l/person day may be found.

Adjustments to the estimated hydraulic flow are necessary in all circumstances where the average figures may not apply; for example where infiltration of ground water is significant. Some guidelines are proposed in Table 2 for a range of non-industrial sources. These guidelines apply to discharges of foul sewage only. Surface water should always be excluded from the treatment plant, though it may be admitted to the effluent discharge in some circumstances. Allowance must be made for any additional sources of waste water, for example the use of domestic waste disposal units can increase the hydraulic and organic loads by up to 50%.

Where communities include small industrial establishments, the discharge from these should be estimated separately. Some types of industrial waste waters can be treated in admixture with the domestic sewage. In other cases, separate, partial, or full treatment is advisable, especially if the industrial waste waters contain any substances that may be toxic to biological treatment processes.

Table 2. **Guidelines for waste-water discharge from various types of accommodation**

Type of source	Volume of sewage (litres/person day)
Small domestic housing	120
Luxury domestic housing	200
Hotels with private baths	150
Restaurants (toilet and kitchen wastes per customer)	30-40
Camping sites with central bathhouse	80-120
Camping site with limited sanitary facilities	50-80
Day schools with meals service	50-60
Boarding schools - term time	150-200
Offices - day work	40-50
Factories - per 8-h shift	40-80

Where populations vary seasonally, as in camp sites or holiday areas, care must be taken to select plants whose capacity can be rapidly expanded as the flows increase, and can be reduced as the flows decrease.

Many of the problems of small treatment plants are associated with the occurrence of gross diurnal variations in flow, usually most severe in the smallest communities. In the section of this report which deals with percolating filters, some measures are proposed to minimise the effects of such flow variations.

It is important to specify that when the volume and strength of the flow to small treatment plants have been established, and plant sizes have been determined, no indiscriminate additions to the loads should be made. Many small plants have been seriously overloaded by neglect of this precaution. Increases in the loading can be accommodated by extending or modifying plant to increase its capacity accordingly.

The selection of a suitable treatment plant for a rural area can be systematised by reference to the check list in Table 3, and the characteristics of the types of plant available are as summarised in Table 4. The criteria used for selecting plant to serve different kinds of community may differ. Particular attention should be paid to the need for regular maintenance of the plant. If this is not met, serious problems may result. New types of plant are introduced from time to time by commercial firms specialising in package (prefabricated) plants, but these can usually be classified into one of the groups listed. When selecting package treatment plants, the manufacturer should be consulted at the earliest possible stage of planning, so that he can co-operate fully. In some cases, manufacturers can modify standard plants or build special plants to suit local conditions.

Table 3. Checklist for the selection of a small sewage-treatment plant

1. Loading parameters
   (a) What is the flow and what is the organic load expected from the population to be served?
   (b) Will there be any other discharges to the plant - e.g. of industrial waste water (foul), or of surface water (clean)?
   (c) Will there be variations in the size of the population served?
   (d) Is there likely to be any increase in the population to be served in the near future?

2. Treatment objectives
   (a) What are the requirements in respect of suspended-solids content and BOD of effluent? For discharges to surface water the Royal Commission 30:20 standard often applies, but the Regional Water Authority may formulate standards based on the report of a 'Working Party on Consent Conditions' and may permit more relaxed standards for small discharges, or may require more stringent standards in areas where the risk of pollution of a water resource is high.
   (b) What sludge-treatment facilities are incorporated in the plant, and to what extent must they be supplemented?
   (c) What degree of odour control is necessary?
   (d) What degree of noise control is necessary?

3. Site conditions
   (a) What space is available for the plant?
   (b) What is the available hydraulic head?
   (c) Is electrical power reliably available?
   (d) How near is the site to sources of water supply, to housing, and to other treatment plants?
   (e) Is skilled maintenance available locally?
   (f) Is the plant in an isolated and exposed position?
   (g) What is the direction of the prevailing wind?
   (h) Is access available for tankers or other vehicles?
   (i) What is the proposed distance from inhabited buildings?

4. Effluent discharge
   (a) If subsurface disposal on land is required, what is the percolation factor of the soil?
   (b) Is sufficient land available for the drainage field?
   (c) Is the drainage field a safe distance from water sources?
   (d) Is there impervious rock or clay below the drainage field?
   (e) If effluent must be discharged to a watercourse, what is the dilution factor available at periods of minimum dry-weather flow?

5. Plant characteristics

(a) What are the dimensions of the plant?

(b) Will it satisfy the objectives 2(a)?

(c) What are the maintenance requirements?

(d) What are the power requirements?

(e) Is any other equipment or service required?

(f) Are there any special operational procedures to note?

(g) Will the plant be reliable and durable?

(h) Will the noise, smells, and fly-protection be a problem?

(i) What are the sludge-disposal requirements?

6. Costing

(a) What is the capital cost of the plant, site works, and all ancillary equipment including effluent-discharge pipes?

(b) What is the running cost of plant including power and maintenance?

(c) What would be the cost of connection to main sewerage, as an alternative?

There is considerable variation in both the capital costs and the running costs of treatment plants. Valid comparison is made more difficult if differences in land requirements, ancillary services such as sludge disposal, site works, and maintenance are taken into account. In general, larger plants have smaller capital costs per head of population served than similar smaller plants. The consistent achievement of higher standards of effluent is more expensive than the maintenance of lower standards. Costs vary from year to year, but examples given in Table 5 relating to 1976 can be taken for guidance.

Plants constructed by conventional civil engineering methods, particularly those using biological filtration, can be extremely durable. The service life of some types of mineral medium is known to exceed 50 years, and the associated structures are also very durable. Some of the earlier types of prefabricated plants, especially those using activated-sludge systems, had relatively short lives. Modern package plants are constructed of good-quality materials, protected against corrosion where necessary, but the mechanical and electrical components of activated-sludge plants, even with careful maintenance, cannot be expected to be as durable as biological filters.

Table 4. The characteristics of small sewage-treatment plants currently available in the UK

	Type of plant	Population size range available	Potential advantages	Potential disadvantages
1.	Cesspool	All sizes - can be prefabricated	No power, no mechanism, no quality control required. Not injured by intermittent use. No effluent discharge	No treatment occurs. Size always large compared with septic tanks. Regular emptying service essential, maybe every 2-3 weeks
2.	Septic tank	Populations up to 300 but can be more if required. Can be prefabricated	No power, no mechanism. Where sub-surface discharge is used, quality control confined to SS removal. Very low headloss required. Average removal of BOD 40-50%, SS 80%. Not adversely affected by intermittent use	Regular desludging required, usually once or twice yearly Partial sewege treatment only. 'Royal Commission' effluents are not possible
3.	Septic tank with biological filter and humus tank	Same as 2.	Where flow and head are adequate, no power required. Where flow is intermittent, recirculation may be necessary. Treatment can be to 'Royal Commission' (30/20) standard where favourable*. Mechanical maintenance minimal. Durability very high	Final settling tank needs at least weekly desludging to septic tank. Septic tank desludging required twice yearly
4.	Extended biological filtration	Prefabricated plant available. 6 suppliers. Sizes from 15 to 450 persons. Can be made to order	No primary sludge produced. Can readily treat intermittent flow. Compact plant possible. 'Royal Commission' effluent can be achieved*	Plant can be >3 m high. Some odour problems have been reported. Final sludge can be difficult to dewater. Efficient operation depends on regular inspection, reliable power supply, regular pump maintenace, and regular desludging. High power requirements

5. Rotating biological contactor	Prefabricated plant. 6 suppliers. Sizes from 5 to 40 000 persons	Power consumption usually low. Head-loss requirement low. 'Royal Commission' effluent is possible*. Fly nuisance can be eliminated. Plant can be inconspicuous	Regular sludge removal and motor maintenance necessary about every 3 months. Efficiency affected by surges of flow, sensitive to over-loading. Power failure causes total loss of efficiency
6. Contact stablisation	Prefabricated plant. 4 suppliers. Sizes from 30 to 20 000 persons	No primary sludge formed. Secondary sludge, partly stabilised, quantity reduced. No odour nuisance. Compact plant. Reserve activated sludge always available. 'Royal Commission' effluent can be achieved*	Power and maintenace regularly required for aeration and pumping. Power failure can be serious. Surge flows can cause loss of activated sludge. Regular inspection advised to check DO and sludge concentrations. Noise can be a problem
7. Extended aeration	Prefabricated plant. 14 suppliers. Sizes from 17 to 30 000 persons	No primary sludge formed. Secondary sludge, partly stabilised, quantity reduced. No odour nuisance. 'Royal Commission' effluent can be achieved*	Highest power requirement of all types. Regular maintenance required for aeration and desludging. Regular inspection advised to check DO and sludge concentration
8. Oxidation ditch	Usually civil-engineered structure. Prefabricated plant available. 2 specialist suppliers	Can be operated as extended-aeration plant. Maintenance similar but can be simpler. Can be flexible in loading capacity. 'Royal Commission' effluent can be achieved*	Not economical in land area required but can be more economical in power consumed than some other types of extended-aeration plants. Inspection and maintenance needs as for Type 7

* Effluents of average 'Royal Commission' standard can only be achieved with plants that are adequately designed and properly maintained.

Table 5. **Some characteristic plant costings, 1976**

<u>Small plants for 8 persons</u>

	Capital cost (£ per person)	
Cesspool, 45-d retention; prefabricated	250	plus site work
Septic tank, concrete-built	70	
Septic tank, prefabricated	40	plus site work
Septic tank plus percolating filter package plant ex-works	160	plus site work

<u>Small communities, 250 persons</u>

		Capital cost (£ per person)	Annual power costs (£ per person)
(a)	Conventional civil-engineered biological filtration plant		
	Primary treatment by settlement or septic tank	16	
	Biological filter	26-36	
	Final settlement tank	6-7	
(b)	Package plants ex-works, site costs to be added		
	Extended aeration 1	40-80	1
	Extended aeration 2	67	-
	Extended aeration 3	52	0.9
	Rotating filter plant	220-240	0.16
(c)	Tertiary treatment by upward-flow clarifier		
	Package unit	14	plus site work

Land costs, access roads and sewerage costs must be considered in all capital-cost estimates.

Inspection, maintenance and sludge disposal must be considered in all annual operating costs.

3. THE DESIGN AND OPERATION OF SMALL SEWAGE-TREATMENT PLANTS USING SEPTIC TANKS

The septic tank is one of the oldest types of small sewage-treatment plant and is still more commonly used than any other type. More enquiries have been received about septic tanks than other small plants, but this may be simply because they are numerous.

The septic tank provides for partial treatment of sewage and is not able to produce effluents of 'Royal Commission' standard. However, there are many situations that permit the discharge of partially treated effluents, where septic tanks can be used without undue risk of pollution if proper precautions are taken.

There have been many publications giving design criteria for septic tanks. The most important of these for the UK is the Code of Practice CP 302:1972 'Small sewage treatment works' published by the British Standards Institution[(2)]. Public Authorities have regard to the recommendations in this publication when considering applications for building consent for tank installations. The most important parameters for design of septic tanks are the capacity of the tank and hence the period of retention available for the settlement of solid matter, and the capacity provided for storage and partial degradation of the sludge. These, together, are expressed in the formula:

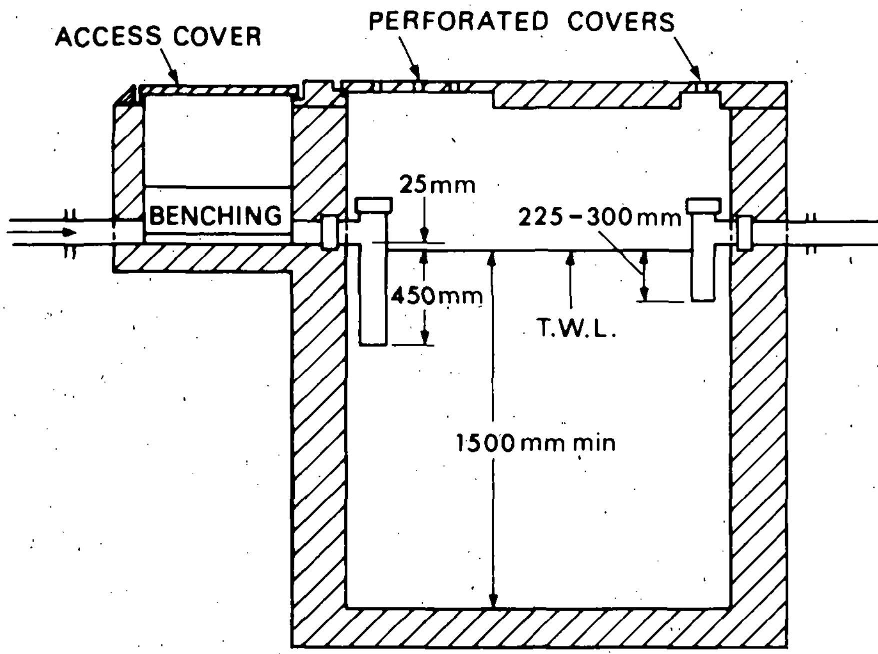
$$C = (180P + 2000) \text{ litres},$$

where C is the capacity of the tank and P is the number of users. There are, however, many septic tanks built to earlier design formulae, and many of these tanks give good results, especially if not overloaded and if adequately maintained.

Septic tanks can be made as single-compartment watertight tanks equipped with inlet pipes discharging below the surface and outlet pipes shielded to prevent the discharge of scum. In Fig. 1, the basic design is shown with the modern alternatives of a two-compartment tank, which can be constructed (if preferred) with two independent compartments, and a typical modern spherical tank that can be supplied in a range of sizes prefabricated from glass-reinforced plastics. Where existing septic tanks are found to be too small, additional compartments can be added to increase the total volume to that recommended for the population.

Tanks having more than one compartment have been shown to produce effluents of better quality than single-compartment tanks of the same capacity. The bad effects of surge flow or neglect of desludging are also less for two-compartment tanks.

(a)



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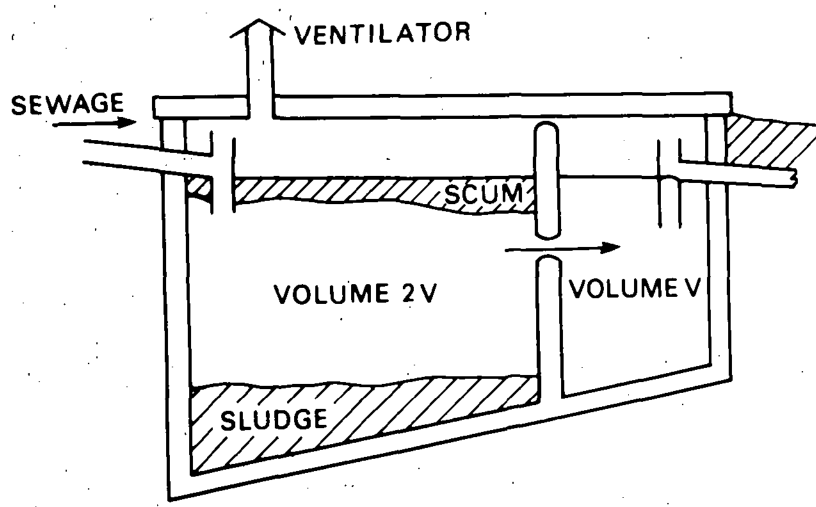

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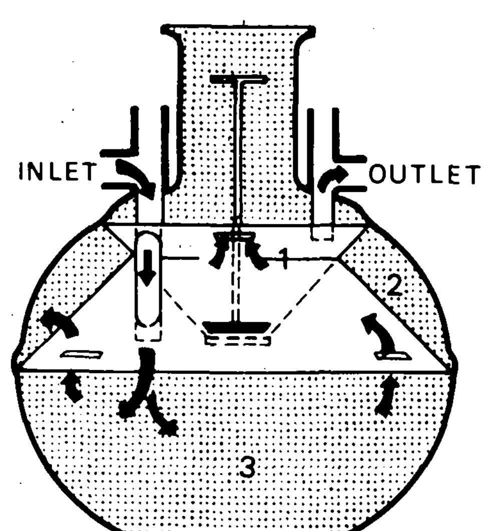


Fig. 1. Examples of septic tanks: (a) single-chamber septic tank, (b) basic 2-chamber septic tank for partial treatment, (c) modern GRP septic tank

(Acknowledgements: (a) and (b), Ref. 2; (c) Messrs Klargester Environmental Engineering Ltd)

Among the less-common faults reported in the construction of septic tanks, have been leaking tanks, and multi-chamber tanks installed in reverse, thus reducing the sludge storage capacity by half; one case has recently been reported where the effluent outlet from a single-chamber tank was installed at the bottom of the tank so that raw sewage flowed across the floor with negligible retention, and no beneficial biological action was possible.

The proportions and dimensions of established tanks should be checked with the recommendations of CP 302. Where they do not depart seriously from CP 302, and no problems have occurred, no action needs to be taken. If the quality of the effluent does not satisfy the standard appropriate to the disposal system, action can be taken to enlarge the septic tank. A second chamber can be added in series, becoming either a primary or a secondary tank according to its position. The additional volume required can be calculated from the formula in CP 302. Oversize septic tanks rarely give any trouble, indeed there can be advantages in that the extra capacity serves as extra sludge storage capacity, thus reducing the necessary frequency of desludging. Undersize tanks, tanks subject to gross surges of flow, or tanks containing excess quantities of sludge, can cause problems as a result of the loss of solids in the effluent and blockage of the disposal fields. Blockages occasionally occur in the pipework, but these can be cleared by rodding. Repeated discharge of sludge to disposal fields may cause the soil surrounding the drainage tiles to become impermeable. This is a rare but serious matter and the only remedy may be to resite the drainage field in unclogged soil. Drainage fields should be constructed with strict reference to the scale recommended by CP 302 after one or more exploratory percolation tests have been carried out on the soil *in situ*. If the area of the drainage trenches, determined according to CP 302, is excessive, or if the underlying subsoil on a site is impervious, subsoil disposal should not be employed.

It is essential that routine desludging is maintained to prevent sludge being discharged in the effluent and clogging the soil around the drainage tiles.

The siting of drainage fields should be considered in relation to the potential risk of polluting ground water. Areas where the ground water rises to within 1 m of the invert of the drains are not suitable. In rural areas, the horizontal distance between drainage fields and wells, or other water sources, is of importance. Recommendations for minimum safe distances vary. A US study indicates that 50 feet to 250 feet is a range for such distances specified in various parts of the USA[(3)]. The minimum safe distance, proposed by Wagner and Lanoix[(4)], between pit privies and wells is 15 m in normal soil conditions, but there is evidence that faecal bacteria are able to penetrate 30 m of soil, and chemical pollution a further 65 m. In sandy soil, considerably purification of well-clarified effluents is possible in much shorter distances; but in fissured rock, pollution can penetrate much greater distances. The advice of the staff of the Regional Water Authority should always be sought in this matter as they will be aware of the local geology.

There are few precautions necessary concerning the wastes admissible to septic tanks. Solid material likely to cause blockages should be excluded. Disinfectants should be used with moderation, because their bactericidal properties can impair the normal biological degradation processes in the tank, and may give rise to serious nuisances from smells during recovery. Disinfectants containing free chlorine cause less severe damage than most organic disinfectants, since reactions occur between the chlorine and organic matter that eliminate the bactericidal properties. Small quantities of acidic or alkaline cleaners do no lasting harm, but attempts to remove accumulations of grease with large amounts of caustic soda can cause sludge to flocculate and rise, and result in solids passing from the septic tank to tile drains, causing blockages. The high sodium content of the effluent would also impair the drainage properties of the soil. Detergents are often suspected of being injurious to septic tanks. Experiments carried out by WPRL in 1964-1967[5] indicated that concentrations of detergent equivalent to 50 mg/l as Manoxol OT had little effect on the physical or biochemical processes in the septic tank. Detergent can reach higher concentrations in sludge. Such sludge could cause some inhibition to digestion if subsequently discharged to an anaerobic digester at a small sewage works as a shock load. The value of 50 mg/l is about double that found in conventional sewage, but may be exceeded on occasions in sewage from small communities.

As septic tanks are designed to operate full, the tank should be filled with water before it is commissioned, and topped up after desludging whenever possible. Biological activity normally takes a few weeks to develop in warm weather. This time can be shortened by adding a few bucketfuls of well-digested sludge from a sewage works or from a mature septic tank: commercial products have been marketed for this purpose, but none has been found to be superior to the above. In a normally operating tank, the contents are stratified in 3 layers: surface crust, clarified liquor below the crust, and sludge at the bottom. When tanks are desludged it is only necessary to remove surplus sludge and add topping-up water. The crust is usually a small part of the total quantity of suspended matter in the tank and, as it plays a useful part in the functioning of the tank, it should not be disturbed more than necessary. If about 10% of the sludge is retained in the tank, this serves as a seed to re-establish anaerobic activity rapidly. There is no benefit to be gained by disinfecting septic tanks.

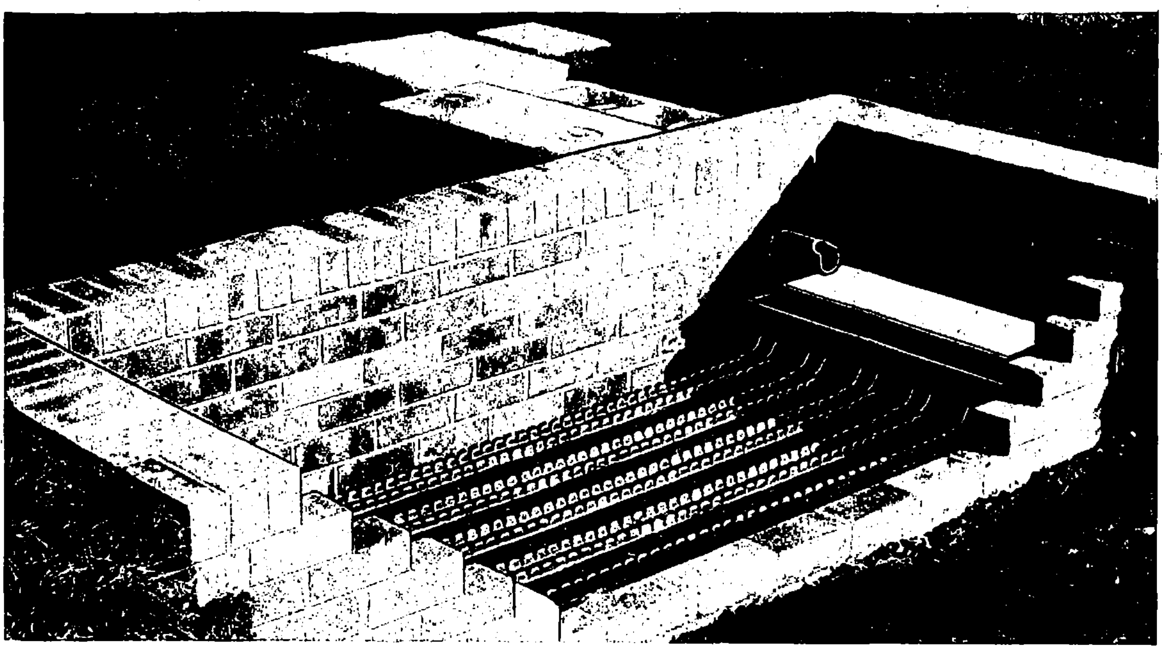
4. IMPROVING THE QUALITY OF EFFLUENT FROM SEPTIC TANKS - THE BIOLOGICAL FILTER

The unit most commonly used for improving the quality of effluent from septic tanks is the biological filter. This consists basically of a ventilated bed of small stones bearing a film of micro-organisms able to metabolise organic matter from the sewage that is distributed on the surface and is allowed to trickle down through the bed. Some attention must be paid to the design and construction of this very simple device. Useful design data and diagrams can be found in CP 302, and further information on the selection of the stones (medium) can be found in BS 1438[6]. Attention should be paid especially to the recommendations regarding the distribution system, the volume, size-grading and durability of the medium, and the ventilation of the filter.

An accessory to the biological filter is a settlement or humus tank, for the final clarification of the treated effluent. If some regular servicing cannot be made available, provision of a humus tank is not recommended. Where final effluents are discharged to tile drains, settlement is necessary to prevent clogging the soil. Specifications are given in CP 302 for the design and construction of suitable settlement tanks, but numerous small works are equipped with tanks of older design that are smaller than present-day recommendations.

Problems do not often occur with small distributors of adequate size, correctly fitted. The smallest types usually comprise a shallow tray fitted with a regular series of level, notched weirs that allow liquid to overflow at a uniform rate at every point (Fig. 2). The tray must be carefully levelled. Sewage is usually admitted, using a tipping trough, so that the flow is adequately spread. The tipping trough is a particularly durable and reliable device needing no more than occasional cleaning and lubrication. Larger filters may be fitted with rotary distributors in the form of an open trough with V-notches in the rim. This is driven by a tipping trough or a small water-wheel turned by the flow of sewage. These distributors are also particularly durable. One was observed still functioning correctly at a small works which had received no maintenance for a period of three years. Although every part of the works was choked with sludge, the distributor, driven by water-wheel, still functioned effectively.

A common problem with small biological filters arises from the flow patterns at small works. Often there are periods, especially at night, during which there is insufficient flow of sewage to keep the filter effectively wetted. If the medium is allowed to dry for periods that may extend for many hours daily, it loses efficiency, and some decomposition of biological film may occur, producing odours and encouraging the filter to become a breeding ground for the flies, *Psychoda* and *Anisopus*, and for midges. The most effective preventative measure is the installation of a very small pump to recirculate effluent from the humus tanks to the filter to maintain favourable conditions. Filters fed by automatic dosing pumps can be improved if the



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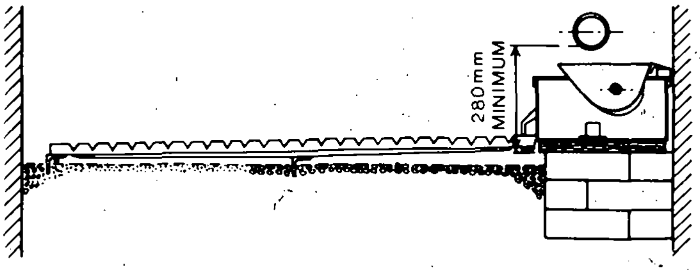
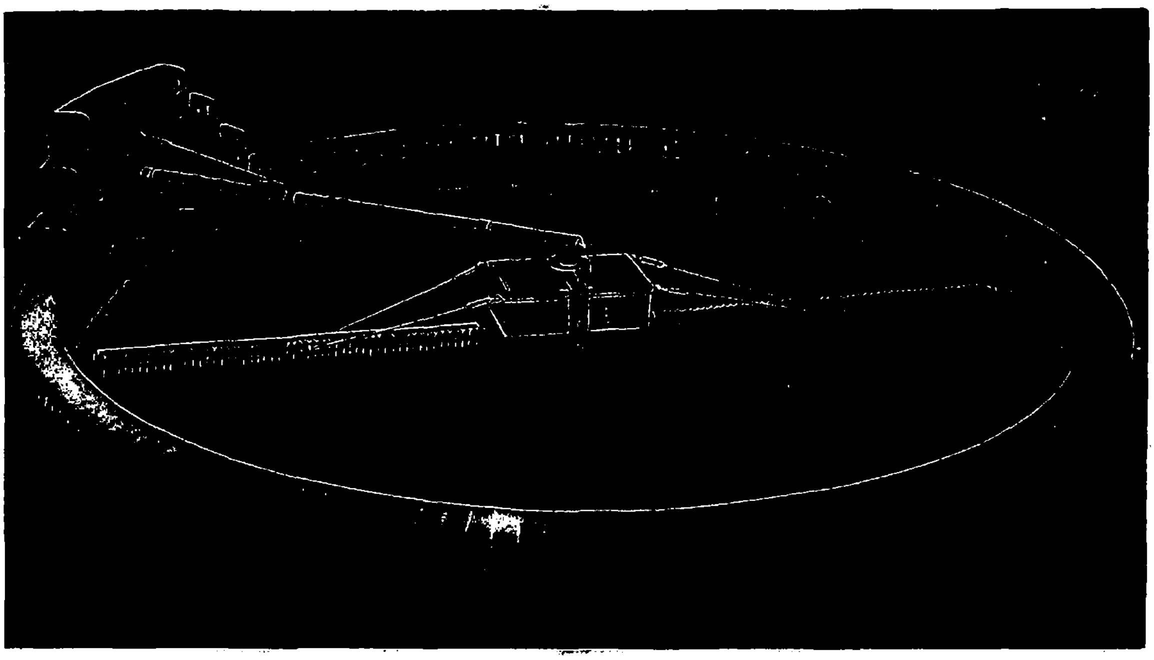


(b)

Fig. 2. Distributing systems for small biological filters (Reproduced by permission of Messrs Tuke and Bell Ltd, Horsham, Sussex): (a) a tipping trough and distributing plate; (b), as (a), in section; (c) a tipper-operated rotary distributor; (d) a water-wheel operated rotary distributor



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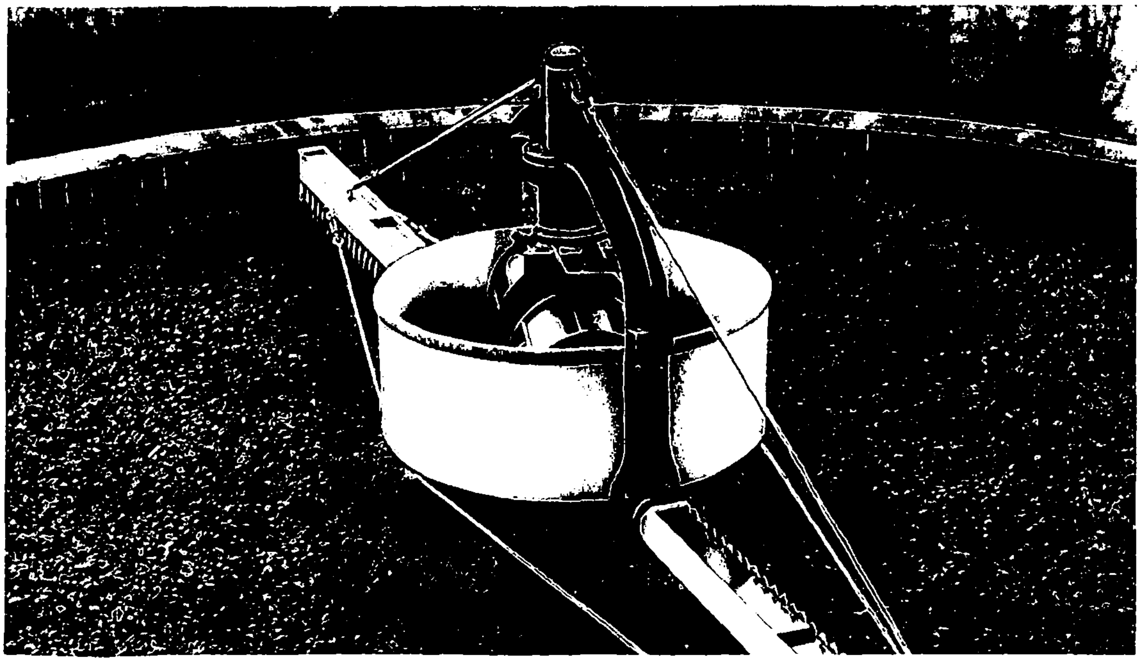


(d)

pump switches are adjusted so that sewage is pumped little and often. Dosing frequency should not be allowed to fall below twice per hour if possible, though the frequency should not exceed the maximum permissible for the motor starters. The advice of pump manufacturers should be sought for the selection of the most suitable types. Where hydraulic levels permit, it is sometimes possible to divert a proportion of the filter effluent back to the pump sump by gravity (Fig. 3).

Odour and fly nuisances may also occur if filters are overloaded or clogged. Normal filters are able to treat sewage at a relatively rapid rate without clogging, owing to the action of the various filter grazing organisms (Metazoa) that feed on the film and maintain a balance between the growth of film and the discharge as humus in the effluent. During long periods of cold weather, the action of these grazing organisms is reduced, and film accumulates. If the void capacity of the medium is

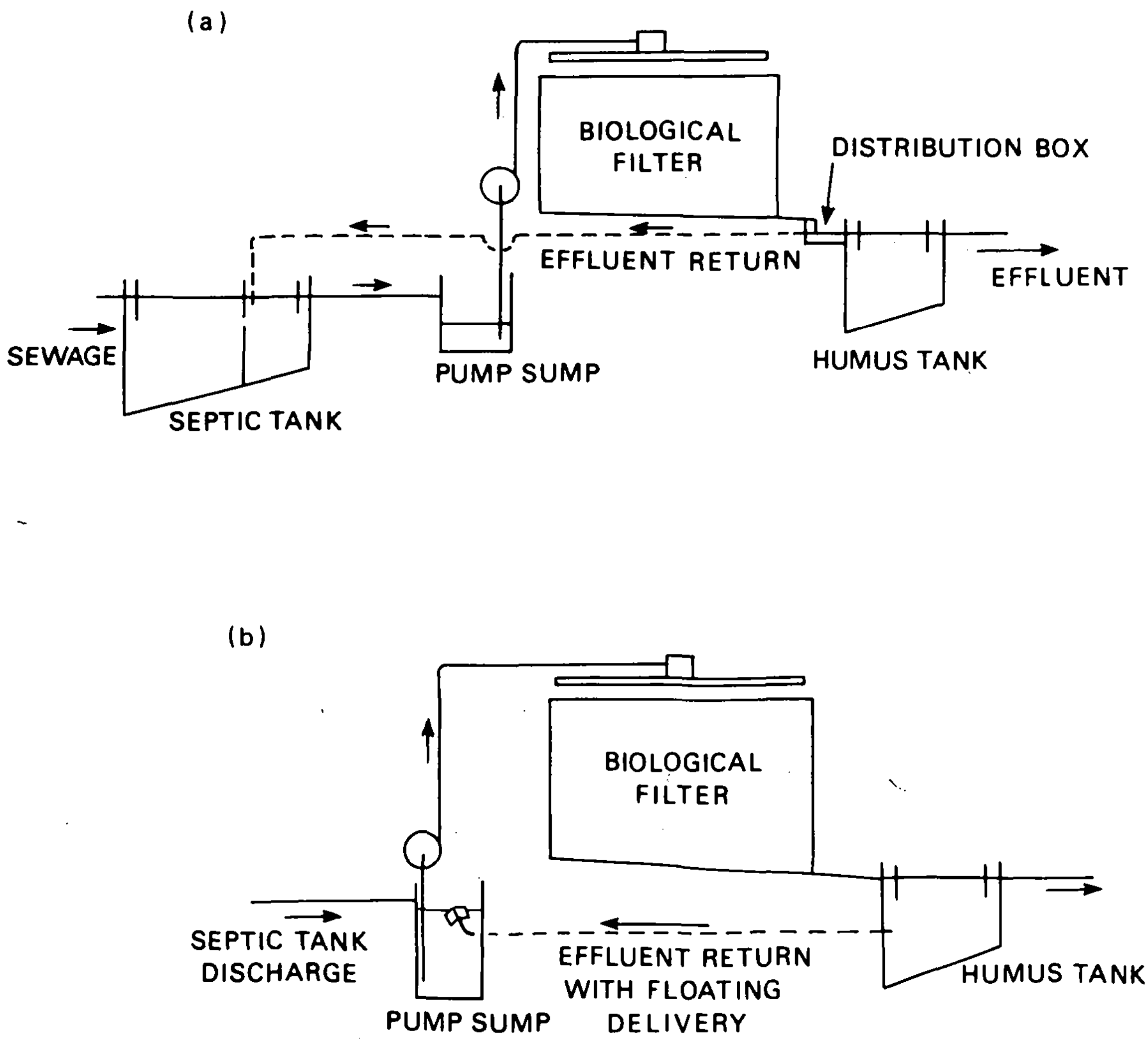


Fig. 3. Simple recirculating systems for small biological filters: (a) using an intermittent dosing pump and a distribution box on the filter discharge to divert a proportion of effluent back to the septic tank; (b) using a continuous-flow pump – effluent from the humus tank can flow back to the pump sump when the rate at which septic tank discharge enters the pump sump falls below the pump rate

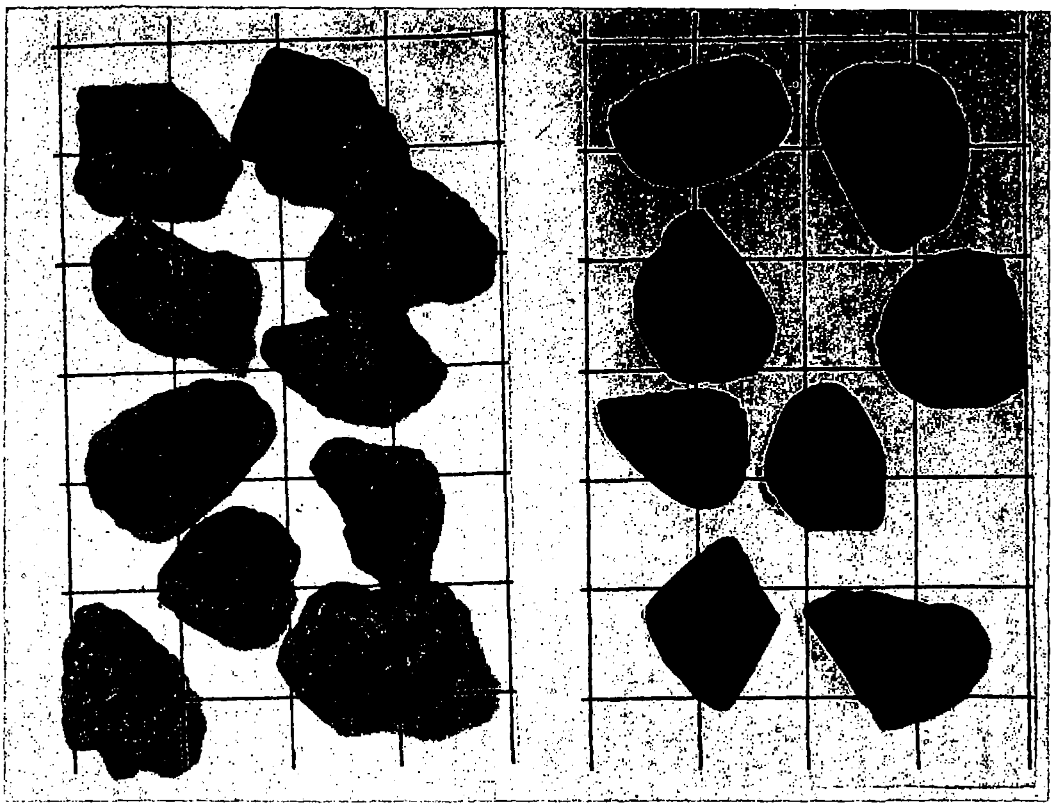
insufficient, or the voids are too small, blockages will occur. If the medium contains a significant proportion of undersize stones, or dust, this can increase the danger of clogging (Fig. 4). In organically-overloaded filters, more biological film can be produced than the voids can accommodate and blockages will result. Some limestones and other minerals break down slowly in filters and the voids can become blocked with debris. Blocked filters can sometimes be cleared by hosing or raking. In severe cases, the medium or the method of operation may need to be changed.

Poorly-ventilated filters are sometimes a source of odour problems. The absence or blockage of ventilation pipes can be rectified, but where filters are built above ground level, a simple cure can often be effected by the judicious removal of a few bricks from the walls at base level.

If humus tanks are fitted, they should be desludged weekly. The small amounts of sludge withdrawn are equivalent to about 1 litre/person day in summer, much less in winter, though there is often a short period in the spring when a much heavier discharge occurs. The humus sludge can usually be stored in the first chamber of the septic tank, where some decomposition will occur. Humus sludge can also be dried on open drying beds, or incorporated into compost heaps, and will be beneficial to the systematic composting of waste vegetable matter. The size and construction of drying beds is described in CP 302. Small quantities of humus sludge may also be buried in areas where no pollution risk is likely. At larger plants, disposal of sludge off-site may be preferred. Drying beds are not recommended for the disposal of septic-tank sludge.

A well-designed and well-run septic-tank and biological-filter system can produce effluents of 'Royal Commission' 30:20 standard (suspended solids and BOD not to exceed 30 and 20 mg/l respectively). Septic tanks are able to tolerate long periods of disuse without any ill effects. This is not characteristic of biological filters.

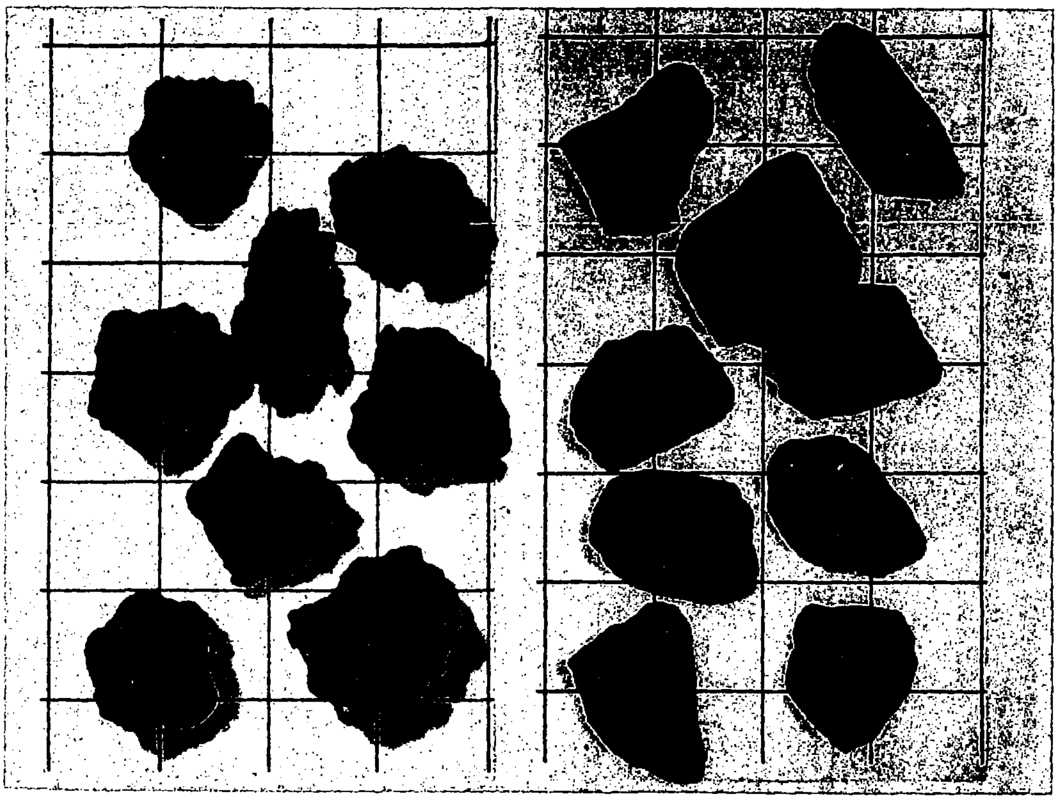
The quality of treated effluents can be improved by adopting a final tertiary treatment system that can either improve effluents to a standard consistently better than 'Royal Commission' quality, if required, or may act as a safeguard to reduce the effects of irregular loading on treatment plants. Four tertiary treatment systems are particularly suited to the requirements of small works in rural areas (Fig. 5). Their main characteristics are given in Table 6. Grass plots and lagoons require a minimum of attention but they can be employed only if sufficient space is available. It is not possible to predict the frequency of cleaning for clarifiers or sand filters: this must be determined by experience. It is not unusual for sand filters to need weekly cleaning, and gravel filters to need more frequent attention. The cleaning of gravel filters is, however, not difficult if they are not neglected. A short period of back-washing, using the clear effluent above the gravel layer, is usually sufficient. It is important that this layer is not less than 30 cm deep, in order to prevent accumulated solids resuspending by wind action. Neglected gravel filters may need more vigorous washing and even raking.



SLAG
Size and shape satisfactory

GRAVEL
Size and shape satisfactory

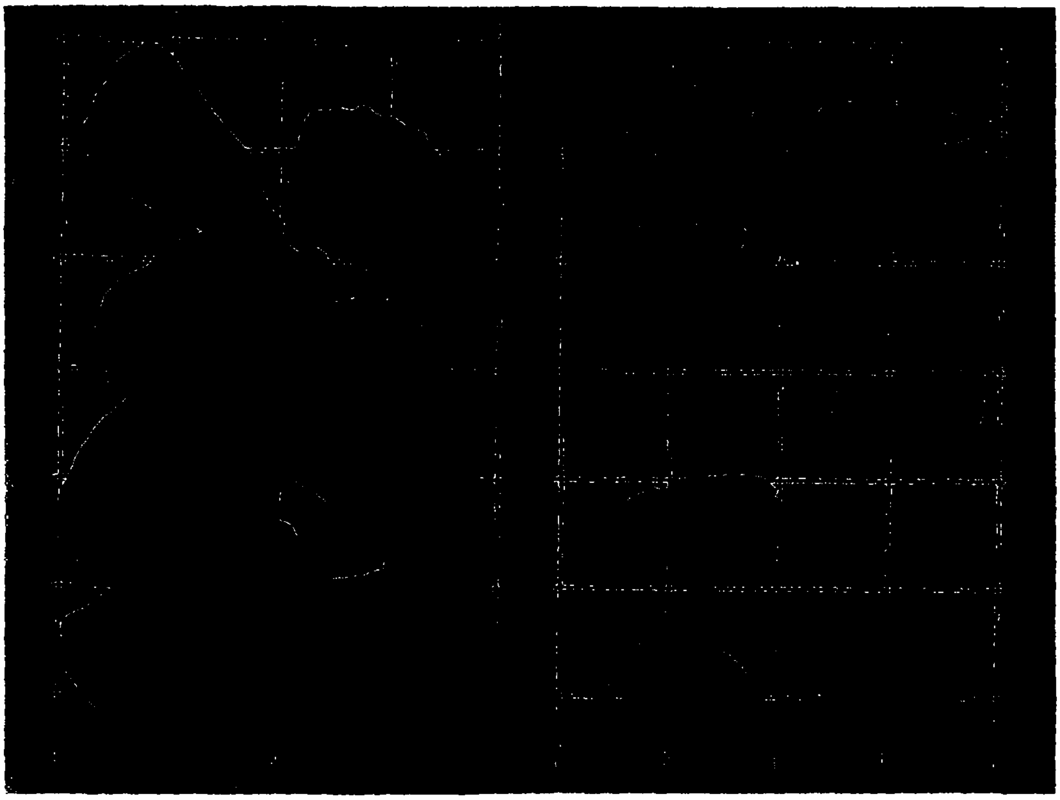
SUITABLE MATERIALS



CLINKER
Size and shape satisfactory

GRANITE
Size and shape satisfactory

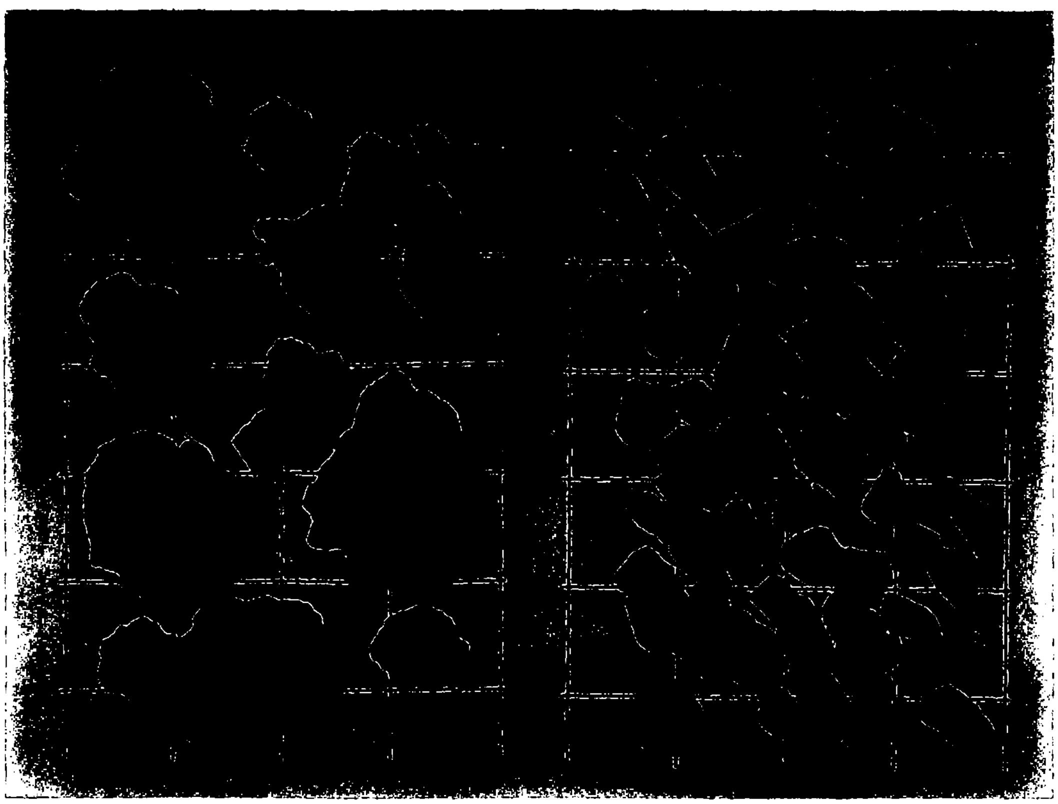
Fig. 4. Some typical media for biological filters. Background scale 50-mm squares. All specimens shown are known to be durable



BASALT
Size too large

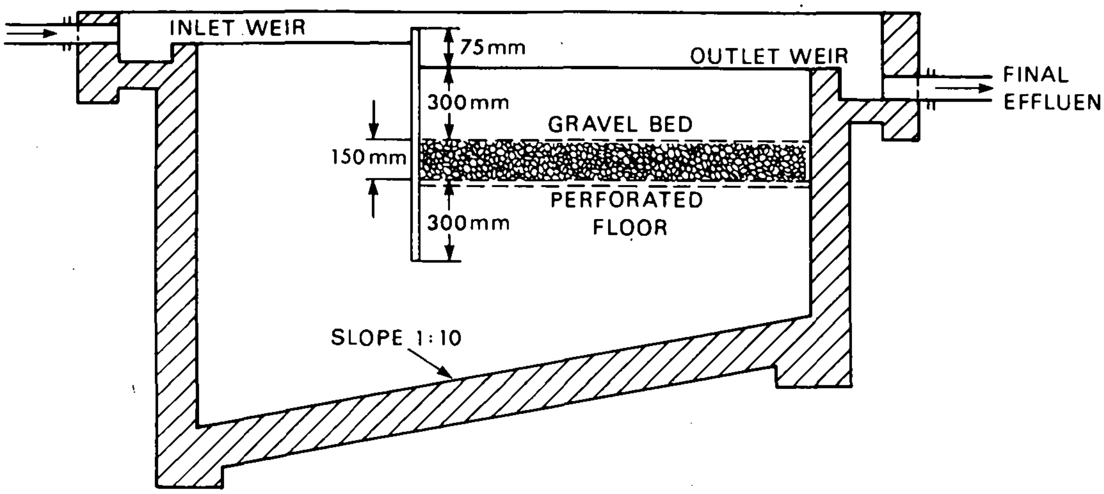
GRANITE
Shape too flaky

UNSUITABLE MATERIALS

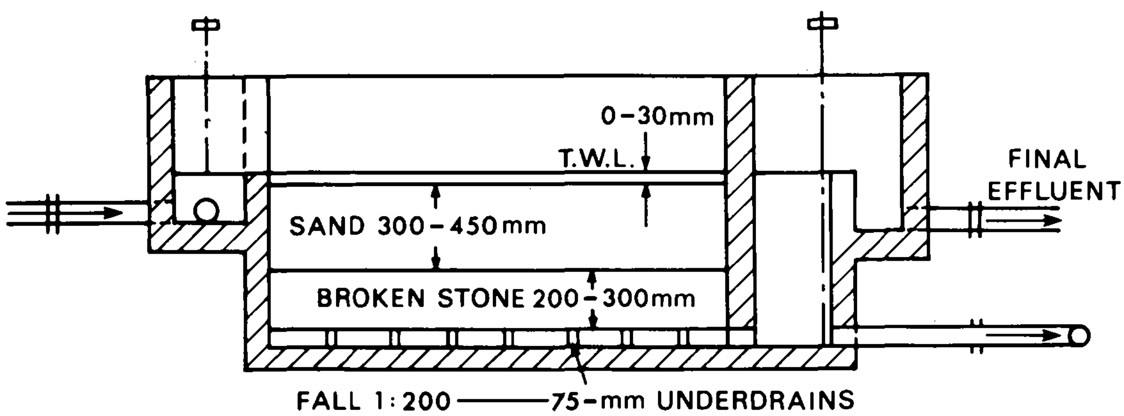


CLINKER
Grading too mixed

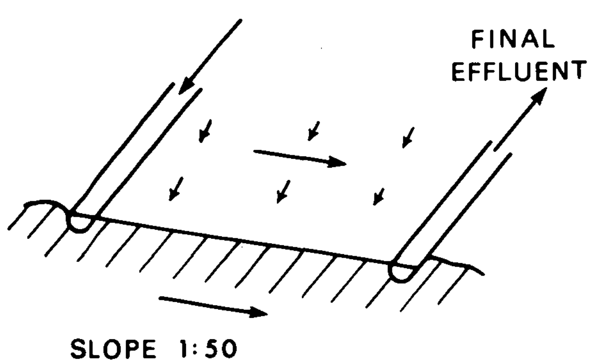
GRANITE
Size too small



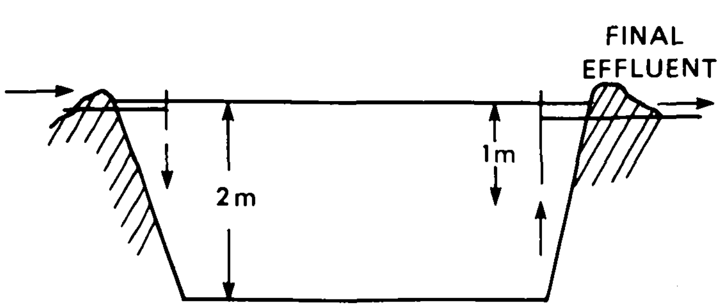
Upward flow gravel-bed clarifier installed in a final humus tank (2)



Slow sand filter: at least two are required (2)



Grass-plot treatment



Tertiary-treatment lagoon

Fig. 5. Some tertiary treatment methods suitable for small works

Table 6. Tertiary treatment methods for small works

System	Hydraulic loading rate (m^3/m^2 d)	Removal (%) BOD	SS	Specific advantages	Potential disadvantages
Upward-flow gravel clarifier	24	30	50	Can be fitted in the top of the humus tank	Requires regular back-washing - not less than weekly.
Sand filter	3.0	40	60	Positive system. Little possibility of short-circuiting	Regular cleaning necessary. Two filters are needed in alternate use. Highest cost system
Grass plots	0.85	50	70	Very low cost, low maintenance, high efficiency	Can be unsightly, if maintenance neglected. Can encourage breeding of flies. A spare plot is needed to permit resting and maintenance
Lagoons	0.5	40	40	Efficiency can be increased by use of lower application rates. Very low maintenance requirements	Lagoons must be watertight. Can be unsightly if overloaded owing to formation of scum. May encourage breeding of insects

5. PACKAGE SEWAGE-TREATMENT PLANTS FOR SMALL COMMUNITIES

The term 'package treatment plant' is applied to a range of plants designed to treat a given hydraulic and organic load using prefabricated components that can be installed with minimal work necessary on site. The term is often assumed to imply a degree of complete treatment that may or may not be provided with any particular plant. The use of package plant does not diminish the need for accurately assessing the hydraulic and organic loads to be treated, and selecting plant suited to the loading and to the required quality of effluent.

Septic tanks, percolating filters, and humus tanks can be obtained in prefabricated forms. In addition, many package plants can be obtained which utilise newer treatment processes that do not have some of the disadvantages of the older systems. These newer processes are described in more detail below.

Modern package plants can be more compact and less conspicuous than conventional biological filters, and many package plants utilising activated sludge are designed to reduce the need for frequent removal of sludge. Primary treatment by settlement or septic tank can be eliminated, though by doing this the organic loading on secondary treatment may be as much as doubled. Secondary sludges can be stored for long periods aerobically with negligible odour, and this storage can partially stabilise and oxidise the sludge, reducing the quantity to be removed for final disposal. Fly and odour nuisances can be greatly reduced with some modern plant. Suitable types of plant can be rapidly commissioned if supplies of activated sludge from another plant are available.

These advantages may only be obtained at some extra cost. Some types of package plant may be cheaper to install than conventional biological filters, but they often have substantially higher operating costs and are very dependent on a reliable power supply. They are usually more complex and require more mechanical servicing than conventional plants. Most responsible manufacturers of package plant are able to make servicing arrangements for their plants that allow for regular site visits for inspection, routine mechanical maintenance, checks on sludge accumulation, and desludging when necessary. Checks are made for blockage caused by scum, etc. Some manufacturers also offer an emergency call-out service in case of breakdown. These services can add significantly to running costs.

The characteristics of the main systems are given in Items 4 to 8 of Table 4. All the systems are able to produce effluents of 'Royal Commission' 30:20 standard, if well designed and well maintained, and not overloaded. A particular advantage of some of the systems is the absence of need to discharge primary sludge; only secondary sludge is discharged, which may be partially stabilised and reduced overall quantity. None of the systems is able to avoid discharge of sludge completely. Most of the package plants utilise extended aeration or contact stabilisation, which are variations of the conventional activated-sludge process. The main parameters of design - BOD loading, retention time, BOD loading of sludge, and air supply - are given in CP 302 and also in a Technical Memorandum published by the Ministry of Housing and Local Government[7]. These recommendations have been varied in a number of successful types of commercial plant.

Two basic designs are used, and they are usually made in a range of sizes. The smallest plants take the form of rectangular steel or GRP tanks divided into compartments equipped for aeration, settlement, and usually sludge storage. Sludge transfer is usually accomplished by air-lift pumps which contain no moving parts. Larger plants utilise the same basic components, but the aerated compartments are arranged in a compact annulus around the central settlement tank. Most of the large plants are constructed of steel. General flow diagrams for extended aeration and contact stabilisation are shown in Fig. 6. Some of the earlier package plants using these systems have given considerable trouble for a variety of reasons, including inadequate design, wrong sizing, lack of maintenance, and poor quality of materials and components. Modern plants have, in the light of experience, overcome these problems. Corrosion and the flimsy nature of some of the earlier plants make repair or reconditioning a doubtful project. It may be preferable to replace sub-standard plants that may have a limited life.

In principle, activated-sludge plants operate by admitting sewage, adding some activated sludge, and aerating the mixture for a suitable period of time. In contact-stabilisation (CS) plants, the contact period is of the order of ½ to 1½ h, to allow the sludge to absorb suspended and dissolved organic matter from the sewage. The right combination of organic matter, activated sludge, air, and time is necessary to ensure completion of this process. The liquid and activated sludge in the mixture are then separated by settlement. The supernatant liquid is discharged and the activated sludge transferred to a second chamber where it is aerated for sufficient time for the micro-organisms present to assimilate the absorbed organic matter and convert it into new cells. A measured proportion of the sludge is returned to the contact chamber to treat further incoming sewage; surplus sludge is segregated in an aerated storage chamber or digester. In extended-aeration plants, the contact time between the sludge and the sewage is very much longer than in the contact stabilisation process. It may exceed 24 h. During this time, the processes of absorption, assimilation, growth, and partial aerobic digestion take place concurrently. No separate stabilisation stage is necessary, though surplus sludge may also be stored in an aerated chamber in which aerobic digestion may continue. The detailed design of plants differs from one manufacturer to another as do the specified concentrations of activated-sludge solids in the mixed liquor, and the intensity of aeration. Manufacturers are able to supply detailed information for all current package systems.

A common routine test to apply to activated-sludge systems is the withdrawal of a quantity of mixed liquor from the aeration chamber; the mixed liquor is then allowed to separate in a clear glass vessel. A healthy system will produce a chocolate-brown sludge that flocculates and settles to leave a clear, almost colour-

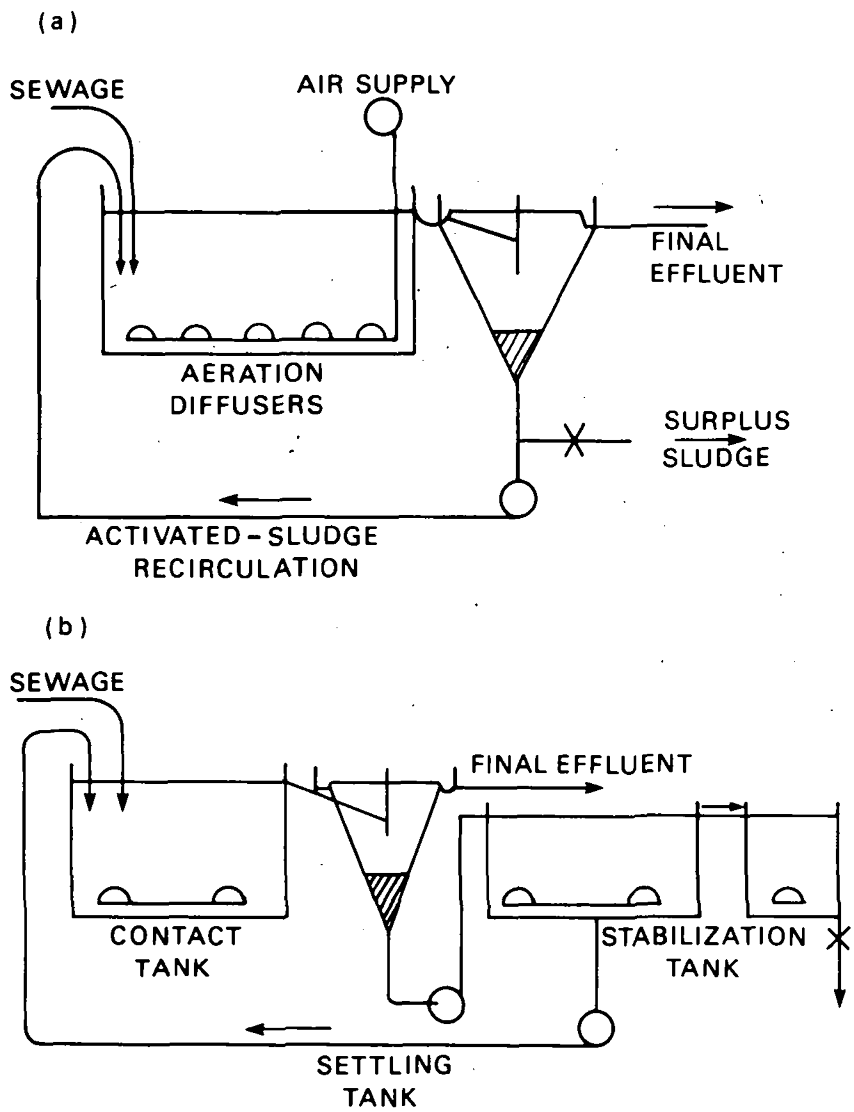


Fig. 6. Flow diagrams for (a) extended-aeration, and (b) contact-stabilisation systems

less, supernatant liquid. Many manufacturers specify a test of this kind carried out with a standard volume of mixed liquor for a standard time (Fig. 7). The volume of the settled sludge can then be used to derive a reasonable estimate of the concentration of sludge, an important operational parameter. If the volume of sludge is too great, surplus sludge should be withdrawn. If the volume of sludge is too small, this may indicate organic underloading of the system. The nature of the sludge is also observed. A fine-grain 'pin point' floc is an indication of probable over-aeration and too long a period of retention of sludge. A sludge that flocculates with little compaction is known as a bulking sludge. It may be caused by a variety of factors. These are still being investigated. In each of these conditions there is a risk that sludge may be discharged with the effluent and that the 'Royal Commission' standard in respect of the concentration of suspended solids (not more than 30 mg/l) may not be consistently met. The loss of sludge can be so severe that the sludge return is insufficient to maintain the necessary concentration in the aeration chamber, and thus purification is impaired.

Fig. 7. A sample of liquor from an extended-aeration plant showing good settlement and good flocculation. The dissolved-oxygen meter shows a concentration of 25% saturation, indicating good aeration

Regular inspection and maintenance should ensure that the correct balance is maintained in the system, and that problems are observed in their early stages and remedial measures taken. If early action is neglected, it may become necessary to replace the sludge by fresh material obtained from a healthy activated-sludge plant.

The package biological filtration plants are available from fewer suppliers than are activated-sludge plants. A number of plants utilise plastics media in systems where comminuted raw sewage is recirculated a number of times before final settlement (Fig. 8). This recirculation means that the process resembles, in some respects, extended aeration. The total quantity of sludge produced by this 'extended filtration' process is less than the sum of primary and secondary sludges produced by conventional plants. However, final disposal of sludge can be a problem, as some types of filters with plastics medium discharged secondary sludge in the form of thick rubbery pieces that are difficult to dewater. Also the sludge is very readily putrescible and may cause more odour nuisance during disposal. Where the sludge is disposed of off-site, these problems are of less importance.

Some problems have occurred as a result of excessive breeding of flies and production of odours in extended-filtration plants. They are not characteristic of the process, but are usually caused by organic overloading, inadequate recirculation, or even inadequate wetting of the medium. These problems can be overcome. Where fly problems are persistent, filters can be protected with fine-mesh wire screens at exposed places, provided that the ventilation is not impaired. The correct siting of extended filters, as with most sewage-treatment units, will do much to minimise risk of nuisances by flies, odours, or noise.

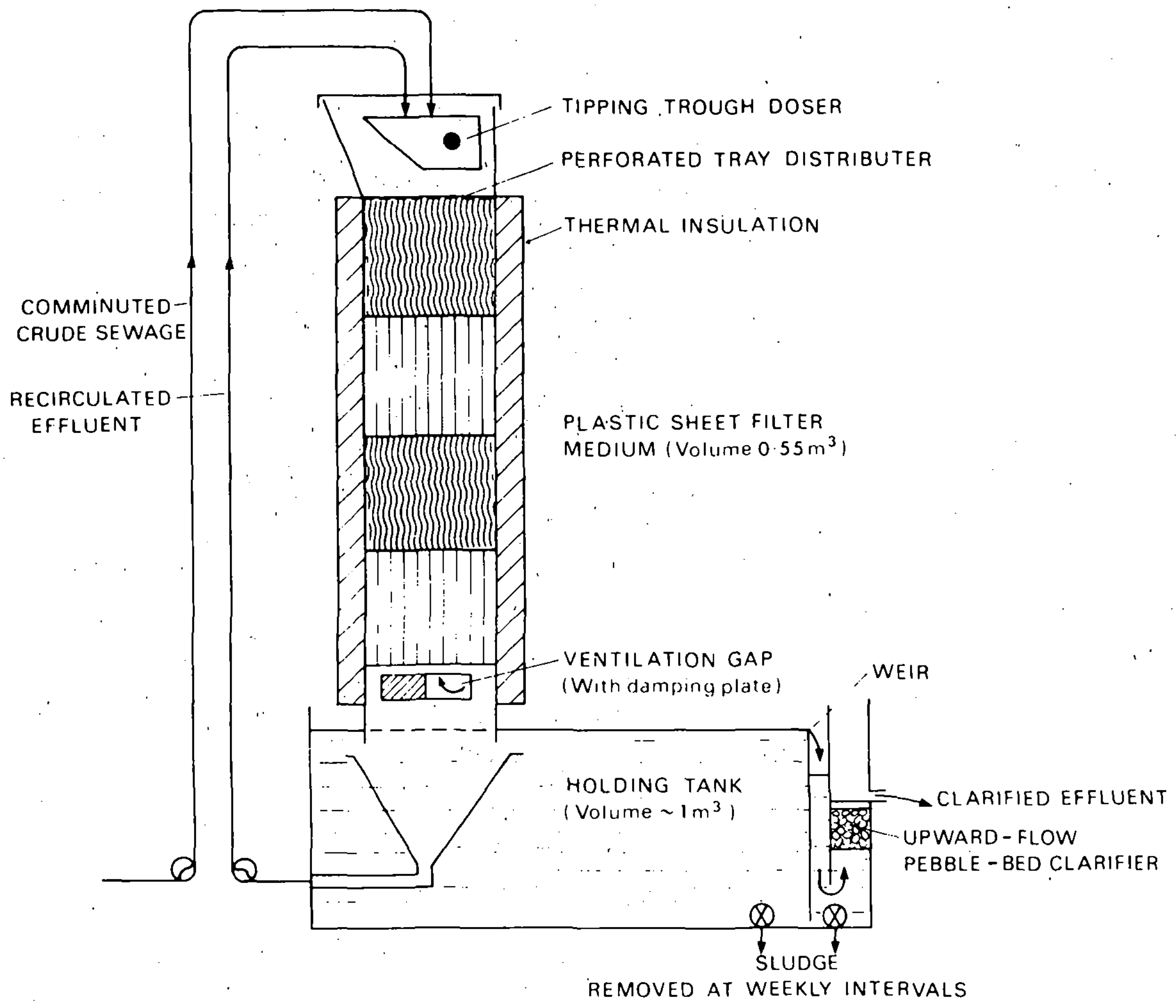


Fig. 8. An extended filter for treating crude sewage (Ref. 8.)

Increasing attention is being given to the rotating biological contactors (RBCs) which are available from 6 suppliers in a wide range of sizes. Although RBCs are comparatively costly, they have a number of special advantages. They can provide full aerobic treatment with no greater loss of head than a septic tank, they have a lower power requirement than most other aerobic systems, they have no distribution problems and recirculation is not necessary, and they are relatively inconspicuous and can be well protected from fly and odour nuisance. Maintenance is particularly simple, as conventional mechanical maintenance is confined to one motor and gearbox. Other maintenance requirements are mainly routine inspection and periodic removal of sludge, which may be at intervals of 3 to 6 months. The basic design of the system is indicated in Fig. 9; the commercial versions differ only in detail. Extensive tests were made in the development stage of the process by WRC, and these have been reported[8,9]. The principle of moving a specially-constructed support medium through a body of sewage so that adhering biological film is alternately exposed to air and to sewage is not new, but the rotating filters now available offer the best mechanical means of effecting this. A small but reliable power source is necessary to rotate the stack of discs. Attempts have been made to utilise sewage flow for this purpose, but so far these have not proved successful.

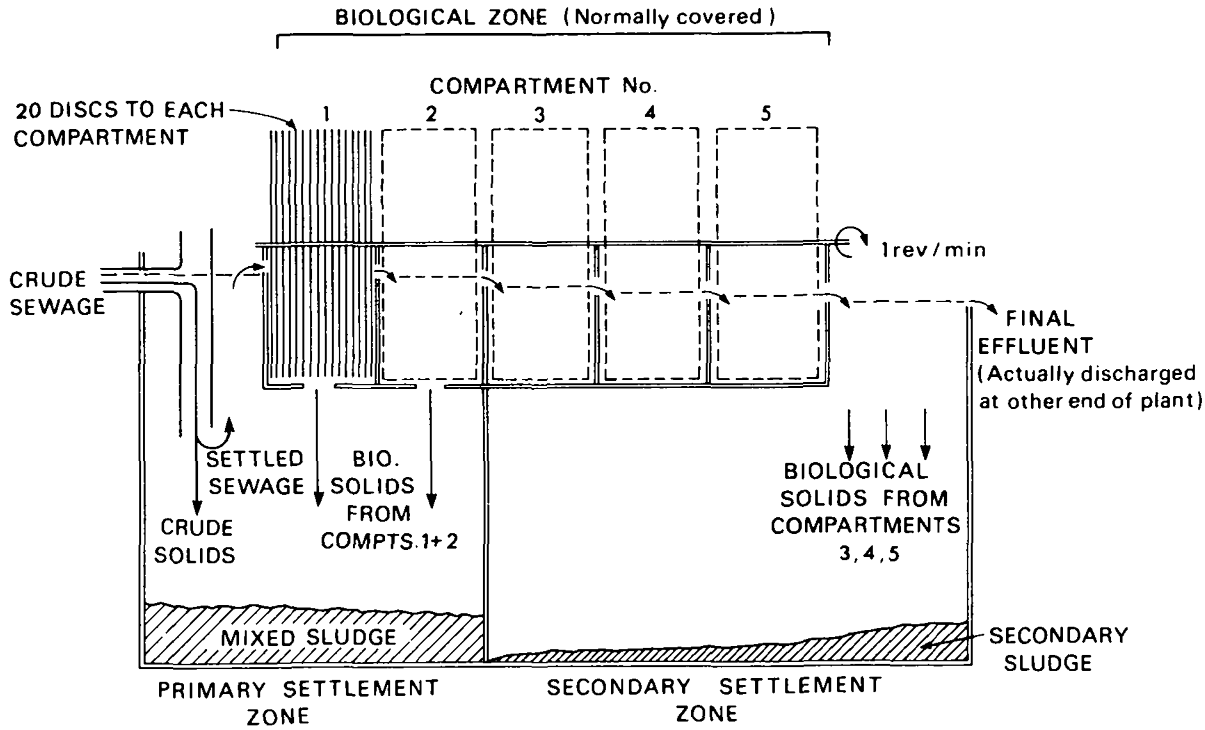


Fig. 9. Flow diagram for rotating filter system (Ref. 8.)

A process of particular value to medium- or large-size communities is the oxidation ditch or Pasveer ditch (Fig. 10). This may be obtained either as a purpose-built simple civil engineering structure, or as a small prefabricated unit. A modified form of Pasveer ditch using a different aeration system is available from another source. In principle, the Pasveer ditch is an extended-aeration plant treating raw unsettled sewage in a tank of loop or annular form, fitted with a surface aerator which agitates the mixture of sludge and sewage, and circulates it around the loop. Effluent displaced from the ditch is usually settled in a separate settlement tank. Most of the sludge is recirculated: the remainder is discharged as surplus sludge to drying beds. Construction costs of Pasveer ditches are often

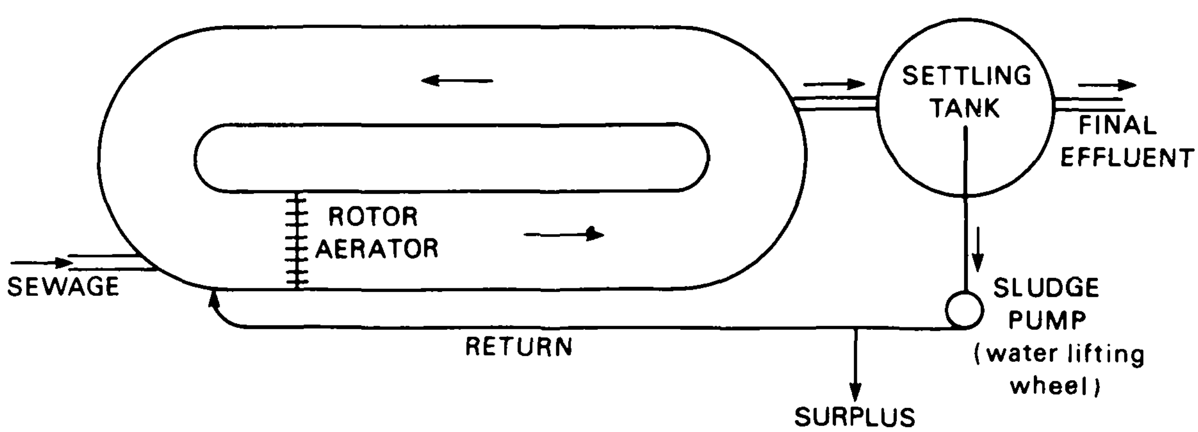


Fig. 10. Flow diagram for Pasveer ditch

relatively low, but land costs are higher than for other extended-aeration plants. Maintenance is relatively simple, though the aerator and the sludge-return pump require regular mechanical servicing. Periodically, checks must also be made to ensure that a correct concentration of sludge is maintained in the ditch and that the correct arrangements for discharge and disposal of sludge are followed. There is considerable expertise available on the use of Pasveer ditches for industrial waste-water treatment in the UK.

6. COMMISSIONING NEW PLANTS AND UPRATING OLD PLANTS

Questions are often asked on the subject of commissioning new plants. Procedures differ with different types of plant. Septic tanks should be filled with water and tested for leaks, then a charge of digested sludge from another works or a mature septic tank, equivalent to about 5% of the tank capacity, should be added. It can take more than a year to establish complete crust cover in a septic tank and care should be taken when desludging to cause minimal disturbance of the crust. The practice of mixing the whole contents of the tank before removal of sludge should not be encouraged. A proportion of the sludge should be left as 'seed'. In the case of multi-compartment tanks, most of the sludge accumulation is in the primary compartment; the presence of significant quantities of sludge in the second or subsequent compartments may indicate surge flow, overloading, or lack of adequate desludging.

All forms of activated-sludge plant should be filled with water and tested for leaks before commissioning. The aeration equipment and pumps should then be tested. An inoculum of activated sludge from another mature activated-sludge plant should be added to the water in the aeration tank before sewage is admitted. A reasonable size of inoculum might be about one-third of the volume of the aeration tank. Normal biological action is established very rapidly after this. It may be advisable to return all activated sludge to the aeration tank until the design concentration is reached, commonly in the range 2000 to 6000 mg/l, depending on the particular plant. This concentration can often be reached in a matter of days. Thus activated-sludge plants are particularly suitable where the need is to have rapidly increasing capacity. Great flexibility can be obtained if several plants can be operated in parallel. If no activated sludge is available, prolonged aeration of crude sewage will allow organisms normally present to multiply and form an activated sludge. Humus sludge can be obtained from the final-settlement tanks at a percolating-filter works and used in the same way. The effect of aerating humus sludge is very similar to using activated sludge. It may be, however, some weeks before the design concentration is reached. All surplus sludge should be retained in this commissioning period. The quality of the effluent will be significantly lower than that from a mature plant during this time.

The same procedures can be adopted with biological filtration plant or rotary biological contactors. The time taken for a filter to reach 75% efficiency, when it is commissioned with crude sewage only, may be as low as 40 d in warm weather; but, in cold weather, the time required could be 150 d or more. The time required for production of effluent of reasonable quality can be significantly reduced if the filter medium is inoculated with a quantity of activated sludge. However, as activated sludge does not contain the full range of organisms present in a mature percolating filter, this method does not reduce the maturing period as quickly as when used with activated-sludge plants. Effluents are incompletely treated during the maturing period; but if they can be partially recirculated with a temporary pump, the maturing period can often be significantly reduced and effluent quality improved.

Uprating old works embraces improvements to satisfy a number of requirements:

1. Reducing intermittent deterioration of the quality of effluent from plants with good average performance.
2. Improving average quality of effluent.
3. Increasing hydraulic and organic loading capacity.
4. Renovation of very run-down works.

In all groups, the dimensions of the plant should be checked to determine that the plant has adequate capacity. Any deficiencies or damage should be made good, particularly in relation to leakage, blockages, and corrosion. Problems in the first two groups may require measures to be taken to reduce the effects of surge or intermittent flows; these may include the installation of balancing tanks or the employment of some form of recirculation of effluent. The latter is particularly useful for biological filtration plants. Effluent of consistently low quality may be a result of overloading; this can be checked. Measures that must be taken to increase the loading capacity of the plant will include expanding or adding to the facilities. Septic-tank capacity can be increased by installing additional tanks in parallel, or in series, with existing tanks. In this way, existing single-chamber tanks can be converted to multi-chamber tanks. Tanks added in series do not necessarily need to be immediately adjacent to existing tanks.

Percolating-filter capacity can be improved to a limited extent by adding layers of medium to the surface. This is only possible if the existing medium is of suitable size and good quality. Where the hydraulic conditions permit, the depth of small filters can be profitably increased to about 2.5 m. Distributors must be relocated with care. Recirculation of effluents can be of benefit in many cases. If the increased load is expected to be consistently more than one-third of the conventional design load of the filters, it is necessary to install supplementary filters in parallel.

Humus tanks are frequently observed to be much smaller than recommended designs. These should be replaced.

Tertiary treatment facilities can be of particular value in ensuring that effluents are of consistently high quality where treatment plants discharge to watercourses. It must be emphasised, however, that tertiary treatment is intended for the improvement of secondary effluents of generally good quality. Tertiary treatment should not be used as a substitute for improved secondary treatment.

It is usually more difficult to uprate activated-sludge plants of fixed capacity. If aeration systems can be modified to increase air output, and thus oxygenation capacity, stronger wastes or larger volumes can often be treated in the same plant. In most cases, however, it is necessary to supplement the treatment capacity with extra plant.

The organic loading on plants without primary treatment can be reduced by 30 to 50% if settling tanks or septic tanks are installed for the first stage of treatment. High-rate biological filters may also be employed for pretreatment in series. Using them, a further 50% reduction in organic load can be achieved relatively simply. There is, however, a risk of creating an odour nuisance.

The renovation of very run-down or abandoned works requires the accurate assessment of hydraulic and organic loads, the repair or replacement of all necessary equipment, and the supply of such additional equipment as may be necessary. This may constitute a fairly simple clean-up operation for many types of septic tank and percolating-filter works or an extensive replacement programme where neglected electrical equipment is employed. The full co-operation of the plant manufacturer should be sought in this type of operation.

7. CONCLUSIONS AND RECOMMENDATIONS

A wide range of systems is available for sewage treatment and disposal for small communities of every kind. The systems range from simple septic tanks discharging to subsurface drains, to more complicated systems employing biological filters or activated-sludge processes that can produce effluents of quality suitable for discharge to rivers.

The characteristics of most of the systems in use have been described and compared, and guidelines proposed for selection of the most suitable system for any particular location. It must be emphasised, however, that a treatment works can only treat waste waters that are discharged to it. Furthermore, the works can only be expected to treat the waste water it is designed to treat. All treatment works need some inspection and maintenance. The work needed can be reduced to a limited extent by employing automated plant at some extra capital cost, and often at much greater running cost.

Problems often occur at small works with the disposal of sludge - an essential operation that is often neglected. These problems can be reduced by employing more sophisticated and costly techniques, including the treatment of unsettled sewage or the use of aerobic sludge digestion, but no system has been devised that completely eliminates the need for disposal of sludge.

Many of the common problems occurring at small treatment works are the result of lack of information, particularly in respect of maintenance requirements.

Old works can be reconditioned and their capacity increased, often at relatively low cost. The high durability of some of the older systems such as percolating filters cannot be overlooked when comparing them with more sophisticated package plants that are also usually much less flexible. Before installing new treatment plant, there should be the fullest consultation with the Regional Water Authority concerned, and with the plant manufacturer.

The Stevenage Laboratory of the Water Research Centre has maintained a close interest in small sewage-treatment plants for many years, and has published a number of Notes, dating from its former designation as the Water Pollution Research Laboratory. Those that may be of value to some operators of small plants include:

No. 5	Operation of percolating filters	June 1959
9	Septic tanks*	June 1960
14	Some recent observations on percolating filters	Sept 1961
15	Synthetic detergents	Dec 1961
22	'Polishing' of sewage-works effluent	Sept 1963

* NB - the design formula given in this Note is not the most up-to-date formula.

35	Sludge dewatering on drying beds	Dec 1966
40	The use of plastic filter media for biological filtration	Mar 1968
42	Synthetic detergents III: the position in 1968	Sept 1968
44	Simple methods for testing sewage effluents	Mar 1969
60	Developments in the treatment of sewage from small communities	Mar 1973
63	Treatment of secondary sewage effluent in lagoons	Dec 1973

In addition, the Centre can assist with advice on the selection, operation and maintenance of small treatment works, and on means of overcoming problems associated with them.

To reduce the number of problems that may arise with small works, owners or operators should ensure that they are aware of the precise nature and type of plant they are using and the size of the population being served. Information should be kept relating to the size of the plant and the layout of pipework to and away from the plant. A logbook would be useful in which to record any changes made to the system, and also to record the results of periodical inspections and maintenance. It is most important that maintenance should not be neglected, lack of maintenance being a common source of many otherwise-avoidable problems.

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