The Institute of Water Pollution Control

NORTH EASTERN BRANCH

PROCEEDINGS OF

SYMPOSIUM

"DESIGN AND OPERATION OF SMALL SEWAGE WORKS"

held in the

High Melton Training College,
DONCASTER.

4th NOVEMBER, 1981.

CONTENTS

ERRATA

1. Page C2, 4th line from bottom. For "110-120 l/hd of population" read "110-120 l/hd of population per day.
2. Pages C13 and C15. All references to organic loading rates of rotating biological contactors to read "g BOD/m^2 d" instead of "g BOD/m^3 d".
3. Page C15, third line from bottom. For "... not at the loading disc stage..." read "... not loading disc stages ...".
4. Page C21, 13 lines from top. For "8.3 m" read "2.6 m (8.3 ft)".
5. Page C26. On line 4, for "0.043-0.34 kW/hd d" read "0.043-0.34 kWh/hd.d." On line 9 for "Nicholl" read "Nicoll".
6. Page D4, 14th line from top. Delete "bed" insert "land".

OPENING REMARKS BY THE PRESIDENT.

The PRESIDENT, Mr. George Eden, said that it was his pleasant duty on behalf of the Institute to welcome those present to this one day Symposium. He pointed out that the Institute, like many other organizations, was reconsidering its functions and one of the policies was to set in train a regular programme of symposia, both local ones organized by the Branches and national symposia organized centrally. This symposium was the first of the one day symposia organized by the North Eastern Branch of this Institute.

The President then introduced the Chairmen for the day, Mr. W.S. Smith the Manager of the Peterborough Sewage Division, Anglian Water Authority, who was to chair the morning session, and Mr. J. Taylor, South Eastern Division Water Pollution Control Manager, Yorkshire water Authority, who was to chair the afternoon session.

Mr. W.S. Smith, Senior Vice-President of the Institute, then took the chair and following some 'domestic' announcements introduced the first author of the day, Mr. K. Staples, and invited him to introduce his paper 'The Design of Small Sewage-Treatment Works'.

DESIGN OF SMALL SEWAGE-TREATMENT WORKS

By K.D. STAPLES, F.I.C.E., F.I.P.H.E. (Member)

Partner, Watson Hawksley

INTRODUCTION

The design of small treatment works embraces several features which may be considered as special in comparison with the design of works of larger capacities. Firstly, the question of cost. Scale effects result in the capital cost of small treatment plants being higher per capita than larger plants. Land areas, the cost of land acquisition, access, electricity supply and general site development, welfare buildings etc., also tend to be high in proportion to the functional treatment units involved. These high-cost influences can only be countered by attention to simple and economic construction and equipment design.

The second, and perhaps most important, special consideration is the question of works' operation. The cost of manned operation has increased significantly in recent years, and in most costs small plant operation is high in comparison with the larger works. Obviously it is not appropriate to man small treatment units continuously, and the design challenge is therefore to build a plant which will function effectively and reliably with the minimum attention.

EFFLUENT STANDARDS AND PROCESSES

Effluent standards will usually be set in the discharge consent, but one may speculate that the Royal Commission Standard will often remain a most useful guide. Economy and convenience will indicate frequently that a 30 : 20 standard is not inappropriate since a more relaxed standard is not always consistent with reliable operation, and a more stringent standard also more expensive and difficult to maintain. The Royal Commission effluent standard was based upon a minimum dilution of 8 : 1, and small plants frequently suffer from the difficulty that the effluent is either discharged to soakaways or to a small stream or ditch, which dries up in summer so the effluent is again being absorbed into the groundwater system. In these systems of groundwater recharge, it will be evident, to avoid clogging the ground pores, that the removal of fine suspended solids from the effluent is probably more important than reducing the BOD. Whatever the standard set, monitoring may not be strict and the real performance criteria may be the absence of nuisance or complaint.

The mass transfer and physical design parameters applicable to larger treatment units apply, but it is usually appropriate to adopt lower loadings and slightly larger units, especially for very small works, in order to deal with flow surges and to cater for the intermittent nature of the operational maintenance.

Well-proven processes are available and should be used, although their application and engineering may have to be adapted. There is the normal need for twin units in order to provide a standby flow path whilst the individual tank is being cleaned or maintained, and the need for standby mechanical plant is accentuated by the planned infrequency of operational visiting.

For all units there are advantages in ensuring that in the event of blockage, mechanical or electrical failure bypassing or emergency overflow is possible. Obviously good design will permit some degree of treatment to continue.

FLOWS AND PUMPING

The assessment of average dry-weather flows as a basis of design is normally relatively simple, and although local conditions will need to be checked an allowance of 150 l/hd/d can be considered normal for a domestic sewage installation[1].

Stormwater or groundwater entering the sewer system can lead to real difficulties and all small works should be based on a strictly separate system. In spite of separation flow multiples will be high, and the resulting difficulties are often referred to as 'surging'.

A simple calculation will demonstrate that for a single ordinary household flushing of a toilet will result in a flow peaking factor of about 30, while a bath emptying can double this factor[2,3]. There are many graphical analyses of sewage peaking factors to show the attenuation effects with increasing populations and these usually suggest peak multiples of between 5 and 10 for population of 1000. For very small plants the peak flows are often of short duration and their surge effect may be balanced to some extent within the treatment process.

In practice capacity for balancing can be achieved in the overall capacity of the first main units, or by purpose-built inlet arrangement with some restriction on rate of discharge to the tanks.

Frequently sewage pumping is inevitable either at the site of the treatment works or offsite to lift the flows to the works, although effluent pumping is preferable to sewage pumping if this can be achieved.

The need for pipes of adequate size to prevent blockages is valid for all works and the use of gravity sewers and sludge pipelines under 150 mm is to be avoided. Similarly for sewage and sludge the use of unchokable pumps is appropriate. This type of pump, taken with the need to have self-cleansing velocities in rising mains above about 100 mm in daimeter, inevitably means that flows will reach the works at high multiples and sometimes infrequently.

The design of pumping stations and balancing arrangements for small works will require a compromise between long retentions and infrequent operation during periods of low flow and maximum permissible number of pump starts per hour. For a 100-mm pumping main or feed pipe served by a single operating pump at self-cleansing velocities the minimum possible capacity will amount to a peaking factor of about 4500 for a single person, more practically to cater for 100 persons a pumping main will deliver flow at a multiple of 45 DWF.

SELECTION OF PROCESS

The choice of treatment process will always be influenced by local factors, not the least being site configuration and the available head across the site. Of equal importance is the availability of power, and the extent to which it may be appropriate to trade off a higher power consumption mechanical equipment system with what might be a higher land usage gravitational system[4].

The choices are therefore strongly influenced by the local circumstances and the size of plant, and a subjective review of the principal options is given in Fig.1.

INLET WORKS

The normal functions of an inlet works are flow measurement, screening and grit removal; the latter two processes principally to protect downstream pipelines and units fron blockage. Generally on very small plants flow measurement can be considered as being an unnecessary complication, whilst grit removal should only be contemplated if there is particular reason to suspect high grit concentrations from the sewers, or there is a special facility for sludge treatment,

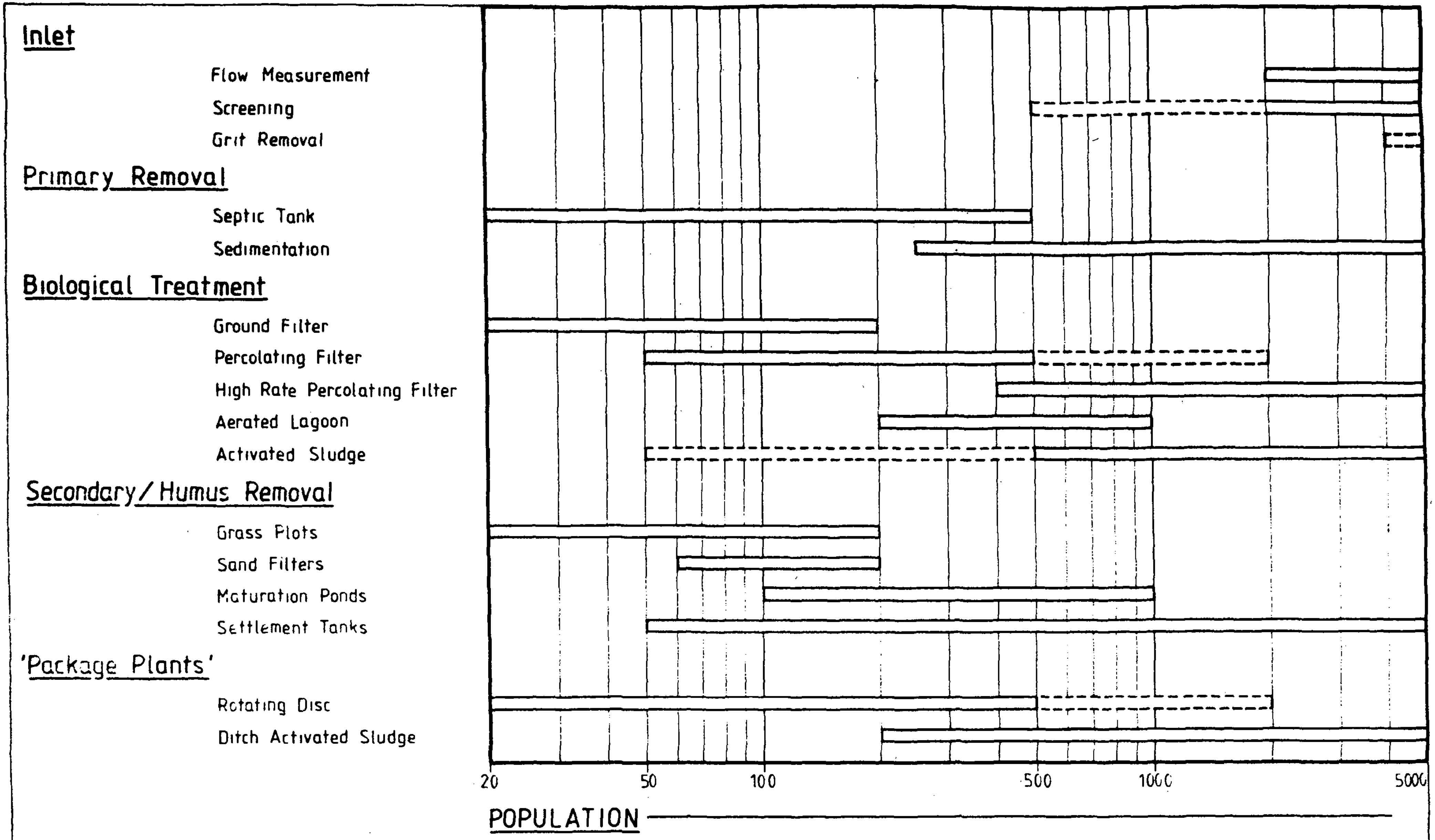


FIGURE 1 — APPLICATION OF TREATMENT PROCESSES TO POPULATION

such as digestion, perhaps on another site.

The need for screening is usually more obvious, although the practice should be avoided as far as possible, simply because if screens are installed they have to be cleaned.

Comminution of screenings maceration may be applied in lieu of screenings, to resolve the question of removal satisfactorily. Screening removal generally would have more emphasis where biological filters are employed.

The design of a conventional screen is usually based on a bar spacing of 25 - 50 mm, with an area sufficient to ensure that the average velocity of flow through the bar screen does not exceed about 0.3 m/s. Since bar screens on small plants are most often hand-raked, the use of screens in the horizontal mode can provide a useful arrangement if there is sufficient head available for a clear outfall over the screen. A useful device on an extended aeration ditch plant has involved the installation of a screen suspended in the ditch so that the screenings are removed on multi-pass and when the bars are clogged flow can stream by on either edge.

Disposal of screenings or grit on small plants is usually achieved by transport to a local refuse tip or other landfill area, or even by excavation and burial on site.

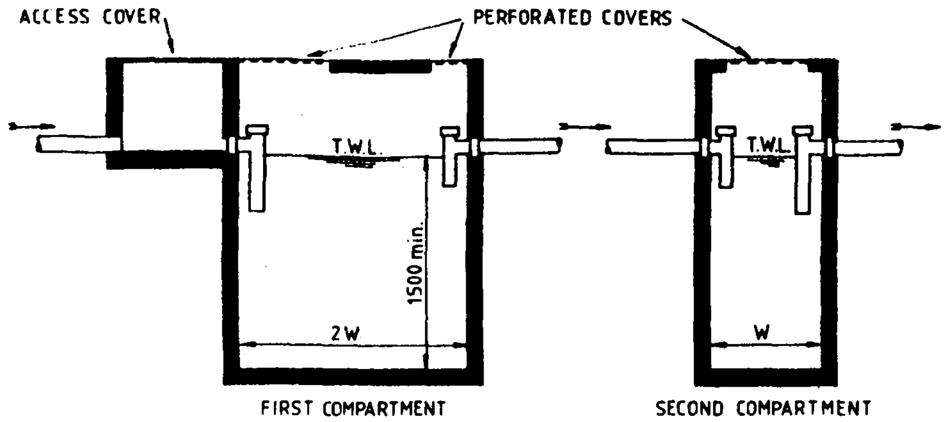
PRIMARY TREATMENT

The term primary treatment reflects sedimentation for the removal of solids, and it is appropriate to conventional sewage-treatment processes, although many of the package units and advanced treatment systems avoid the use of primary treatment.

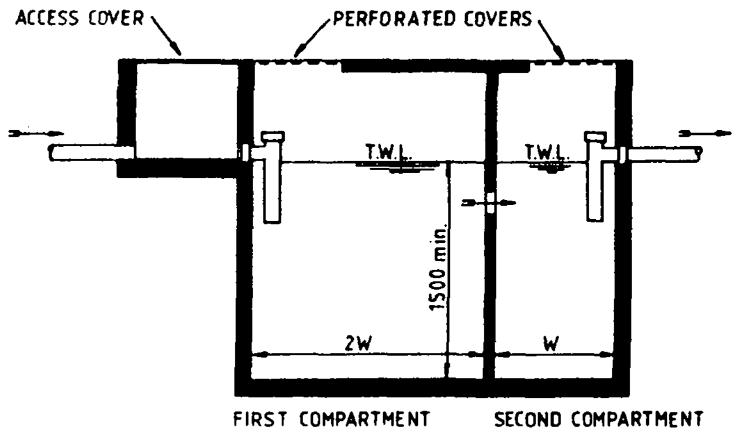
SEPTIC TANKS

Septic tanks provide a useful facility for the treatment of sewage on small plants. It should be stressed that cesspools are not treatment units but only storage vessels and now too rarely justified to require consideration.

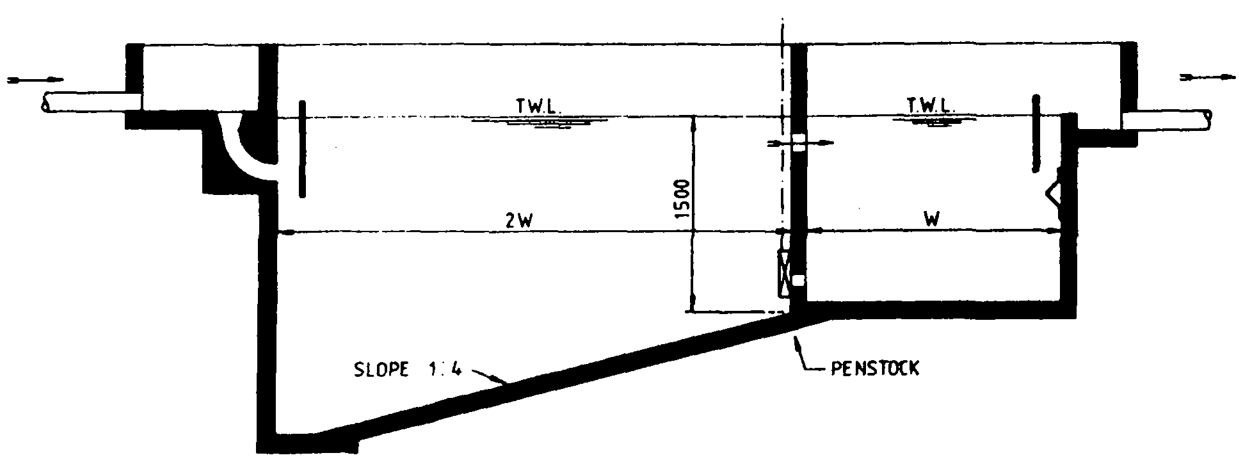
The recommended basis of design[1] for septic tanks should normally be followed with a capacity of about 180 P + 2000 l, where P is the design population and a minimum value of 4, and half the per capita capacity of 180 l is usually associated with sludge storage, and the assumption is made that tanks of this capacity will be desludged at least annually[2].



(a) Single tank with provisional second compartment - up to 12 persons



(b) Double tank - 12 to 60 persons



(c) Double tank - over 60 persons

FIGURE 2 — SEPTIC TANKS

Multiple-compartment tanks are usually favoured for populations above 30, when about two-thirds of the capacity is provided in the first compartment. For installations serving over about 60 people, there are advantages in having two separate tanks operating in duplicate. Typical arrangements and types of tank are shown in Fig.2.

The arrangement for internal baffles at inlet and outlet are important, since obviously the introduction of crude sewage and the removal of clarified liquid should cause the least possible disturbance of the settled sludge and the surface scum. For small tanks T-pipes are effective. Vents are required to the tank compartment and access chambers should be arranged to facilitate desludging, usually by a tanker prior to removal from site. There are good designs for prefabricated units, either constructed virtually at site from concrete pipes, or brought to site ready made in glass-reinforced plastic.

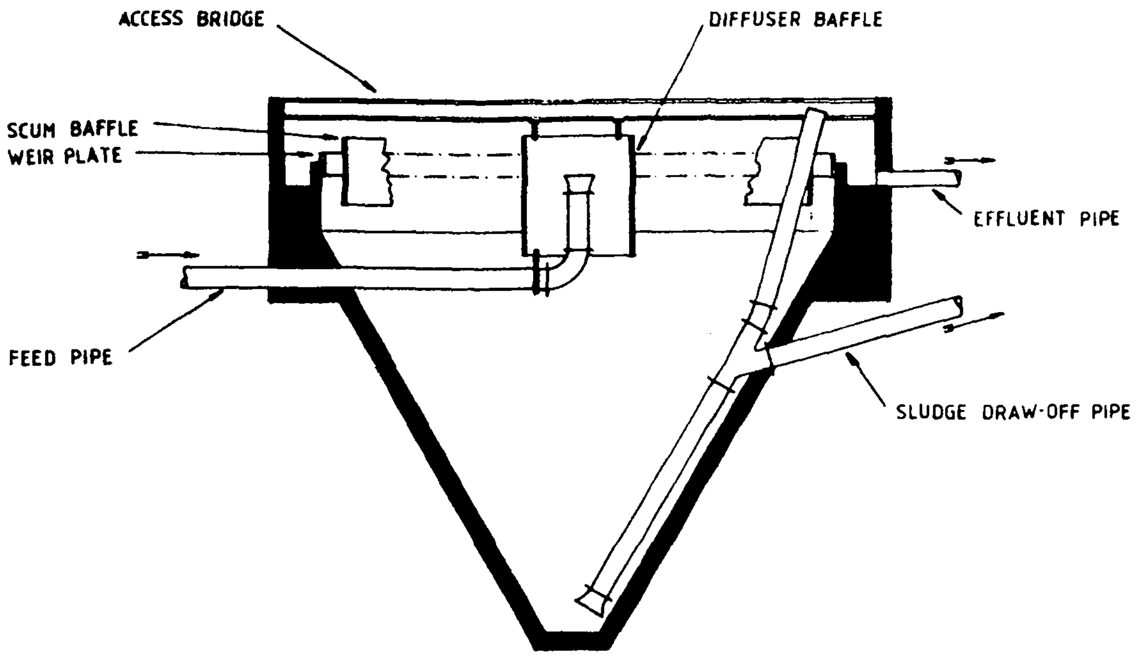
The case for providing septic tanks in two separate parts has been pressed[1,5], and is perhaps strongest where there is any doubt regarding the regularity or reliability of the tank management and sludge removal. The second tank has significant advantage as a 'catch fence' and should be adopted generally for individual tanks serving 12 - 100 persons.

The upward limit on the size of septic tanks is perhaps mainly dictated by the nuisance effect of desludging, and the sludge volumes which accumulate. There is no doubt that the desludging of septic tanks usually leads to offensive odours in the vicinity of the tank, which lasts for an hour or two during the process, and it cannot be to strongly emphasized that routine desludging is vital to proper operation. It should also be mentioned that the complete removal of the contents of the tank is not necessary and even possibly harmful.

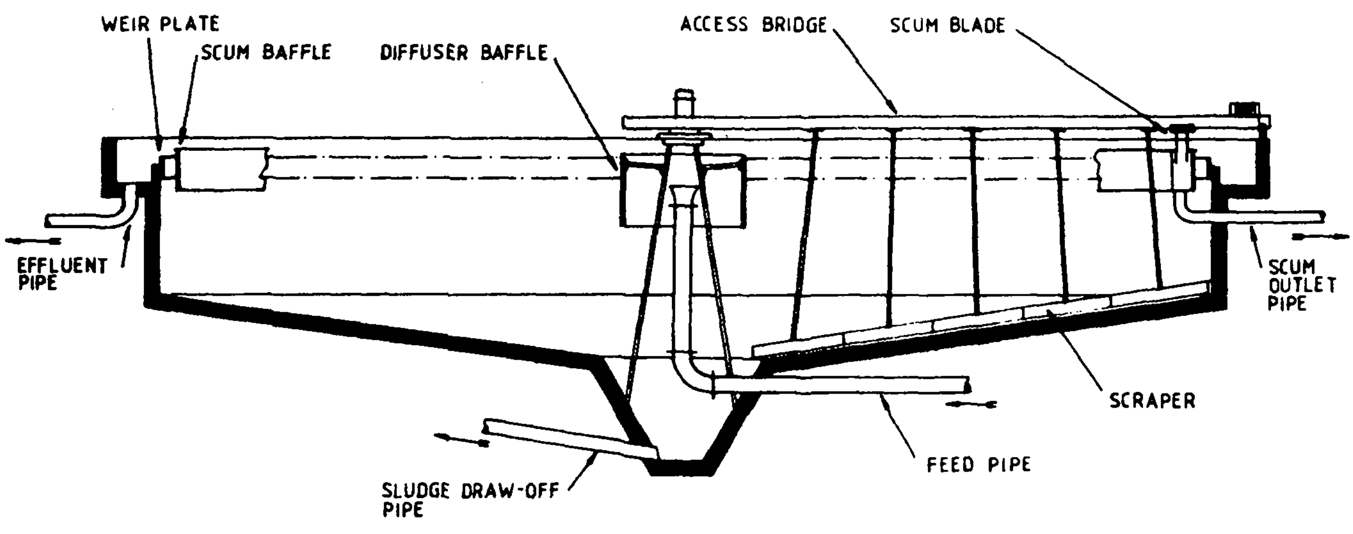
Desludging on a six-monthly basis usually requires the removal of 50 - 70 l/hd and the sludge moisture content is often found to be 90%[3]. Assuming a normal septic tank an emptying vehicle will have a capacity of the order of 10 m^3, it will be apparent that a single tanker can deal with the sludge from populations of about 150 people on a single six-monthly visit, larger units will therefore require multiple visits with some increase in nuisance.

SEDIMENTATION

Sedimentaion tanks will usually be designed on the basis of surface loading, although for small units a capacity basis is often suggested, with a conventional capacity of 10-15 h at DWF being normal. More scientifically, the tank



(a) Pyramidal, hopper bottom



(b) Radial flow equipped with half bridge scraper

FIGURE 3 – SETTLEMENT TANK SHAPES

surface area can be estimated assuming a maximum surface loading of 30 m^3/m^2 d increasing to 45 m^3/m^2 d for the largest units.

The inlet and outlet arrangements, combined with the tank shape, is of particular importance in obtaining quiescent settling conditions[6]. Typical tank shapes are shown in Fig. 3 and these can be assessed and selected on the basis of capacity, construction cost or difficulty on the specific site. Scum baffles are essential on all primary sedimentation tanks and inlet baffles appropriate on most. Small horizontal-flow tanks are rarely installed nowadays and probably appropriate only for very small works; the upward-flow single-hopper tank is economic up to about 7 m square reflecting a peak flow of about 2 tcmd and the circular hopper-bottom scraped tank might be considered for peak flows above about 1 tcmd.

GROUND TREATMENT

The effluent from a small septic tank is most commonly dealt with by discharge to a soakaway system either in the form of a hardcore filled pit or as the size increases by percolation through a field drain system. The permeability of the soil is most relevant to the system and should be assessed or tested before the system is sized.

A normal design is based on tested ground permeability and calculated by:

$$A = P \times Vp \times 0.3$$

where A is the floor area of percolation system

Vp is the tested permeability, essentially the number of seconds per mm percolation from a test hole

P is the population to be served

Ground treatment in nominally impervious soils is obviously difficult, but a ground filter consisting of a ventilated stone filled trench system can be effective if the size is sufficient, the treatment being achieved partly by ground percolation and partly by biological oxidation, provided that the water table is below surface or percolation into the topsoil at a lower level can be managed. It is, of course, essential that septic tanks upstream from any ground percolation or treatment system are regularly desludged.

BIOLOGICAL FILTERS

Simple biological filters have traditionally provided the system of biological treatment for most conventional small treatment plants with a population exceeding 50 people. The loading adopted with a normal stone, or slag media of about 60 mm grading and a filter depth between 1.5 and 2.5 m varies according to the size of the plant, but usually falls within the range 0.05 - 0.10 kg BOD/m^3 d, which is equivalent to a DWF of 200 - 400 l/m^3 d or 1.3 - 2.7 persons/m^3 media.

Performance can be improved if recirculation of effluent is practised, and for a simple recirculation system giving a constant dosing of about 3 DWF the BOD load can be increased to about 0.15 kg/m^3 d. Recirculation can sometimes be affected simply where sewage pumping on site is required, and in some cases humus sludge return pumps can be utilized. The attractions of high-rate systems with recirculation include; higher loadings leading to a smaller site area (a biological filter is usually the largest treatment unit in terms of land area); ecomony in capital cost; improvement in the treatment of shock loads; better treatment of small industrial effluents, such as dairies which, while rarely reaching very small plants, may well arise in rural areas with equivalent design populations above about 1000 persons.

The detailed design and equipment of biological filters warrants considerable care. For units serving less than, say, 100 people, flow distribution by tipping trough to perforated channels, or V-notched troughs, can be effective, but thereafter a travelling distributor is usual, and for small plants this is normally a rotary machine. The variety of distributors is fairly wide, and often elaborated for small plants to provide a waterwheel drive. More usually a rotating filter is jet driven, thereby requiring a specific minimum flow and consequently dosing arrangement, usually a storage chamber and siphon unless a pumped flow is involved.

The feed pipes and distributor jets will readily accumulate solids passing forward from the sedimentation phase, and this problem alone can sometimes warrant sewage screening, certainly careful baffle design in the sedimentation tank and arrangements for flushing out the feed pipework and brushing and flushing the filter arms.

Adequate ventilation of a percolating filter must be provided, often by raised vents operating through the underdrainage system.

SYNTHETIC MEDIA FILTERS

The use of plastic media can intensify the process: loadings of up to 0.3 kg/m^3 d can be applied to media with a specific surface area of about

90 m^2/m^3 and generally the same design elements as a low-rate filter will apply.

High-rate filters have been used successfully to treat macerated crude sewage, but the retention of unsightly coarse solids on the media surface is unavoidable and the material requires removal periodically if blinding is to be prevented.

ACTIVATED-SLUDGE SYSTEMS

Due to their complexity, conventional activated-sludge systems are not normally applied to small treatment works. However, modifications of the system are most effective and can be applied in small plants to unsettled crude sewage. The common processes are usually contact stabilization or extended aeration systems, and these processes use a variety of aeration devices to mix and aerate the mixed liquor. Perhaps the most common are compressed-air systems, supplying air to both coarse-bubble diffusers and simple yet effective air-lift pumps for sludge return and flow-balancing functions.

Contact stabilization involves high intensity, short period of contact with the incoming sewage flow, followed by a prolonged reaeration of the activated-sludge solids. Recommended design parameters would involve a total retention period of about 18 h with a contact period of about 3 h at DWF. Generally the plants also incorporate an aerobic sludge digestion, storage and thickening zone. Aeration by coarse-bubble diffused-air systems will often absorb 3 kWh/kg BOD.

EXTENDED AERATION

For extended aeration a lower aeration intensity is appropriate with retention periods of 24-28 h commonly adopted. Simple structures are usual with total power requirements similar to those for the contact stabilization-aerobic digestion process. As a guide, the tank loadings will be 0.15 - 0.25 kg BOD/m^3 of aeration tank.

Apart from the obvious ability to dilute and treat high shock loads and flow surges, the long sludge retention period provides some treatment and conditioning of the sludge. There are several particular well-known extended aeration processes, including the oxidation ditch.

AERATED LAGOONS

For small plants the use of aerated lagoons merits attention, since these have the potential benefits of simple operation. Lagoons may form the complete system, e.g. an aerated lagoon retention 5 - 10 days, followed by a series of settling and maturation lagoons give an overall retention of 15 - 20 days. Aerator power inputs of 1.5 to 2.5 W/m^3 provide oxygen, whilst allowing a proportion of the solids to settle.

OTHER PACKAGE SYSTEMS

A number of ingenious and sometimes complex package systems are available[7], but perhaps the rotating biological[8] contactor system merits particular mention for small treatment units. The biological medium is immersed in the settled sewage to nearly half of its depth and is rotated slowly as 1 - 3 revs/min. It will be evident that both power consumption and DO transfer will increase with speed, and both the specific surface of the media as well as the strength of the sewage will influence the design. Normally the manufacturer will be closely involved in the design, and for most leading designs there are published independent results to allow the process design to be checked.

Specific surface areas of 65 - 130 m^2/m^3 are usual and a BOD loading of 5 - 12 BOD/m^2 d specific surface area is not uncommon.

SECONDARY SOLIDS REMOVAL

Following all forms of biological treatment, solids are present as humus, activated sludge or partially oxidized sewage solids, and such solids must be removed from the effluent of all but the smallest plants. Removal in settling tanks is conventional but introduces operational demands, since desludging has to be undertaken regularly to avoid deterioration in sludge quality, rising sludge and nuisance.

GRASS PLOTS

For small flows distribution over an area of grassland is an effective method of solids removal which also achieves a considerable polishing effect on the effluent. The land requirement in the UK is about 500 m^2/100 population, and usually a simple distribution and collection channel system is easily managed. The principal operational need is for maintenance and cutting of the grass area.

SAND FILTERS

Simple slow gravity sand filters can be provided for small plants, often in an earth embankment bed with a simple system of agricultural underdrainage and a divided feed system. Duplicate units are required to allow the periodic removal of solids from the sand surface, the bed out of operation acting as a simple drying bed. The choice of a sand as a medium is important and a bed depth of about 400 mm including the drainage system is effective, and on very small works an area of 25 m^2/100 persons would be typical.

MATURATION PONDS

Whilst maturation ponds are most often associated with polishing and the attainment of high quality effluents, they also provide a simple low-maintenance reliable system for the removal of biological solids, particularly humus sludge. Lagoons should have a nominal water depth of 1.2 - 3 m, and a capacity of about 7 days' retention at average flows. Duplicate units are often provided so that the lagoon can be inspected and cleaned, but their maintenance is usually so infrequent that a single lagoon can be adopted for all but the larger plants.

HUMUS AND FINAL SETTLING TANKS

The use of humus tanks and final settling tanks for biological-filter and activated-sludge plants respectively is conventional. The design of the tanks will follow the principles adopted in primary sedimentation but the surface loading will normally be lower at about 17 - 24 m^3/m^2 d, and close attention should be paid to good inlet and outlet design, as well as the proportions of the tank.

In the past shallow horizontal-flow tanks were frequently used for humus settlement on small biological-filter plants, but desludging can only be effective by draining down and for adequate performance manual cleaning at least weekly is required. Humus tanks have also been fitted with coarse gravel filters (Banks filters) at the outlet weir, but their effectiveness in polishing an effluent depended on a fairly rigorous maintenance routine.

For the circular scraped tanks with 1 in 2 floor slopes, chain scrapers may be used, but blade scrapers are required for floor slopes in the range 1 in 5 to 1 in 10. Activated-sludge final tanks may have flat floors and blade scrapers providing that their diameter does not exceed 10 m and the liquid depth is at least 3.0 m.

SLUDGE DISPOSAL

The majority of small works is either in, or close to, a rural environment, and the disposal of sludge to agricultural land must be the general rule. With the large-scale management involved today the regional or area policy for treatment and disposal will usually have been decided, thus dictating the facilities to be provided at the small works.

TANKERS AND STORAGE

At present the most common form of sludge disposal from a small works in the UK will be by road tanker to a central treatment or distribution base. The design requirement therefore becomes storage and tanker loading facilities.

In the case of a septic-tank installation, sludge is both treated and stored within the unit. Many of the extended aeration and other package units operating by the biological treatment of unsettled sewage will also have the advantage of producing a more stable sludge than ordinary primary tank raw sludge. Such plants may also produce a well-stabilized secondary sludge, but in general require desludging at regular intervals.

Generally there seems little justification for attempting to remove water during storage, and much can be said for removal from site as frequently as practicable. Assuming a small works collection tanker might have a capacity of 10 m^3, a minimum storage facility of about 15 m^3 would be appropriate, and a fortnightly single tanker visit would cater for a population of about 300. As the size of the works increases, more frequent collections may be appropriate, and the storage tanks should be sub-divided so that the tank can be completely cleared regularly. Obviously sloping floors and sumps will facilitate clearance and for economy the design of storage with cubical proportions will be appropriate to smaller units, whilst circular tanks are structurally more efficient in the larger sizes.

SLUDGE DRYING BEDS

Where local tankering is not practised, the use of drying beds may be appropriate for small works. The beds may have concrete floors and walls or if site conditions are appropriate an earth bank form may be adopted. In general the design will provide sloped floors, land-drain underdrainage with a facility for decanting supernatant water, and a 150 - 225 mm layer of gravel or clinker media. The area provided for drying should be generous and certainly for the UK not less than 40 m^2/100 population. Normally disposal from site of the dried cake will be to farms or gardens and a simple stacking area will not only provide storage but also useful conditioning and pathogen reductions, if left to stand for about one year.

SLUDGE LAGOONS

The use of relatively large sludge lagoons on a small treatment works can provide an economical solution to sludge treatment and long-term storage. Such lagoons with earth banks can be designed as duplicate units, each with a sludge reception capacity of about 3 years, leading to a clearance cycle of 6 years. Lagoons are normally constructed with a balanced cut and fill excavation to provide the retaining banks. It is very important to carefully determine the soil characteristics and strength of the earth embankments.

Design will usually allow for access by an excavator and lorry gang access to the whole lagoon by excavating through the retaining embankment after the sludge has fully matured and partially dried.

MECHANICAL DEWATERING

Sophisticated sludge treatment, conditioning or dewatering will not normally be appropriate for any small works. Where for particular reasons tankering, air drying or lagooning cannot be adopted, mechanical dewatering by small filter-belt press offers an effective solution.

SLUDGE PUMPING

Where possible the pumping of sludge on a small treatment works is to be avoided. For tanker removal it may be possible to ensure that the tanker lifts the load by vacuum on the main tank. The most reliable small return activated-sludge pumps are probably air lift, paddle wheel or screw types. For humus sludges submersible centrifugal sewage pumps operated under manual control may be used.

SITE WORKS

The need for site works such as landscaping, fencing, lighting and alarm systems, will obviously vary widely with the specific circumstances, but they all require careful thought and the question of security both to protect the works and the infant public is increasingly difficult.

SITE ROADS

Vehicular access is essential even to the very smallest works and a simple access road should be provided generally with a facility for turning. Where sludge removal by tanker is planned, the size of tanker must be checked to ensure that the pavement design is adequate for the load and the bends or turning layout can be negotiated. Concrete roads are better where sludge spillage is likely and 'grasscrete' is attractive on small rural sites.

BUILDINGS

Since most small works will not be manned, the need for accommodation buildings is limited. For works serving a population of more than about 500 people it is probably justified to provide at least a small storage building, and where a group of works is served by an operating gang the provision of simple washing and messing facilities at one or more sites in the group is usual. Frequently the amenity buildings can be associated with a site pumping station.

Compressors required for the activated-sludge process may be housed in simple prefabricated concrete buildings.

SERVICES

For sizeable treatment works and certainly the group base referred to a telephone and water supply will be appropriate.

Although washwater is a most useful aid to works maintenance it will not normally be justified for small works, but in many cases a lightweight petrol driven pump and hoses can be maintained and used by pumping final effluent.

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AUTHOR'S INTRODUCTION

Introducing the paper, MR. STAPLES said that in the context of the Symposium small treatment works had been defined as plants treating sewage from populations of less than 5000, and that it was appropriate to discuss the principles as well as the various processes and types of plant, it being implicit that there were factors relating to the design of such plants which were special or unique.

Although, regrettably, recent personal experiance had been limited for lack of opportunity, past experience of designing small plants had shown the task to be as challenging and interesting as the design of larger works, and success depended upon attention to detail and an inventive approach. However, it was easy for the design costs to assume a significant proportion of the relatively modest total capital expenditure, particularly if a careful detailed design and management effort was applied.

Mr. Staples said that there were many published guidance notes and technical papers on the design and operation of small treatment works, some of which had been referred to in the paper, but there were the usual conflicts and the guidance should not unduly restrict the designer's discretion. The factors which define a small sewage-treatment works also provide the principles which should be borne in mind throughout the design of the plant.

He considered that the need to establish the competence and experience of the operating organization and the method of operating the plant, early in the design process, must be stressed. The paper noted particularly the effect of different systems of sludge disposal and the impact and effect of varying degrees of static or mobile operating management.

Mr. Staples felt that other design topics which warranted stress included the measures to deal with flow surging; there were many small plants which were regularly overwhelmed by flow, particularly during wet weather.

The origins of the high peak flows from small communities was illustrated by Fig. A, which was drawn from the US EPA guidelines for small communities; the flow from a single household would clearly be even more sharply peaked. He said that when pumping was required the flow-peaking factors were further accentuated and provision for balancing virtually essential, although the use of ejectors, solids diverters and similar devices could be helpful.

He said that the biological stage of treatment offered many options, but it may be argued that there was a rough correlation between cost, land utilization

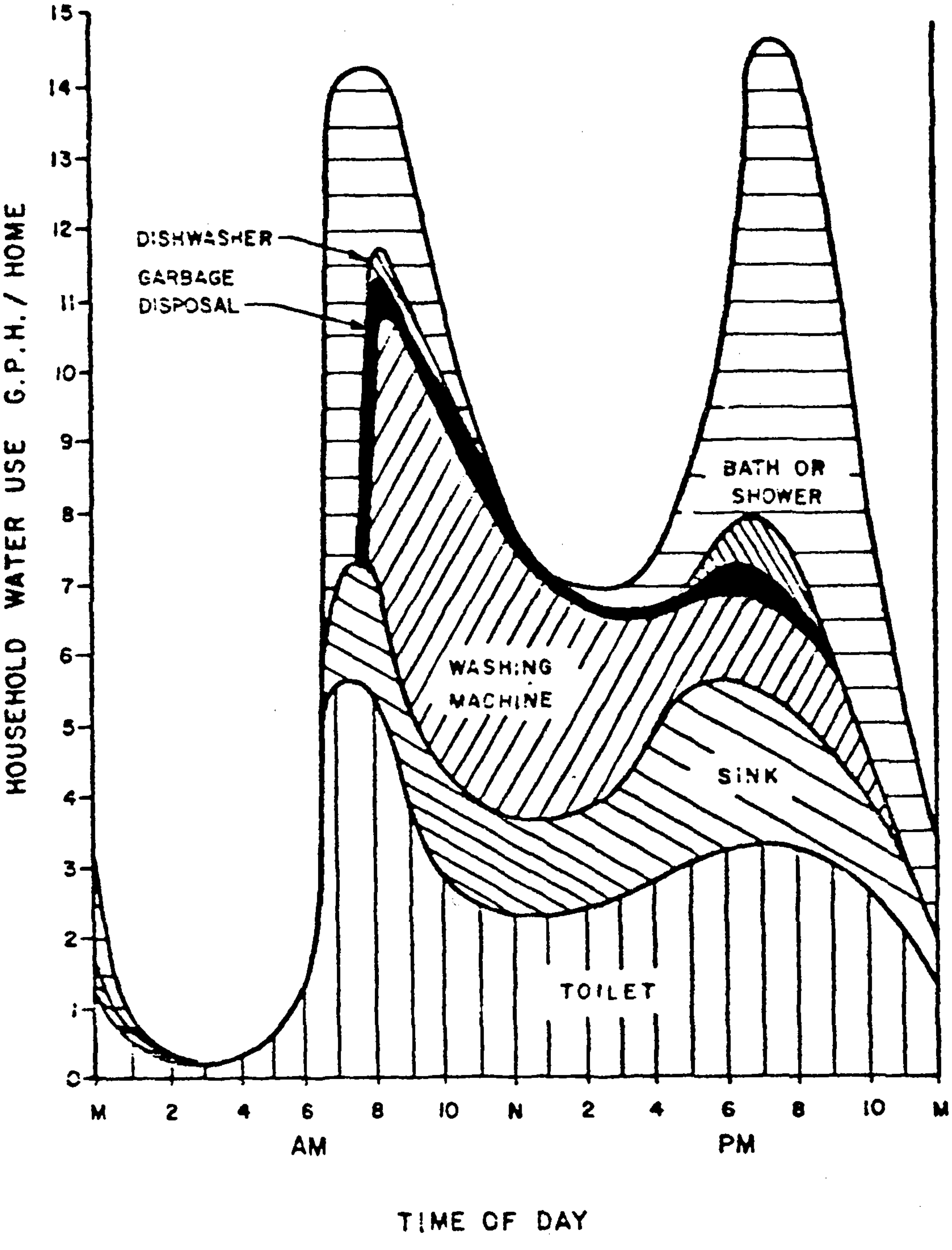

FIGURE A

DAILY HOUSEHOLD WATER USE

(With acknowledgment to the USA - EPA Manual) and power, and a similar correlation applied to power and operating labour requirements and skill. Table A was offered as an illustration and athough the costs were modelled, the operator comparison was more subjective, seeking to relate both skill and effort.

TABLE A. DESIGN OF SMALL TREATMENT WORKS
RELATIVE DEMANDS OF POWER, LAND, CAPITAL AND OPERATOR REQUIREMENT

Process	Land	Capital cost	Power consumption	Operator demands
Activated sludge	1	1	1	1
Extended aeration	1.2	1.16	2.2	0.5
Biological filter	4.5	1.83	0.4	0.7
Rotating contactor	1.6	2.22	0.5	0.4
Oxidation ponds	78	1.07	0.08	0.1

He felt that sludge solids retention within the plant was important, and many early extended-aeration plants during periods of peak flow regularly discharged a significant proportion of the MLSS. Although the solution would frequently lie in the operating procedure for solids removal, the design must facilitate sludge removal. A simple example was the septic tank with a soakaway, where the tank performance was frequently unsatisfactory, due to blinding of the soakaway as a result of the simple failure to regularly clear the accumulated solids.

The engineering 'niceties' of design would be apparent, obviously to utilize site gradients and levels was essential and where there was a good head available between the outfall sewer and the receiving water, it would be evident that this could probably be utilized by biological filters, to yield the head needed for the biological treatment stage, and the introduction of a powered aeration system would be difficult to justify.

In conclusion, Mr. Staples said that alternative technology in the third world was a popular subject, but even in the UK there was developing some underlying doubts about the concept that regional treatment facilities were the only efficient means of applying sewage treatment. A recent study for Greater Athens had found that in the developing suburban areas of that city, unless the water table was high or ground conditions particularly difficult, the continued provision of septic tanks and their effective operating and maintenance yielded a more economic solution than trunk sewerage. New attention should therefore be paid to small treatment works and since the design offered so much satisfaction it was an attractive prospect which most engineers would enjoy.

DISCUSSION

MR. P. MILLER (Yorkshire WA), opening the discussion, said that he would like to discuss the principles, rather than the details of the paper. In terms of water authority service objectives, sewage treatment was fading into the background compared with the primary function of water supply and, within the sewage-treatment function itself, the 'small end of the market' was being pushed to the back of the priority queue for capital expenditure. Because of their size, small works usually had minimal impact on watercourses due to the dilution effect and this often precluded capital expenditure. In addition, the economy of scale showed that capital expenditure on small works had a high cost/population served, and therefore it was difficult to justify such schemes in terms of service objectives.

Mr. Miller said that the need to design for variable effluent standards was becoming apparent. In the past, one could design a works for the traditional 30:20 effluent standard. However, now that less rigorous final effluents were frequently required to meet water quality objectives, guidance was necessary on how to design for such standards. In the past, engineers seemed to have taken the view that there was a lack of professionalism in designing septic tanks. This should not be so because if the receiving watercourse dictated that a septic tank provided adequate treatment, then this type of plant should be installed.

Mr. Miller considered that at the outset one must remember that one was designing a works for someone to operate and therefore the views of the operational staff should be sought, i.e. mode of operation, frequency of visits and methods of sludge disposal, so that the design could be made as practicable as possible. On small works operated by mobile teams it was imperative that maintenance requirements were minimal and that a premium might have to be paid in capital investment for this to be achieved.

Mr. Miller agreed with the author on the problem of blockage due to scaling down sizes on small works; consequently, there must be minimum sizes of sludge pipework,orifices, etc. Designs may appear perfectly adequate on paper, but the item had to be envisaged in practice. In addition, adequate allowance must be made for shock loads, both hydraulic and organic, particularly in rural areas where farm wastes were received.

MR. N.G. GRANT (J. Haiste and Partners) referred to the problems of peak flows and pumping and the high factors that were usually encountered with small works to which Mr. Staples had made reference, due largely to the necessity of maintaining self-cleansing velocities in the rising mains. In the past Mr. Grant said that his company had found that such problems could be overcome by the use of Mono mutrator type of equipment, which was **a well known** arrangement comprising a combination of a macerator and positive-displacement pump which allowed the use of much smaller diameter rising mains and could reduce the factor of 45 DWF, referred to by the author, to perhaps 6–8 DWF. There were substantial savings in capital cost involved and he considered that this, together with removing the requirement for screenings removal plant at the works, outweighed the disadvantages of the rather heavy maintenance costs which were sometimes associated with this type of plant.

With reference to Fig. 1, Mr. Grant said that he was surprised that the biological filter line was dotted at a population of 500 and then cut off at a population of 2000. He asked if the author was suggesting that filters with recirculation facilities should be ruled out for populations of 2000 - 5000, or if this was included in the high-rate biological filters.

Referring to Fig. 3, the author had recommended a primary sedimentation tank of the hopper-bottommed pyramidal type for works serving a population in excess of 250, with desludging by hydrostatic head. He asked the author if he would advise that perhaps a simple screenings and grit removal tank should always be installed to protect sludge lines from blockage.

Finally, Mr. Grant enquired what method of sludge removal the author would recommend for secondary settlement tanks on activated-sludge systems, bearing in mind the need for continuous recycling of activated sludge and the obvious problems involving lack of permanent manning.

MR. K.G. PULLEN (POSSET, Engineering & Pollution Control Advisory Service) questioned the statement that there was normally a need for the provision of twin units on small works to cater for emptying and maintenance. He suggested that for many small plants such a requirement was unnecessary because there was little, if any, maintenance work required on them, which was particularly true of primary sedimentation tanks, where it was only necessary to provide a single Dortmund-type tank which had no moving parts and provided that desludging was carried out at the normal frequencies, presented no problems with sludge consolidation in the bottom of the tank. Similar comments would also apply to secondary settlement tanks.

Mr. Pullen said that he agreed with the author's comments on the need to design pumping stations which gave self-cleansing velocities in the rising mains, but operators knew only too well the result of some pumping installations with two large pumps of equal output delivering the sewage up the rising main to be received at the head of the treatment works in a matter of minutes and completely overwhelm any so-called balancing tank provisions. He therefore considered that further thought had to be given to the design of pumping stations and maybe, to some extent, to forget about self-cleansing velocities. He thought that some of the most successful pumping stations were those with a duty pump and a standby pump, not two identical pumps, but a smaller DWF pump much more 'sedate' in its operation which delivered the sewage at a much more acceptable rate to the sewage-treatment works. The second pump would be a storm-sewage pump which would operate when the smaller pump was unable to deal with the incoming flow. Mr. Pullen considered that it had previously been a misconception that it was a necessity to have two similar pumps, one duty and one standby, which every week must be religiously changed over so that they receive equal wear. He questioned the wisdom of equal wear suggesting that this resulted in both pumps becoming worn out at the same time. He felt that it was preferable to provide one pump which would be in continuous service as a duty pump and would reach the end of its useful life long before the purely standby pump; this would ensure that only one pump required an overhaul at any one time.

Mr. Pullen said that he initially agreed with the comment in the paper of avoiding the provision of screening facilities if at all possible because of the disproportionate attention that they required, but he wondered how many designers had visited really small works, gravity fed and witnessed what happened to their distribution systems, particualrly if there was no screen. Without screening, excreta and other material would settle in distribution channels during periods of low flow, and with the present low frequency of visits solids would build up on that original deposit until the flow to one unit would be effectively be cut-off (assuming that there was more than one unit).

He wondered whether, on the size of works under consideration,there was any alternative to the pyramidal type of sedimentation tank. It was reliable, with virtually no operating and maintenance costs and should normally be installed on small works assuming that the ground conditions were suitable.

Referring to the unsatisfactory operation of dosing syphons, he considered that they appeared satisfactory on a plan and on newly commissioned works they invariably operated successfully; however, a visit to the same works a number of years later would in most cases reveal a different situation. Frequently the syphon did not break cleanly, resulting in a constant dribble from the distributor arms or the syphon did not activate resulting in dosing chamber overflows operating. He wondered how many manual operators understood how a dosing syphon worked. Mr. Pullen said there were alternatives to the dosing syphon and although he did not know why, alternative systems seemed not to have been incorporated in recent years. Examples were the water wheel, which ran on the periphery of the filter bed or the turbo-wheel, which was mounted in the central basin on a distributor and usually ensured on small works that all the flow passed through the turbo-wheel before passing to the distributor arms. Such arrangements were simple although they required some maintenance, but Mr. Pullen considered that they were generally more reliable than the dosing syphon.

Finally, Mr. Pullen agreed with the author that grass plots were effective for the removal of solids and associated BOD, and said that on small works they could replace humus tanks.

MR. I. STRACEY (Anglian WA) referred to the comments that had been made concerning hopper-bottommed tanks and the problems of rag blockage; he said that he had not really found this to be the case and that rags became fairly well digested in the bottom of such tanks. However, he agreed with the problems on distribution systems, but his experience had shown that the problem could be overcome by the provision of a flooded distribution chamber before the primary tank.

Mr. Stracey agreed with the idea of a standby and duty DWF pump and had involvement with such. However, in the case in question the problem had been that the standby pump provided had not been large enough, design providing for 3 DWF and in practice there was a requirement for 5-6 DWF.

In conclusion he referred to the availability of a polyester mesh which was a much cheaper alternative to wedge wire with similar results.

MR. A. TONG (Northumbrian WA) referring to primary sedimentation tanks that did not have automatic desludging devices, such as the pyramidal-bottommed ones, drew attention to the situation that could arise at a small works with twin tanks. He said that often these had excessive retention periods of, say 10 h, and because of the size of the installation a relatively large pump had to be installed to return liquors. Under these circumstances with a retention period of 6 - 10 h in the primary tanks, if the liquors were returned during a period of an hour (which would be inevitable with present manning arrangements) then there would be a flow rate of 9 - 12 DWF going through the works which would obviously be excessive.

MR. R.J. EVANS (Severn-Trent WA) said that there was a particular problem of the drying out of the medium on biological filters on small plants, and he noted that the author had suggested a size of 60 mm which he considered was too large. Mr. Evans said that ideally on any biological filter the bed required keeping wet and should have as long a retention period in the bed as possible and a smaller grade of medium, about 25 mm, would achieve this requirement. Maintaining the bed wet would also deter the fly problem.

MR. J. ARNOLD (Yorkshire WA) said that drying beds were seldom used nowadays except in an emergency, as a result of their drying capacity being too variable and the task of emptying them requiring labour that was not normally available on a seasonable basis. He said that, after initial draining most drying beds relied upon surface drying by evaporation; but this almost ceased when a crust was formed, and only continued when the crust had cracked. He considered that drying beds would be better designed so that they could evaporate from below, i.e. within the drainage system. By so doing drying would be continuous because no crust would form and the process would be less dependent on weather. Therefore drying beds should be elevated with the drainage tiles fully open at both ends and aligned to the prevailing wind. Furthermore, if pumping of the sludge was involved, the beds should be built on the highest ground within the site where the effect of the wind would be greater. He said that if the drying beds had been designed on these principles, they would not have been so readily disregarded because the sludge would dry readily even during the winter months if the rainfall was not excessive; and the surface area required would be less than otherwise needed because the beds could be re-used throughout the year.

MR. J.P. MASON (Northumbrian WA) said it should be realized that a good secondary treatment of average strength sewage did not in fact produce a 30:20 standard effluent on a 95 percentile basis : most effluents would be 45:30 or even 60:40.

Mr. Mason asked the author why he had stated that there was little justification for the removal of water during sludge storage prior to tankering. Sludge thickening could effectively reduce the volume of sludge and reduce tankering costs, and certainly should be considered in the design of small works.

He felt that one omission from the paper was that grounds maintenance was now a significant operating cost and works should be designed to have a minimum of vacant land. Grassy banks, which were dangerous and costly to maintain, should be minimized and where grass was used it should preferably be in open areas where gang-mowers could be utilized at lower cost. Certainly small areas between tanks should not be grassed. If land was required for future extensions there was no reason why such land should not be left outside the boundary fence in care of the farmer. He said that the boundary fence itself was an expensive item and should be as short as possible and only surround vital installations, because at about £50 per metre for effective security fencing it could be a substantial cost.

MR. N.F. LEVITT (Farrer-Wallwin International Ltd), referring to dosing syphons and their lack of maintenance, said that galvanized steel pipe which was used for the air filter did deteriorate and it was normal for water authority employees or local tradesmen to replace pieces of pipework. The dimensions of these pieces were critical, and these gradually changed as rusty pipes were replaced, thus loosing the critical dimensions. Considering the number of syphons that his company had supplied over the years, the number of sets of new air pipes that had been requested had been minimal. The requesting of a drawing or the purchase of a new set of air pipes from the manufacturer for about £15 would solve many problems.

MR. J.A. BARKER (Anglian WA) referred to the comments from Mr. Miller concerning the utilization of a capital sum to supplement the disappearing manpower, and said he considered that the installation of automatic screening facilities should be provided at a much lower population level than was suggested in Fig. 1 of the paper. He had experience of small plants with small sparge holes on the filters which had completely blocked because screens had not been installed.

MR. A. TONG (Northumbrian WA) made a supplementary comment on dosing syphons saying that normally the filter distributor arms were made of steel and therefore had a higher energy requirement to get them moving. He said that at one works in his area such arms had been replaced by much lighter plasic pipes and hence required less energy to move them which has resulted in an improvement in the operation of the filter.

MR. D.W. LEE (Anglian WA) said that Mr. Staples had omitted any reference to the question of implimenting telemetry automation on small works, and wondered if this could be introduced to reduce the manpower requirements.

MR. B. METCALF (Yorkshire WA), in a written contribution, said that there were operational problems with Dortmund-type tanks since some tanks were prone to blockages, and rodding or blowing out with a compressor was required to remove sludge hydrostatically. He felt that on rare occasions they needed to be emptied and in such circumstances a second tank was useful so that some settlement capacity was still available for the incoming flow and returned liquors. Furthermore Dortmund tanks were prone to the accumulation of large quantities of scum, which occasionally required removal, especially when tanks were overloaded. He suggested that it would be useful if a scum-removal device was designed for such tanks.

REPLY TO DISCUSSION

Replying to Mr. Miller, MR. STAPLES said that water authorities had a major problem in determining priorities; the provision of clean water was the main priority with sewage treatment being of secondary importance. A sewerage priority was really only apparent when the public complained, and a system for according priority for sewage treatment on the basis of cost per head for capital and operation was not as relevant as indicated in the question. Therefore a rural sewage-treatment programme could be justified if it was demanded by the local residents, even though it could be expensive.

Referring to effluent standards the author considered that whilst 30:20 standard effluent may not be scientifically justified or appropriate, because dilutions were either small or great, it was an appropriate standard because it could be argued by the pollution control officers on a historical basis, and from a design point of view it was a practical level at which to seek treatment. If one tried to design for a 100:100 standard he submitted that the operation of the plant would become much more difficult without a commensurate economy.

With reference to the comments on the population level at which biological filters should be provided, Mr. Staples said that the point he was trying to make in Fig. 1 was that high-rate filters became increasingly attractive even on a small treatment plant as the population increased, and usually the land area required for ample filters became more difficult to provide for higher populations. The figure was admittedly subjective and only intended for broad guidance.

In reply to Mr. Grant, concerning activated-sludge removal, he felt that the mechanical system needed to be simple and virtually continuous, with the operators managing wastage regulation periodically.

Mr. Staples said that he did not agree with Mr. Pullen's suggestion that twin units were unnecessary, and he explained that from the design point of view cost was not doubled by providing twin units; for example in the case of sedimentation tanks, one divided the capacity for the maximum flow, so although it was more expensive to provide the required capacity in two units rather than one it was not proportionately so.

On the suggestion that the Dortmund-type tank should always be selected, Mr. Staples said that for small works he basically agreed, but he felt that with increasing population there would be many situations where, for economic and other reasons, it would be preferable to install a circular tank, and the paper had mentioned the engineering aspect of an optimum tank shape.

The subject of pumping station design obviously meritted the attention to detail suggested in the paper. The author said he could not agree with the suggestion that rising mains need not be self-cleansing, but he saw much merit in the careful selection of pump sizes and types, and the logic of wearing pumps out in sequence rather than together seemed practical. For small flows there were significant difficulties in seeking separate dry-weather pump and peak-flow pumps, and the choice of equipment was important.

During recent years the use of submersible pumps with rapid changeability for maintenance and the availability of standard units in the operator's armoury has affected the design options. With regard to Mr. Grant's comments on the use of mutrator type pumps, whilst these pumps, solids diverters or compressed-air ejectors might all have particular and sometimes useful features, which could assist in dealing with the periodic operation of pumping plant and the consequent flow surges, the problems of practical pump sizes and self-cleansing flow velocities associated with minimum mains diameters would persist. The author believed that in practice the introduction of a simple flow-balancing facility within the works design was frequently the most useful and reliable method of accommodating flow surges.

Mr. Staples said that several contributors had debated the need to provide for the removal of screenings and grit, and he repeated the views expressed in the paper, that screen raking and screenings handling was a nuisance and that it should be avoided if possible by maceration or horizontal screens or by not screening at all. He again suggested that the greatest need for screening arose not with the sedimentation tank but with the biological filter distributor.

Replying to Mr. Barker, the author considered that the real objection to the use of mechanically-raked screens was not the question of the cost of capital versus manpower, but the reliability of automatic screening mechanisms and screenings disposal systems. The screenings arrived in slugs, and if the works was only to receive operational visits, say, once a week, then the screenings accumulation could produce a problem which automation would not necessarily overcome.

Referring to the possibility of blockages in distributors and dosing syphons Mr. Staples felt that one of the main problems had been due to solids, usually scum not retained by primary tank scum boards, blocking the distributor jets, which resulted in a surcharge and flow backing up and consequently further scum overflowing the scum boards. Such material was often a greater nuisance than larger screenings type solids, and he agreed with other speakers that if adequate pipe sizes and good pipe gradients were selected the problem of solids stranding could be readily minimized.

Mr. Staples agreed with Mr. Levitt that dosing syphons could be a maintenance problem, but he said that in his experience the water-wheel types of distributors were often a much greater one. Mr. Tong had cited the substitution of light-weight distributor pipes but the author suspected, perhaps with support from Mr. Levitt, that the original seals, bearings, or other mechanical plant design, might be checked with advantage.

The author said that he was not entitely clear about Mr. Stacey's comments about a flooded distribution chamber before the primary tank reducing distributor blockage, but suspected that this reference related to the provision of a balancing facility which prevented surging and retained scum, in which case he agreed that such a device was an ideal feature.

Replying to Mr. Tong, Mr. Staples said that such an illustration of surging due to tank desludging retention liquors, confirmed his comments that the designer had to be inventive. He explained that on small horizontal-flow tanks he had normally installed decanting valves at a low level to pass a good proportion of the tank contents forward to discharge, rather than return it all to the inlet.

In reply to Mr. Evans, he said that from a process point of view the smaller media size would give a larger surface area and more effective treatment, but on a small plant the risk of ponding would be significantly greater. Since, he argued, reliable performance with low maintenance was a critical factor in the design of a conventional biological filter, he maintained that the larger media size was less of a maintenance problem, more robust in operation and therefore preferable.

Mr. Staples said that the comments from Mr. Arnold on sludge drying bed crusting and drying were interesting; he agreed that the drying mechanics were as described, and that a problem existed. The ideas for underventilation were interesting, but he felt that these would be difficult to achieve. The fact that drying beds had a poor reputation was mainly because they were too small and if the use of drying beds was an essential feature of a small works, then they should be kept relatively large and for reasonable economy this implied a fairly simple or primitive design.

Replying to Mr. Mason, the author explained that he had argued against thickening sludge for the small works because the amount of operator attention and the risk of problems arising with decanting pipework did not compensate for the tanker cost saving. The case for dewatering on the larger works was obvious, and he accepted that with increasing costs of tanker disposal it would be appropriate to re-examine the scale of small works at which simple dewatering was relevant.

Mr. Staples accorded with the comments on the ground maintenance problems and costs, and obviously designers should attempt to minimize it. However, the fact was that land surface between units had to be left for inter-connecting pipework. Design and operating maintenance performance now tended to be measured in terms of economic efficiency, but in the present employment climate the meeting might imagine a time approaching where people would again be employed to cut grass and it would have some social and other advantages.

Mr. Staples said that whilst on the larger works telemetry was almost becoming the norm, he believed that a problem for the industry could be in retaining the correct level of technical competence to operate and maintain such systems, and it might be better to employ a few more people instead. There were different levels of telemetry, and Mr. Staples thought that for even the largest 'small works' a system to warn when something had gone wrong was the limit, and probably more attractive than automation type telemetry designed to reduce manning levels.

In reply to Mr. Metcalf, the author suggested that the experience described might be constructed to reinforce many of the suggestions in the paper and in the discussion. Provided that pipes were of adequate size, desludging practised regularly, and with sufficient frequency, (and this was facilitated by the installation of twin units), sludge blockages were unlikely to arise. Scum trapping, retention and removal was, in the author's view, essential to good design.

At the conclusion of the author's reply Mr. W.S. Smith, Chairman, proposed a vote of thanks to the author which was carried by acclamation.

OPERATION OF SMALL SEWAGE-TREATMENT WORKS

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INTRODUCTION.

There is a variety of opinion on what is a small sewage-treatment works. The British Standards Code of Practice CP302:1972 used a maximum contributing population of 300 persons, but the revised CP302 proposes 1000.

In the opinion of many managers a small works is one which does not engage a full-time resident operator and with perhaps a few exceptions this usually includes works serving up to 10 000 persons.

In England and Wales it is estimated that there are 5431 works serving populations up to 5000 and a further 372 works serving 5000 to 10 000, and in addition there are numerous privately owned installations serving isolated single and groups of dwellings. Table 1 shows the estimated numbers and distribution of publicly-owned works, including figures for Scotland and Northern Ireland.

TABLE 1. ESTIMATED NUMBERS AND DISTRIBUTION OF PUBLICLY-OWNED SEWAGE TREATMENT WORKS IN THE UK AND RANGES OF POPULATION SERVED[1].

Area	Population range served				
	< 500	501–1000	1001–5000	5001–10 000	Total
Water authorities:					
Anglian	550	158	270	83	1061
Northumbrian	240	36	61	15	352
North West	360	46	95	37	538
Severn-Trent	535	119	250	67	971
Southern	163	61	114	24	362
South West	319	62	84	13	478
Thames	161	63	111	28	363
Welsh	613	76	126	33	848
Wessex	112	52	105	28	297
Yorkshire	309	59	121	44	533
Sub-totals	3362	732	1337	372	5803
Scotland (inc. Islands)	399	103	189	38	729
Northern Ireland	358	65	60	12	495
Totals	4119	900	1586	422	7027

There has always been a need for a guidance on the operation of small works, and a number of publications has been produced, such as The Ministry of Agriculture guide notes for Hostels, 1941[2], BSI CP302 1956[3], Ministry of Housing and Local Government 1965, the latter being revised and published by the National Water Council 1980[4], WRC Technical Report TR 107[5].

Prior to the formation in 1974 of the regional water authorities in England and Wales, the operation and maintenance of small sewage-treatment works was the responsibility of local authorities, many of which carried out the work efficiently and enthusiastically. In most cases an assistant engineer responsible to the rural or urban district engineer was the only management provided and in many situations the operation was left solely to a semi-skilled operator, and it was obvious in 1974 that there were many works which had been totally neglected.

Obviously, there had to be a new approach, since the majority of managers who became responsible were mainly experienced in the operation of larger urban treatment works and early ideas of abandoning small works and creating larger district works had to be changed on financial and operational grounds.

The major difference between the large works and the small works, particularly those serving less than 1000 population, is the intermittent nature of the flow pattern of the latter. In general these works receive three or four slugs of sewage during the period of 06.00 hrs to 22.00 hrs, the flow during the night and early morning being almost nil in dry weather.

Small sewage-treatment works range from the most rudimentary to the more complex package unit and methods used include simple land treatment, septic tanks (with or without biological treatment which may or may not be followed by final settlement tanks), conventional settlement followed by biological filtration or the activated-sludge process and settlement, package plants using rotary biological contactors or activated sludge, and finally the oxidation ditch. A schematic diagram on processes which amy be used in sewage treatment is given in Fig.1.

Their performance, based on production of the traditional 30:20 standard effluent, varies depending on the type of plant; the least satisfactory being simple land treatment, septic tanks and plants without final settlement tanks. However, in the author's experience, with most plants of this type the degree of dilution afforded by the receiving water course is such that the impact of the effluents is significant.

The effect of the 1973 Water Act was the bringing together of all publicly owned sewage-treatment works under, in most cases, single-function responsible operational management whether it be at regional, divisional or area level. The transferred manpower became available to maintain the system and to improve in those areas where there had been neglect. Refinements in the distribution

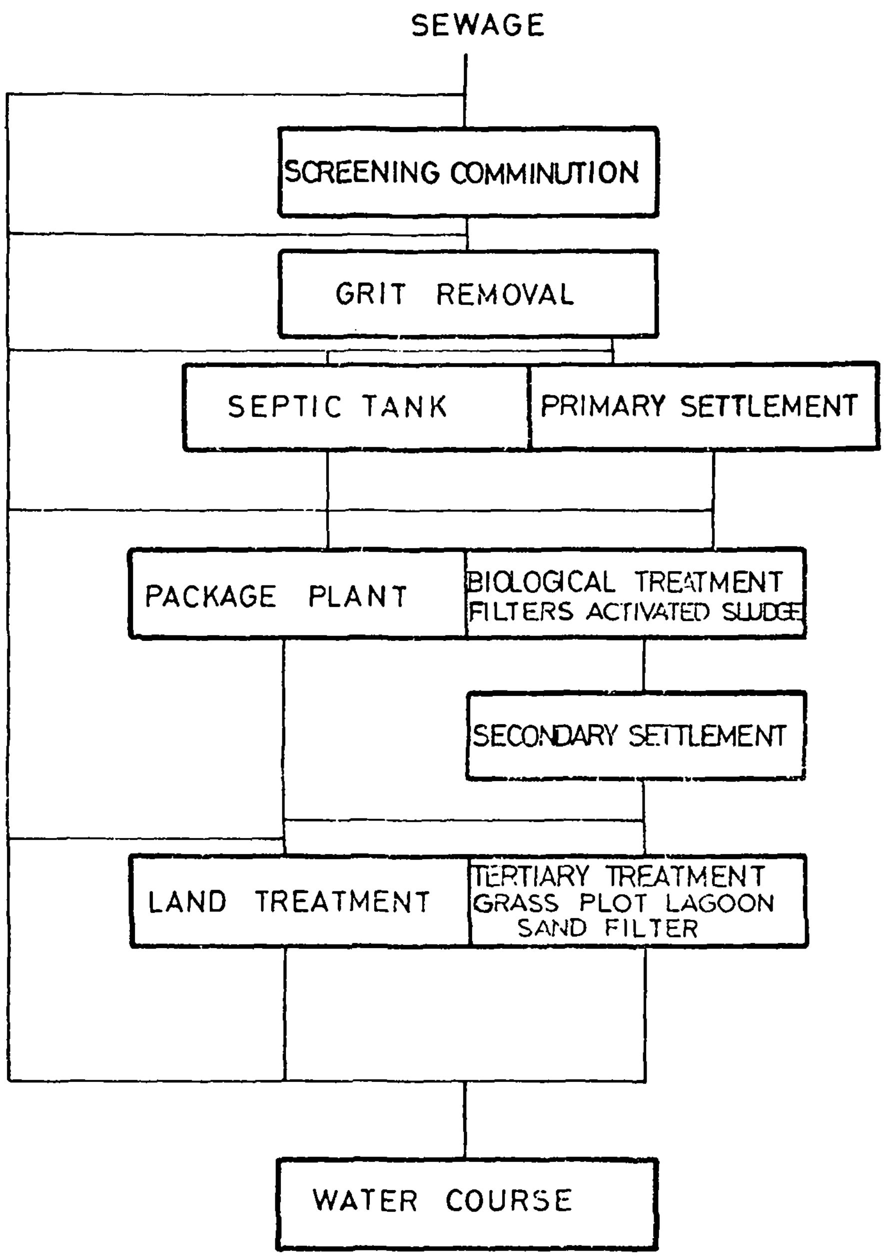

FIG. 1. UNIT PROCESSES USED IN SEWAGE TREATMENT

and allocation of manpower followed in the light of operational experience and requirements.

As time progressed incentive bonus schemes were introduced and in most cases this led to a reduction in manning levels. Apart from sewage-treatment works which function as a depot, the majority of the small works is operated and maintained by mobile gangs.

SEWAGE PUMPING

As a result of the topography of the areas served and the location of many works, it is often necessary to lift the crude sewage from the sewer into the inlet works. Such pumping may be carried out by centrifugal pumps, ejectors and more recently Archimedian screw pumps.

Unchokeable centrifugal pumps usually function satisfactorily, but there are installations where the size is so small (75mm) that they readily block, particularly in storm conditions following a dry spell and in autumn due to leaves. Such installations require frequent attention and can demand a disproportionate amount of operator time. Standby pumping capacity is usually provided, which automatically operates should the duty pump malfunction.

Ejectors using compressed air usually operate satisfactorily and cope with larger objects than small pumps, but difficulties can occur if reflux valves become wedged. Archimedian screw pumps handle most solids and work satisfactorily over a wide range of flows. It is important that the operators ensure an adequate supply of grease for bottom bearing lubrication on screw pumps.

Submersible centrifugal pumps have many advantages because they do not require a dry well superstructure. Standardization of the pump size for small sewage-treatment works would allow a spare to be retained by a mobile gang, so that a faulty pump could be quickly replaced with a minimum of delay in maintaining operations and permitting the repair to be carried out at a central workshop. A flanged or Bauer-type connexion on the rising main outside the pumping station provides a facility which speeds up the operation of standby mobile pumping equipment in the event of station failure and removes the need to dismantle pipework in what could be difficult conditions.

SEPTICITY

Small sewage-treatment works with low flows are liable to experience septic conditions during warm periods. The likelihood of septicity is increased where the sewage is pumped from a number of small sources to a small district treatment works. When the problem is serious, affecting works performance and creating odour nuisance, consideration should be given to injecting oxygen into the rising main. In addition to reducing septicity, the oxygen is utilized and reduces the BOD of the sewage, thus reducing the load to the works.

Small portable generators could be extremely useful to mobile gangs which service works that are remote from a power supply. Coupled with a small submersible pump, operations could be speeded up and become more reliable than the petrol driven portable centrifugal pump.

A depot holding diesel-driven vacuum type pumps on towing chassis would provide back-up equipment for dealing with thick sludges, blockages and pumping station failures.

LAND TREATMENT

This is the simplest method of treatment, having low capital cost and minimum operator time, and some small units are still operational in remote rural areas. Effluent quality is usually better than a settled sewage of, say 100 mg/l BOD. Operator involvement is normally periodic grass cutting and each year a section of channels is isolated to allow the sediment to dry and be removed.

SEPTIC TANKS

The sewage from many isolated single houses and small communities is often treated by septic tanks. If correctly sized maintenance needs are minimal and desludging by tankers will be needed at intervals of six to twelve months.

Some effluents are discharged directly to watercourse, but where consent conditions are more restrictive, it may be necessary for septic-tank effluents to receive biological treatment either by a conventional small filter or by land treatment[3].

SCREENING

Screening of crude sewage can be a blessing or a curse. With very small works the screen can be eliminated, particularly if the primary sedimentation tank contents are to be completely removed by gulley emptier or vacuum tanker. The ideal screening unit is automatic, actuated by level control or time switch. Such units remove most course material, but where there is a relatively short length of sewer there is also a tendency to remove a large proportion of faecal matter. Depending on the relative size of the installation and the quantity of screenings, a belt conveyor discharging into a skip has obvious advantages, permitting periodic removal by lorry to a central disposal point. The conveyor operation is initiated when the screen operates, but adds another maintenance item and possible source of difficulty. Disposal of screenings is usually carried out by burying on site, but at the larger works nearer domestic property the screenings may be macerated and returned to the flow or stored and periodically transported to tip. A hand-raked screen, depending upon the bar spacing, can require frequent attention. It is essential that an overflow weir and by-pass are provided for both hand-raked and mechanical screens in the event of blockages or power supply failure.

The frequency of attendance will vary with the time of the year and nature of the sewage. Experience will determine this and the frequency should be flexible. Some works use comminutors which eliminate the screenings disposal problem, but depending on their location (before or after grit removal) can cause other difficulties. Both macerators and comminutors require frequent adjustment and sharpening of the cutters. A poorly maintained comminutor can produce long 'strings' and 'ropes' from rags if the recommended clearances are not maintained and it is essential that frequent adjustment and cutter sharpening is carried out by a fitter once the pattern of wear has been established. Comminutors located downstream of grit removal experience a lower rate of wear, but the grit removal system tends to collect rags and other course debris.

GRIT REMOVAL

It is important that grit is removed from the incoming sewage prior to primary sedimentation, since with small works the dimensions of channels and pipes tend to be small and there is greater risk of blockage. However, with the very small works it is preferable not to have separate grit removal, particularly if the whole contents of the primary sedimentation tanks are to be removed by tanker.

Some older works have detritus pits, which arrest almost everything and are not easy to empty. A mobile pump is probably the most effective method, but there are still some situations where an operator has to enter the pit and use a shovel and rope hauled bucket.

The constant-velocity grit channel[6,7] removes most of the inorganic matter and, depending on the size of the works, removal may be by draining and digging out the grit manually or by suction dredger.

The Dorr-type detritor[7] is a most effective and reliable unit but, when scaled down, problems can arise with the grit elevator, particularly in freezing conditions.

Pista grit traps[7] can be effective and many have been installed on small works. However, attention should be paid to the moving parts which can collect rags which then adversely affect the performance.

Disposal of the grit generally presents little difficulty and it is usually dumped on site, but large quantities may require removing from the works.

PRIMARY SEDIMENTATION

Depending upon the flow and size of the works, primary sedimentation may be carried out in simple horizontal-flow, manually-desludged tanks, hopper-bottomed tanks hydrostatically desludged, or mechanically-raked radial-flow tanks.

Horizontal-flow tanks on most small sewage-treatment works are manually desludged, although there are a few with mechanical scrapers. The major disadvantage of the manual system is the fact that operators have to enter the tank to squeegee the sludge to the outlet valve. Its advantage is the fact that the tanks do not require frequent desludging, and provided that the tank effluent does not deteriorate due to rising sludge, particularly during warm weather, there is the benefit of thicker sludges and storage. The frequency of desludging will depend upon experience, but it is important that sludge disposal considerations do not over-ride effluent quality requirements.

With horizontal-flow tanks it is necessary to decant the supernatant liquor either by pump or floating arm. In order to avoid hydraulically over loading the remaining sedimentation capacity this should be carried out if possible during periods of low flow. Where only one small tank is installed the whole contents may be removed by vacuum tanker.

Hopper-bottomed and mechanically-scraped tanks do not require supernatant liquor removal, but do require more frequent desludging, depending upon weather conditions and sludge thickness. Mechanically-scraped tanks usually require daily desludging, otherwise blockages may occur. With this frequency it is necessary to have sludge storage facilities to buffer other operations such as on-site dewatering or tankering off-site.

SECONDARY TREATMENT

Biological Filtration.

By far the greatest number of small sewage-treatment works providing secondary treatment utilize filtration. This process is robust and copes with most conditions, but performance falls off during winter and quite often there is a local fly problem during warm weather. In general biological filters fail to produce the bright sparkling effluent that activated-sludge plants can produce.

Most small works utilize circular filters with distributors that are driven by jet reaction, although some are driven by electric motor through a gear box.

Some small works use a water wheel driven distributor or a tippler with fixed notched distribution channels and there are works with fixed distributor pipes discharging on to splash plates. All these variations are designed to evenly distribute the settled sewage and therefore it is important that jets, whether fixed or rotating, are kept clear. This task is normally carried out daily, but local conditions may allow a reduced frequency. In wet weather and autumn (due to leaves) jets block more frequently and there is a risk of the distributor blowing a centre seal whether it be an air-lock or a mercury seal. Depending upon local conditions, the distributor arms should be rodded and flushed weekly or fortnightly, which should reduce the frequency of jet blockage. Attention should be paid to end caps and centre seals, as leakage causes short-circuiting of settled sewage with consequent deterioration in effluent quality.

The lubrication of the centre column, bearings and rollers, and attention to guy ropes and the alignment of arms is important, as all these can effect the free rotation of the distributor. The pivot on tipplers should be lubricated and free movement checked. It is important that the bed surface should be kept clear during the winter, when ponding may occur on the surface. This may be due to the wrong grading of bed medium or organic overloading. The short term relief may be affected by forking the bed surface medium.

Air is an essential ingredient in the biological process and it is therefore important that ventilation is kept free, particularly with filters which are built into the ground. Ventilator pipes are usually fitted with grates and these should be kept clear.

Dosing Siphons

Because the flow of sewage to small works is spasmodic, dosing siphons are installed upstream of biological filters to provide an adequate rate of flow to drive the distributors and ensure even distribution. Failure to do this would lead to dribbling of settled sewage and short circuiting.

Attention should be paid to the dosing siphon to ensure smooth operation and a clean break of flow when the chamber has emptied. It is important that the pipe work in the siphon unit is airtight. On the very small works the siphon pipe sizes are small and liable to become blocked, particularly in the autumn.

Rotary Biological Contactors

These are package units commonly known as 'Biodiscs' and are a total treatment plant receiving crude sewage and producing a final effluent suitable for direct discharge to watercourse.

The rotating discs are partly immersed in sewage and build up a biomass on the disc surface which periodically sloughs off as humus sludge. The greatest biomass build up is on the inlet end discs and it is important that the gaps between discs should not be bridged. Earlier equipment suffered from supporting mesh and rod collapse due to the weight of the biomass, but more recent machines using fibre glass should be more reliable. Even so, periodically the operator should clean off excess biomass, which may be carried out using a scraper or water jet.

The discs should rotate freely and the shaft bearings must be lubricated at the frequency recommended by the supplier.

The unit should be desludged regularly at two to four week intervals, but this frequency may vary depending upon time of the year. A vacuum tanker or gulley emptier is the most commonly used equipment for sludge removal.

If power is unavailable for a long period, the weight distribution on the discs will cause an imbalance and it will be necessary to clean the disc before restarting.

Activated-Sludge Process.

Until the advent of the package plant, in situ constructed activated-sludge plants were mainly limited to the upper end of the small works classification. Size, operator skill and laboratory facilities are no longer limiting factors. Provided that there is a power supply, then an activated-sludge plant can be installed.

Advantages are minimum head requirement, little smell and no flies. Noise can be a problem and the sludge can be more difficult to dewater, although with extended-aeration plants the sludge is generally less difficult. Occasional sludge bulking on some plants can cause operational problems and poor effluents.

Air-blowing plants generally use coarse-bubble aeration and maintenance is limited to lubrication of the air blower. With fine-bubble aerators, use of clean air is important and attention must be paid to the air-filtration system. In this type of plant the air blower is more precisely engineered and adequate lubrication is essential. Oil traps on air lines require attention and the air lines need 'blowing off' to remove condensate, particularly during the winter; the frequency of this varies with atmospheric conditions and will be determined by experience.

In an air-blowing plant the operator should report immediately if there are any areas of low turbulence in the aeration basin, this being most likely due to blocked diffusers.

Mechanical aerators are either horizontal brush-type or vertical cones.

Attention must be paid to the oil level in the gear boxes.

The optimum MLSS concentration will be determined by experience, as will the rate of return of activated sludge and the frequency of withdrawal of surplus activated sludge. Interested operators can get 'the feel' for the MLSS concentration by measuring the volume to which avtivated sludge settles in a 1-l cylinder after 30 mins, a rough guide but better than nothing at a time of reduced laboratory service.

The return of activated sludge may be by centrifugal pump, screw pump or air lift. It is essential that this is checked otherwise the MLSS concentration may reduce to below the optimum and there could be a build-up of sludge in the settlement tank.

Activated-sludge plants are dependent on an adequate supply of oxygen and it is vital that the power supply should be maintained. Automatic restart facilities should be provided to deal with temporary power failure and if the electricity supply is to be off for more than 12 hours then consideration should be given to the provision of a mobile generator. This is particularly important if the receiving watercourse is of high quality and high amenity.

Grease and fat particles present in sewage tend to accumulate in the aeration zone and can build up into large grease balls which require removal.

'Package' plants may have special fetures and it is important that the manufacturer's maintenance instructions be studied and applied.

<u>Secondary Settlement</u>.

One of the by-products of biological oxidation processes used in sewage treatment is suspended solids, even solids-free substrates produce solids. In order to complete the benefit of the oxidation phase it is essential that the solids content of the effluent is reduced as much as possible.

The most common method used for solids separation from the effluent is settlement in tanks which are basically similar in design to those used in primary sedimentation.

The main difference between settlement facilities for biological filters and activated-sludge plants is the difference in time-scale necessary for the removal of solids from the tanks. With the former process the humus tanks may be rectangular horizontal-flow, pyramidal upward-flow, or circular radial-flow, Horizontal (humus) tanks should be desludged weekly, although this frequency may be reduced during the winter and should be increased during the spring slough and warmer weather when denitrification in the sludge could cause rising sludge. This type of tank, of course, requires manual desludging after drawing off the top water. During this period the settlement capacity at most small works is reduced to half and therefore it is important to select a period of low flow. With pyramidal tanks sludge is drawn off under hydrostatic head. The frequency is determined by experience depending upon the thickness of the sludge and its ability to flow from the draw-off pipe and the risk of rising sludge. Radial-flow tanks are fitted with mechanical scrapers and sludge is removed daily.

Settlement of activated sludge can be carried out using pyramidal upward-flow tanks or circular radial-flow mechanically-scraped tanks. It is essential that the settled sludge is removed from the tank as soon as possible, so that it can be returned back to the aeration process. To do this the tanks are continuously desludged through a sludge valve using hydrostatic head. Setting the valve at a level to avoid drawing off water instead of sludge can be difficult and at times the partially opened valve may become blocked due to thick sludge or leaves. Telescopic valves can help to overcome this difficulty.

With hydrostatic sludge draw-offs the operator should occasionally flush the system by fully opening the valve to dislodge accumulations of heavy sludge and other debris.

All tanks should be emptied at least once a year to clean out accumulation of debris and check scraper blades.

EFFLUENT POLISHING

For many years designers have tended to provide tanks with too low a retention period, particularly at high flows, with the result that sewage-treatment works consistently fail to achieve satisfactory effluents.

Increasing the capacity is an obvious method of overcoming this difficulty, but this would need additional tanks. A simpler and effective method of improving effluent quality from humus tanks is the provision of a clarifier section, popularly referred to as a Banks clarifier[8], which physically filters out fine suspended matter. The clarifier is usually built into existing rectangular horizontal-flow humus tanks and is not normally applied to activated-sludge plant effluents. The strainer may be wedge wire, pebbles supported on a perforated tray or plastic mesh.

Not all clarifiers are sufficiently robust to withstand the weight of a man and this should be checked and suitable warning notices displayed.

Once or twice weekly accumulated solids should be hosed out using high-pressure jets after lowering the water level in the tanks to about 300mm below the strainer level. The frequency may be varied depending on effluent quality and therefore it is important that humus sludge is removed frequently to minimize the solids passing through the strainer. Cloudy, poor oxidized effluents will not be significantly improved by this process.

Other methods for the removal of residual suspended solids in final effluents are sand filters, grass plots and lagoons.

Sand filters are not in general use, although there are few installations where the receiving watercourse has special requirements. Modern sand-filter installations are usually fully-automated with minimum operator involvement, but with simple slow sand filters as the head reaches a prescribed height, the bed should be taken out of service and the top layer of sand skimmed off and replaced with clean sand.

Grass plots are the most commonly used method of effluent polishing, particularly on small works. It is important that more than one area is provided so that the operator can alternate the flow to permit drying off and grass cutting. Over a period there will be a build up in levels, and it may be necessary to remove the accumulated solids and regrade and reseed the plots.

Polishing lagoons function in a similar manner to grass plots, but are operated with a greater depth of water. Operator involvement is mainly alternation of flow and bank maintenance.

Both grass plots and polishing lagoons tend to reduce the BOD in addition to SS and have the advantage of being available to retain activated-sludge solids when sludge bulking occurs.

SLUDGE TREATMENT AND DISPOSAL

Within the size range for small sewage-treatment works, sludge treatment and disposal can vary from simple lagooning to automated dewatering processes.

By far the greatest number of works utilize sludge drying beds, shallow lagoons or deep lagoons; the latter at its conception is usually thought of as a temporary expedient, but tends to become a long-term liability. In the author's experience, few deep lagoons are ever reclaimed although they present a permanent hazard and should have warning notices and be fenced.

Drying beds and shallow lagoons do eventually dry sufficiently for removal by an operator manually or by a mechanical lifter. The dry cake is usually disposed of 'over the fence' to the local farm. Attention should be paid to removal of separated top water, which should be returned to the works inlet. Maintenance is limited to replacement of bed surface material and bank maintenance.

Drying beds are generally unacceptable due to manpower requirements and the nature of the work, but they do fulfil a useful long stop when other outlets are no longer available.

Tankering sludge to agricultural land or to other larger works for processing is becoming more prevalent, but can be expensive. However, for environmental reasons disposal of raw sludge to land, even in rural areas, is not always acceptable and with the advent of the package digester it is now possible to install such units on small works, which were hitherto considered to be out of the question.

Continuous or freqent digester feeding with raw sludge using Mono type pumps drawing from small sludge storage tank has almost eliminated operator involvement and evened out gas production so that the unit is self-supporting. Operators must ensure an adequate supply of sludge and space in the digested sludge holding tank from where it is removed for recycling to land.

The operator must check that pipelines are free and that the gas-recirculation mixing system and gas-fired water heater are operating. The water seal in the gas holder compartment should be checked weekly, particularly during extreme weather conditions; antifreeze may be required during the winter, and frequent topping-up with water needed during the summer.

Mechanical dewatering plants have been installed at many of the 'larger' small sewage-treatment works, although recently there has been economic pressure to consider 'mothballing' where recycling liquid sludge to land is considered to be less expensive. With mechanical dewatering plants, particularly those using fabric filter medium, it is important that the fabric is washed frequently to reduce 'blinding' and care should be taken with the mixing and application of chemical coagulants to ensure that the optimum dose is applied. If filter press performance deteriorates it may be due to the drainage channels on the press plate surfaces being blocked. These should be examined and if necessary cleaned by high-pressure water jetting. It may be necessary to use diluted acid to remove lime scale.

MANPOWER CONSIDERATIONS

The inherited labour situation in 1974 revealed a range of manning levels. Many areas were overmanned, although in some rural locations there was a deficiency. Poor wages attracted only mainly unskilled operators and there was an ageing labour force.

Losses by natural wastage and voluntary severance on the introduction of bonus incentive schemes resulted in a significant reduction in manpower, in some areas by 40%.

Training of operators, both by the NWC courses and 'on-the-job', has led to a greater appreciation of the job requirements and improved their ability and skill. The relatively higher wage rates and probably the general employment situation have improved the calibre of new entrants. Recruitment of craftsmen no longer presents difficulties.

Single-manning on individual works is now considered to be wasteful in manpower and unsafe in most situations. Experience during recent years has led to the extension of the practice of using two-men mobile gangs to operate and service small sewage-treatment works and district pumping stations. Gangs are based at strategically situated works with garage and storage facilities, together with messing and ablutions, and their routine tour of duty is normally scheduled to cover a section of watershed/river to minimize unproductive travelling.

Frequency of visits to particular works and task frequencies have been established by experience and certain infrequent tasks are built into the long-term schedule of work.

It should be stressed that the frequency of routine operational tasks should be determined by operational managers, based on experience and the individual works or process requirements. There is a danger that nationally determined frequencies could be written into productivity schemes without the full appreciation of operational needs and it is important that managers should be able to support their operational requirements. One should adopt a flexible approach to routine duties and make allowances for breakdowns and blockages.

The provision of VHF radios for mobile gangs has many advantages. Supervisors are able to pass on instructions and redirect the labour to other locations to deal with emergencies. The mobile gangs can save considerable time by calling in information on faults requiring more skilled attention and in the event of accidents involving personnel.

GENERAL CONSIDERATIONS

Access to small works is often poor and in some situations it is almost impossible to reach them by motor transport. Where vehicular access is possible, consideration should be given to widening gate openings to allow access of tankers which would permit a significant change in operational methods and reduce frequency of visits.

Pipe sizes at most small works are of such a size that apart from normal blockages they are liable to freeze in cold weather. In addition to causing pipe fractures, the thawing process is slow and this could result in a section of the works being out of commission. Such pipes should be insulated or receive adequate soil cover.

Landscaping is often a feature of works and at many small works ground maintenance can occupy a major part of the operator's time. Gravel areas with persistent weed control will reduce operator requirement and costs. Trees are often provided to screen the works fron nearby developments. During the autumn, leaves can cause serious operational difficulties and often adversely affect effluent quality by interference with filter distribution. If a screen is needed deciduous trees should be avoided and if necessary replaced by conifers.

Vandalism is a scourge on the increase and frequently sewage-treatment works are the target. In addition to the losses and cost of repair to damage inflicted often the works' performance suffers and vandalism can account for a considerable proportion of the pollution incidents in some areas. There is also a risk of personal injury to the vandals. The erection of a substantial fence round the works is a deterent and should minimize the problem, although a determined person will still gain entry.

SAFETY

The construction of many small works appears to have complete disregard for the safety of operators. Fortunately, the situation has improved, but there is still much to be done, progress being restricted by cash constraints. Even so managers should not expect operators to carry out tasks in dangerous locations; temporary inexpensive safety precautions are better than nothing. Post and wire or split chestnut fencing is relatively inexpensive and is easy to install, and whilst its appearance may not be as impressive as galvanized steel or aluminium hand railing it provides an acceptable level of protection.

Cleaning weirs and channels is a task which is frequently carried out. Its value, apart from aesthetic considerations, is questionable and yet in many locations it is extremely dangerous, particularly with inset channels. On works where there are circular scrapers it is possible to fit brushes to perform the job, but in most situations one should consider seriously the benefit against the risk.

It should be remembered that an unsafe place for one man is still unsafe for two.

UPRATING

Many small sewage-treatment works and pumpimg stations have been built to deal with the sewage from estimated ultimate populations which have yet to be realized. In such cases, channels and tanks are too large and can cause intermittent surge flows, silting in channels and pipes, septicity in primary sedimentation tanks and rising sludge in humus tanks. At the other extreme there are many works which are undersized, causing premature operation of overflows, inadequate primary sedimentation passing solids to the already overloaded biological stage and inadequate secondary settlement.

An obvious constraint on the performance of sewage-treatment works is the lack of an electricity supply and serious consideration should be given to its provision, which would facilitate a number of features capable of improving performance.

The spasmodic flow to small works has been referred to as an obvious difficulty in the satisfactory operation of works. Some form of flow balancing can be achieved in primary sedimentation tanks by raising the effluent weir and installing orifice plates or pipes. The variable head does not allow uniform flow, but the flow is spread over a longer period. The orifice is liable to become blocked and will require attention. Where a power supply is available, small submersible pumps situated in the final effluent channel delivering to either the inlet or dosing-siphon chamber will reduce septicity during warm weather and improve the operation of the filter distributor; an additional benefit is the increased potential loading to the filters.

Where there is only one tank provided, the building of a central wall will permit some settlement to be continued whilst half is being desludged and avoid backing up and discharge of sewage via the overflow.

The use of oxygen to uprate works or to deal with seasonal load increase has been applied with success at Bournemouth, but it has not found general application. The BOC Vitox oxygen system is relatively simple to install and has a utilization in excess of 60% in open-air systems and over 85% in closed systems.

An additional benefit of improved primary sedimentation following oxygen injection has been claimed.

Relief can be obtained at a biologically overloaded works by the addition of chemicals into the inlet channel prior to primary sedimentation. Placing blocks of aluminoferric in the channel is the simplest method.

Some dosing siphon chambers can be too large, resulting in long periods between operation. The capacity can be reduced by building brick walls in the chamber to physically reduce the size, or by placing concrete blocks in the chamber.

Alteration of the periodicity of dosing to filters can effect an improvement in performance. Adjustment of the arms so that only one section is driving can achieve this objective, but care should be exercised if the head is insufficient as one may encounter problems due to distributors stopping. The provision of motorized drives to distributors has obvious advantages and overcomes short-circuiting caused by dribbling during the beginning and end of the siphon operation and during low flows.

Rodding and pricking-out of filter arms can demand considerable operator time. Where the situation is acute, consideration should be given to the provision of a brushed sieve screen before the siphon or filters.

On works where the filter is biologically overloaded, it is possible to relieve the situation by constructing a simple filter. Quite often surplus large diameter concrete sewer pipe sections are available and if these are filled with random-pack plastics and fed by a submersible pump to a fixed splash-type distribution system, works performance can quickly be improved.

Desludging humus tanks and returning to the inlet works can cause a hydraulic overload and result in solids being scoured out of the primary sedimentation tanks. A steel-section tank fitted with an orifice plate can be used to receive the humus sludge, which can then be fed back to the inlet at a much lower rate. The storage tank should be positioned such that the sludge can gravitate to the inlet.

Storm-sewage tanks are not normally installed at very small works, but where they are provided, consideration should be given to their utilization for tertiary settlement[9]. This would involve additional pumping, but would maximize the use of an asset which is normally only in use 10% of the time. Storm-sewage discharges would, of course, displace the final effluent and after such occasions it would be necessary for the operator to return the contents back to the inlet for treatment and to desludge the tank.

Effluent polishing using pebble-bed type classifiers and grass plots have been referred too, but it is worth considering abandoning humus tanks on very small works and replacing them with grass plots. This is particularly worthwhile where primary treatment is by septic tank, which only requires one or two desludgings per annum. Eliminating the humus tank removes the need for desludging and considerably reduces operator attendance.

CONCLUSIONS

Small sewage-treatment works fill an important role in preventing pollution and improving river quality. Large dilution may reduce the need for high quality effluents in some areas, but pollution of a small stream or beck can be significant and cause localized problems.

The relatively high capital and operating cost of small works makes it all the more important that details of design are carefully considered with a view to reducing operational and maintenance requirements.

The introduction of simple devices to uprate and improve effluent quality, and the abandonment of traditional systems in some locations could reduce costs and still protect watercourses.

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AUTHOR'S INTRODUCTION

Introducing his paper MR. O'NEILL said that most senior managers responsible for sewage treatment had gained their experience in the operation of medium to large sized works prior to April 1974. After that date one had to adopt a new philosophy and indeed for a period a disproportionate amount of time had to be devoted to organising management, manning and appraisal of the state of the many small works inherited. During the first year firm ideas on operational methods had to be adjusted and one realized that although big was not always beautiful it had its advantages.

He said that there were many people engaged in the water industry at various levels of management and disciplines who were relatively inexperienced in sewage treatment; there were unfortunately a number of 'instant experts'. The career structure pre-reorganization ensured that most engineers and scientists had a grounding in the fundamentals and had a 'feel' for the operational aspects of sewage treatment. He said that the traditional promotional chain of chemist, technical assistant, deputy manager to manager, no longer existed and that regretfully many potential managers were lost in the cul-de-sacs of new works and scientific sections. Mr. O'Neill considered that unless there was a change many people engaged in the water industry, including finance and work study personnel, would have only a superficial knowledge of the needs and difficulties of operations.

Mr. O'Neill explained that his paper had been written not for the expert or experienced, but for those at the start of their careers and those previously mentioned in the service sections and higher management. He said that it was certainly not intended as a definitive work full of statistics and financial information since much of that was specific to a location and quickly outdated.

He informed those present that the Oxford Dictionary quoted two definitions of the word 'symposium':

(1) Ancient Greek after dinner drinking party with music, dancers or conversation.

(2) Philosophical or other friendly discussion, set of contributions on one subject from various authors and different points of view.

He suggested that whilst most might welcome the former, the object of today's proceedings was for the latter and the purpose of his paper was to promote discussion and interchange of ideas.

Mr. O'Neill said that the introduction in the paper attempted to indicate the magnitude of the problem when one considered the number of small sewage works that were known of - during the first few years after reorganization previously 'unknown' small works were constantly being located and eventually one obtained what was thought to be a full record of water authorities' inheritence.

The author said that there were obvious areas throughout the UK that had a proponderance of small sewage works and he hoped that their experiences would be forthcoming in the discussion.

During the initial days of reorganization he said that there were thoughts and great enthusiasm to phase out small works and concentrate on centralization. More recently views seemed to have changed, and Mr. O'Neill said that in his own area views had necessarily had to change in that in a rural area there was a plan to centralize works, but because of the high cost of the scheme the exercise had been curtailed and only the works dealing with the larger urban population had been built and the other sections would be dealt with at a later date. He said that it was now apparent that there was much greater saving in retaining the works on the original sites and installing package plants, rather than installing pumping mains.

Mr. O'Neill said that he wished to briefly highlight certain facets of the paper, if only to stimulate discussion. He acknowledged that he had only dealt briefly with package plants and sludge treatment because these were the topics of papers to be presented later during the proceedings. Firstly he referred to the inlet works at small treatment works stating that this was generally a designers 'nightmare' as well as presenting problems for the operator. He felt that at very small works for operational reasons it might be preferable if inlet arrangements were abandoned and periodically tanker emptying of the complete contents of the primary sedimentation tank to a larger works was carried out.

He said that small works were often in remote locations and that careful consideration had to be given to access roads and where possible a power supply, because the latter provided for many possible improvements.

Mr. O'Neill referred to several operational aspects. For example, he wondered how many operators had been given guidance on the adjustment of tension on filter distributor arms; this could be particularly apparent when there was a drastic change in temperature causing contraction of steel support ropes and resulting in uneven distribution. He said that during the discussion of the previous paper mention had been made of the media size to improve the retention of moisture in a biological filter. He said that there was obviously an optimum size and considered that if one endeavoured to scale it down to such a size as to retain the moisture then this would quickly create problems of 'ponding'. He thought that if there was a problem with maintaining flow onto filters the most satisfactory answer was to install some form of effluent recirculation which, provided that a power source was available, could be simply achieved by the use of a submersible pump in the final effluent channel.

The author considered that another important aspect was ventilation pipes on biological filters, which were quite often neglected becoming blocked with grass, moss and leaves. One of the essential features was an adequate supply of oxygen, and its neglect could adversely affect plant performance and lead to septicity in the filter.

Mr. O'Neill said that in his experience rotary biological contactors were a great asset for a small installation. They were efficient, relatively trouble-free and present design had overcome some initial problems. He considered that there was a high proportion of the biomass build-up on the inlet part, which undoubtedly placed an unbalanced strain on shafts and bearings, and he wondered whether it was worthwhile considering some sort of step-feed arrangement.

He commented that a well-oxidized effluent could be spoilt by ineffective settlement and he felt that in the past humus tanks had tended to be undersized. In such circumstances he considered that the use of grass plots or earth-banked maturation lagoons could readily be installed to realize improvements.

The introduction of bonus schemes had resulted in reductions in manning levels, particularly in rural areas, and Mr. O'Neill expressed concern about the possible use of nationally agreed frequencies for operational requirements. He said that the local situation always needed to be examined. Manning reductions had been brought about by the use of, normally, 2-man mobile operating teams, but he said that there was no reason why a single mobile operator could not be used. It may be argued that a 2-man team should be used for safety reasons, but he said that if a location was unsafe for one man then it was also unsafe for two. One needed to be aware of a working situation in which the operator was being placed and any hazards that may be involved. Simple post and wire fencing could overcome some of the dangers.

Mr. O'Neill felt that the provision of two-way radios to mobile gangs could be a real asset, saving considerable time and giving the facility of redirecting labour or them calling for spares or other requirements.

He said that vandalism was a major problem at small works, and, although it could not be completely prevented, it could be deterred by the provision of adequate fencing. This provision had been neglected in the past, possibly because the problem was not then so apparent.

Reference had already been made to the change in emphasis on capital expenditure, and there was no doubt that sewage treatment was of lower priority in a limited cash situation. The water quality of watercourses fitted into this low priority. However, he said that this did not necessarily mean that nothing could be achieved and that by simple methods of uprating works one could realize dramatic improvements in effluent qualities. Most rural works were situated in relatively stable population zones and this would not require large capital investment. With the installation of devices such as pebble-bed clarifiers, wedge wire or plastic mesh and grass plots he was sure that better performance could be achieved. The use of chemical settling aids, for example alumino-ferric blocks in channels, could significantly improve the performance of some small works, without the need for capital expenditure.

Regarding telemetry, Mr. O'Neill said that many of the instruments installed on works were totally unreliable at present without confusing the issue by the use of more sophisticated equipment. He suggested that the best application of automatic devices would be in the context of removing some of the more physical tasks for operators - for example electrically-operated penstocks, but not remotely controlled.

DISCUSSION

MR. T.D.A. TRICKER (Severn-Trent WA), opening the discussion, said that of the many changes that the water industry had experienced on reorganization in 1974, he suspected that the operation of small sewage-treatment works was one of the greatest. He considered that this fact, coupled with the present financial stringencies, made it appropriate that the established operational practices on small sewage-treatment works were re-examined. He suggested that management of a large flexible works was relatively easy, particularly with on-site support from technical staff and an adequate pool of labour. At a remote smaller works which still required a consistent high quality effluent, without all the necessary resources continuously available, management becomes much more difficult.

Mr. Tricker said that his comments on the paper would be based on his experience in the Derwent Division of the Severn-Trent WA, which covered most of Derbyshire and North Staffordshire, including a large part of the Peak District National Park. The area contained about 90 works, many of which were in the Peak District itself, which presented particular problems with regard to the quality of the effluent and the appearance of the works.

He asked the author if, in the section on septicity, he had deliberately omitted the use of Chloros and if so whether he had found it less than satisfactory. He said that he was using four, somewhat crude, drip feed installations which operated satisfactorily at low operating cost. He thought that the use of oxygen on the small scale under discussion was perhaps an expensive option.

Mr. Tricker noted that the author had rehearsed the arguments for and against the various methods of dealing with screenings, but had not come out in favour of anything. He confirmed that his experience would lead him to agree entirely. Since it was usually the dealing with a screenings installation and the poking out if the filter distributor arms which dictated the frequency of visiting a site, and since the reduction of a visit per week could potentially save considerably on the budget, he wondered whether if this saving was capitalized it would well enable the installation of more sophisticated screenings facilities than hitherto considered. He had experienced considerable success with the use of the Screezer in the larger range, replacing the 25R and 36T comminutors, and he hoped that similar success might be obtained with the smaller units. The pressed screenings were being delivered directly into a skip and then disposed of to a local authority tip, without odour problems.

Mr. Tricker asked the author how small works should be to exclude provision of grit removal facilities. He said that he would question the need for grit removal on most of the works under a population of 5000, depending upon the nature of the catchment area. He had experience of several works with combined catchments, including surface water from limestone quarries, and the problems created had not been as great as those that had been predicted.

He was suprised that in the section on primary sedimentation the author had not been more critical of the use of horizontal-flow tanks. He recommended that their installation should be avoided wherever possible, for two reasons which he wished to stress. Men working on sewage works had enough unpleasant jobs to perform, some of which had a degree of hazard in them, and to perpetuate the task of climbing down into filthy tanks with slippery floors to squeegee sludge down was wrong if it could be avoided. Secondly, the use of horizontal-flow tanks in both primary and secondary roles almost invariably caused poor effluent quality every time they were emptied. In a critically placed works this could be a severe problem.

Mr. Tricker said that at the biological stage of treatment it was often the little things that could adversely affect performance. He added that it was difficult to write a job schedule for the 'feel' for a plant, to which Mr. O'Neill had referred, and it was sometimes difficult to gain operators' interest. When a works was continually manned an operator often felt an affinity for his works and this was especially true of the traditional rural works' operator. This feeling was not always so prevalent amongst the operators of a mobile team. Mr. Tricker said that his efforts to engender such interest had centred round the operator monitoring his performance, e.g. effluent clarity assessment. Regular, somewhat unscientific, tests such as this were a much more useful feed-back to operator than a once per month analytical result received a week or so after the sample was taken. He said that this was surely also the way to develop the learning curve for the 'feel' of the works - a poor result prompting the operator to look around for reasons.

Mr. Tricker explained that within the Derwent division there were about 16 works which employed a variety of effluent polishing methods, including large sand filtration plant, various types of clarifier, grass plots and a lagoon. Based on experience of these works in terms of capital and operating costs he submitted that it was difficult to justify any other form of teriary treatment for small works other than grass plots, if adequate land was available, or if not the plastic-mesh upward-flow clarifier. He considered that the slightly better performance of pebble clarifiers did not justify the costly structure and the length of time required for backwash.

He felt that an omission from the paper was the subject of costs. Mr. Tricker said that perhaps the author had decided to leave this to the one day meeting that the East and West Midlands Branch had arranged on 'The Cost Effectiveness of Sewage Treatment', which would be held on the 16th February, 1982. He considered that reference to costs, especially under the manpower section, would have been useful. In his experience 65-80% of direct operating costs on small works were attributable to wages and in transporting men to the site. He totally agreed that financial considerations must not over-ride operational needs, but the frequency of operational visits could sometimes be decided subjectively by a local manager, and the reasons why works were visited should perhaps be questioned more ruthlessly. Maybe with a small investment and modifications to the plant that frequency could be reduced.

In conclusion Mr. Tricker said that when commenting on a paper such as this, one tended to look through in detail and in doing so one recognized the vast amount of work that had been put into it and in this case the experience that was behind it. He expressed his pleasure in having the opportunity of opening the discussion and thanked the author for producing such a wide ranging and thought-provoking document.

MR. R. WILKINSON (North West WA) described some of his experiences during and since the reorganisation of the water industry in 1974, and his realization that often the discharge of poor quality effluents from small sewage-treatment works had almost insignificant pollution effects on receiving watercourses in general. There could of course be localized problems. This realization had tended to change his view on operation, which had previously been to operate works as efficiently as possible, with the associated cost of operator attendance time, etc.

With regard to the pumping of sewage, Mr. Wilkinson said that the mutrator type of pump, which delivered through small-bore rising mains, made it economical to lift small volumes of sewage over long distances effectively.

He considered that the use of oxygen injection into rising mains was probably only economical in situations where septicity was a continuous problem. At most works the problem arose only during periods of low flow for only a few weeks of the year. He said that in such cases his experience had been that dosage of ferric sulphate/nitric acid or hydrogen peroxide could be more economical with the same results.

Mr. Wilkinson recommended upward-flow screening chambers for very small works - with bypass facilities in case of screen blockage. An outlet from the bottom of the chamber allowed the complete contents to be drained weekly onto drying beds, the screenings being washed back from the horizontal screen. He said that such a system was also likely to remove excessive grit.

With regard to horizontal-flow tanks, although these may not be desirable, many would remain in existence for some time. He said that the provision of a high pressure pump to the mobile teams was usually sufficient to push the sludge to the outlet point without necessitating operators entering tanks.

He continued by saying that the frequency required for cleaning biological filter distributor arms was probably the main deciding factor for the frequency of visits to works, and that distributors should be provided with this in mind. A fine mesh screen on the primary sedimentation tank outlet, which could readily be removed for cleaning, could help in this respect.

Mr. Wilkinson considered that caution should be taken in the design of rotary biological contactors. The package unit with settlement compartment under the discs could be extremely difficult to desludge. His preference was for a modular unit with separate septic tanks incorporating balancing facilities, a disc unit, and secondary settlement tank with the facility to return sludge continuously to the works inlet. He considered that the provision of a dial-alarm unit to indicate plant failure allowed for such a plant to operate satisfactorily with visits at 1-2 week intervals. He said that it was preferable to have the disc unit built up in sections with intermediate bearings, which would reduce the risk of shaft failure, and if shaft failure did occur then one section could be removed for repair whilst the rest remained in operation.

He said that the activated-sludge oxidation-ditch system was well able to withstand shock loadings. In installations where spare capacity was available he had used such plants for reception of private septic tanks contents, with considerable success. He said that the frequency of visits depended upon the reliability of the return sludge arrangements and that a dial-alarm system helped to reduce maintenance costs.

He thought that the provision of a balancing tank at the works' inlet to receive humus tank contents and return these slowly back into the flow was a useful provision. He could not see the necessity of emptying pyramidal upward-flow tanks every year if they were operating satisfactorily, and this could be an unacceptable demand on labour requirement.

Mr. Wilkinson urged caution in the provision of clarifiers to uprate overloaded secondary settlement tanks because, although they were a useful asset where an already reasonable effluent required improving, they could cause operational problems on works where tanks are volumetrically overloaded.

He said that he did not agree with the author's view on temporary inexpensive fencing, in that such measures became permanent and if temporary fencing began to fail it could be more hazardous than having no fencing at all.

MR. H.B. TENCH (Yorkshire WA) added his congratulations to the author, but said that he did not agree with all that was included. An important exclusion from the paper he thought was the effluent quality statistics which could prove or disprove the claims that were made. In the Southern Division of Yorkshire it was found that the very small works serving populations of less than 200 people produced very poor effluent, the average BOD during 1979-80 being 58 mg/l. One of the reasons for this poor quality was the fact that some of the works were just septic tanks, but also vandalism and the high flows received during storm period were others. He wondered whether experience elsewhere was similar and whether the results achieved were generally as good as the designer or the code of practice intended.

Mr. Tench also noted the author's condemnation of standard frequencies for sewage-works operations and said that he himself found these very useful and that they were in operation in his division. There was, of course, a number of works to which the frequencies had not been applied for special reasons, but where this was so the reasons required detailed investigation to see what improvements were possible. He considered that standard frequencies were useful as a norm against which to judge operational and design difficulties.

MR. D. McLEAN (NCB, Scottish Area) referred to small sewage-treatment works in the Scottish area and poor effluent results during the last few years. It was felt that the design of the bio-filters could have been better - they were similar to those shown in Fig.8 of 'Code of Practice for Small Sewage-Treatment Works' (CP 302:1972). On one site this had been replaced by an entirely new filter with radial flow to a central well. The grading of the medium was changed to three layers; the top metre of 50 mm, the middle 0.5-m section of 50-100 mm and the bottom layer of about 0.7 m of 75-150 mm. Mr. Mclean quoted effluent quality figures from April 1981 and said that he did not know whether the improvements were the result of design changes or because of improvements in the operation as a result of design changes.

MR. D. FOLLINGTON (Northumbrian WA), in a written contribution, stated that in the Wear Division of the Northumbrian WA the problems associated with the removal of screenings at small sewage-treatment works had been examined, the conclusions reached being that screens could be effective in preventing blockages in the later treatment processes and that such measures prevented the sludge being rejected by farmers due to it containing rags and plastics. However, the provision of mechanically-raked screens at works serving less than 5000 population produced an unacceptable material, because the screenings contained excessive quantities of faecal solids. Different designs of hand-raked screens were currently being evaluated in an effort to find a screen that would remove material which caused blockages and rejection of the sludge by farmers, but which would not block when unattended for three days and would not remove excessive amounts of faecal solids. He asked if the author had experience of a type of screen that would achieve these requirements.

He said that in the Wear Division a survey had revealed that when a works was attended daily an average of 12% of the sparge holes on filters were blocked by the following day, and 20% when unattended for two days. Investigations had been made to determine practical ways of reducing this excessive blockage rate and the conclusions were that the extent of blockage could be reduced by:

(1) Installation of a 2 mm polypropylene mesh screen in the dosing chamber surrounding the system.

(2) By enlargement, provided that there was sufficient driving head, of the sparge holes to 15 mm.

(3) By coating the sparge holes with a plastic film.

(4) By rodding out the distributor arms during every visit.

He also said that problems had been experienced with the non-operation of dosing syphons, particularly at low flows during the night when the sewage just dribbled onto the filter. Works where this might occur had been identified by the installation of a portable level recorder in the dosing chamber. The dosing chambers at all works were now monitored on a routine basis to identify when a dosing syphon was not 'making' or 'breaking' properly.

With regard to the frequency of the desludging of horizontal-flow humus tanks, he commented that this had been examined during a period of four years and the conclusions had been that at normal flow rates the tanks could be left for three weeks before desludging, without detectable deterioration of effluent quality. However, during storm flows the accumulated humus sludge was displaced with the effluent. He said that to overcome this problem, plastic mesh screens had been installed 300 mm below the water surface in the humus tanks and these had proved successful in retaining the humus solids in the tanks at all flow rates, thus enabling desludging at intervals of three weeks without effluent quality being affected.

MR. A. BATTERSBY (North West WA), in a written contribution, said that, even after screening, activated-sludge plants of the oxidation-ditch type could experience problems due to the deposition of rags and other debris if not preceded by primary tanks. He quoted the example of DO electrodes becoming covered in rags and entrained sludge which created an anaerobic zone around the sensor, thus resulting in false readings. He said that problems could also be experienced in final tanks and it was desirable that scum boards should be fitted, particularly if the effluent was discharged into a watercourse with high amenity value.

Although the provision of a Banks type clarifier was a simple method of improving effluent quality, compared with provision of extra tank capacity, he said that in his experience it was not necessarily a simple operation. Care needed to be taken to ensure that hydraulic loadings were not excessive and choice of the correct size medium was important.

He said that studies carried out in the North West WA into the effects of oxygen injection into primary sedimentation tanks had shown that the performance, in terms of increased BOD and/or SS removal, was not enhanced by such measures. However, the performance of the activated-sludge plants overall had shown a marked improvement during such trials.

He said that vandalism was also a real problem in the Pennine Division and that one works was regularly rendered inoperable by wreckage of the biological filter distributor. He considered that adequate fencing was essential to protect the general public, but would not deter vandals. In fact, thefts of chain link fencing up to 30 m in length had recently been experienced.

He said that he had been disappointed that the paper had made no reference to telemetry and remote control. Whilst he wholeheartedly agreed with the author's comments in his introduction he asked for his views on the transmission of alarm states at the more important sites to a central control room, particularly in relation to reducing the frequency of visits and hence manning.

MR. A. TONG (Northumbrian WA), in a written contribution, suggested that the centralization of small sewage-treatment works serving populations up to 500 could avoid the disadvantages of a multiplicity of small works, particularly if pumping was avoided and the sewer length was relatively short.

He considered that the period of travel and associated costs of operational staff were a recurring penalty not readily identifiable in the operation of many small units, and he was concerned at the lack of detailed supervision which such a system entailed.

He felt that the location of small works, often at the head waters of small streams, did not give adequate dilution to the effluent, leading to cattle having access to such waters making a nonsense of the attempts of sludge disposal guidelines to minimize pathogen/ova infection by sewage.

Mr. Tong drew attention to the design/construction problems of small-scale works resulting in difficulties of storm-sewage separation, desludging and storage leading to difficulties of collection and final disposal of such sludges.

MR. J. ARNOLD (Yorkshire WA), in a written contribution, said that a fundamental consideration at small works, when flows were pumped through long rising mains, was septicity. This particularly applied to installations which were sized to cope with a large influx of holiday visitors because during the major part of the year both the works and the pumping stations were significantly underloaded. The increased retention period of the sewage in rising mains was therefore contributory to the onset of septicity. He contended that sewage could become septic if this anoxic period exceeded about 12 h.

He said that, in addition to the methods mentioned by the author and other speakers, another possibility of overcoming such conditions had been mentioned in a paper written by himself ['Basic Thinking in Water Pollution Control', Wat. Pollut. Control, 1971, 70, (6), 601] as being much simpler and cheaper and could be called 'artificial infiltration'. In this a supply of water, whether mains or from a stream, would be admitted to the pumping well following a period of, say, 4 h after the pumps had last operated. The only requirements would be a timing device and valve. He said that during the daytime it was normal for the pumps to operate reasonably frequently, thereby obviating the septicity producing circumstances; but during the night the sewage in the long rising main may be stationary from 21.00 to 10.00 h, and even then the sewage may not arrive at the treatment works until the afternoon, and it was during this extended period that septicity occurred.

MR. I.G. STRACEY (Anglian WA), in a written contribution, commented on the author's reference to mechanically-scraped tanks usually requiring daily desludging, saying that in his experience this was probably excessive and that desludging three times per week would seem to be more appropriate. He asked Mr. O'Neill what his basis for this frequency was.

MR. C. JEFFRIES (BOC LTD), in a written contribution, referred to the work carried out by Boon et al[1] which showed that oxygen injection not only prevented the formation of hydrogen sulphide, but also reduced the biological loadings, after primary sedimentation, by 50% in summer and 30% in the winter compared to normal operation without oxygen injection.

An economic appraisal published by the Wessex WA[2] had demonstrated that the use of the oxygen system has provided a saving of £814 000 when compared to a conventional extension and £94 000 when viewed solely in terms of preventing septicity over the use of chlorine.

He asked the author's views of using a bacteriocide to prevent septicity in these rural locations, bearing in mind that the treatment processes employed relied on bacteria.

He said that the author made reference to the use of the Vitox oxygenation system as a method of uprating conventional works, and had quoted utilization figures for the process. Values in excess of 90% utilization had been measured by the regional water authorities[3,4] in open tank systems, and therefore he asked if the author could make reference to his utilization figures and the circumstances of the Vitox application.

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MR. B. METCALF (Yorkshire WA), in a written contribution, said that on small works final effluent need not necessarily be recirculated to the syphon chamber, because often primary sedimentation tanks were overdesigned and could cope with a little extra flow. Hence use could be made of works' liquor return or specially low-rated pumps to recirculate water from the humus tanks to the inlet. He said that this had been carried out at the Eggborough works of the Yorkshire WA and had proved to be as effective and cheaper than dosing the incoming flow with hydrogen peroxide to combat septicity, thereby improving performance of the works.

He said that where electrical power was available and an electric pump was used to recirculate effluent, local controls could be over-ridden by level sensors to stop the pump during high flows and to restart it when the flow plus recirculent would be less than a predetermined critical level.

REPLY TO DISCUSSION

In reply to Mr. Tricker, MR. O'NEILL said he had no reason to believe that Chloros was not a satisfactory method to control septicity, and although he had no experience of its application he understood the method did not require much expertise. Oxygen injection had its advantages for long rising mains and some additional treatment was achieved, as illustrated in the trial at Bath. Mr. O'Neill suggested that this could also be satisfactory in a rural situation where a works served a number of small communities which involved long pumping mains.

Mr. O'Neill said that he agreed with the comments on considering capital investment for providing screening facilities to reduce manpower, because tasks such as pricking out filter arms was time-consuming, although the installation of more sophisticated screenings facilities might only be justified at the larger population end of the small works' classification. The majority of plants served less than 1000 population, and many of these did not have a power supply.

Study work being carried out by operation research staff had indicated that there was no significant change in filter performance if the arms were only pricked out every three days. However, at certain times of the year, particularly during the autumn, leaves could be a severe problem, which could be reduced by installing a small wire basket in the distribution chamber; however, this required regular attention.

Mr. O'Neill confirmed that consideration was being given to the installation of screezer units to replace comminutors. Concerning the question of the size of works at which grit removal plant should be installed, he said that works of a population of 1000 would be generally the case. Much depended on the type of catchment area and the amount of surface water that entered the system. Works receiving a considerable proportion of highway drainage could experience grit problems.

He said that most of the works that were inherited were installed with horizontal-flow tanks with the present capital availability it was unlikely that these would be replaced by a suitable alternative. It was therefore a fact of life that such tanks needed manually emptying and this was one reason that he had suggested that at small works periodic complete emptying of tanks by tanker was preferred.

The obvious alternative to horizontal-flow tanks where no power supply was available was the Dortmund-type tank, which could be desludged hydrostatically, but was more expensive to construct.

Mr. O'Neill said that in his experience the more conscientious operators were those that were 'inherited' who had previously been basically on one works and were now part of a mobile gang. These operators had considerable experience and Mr. O'Neill agreed that the use of simple 'performance indicators' such as effluent clarity, sludge settlement and sludge blanket depth, could be useful in developing operator skill and interest.

He agreed that grass plots and plastic mesh were the least expensive of the effluent polishing options.

Referring to the use of drying beds, he said that there were times of the year when it was impossible to remove sludge from site because of access problems, and drying beds or lagoons were a useful stopgap in such circumstances. He said that he would not advocate designing a works with drying beds, but where they were already on site they could be utilized in appropriate circumstances.

Mr. O'Neill explained that he had decided to omit costs because they covered a wide spectrum. Small works were very expensive in terms of labour and capital investment per head, and during previous deliberations concerning the Authority's trade effluent code of practice as to whether to charge on the basis of a number of areas or regionally it was found that the treatment costs in some rural areas were a factor of four times those of the urban areas.

It was difficult to extract accurate costs for individual small works and the current YWA practice was to group small works into operating areas and a single cost centre. However, as a guide during 1980-81 urban works cost £3-5/hd whereas the rural works, operated by mobile gangs in one valley cost £14/hd and another valley cost £8/hd. The former was all full treatment works whereas the latter included a number of land treatment works and septic tanks.

In reply to Mr. Wilkinson, Mr. O'Neill agreed with many of his comments, particularly the point concerning the provision of intermediate bearings on disc units. As a result of shaft failures in Western Division works, modifications had been carried out and in addition to extra bearings, flexible couplings had been fitted between modules.

He disagreed with Mr. Wilkinson's views concerning inexpensive temporary fencing. With limited funds available, provided that suitably treated materials were used, a work situation could be made safer for the operator.

Replying to Mr. Tench, he said that many of the small works in the 1974 take-over period produced unsatisfactory effluents. He was pleased to report that the majority of small works in his division which he knew were capable of producing the required quality of effluent did in fact achieve this. The problem was with plants which were known to be overloaded or which had some particular element of process missing. However, these works were located where there was a high dilution factor and the consent was not severe.

The data in Table A for the period 1980-81 for different types and sizes of works was obtained from 'snap samples' and he could not vouch for their randomness, nevertheless they did indicate a satisfactory performance.

With regard to standard frequencies, Mr. O'Neill's main concern was the risk of rigid application by relatively inexperienced personnel. They could form a guide to build-up work loads and manning levels, but each location had its own peculiarities.

In reply to Mr. McLean, he said that without knowing the particular installation and the relevant facts it was difficult to comment on that particular experience, but he had found that where filters had failed to produce the results quite often the medium had been at fault or there had been inadequate drainage or ventilation. It was possible that now someone had taken an interest the works in question was being operated more efficiently. Mr. O'Neill said that his experience with many sewage works associated with industrial installations was that they became neglected, the main purpose of the factory being to produce a saleable product.

TABLE A. EFFLUENT QUALITY OF VARIOUS WORKS 1980–81

Process	Location	Population	SS (mg/l)	BOD (mg/l)
<u>Works serving less than 1000 population</u>				
Biodisc	Beamsley	640	14	7
	Malham	200	15	6
Activated sludge	Kettlewell	300	11	7
Biological filters	Appletreewick	75	19	11
	Buckden	130	26	17
	Burnsall	200	27	4
	Conistone	90	15	8
	Cononley	800	21	12
	Draughton	260	19	17
	East Marton	210	23	10
	Hebden	340	25	16
	Hetton	300	27	14
	Lothersdale	300	27	24
Land treatment	Airton	220	35	21
	Salterforth	480	120	44
	Thornton	290	60	79
<u>Works serving more than 1000 persons</u>				
Activated sludge	Grassington	2100	11	4
Biological filters	Doe Park	3000	31	11
	Rawdon	2800	25	15
	Embsay	1600	16	7
	Foulridge	1250	21	12
	Gargrave	1600	19	13

He said that he did know that many NCB works in the past had been well constructed but poorly operated. He thought that there was a change of policy now, so that it could well be that Mr. McLean's interest had resulted in a better utilization of the resources.

Replying to Mr. Pollington, the author said that the search for a suitable screen which would not remove excessive amounts of faecal solids was difficult. The relatively high proportion of faecal solids in small works was due to the relatively short length of sewer from source to screen. In urban areas the bulk of the matter was mechanically broken up during its passage to the works. He thought it extremely unlikely that a screen could be produced for small works which would remove rags and other coarse solids effectively and yet not remove faecal matter. If the problem was with the acceptability of sludge for land disposal then it might be better to consider screening the sludge and using a coarse screen at the inlet works.

Mr. O'Neill expressed his intrest in Mr. Pollington's comments on the frequency of blocked sparge holes and proposed methods to alleviate the problem.

Fine screening of the settled sewage had obvious benefits in reducing the frequency of blocked sparge holes. One of his works with a problem caused by chicken feathers had a Parkwood-type brushed screen situated upstream from the filters with noticeable benefit. However, blockages still occurred. Dribbling syphons could be due to minor air leaks, and it was important that the correct size and length of pipes were used as mentioned in the paper; quite often the syphon chamber was too large and benefits could be achieved by reducing the capacity.

Mr. Pollington's experiences with humus tank desludging was interesting, but the author said that he would have expected that there would have been serious rising sludge problems during the warmer periods due to denitrification in the sludge.

Replying to Mr. Battersby, Mr. O'Neill said that one more example of the difficulty in completely removing coarse materials from sewage had been given. He was interested in the application of the DO electrode; was it for purely record purposes or for maintaining an optimum DO concentration? In the author's opinion on small works such sophistication was not justifiable, a simpler way of saving energy was to use a time switch to 'knock off' the aerators during low loading at night.

He was not suprised that simple injection of oxygen into the primary sedimentation tanks did not produce any significant benefit; at best one would only expect 1 kg BOD for each kg of oxygen; however, when used in rising mains some operators had experienced changes in the character of the sewage which resulted in an improvement in the performance of the primary sedimentation tanks.

With regard to telemetry and remote control, the author said he had stated in the paper that many sensing devices were not reliable and that one must be able to justify remote monitoring and consider what action could be taken if an alarm was raised and what would be the consequences if no action was taken. The cost of providing a standby service could be high and, unless there was a serious risk situation, it was often difficult to justify. Nevertheless

Mr. O'Neill had recently installed a dialarm type system on two larger works where manning had been reduced by reducing cover at night and weekends; in such situations pump failure and loss of power supply at various locations were monitored and faults relayed to a control centre.

Replying to Mr. Tong's suggestion that works serving less than 500 people should be centralized if pumping was avoided and sewer lengths short, the author felt sure that such situations had been examined and, where feasible, changes effected, but in his experience one seldom had a text book distribution of works.

The author agreed with Mr. Tong that at small works it was difficult to design an installation to adequately cope with storm sewage as the sewerage system was usually combined and 'flashy' producing flows of 20-40 DWF over short periods.

In reply to Mr. Arnold the author stated that he had no experience of 'artificial infiltration' in controlling septicity, but it was an interesting concept.

With regard to the frequency of desludging mechanically-scraped tanks raised by Mr. Stracey, Mr. O'Neill was referring to his experiences with primary sedimentation tanks and at a number of installations an incidence of blocking of draw-off pipes due to thick sludge had been experienced. It was obvious that each location required different treatment and that this condition occurred more frequently after storms, but he felt that it was simpler to desludge more frequently rather than have a problem of dealing with blockages.

In reply to Mr. Jefferies, Mr. O'Neill considered that his statement regarding the use of oxygen for uprating was reasonable in that there had not been universal application of the technique even though it has been proved technically and economically.

He said that his statement on oxygen utilization in the Vitox system had been taken from a Severn-Trent WA document, Uprating Sewage Works, in which scientific services staff had examined a variety of uprating methods on all aspects of sewage treatment, and he presumed that the conclusions were based on experience within the Severn-Trent WA and on other information from other sources.

In conclusion the author agreed with the comments raised by Mr. Metcalf concerning recirculation. It reinforced the viewpoint that each location required individual consideration.

The Chairman proposed a vote of thanks to the author for an interesting and informative paper, which was carried by acclamation.

The proceedings then terminated for lunch.

THE USE OF PACKAGE PLANTS FOR TREATMENT OF SEWAGE FROM SMALL COMMUNITIES

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INTRODUCTION

The IWPC Glossary of Terms used in Water Pollution Control[1] defines a 'package sewage-treatment plant' as: " a sewage-treatment plant which is fabricated at the factory and is taken to site as a complete unit ready for use". Also termed "packaged sewage-treatment plant". The Glossary similarly describes a 'small sewage-treatment works' as: "a works treating sewage of a domestic character from small groups of houses and from individual establishments, e.g. country houses, schools, institutions, factories and similar buildings containing up to 350 persons".

The limiting size of population within this definition is a matter of opinion and therefore arbitrary. For example, the British Standard Code of Practice CP 302:1972[2], uses the same definition as the Glossary[1] but specifies "a maximum population of about 300 persons". At the time of writing (June 1981), the draft for public comment of the new British Standard Code of Practice for Small Sewage Treatment Works and Cesspools[3] which will replace the provisions of CP 302:1972, recognizes the larger prefabricated (package) units are now being produced and so deals with sewage-treatment plants suitable for domestic and industrial communities ranging from single households up to about 1000 people. A rider is added: "although modern developments make it possible to prefabricate units to cater for populations in excess of 1000 and these are included in the code. 'Domestic' is taken to include schools, hotels, restaurants, etc with their special problems, but the code does not deal with the treatment of industrial effluents, or the effluent from chemical closets."

For the purpose of this symposium, 'small communities' have been defined as those serving populations less than 5000 persons and it is this definition which will be used here, whilst, recognizing that the main constraint upon size of package plants will be the largest size of unit which can be delivered to the site by road. Large units may therefore be assembled on site from smaller units or from prefabricated sections. Thus, within the conception of the Glossary[1], a package plant would be a single unit capable of carrying out treatment of the required standard as delivered and installed, but this paper will also consider those which would be assembled on site from separate package units providing for sedimentation, digestion of sludge, biological treatment and clarification. This size definition will necessarily include works serving large villages and which will therefore, in many cases, be of traditional design and construction, usually with biological filtration. In such cases where such works are becoming overloaded by increases in the population and by deterioration of filter media and structures, the package plant, installed in parallel, may offer a convenient method of uprating performance.

This paper considers those package plants which have as their main design feature septic tanks, activated-sludge palnts, biological filters and the rotating biological contactor. The biological and physical processes which control their performance will only be discussed in relation to the ways in which they are affected by the special features and problems of small sewage works. Questions of design are covered fully by the draft BS Code of Practice[3] and the implications of design and of operation are to be dealt with by the other papers in this symposium.

Cesspools, which are watertight storage tanks of sufficient size to store sewage between visits of the collecting tanker, are not considered here, since they do not treat sewage. They are, however, discussed in the draft BS Code of Practice[3].

Useful and comprehensive guides to the selection, operation and maintenance of small sewage-treatment plants, including package plants are given by Mann[4] and the National Water Council[5]. It is not intended to duplicate their treatment of the subject in any detail.

SPECIAL FEATURES OF SMALL COMMUNITIES

Average Strength and Flow of Typical Domestic Sewages

Domestic sewage from normal residential areas and housing estates is likely to have an average (24-h composite) strength and composition similar to that shown in Table 1, with an average DWF of 110 - 120 l/hd of population.

Where the community includes a high proportion of schools, restaurants or other catering establishments the discharge from these should be estimated separately, and Table 2 provides some guidance for the likely DWF in these cases.

TABLE 1. AVERAGE (24-H COMPOSITE) ANALYSES OF THE CRUDE SEWAGE FROM THE BEDWELL DISTRICT OF STEVENAGE (Data of Painter[6])

Analysis	Concentration (mg/l)
COD	650
BOD	326
Org. carbon	173
SS	127
Org. N	19
Amm. N plus urea nitrogen	47
Total nitrogen	66
pH (value)	
Anionic detergents	16
Sodium	100
Potassium	20
Calcium	110
Magnesium	7
Chloride	70

TABLE 2. GUIDELINES FOR THE DRY WEATHER FLOW OF SEWAGE FROM VARIOUS ESTABLISHMENTS (From Mann[4])

Type of establishment	Volume ofsewage (1/hd d)
Small domestic housing	120
Luxury domestic housing	200
Hotels with private baths	150
Restaurant (toilet and kitchen wastes per customer)	30 - 40
Camping site with central bathhouse	80 - 120
Camping site with limited facilities	50 - 80
Day schools with meals service	50 - 60
Boarding schools - term time	150 - 200
Offices - day work	40 - 60
Factories - per 8 hour shift	40 - 80

Diurnal Variations in Strength and Flow

The flow of sewage from small communities and individual dwellings normally shows very sharp diurnal variations and, as shown in Fig.1, most of the daily flow of sewage from residential areas is discharged betweem the hours of 8 am and midnight. In the particular example shown in Fig.1, the peak DWF is itself almost twice as large as the average DWF during the same day. The peak flow also coincided with the strongest sewage. Package plants for small communities need a certain amount of additional capacity to cope with this.

At the other extreme, low flows during the night may require the use of recirculation pumps to prevent the drying-out of biological filters (if used).

Other Variations in Strength and Flow of Sewage

Other sources of variability in flow and composition of sewage can be attributed to seasonal and non-recurring factors (e.g. rain). These variabilities will affect the performance of the plant but their detection and relative importance is inextricably linked to the sampling programme used by the water authority to gauge whether the consent standard is being complied with or not. It is a feature of very small works that variability is often extreme, because of such factors as the shortness of sewers (as with units serving a few houses), and distorted patterns of flow throughout the day as a result of discharges from schools, public houses and other catering establishments. Seasonal variations such as the sudden influx of visitors to places like caravan parks and motorway service stations at the start of the tourist season and during national holidays pose particular problems for small sewage-treatment works.

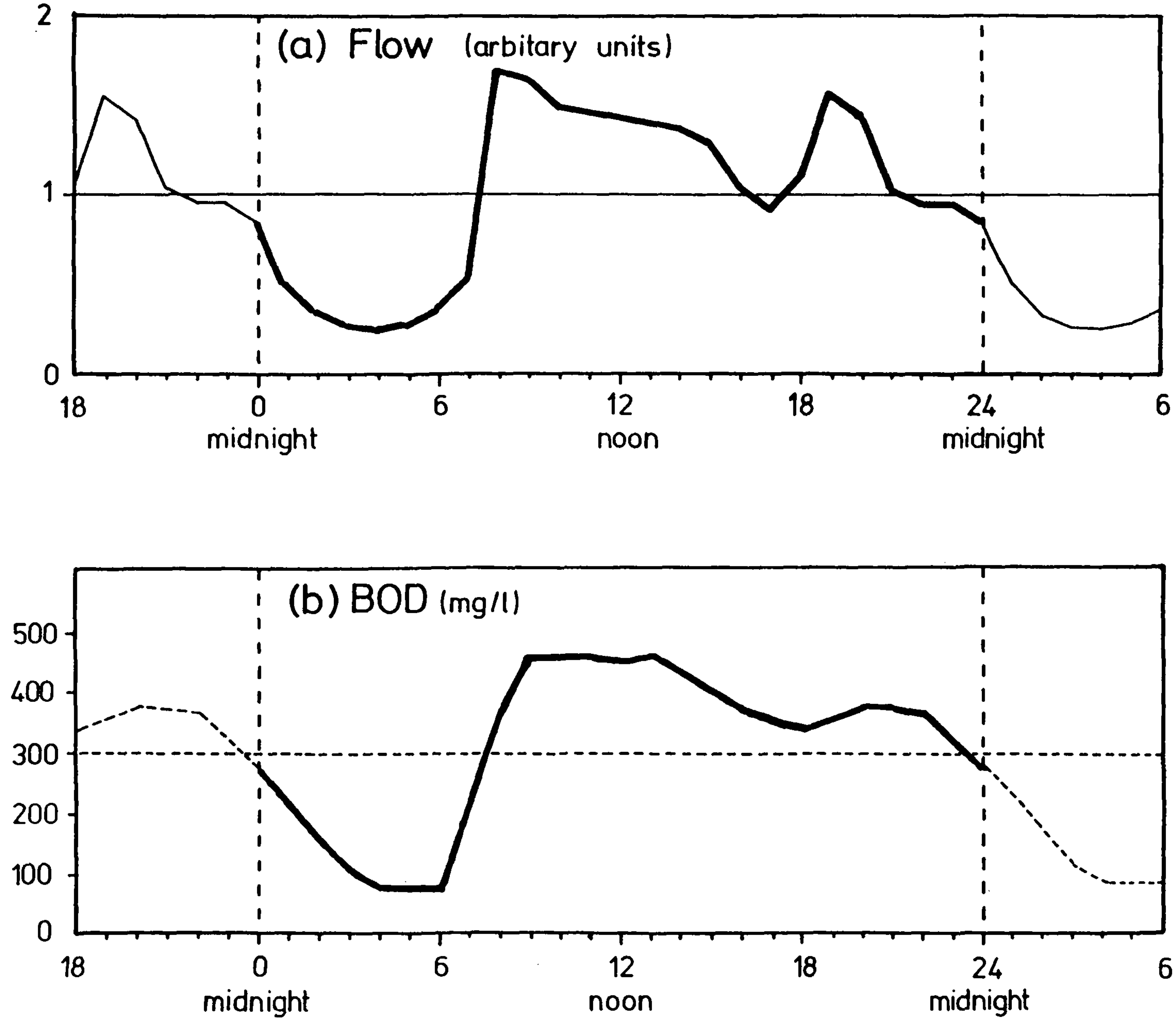
FLOW BALANCING AT SMALL SEWAGE WORKS

The effect of surge flows and surge loads on performance can be overcome by over-design of treatment units relative to equivalent population, or by installing suitably-sized balancing tanks, with pumping, in line with the flow (to balance flow and to some extent concentration changes) or in a side stream (to balance flow changes).

The principle of balancing flow as an alternative to over-designing the treatment units has often been proposed by engineers[7-10], although until recently without concern for the effectiveness or economics of such modifications. A study of the subject yields the following conclusions:

(i) Balancing flows to primary treatment considerably reduces the variability

FIGURE 1 Diurnal variations in the strength and flow of sewage from the Bedwell District of Stevenage (drawn from the data of Painter [6]).



of the strength of the settled sewage, but has little or no effect on the average strength, compared with unbalanced flow[11].

(ii) The major effect on primary sedimentation of balancing the flow is a reduction in the average concentration of SS in the settled sewage[12,13].

(iii) Balancing of flow has only a minor[13] or insignificant effect [14] on the quality of effluent from activated-sludge plants.

(iv) Unpublished data from the WRC showed that, with matched pairs of pilot-scale biological filters fed at three rates of constant and of diurnally varying loadings typical of those at small works, there was little difference in effluent quality during 12 months operation between the two modes of operation, except at the highest loading, where more complete nitrification was obtained with steady flow.

It is noteworthy that CP 302:1972[2] and the new Code of Practice[3] both allow for disproportionately larger volumes, with decreasing equivalent population, for septic tanks, primary and secondary settlement tanks and media for biological filters. Problems likely to arise from highly variable flows should be considered at the design stage. Some important considerations are:

(a) Surges in flow caused by oversized sumps in pumping stations should be avoided, as should excessively large dosing syphons feeding biological filters. Dosing of biological filters and rotating biological contactors should not be less frequent than once every 30 mins over 18 h of the day.

(b) If the flow during the night ceases or is insignificant for more than 6 h, some means of recirculation of effluent should be provided.

(c) Serial compartments in septic tanks and baffles in the treatment chamber of rotating biological contactors are valuable means for nullifying some of the effects of surge flows and short-circuiting on performance.

(d) With systems serving tourist facilities (hotels, caravan parks, roadside services and restaurants) there is a need to respond quickly to stepwise increases in load, as at the start of the season or on public holidays. No biological treatment process is capable of immediate response but the order of increasing rapidity is probably biological filtration, activated sludge and rotating biological contactors. A slow-recirculation of final effluent will assist in maintaining activity over long periods with low loadings. Where it is desired to bring a package plant into an active state to meet a sudden application of load, seeding may be used. Examples are the addition of an active sludge to an aeration tank of an activated-sludge plant or the **priming** of a rotating biological contactor with a dose of sewage or milk waste for about a week before the load is applied.

NEED FOR ROUTINE MAINTENANCE AND RELIABILITY

The availability of labour and the effort required to operate the works are major considerations, which should be evaluated at the design stage. This will greatly influence the decision concerning the most appropriate system to install and may even cause the isolated works to be abandoned for a regional drainage scheme. Where the works is to be installed on private premises and its maintenance is outside the control of the water authority, the paramount need will often be for a robust and reliable installation relatively tolerant of neglect, misuse and overloading.

Septic tanks need desludging once or twice yearly. With rotating biological contactors, desludging is required about every three months, depending on design, but must be carried out when required or performance will be severely affected. At least weekly attention is required for desludging secondary and humus tanks and for inspection of activated-sludge plants. Biological filters may need to be checked daily for choked jets on rotating distributors.

When a package plant is selected from a manufacturer's range, it is necessary to check that the plant is capable of treating sewage from the maximum equivalent population likely to be encountered during the service life of the plant and that the manufacturer's design loadings are not over-optimistic in comparison with those recommended independently[2,3,4,15].

Problems will be experienced with package units at caravan parks, hotels and roadside services, if allowance is not made for the maximum loading at the peak of the summer season. Nuisance from flies and odour will occur just when there are the most people available to experience it. One author recalls visiting a rotating contactor drowning in its own effluent because grease from the kitchen of a golf club had completely choked the sub-surface system.

SEPTIC TANKS

Purpose

For small, unmanned, sewage works there is an obvious attraction for the idea of a primary sedimentation tank that only requires desludging once every

6 - 12 months. Septic tanks fulfil precisely this function. A septic tank is simply a primary sedimentation tank designed to provide long-term storage for settled sludge.

Although liquid retention periods of 12 - 24 h are intended primarily to promote efficient sedimentation, this coupled with the long-term storage of a highly putrescrible sludge, provide ample opportunity for biological action. This is, at best, a very mixed blessing!

In the UK, with sewage temperatures around 8 - 17°C, methane fermentation is both intermittent and unreliable. However, an "acid-fermentation" will continue unabated, causing partial liquefaction of the accumulated sludge and it will release intermediate metabolites such as acetic and propionic acids into the main flow of the sewage. Whilst this reduces the accumulation of sludge it also reduces the purification of the sewage and the effluents from septic tanks show large but variable removals of SS combined with relatively low removals of BOD. Such partly reduced organic compounds are readily oxidized by bacteria under aerobic conditions, so that the immediate rate of respiration and requirement for oxygen is higher near the inlet of aerobic treatment units treating septic tank liquors than for units treating settled sewage.

Design Criteria for Septic Tanks

Design criteria for septic tanks are outlined in CP 302[2] and in the new draft Code of Practice[3] which recommends that the total size of a septic tank installation should be calculated using the formula:

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

where C = the total septic tank capacity

and P = the design population (with a minimum value of 4)

This is a general formula intended for use with residential areas (normal domestic housing with a sewage flow of 110 l/hd/d. For buildings in part-time occupation, such as day-schools, the value of P in the formula can be reduced according to the flows shown in Table 2. For luxury housing and where garbage-grinders are known to be used there is an alternative formula:

$$C = (250P + 2000) \text{ litres}$$

Wherever practicable it is recommended that the total septic tank capacity should be installed as a two-compartment tank or as two single-compartment tanks in series rather than as one single-compartment tank.

As a guide to design, Fig.2 shows the recommended layout of a rectangular, horizontal-flow septic tank, together with some of its recommended dimensions

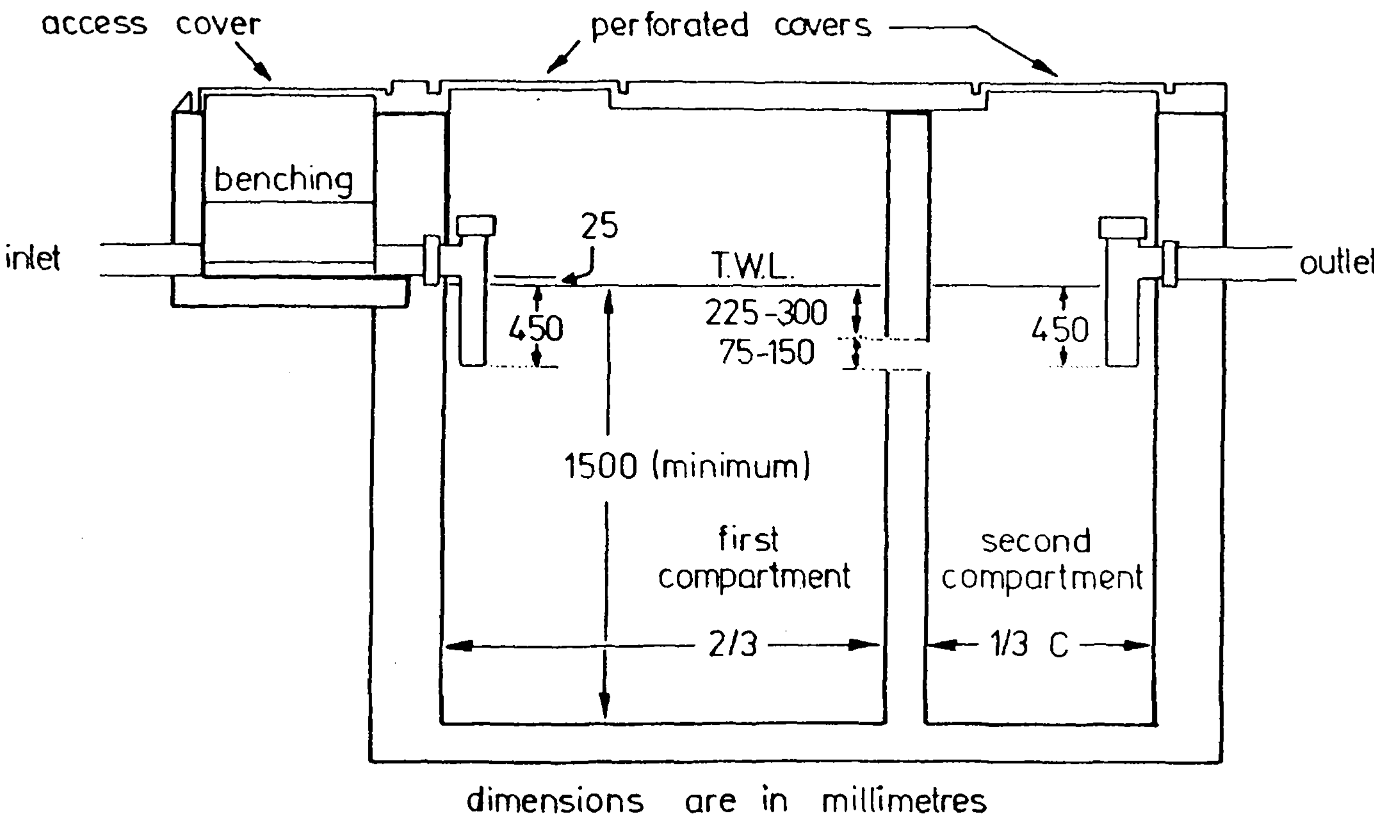


Figure 2 BSI Recommended layout and dimensions for a rectangular, horizontal-flow, septic tank for up to 30 persons (reproduced courtesy of the British Standards Institution)

Some Commercially-Available Units

Prefabricated concrete septic tanks. A range of cylindrical concrete tanks that are assembled on site from precast concrete sections is offered by Albion Concrete Products. Components are supplied for the assembly of single-compartment septic tanks which are then connected in series using plastic pipework to provide a complete septic-tank installation for up to 140 people, based on CP 302 design recommendations. Installations of this size will reqüire secondary treatment using biological filters where a high standard of effluent is required.

Ready-built, glass-fibre septic tanks. Several manufacturers supply ready-built, glass-fibre septic tanks. The external shape of these units are all similar, resembling that of a wide-necked bottle or round-bottomed flask but the interior fittings and flow patterns vary widely from manufacturer to manufacturer. The particular example illustrated in Fig.3 is a three-chambered, upward-flow sedimentation tank with capacity for sludge storage in the bottom (inlet) chamber. Like all lightweight treatment plants it requires careful handling during installation.

Although intended primarily for small installations serving 4 - 22 people, larger units are available direct from the manufacturers.

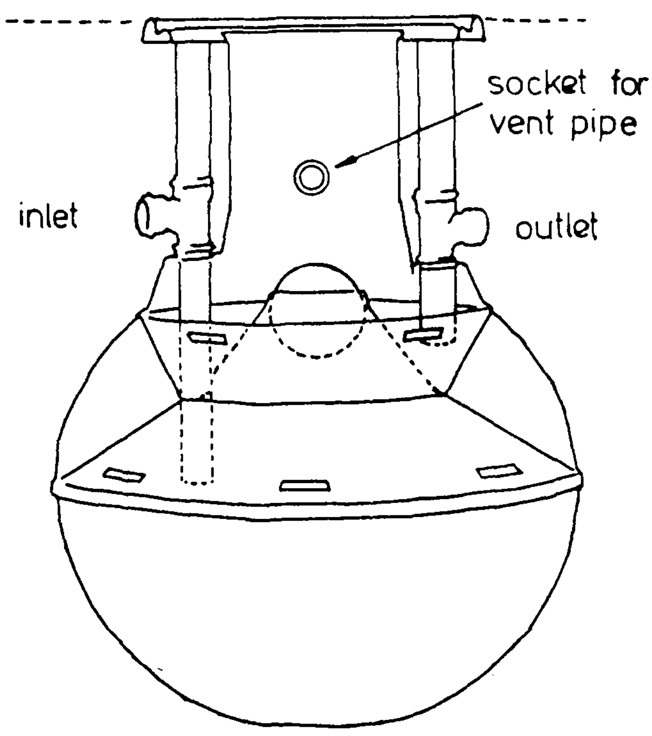


Fig. 3 Three-chambered, upward flow septic tank for 4 - 22 persons (reproduced courtesy of Klargester Environmental Engineering Ltd.)

Performance of Septic Tanks

Performance data for commercial septic tanks treating sewage from individual households and small communities are notable mostly for their scarcity. This is largely due to the great difficulty of obtaining representative samples and measurements from small, intermittent flows of unmacerated crude sewage.

However, studies by Truesdale and Mann[16] using small (3 m^3 capacity) single-compartment septic tanks confirm that well-operated units can provide efficient primary sedimentation of crude sewage.

The average performance data for these experimental septic tanks during the period June 1964 to July 1966 are summarized in Table 3, where it can be seen that the tanks removed about 80% of the SS. As expected, the removal of BOD was limited to about 35% because of liquefaction of sludge solids within the tanks.

TABLE 3. AVERAGE PERFORMANCE OF EXPERIMENTAL SEPTIC TANKS (Truesdale and Mann[16])

Period	Influent	Effluent
June 1964-January 1965		
Flow (m^3/d)	1.27	-
SS (mg/l)	462	99
BOD (mg/l)	257	218
June 1964-January 1965		
Flow (m^3/d)	1.02	-
SS (mg/l)	516	106
BOD (mg/l)	281	177
June 1964-January 1965		
Flow (m^3/d)	1.05	-
SS (mg/l)	424	87
BOD (mg/l)	359	179

The study also showed that the septic tanks continued to operate satisfactorily when the concentration of anionic detergent in the crude sewage was increased to 50 mg/l (as Manoxol OT) by the addition of the detergent Dobane JNX. The average concentration of anionic detergent in sewages in the UK is about 22 mg/l (as Manoxol OT), but concentrations as high as 50 mg/l can sometimes be found in domestic sewages from small communities.

ROTATING BIOLOGICAL CONTACTORS

General Features and Development of Process

The rotating biological contactor is a type of fixed-film reactor, in which the biological film responsible for oxidizing pollutants forms on the surfaces of rotating discs which are partly submerged in a trough through which settled sewage is passed. Attempts to develop the process in the late 1920s failed because of excessively high surface loading rates, but three parallel and independent courses of development led to commercially available units by the early 1970s[17].

Most designs are marketed as integrated packages capable of providing full biological treatment of domestic sewages from equivalent populations of 4 persons upwards to at least 500 persons in stepped ranges. Modular systems, in which independent units are supplied for primary and biological treatment and humus settlement are marketed by at least three major suppliers. The modular system of Autotrol Corporation allows for works to be constructed to serve multiples of 3000 population-equivalents by providing multiples of rotors in series-parallel.

Rotors are electrically driven with the exception of Autotrol's Aerosurf system which uses the energy from coarse-bubble aeration to drive a rotor of patented honeycomb construction and the similar surface rotor which is intended for use in uprating performance of the spiral-flow coarse-bubble aeration system widely used in the USA[18].

Loading and Performance

Being a relatively recent development, there have been no recommendations for construction, loading and operation of rotating biological contactors until the Draft BS Code of Practice[3]. Most manufacturers of package plants claim that the primary treatment area complies with the recommended area for septic tanks in CP 302:1972[2]. This is entirely reasonable. Since the shape of this primary treatment area is often necessarily complex, it is considered that the flow patterns should be adequately baffled to prevent short-circuiting and the stirring-up of settled sewage during surges of flow. It is also essential that the volume is adequate to permit storage of at least 3 months' deposition of sludge and that clear instructions about desludging are given. The authors have found that performance will deteriorate when desludging is overdue and that an optical sludge-level detector is a useful portable device for routine inspection to determine when desludging is necessary.

Whenever possible, rotating biological contactors should **be gravity fed, but** where pumping is needed, the average frequency of pumping should not be less than four times per hour.

The performance of the biological stage is extremely difficult to model, since the complex patterns of flow of the liquid film over the discs as they pick up water are added to those of diffusion limitations of substrate and DO typical of all fixed-film reactors. An account of these difficulties was given by Pike **et al**[17]. The principal variables affecting performance are well known and were quantified early in development by Popel and Hartmann and published as design curves, e.g. the English translation of Hartmann's curves by Steels[19]. These are flow rate and disc surface area relative to liquid volume in the trough, rate of revolution of the discs, strength and temperature of the sewage. It became clear, when commercial units were examined at sewage works, that rotating biological contactors were incapable of meeting consistently (e.g. 95% of the time) an effluent quality of 30 mg/l SS and 20 mg/l BOD ("30:20") if loaded at a rate higher than about 5 - 6 g BOD/m^3 d (equivalent to about 7.5 g BOD/m^3 d as crude sewage entering in integrated package plant). This was noted in the following studies:

1. Krauth and Staab[20], in a statistical study of works in Germany, concluded that a mean value of 25 mg BOD/l or less would be achieved with a loading no higher than 10 g/m^3 d and that for 90% compliance with this standard, the loading should not exceed 3 - 4 g/m^3 d.

2. In a study of a rotating biological contactor at a forest camp in West Virginia, USA, a settled sewage of 210 mg/l BOD was treated at a loading of 6.6 g BOD/m^3 d and gave an average effluent of 32 mg/l[21].

3. Studies by Bruce and others at the Water Pollution Research Laboratory with modified Biodisc and pilot plant of novel design suggested that an appropriate loading rate was 5 - 6 g BOD/m^3 d as settled sewage[22,23]. This was substantiated by Pike and others[17] from observations of seven plants in the field and a two-year intensive study of CBJ-Stengelin 30-population equivalent unit at Kirk Hammerton, Yorks.

4. Studies in Canada[24] suggested that loadings of 6.0 - 6.5 g total BOD/m^3 d would be needed to meet an average objective of 15 mg/l for BOD and SS at

a minimum sewage temperature of 8–10°C. The recommendation carries the rider:

"This loading is 20–30% higher than the design guideline for RBC's established by the Ontario Ministry for the Environment, but is substantially less than those calculated from the design manuals of RBC manufacturers."

The Canadian study [23] confirms a finding made in the survey of Pike et al [17] that the standard of 20 mg/l BOD is met more easily than that of 30 mg/l SS, presumably because the effluent often contains fine solids, perhaps free-swimming bacteria, not settleable within the 30-min period provided. The Canadian recommendation is:

"Some of the settleable solids in the treated RBC effluent had low settling velocities, and conservative overflow rates (e.g. not exceeding 1.0 m/h) should be selected for the final clarifier in order to obtain their maximum removal."

It is noteworthy that the new Code of Practice [3] does not refer to surface loading or overflow rates for humus tanks attached to biological filters or rotating biological contactors, but calls for a minimum capacity of (30 x equivalent population + 1500) litres and the ability to store at least 3 months' discharge of humus sludge, with the option of provision for return of humus sludge to the primary treatment zone.

As explained earlier, the need for flow balancing (equalization) is inextricably related to the need to prevent surges in flow through incorrect design of pumping wet wells and to control storm sewage (in combined sewerage systems). Bruce found that the performance of a Mark II BioDisc plant deteriorated – compared with constant-flow operation over 24 or 16 h of the day – when 3 peaks of flow were introduced over 16 h of the day [22,23]. The Canadian study suggests that with a flow pattern experiencing a minimum:average:peak ratio of 0.5:1:2, the extra surface area required should be 25% for BOD removal and 35% for removal of BOD and nitrification [24]. However, in the matched trials of the CJB-Stengelin plant at Kirk Hammerton, imposition of Bruce's variable flow pattern in the second year of operation gave a significantly greater degree of treatment and lower rate of production (despite a 65% increase in the median BOD of the settled sewage), compared with steady feed over 24 h in the first year [17].

The effect of introducing approximately plug-flow characteristics into the régime in the trough, with the objective of preventing mixing and short-circuiting, is to improve performance considerably. This was noted by Bruce [25] in the trials of the original Mark I BioDisc and the modification adopted was to provide partitions between the compartments wetting the five banks of discs on the rotor, to give a small head loss between compartments. Introduction of the partly plug-flow characteristics is also inherent in Autotrol Corporation's policy of recommending "staged" installations in parallel for all but the smallest works [26].

The rotor with its discs can be regarded as a simple aeration device which, because of the thinness of the liquid and its continuous renewal, is probably highly efficient, with little resistance to transfer to the top layers of the biological film. Evidence discussed by Pike et al [17] suggests that, with discs, there is, because of the low degree of turbulence, considerable resistance to transfer of oxygen to the microbial growth suspended in the trough liquor. Therefore introduction of turbulence by redesign of the rotor might be considered to increase the rate of treatment in the trough itself and this is indeed a feature of Autotrol's "Aerosurf" air drive and the "Surfact" system for uprating activated-sludge aeration tanks [27].

Applicability and Suitability

When the process was first marketed, the packages were claimed to be ideally suited for installation in isolated areas, at caravan parks, clubs and hotels, and in tourist centres. Reasons given were the low environmental impact, since the package can be sited unobtrusively and partly, or almost completely below ground level, the low consumption of electricity, the absence of noise, odour and flies during operation and the relatively infrequent need for desludging. These claims can largely be met although they do require proper attention to detail from the designer, the engineer and the operator. Some of these details have been mentioned above, but they may be summarized as follows:

1. Foolproof, rigid construction, so that alignment of shafts and other rotating parts is maintained, despite stresses imposed on delivery, on filling and commissioning, on desludging, by soil movement and by changes in temperature.
2. Robust construction of rotor, drive, gearboxes and motors, to withstand stresses imposed by restarting after power failure when discs have drained and the rotor is unbalanced.
3. Proper estimation at the design stage of maximum and ultimate equivalent population to be served during the life of the plant, of pumping frequencies, of labour availability for maintenance and for catering establishments, adequate design of grease traps. Accurate estimation of organic load to be treated at the design stage and not at the loading discs stage at rates exceeding 5 g BOD/m^3 where a 20:30 standard effluent is required consistly, without good reason.

4. Adherence to maintenance schedules and desludging. When necessary, ensuring that operators understand the instructions, particularly when the unit is privately owned.

Two outstanding attributes of the rotating biological contactor package are that it can be run for several weeks without being visited - a useful feature in regions that are snowbound in winter - and its ability to acclimatize fairly rapidly, as at the start of a holiday season.

One use for this package is for the temporary uprating of overloaded village works, pending reconstruction. The relative portability of the package ensures that it can be resited elsewhere once works have been reconstructed. At works 8 of Pike et al [17], a Mark I Biodisc had originally been installed [28] to treat settled sewage in parallel with the existing biological filters, which had become overloaded because of heavy growth in population. The performance of this unmodified design of unit was unsatisfactory and the decision was taken to use it to polish the effluent from the biological filters. Table 4 shows that the filters and Biodisc were performing similarly and equally unacceptably when in parallel, receiving equal flows, whereas after rearrangement, the Biodisc was able to remove half the residual BOD and to nitrify although it was not able to capture all the settleable solids, since the design flow of the humus settling stage was exceeded.

TABLE 4. PERFORMANCE OF A ROTATING BIOLOGICAL CONTACTOR (RBC) INSTALLED AT A VILLAGE WORKS WITH OVERLOADED BIOLOGICAL FILTERS, TREATING (a) HALF TOTAL FLOW OF CRUDE SEWAGE AND (b) TOTAL FLOW OF BIOLOGICAL FILTER EFFLUENT.

Parameter	(a) In parallel		(b) In series	
	Filters	RBC	Filters	RBC
Flow (m^3/d)	48	47	101	101
Load* (m^3/m^3 d)	0.31	-	0.67	-
(kg BOD/m^3 d)	0.12	-	0.24	-
(g BOD/m^2 d)	-	4.4	-	0.65
Effluent (mg/l)				
BOD	28	32	23	11 (9)
SS	30	28	52	30 (17)
Amm.N.	11	30	12.3	- (1.9)
Notes	130 composite samples taken over 24 h each; 1973-74		10 discrete samples; conditions are at time of sampling, 1978. Values in parentheses are for samples given additional settling for 0.5 h.	

* Loads are for 70% of crude sewage value.

Because of the difficulty of removing fine solids which are often produced by package rotating biological contactors, some form of polishing treatment should be considered, where high quality effluents are required. The Biospiral plant contains an integral cloth-drum microstrainer, instead of humus settling, to overcome this problem. Often the most appropriate system at village works is grass-plot treatment. The detailed recommendations given in CP 302:1972 [2] and the new Code of Practice [3], apart from the general statement that the rate of treatment, for the area in use at any time, should not exceed 0.85 m^3/m^2 d, are specifically for treatment of biological filter effluent without humus settlement. These are that the total area of grass should be 3 m^2/head of population, that the slope should be about 1:60 to 1:100 and that the vegetation should be cut when necessary and removed.

The use of rotors mounted over primary sedimentation tanks for carrying out roughing treatment or for uprating performance at overloaded works has been suggested by Antonie [26].

Capital Operating Requirements

There is little collected information upon capital costs of plant and sitework or running expenses for package plants at small works. Table 5 shows information kindly provided by regional water authorities and other owners of rotating biological contactors, works 1-7 and 10 being those described by Pike et al [17]. Costs are shown for the year in which they were incurred. What is apparent is as follows:

1. The smaller units are disproportionately more expensive than larger units. (Plants 1-4 are from the same range).
2. The costs of preparing the site are often substantial in comparison with those of the plant transported to the works.
3. Power consumption is not proportional to size of plant, expressed as population equivalent (Fig. 4), but the larger works are more economical.
4. The sums allocated by owners for maintenance labour are not clearly related to size of works, with the implication that the larger works may be more economical of labour relative to size.
5. Desludging frequencies, as found by owners, vary between 5 weeks and 6 months. The shortest intervals, 2-4 weeks, were at plants 5 and 6, which had separate sedimentation and where humus sludge was returned automatically to the primary Imhoff tank.

TABLE 5. CAPITAL OUTLAY, ELECTRICITY CONSUMPTION AND MAINTENANCE REQUIREMENTS FOR TEN ROTATING BIOLOGICAL CONTACTORS

Works*	Equivalent population†	Costs; purchase of plant; total, including site work; year (£K)	Electricity consumption metered (kW)	Maintenance budget	Desludging frequency	Notes
1	50	5.9, 16, 1975	0.31 (including pumping)	£100 including desludging, 1978	4 months	Pumped
2	50	5.9, 13, 1975	0.15	£100 including desludging, 1978	6 months	
3	110	8.9, 9.3 1975	0.36	£1K overall, 1977-8	4 months	
4	200	14.1, 29.3, 1975	0.45	£720, 1977-8	7 months	
5	450	not known	0.41	Labour £520, sludge disposal £1K, 1978	3-4 weeks	Not packaged
6	1325	not known	1.67	Labour £970, sludge disposal £1.7K, 1978	2 weeks	Not packaged
7	500	not known	1.68 (including pumping)	£1K, 1978, includes (hours/year):operation 580, grass plots 210, desludging 60, electrical + mechanical 12	3 months	
8	350	9.4, 10.1, 1972	0.45	30 min/d	5 weeks	Treating biological filter effluent
9	100 000	136, 166, 1973	6.7 (estimated)	£11.7K, 1978	-	Industrial, not packaged
10	50	7.5, - 1976	0.15	-	-	Kirk Hammerton disc unit [17].

* Nos 1-8 and 10 from Pike and others [17]

† Manufacturer's specifications

Figure 4 Relationship between equivalent population rating specified by manufacturers of rotating biological contactors and electricity consumption, measured on site for gravity-fed plants in WRC study (Table 5 and Reference 17) or as specified by the manufacturers.

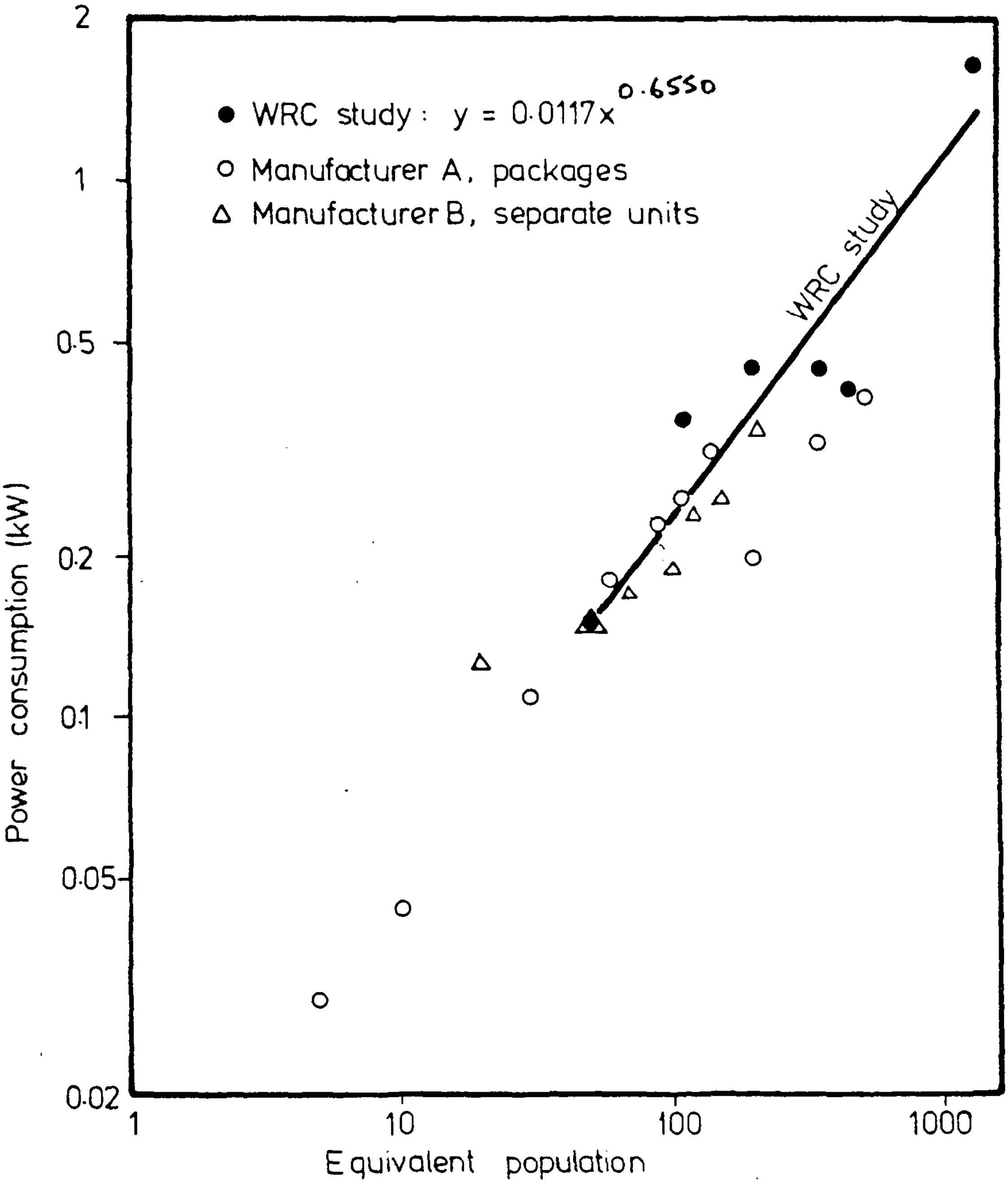
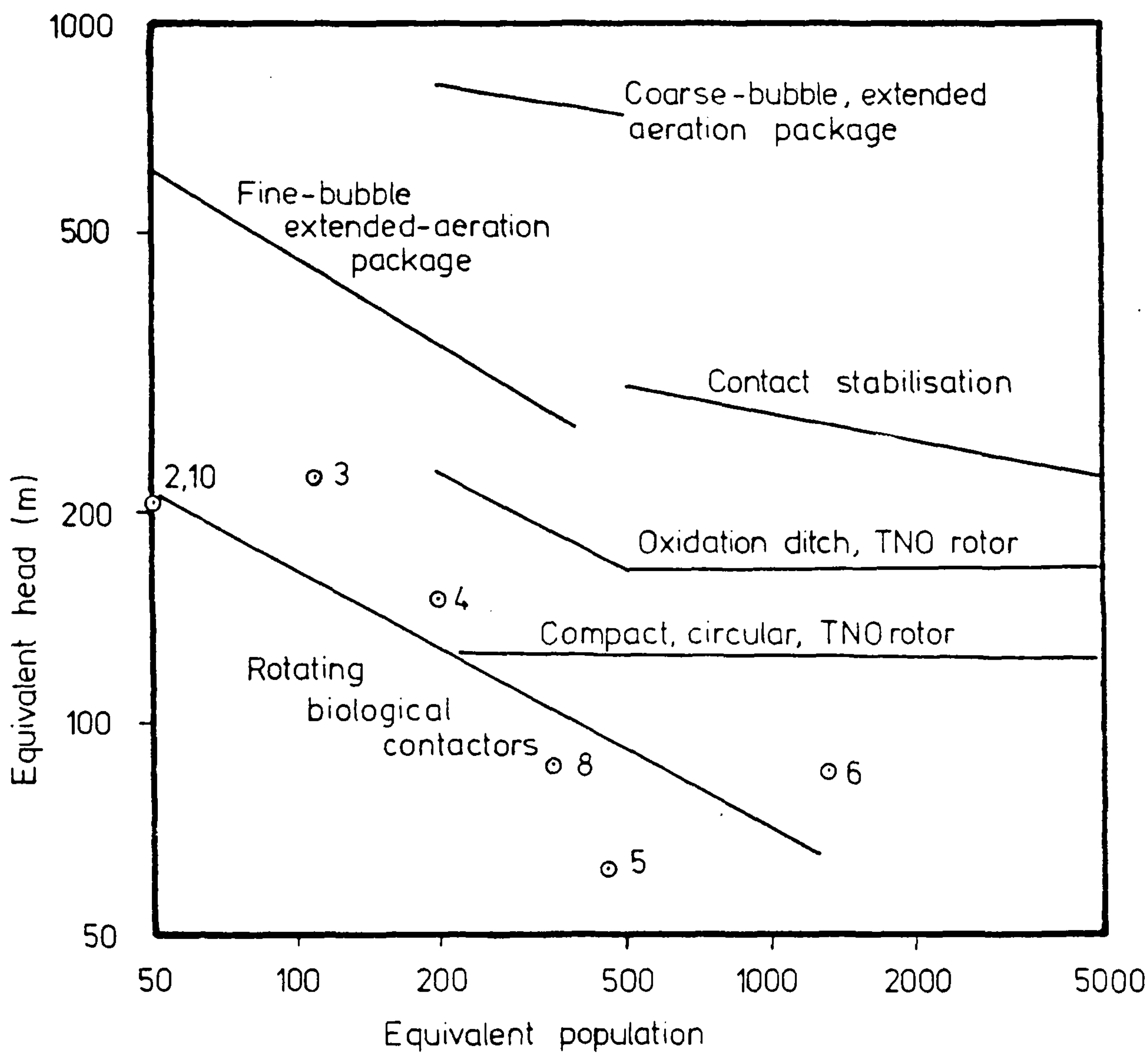


Figure 5 A comparison of the relative efficiencies, as electrical power absorbed per unit rate of flow (equivalent head = 8808 x kW/(m^3/d)), of seven rotating biological contactors examined by WRC (Table 5) and of five commercial ranges of activated-sludge plants.



The analysis of power consumption in Fig. 4 shows that the two manufacturers' ranges of plants showed only minor deviations from the general power law relationship shown in the regression equation for the seven plants in the field. Manufacturer A's range of packages were consistently less efficient below 200 population-equivalent size and manufacturer B's range of non-packaged contactors became more efficient in the larger sizes than indicated by the WRC relationship.

Calculation of equivalent head - the head to which the daily flow of sewage could be pumped (assuming 100% efficiency) by the electrical power absorbed by the plant enables the relative efficiencies of different types of sewage-treatment plant to be compared, even those not requiring electricity. A typical gravity-operated biological filtration works can be constructed to operate with a total head loss from primary tank to humus tank weirs of about 8.3 m. Fig. 5 shows that the equivalent heads of seven rotating biological contactors examined by the WRC [17] (Table 5) were considerably greater than this and that the equivalent head was greatest at the smallest works. All the rotating biological contactors appeared to be more efficient than any of the five ranges of different types of activated-sludge plants, except for the smallest (200 equivalent population) size of a compact circular activated-sludge plant. As might be expected, the least efficient type of package was the coarse-bubble, extended-aeration system. The remaining three systems, fabricated on site from standard parts, were intermediate, relative to the rotating biological contactors and the two activated-sludge packages. The differences in electrical power absorbed between the package activated-sludge plants and the rotating biological contactors designed for the same equivalent population represent savings in favour of the latter, to be offset against amortization of capital and labour charges. It is likely that the rotating biological contactor may show advantages in lower labour charges, since maintenance intervals are much longer [4] and these plants are mechanically less complex than package activated-sludge plants.

ACTIVATED-SLUDGE PLANTS

Development and Features of Package Plants

The forerunners of modern package activated-sludge plants were in use as early as 1934. In the earky 1950s rapid development took place in the USA, particularly of extended aeration. During this period, Ullrich and Smith [29] described a modification of the activated-sludge process, known as "biosorption" which subsequently became termed the "contact stabilization process". In 1950, only four package plants were in service in the UK.

The first factory-built extended-aeration plant in the UK was an Oxigest plant installed in a school in Scotland in 1961. During the severe winter of 1962-63 a small Oxigest unit at Newmarket continued to function efficiently with ice on the surface of the settlement tank, whereas conventional filter plants failed (personal communication, D. Hipgrave, Satec Ltd). This lent credibility to the process in the UK. Initially the Ministry of Housing and Local Government (MHLG) only granted loan sanctions for five years to local authorities. This was extended to 15 years in 1965 and later to 20 years.

Detailed studies of the performance of three extended-aeration plants were made by Downing et al [30] at the request of the MLHG; two were package plants. These showed that, although operation of such plants without removal of surplus sludge caused excessive SS concentrations to appear in the effluent, normal operation with wastage of sludge to keep the MLSS concentration in the range 2000-5000 mg/l could be expected to produce an effluent of 20:30 standard, although some form of "polishing" of effluent seemed desirable.

The first detailed guidance on design and operation of these processes was the MHLGs Technical Memorandum on Activated-Sludge Sewage Treatment Installations Providing for a Long Period of Aeration in 1960 [15]. The criteria specified for the three types of plant considered - extended aeration, contact stabilization and oxidation ditch - were later incorporated into CP 302:1972 [2] without significant alteration and, with a few additions, into the new draft Code of Practice [3].

For the smallest package plants, rectangular steel tanks are used. These are usually 6-mm steel plate, shot-blasted and painted with an epoxy resin. One company uses glass-coated steel panels. For the larger, sectional units, circular tanks are used. These are either fabricated from steel panels or, for more permanent structures, made of concrete. One company uses prefabricated concrete panels which merely require locating and grouting on site. The tanks may be sited above or below ground. Steel tanks below ground have a magnesium anode pack for cathodic protection.

The most common system for communities up to about 500 persons is extended aeration, using either coarse-bubble or fine-bubble diffusers. The latter have a greater aeration efficiency (e.g. 1.8-2.2 kg O_2 dissolved/kWh in deoxygenated water) than the former (e.g. 1.0 kg/kWh) are thus cheaper in terms of electrical power absorbed for a given degree of treatment but are, with associated compressors, more expensive to purchase and maintain. This is demonstrated in the section on rotating biological contactors (Fig. 4).

In the larger, prefabricated plants, which may serve populations from 200-10 000, circular construction with concentric tanks for aeration (outermost) and secondary sedimentation may have economic advantages. Where contact stabilization or aerobic digestion is used, this is situated as a segment of the outer ring. Contact stabilization as a process, when fully treated effluents are required, has not been shown to offer greater efficiency in terms of BOD removal compared with conventional aeration plant of similar overall volumetric and organic loading [31], but has the advantage that sludge is stabilized by a measure of aerobic digestion before disposal. Oxidation ditches, operated either discontinuously ("fill and draw") or continuously with external settlement tanks, are not packages, although they can be constructed to treat sewage from populations of 200 upwards. Aeration is by variations of the horizontal brush or TNO rotor.

Operating and Design Criteria

The criteria specified successfully in the MHLG Technical Memorandum [15], in CP 302:1972 [2] and in the new draft Code of Practice [3] are consistent, apart from a few additional recommendations in the new Code of Practice, mainly concerned with air supply and design of settlement tanks. It is not proposed to deal with recommendations in detail but it should be noted that there are inextricable relationships between flow and strength of sewage, the size of aeration and sedimentation tank, sludge loading rate, oxygen requirements, production of sludge and concentration of MLSS. Table 6 summarizes the recommendations for three basic types of small activated-sludge plants in the new Code of Practice [3]. The loading criterion (0.05–0.15 kg BOD/kg MLSS d) is to enable operation to proceed in a range above that likely to cause foaming problems and autolysis of the sludge and shortage of dissolved oxygen.

Final Settlement Tanks

Final settlement may be carried out in a quiescent zone within the aeration tank or in a separate clarifier. In all cases the upward-flow velocity should not exceed 0.9 m^3/m^2 h. For plants serving up to 1000 persons, an upward-flow clarifier is normally used with a floor slope of 60 degrees. The larger installations have shallower radial-flow tanks with scrapers. Some manufacturers dispense with settlement tanks completely and offer duplicate aeration tanks for each installation; these alternate as clarifiers. The aeration devices are controlled by a timer which switches off at preset intervals - the tank then acts as a clarifier.

In package plants, hydraulic considerations are more important than the organic loading and correct sizing of the settlement tank is critical. To overcome the problem of washout of solids due to widely fluctuating flows, most manufacturers prefer to design the settlement tanks to treat 4.5–6.0 DWF. One manufacturer has overcome the problem by having a fixed draw-off of mixed liquor from the aeration tank which in turn acts as a crude balancing tank.

TABLE 6. RECOMMENDATIONS OF THE NEW DRAFT CODE OF PRACTICE FOR SMALL SEWAGE TREATMENT WORKS AND CESSPOOLS[3] RELATING TO ACTIVATED-SLUDGE PLANTS

Criterion (and units)	Recommendations		
	Extended aeration	Contact stabilization	Oxidation ditches
Aeration compartment, capacity (l/head)	Not less than 230	For contact and re-aeration compartment together, 114; aerobic digester - not less than 90	260
Retention period (h)	24-48	-	-
Sludge loading at peak flow (kg BOD/kg MLSS d)	0.05-0.15	combined stages, 0.05-0.15	0.05-0.15
MLSS (mg/l)	2000-5000	-	2000-5000
Settlement tank, surface loading (m^3/m^2 d)	22	22	22
Air supply:			
diffused air (m^3/head d)	Up to 17, dependent upon bubble size and depth	Up to 9.5 with depth of 3.5 m, dependent upon bubble size*	-
mechanical aeration (g O_2/g BOD)	Not less than 2	-	Not less than 110 g/hd d

* Air input allocated in ratio 2:2:3 respectively for contact, re-aeration and aerobic digestion stages

Sludge Recycle and Skimming Devices

The rate of recycle of sludge is normally in the range 0.5-2.0 DWF. This is accomplished by hydrostatic head, by air-lift or by means of a small pump. In the smallest plants the first option is most often used. One problem with recycling sludge by gravity is that pockets adhere to the sides of the tank and may give rise to denitrification. A positive means of recycle is to be preferred, but this is only economical in the larger plants.

Surface scum on the settlement tank is removed either by surface eductors or else by a scum-removal device connected to the sludge scraper mechanism. One manufacturer offers a small surface rotor pump which drives the scum from the surface of the settlement tank to the aeration zone.

Sludge

Extended aerators, contact-stabilization plants and the oxidation-ditch process produce a well oxidized sludge. This is because of the low loading and consequent long sludge age. The sludge age usually exceeds 15 d and sludge production is about 0.5 g/g BOD applied.

The sludges are well oxidized and contain less organic matter than from conventional processes. Consequently dewatering is efficient and the drying characteristics are excellent.

Polishing

CP 302:1972 [2] recommends further treatment of effluents ("polishing") to achieve an effluent of 30:20 standard at all times. Most manufacturers dispense with tertiary treatment, but may recommend grass plots. Separate or in-situ pebble-bed clarifiers are often installed as optional extras. The manufacturers claim that with adequate hydraulic capacity the washout of solids is minimized.

Running Costs and Maintenance Requirements

Information on capital costs has not been collected, but as suggested for rotating biological contactors, the cost of the unit delivered to the works should be compared carefully with the cost of site works, which may be greater. Nearly all manufacturers give running costs, as kW absorbed and the examples for four different types of plant (given as "equivalent heads" of water, to normalize for flow rate treated or specified) shown in Fig. 4 vary greatly between type of unit. The consistency of such data within ranges of plant leads one to suspect that curves are idealized and it is not often clear whether the power absorbed is merely for aeration or reflects also that of associated pumping and for operating comminutors. If these are not taken into account, the relative total power absorbed (as "equivalent head") by activated-sludge systems are higher compared with rotating biological contactors than indicated in Fig. 5. Thus, for the four systems in Fig. 5 the manufacturer's quoted values for power absorbed lie in the range 0.0018-0.014 kW/hd or 0.043-0.34 kW/hd d. For a given pair of 1000-population equivalent, mechanically-aerated, extended-aeration units installed at Kidlington [32] to provide temporary uprating in an overloaded works (resident population 18 000) the average consumption of electricity was 237.5 kWh/d, or 0.12 kWh/hd d, i.e. an intermediate value.

Nicholl [33] has estimated the following maintenance requirements for package extended-aeration and contact-stabilization plants:

Labour - 300 visits yearly of 1.5 h each.

Transport - 300 visits yearly.

Desludging - One tanker visit per month.

At daily visits some, or all of the following might be noted or carried out [33]:

Time, flow rate, power consumption (kWh), weather.
Appearance of crude sewage, mixed liquor and effluent.
Sludge volume in 30-min settling test.
Inspection of inlet, outlet, aerators, compressors and air-lifts.
Raking of screens, cleaning of weirs and baffles, removal of grease, scum and fat.

BIOLOGICAL FILTRATION

Biological filters of traditional design, e.g. to CP 302:1972 [2], have long been accepted as ideal for small works, to follow treatment by septic tanks. When mineral media are used they do not lend themselves to package construction. However, several manufacturers specialize in the supply of individual assemblies, such as distributors, dosing siphons, filter-floor tiles and pre-cast walling. They will often supply complete packages to enable a filter to be assembled on site.

Plastics filter medium, with its lower bulk density (e.g. 40-80 kg/m^3 dry, 200-750 wet [34]), compared with mineral media (600-1600 kg/m^3 dry, 1100-2000 wet) enables lighter, tower-shaped structures to be made and to be delivered as prefabricated units. The authors' enquiries have found only two manufacturers in the UK who advertize package biological filter plants, although other manufacturers have expressed a readiness to construct packages to the customer's individual requirements.

Both of these packages treat macerated crude sewage using plastics filter medium arranged in a tower located on top of the humus sedimentation tank. Recirculation of liquor is necessary in both cases to maintain the irrigation rate (m^3/m^2 d) above a minimum value.

The Acalor package sewage-treatment unit (Acalor International Ltd, Crawley, Sussex) uses the company's Biofil random-fill plastics medium and is made in ten standard sizes to treat sewage from equivalent populations from 25 to 350 (DWF range 10-60 m^3/d). Operating loadings are quoted as 0.3-0.7 kg BOD/m^2 d and the humus sedimentation tank, designed to CP 302:1972 [2] will treat flows up to 6 DWF. Larger packages with separate filter beds and humus tanks are also made.

The Mono Towapak (Mono Oakes Ltd, Macclesfield, Cheshire) contains sheet plastics medium in a tower mounted above tanks for mixing recirculating liquor and macerated sewage and for humus settlement. There are seven sizes treating sewage from equivalent populations of 22-210 and flows of 2.7-27.0 m^3/d.

In both designs, the tanks can be mounted below ground level so that only the tower protrudes.

An early version of the Mono Towapack was tested by the Water Pollution Research Laboratory, as the "extended-filtration" system [23] during a period of 13 months. The main conclusion was that with the maximum rate of application of crude sewage (1.9 m^3/m^3 d, 0.87 kg BOD/m^3 d) over a period of 18 h daily, an effluent meeting a 30:20 standard could be produced in summer with partial nitrification, although in winter a lower rate (about 1 m^3/m^3 d, equivalent to about 0.5 kg BOD/m^3 d) was more appropriate. The main operational difficulty was with rising sludge in the settlement tanks and clogging of the upward-flow clarifier. It is therefore recommended that the settlement tank should be desludged at least weekly. Sludge production was estimated as 0.6 kg/kg BOD removed. The sludge became malodorous on standing. At no time during the 13 months did the medium become clogged despite the use of comminuted crude sewage and this was understood to be the experience of plants in the field. Similarly, experiments at the Coleshill experimental plant of the WRC are testing four types of random-fill plastic medium for treating fully, sewage which has been finely screened but not settled. No clogging has been noted in the first two months of operation.

This extended filtration system would therefore appear to have several advantages for use in isolated communities, since it is simple, requires only weekly attention and is compact. A major element of running costs is the electricity consumed to maintain the necessary ratio of recirculated to incoming flow (6 to 12:1 in the WPRL trials). If the head from humus tank weir level to distributor feed and the recirculation ratio are known the equivalent head can be calculated (as the product) and used to compare efficiency with dissimilar package plants and traditional biological filters. In the case of one range, the manufacturer has quoted a power absorption of 0.25 kW for a unit treating 10 m^3/d (equivalent head 220m) and 1.1 kW for60 m^3/d (161 m). These two values are in the same range as rotating biological contactors and the compact circular activated-sludge plants (TNO rotors) shown in Fig. 5 so that this type of plant may be expected to show similar costs for power, whilst requiring attention perhaps only weekly.

SLUDGE DIGESTION

Package Anaerobic Digesters

Anaerobic digestion is traditionally considered to be an expensive but essential process for the stabilization of sludges and is normally only carried out at major regional sewage-treatment works using large concrete digestion tanks ranging in size from 1000 m^3 to 10 000 m^3. Recently, however, several manufacturers have started to produce a range of small, package anaerobic digesters. Designed originally for use on farms, these digesters are either factory-built or constructed from prefabricated, glass-enamelled steel tanks fitted with a fixed roof and a separate gasholder. Heating and mixing of the digester contents are usually carried out using unrestricted gas recirculation and heating coils set in the centre of the digestion tank where mixing is most likely to be the most efficient. A reasonable flow of sludge past these heating coils is essential to prevent local overheating which would otherwise cause sludge solids to become baked onto the heating coils causing a gradual loss of heat-exchange efficiency. Early designs of traditional sludge digesters which were fitted with heating coils just inside the perimeter of the tank suffered severely from this effect.

The prospect of being able to use relatively low-cost digestion equipment at small sewage-treatment works has caused considerable interest amongst the water authorities and this has coincided with a renewed general interest in the process itself which has considerable amenity value for water authorities faced with the problem of sludge disposal.

One of these prefabricated steel digesters (Farm Gas Ltd) has been installed at the Pitts Mill sewage-treatment works of the Severn-Trent WA to assess its suitability for use on small sewage works. This unit, has been described in detail by Noone and Boyd [37] but briefly, the installation comprises an 80-m^3 glass-coated steel digestion tank plus a 10-m^3 raw sludge holding tank and a 5-m^3

prefabricated GRP gasholder. Thermal insulation for the heated sludge digestion tank is provided by a 100-mm layer of polyurethane sprayed onto the inside of the digester walls and a 50-mm layer of polyurethane sprayed on the inside of the digester roof. This complete digestion installation was assembled on-site in a total of 18 working days and at a capital cost of £20 950 and provides sludge digestion for a works serving 2600 people.

Another small (30 m^3) factory-built digester has been undergoing performance trials at Stourpaine sewage works (Wessex WA), where it has been digesting the primary sludge from a population of about 1200. Based on experience with this small unit, the manufacturers (Hamworthy Engineering Ltd) are now also offering an improved range of much larger prefabricated anaerobic digesters that can be rapidly assembled on site.

Performance of Anaerobic Digestion Equipment

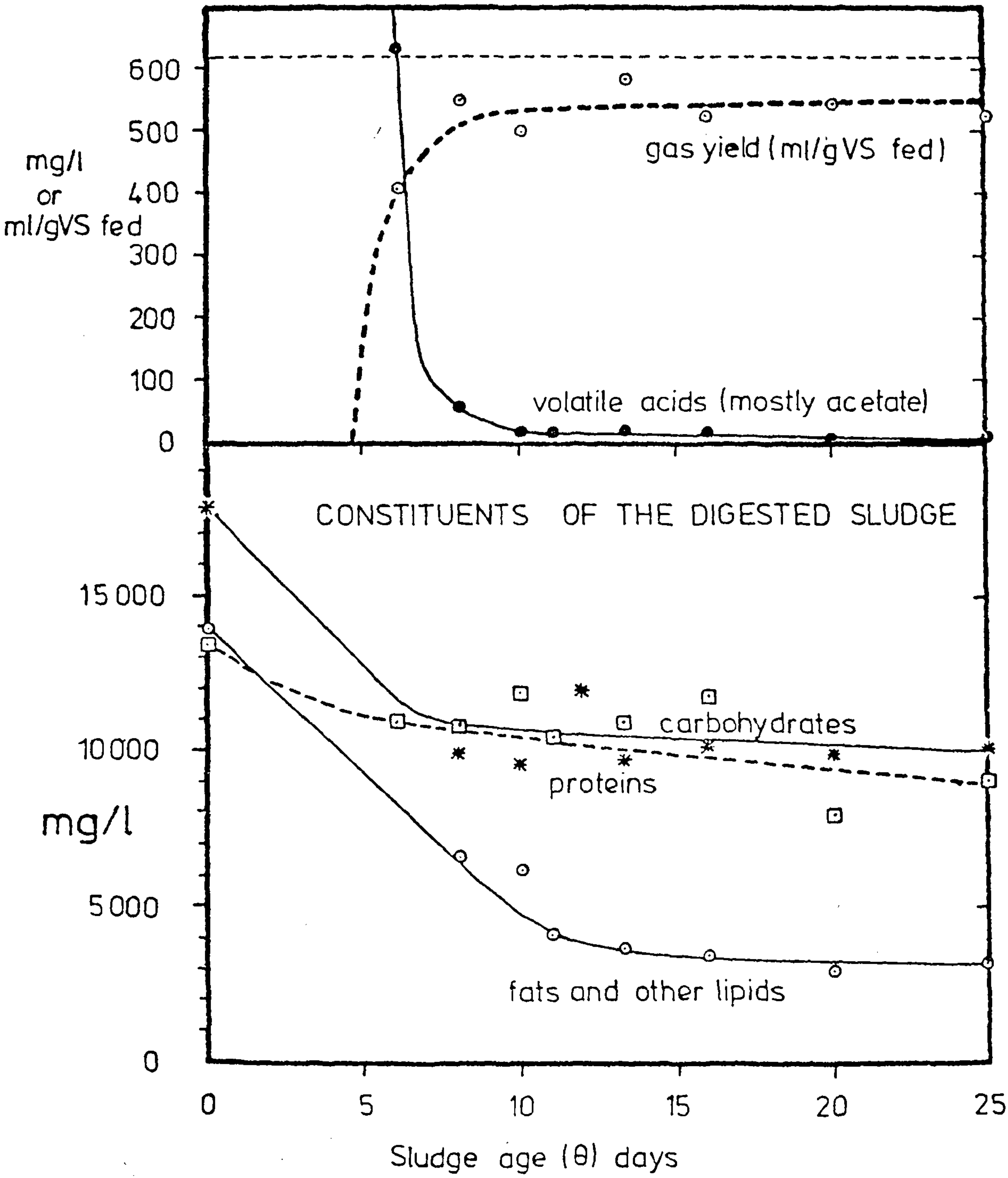
The current designs of package plant and prefabricated digestion equipment are all relatively new and were intended originally for use on farms. Their adoption by the water industry will probably require (and stimulate) an intensive period of modifications and developments to provide units tailor-made to fit the requirements of the water authorities. A detailed assessment of many of the engineering components of both these and of traditional sludge digesters has been published by Noone and Brade [36]. For example, Noone and Brade [38], when modifying and uprating traditional sludge digesters, found that a heating coil of the type commonly used in these package plants tended to accumulate an excessive amount of rags and paper and it was subsequently modified to discourage this. As an alternative, the Rowett Research Institute in Scotland prefers to use small updraft tubes similar to those commonly installed in traditional digesters to provide heating and mixing for their small farm waste digesters. The obvious advantages and competitive prices of these plants probably ensure that operating problems will be quickly solved as and when they arise.

Performance of Anaerobic Digestion Process

Over the years the anaerobic digestion process has aquired the reputation for being a slow, sensitive and unreliable fermentation. However, digestion failures are rare but memorable and because of this there has been a tendency in the past to overdesign and oversize digestion tanks in the belief that long sludge retention periods, upwards of 25 d, provide greatly increased process reliability.

More recent studies [37] are now starting to confirm the inherent reliability of the process and its ability to operate at high loadings. Fig. 6 shows the steady-state performance of a typical laboratory digester at the WRC [37] where it

Figure 6 Performance curves for the anaerobic digestion of sewage sludge at 35°C



can be seen that mesophilic sludge digesters require about 10-15 d retention period to provide maximum gas production and a good reduction in the grease content of the sludge but that the fermentation actually remains stable at retention periods down to 6 d. A side-benefit of short retention periods and of thickened feed sludges is that the vigorous fermentation obtained at these high loading rates provides a substantial degree of self-mixing and assists in preventing stratification of the digester contents.

Studies are now being undertaken by staff of the WRC to predict the performance of these high-rate digesters under erratic and variable loads and to provide rapid recovery techniques for accidental overloads.

NOVEL SYSTEMS

Aerated Submerged Filters

In this system a medium of high specific surface area supporting growth of biological film is submerged in a tank through which sewage flows and which is aerated by diffusers in the base of the tank. The only UK commercial system to the authors' knowledge is that of Mono Oakes Ltd - the Monopack sewage-treatment plant. This is available in four sizes to treat sewage from equivalent populations of 150-450 persons. The plant consists of three tanks in series:

(a) A primary treatment tank receiving macerated crude sewage in a central sedimentation section and providing for aerobic digestion of primary sludge in the concentric outer section.

(b) An aerated treatment tank packed with plastics medium.

(c) A secondary settlement tank.

Settled humus solids and scum are returned to the aerated treatment tank and the aerobic digester is stated to be of significant size to contain one month's production of sludge. No further details are available. Full-scale trials of the early Aermedpack package plant were made at Narborough sewage-treatment works by the WRC in collaboration with the Anglian WA and Monopumps (Engineering)Ltd, and details are available in an unrestricted report [38]. It is emphasized that experience gained in these trials was incorporated in the design of the Monopack treatment plant.

Suspended Biomass Support Particles

The Captor process has been developed in the UK by Simon-Hartley Ltd (Stoke-on-Trent, Staffs) from an idea originated in the Chemical Engineering Department, UMIST [39,40]. It is an intensive activated-sludge process in which an aerated tank contains in suspension, biomass support particles about 25 mm square x 10 mm thick, made of open polyurethane foam upon which the biological slime accumulates.

About 40 000 particles are added per m^3 of tank capacity and in operation the concentration of biomass accumulating is within the range of 8-15 g/m^3 of bulk tank volume. This represents an increase in biomass of about 2-4 times over conventional activated sludge, requiring a proportional intensification of aeration capacity but resulting in a corresponding reduction in size of aeration tank. The merit of the foam support particles is that they can be recovered mechanically and that surplus biomass can be removed as a thick paste containing 8-10% DS (w/v) by passing them between rollers. The need for conventional sedimentation is therefore eliminated in theory [35,36]. The smallest size of plant listed, treating 250 kg BOD/d, and therefore suitable for a population equivalent to about 5000 persons, has an aeration tank volume of about 78 m^3 overall.

The system is primarily intended for treatment of strong industrial wastes. At present there are no data to indicate the efficiency of the process when treating sewage. Desk studies by WRC staff have indicated that the process could be economic in competition with other processes, depending upon the lifespan of the support particle. If 10% of the medium required replacement annually, the study indicated that the process could be 20% cheaper than a conventional activated-sludge plant at a new works (based on net present value for a discount rate of 5%) [36]. A co-operative project for evaluating the system is awaited.

CONCLUSIONS

1. This paper surveys the various types of package sewage-treatment units and those delivered in prefabricated units which are available from manufacturers in the UK to serve populations up to 5000. It also discusses the implications of official recommendations for design and operation, in particular those of the new British Standard Code of Practice [3] which, at the time of writing (July, 1981) was at the public draft stage. The recommendations appear to build upon those of earlier codes [2,15] by including treatment on rotating biological contactors and requirements for aeration capacity and secondary settlement for activated-sludge plants.

2. The importance of correct maintenance schedules is often overlooked in small works. The advice given results from the experience of the authors and their colleagues under field conditions. It is thought that an analytical survey of maintenance schedules , operational practices, and of the costs of installation, running and maintenance of package plants would give valuable information to operations directorates in the UK water service, but this is beyond the scope of this paper. Those comparisons which are made suggest that costs of site works and preparation can exceed that of the package plant and are a significant proportion of the total cost of a package installation. The costs for electricity absorbed

by plants in the population range up to about 300 are similar for rotating biological contactors, compact circular activated-sludge plants with TNO rotors and for extended filtration. The limited data would indicate relatively high electricity costs for coarse-bubble activated-sludge packages and relatively low costs for rotating biological contactors serving populations greater than 300.

3. It is noted that care must be taken in design of packages and also of pumping stations to minimize the effects which surges in flow - often extreme at small works - have on effluent quality and that some form of "polishing" of the final effluent is needed where these are required consistently to meet a 20:30 standard.

4. Note is taken of some new developments in package plants but not of those based on the oxygenic or anaerobic fluidized bed, apart from remarking here that a 350 m^3/d capacity fluidized bed (volume of reactor 20 m^3) is now being tested at the Coleshill experimental plant of the WRC [41] and that such units, in virtue of their small size, relative to treatment capacity, would appear ideal for development as packages.

5. The suitability of certain types of package, notably the rotating biological contactor and the extended filter for isolated communities, particularly because of the low frequency of maintenance, is suggested. A further application of package plants, because of their relative portability, is for the temporary uprating of overloaded village works prior to extension or rebuilding.

ACKNOWLEDGEMENTS

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APPENDIX I

A GUIDE TO UNITED KINGDOM MANUFACTURERS OF PACKAGE SEWAGE TREATMENT PLANT SERVING POPULATIONS UP TO 5000

By D.W. Harrington, LIBiol, (Associate Member)
Water Research Centre, Stevenage Laboratory

This guide has been compiled from manufacturer's brochures and other literature obtained in reply to enquiries of manufacturers received at up to the time of the Symposium. It is offered for guidance only. The compiler would be pleased to receive details of any discrepancies or additional information. Readers are asked to confirm details with manufacturers. Although intended as a comprehensive list of package plants it has been recognised that individual components for construction of biological filters, such as dosing siphons, distributors and media are offered as packages by some manufacturers and these are included. The guide contains references to plant and products specifically used in treatment of domestic sewage from small communities and not necessarily to those for treating other liquid wastes.

Manufacturers of Septic Tanks

Manufacturer, address, telephone no.	Description
Albion Concrete Products Ltd Llangadog Dyfed, SA19 9LT 05503-3271	Fabricated in circular concrete rings to CP302:1972.
Clearwater Systems Ltd Riverway Estate Portsmouth Road Guildford, GU3 1LZ 0483-33831	Manufactured in GRP to CP302:1972. Onion shaped structures.
GBP Ltd Dial Glass Works Audnam Stourbridge, DY8 4YN 038-43-2074	Manufactured in GRP to CP302:1972. Onion shaped structures.
Klargester Environmental Engineering Ltd College Road Aston Clinton Aylesbury Bucks 0296-630190	Manufactured in GRP to CP302:1972. Onion shaped structures. Also supplied from Company's offices/factories at Belfast, East Kilbride and Okehampton.
Marine Ventures Ltd Fifth Floor 8 Waterloo Place London, SW1Y 4BE 01-930-0515	Manufacture the Bi-A-Robi system. Method for uprating existing septic tanks by installing an aeration device.
Treatment Plant Contracts Ltd Bridge House 56 Lampton Road Hounslow Middx 01-570-7241	Manufactured in GRP to CP302:1972.
Hibbing Limited Station Road Kirby Cross Frinton-on-Sea Essex, CO13 OLU 02556-71565	Manufactured in GRP to CP302:1972.

UK Suppliers of Biological Filtration Plant serving populations up to 5000

Manufacturer, address, telephone no.	Description
Adams Hydraulics Ltd PO Box 15 York YO1 1XA 0904 22047	Offer a range of distributors.
Acalor International Ltd 6-10 Crompton Way Crawley Sussex, RH10 2QR 0293-23271	Package sewage plant. Prefabricated in steel or GRP. Plastic random medium of polypropylene (Biofil). Tower filter in 10 sizes for populations under 350. Larger sizes made to order. Comply with CP302:1972. Hydraulic load 200 l/hd d.
Albion Concrete Products Llangadog Dyfed, SA19 9LT 05503-3271	1) Albion Rectangular Tippler Biological Filter. Complete units for 4-6 persons. 2) Circular (Ring Type) units made from concrete rings (7 persons) 3) Circular (Wall Type) units made from concrete precast panels. Serve 8-222 persons (7 sizes). Comply with CP302:1972.
Ames Crosta Babcock Ltd Heywood Lancs, OL10 2DX 0706-67555	Offer a range of distributors
bs flocor Ltd 37 High Street Bridgnorth Shropshire, WV16 4DB 07462-61431	Offer Flocor R plastic medium (uPVC) of specific surface area (230 m^2/m^3). Used for uprating existing works or for new plant. Loadings 0.25-0.4 kg BOD/m^3 d and irrigation rates in excess of 1 m^3/m^2 d.
Clearwater Systems Ltd Riverway Estate Portsmouth Road Guildford, GU3 1LZ 0483-33831	Offer 'Monojet' automatic trickling filter distribution system. Self dosing. 5-200 persons. Comply with CP302:1972 Hyd. load 200 l/hd d. Org. load 60 g/hd d.
Davenport Eng Co Ltd 72 Harris Street Bradford, BD1 5JD 0274-29361	Offer a design and installation service.
Dorr Oliver Co Ltd Norfolk House Wellesley Road Croydon, CR9 2DS 01-686-2488	Offer a range of distributors.
Eta Process and Effluent Plant Ltd The Levels Brereton Rugeley Staffs, WS15 1RD 08894-6524	Offer a high specific surface area medium for uprating existing works or new works (210 m^2/m^3). Random plastic medium made of polypropylene (Etapak).

Manufacturer, address, telephone no.	Description
Farrer Wallwin International Ltd Millers Road Warwick, CU34 5PE 0926-495231	Offer a range of small rectangular and circular self dosing units. Comply with CP302:1972.
Farrow Effluent Engineering Cosmos House Bromley Common Kent, BR2 9NA 01-464-6556	Offer a design and installation service.
Hawker Siddeley Brackett Ltd Hythe Colchester Essex, CO2 8LB 0206-49881	Offer a range of distributors.
Macleod and Miller Engineers Ltd Whistleberry Road Blantyre Lanarkshire, G72 OTG Blantyre 2231-3	Offer a range of distributors.
Mass Transfer Ltd 124 Highgate Kendal Cumbria, LA9 4HE 0539-24232	Will offer a random plastic medium of high specific surface area for uprating existing works or for new works. (Filterpak).
Mono Pumps Ltd Martin Street Audenshaw Manchester 061-330-3031	Mono Towapak. Biological tower positioned on the settlement tank. Uses plastic sheet medium. Steel tower and settlement tank. 22-210 pop. (7 sizes).
Norton Chemical Process Products King Street Fenton Stoke on Trent 0782-45561	Will offer a random plastic medium of high specific surface area for uprating existing works or for new works.
Satec Ltd PO Box 12 Weston Road Crewe, CW1 1DE 0270-58311	Offer a range of distributors.
Simon Hartley Ltd Stoke on Trent Staffs, ST4 7BH 0782-29541	Offer a range of distributors.

Manufacturer, address, telephone no.	Description
Treatment Plant Contracts Ltd Bridge House 56 Lampton Road Hounslow Middx 01-570-7241	Package biological treatment. Prefabricated GRP tanks and filter arms. Also refurbishment service. 1-200 pop. (6 sizes). Conform to CP302:1972. Hyd. load 180 l/hd d. Org. load 55 g/hd d.
Tuke and Bell Ltd 43 East Street Horsham Sussex, RH12 1HR 0403-4371	Offer a range of distributors based upon the Code of Practice CP302:1972.
Whitehead and Poole Ltd PO Box 9 Radcliffe Manchester, M26 9NU 061-723-3821	Offer a range of distributors.

UK Suppliers of activated sludge plant serving populations up to 5000

Manufacturer, address, telephone no.	Trade mark or model	Equivalent pop. served, range (no. of sizes)	Description of plant		
			Principle	Construction	Design basis and loadings - hydraulic, organic (BOD)
Ames Crosta Babcock Ltd Heywood, Lancs, OL10 2DX Heywood (0706) 67555	Oxylac	>500	Extended aeration, surface aerator	Shallow rectangular excavations with slab or membrane linings. Separate settlement tanks.	Designed to CP302:1972. 180 l/hd day, 55 g/hd day
British Oxygen Company Deer Park Road London, SW19 3UF 01-542-6677	Megox		Extended aeration, external oxygenator, pure oxygen process, high MLSS	Steel circular tank. Single reactor includes integral settlement zone.	Non-conventional process.
Davenport Eng. Co Ltd 72 Harris Street Bradford 0274-29361			Extended aeration, surface aerator	Mild steel, concrete or GRP tanks	
Degremont Laing Ltd Aquazur House Elstree Way Borehamwood Herts, WD6 1WF 01-207-0222	Minibloc	100-500 (5 sizes)	Extended aeration, diffused air	Steel tanks preassembled at the factory	Conforms with Technical Memorandum on Activated Sludge Treatment, Ministry of Housing and Local Government 1969
	Diapac II	500-5000	Extended aeration, surface aerator or diffused air. Combined tank concept - no separate settlement. Two tanks alternating between aeration and settlement	Steel or concrete circular tanks	
Ditton Associates 4 Portman Mews London, W1H 9AU	Extended aeration plant	150-500 (8 sizes)	Extended aeration, diffused air	GRP tanks	Conforms to Technical Memorandum. 180 l/hd d, 55 g/hd d
Flyght Pumps Ltd Colwick Nottingham NG4 2AN 0602 241321	Flyght ejector	>150	Extended aeration, batch treatment (fill and draw process) Coarse bubble	Concrete circular tanks (3 tank system, buffer, treatment and sludge)	
	Foamed aerator		Fine bubble diffusion	Concrete tanks	

Manufacturer, address, relephone no.	Trade mark or model	Equivalent pop. served, range (no. of sizes)	Description of plant: Principle	Description of plant: Construction	Description of plant: Design basis and loadings - hydraulic, organic (BOD)
Dykecrest Ltd Gordon Chambers 36 Cheapside Henley Stoke-on-Trent, ST1 1HE 0782 274777		Individually		Steel or concrete tanks	
Eflo Internation Ltd Bath Road, Padworth Reading, RG7 5HR 073-521 2648/3711	Modular Filandraw Units and Filandraw Land Units	3-30 and 30-800 respectively	Extended aeration, diffused air. Second aeration zone is used intermittently as a settlement tank	Concrete or glass-coated circular steel tanks	Conforms with Technical Memorandum
	Constant Transfer Land Units	<500	Extended aeration, diffused air. Constant transfer of aeration tank contents to settlement tank	Concrete or glass-coated circular steel tanks	
Esmil Ltd Station Road St Neots Huntingdon Cambs PE19 1QF 0480 73461	ADR	75-500	Extended aeration, diffused air.	Steel tanks	Conforms with Technical Memorandum 227 l/hd d, 57 g/hd d
	CSC	600-4000	Contact stabilisation, diffused air	Steel or concrete circular tanks	
Farrer Wallwin International Ltd Millers Road Warwick, CV34 5AE 0926 499231	Oxytank	>200 (13 sizes up to 10,000)	Extended aeration. Oxidation ditch principle. Horizontal rotor or surface aerator	Steel or concrete circular tanks with integral settlement	Conforms with Technical Memorandum 230 l/hd h 55 g/hd h
	Contact stabilisation	>500 (15 sizes up to 8000)	Contact stabilisation diffused air	Steel or concrete circular tanks	
Klargester Environmental Engineering Ltd College Road Aston Clinton Aylesbury Bucks 0296-630190		150-600	Package extended aeration	Glass fibre	
		<5000 and 10 000	By modular increments. Extended aeration and contact stabilization options, diffused air	Steel or concrete circular tanks	Conforms with Technical Memorandum or to suit other criteria

Manufacturer, address, telephone no.	Trade mark or model	Equivalent pop. served, range (no. of sizes)	Description of plant		
			Principle	Construction	Design basis and loadings - hydraulic, organic (BOD)
Hamworthy Engineering Ltd Fleets Corner Poole Dorset BH17 7LA 020-13-5123	Super Trident	5-600 (13 sizes)	Extended aeration, diffused air. For use on ships, relaxed standard, chlorinated fill and draw tank before final discharge	Steel prefabricated tanks	Designed to IMCO requirements ('50:50' standard) 70 l/hd d, 60 g/hd d
	Super Trident (Land model)	25-200 (5 sizes)	Extended aeration, diffused air	Steel prefabircated tanks	Designed to CP302. 227 l/hd d, 60 g/hd d
Hawker Siddeley Water Engineering Molly Millars Lane Wokingham Berks, RG11 2PY 0734-782243	Package Plant	400	Extended aeration, diffused air (designed to order)	Steel prefabricated tanks	Conforms with Technical Memorandum.
	Oxidation ditch	Range of sizes	Extended aeration, surface aerator, no final settlement tank (fill and draw principle). Air bubble system connected to the rotor bridge. Larger sizes include a settlement tank and may incorporate a denitrification stage	Preformed concrete channels	
A Johnson Construction Company Ltd Claremont House 20 North Claremont Street Glasgow, G3 7LE 041-332 7364	Inka Bioreactor	50-200	Extended aeration and contact stabilisation, diffused air	Prefabricated concrete or steel tanks. Smaller units have two circular steel tanks. Larger plants have single circular tanks	National Swedish Environment Protection Board (Higher standard than UK) 230-300 l/hd d, 55-60 g/hd d

Manufacturer, address, telephone no.	Trade mark or model	Equivalent pop. served, range (no. of sizes)	Description of plant		
			Principle	Construction	Design basis and loadings - hydraulic, organic (BOD
Lightnin Mixers Ltd Poynton Stockport, SK12 1LH 0625-876421	Lightnin Treatment System	>500	Extended aeration, surface aerator	Square concrete tanks	Designed to US practice. Conservative on hydraulics 180 l/hd d, 55 g/hd d
	Draft Tube System	>500	Extended aeration, oxidation ditch principle, surface aerator	Square concrete tanks	
Macleod and Miller Engineers Ltd Blantyre Works Whistlebury Road Blantyre Glasgow, G72 OTG Blantyre 82231-3	Biox 1	30-500	Two aeration sections, extended aeration, diffused air	Prefabricated steel tanks with integral settlement	Conforms to Technical Memorandum.
	Biox 1EA	30-500	One aeration section	"	
	Biox 2	>1000	Contact stabilisation, diffused air. Comminuter supplied as standard	Circular steel tanks	
	Biox 3	>1000	Extended aeration, diffused air. Comminuter supplied as standard	Circular steel tanks	
The Manor Engineering Co Ltd Longton Stoke, ST3 4DD 0782 313081			'Cascade' surface aeration (horizontal aerator)		'Custom-designed' package units
Molex Ltd The Trading Estate Farnham Surrey, GU9 9NN 025-13-21201	Molex Extended Aeration Sewage Treatment Plant	>10	Extended aeration, diffused air, two tank system	GRP tanks	Designed to CP302. 135 l/hd d, 40 g/hd d

Manufacturer, address, telephone no.	Trade mark or model	Equivalent pop. served, range (no. of sizes)	Description of plant		
			Principle	Construction	Design basis and loadings - hydraulic, organic (BOD)
Mono Pumps Ltd Martin Street Audenshaw Manchester 061-330-3031	Monopak	150-450 (4 sizes)	Extended aeration. Three-tank system includes primary and aerobic digestion. Diffused air. The aeration system contains plastic medium	Circular steel tanks	Non-conventional treatment process. 130 l/hd d
	Mono Aermedpak	200-600 (4 sizes)	Extended aeration. Three-tank system, no primary stage. Diffused air. The aeration stage contains plastic medium	Circular steel or GRP tanks	
Permutit-Boby Ltd Permutit House 632-652 London Road Isleworth Middx, TW7 4E2 01-560-5199	Permak (HS)	50-250 (6 sizes)	Contact stabilisation, diffused air. Hand-scraper model with integral settlement tank	Steel circular tanks	Conforms to Technical Memorandum. 180 l/hd d, 54 g/hd d
	Permak (MS)	250-5000 (11 sizes)	Contact stabilisation, diffused air. Mechanical-scraper model with integral settlement tank	Steel circular tanks	
Polcon Environmental Control Systems Ltd High Street Much Hadham Herts, SG10 6DA 027-984-3103	Helixod aerators		Package plants designed to order	Concrete square tanks	

Manufacturer, address, telephone no.	Trade mark or model	Equivalent pop. served, range (no. of sizes)	Description of plant		
			Principle	Construction	Design basis and loadings - hydraulic, organic (BOD)
Satec Ltd PO Box 12 Weston Road Crewe, CW1 1DE 0270-58311	A-D	100-2300 (64 sizes)	Extended aeration, diffused air	Prefabricated rectangular steel tanks	Conforms to both CP302 and Technical Memorandum 230 l/hd, 55 g/hd d
	R	1500-21,000 (117 sizes)	Contact stabilisation, diffused air	Prefabricated sections in steel or concrete	
	MM	300-1600 (13 sizes)	Extended aeration, surface aerators	Rectangular concrete tanks	
	MD	100-1600 (17 sizes)	Extended aeration Diffused air	Rectangular concrete tanks	
Simon Hartley Ltd Stoke on Trent Staffs, ST4 7BH 0782-29541	Capitox	100-5000	Extended aeration, surface aerators. Two-tank system. Patented 'Spiroflo' device	Steel or concrete tanks	Conforms to both CP302 and Technical Memorandum. 200 l/hd d, 55 g/hd d
Venturator Ltd 129 High St Guildford GU1 3AA 0483-505277	M.F.		Extended aeration contact stabilisation. Course bubble multi-directional aerators.		
	D.F.		Oxidation ditches. Course bubble directional flow aerators.		
Whitehead and Poole Ltd PO Box 9 Radcliffe Manchester, M26 9NU 061-723-3821	Package Units	50-1000 (13 sizes)	Extended aeration, two aerators available; vertical shaft or TNO rotor	Steel prefabricated tanks	Conforms to CP302 and Technical Memorandum. 180 l/hd d, 55 g/hd d
	Compact system	>200 (13 sizes)	Extended aeration, surface aeration	Concrete or steel circular tanks	
	Oxidation Ditch	>200 (20 sizes)	Extended aeration, surface aeration	Concrete channels	

Suppliers of Rotating Biological Contactors serving populations up to 5000

CJB Developments Ltd
Airport Service Road
Portsmouth
Hants, PO3 5PG

Tel: 0705-64911

UK licensee for the range of RBC units marketed by Autotrol Ltd, Basle, Switzerland. Disc material of alternate plain and corrugated polyethylene.

(a) Biosurf process - mechanically driven

(b) Aerosurf process - drive unit is replaced by a low pressure blower which drives air into the RBC tank below the media into cups fixed to the disc perimeter.

Clearwater Systems Ltd
Riverway Estate
Portsmouth Road
Guildford
Surrey, GU3 1LZ

Tel: 0483-33831

UK licensee for the range of RBC units marketed by Mecana SA, Switzerland.

(a) Biospiral - Mechanically driven. Disc pack is assembled in the form of a continuous spiral from thin PVC. The second unique design is the provision of an automatic drum filter. Loadings 12-16 g/m^2 d. Compact self-contained package plant.

(b) Biodrum - Drum of hollow polythene balls. Floats semi-submerged on the surface of the effluent. All units are custom built.

Eflo International Ltd
Bath Road
Padworth
Reading, RG7 5HR

Tel: 073-521-2648/3711

Manufacture a range of packaged rotating biological contactors serving 10-500 persons. Incorporate a two-stage septic tank.

Farrer Wallwin International Ltd
Millers Road
Warwick, CV34 5AE

Tel: 0926-495231

Sewpadisc - Manufacture a wide range of disc units which are packaged for up to 500 pop. The septic tank provides two stage sedimentation. The discs are convoluted for rigidity and made of GRP. Design based on CP302:1972 with a disc loading of 6 g/m^2 d. Hydraulic and Organic loads are 227 1 and 55 g/hd d. Larger units custom built.

A Johnson Construction Co Ltd
Claremont House
20 North Claremont Street
Glasgow, G3 7LE

Tel: 041-332-7364

Biorotor - Manufacture a rotating biological contactor under licence from a Swedish company, Nordiska Vattenprojekt AB. Several process combinations are available. The discs are open-mesh plastic with radial support arms.

Klargester Environmental Engineering Ltd
College Road
Aston Clinton
Aylesbury
Bucks

Tel: 0296-630190

BioDisc - Manufacture a wide range of disc units in GRP. Discs are convoluted for added rigidity. Manufactured under licence from Ames Crosta Babcock Ltd (q.v.). Agrément Board Certificate Package units available in eight sizes up to 500 pop. Larger sizes available with separate primary and secondary settlement stages. Disc loadings 6.0-9.0 g/m^2 d. Hydraulic and organic loadings 200 l/hd d and 60 g/hd d.

Modular Disc Plant. Disc units available separately and as rotors for installation into BC range of concrete tanks. Single-house to 2000 pop.

Large rotor for installation in larger rotating biological contactor systems. Plastic pack, 3.66 m dia. of glass fibre and other plastics, with surface areas of 10 000, 14 000 and 18 000 m^2.

Biorotor - "Rotorsystem" manufactured under licence from a Swedish Company, "Rotorsystem" Miljo AB. This is a revolving drum on rollers. The rotor is built of circular corrugated discs. They are formed in such a way that water and air move from disc to disc in series. The drum is totally enclosed and a compressor supplies air to the contents. Sewage is fed into the unit halfway up and the cascade effect aids oxygen transfer. A range of 10 sizes are offered serving 100-5000 persons.

Macleod and Miller Engineers Ltd
Whistlebury Road
Blantyre
Glasgow, G72 OTG

Tel: Blantyre 82231/3

Biox Rotating Disc - Manufactured as package units for populations up to 500. Tank is of mild steel and the discs of polypropylene. Disc loading is 9.5 g/m^2 d and hydraulic and organic loadings of 180 l/hd d and 54.5 g/hd d. Various process options available.

AUTHORS' INTRODUCTION

Introducing the paper DR. PIKE said that the package plant had been defined in the paper as one 'which could be delivered from a lorry to the treatment works', and this imposed an indefinite limit on size. He said that because of their size and nature, package plants would be purchased not only by water authorities but also by small businesses, holiday villages and householders. The authors therefore felt that the main consideration was the need for extreme reliability despite neglect, as the owner might be unwilling to care for the plant once it was installed. Since the publication of the British Standard Code of Practice (CP 302:1971) and the Ministry of Housing Technical Memorandum in 1969 there had been a substantial increase in the acceptance and sale of package plants - there was now about 20 years' experience of the extended-aeration system and 12 years' experience of the rotating biological contactor in the UK. He said that experience in operation had led to acceptance of the design criteria and that the factors which governed performance were known. Although the package plant had been accepted, there were still problems of operation, and Dr. Pike wished to highlight these.

He said that, firstly, the failure at design stage to appreciate the special features of packages and small works was the cause of many problems. It was essential at the design stage to survey the site, to ascertain what labour was available for operating the plant, to ensure that the demand was calculated correctly, to assess the maximum contributory population-equivalent and to note whether there were any special features such as the varying loading at a tourist site, accessibility during adverse weather conditions and then to select the most suitable type of plant. Secondly, he said that they had stressed the need for paying particular attention to strength and reliability of the components, but he considered that the problems in this respect had been appreciated during recent years and that present-day plants were quite reliable. Thirdly, it had to be realized that CP 302 and the new Code of Practice were intended as guidelines and not as instructions for design. Hence manufacturers were left with considerable scope for constructing plant within a few constraints, but because they were packages this implied that designers were often forced to adopt unfamiliar, and perhaps not the most suitable, shapes for items such as sedimentation or settling tanks, in order to accommodate them within the package, so that 'dead space', short-circuiting and poor mixing may be created as a result. Finally, it was important to ensure that the purchasers understood the instructions.

Dr. Pike felt that it was lengthy and costly to evaluate the basic criteria governing performance and to construct mathematical models of performance by experimentation. It required controlled experiments on many plants or alternatively many experiments on one plant over a long period.

He referred to the use of package plants to uprate overloaded works. These could be utilized and then moved to another site. Two examples given were of the Biodisc placed in **series at the small village works (Works 8)**, where it achieved not only polishing but complete nitrification extended-aeration plant at Kidlington[32]. A further type of uprating was the suggestion of Autotrol Corporation of using discs mounted above, for example primary tanks, or above coarse-bubble activated-sludge plants.

Dr. Pike said that in writing the paper, the authors became aware that there was a shortage of published information on topics such as costs of purchase, site works, operation and labour requirements. Dr. Pike said that Table 5 incorporated information that had been collected during field work on rotating biological contactors, and the conclusions had been drawn from them in the paper. He said that Figs. 4 and 5 were an indication of relative power costs reduced to equivalent head so that it was possible to compare plants requiring electricity with those which were gravity-operated such as biological filters. The results of Fig. 4 implied that the larger rotating biological contactors were more economic in electricty consumption than the smaller ones. Fig. 5 utilized the equivalent head concept in which the electricity consumption was converted through mechanical considerations into the head to which the rate of power consumption would increase that flow of water per day. The conclusions were that rotating biological contactors serving populations exceeding 200 equivalents were more economical in power consumption than the most efficient type of activated-sludge package, the TNO compact circular plants with sludge digestion (which were not affected by size) and that coarse-bubble aeration plants were expensive on power. The two types of package tower filters described, which had sedimentation underneath them, were comparable in power consumption with rotating biological contactors.

Dr. Pike said that if one pursued the equivalent head argument further and regarded the plant as a kind of respirometer, one could calculate the daily mass of oxygen consumed in treating the sewage from one population equivalent. With typical strength settled sewage treated to meet a 30:20 standard, this would account for about 46 g of oxygen, assumimg that nitrification was occurring. One could then calculate the power absorbed in the biological filter, which in treating one population-equivalent of sewage amounted to 125 kg water falling 2.6 m in 1 day. This rate over the day was only 3.7×10^{-5} kW. The estimated aeration efficiencies could then be calculated for various units. For a 1000 population-equivalent rotating biological contactor this was about 1.8 kg O_2/kWh, which he said was about the maximum for a fine-bubble diffused-air system working into fully de-oxygenated water under ideal conditions. For the biological filter the calculated aeration efficiency was extremely high at about 58 kg/kWh. As delegates were aware, filters occupied large areas, used large surface areas and had very thin biological films. Dr. Pike said that consideration of such calculations showed that the biological filter gave some leeway for spending more money on attention if one costed electricity in the same way as manpower. However, he had pointed out in the discussion to a previous paper on this subject[17] that the cost of 30 min daily maintenance to a biological filter at about £625/annum was greater than the power costs of a rotating biological contactor at about £263/annum for 1000 population equivalent.

Finally, Dr. Pike said that several speakers during the presentation of the previous papers had referred to effluent standards and the difficulty of estimating 95 percentile values. He said that sewage entering a works varied in strength throughout the day and with time, so that one could measure its variance. One could also measure this variability as variance at all stages in the process. How did one obtain the relationship between variance and mean? He explained the significance of Taylor's power law, which said that variance and mean were often empirically related by a power factor in certain types of statistical distribution departing from the normality - mainly those involving biological systems. This meant that with any type of plant if this relationship holds one could, by repeated sampling of liquors at different stages of treatment, work out the relationship between variance and mean as he had suggested in a former paper[17]. By selecting a value for the mean effluent quality, the variance could be calculated, and thus the standard deviation, which multiplied by a factor of 1.65 gave the 95 percentile value corresponding to the mean.

DISCUSSION

MR. P.L. WALKER (Klargester Environmental Engineering Ltd), opening the discussion, said that the paper was so adequately and completely prepared that it left little else to be said. He said that as a manufacturer he valued the work that had been carried out by the WRC and generally manufacturers' own work and the experience of many package plants tended to identify closely with the research results and design criteria indicated by government bodies, the WRC in particular. He made an exception in the case of the early addition of British Standard CP 302 with which they had been at variance for some time, but was pleased to say that they were in reasonable harmony with the revised draft edition.

He said that in the paper Table 2 gave useful guidelines for DWF from various sources and indicated in the case of small domestic housing a figure of 120 l/h.d and that peak DWF rate was often more than a factor of two. However, many package plants served populations of 20 - 100 and in design specifications usually supplied by specifying bodies a figure of 200 - 250 l/hd.d was necessary. He wondered if the authors considered that this figure warranted closer scrunity. He said that the figure certainly allowed for variation in peak flows, but he wondered if this was at the expense of excessive retentions in the primary sedimentation tanks with resulting generation of septicity. He suggested that the value of Table 2 would be enhanced if organic loadings had also been included to complement the hydraulic figures.

Mr. Walker said that the authors stressed the need for routine maintenance of package plants and that it was his experience that the majority of problems arising from well designed package plants emanated almost solely from the lack of basic maintenance and desludging, as indicated by Dr. Pike's earlier comments.

He considered that in the application of septic tanks the sub-surface irrigation capacity of the ground was important. His experience had indicated that the results obtained were virtually useless unless the ground was suitable for sub-surface irrigation. CP 302 indicated simple tests that could be carried out to establish porosity, and he considered that this was absolutely essential. He said that the authors had stated that septic tanks were available for populations of up to 40, but he wondered if a figure in the region of 10 persons was more practical, because from experience it had been found that usually for higher populations there was insufficient ground for adequate percolation.

Mr. Walker referred to biological filter units in conjunction with septic tanks, privately operated, in remote areas and said that these were usually to be found in a totally inoperative condition. They were usually covered in debris and a breakdown of the distribution system resulting in 'ponding' and short-circuiting. He asked the authors if they considered that the use of a good sub-surface irrigation system in conjunction with a septic tank was probably more preferable than the addition of a biological filter in such circumstances.

He said that cesspools had tended to be disregarded and this was perhaps understandable, but nevertheless he knew from experience that there were at least three cesspools installed every week in the UK; this was perhaps a greater number than that of small package plants of, say, up to a 100 population. This indicated that they obviously fulfilled a need. Their great disadvantage was that the emptying cost was ever-increasing.

Mr. Walker said that the authors had considered the rotating biological contactor in some depth and the method was becoming the conventional treatment system for small communities in both the private and public sectors. Its advantages were adequately detailed in the paper, but the system still had to compete with conventional activated-sludge plants based on extended aeration and contact stabilization, and in the case of larger plants with oxidation ditches. The advantages could be summarized as minimal operating and maintenance costs and aesthetic acceptability, whilst the main disadvantage was a higher capital cost. He said that a single-house disc unit had operated for more than 12 months in the Thames WA area without any maintenance or desludging and he understood that it had maintained a 30:20 standard effluent.

Mr. Walker stated that manufacturers were constantly striving to achieve a more economic solution with alternative systems. In this context increasing the loading to a Biodisc unit was not always satisfactory, but in some instances an increased loading could be satisfactorily achieved by applying some form of recycle. Recirculation reduced the incoming BOD concentration, reduced septicity problems by increasing DO content and innoculated beneficial organisms. Many recycling systems were used, and he felt that the benefits and disadvantages were worthy of consideration. The benefits could be summerized as basically a more efficient utilization of disc area, a reduction in solids loading passing to the humus tank, a reduction in septic conditions on the first disc bank, a more uniform flow pattern for the biological stage of the system and a reduction in the thickness of biomass allowing more efficient oxygenation. He said that such benefits were realized at the expense of losses in other areas, for example there was a lower retention period in the bio-zone which could cause a problem with sewages which were particularly difficult to treat and less likelihood of nitrification occurring, and if it did occur the returned nitrified liquor may result in rising sludge problems in the septic tank as a result of denitrification.

Mr. Walker said that he generally agreed with the authors' findings concerning activated-sludge plants and that such plants designed in accordance with the Minsitry of Housing and Local Government Technical Memorandum, 1969 operated satisfactorily, provided that they received adequate maintenance. However, he said that there were comparatively expensive to operate and maintain and in terms of maintenance requirements the standard of skill was higher. Considering the design recommendations in the new code of practice and indicated in Table 6 of the paper, plants had been operated with aeration capacities lower than those indicated. He believed that many plants operated with a MLSS concentration between 5000 - 6000 mg/l and he had experience of some plants which had consistently produced good quality effluents using 9000 - 12 000 mg/l MLSS.

In conclusion Mr. Walker felt that considerable attention should be given to modern manufacturing techniques and materials, which could constitute a major advantage and cost saving effect in the maintenance of treatment systems.

He said that the paper would prove to be of considerable value to those engaged in the use of package treatment plants, but he felt that it would be of even greater value in filling a major gap in the educational field and an invaluable treatise for students and people joining the field from other disciplines.

MR. A. ROE (Anglian WA) said that when the term package plant was used in the company of sewage works managers it was often met with mixed feelings, usually as a result of previous experiences of unsatisfactory performances possibly caused by over-optimistic claims by the suppliers, the unreliability of the equipment provided and an under-estimate of the amount of time required for operation and maintenance. He felt that this was the background against which the suppliers of package plants had to operate. With the present financial climate, and to a lesser extent the use of a section 16 requisition procedure whereby district councils could requisition regional water authorities to provide sewage works within a 6-month period of requisitioning, and possibly the philosophical question of whether at a time of increasing technology it was worth installing structures which would last 60 years when perhaps 25 years would suffice, he thought that the age of the package plant was here.

He agreed with the authors that a survey of the package plants operated in the UK would be useful, and was pleased to note the relevant progress to which they had referred (Appendix I).

He confirmed that the rotary biological contactor had been used in the Anglian WA for the relief of overloading prior to extensions. The package plant referred to was then moved, renovated and transferred to another site for further use, and he considered that this was a useful feature.

With referrence to Table 2, Mr. Roe said that he would have wished to see more information on the nature of the wastes arising from the various establishments. Examples were given by him of the extreme variation that could occur.

He noted the authors' comments about flow balancing. Many operators had experience of the difficulties of retaining activated-sludge solids in the settlement tank during peak flows. He asked if the authors' reference to the use of recirculation during low flows at night-time also applied to activated-sludge plants. He said that he was mindful of the problem of over aeration during periods of low flow, but he felt that to link oxygen input with DO probes on a small works may be over-sophisticated.

He said that his experiences with the use of grass plots and pebble-bed clarifiers were somewhat mixed. They tended to be fairly labour-intensive and if one needed this to produce a reasonable quality effluent after a package plant, then he felt that it was a disadvantage to the concept.

He asked the authors if the rotary biological contactor exhibited a spring shedding similar to that of the biological filter.

He said that in their conclusions the authors had made reference to the cost of site works exceeding the cost of the package plant. He thought that it may be of interest that on a recent biological contactor scheme approximately 53% of the total cost related to the contactor and the remaining 47% related to such items as fencing, land purchase, provision of electricity and roads.

He considered that the lack of requirement for power was an important feature of any plant, and he was pleased to note that the authors had referred to the package approach to conventional stone media filters and that some manufacturers did offer such a package. Furthermore, with package settling tanks and the proven performance of stone media, one should be able to provide a reliable, simple and low energy demanding package plant which if properly maintained should produce a good quality effluent without requiring polishing. He accepted the requirement for a larger area of land.

MR. I.G. STRACEY (Anglian WA), in a written contribution, said that the authors had referred to a paper by Nicol and quoted 300 visits/annum for maintenance of package plants, and he asked them to explain why they had quoted this figure. He wondered if they considered it to be normal, recommended or minimal. He said that normal attendance at that type of plant in his division would be twice weekly, allowing about 1.5 man hours including travelling and site allowances.

MR. J. ARNOLD (Yorkshire WA), in a written contribution, said that the paper brought together a host of information, and more particularly, advice on the use of prefabricated small sewage-treatment plants. He said that flow balancing was required not only to cater for pumped flow, but also applied to gravity feeds, particularly from those sewerage systems which 'on paper' may be 'separate', but in reality were more 'combined'. He said that on combined systems it was virtually impossible to provide an overflow arrangement on small diameter sewers which limited the forward flow as intended. It was not infrequent therefore for all the solids in an aeration unit to be washed out of the plant during a storm. The effect on the receiving watercourse might be of little consequence initially, but he said that the treatment capacity of the plant might take some time to recover, and it was during this period that the stream became polluted.

MR. E.R.E. BRISCOE, in a written contribution, said that where technical advice was available and there were effective arrangements for proper maintenance, experience had shown that package plants would perform satisfactorily within the specified design limits. However, the actual requirements frequently differed considerably from the forecast made by the manufacturer when submitting proposals.

He agreed with a previous speaker that the display of equivalent BOD loadings in Table 2 would be helping in estimating probable loads. He also suggested that a distinction should be made in respect of the luxury domestic housing and restaurant categories, between those with garbage grinders and those without.

Mr. Briscoe said that he would like to see some method of general guidance whereby the assessment of requirements was not left to individual manufacturers, or possibly manufacturers should liaise on a standard method of assessing required performance, so that plants offered were comparable.

He stressed that an essential requirement for package plants installed for private use was simplicity. The Pasveer oxidation ditch system was evolved with this in mind and, although the authors dismissed this form of treatment as not packages, they were incorrect, since what was essentially the same process was available in package form. He commented on the method of aeration for that method which was not limited to a brush-type rotor. He had successfully used the Flygt 'air injector', both in ordinary oxidation channels and in circular tanks, and had found that the system had the merits of extreme simplicity and easy maintenance, as well as economy in purchase cost.

MR. D.J. HIPGRAVE (Satec Ltd), in a written contribution, said that contrary to the authors' statement that balancing of flow had only a minor or insignificant effect on the quality of activated-sludge plant effluents, his company's experience had indicated that in certain cases balancing, or limiting, the flow was vital to small activated-sludge plants.

He referred to the section on running costs and maintenance requirements in which the authors had given estimated maintenance requirements for package extended-aeration and contact-stabilization plant, noting that the figures had been prepared by Nicoll prior to the issue of the revised Technical Memorandum in 1969, which suggested additional features which had been incorporated into most such plants that have been supplied since then. He suggested that discussion with operating personnel of water authorities would produce a different picture regarding the number of visits, transport, desludging and necessary work involved with extended-aeration and contact-stabilization plants.

MR. J. DAWSON (Clearwater Systems Ltd), in a written contribution, referred to the comments of Mr. Walker concerning the increase in loading to rotating disc filters by the introduction of recycle, and said that such loading could be increased to in excess of 9 g BOD / m^2d, whilst still maintaining 95 percentile 30:20 effluent standard. He said that this could be achieved by incorporating the following features:

(i) A separate primary tank designed to give minimum retention, which would result in fresh settled sewage arriving at the discs with positive concentration of DO.

(ii) A tank to house the discs which was carefully designed so that suspended or colloidal solids passed forward from the primary tank did not settle out.

(iii) A design of disc medium that gave good contact between solid and liquid interfaces and that gave optimum flow patterns in the purposed-designed tank. Variables such as depth of disc, speed of rotation, tank volume and retention period must be optimized in conjunction with other design parameters.

(iv) A completely variable recycle pump which, by returning liquors and biological solids into the primary tank, would keep the contents of the tank fresh and maintain positive DO concentration under all conditions.

(v) A novel drum filter to positively filter out humus sludge and return it into the primary tank.

He said that disc loadings of 11 - 14 g/m^2 d were possible,as had been illustrated in a paper given by Dr. Pike <u>et al</u>[17]. The WRC had carried out analyses at seven different rotating disc installations, and the results were given in Table 1 of the above paper. Site No.5 showed a disc plant loaded at 14 g/m^2 d which was producing an effluent of better than 30:20 standard for 100% of the time.

REPLY TO DISCUSSION

In reply to Mr. Walker, DR. PIKE suggested that in situations where there was a flow figure of 250 l/hd d there was probably considerable infiltration. At village works, where there was no possibility of infiltration, the typical domestic consumption was 125-150 l/hd d.

He agreed that oversizing might lead to septicity problems through excessively long retention periods.

Dr. Pike agreed that a consideration of sub-surface drainage capacity of soil was important when this method of discharge was contemplated, and could be a major problem. One had to consider the effects of fat.

Small works in isolated areas were perhaps sometimes neglected and one problem which did occur was the case of discharges from small works into streams where cattle had access. The biological filter would provide a barrier against problems arising from this source in that pathogens of certain types were removed, but there had been some outbreaks of salmonellosis documented in which infection was traced to discharges of septic tank effluent from single households with a carrier.

He said that emptying costs could be considered as a major reason that decided private householders not to empty their septic tanks at all, so that they discharged untreated sewage after a period of about one year.

Dr. Pike did not doubt that recycle could have a beneficial effect in helping to achieve a higher disc loading, in fact anything which would assist the transfer of oxygen into the liquor in the trough would increase the loading that could be applied to the discs. It was a matter for design and perhaps treating the rotor as a kind of slow-speed aeration system and trying to improve it. The major factor was probably not transfer to the liquid film on discs, but transfer into the body of the liquid in the trough, and the smaller the relative volume of liquid in the trough and the more completely mixed it could be, then the more efficient the plant would be. Recycle of nitrified effluent during the night could be useful in meeting the morning load. Recycling and also step-loading had the disadvantage in theory of converting a plug-flow system into one which was more completely mixed, thereby reducing the driving force for oxidation.

With using high MLSS concentrations in extended-aeration plants Dr. Pike said that the problem was either dissolving the oxygen to supply the respiration rate with high sludge loadings, or with low sludge loadings in the creation of autolysis of the sludge bacteria, growth of Nocardia spp. and production of 'chocolate mousse' foam. He said that earlier experiences during the 1960s had shown conclusively that extended-aeration plants did not consume their own sludge and that ultimately the plant gave trouble with foaming and autolysis of sludge. These plants could not be used to store sludge indefinitely.

In reply to Mr. Roe, Dr. Pike considered that during the design stage detailed enquiries should be made concerning the nature and discharge of industrial waste waters.

Dr. Pike said that he could not see any advantage in recirculation at night-time on activated-sludge plants, although one possible use might be to provide oxygen in recycled nitrified effluent. The activated-sludge system inherently provided a degree of recycle of liquor in the returned sludge.

Referring to the variable results of the use of grass plots, Dr. Pike stated that at works 7, the authors had found an increase in the SS passing through the grass plots, no change in BOD but, on one occasion, a considerable degree of nitrification. He speculated on the proportion of solids in the grass plot effluent that was represented by soil particles.

Dr. Pike said that he did not think that rotary biological contactors experienced a spring slough; although they showed variation in film thickness throughout the year, they sloughed more or less continuously. Grazing effects of the worms which occurred in largest numbers near the rear end of the contactor would increase in the summer, therefore one might observe that the last few discs became cleaner or turned redder because of increases in the worm population.

Dr. Pike drew delegates' attention to a guide to UK manufacturers of packaged sewage treatment plant which Mr. Harrington had prepared (Appendix 1).

In reply to Mr. Stracey, he suggested that the frequency of visits to small works would depend upon the nature and complexity of the works, with the added consideration that reduced frequency might be accompanied by a reduction in performance. The authors thought that more information was needed on manpower allocations and costings for the maintenance of small plants.

Mr. Pike said that his remarks on flow balancing were concerned with the effects that equalization of diurnal variations might have on performance, and the indications were that these benefits were not as great as claimed in the past. He had pointed out in an earlier paper[17] that experiences with two works (works 7 and Kirk Hammerton) had shown that non-periodic variability (e.g. through storms) could make a greater contribution to the overall variability in sewage strength and effluent quality than diurnal variability or seasonal variability. If so, it was obvious that attention should be given first to eliminating the effects of this non-periodic variability (e.g. by providing facilities for reception of storm sewage) than by balancing-out diurnal variability.

Both Mr. Briscoe and Mr. Walker had asked for information on per capita BOD loadings to supplement the information given in Table 2. Dr. Pike explained that this information was not directly available, but referred them to Table A taken from a previous report[34], specifying population-equivalents for different types of usage.

Table A. Definitions of a number of persons or equivalents (E. Einwohner) to be considered in calculating polluting loads from dwellings and other buildings (German Standard, DIN 4261, Reference 42)*

Building unit	Value of E
Dwelling house	1 person, minimum 4 per house
Lodging houses, hotels	1 bed = E
Caravan and camp sites	2 persons = E
Factories, workshops	2 employees = E
Shops, offices	3 employees = E
Catering establishments: normal occupancy	3 seats = E
9-10 occupants/seat in 24 h	1 seat = 3E
11-14 "	1 seat = 4E
15-18 "	1 seat = 5E
Summer tea-houses (gardens)	15 seats = 5E (outdoors)
Clubs, associations, boat-houses (no catering)	10 users = E
Schools, without baths and showers	10 persons = E
Assembly rooms, sports and games facilities without catering	30 visitors = E

* Reproduced from Table 7 of Reference 34

In reply to Mr. Briscoe, Dr. Pike thought that no standard formula could substitute for direct enquiries of other users of similar plant or of sites with similar features. Similarly one could not expect, in a competitive market, that manufacturers would be reticent about performance, particularly if some promising novel feature required field trials. The authors had not wished, by omission, to overlook the value of the Pasveer oxidation ditch, although it was not a package within their definition. They would agree that the simple systems, as described by Mr. Briscoe, were cheap to construct and operate and moreover, usually produced rapidly settling sludges.

Dr. Pike said that he agreed with Mr. Hipgrave that up-to-date information on running costs and maintenance of small plants was needed, and that he had suggested to the WRC that a suitable area for a survey might be in Scotland, particularly since records of discharges were now held centrally by the Scottish Development Department.

In reply to Mr. Dawson, Dr. Pike understood that the critical disc loading value of 5 g/m^2 d referred to in the New Code of Practice was understood to be a reference value, which could be exceeded only if manufacturers could provide evidence to support their claims. The new Code was not intended to inhibit development. Dr. Pike had noted in the earlier paper[17] that the two of the seven rotating-disc plants which gave superior performance when examined by discrete sampling were those (works 5 and 6) with separate primary treatment, although noting that these treatment units also provided for digestion of primary and returned humus sludge. He thought it was important that there should be no excessive hold-up of sloughed humus solids in the liquor of the disc compartment. Indeed, when his team were developing the rotating biological units to be used in studies of treatability of Scottish sewages[43], performance had been poor until turbulence was induced to prevent humus solids settling out in the disc compartment. He had referred in the paper for a need to consider the rotor as a simple aerator and in doing so to improve its mechanical efficiency. He considered, however, that the remarks on loadings of 11-14 g/m^2 d (works 5 and 6) taken from Table 1 of Reference 17 were taken out of context. The table specified that these organic loadings were averages for visits at which discrete samples were taken. These two works, which were only a few km distant from each other, were sampled between 09:30 and 13:15 hours at average times of 11:40 (works 5) and 11:04 (works 6) hours, i.e. at a time of day when sewage strength would be above average. At none of the works quoted in this Table was it possible to check the calibration of flow recorders, although in most cases, flows were reasonably consistent with those expected from the contributory populations.

The Chairman then proposed a vote of thanks to the authors for the presentation of their paper, which was carried by acclamation.

ADDITIONAL REFERENCES

42. DIN 4261. Blatt 1 (October, 1970). Kleinklaranlagen. Anwendung, Bemessung Ausfuhrung und Betrieb. Anlagen öhne Abwasserbelüftung (Small type sewage treatment plants. Application, design, construction and operation. Plants without aeration.) Obtainable from Beuth-Vertrieb GmbH, Berlin 30 and Köln.

43. SCOTTISH DEVELOPMENT DEPARTMENT. Treatability Studies of Two Scottish Sewages. Applied Research and Development Report No. ARD 7. Engineering Division, Scottish Development Department, Edinburgh, 1981, 39 pp.

SLUDGE TREATMENT AND DISPOSAL AT SMALL SEWAGE-TREATMENT WORKS

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INTRODUCTION

Whilst sludge disposal forms the major constraint at most sewage works the problems posed at small works are invariably greater. The development of the use of the 'mobile gang' and extensive tankering can be viewed as the revenue option to compare with the capital intensive contender - namely the 'regional' scheme. This mobility option already produces savings over previous operating practices. In the case of the 'regional' or centralized sewage-treatment facility (ignoring such philosophical arguments as concentrating effluent discharge and sludge disposal from a single site and the resultant strategic implications), a more economically realistic approach outlined within this paper is to re-examine the 'capital' approach and elucidate whether alledged economies of scale in treatment at the larger works can be attained within much smaller works. For sludge treatment and disposal the overall route could then be revised giving local facilities at attractive costs.

The added dimension which allows comparable and sometimes lower unit costs for treatment routes at these smaller works is that of standardization applied to all aspects of plant provision. A package approach using prefabricated systems employing maximum off-site assembly, coupled with a similar approach towards design, erection and commissioning yields significant savings. In the digestion plant detailed as an example of such an approach, it can be clearly seen that as well as the financial savings arising from providing comparable or improved sludge treatment facilities at the small works, additional bonuses accrue. The availability of suitably treated sludge increases the number of reasonable ultimate disposal destinations thereby decreasing dependence on finite resources such as tipping or lagoon storage. Other processing units suitable for exploitation by this approach will also be indicated.

The primary consideration in route choice is of course the suitability of that complete sludge treatment and disposal route. Route suitability includes many factors, not all of which can be assessed in absolute economic terms especially at the time of plant option comparison. Whilst many factors e.g.

equipment reliability, are capable of immediate translation into costs, a technical 'veto' based on 'acceptable practice' must be retained in assessing plant provision.

This concept of 'acceptable practice' mentioned as a major consideration in the choice of the capital plant(s) is at least as important when defining works operational practices. Where works operation unavoidably encompasses a 'waiting period' i.e. a period during which the operator has no direct process input, this must be recognized and retained. Any bonus scheme should aim to explore, define and facilitate economic works operation not to determine such.

SLUDGE TREATMENT AND DISPOSAL ROUTES

As mentioned above, the total sludge flow sheet requires definition before any separate unit is considered. The treatment unit used (if any) is primarily determined by the disposal option with the sizing and/or choice further modified by the nature and composition of the sludges to be treated.

Even at the size of works under consideration at this symposium, (< 5000 population) there is a multiplicity of route options. Fig.1 shows the generalized sludge treatment and disposal flow sheet. The object of any economically validated route is to use the minimum number of route stages compatible with environmental acceptability and sensible operation.

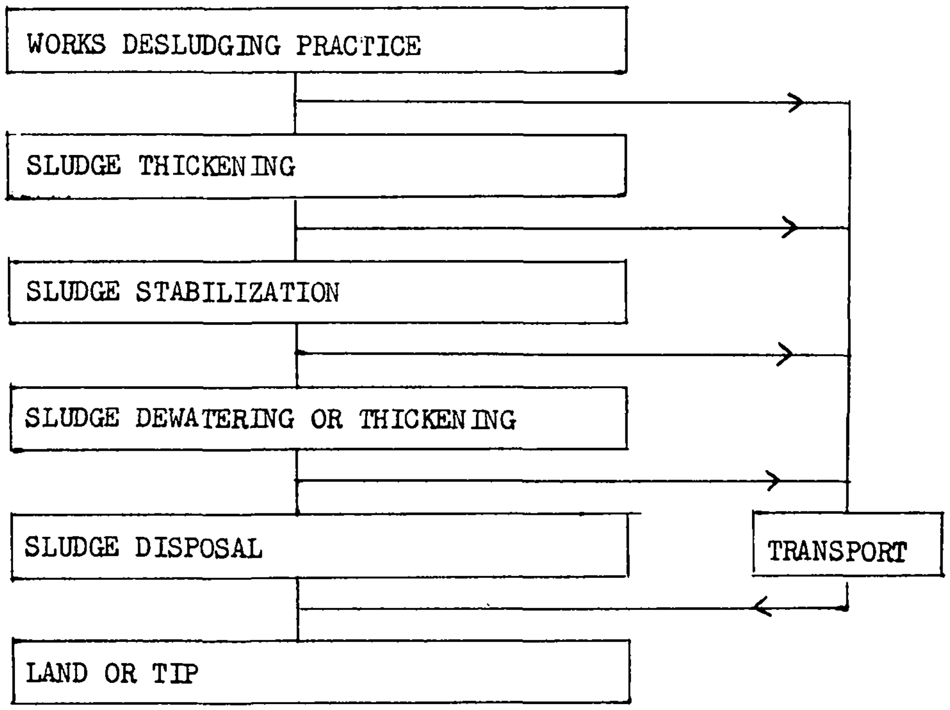

Fig.1 General Sludge Treatment and Disposal Routes

It is not the intention of this paper to detail the many combinations available from this general flow sheet but rather to demonstrate the application of total route costs in the case of options available at Pitts Mill sewage-treatment works of the Authority. The basic approach to be adopted at any works must be an examination of the whole sludge route from production to ultimate disposal. By adopting this procedure it is possible to identify and remedy the rate limiting and/or any vulnerable areas of the whole route.

Overall routes and their economics have been described for many varied works in the WRC Technical Report TR 42[1]. The sludge treatment and disposal procedures previously considered for small works relate almost exclusively to disposal rather than treatment options[2].

The principal routes included:

(a) Raw sludge storage within tanks (with or without any dewatering facilities).

(b) Sludge drying beds - manually lifted.

(c) Lagoons - used for both temporary storage and permanent disposal.

The treatment route previously considered for smaller works has essentially centred around what is rather loosely termed 'cold digestion'. Whilst it is true that sludge will digest under all anaerobic conditions, the reaction rate in the absence of any heating or more importantly mixing is so slow that 'ambient consolidation' might be the more accurate process description for this procedure.

The current guidelines relating to the disposal of sludge to land[3] give rise to restrictions when compared with many of the previously used procedures particularly for sludge applied to grazing bed. This results from a requirement for a sludge treatment stage prior to disposal, the alternative procedure to an acceptable stabilization route being raw sludge storage for periods of a year or more depending upon circumstances. Where this constraint is accepted for raw sludge it is unlikely that existing site resources can satisfactorily meet these requirements even with sludge in the dried form, and this situation has added impetus to the adoption of large-scale tankering of liquid sludge to area sludge centres in order to achieve sludge treatment or sludge volume reduction. At smaller works where the surrounding land is grazing land this largely relates to a desire for a reduction of pathogens in the sludge to facilitate land disposal. Concurrently, many works also face an increasing situation of operational restriction on site with respect to odour nuisance. Solution or abatement of these two difficulties can be achieved by the use of anaerobic sludge digestion as the sludge stabilization or treatment route. The previous difficulty in applying the process at small works has centered around its capital cost and the inability to maintain an adequate process heat balance without the use of supplementary fuel.

The detailed appraisal of the routes outlined in Pitts Mill confirm the high cost of the tankering option[4]. The design concept, construction and current operation of the package digestion plant, which provides the preferred option namely 'on site digestion', is detailed in Appendix 1. The relative economics of this and a drying-bed route are considered within the main body of the paper and are compared with the 'inherited' route of raw sludge tankering to a pressing plant followed by farm stockpiling of the press cake for agricultural use.

SLUDGE TREATMENT AND DISPOSAL AT PITT MILL

Plant Details

Works population served	-	2600 persons (dormitory area)
Raw sludge holding tank	-	191 m^3 capacity
Sludge drying beds	-	24 beds 12 m x 7 m
Weekly sludge make (tankered)	-	34.1 m^3, 1022 kg DS (3% DS)

The works was commissioned in 1974-75 just after formation of the Authority. The sludge route originally adopted involved the following stages: unthickened raw sludge tankered to Newent sewage-treatment works (a round trip of 22 km), mechanically dewatered in a plate press and taken to stockpile on agricultural land (round trip 10 km by tractor and trailer unit) for spreading by the farmer. Costs of this original route are detailed for the financial year 1979-80, i.e. its last year of operation.

(NOTE - In all of the route options considered, operating costs quoted are direct costs calculated at the standard rate of bonus. They do not include establishment 'on costs'. Capital costs are not included).

Option A PITTS MILL - NEWENT - PRESS - TIP ON AGRICULTURAL LAND

Data

(1) Journey round trip - 22 km

(2) Vehicle used - nominal 10 m^3 - actual 8 m^3

(3) Vehicle costs (1979-80) - £7230 per annum (includes vehicle leasing charge £3050)

(4) Vehicle downtime - 12 weeks per annum.

(5) Sludge removed - 35 m^3/week (1979-80 average)

Costs

(a) Apportioning tanker and driver costs to the Pitts Mill to Newent journeys:

Total vehicle cost/week = £14.53 (including leasing charge - cost is £25.15)

Total driver cost/week = £14.17

Total sludge transport cost = £28.70 /tonne DS (exclusive of leasing charge)

(b) Plate pressing at Newent - cost (actual 1979-80)
(Aluminium chlorhydrate conditioning; single press)

Total sludge pressing cost = £39.90 /tonne DS

(c) Actual cost of press cake to stockpile on agricultural farmland (tractor and trailer unit)

Total pressed cake disposed cost £14.28 /tonne DS

Thus for A, overall route cost is £82.88 /tonne DS

Option B PITTS MILL ON SITE DIGESTION - LIQUID DISPOSAL TO ADJACENT FARMLAND

Costs

(a) Package digestion plant - annual operating costs (1980-81)

(1) Labour - £327
(including disposal, driver cost £180)

(2) Electricity - £520 (including additional period of standby heating during commissioning)

(3) Spares - £260 (projected - none spent in 1980-81)

(4) Other - £140 (additional supervision immediately after commissioning)

Actual digester operating cost = £18.57 /tonne DS

(b) Sludge disposal costs

After digestion the stabilized sludge is thickened to 6% DS in two converted drying beds (large surface area /volume ratio to promote cooling and thus aid thickening) prior to transfer to the existing 191 m^3 holding tank. Assuming a solids reduction of 30%, the sludge for disposal is 11.8 m^3/week or 1.48 tanker loads/week.

Tanker operating cost = £6.56 /tonne DS.

Thus for B overall route cost is £25.13 /tonne DS.

Option C USE OF PITTS MILL EXISTING DRYING BEDS FOR RAW SLUDGE WITH CAKE DISPOSAL

For completeness the original raw sludge disposal route provided but never used at Pitts Mill, namely by drying bed, has been costed, at 1980-81 prices.

Costs

(a) Use of drying beds

Manual sludge lifting = £10.74 /tonne DS

Bed re-ashing - £9.96 /tonne DS

Total cost of drying bed use - £20.70 /tonne DS

(b) Cake disposal

As before, only now assuming it would be possible to dispose of this cake within the previous 10-km round trip, the cost figure of £14.28 /tonne DS for cake disposal to stockpile on agricultural land is used for comparison.

Thus for C overall route cost is £34.98 /tonne DS.

The summarized costs for the routes described are shown in Table 1.

Table 1. SLUDGE TREATMENT AND DISPOSAL ROUTE COSTS AT PITTS MILL

Route	Route cost (£ / tonne DS)
(A) Tanker to Newent, press with cake disposal to farm stockpile	82.88
(B) Digest at Pitts Mill, thickened liquid sludge to adjacent land	25.13
(C) Raw sludge to drying bed, cake disposal to farm stockpile	34.98

DISCUSSION

Route Options

The route costings for sludge treatment and disposal at Pitts Mill indicate the most cost attractive route to be via package anaerobic digestion and liquid sludge disposal to adjacent land. The digestion route when compared to the previous tanker/press option is in fact even more attractive than would appear from this table due to the following factors:

(1) Tankering and pressing (Route A) uses a 1979-80 cost basis and 2600 population.

(2) Digestion (Route B) was costed at 1980-81 and a population of 2600 whilst it is in fact treating a population of approx. 4000 by the interception of sludges from other works even more distant from Newent than the Pitts Mill site. Irrespective of the additional savings on the 'area' basis the unit treatment cost of digestion will thus be significantly lower than that presented in Table 1 for comparison purposes. The import of sludges has also compensated for the low DS concentration in the sludge solely from the dormitory area serving the works; This low DS level illustrates the general difficulties encountered at the option planning stage due to paucity of works' operating data.

A further and perhaps major consideration relating to the routes as costed is the fact that they each offer a different 'quality' of route.

This 'quality' of route refers to the differing intrinsic flexibility and reliability of the options offered. The inherited tankering and press cake disposal route requires considerable on-site storage to allow compliance with disposal guidelines. Press cake can be a relatively difficult material to dispose of, and this is usually reflected in relatively long disposal distances. However, given adequate storage for cake disposal (a factor which will also facilitate significantly reduced cake disposal costs) this route is attractive in minimizing the volume of sludge in the event of disposal difficulties due to bad weather or animal movement restrictions. The liquid sludge tankering element of this or indeed any route incorporating such, is usually the most vulnerable as well as the most expensive. Together with the strategic consideration, tankering has seen consistent increases in fuel, vehicle and labour costs, although standardization can afford savings in this area.

The drying-bed route would initially appear to be a cost attractive alternative to the above tankering and pressing option. However, a number of factors mitigate against this route and have contributed to its decline, especially since reorganization. The performance and thus lifting of drying beds is essentially a seasonal activity and coincides with other demands. The use of sludge conditioners should allow removal of this constraint, although at an additional cost. Peak requirements for grass cutting (possibly alleviated by greater use of retardants and or gravel) are outweighed by holiday committments. The task of manual lifting of drying beds is also becoming less compatible with the type of operator and scheduling of the 'mobile gang' operating system now invariably adopted at small works.

The preferred option of 'on-site' anaerobic digestion and local disposal has further inherent benefits capable of exploitation. As well as the virtual universal disposal acceptability of the digested sludge, the excess gas available from the package plant can be used. The principal constraint upon sizing of a package digester is availability of secondary sludge storage. At Pitts Mill the works' storage capacity can supply suitable nutrients[5] for a 4-ha field i.e. approx. 20 weeks storage of sludge. Intensive disposal is a further benefit of such storage. Where sufficient storage is not available the standardized tanks as used in the digester package offer cost effective storage provision. Whilst a plant of at least twice the size of the Pitts Mill digester would be needed to power even the smallest power generation package (with solution of problems of engine reliability and power usage being first required), current excess gas would be sufficient to operate a small package screenings incinerator thereby eliminating a further works' problem.

In concluding this discussion section of the specific options at Pitts Mill it is pertinent to point out that the capital cost of the plant / tonne DS based on current operating data[6] is £32.30. In the case of drying beds, the capital cost (not available for Pitts Mill) will exceed that of the digestion package. The actual disposal route replaced by the digestion option, i.e. tankering/ pressing operating costed at £82.88 /tonne DS compares with a combined operating and capital cost of £57.43/tonne DS for the digestion route. This transformation of costs relating to the digestion process which even at the large scale with design and construction has always been considered of high capital cost, conclusively demonstrates the potential of standardization as applied via a package digestion system.

Alternative Routes

The lagooning of sludge is often proposed as offering a cheap and satisfactory solution for sludge disposal although current practice within the Severn-Trent WA is not to provide any non-operational lagoons. Disposal lagoons filled for posterity contradict the concept of sewage treatment. Irrespective of capital and manpower requirements, odour problems (with even the smaller works now being engulfed by housing developments) are likely to eliminate such practices.

Lime treatment is a further treatment option which should apparently lend itself to small works' operation. The current DOE Sub-Committee on the Disposal of Sewage Sludge to Land[3], however, places lime treated and aerobically digested sludges under the same disposal restrictions as surplus activated sludge and humus sludges. Trials with lime stabilization have been carried out within the Authority, although pHs above 12 were required to produce a stabilized sludge[7]; this was achieved by using approx. 15% (w/w) of a 10% lime dispersion. As well as causing a considerable increase the bulk of sludge for disposal a further major drawback is the release of free ammonia during treatment.

Aerobic digestion, being an intrinsically low capital option may also be considered suitable for small works. Operating costs are high for the conventional air systems, a large-scale trial in the Authority having indicated operating costs (power only) of about £35/tonne DS at 1980 prices. This work was carried out with surplus activated sludge which could be regarded as part digested. The comparable cost for primary sludges at current cost would be approximately £80/tonne DS[8]. This, in combination with its disposal category (at conventional operation), must lead to question its adoption at smaller works.

Two further options are available for the smaller works. The first involves the use of mobile dewatering plant in an operating area. Within the Authority a mobile filter-belt press and centrifuge have been used in separate divisions. One of these devices has been 'hijacked' as a permanent installation, perhaps indicating a problem of availability of suitable, sufficiently mobile, operating labour. Within authorities, if the operating areas are to be run with tighter equipment usage and reduced standby, the provision of mobile equipment will be an 'insurance' requirement. The further option, sub-soil injection, also contains an element of mobility. Assuming the technique to be effective in pathogen control, used within suitable soil types and at acceptable rates, then economics are the governing criteria. At high capital and operating costs of the vehicles involved, it would seem that a tankering stage (to the injector) will be required with its attendant costs.

Standardization

Determination of the highest operating cost element in any route usually identifies liquid sludge tankering. It is also of interest to note at this point the impact of tankering in the whole sludge route of Fig. 1. The basic observation is that the earlier in the flow sheet any tankering appears, the more expensive will be the route since the principal cost factor in the make up of total tankering costs[6] is the DS concentration of the sludge to be removed. The cost make-up of tankering at Pitts Mill to Newent shows a comparable tanker travelling time (37 mins) to the tanker fill and discharge times (35 mins). A standardized thickening/storage module of sectional glass lined steel with hopper-bottom mounted above ground could be sized to works sludge make and to suit the area tanker. An above-ground unit will also facilitate more rapid tanker filling. Standardized, large diameter connexion fittings and simple dewatering/mixing facilities would be available within this tank.

A similar improvement in sludge solids removed from oxidation ditches, and thus the time on site for desludging, can be achieved by the addition of a low-cost tank in hydraulic continuity with the ditch to act as a separate sludge store/thickener. This unit, fitted with a large diameter withdrawal facilitates rapid removal, thereby redefining the financial balance between the costs of tankering water and the labour costs of desludging.

CONCLUSIONS

In the wake of restrictions inherent in sludge disposal guidelines, many current disposal options will require the addition of a sludge treatment stage. Against a background of reducing capital and operating budgets, a treatment process is proposed which has allowed guideline compliance at reduced overall route cost. The preferred solution utilizes an accepted and proven sludge treatment process namely anaerobic digestion. By re-examination of its principal drawback, i.e. capital cost, the major contributing cost components were identified and a new approach adopted based upon standardization and prefabrication. Plant reliability and operating cost reduction with respect to labour and energy costs completed the design objectives.

The evaluated route options demonstrate the high cost of tankering liquid sludge, especially when unthickened. In many cases the interplay of flexibility offered and premium required by tankering is crucial to a successful sludge operation. Whilst a considerable number of apparent options fail on practical, philosophical or cost grounds it is often instructive to cost these alternatives since many sites have associated special factors which are sufficient to outweigh general assumptions. An example of such could be a remote drying bed installation local to suitable land with a co-operative farmer.

The adoption of sludge area centres will inevitably continue although caution must be exercised in assessing the notional benefits of such schemes. Economically and operationally viable single site options may exist which include an added benefit of greater inherent suitability.

ACKNOWLEDGEMENTS

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The views expressed in this paper are those of the authors and do not necessarily represent those of the Severn-Trent Water Authority.

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APPENDIX 1

PREFABRICATED SYSTEMS FOR LOW-COST ANAEROBIC DIGESTION*

SUMMARY

This Appendix outlines the development of a low-cost anaerobic digestion plant which accrues the cost benefits of standardization components within a prefabricated structure. The examination of process and cost sensitivities has resulted in a revised plant design using non-conventional (within the UK water industry) materials and construction techniques. The development of such plants allows digestion provision for much smaller plants than previously considered, thereby reducing overall sludge tankering requirements.

The plant described shows two particular advantages over its conventional counterpart namely cost: at £6/person compared with £40/person and rapid construction: with erection and commissioning within 18 working days.

INTRODUCTION

The term 'prefabricated' as used by the authors of this paper refers to the accepted use of the term, namely; "manufacture sections (of building, etc) prior to assembly on site-produce in a standardized way".

The most important connection between the above definition and the term low-cost lies with the word 'standardization'. Whilst a plant item such as the conventional floating roof gas holder may be prefabricated off site, standardization of panels etc. is not usually found and certainly not reflected in price.

Examination of many aspects of the process engineering of anaerobic sludge digestion continues [1,2,3,4] within the Severn-Trent WA, and this short paper highlights some aspects of one study topic. The approach adopted throughout the studies has been the application of sensitivity analysis to both the processing and cost aspects. Early work was centred upon optimizing operation of existing plant resources in an attempt to meet a shortfall of sludge treatment capacity in the light of the twin constraints of a short time scale and shortage of capital for the conventional solution.

*Updated from the original paper presented at E.E.C. Symposium on Sludge treatment. Cost bis '68 Vienna. October, 1980.

A critical survey of existing plants highlighted the 'sensitivity' of process operation with respect to mixing and heating inadequacies of these plants. Further examinations have indicated other interlinked contributing parameters e.g sludge feeding regime, reactor aspect ratio, etc. In the definition of an "order of sensitivities" then this is equivalent to a priority listing of process rate determining stages. Correction of mixing and heating inadequacies has afforded an extremely low-cost provision of additional digestion provision, as well as redefining the major design parameters for futher 'new' plants.

The fundamental process design parameter of retention period has been reduced to about 15 days:(approaching half that previously adopted) all of which has a profound effect on the distribution of plant capital costs. Historically, 70% of the plant costs were consumed within the civil-engineering structures, allowing 30% for provision of all equipment[1]. In recent years this balance has been moving towards a larger share being allocated to processing equipment. However, a close analysis of current major cost items, when compared with a number of less conventional options, underlines a number of areas for 'structural' cost savings. These include reactor vessel, housings for process equipment and gas holder provision.

The plant was funded as a research and development evaluation plant to gain operating information for standardized larger plants based on approximately 10 000 and 25 000 persons.

The Pitts Mill sewage-treatment works is a rural plant serving a population of 2600 persons. The works' flow is delivered via a number of pumping stations, and the original sludge flow sheet allowed for raw sludge storage and/or use of manual drying beds. Prior to erection of the digestion plant, the works raw sludge (mixed primary/humus) was tankered to a filter-press plant on a neighbouring works, a round trip of about 22 km. This cake was then disposed of by stockpiling on farmland (Fig. 1).

The completed digestion plant allows for the revised sludge flow (Fig.2), i.e. raw sludge to consolidation/storage tank on to digester and then to the secondary digester (previously the raw sludge storage tank) via a sump. The thickened liquid digested sludge is then disposed of 'over the fence' to the surrounding field which can receive all of the works' sludge and remain within the UK guidelines for sludge disposal. Prior to stabilization (and inherent solids disposal) route, the sludge was not acceptable to the farmer.

Fig.1

Fig.2

EXISTING RAW SLUDGE SUMP

RAW SLUDGE HOLDING TANK → TANKERING → PLATE PRESS → STOCKPILE (on farmland)

MANUALLY LIFTED DRYING BEDS → STOCKPILE (on farmland)

RAW SLUDGE CONSOLIDATION AND HOLDING TANK → ANAEROBIC DIGESTION → SECONDARY DIGESTION SLUDGE STORAGE → LIQUID DISPOSAL TO SURROUNDING FIELDS pumped or tankered

The digestion plant has been erected on two of the existing 24 drying beds. The foundation requirement for the main reactor itself was excavated through the existing concrete membrane. On inspection, this existing membrane would have been adequate for immediate erection of the reactor tank.

The package plant comprises two glass-coated steel sectional tanks, a roofed reactor tank of $80m^3$ and a consolidation/sludge storage tank of $10m^3$, with a gas holder of $5m^3$, each in glassfibre reinforced plastic, together with all associated process equipment. This process equipment has 100% standby of feed pump, gas compressor (for mixing), submersible digested sludge sump discharge pump, hot water circulating pump, with all process controls mounted within a single electrical panel. Details of the individual plant items are given below.

REACTOR/DIGESTER

The main digester is an $80m^3$ steel (glass coated) tank of 4.3m dia. and 6.5m height, and the steel panels are bolted together and use a mastic sealant, (Fig.3). The tank base is of sloped concrete, insulated with block polyurethane and complete with a 150mm bottom drain gate valve. Also included are two full access hatches. Wall and roof ladders complete with safety rails, together with four 100mm ports (for future developments) were also included.

Great care was taken to provide low-cost anti-blockage sludge inlet and outlet arrangements. Outlet is provided to a sump by positive displacement and the roof fitments include a mechanical excess pressure relief valve, a solenoid operated gas release, together with inspection and lighting panels and splash trap serving the roof gas take off point.

One drawback of a thin-wall steel tank is its relatively high thermal conductivity with its conventional concrete counterpart. This drawback is remedied and, indeed, improved by an internal lagging of the digester using 100mm thick sprayed polyurethane on the walls and 50mm depth on the roof underside. Mechanical protection of the insulation is also provided.

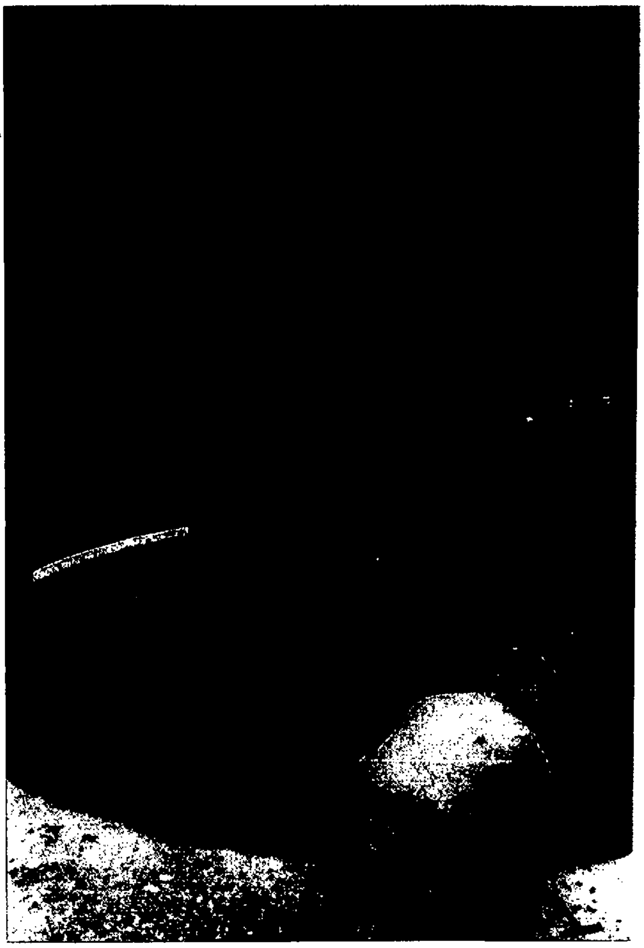

Fig.3 REACTOR/DIGESTER FABRICATION

The lagging integrity and performance has been established by infra-red photographic and radiometric techniques. Current performance indicates a standing heat loss of approximately 50% of that norm found at conventional digestion plants within the Severn-Trent WA.

SLUDGE HOLDING/CONSOLIDATION TANK

This glass-coated sectional steel tank of 10 m^3 provides 2 days' sludge feed and is equipped with dewatering facilities mounted from a surface support. A concrete floor slope to a hopper bottom is included. Separate 150mm valved outlets to individual feed pumps are provided (Fig.4).

GAS HOLDER

This is a bell over water type of $5m^3$ capacity prefabricated in GRP of a double-skinned insulated construction. Gas supply and delivery pipes enter from below, with the floating lid ballasted to provide a gas pressure of 125 mm water

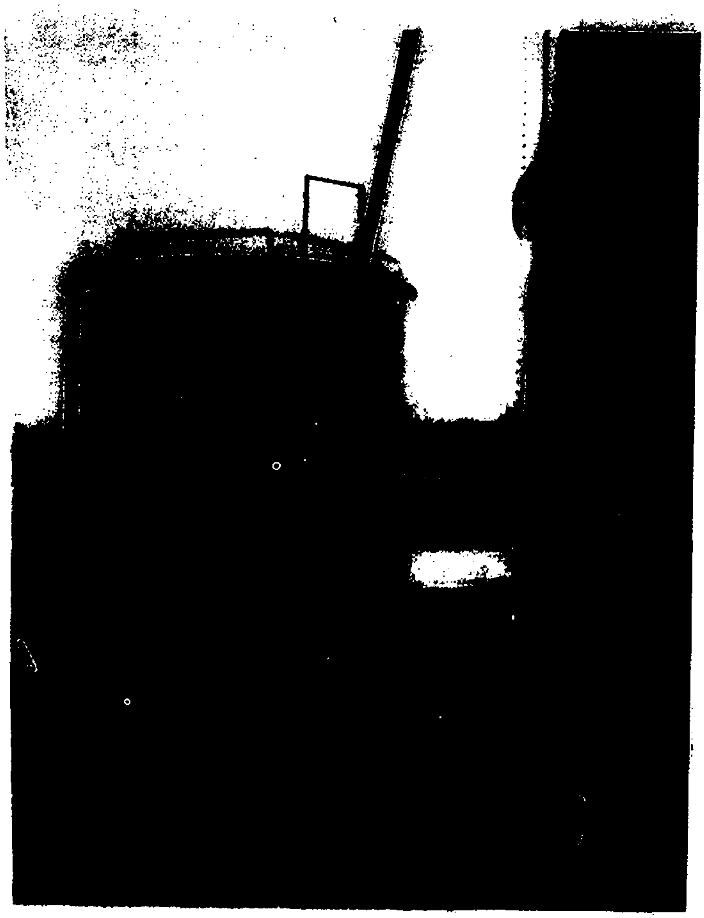

Fig. 4

SLUDGE HOLDING/CONSOLIDATION TANK.

Fig. 5

GAS HOLDER

gauge (Fig.5). A sensing system provides excess gas release from the digester roof solenoid.

DIGESTED SLUDGE SUMP

The distance from the digester vessel to the re-allocated secondary digester requires the use of a separate sump. This covered sump in GRP allows a vertical digested sludge discharge, giving further protection against digester outlet blockage. A multiple-valving arrangement allows for either gravity discharge to the secondary digester or use of the duty or standby submersible sludge pump.

PROCESS EQUIPMENT HOUSINGS

For reasons of safety and convenience, three isolated housings (also in GRP) are provided for the process equipment. One unit contains the primary electrical supply and control panel, the second contains the gas compression and mixer solenoid equipment, whilst the third includes the sludge gas boiler, circulating water pumps, make up water tanks and standby heating via in-line electrical immersion heaters.

PLANT ERECTION AND COMMISSIONING

One of the more notable aspects of the use of prefabricated systems is the possible speed of erection. In the case of plant described above, the erection period as defined from a starting point of uncleared drying bed (also without electricity and water services) to digester gas in a fully charged gas holder took a total of some 18 working days. Were that period to be 18 weeks it would still be unapproachable for construction of a conventional plant.

The size of plant facilitated start up within a day by the importation of digesting sludge, although this plant was placed on full raw sludge feed within seven days of start up.

Within the overall 18-day erection period, site clearance to tank erection was completed within three days with internal insulation requiring two further days. These periods included the difficulties experienced in trying to penetrate the existing drying bed membrane for which any temptation to use this as the tank foundation was resisted.

All services within the package area, namely; water, gas and electricity are all suitably protected and buried under the original drying bed gravel now returned and augmented (Fig.6).

Fig.6

GENERAL VIEW OF PLANT

DIGESTER OPERATION

Digester start-up at half sludge feed was introduced to give a higher degree of process assurance in the event of a reduced monitoring staff availability which restricted the anticipated, frequent monitoring of pH, bicarbonate alkalinity and volatile acid levels so critical on start-up. Since that period, sludge loading has been increased by tankering sludge in from other works so that the population now served varies between 3500 and 4000 persons, with a retention period of 17 - 20 days.

The plant has operated successfully from start-up to date (18 months), although minor modifications and corrections to the plant have been made. These derived wholly from the different requirements of the contractors previous agricultural clients, and were restricted to a few items of detail which were not totally eradicated during the design and construction stages. Plant operation is entirely automatic with current operator requirement restricted to reading of the hours run meters on the control panel and performing switchovers between duty and standby equipment.

PLANT PERFORMANCE

Since commissioning the average retention period has been 18.5 days with full mesophilic conditions of 35^{o} C having been maintained throughout.

Volatile matter reductions have averaged 47% as derived from gas production data (an intrinsically integrating parameter). Stable reactor performance has been verified by the total volatile acid to total alkalinity ratio maintaining a low (<0.01) and consistent value.

Concentrating upon the practical aspects of plant performance the peak digester gas consumption for heating purposes has been about 40% of gas production.

Total modifications to date have comprised duplication of the digester bottom drain valve (in the event of failure of the bottom valve during the weekly base flush), the replacement of the sump pump float switches by fixed electrodes and the installation of a floodlight.

COSTS

Returning to the title of this paper, the low-cost component is now self-evident:

Cost of basic plant (April 1980): (digester, gas holder, sump and all process equipment)	£14 655
Cost of consolidation/holding tank	£ 2 085
Cost of standby (all plants)	£ 3 850
Total	£20 590

CONCLUSIONS

This is one example of a low-cost prefabricated plant and embodies a number of aspects. Other areas of prefabrication are also being studied within the Severn-Trent Water Authority. At a population served of 3500 persons, the capital cost per person is approximately £6, a figure which compares most favourably with conventional plants (up to £40/person) especially in view of inherent diseconomies of scale in this small plant. A 10 000 - 15 000 person plant would cost approximately £4/person. Although these tank types have been available within the USA for about 30 years, plant life is estimated at twenty years minimum (the known life of such tanks to date within the UK). Operational manpower requirements are drastically reduced in comparison with conventional plant, this resulting from the automatic cycle of feeding and mixing which repeats every 20 mins throughout a 24-h period.

ACKNOWLEDGEMENTS

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AUTHORS' INTRODUCTION

Introducing the paper DR. NOONE, with the aid of slides, referred to the larger area scheme being viewed as the capital option to providing treatment for small works, and the fact that Pitts Mill plant was such a 'regional' scheme, albeit on a small scale. Some of the drawbacks of such regional schemes were referred to in the paper. He said that the revenue option was essentially tankering and mobile gangs. The options had to be carefully considered and then controlled in terms of cost.

Dr. Noone explained that the theme in this reported work, and indeed throughout the authors' work on digestion, had been to try to achieve elements of plant standardization, because it was only by standardization in design and construction that one could contemplate production of a package digestion plant. This should comprise not only the economies of plant manufacture, but also the internal economies of initiating and designing schemes.

Referring to Fig. 1. Dr. Noone said that such a schematic approach was crucial, because unless the entire sludge route was considered it could be difficult to identify and quantify the major problems. He said that thickening was important in financial terms, and the earlier in the flow sheet that tankering appeared, the more expensive would be the resultant overall route cost. He said that the technical requirements of any process route must remain paramount and that financial considerations offered a 'disipline'; they were not an end in themselves. Work study could point one along the way, but could not totally define the path.

He explained that the approach in the paper had been to use route costs, a commonly adopted technique, as this allowed truer comparisons of options.

MR. BOYD outlined the sequence of construction at the Pitts Mill plant, and said that it had been decided to erect the digestion plant on the existing drying beds which had been deemed 'redundant' as soon as the main works had been completed during 1975. With the aid of slides Mr. Boyd described the various stages of construction of the package digestion plant. He said that the total erection period had been only 18 working days and this was despite some loss of time during the removal of unexpectedly thick concrete from the drying bed base. On completion of the tank erection and equipment fitting, it had been filled with actively digesting sludge. On-site digestion was therefore available and operating within 18 days of the commencement of construction.

He explained that after the plant had operated for an initial period of three months, it was decided to modify the housing of the process equipment for reasons of added convenience and safety. This resulted in three isolated housings, one containing the primary electrical supply and control panel, the second containing the gas compressors, and the third housing the boiler. He said that there were three process timers controlling delay, mixing and pump feed and that the plant had now been operating completely automatically for about 16 months. The operators spend 30 minutes per week ensuring that the sludge feed tank was full and maintaining records.

Mr. Boyd said that on completion of the plant, sludge was not being imported into the works, and these figures had been used in route option B in the paper.

Dr. Noone then discussed further aspects of the route costing. Tankering, filter pressing at a distant works followed by cake disposal to farmland had been the inherited route. He said that, despite the works being of recent construction, the authors had not been able to ascertain the capital costs of the unused drying beds. He added that the principal existing asset to be incorporated in the digestion plant was a raw sludge holding tank which had become the digested sludge holding tank. Prior to erection of the digestion plant, the sludge was tankered via a round trip of 22 km to a filter press plant at another works, where the pressing cost was about £40/tonne DS within an overall cost of about £83/tonne DS. In route option B within the paper, he said that an allowance was included for tankering from the works to local disposal. More recently, sludge was being transported to the digestion plant from the Newent works to which the Pitts Mill sludge had previously been transported.

Dr. Noone said that option C, that of drying beds followed by cake disposal to farmland, had not actually been operated and that the costings had been produced from divisional and national works study data.

He said that, whilst it was obvious that package digestion (option B) was the most cost attractive route option, the question of whether the cost reductions were sufficient to finance the plant installation required careful evaluation.

Dr. Noone briefly referred to other possible treatment routes. He said that lagoons were considered to be an unsatisfactory method for the reasons referred to in the paper. Aerobic digestion was considered to be excluded because of the high energy requirement and guideline restrictions. He said that lime treatment had been tried, but discontinued, at Pitts Mill because it suffered from a number of problems, one of these again being compliance with the current DOE guidelines on the disposal of sludge to land. Consideration had been given to the possible use of mobile dewatering plant, such as the filter-belt press, both as being a back-up and a useful option. Suitable operators and their mobility may be a problem. He added that at this stage sub-soil injection could only be regarded as a relatively expensive option to a stablization stage.

In conclusion, Dr. Noone said that the demonstrated thread of standardization was the prime factor to enable package digestion and that the same standardization approach could also reduce the tankering problems, especially loading periods.

DISCUSSION

MR. C.F. SKELLETT (Wessex WA), opening the discussion, said that operational staff were currently in a difficult position with, on the one hand constraints and guidelines being imposed, and on the other hand financial restrictions. In the Wessex WA considerable work had been carried out on unit costs and the results for sewage treatment, excluding sludge costs, had confirmed that the larger the treatment works the lower the per capita running costs. However, this had not been found with sludge treatment and disposal costs which showed an almost random distribution. Detailed investigation had shown that the two principal factors were the high cost of operating plate presses and the importance of thickening sludge prior to tankering. The cost of sludge tankering had escalated; it currently cost about £20 000 per annum for a tanker and driver, and sludge thickening had become increasingly important. The Wessex WA had achieved considerable success in using wedge-wire cells to dewater sewage sludges.

He said that a novel way of transporting sludge had been used in the Bath/ Bristol area where sludge from the Bath and Keynsham treatment works was pumped into a trunk sewer on the Bristol sewerage system. It was then transported via the sewerage system to the Avonmouth works for treatment. Sludges containing up to 8% DS had been transported in this way, and the only problem that had been encountered was the need to improve ventilation on a poorly ventilated section of the sewer to prevent septicity.

Mr. Skellett said that he had reservations concerning some of the costings given by the authors in the option routes. It appeared from the data presented that the initial raw sludge contained only about 3% DS and he asked the authors if thickening had been considered in the tankering option or whether the costings were based on tankering this thin sludge. He also commented that he did not consider that the leasing costs of a tanker should be excluded from the calculations and that if these costs had been included then option B would be financially much closer to option C.

Mr. Skellett asked why the cost of cake disposal given in option C was more expensive than the cost of disposing of liquid digested sludge in option B.

He asked the authors if they had considered pre-thickening prior to digestion and whether this was worthwhile for small-scale plants. He also asked for any views on the use of mobile dewatering plant for dealing with surplus activated sludge.

In conclusion Mr. Skellett thanked the authors for their paper which, in demonstrating that digestion could be attractive for small-scale works, provided an important contribution to the future of sludge treatment and disposal.

MR. P. LOWE (Yorkshire WA) considered that when the water authorities had been created in 1974 many people had decided, without any critical assessment, that small works should be abandoned in favour of centralized sewage-treatment and sludge-disposal facilities. Many of these grand schemes had soon been disregarded when the costs of sewerage and sewage-treatment works extensions had been realized. As far as sludge disposal was concerned, however, the centralized concept prevailed; drying beds were closed down and tankering to the nearest 'large works' was introduced. The solution had the feeling of standardization and uniformity, coupled with a 'gut feeling' that it was cheap as well as giving managers time to concentrate on the more immediate problems posed by the larger works. It was only when many of the operators had been redeployed into mobile gangs and could no longer afford time to lift drying beds (a job that they disliked anyway), and when some of the large articulated tankers had become stuck a few times on the cart track access roads or could not turn round when they reached the works, that this universal solution began to be questioned.

He said that the increase in the volume of sludge disposed of as liquid using road and land transport from larger works and its resulting low cost could, as the authors had identified, lull the manager into thinking that using tankers to transport sludge to large works was equally as cheap. He therefore supported the authors' view that the whole sludge route from production to disposal must be examined to find the cost of sludge disposal from a given works. In 1979 the staff of his division had devised a system of determining such costs based on three distinct elements:

(1) The unit process index cost (UPIC) defined as the average cost incurred by processing one tonne DS through a single stage of its treatment route; the weight of the sludge entering the unit of process being deemed to have passed through the unit of process.

(2) The process route index cost (PRIC) defined as the average cost incurred by processing one tonne DS through a sequence of treatment stages which comprised the process route; the weight of sludge entering the route being deemed to have passed through the route.

(3) The through routes index cost (TRIC) defined as the average cost incurred when one tonne DS produced at a works is divided into its separate parts and each part is processed through a specific route.

By a series of mimics these costs could be represented diagrammatically. What had been realized when these diagrams were considered for the first time was that centralization of sludge treatment from small works was not the cheap answer it was first thought to be and, in fact, the transportation costs formed by far the largest element within the overall cost. The 1981-82 assessment based on the particular tanker fleet operating in the Lower Calder area showed that the average cost of transport amounted to £1.19/km.

He said that when process costs were considered and, in particular the unit process cost, it should be borne in mind that the tankering of sludge from small works to large works could significantly reduce the unit process cost at the large works. He had noted in the paper (page D8) that the Pitts Mill site had become a small centralized sludge-treatment works. He therefore asked the authors what had been the effect on the process cost at the Newent works by diverting sludge to Pitts Mill and whether this 'loss of profit' should not have been set against the route cost of the Pitts Mill plant in Table 1. He also enquired if there had been any significant saving in the cost at the exporting small works, bearing in mind the relativity of the three elements of sludge loading, journey period and unloading. He also wondered how many small works were catered for at the Pitts Mill treatment plant.

Mr. Lowe asked if the extra sludge at Pitts Mill was needed to make the plant operate more efficiently or to reduce this particular process cost, and was there perhaps a minimum size of digester, as described in the appendix of the paper, below which this type of installation would not be considered worthwhile.

He said that using his own method of presenting the cost, the Pitts Mill system would have been costed to show in a little more detail, not only the cost of digestion and disposal, but also the cost of operating the thickening and storage tanks and he wondered if the authors could state whether this element was included in the tanker operating costs of £6.56/tonne DS.

He said that his particular method of costing showed that there were 'operating lagoons' capable of holding one year's production of sludge with cold digestion having been established and, where the works was surrounded by accessible land, the process route index cost for this method of treatment was much lower than centralized treatment. As stated by the authors the method relied on a system that might not always be effective, as well as requiring large land areas, which may not be available at the small works. If, however, a more controllable system could be devised, and the cold digestion process accelerated, such a system would be of benefit as a means of sludge stabilization at the small works. Even with a heated sludge digestion plant at a small works he considered that the storage capacity for the digested sludge would still have to be designed on the minimum volume required to give a reasonable application rate to any one of the nearby fields. He said that he had noticed in the paper that for Pitts Mill the storage capacity was given as 20 weeks, so allowing a four hectare field to be spread (by calculation on page D6). If this storage capacity and the retention period could be harnessed to stabilize the sludge then the cost could, he suggested, be significantly reduced.

At the Great Cliffe works near Wakefield (population 1500, annual sludge production 33 tonnes DS), following successful laboratory work, a full-scale experiment was set up to ascertain if cold digestion could be established. Instead of tankering raw sludge from Great Cliffe to the larger works for digestion the system was reversed and heated digested sludge freshly withdrawn from the digester was transported to Great Cliffe.

He said that at this works three drying beds had been converted into three sludge-holding tanks, each having a capacity of 83 m^3. The tanks had been connected to operate in series so that by pumping sludge into tank 1, sludge would be displaced into tank 2 and eventually into tank 3. Dewatering valves had been fitted to each tank, together with connexions to allow the recirculation of the tank contents. 68 m^3 of digested sludge were transferred by road tanker to Great Cliffe and discharged into the tank. Raw sludge was then pumped into this tank three times per week where it was mixed with the imported digested sludge, eventually filling the tank and displacing it into the second tank. Thus the first tank had become the reaction vessel and, as the sludge was displaced from tank to tank, the reaction slowed down thereby allowing dewatering to take place in the second and third stages.

Mr. Lowe supported the authors that the secret of maintaining any digestion process and, in particular, cold digestion, was to provide adequate mixing. This had been demonstrated when, after 15 weeks, the volatile acids concentration which had been low suddenly began to increase, but when better mixing was introduced the system recovered. When all the tanks were full there would be sufficient fully digested sludge to give an adequate application rate for 13.4 ha of land, and the process would be recommissioned by filling the first stage with freshly digested sludge and recommencing the cycle. He said that it was interesting to note that the first inoculation had, to date, supported active digestion for 22 weeks or 11 times its own DS weight. It was worthy of note that if digestion could be established in the fully controllable system as presented by the authors, or even in the less predictable accelerated cold digestion process as just described, then sludge was being destroyed continuously which had the advantage of reducing the quantity for disposal.

MR. K.G. PULLEN (POSSET, Engineering & Pollution Control Advisory Service) said that prior to the publication of the DOE guidelines on sludge disposal to land many operators were quite happily disposing of liquid sludge to land. The guidelines made reference to the restrictions imposed on the disposal of raw sludge in such a manner, and he agreed that preferably sludge should be digested before spreading onto agricultural land. However, he wondered in the context of small works whether one was really considering raw sludge, because there would be a considerable period of retention of the sludge either in the sedimentation tank or in a sludge holding tank caused by the infrequent visits of a tanker. Such retention would allow digestion to commence and such sludge could probably be disposed of quite safely to land without undergoing further treatment.

Secondly he said he was suprised that sludge had apparently been tankered at a DS concentration of only 3%, a point to which a previous speaker had referred, particularly when the flow diagram had indicated that the works in question had sludge holding tanks. Decanting of supernatant liquor would surely have made a considerable difference to the costing exercise.

Finally, with reference to the costing involving sludge dewatering plant he asked what conditioning agents were considered for aiding filtration. He suggested that if only lime and copperas had been used then costs might have been considerably reduced if polymers had been used.

MR. B. METCALF (Yorkshire WA) asked the authors if excess gas had been produced during the operation of the Pitts Mill digester, and if this was the case he wondered how it was utilized. He also enquired if the liquors produced from the thickening of the digested sludge caused any problems on the small works.

MR. J.L. ARNOLD (Yorkshire WA), in a written contribution, said that there was a real need to develop the sludge digestion process so that it utilized equipment that was less expensive in capital cost, was trouble free and more efficient in operation. Even so, he wondered why it was thought necessary to provide such a unit at the Pitts Mill works. He said that digestion was only necessary where environmental constraints prevailed to the extent that overcoming them incurred unacceptable additional expenditure in transporting to other more suitable areas, such that digestion provided the overall cheaper solution. He saw no reason to digest the sludge if this proviso did not apply and could not envisage any environmental reason for this requirement at the Pitts Mill works.

He recognized that digestion may provide a cheaper route than the transporting of thin sludge to Newent works, but suggested that an even cheaper option would have been to dispense with the sludge direct to land without treatment, because there was sufficient arable land available in the area and no housing to impose environmental constraints.

He said that he would be interested to know the philosophy that prompted this worthwhile project being undertaken in a rural area when there must surely have been more urban areas which would have obtained greater benefit from the installation. He asked if previously any real effort had been made to introduce farmers in the area to the benefits of application of undigested sludge to land, with the resulting much slower but continuing release of nutrients.

MR. K. STAPLES (Watson Hawkesley) enquired about the basis of the route costing adopted within the paper, and particularly the fact that the costs were defined as not including capital cost. For the comparison made between the three options, it appeared that the capital investment involved, both in the provision of the package digester at Pitts Mill and the tanker fleet for handling liquid sludge, would be of such significance as to materially affect the comparison.

REPLY TO DISCUSSION

In reply to Mr. Skellett, DR. NOONE said that it was also being confirmed that tankering costs were beating inflation by a significant amount. With reference to the use of wedge wire dewatering cells, MR. BOYD had experience of these on a plant where the unit had been contained in concrete tanks. It had been a batch system and unfortunately there were only two tanks available, a fact which of itself had imposed problems; however, the authors agreed that the system could work satisfactorily.

Dr. Noone confirmed that the raw sludge contained only 3% DS. He said that one problem in assessing the size of a works was the paucity of reliable information, and in this case the volume of sludge was known but only limited information of the DS content had been available, and therefore reference had been made to standard data for the anticipated dry solids level. He said that a figure of 3% DS had been estimated (and later confirmed practically) because at this site there had been no specific thickening process available. The actual cost figures for the inherited route were for 1979-80 which was the last year that the treatment route had been used. In connexion with the omission of leasing costs for tankers he said that this had been the subject of debate, and he had taken the view that the leasing cost was the 'capital' element of the tanker. However, he said that if such costs had been included then option A would have been even more expensive compared to option B (package digestion) due to the greater tankering involvement in this route.

The authors agreed with the use of sewers for sludge transport and indeed within the Severn-Trent WA this was crucial to the Minworth/Black country scheme. However, they could not see its relevance in the context of small works.

Dr. Noone explained that the cake disposal costs were higher because these costs reflected the fact that the plate press process had virtually exclusive use of a tractor and trailer unit, whereas the route costing of the liquid disposal with the digestion option was based on an operating practice which allowed pro rata use of the tanker. He said that, whilst figures for cake disposal within the Severn-Trent WA (with the driver on cost) ranged from £3 - 32/tonne DS, the average figure was marginally higher than that used in this paper.

Pre-thickening was included within the design and subsequent erection of Pitts Mill as recognition of the major benefit of thicker sludges within the digestion process. By this means sludge solids concentrations from the existing plant had improved so much that there was always surplus gas production. Small mobile plant for thickening from small SAS plants (presumably oxidation ditches) may suffer from setting-up problems (e.g. polymer dose/type) if used at a large number of works.

In reply to Mr. Lowe, Dr. Noone thanked him for his comments about his trials using cold digestion. He said that Mr. Lowe's figures had confirmed the basic tankering costs; it was interesting that in every case presented of his own works, the plate pressing costs had exceeded the total route costs for the Pitts Mill option. With reference to Pitts Mill works he said that it would be possible to produce a table of differing process costs versus various loadings and, although the plant had been operated at many sludge throughput levels, those in the cost calculation were for the lower population and therefore reflected the most expensive costing. With reference to costs, no elements had been included for the benefits of cost savings from the Newent pressing stage or the reduced tanker travel distance realized by diverting sludge from the other works (more distant from Newent) to the Pitts Mill digester. Three other works now contributed to the Pitts Mill sludge make. The additional profit from the diversion to Pitts Mill had not been included. This would be the contributing population multiplied by the Newent from Pitts Mill route cost as all of these works were 'beyond' Pitts Mill in relation to Newent. He confirmed that the additional sludge was not required to maintain operation of the plant. The heat balance at 2600 population and 3% DS was satisfactory. This was aided by the tank insulation being twice as effective as any concrete digestion tanks. Operation was sustained under these conditions at about a 20-day retention period with average gas usage for maintaining the digestion process being approximately one third of production.

The cost of operating the thickening stage was included within the digestion portion and did not contribute to the rather conservative costing which resulted in a relatively high 'over the fence' final element of cost for Pitts Mill.

Regarding the reported work on cold digestion, Dr. Noone reaffirmed that control of the operational conditions would be a major concern, e.g. mixing and maintaining essentially isothermal conditions. In view of the low overall cost of the package operation, especially with respect to operation, the authors felt that the 'cold' option, whilst maximizing usage of the available retention period, could require significantly greater operating effort and surveillance. Such a process would be appealing given adequate control and an existing asset of a large storage tank of suitable shape for mixing and reasonable heat retention. The package could utilize any form of subsequent storage to comply with the requirements of a suitable volume for final disposal.

In conclusion, the authors thanked Mr. Lowe for re-affirming two significant points; (a) assumptions and 'gut' feelings about route costs and indeed any process considerations must be rigorously examined to verify the situation, i.e. defining the problem is a prerequisite of finding the solution and invariably points one towards the solution, and (b) sludge digestion (with adequate post digestion thickening) also performed the function of a 'disposal' route due to solids destruction.

Replying to Mr. Metcalf, Mr. Boyd confirmed that excess gas was produced and about a third of the production was used to heat the digester. However, the gas production at this size of installation was small and the surplus was not really sufficient to consider its use for power production. He said that some preliminary work had been carried out on utilizing the gas for incineration of screenings, but the details had not yet been collated.

He said that the liquors produced from thickening had not to date produced any noticeable increase in load on the works, although in common with many new works it was not operating at its full design loading. On this aspect Dr. Noone commented that there was a number of benefits of cooling in terms of thickening the digested sludge. Two inherited drying beds had been converted into shallow digested sludge coolers which enabled the achievement of a sludge of 6% DS. An additional benefit also was the clarity of supernatant liquor which was removed, this further reducing the possibility of any noticeable return load to the works.

In reply to Mr. Pullen, Dr. Noone said that with reference to the degree of digestion that occurred during the 'storage' of raw sludge at small works and its suitability for land disposal, this was largely a matter of policy decision as satisfactory volatile matter reduction will not occur. Any supposition that storage is equivalent to controlled anaerobic digestion presumes an act of faith much too great for the authors to contemplate. Partial digestion to the acid phase should merely conspire to achieve the worst of all worlds.

He added that the WRC thickening survey had indicated the production and tankering of much thinner sludges, indeed there was a massive potential market for the application of methods of improving this aspect. At the many works in question thin sludges had been disguised by the use of the ubiquitous tanker.

Dr. Noone said that the chemical conditioner used was aluminium chlorohydrate, as had been referred to in the paper. He admitted that this was not a cheap conditioner and the use of polymer may realize some reduction in cost, but again as adequately described in the paper itself the pressing route costs were approaching double the costs of the digestion option at the lowest throughput of the digester.

In reply to Mr. Arnold, having regard to the national and international concern with respect to the disposal of raw sludges, the authors could only admire the stoicism required in maintaining what may be deemed by others to be a Canutian approach to the agricultural disposal of sewage sludge.

The supposition that Pitts Mill and rural works were invariably free of any environmental constraints requiring sludge stabilization was totally inaccurate. The prime constraints of Guideline compliance (pathogens, etc) applied equally to rural and urban situations. Odour complaints (nearest house to Pitts Mill is 100 m) were not perculiar to urban sites; indeed a most vociferous complainant to a Severn-Trent WA rural sewage-treatment works was the owner of a pig farm some 600 m distant.

In replying to the questioning of "why provide a 'rural' plant", the authors said that an 'urban' site would have required a larger package project with correspondingly larger risk capital. The other papers by one of the authors quoted in the references covered work on digestion plant provision at various urban works (from 10 000 to 200 000 population). The package system of Pitts Mill had been extended to 25 000 population and a plant for 40 000 population was proposed in another Authority. All these factors apart, the development of the small digestion plant as an 'antidote' to the large centralized sludge treatment facility remained a major thrust of this work.

In reply to Mr. Staples concerning the basis of the route costings, the authors said that the inclusion of capital considerations merely served to accentuate the attractiveness of package digestion (option B). As described fully in the paper the inclusion of capital costs for the digestion package still resulted in a total route cost significantly below the 'operating only' cost of the inherited tanker, pressing and cake disposal route. The paper gave the costs of capital for the tankering stages, although they were not included in the comparisons which remained on an 'operating cost only' basis.

Including capital costs for the pressing and tankering stages (option A) and the drying bed and tractor stages (option C) merely served to demonstrate that the package digestion was even more attractive given a 'green field' choice. The direction of the paper had been to demonstrate options to apply to existing works assets, and in these cases any plant revision could only be financed from the combined revenue savings of the 'replacement' route.

At the conclusion of the discussion the Chairman proposed a vote of thanks to the authors which was carried by acclamation.

CHAIRMAN'S CONCLUDING REMARKS

In summing up the day's proceedings the Chairman, Mr. J.M. Taylor, said that when arrangements for the Symposium had been initiated there had been some concern about the choice of subject. However, he said that it was obvious, judging from the response, the quality of the papers submitted and the discussion during the day, that the correct subject had been chosen.

With reference to the paper by Mr. K. Staples on the design of small sewage-treatment works he said that he liked the reference to the uniqueness of the requirements of small works, because so often in the past too many designers had regarded them as being small versions of larger works and this had been to the operator's cost. He endorsed Mr. Staples' comments on the importance of the designer's reference to the personnel who would be responsible for the operation of plants. He said that Mr. Pullen's comments on the paper, although not everyone would agree with them, were very thought provoking. He agreed that the design of pumpimg stations which delivered to small works was an area which had been sadly neglected and the question of standby pumps and duty pumps was relevant.

Mr. Taylor thanked Mr. O'Neill for his paper and recalled, when they had worked together in the past, the interest in ventilation holes on biological filters. He remembered the concentration on this aspect from time to time, but whether such efforts had been beneficial was another question. He considered that the reference to vandalism was extremely important; this had also been referred to by Mr. Tench. Certain districts could suffer very badly in this regard and certainly anti-vandal measures should be designed into the works. Mr. Taylor agreed with Mr. Tricker's comments on unsophisticated methods of testing - these could be a great encouragement to an operator. He considered that the application of standard frequencies needed regarding with a degree of circumspection; they could, like performance indicators, be misused if incorrectly applied.

He thanked Dr. Pike, Mr. Harrington and Mr. Mosey for their excellent paper, which was of a high standard that one had come to expect from the WRC. He agreed that it would become a reference document for students and indeed anyone wishing to familiarize themselves in this particular aspect.

Mr. Taylor said that the paper by Dr. Noone and Mr. Boyd, with its accent on on-site treatment, was very thought provoking and thought that their presentation at the meeting had been excellent. It had fully justified the decision to include a paper on that subject.

In conclusion he expressed thanks to the President, Mr. G. Eden, for being present, and on behalf of the North Eastern Branch he expressed thanks to the authors, to the delegates who had attended and contributed and to the manufacturers who had participated in the trade exhibition, for the respective parts that they had played in making the Symposium successful. He said that a great deal of effort had been expended in the organising of the symposium of this nature, particularly for the first time. This had been achieved by the setting up of a small working group and he wished to express his personal thanks to the people who had been involved in this for the great amount of work and their enthusiasm. He also thanked members of the Branch Committee, who had proferred advice, (some of which was actually taken notice of), and the members of the National Symposium Sub-Committee who had been of great help.

THE PRESIDENT'S CONCLUDING REMARKS

The President of the Institute, Mr. G. Eden, said that as one who had been priveliged to take part in the day's proceedings, albeit mainly as an onlooker, he hoped that those present agreed that the Symposium had been well worthwhile. The papers presented had been very good, there had been good discussion and the general arrangements at the venue had worked very well. He said that much of the value of such a conference depended upon the planning and thought that went into its preparation. Mr. Taylor had acknowledged the work of the organising Sub-Committee and Mr. Eden wished to endorse these sentiments and added that much of the initiative and enthusiasm had emanated from Mr. Taylor himself. He proposed a vote of thanks to Mr. Taylor, which was carried by acclamation. He also thanked delegates for supporting the Institute by their attendance at the Symposium.

LIST OF EXHIBITORS

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