Ministry of Works
and Development

INTERMITTENT BIOLOGICAL SAND FILTERS FOR WASTEWATER TREATMENT

Civil Division Publication

CDP906/A: 1982

CONTENTS

1 SCOPE

This document is an update of the May 1974 publication entitled 'Intermittent Sand Filters for Sewage Treatment'. It is intended to provide guidelines for the design, installation and operation of intermittent biological sand filters for use as 'secondary' or 'tertiary' units for the treatment of domestic wastewater.

The design guidelines given do not differ a great deal from those contained in the earlier publication, but minor modifications have been made and more information given on matters of design detail.

It is emphasised that the design information given relates only to intermittent biological sand filters operated as 'secondary' or 'tertiary' treatment units treating domestic wastewater. It is not relevant either to rapid sand filters used for either the treatment of water or wastewater, or to slow sand filters used in water treatment.

2 DESCRIPTION OF THE PROCESS

2.1 Basic Layout and Method of Treatment

An intermittent biological sand filter is essentially a bed of sand supported by graded gravel underlays. Wastewater effluent is passed through this sand layer before either percolating into the ground or being collected for disposal elsewhere. With appropriate adjustments to the loading rate a filter can be used for either 'secondary' treatment of wastewater which has been through a sedimentation process (septic tank, Imhoff tank or other settling tank) or 'tertiary' treatment of wastewater which has already been biologically treated (in a trickling filter or by an activated sludge process in a 'package' type plant). A schematic layout of a 'secondary' sand filter plant is shown in Figure 1. For both 'secondary' and 'tertiary' filters a minimum of two beds is required.

Treatment by intermittent biological sand filters involves both physical and biological processes. The top surface and upper layers of the sand physically filter out some of the particulate matter contained in the partially treated wastewater. However, the more significant treatment processes are the biological ones in which micro-organisms adhering to the sand particles utilise the organic matter in the wastewater. Aerobic processes dominate in the filter and it is therefore important to ensure that air can circulate through the bed.

A bed is operated in a 'plug-flow' manner by first flooding the bed with a predetermined volume of effluent and then resting it for a period long enough to allow the wastewater to flow completely through the bed and air to get into the bed. As with trickling filters (and other fixed media biological reactors), because the treatment process relies for its effectiveness on intimate contact between the fixed micro-organisms adhering to the filter media and the moving wastewater flow passing the media, uniform distribution of wastewater through the filter is vital for good treatment. Short-circuiting leads to rapid clogging of the bed, surface ponding and a deterioration in effluent quality.

2.2 Effluent Characteristics

The quality of effluent from intermittent sand filters is as good or better than that from other simple forms of treatment. Properly operated, expected performance is:

(a) 'Secondary' filters - 95% applied BOD removed.
95% reduction in total (37°C) coliform bacteria.

(b) 'Tertiary' Filters - 95% applied BOD removed
99% reduction in total (37°C) coliform bacteria.

In both cases the effluent will be highly nitrified and virtually free of suspended solids.

2.3 Process Applications

The process has the ability to cope with some fluctuations in wastewater quantity and strength. The process is simple to operate requiring only limited operational expertise although larger units need proportionately more operating input than smaller units (see 'Operation and Maintenance'). 'Secondary' filters are useful for small subdivisions, schools, motels, motor camps and similar establishments. One of the larger 'secondary' installations designed by the Ministry of Works and Development serves a permanent population of 1100 persons at an overseas location; another, in this country, serves a motor camp with a holiday population of up to 1800 persons.

As a 'tertiary' treatment system the process finds most use for improving the bacteriological quality of 'package' wastewater treatment plant effluents. It can also be used to improve effluent from larger activated sludge and trickling filter plants.

3 DESIGN CRITERIA

3.1 Siting

Most level or nearly level sites can be adapted for the installation of the system, but a few points should be watched. Leaves and other windblown debris can interfere with filter operation so the site should be well clear of sources of such debris.

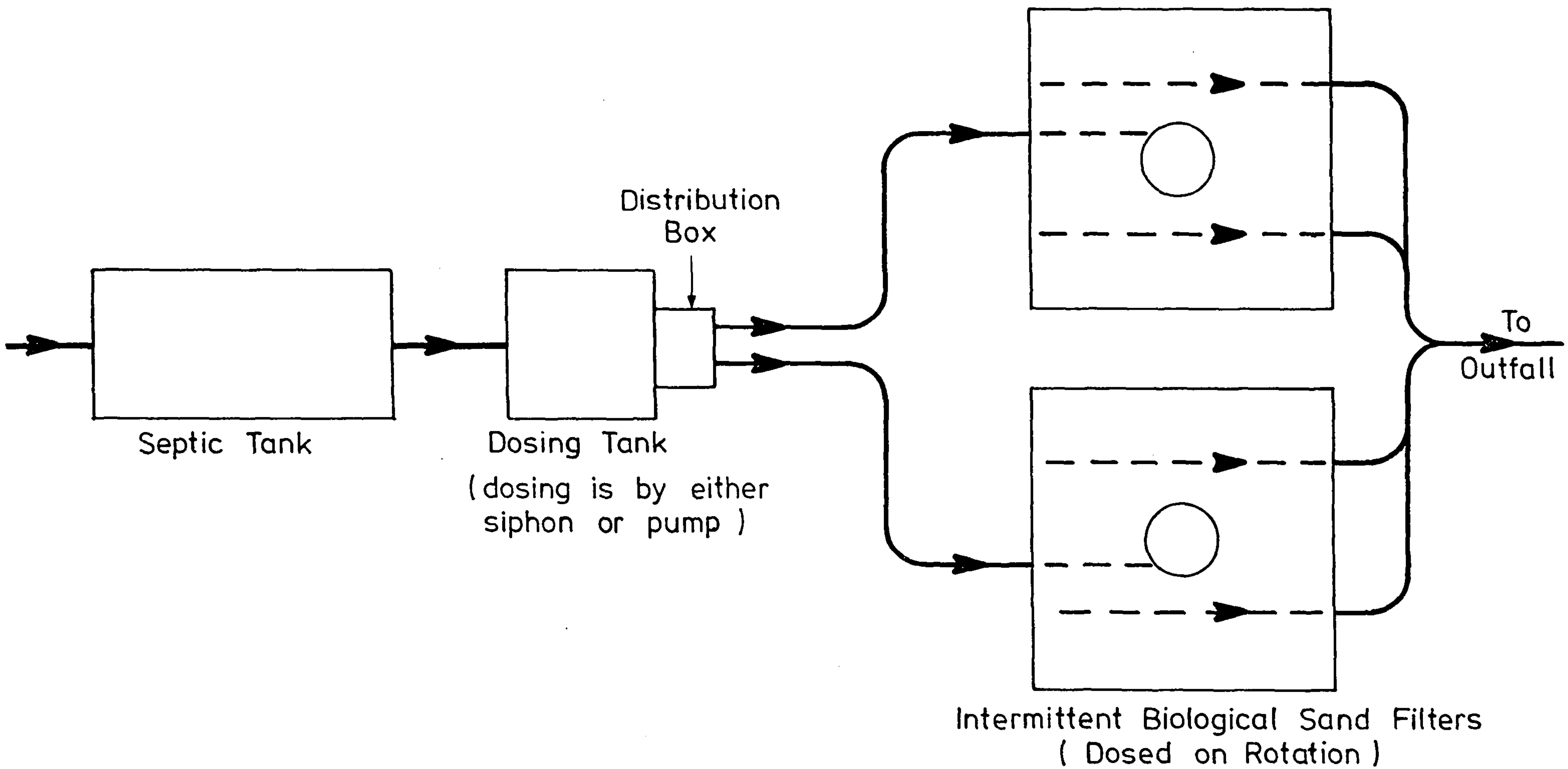


Figure 1: SCHEMATIC LAYOUT OF TREATMENT PLANT INCORPORATING INTERMITTENT BIOLOGICAL SAND FILTERS AS 'SECONDARY' TREATMENT

Where the intention is that the treated effluent soak into the subgrade, checks should be made to ensure that the subgrade is suitable for such a system.

The filters are not visually intrusive, nor, if they are properly designed, operated and maintained, do they give rise to odours. They can therefore be sited close to public places, although a minimum clearance of 30 metres from dwellings is recommended for small plants. A greater distance is advisable for larger plants.

To reduce vandalism and in the interest of public health and safety the site should be fenced.

3.2 Loading Rates

'Secondary' filters should be designed for a total filter area of between 7 and 10 square metres per cubic metre of effluent per day (at flows of 200 litres/person day, this is equivalent to an area of between 1.4 and 2 square metres of bed/person).

Loading rates for 'tertiary' filters can be significantly higher due to the more stable nature and lower solids content of the effluent. Total bed area should be between 0.67 and 2 square metres per cubic metre of effluent per day, (0.133 and 0.4 square metres/person at 200 litres/person day).

These areas are for the total filter area of the system (e.g the total of both bed areas of a two bed plant). The choice of dosing rate within the ranges given above depends upon two main factors. Firstly, the dosing arrangement: if the beds are automatically dosed in rotation (secondary beds each dosed twice daily, tertiary beds each dosed three or four times daily) the beds work more efficiently and can be sized on the higher dosing rates. Where the beds are alternated weekly they should be sized on the lower dosing rates. Secondly: where filters are put in at holiday resorts or other places which have marked variation in seasonal load, filters should be sized for the high season load, but on the high bed loading rate.

3.3 Number of Beds

At least two beds must be provided and up to four may be used if topography or total bed area requires this. All beds at a given installation should be the same size to ensure equal dose rates.

The maximum size of an individual bed is determined by the need to ensure that the bed receives an even dose over its entire area. As a guide, the largest beds installed by the Ministry of Works and Development each cover an area of approximately 630 square metres, although in this case the beds were rectangular and fitted with twin dosing points.

4 DESIGN DETAILS

4.1 The Beds

The beds are made up of four distinct layers of material (see figure 2). The top 750 mm should consist of a fairly uniform medium sand. Sand with particle sizes between 0.3 amd 0.6 mm and a uniformity coefficient of not greater than 4 has been used successfully. However, if this is not readily available a slightly coarser sand may be used although for 'secondary' filters it is important not to have the sand so coarse that solids in the applied wastewater will be washed deep into the bed. In general a uniform river sand with particle sizes generally in the 0.3 to 0.6 mm range will prove suitable.

The sand layer should rest on a 100 mm layer of 3.5 to 6.5 mm particle size 'pea' gravel beneath which is an 150 mm layer of 12 mm stone chip.

The underdrain system should be beneath this layer and bedded in 18 mm stone chip to a minimum cover depth of 40 mm.

Each layer should be levelled as accurately as is practicable. Particular care should be taken to ensure that the top surface of the bed is dead level as failure to do this leads to uneven dosing. As the bed is designed to act as a filter, the bed material must not be densely compacted. Mechanical compaction equipment should not be used, rather each layer should be lightly compacted by hand.

4.2 The Underdrains

These serve both to provide for the collection of treated effluent and to keep the bed aerobic. It follows therefore that an underdrain system should be provided even for those beds which are designed to have the treated effluent soak into the subgrade.

The underdrain system should consist of a network of 100 mm field tile drains at not greater than five metre centres. The drains should be laid on a grade of 1:100 or steeper and should drain to a main collector pipeline (usually 150 diameter and of conventional pipe rather than field tiles). This collector pipe may be either within the filter bed area or outside it.

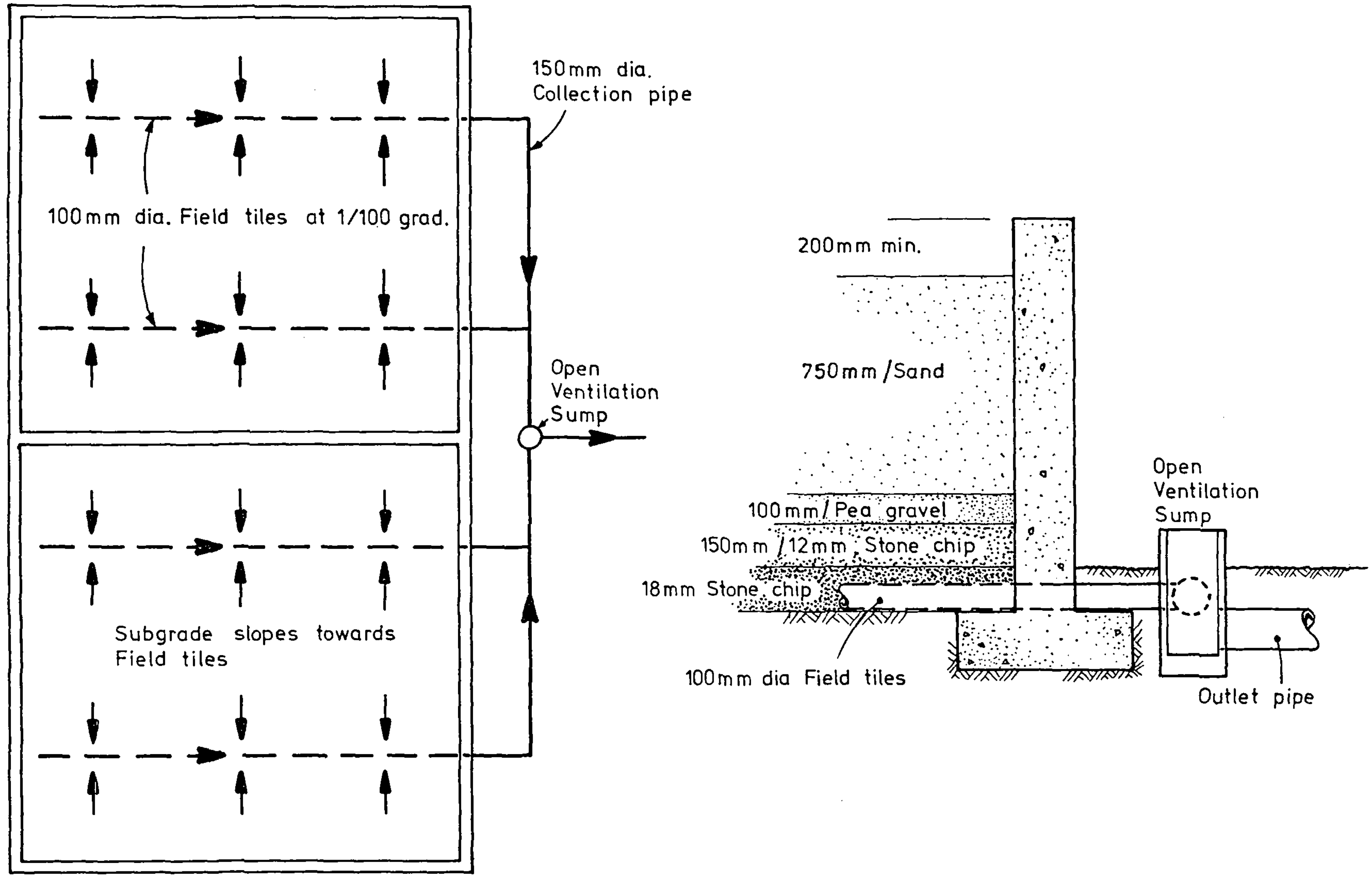


Figure 2: TYPICAL UNDERDRAIN ARRANGEMENT
(Shown as for filters constructed above ground)

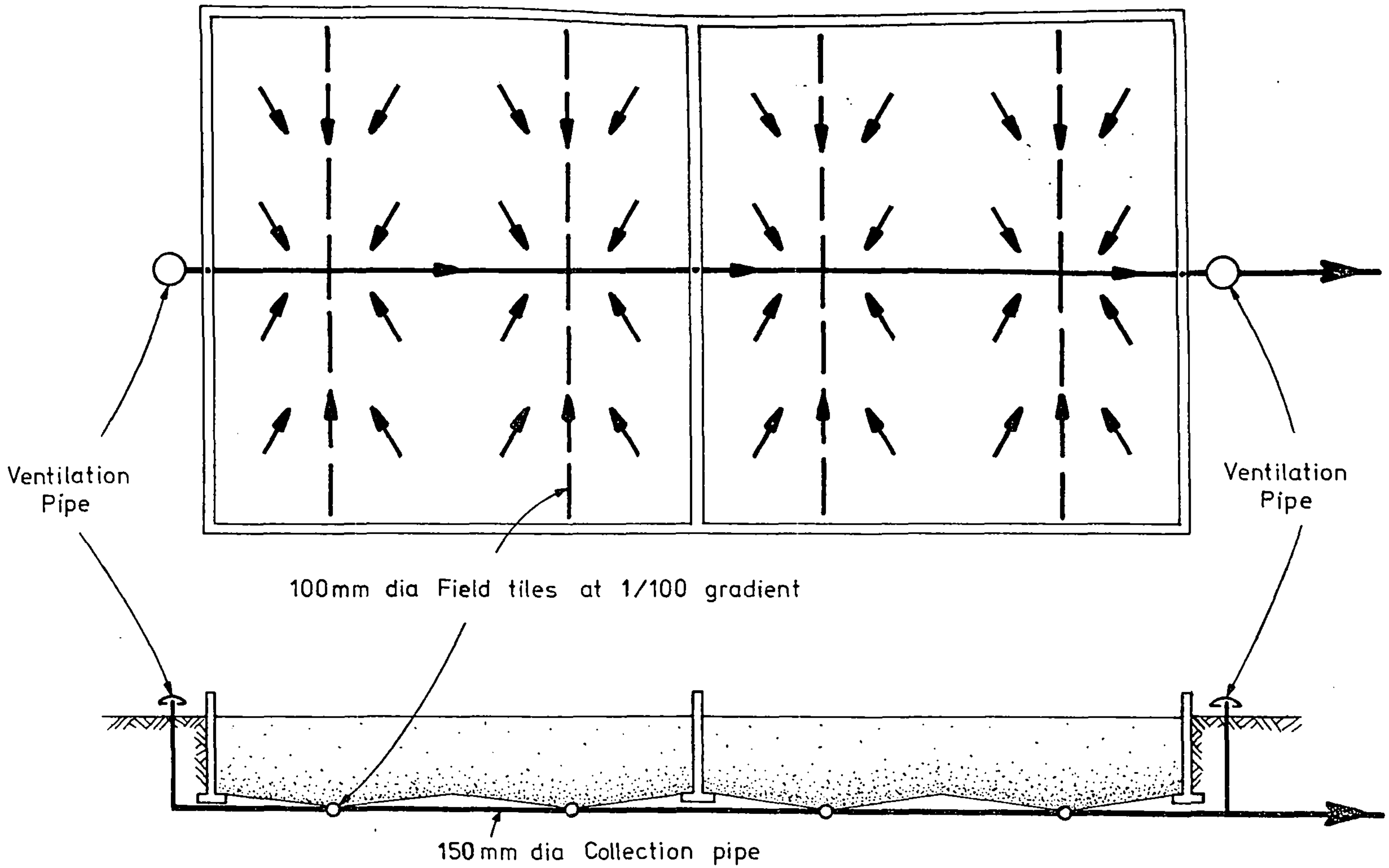


Figure 3: ALTERNATIVE UNDERDRAIN ARRANGEMENT
(Shown as for filters constructed below ground)

The field tiles should be laid with 10 mm gaps between tiles and, to prevent stones getting into the drain, the top half circumference of the gap should be covered with a durable membrane (malthoid or similar). The subgrade should be evenly sloped toward the field tiles. The use of perforated pipe type field drains is not recommended as the drain holes are too small and liable to be clogged by the build up of biological slimes.

The underdrain system must be vented to atmosphere to ensure a good airflow. Where filters are constructed above the surrounding ground level, underdrain ventilation should be provided by means of an open sump on the collection pipe outside the filter bed (see figure 2). Where filters are constructed below, or partly below, ground level, the collection pipe should be extended to each side of the bed and vertical upstand ventilator pipes should be fitted to each end (see figure 3).

4.3 The Structure

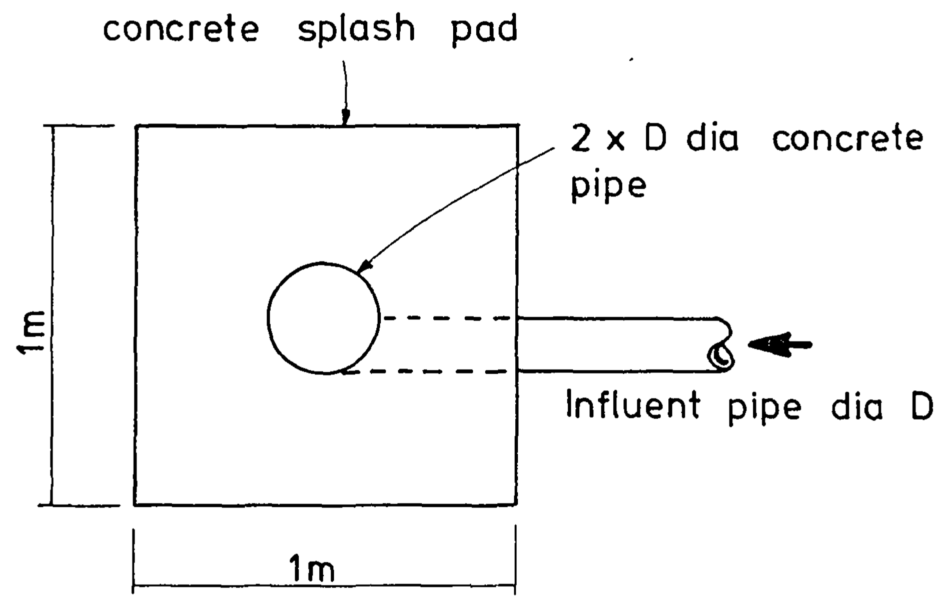
Each filter bed should be confined by a vertical wall a minimum of 200 mm above both the top of the bed and the surrounding ground. The wall should be of permanent materials. Reinforced concrete and concrete blocks on a concrete footing are commonly used (see Figure 2).

Filters can be built on any reasonable natural subgrade. The subgrade should be graded in accordance with the requirements of the underdrain system and, if it is intended that some or all of the effluent should soak away through a permeable subgrade, the surface of the subgrade should not be compacted but may be lightly scarified.

4.4 Dosing System

The dosing chamber need be no more than a simple concrete tank. Its capacity should be equal to the quantity of effluent required for one complete dose of one bed, (i.e sufficient to completely flood the bed to a depth of 75 to 100 mm; see 'Operation and Maintenance').

Dosing of the beds can be either by single or alternating dosing siphon or by single or alternating pumps. With a single siphon or pump a simple distribution box or pipework valving can be used to manually change the duty bed. For larger systems automatic rotation of beds is desirable and this can be achieved either by alternating dosing siphons designed such that each siphon's discharge primes the next siphon and each siphon controls the discharge to one of the beds, or by the use of alternating pumps with automatic rotation of the duty pump. In either of the automatic cases provision must be made for manual switching to enable any one of the filters to be taken out of operation for maintenance without affecting the operation of the others.



Note:
tangential inlet of influent pipe to inlet well

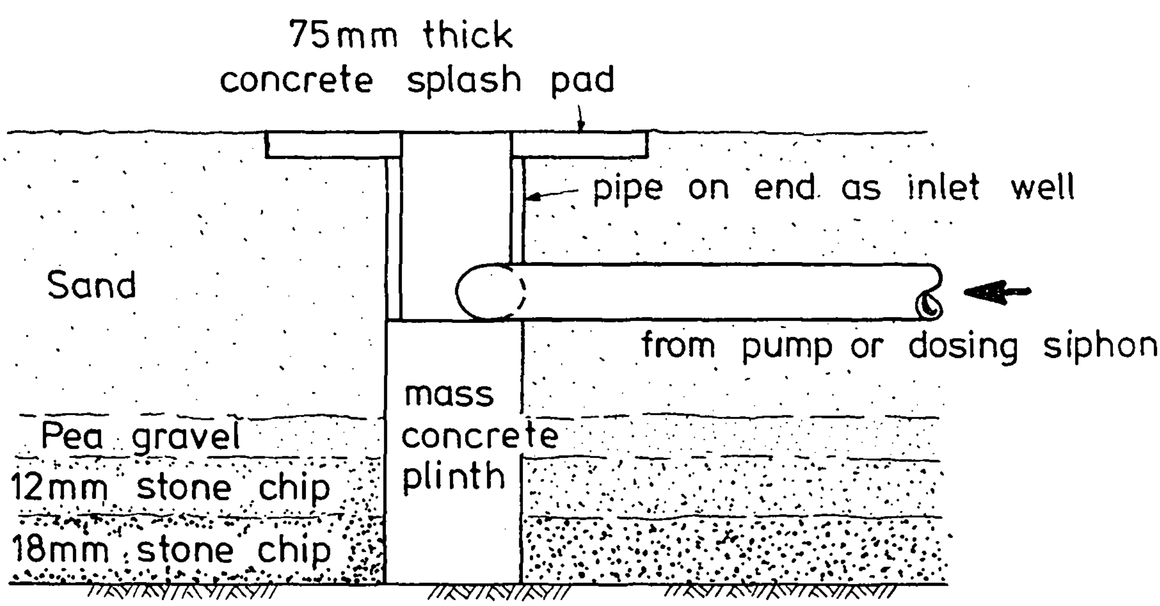


Figure 4: GENERAL ARRANGEMENT OF INLET TO BEDS

The Public Health Engineering section of the MWD has available information on the design of single and multiple dosing siphons.

The preferred arrangement for dosing the bed is shown in Figure 4, with the pipe coming in from below the top of the filter and tangentially fitted to a larger diameter upflow well. The upflow well should be approximately twice the diameter of the incoming pipe. This arrangement avoids effluent splash and the consequent problems of odour and scouring of the filter surface. To further guard against splash and possible odour problems, the discharge head should not be higher than necessary. Where a high head is unavoidable the depth of the upflow well should be increased. Pipes which discharge downwards onto the filter bed are not recommended.

5 OPERATION AND MAINTENANCE

The preferred method of operation is to have each bed dosed in rotation, with beds sized such that filter beds used for 'secondary' treatment are dosed twice daily under normal flow and 'tertiary' beds dosed three or four times daily. However, such a regime requires automatic alternating dosing arrangements. Where manual changeover of beds is used, the preferred method of operation is to change the duty bed weekly. Dosing of the beds must be by flooding them with a volume of effluent equivalent to a uniform depth of 75 or 100 mm over the bed area (75 mm for 'secondary' beds, 100 mm for 'tertiary'). Continuous trickle dosing is unacceptable as it prevents re-aeration of the bed.

A bed should be regarded as clogged when it takes longer than 30 minutes for the applied effluent dose to soak away. Under normal operation the beds should work for some months without clogging, although heavily loaded beds may need more frequent attention. When a bed does clog it should be left to thoroughly dry out. It should then be swept with a yard broom to remove the surface mat of dry organic material and then raked with a rake with 25 mm tines. Under no circumstances should the bed be dug over as this has the effect of pushing the organic material, which is the cause of the clogging, more deeply into the sand.

Beds should be kept free of weeds by hand weeding. Weedkillers must not be used as the roots of the dead weeds remain in the filter blocking it.

Over a period of time the top layer of sand may show signs of becoming clogged to the extent that normal sweeping and raking becomes ineffective. When this occurs the top 50 - 100 mm of bed sand should be removed and replaced with fresh clean sand. Typically, this sand replacement will be necessary about once every five years.

Proper functioning of intermittent biological sand filters depends on the quality of the influent to the filter. It is therefore very important that the upstream treatment plant and reticulation is well maintained and operated. Septic tanks must be desludged as necessary. Also, care should be taken to minimise entry of stormwater containing clay or similar material as this material can clog the filters.