5. CONCLUSIONS AND RECOMMENDATIONS

5.1. Introduction

This chapter presents the conclusions, which were drawn from the results and experience gained through this study, and makes appropriate recommendations for sewage disposal systems based on this study. Section 5.2 deals with guidelines for the design and application of each of the unit processes in turn, while section 5.3 deals with the selection and application of the unit processes to design treatment systems for each of the different categories under consideration. Section 5.4 discusses some of the appurtenances which were found to be important to the proper functioning of the systems in practice, while section 5.5 deals with issues relating to the actual implementation of the systems in the field. Section 5.6 discusses some of the anomalies in the national effluent discharge standards as is relevant to this study and proposes appropriate amendments.

5.2. Unit Processes

5.2.1. Septic tanks

Given the very satisfactory performance of the tanks designed according to Mara's method, in the field, and given the fact that it would significantly lower the cost of septic tanks in Sri Lanka as well, it would be more appropriate to adopt this method for septic tank design in Sri Lanka, with the following adaptations. These are based on the assumptions made in the course of this study, which have been verified against field experience.

a) Water height for settling to be based on a terminal settling velocity of 0.18 mm/s[34].
b) Volume of fresh sludge per day to be taken as 0.001 m^3/person/day for black and grey water, and 0.00055 m^3/person/day for black water only.

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[34] This was the value assumed in this study and appeared to work quite well.

c) A sludge accumulation rate of 0.04 m^3/person/year for black and grey water, and 0.022 m^3/person/year for black water only.
d) An overall internal tank depth between 1.5 metres and 2.5 metres[35].
e) A minimum design sludge storage period of 1 year for large tanks and 5 years for small tanks - particularly for individual houses, day-time occupancy buildings etc.
f) A minimum per capita flow contribution of 160 l/person/day for black and grey water and 36 l/person/day for black water only[36].

Tanks should be emptied when one third full of sludge in the case of 1-year tanks, and half full of sludge in the case of 5 -year tanks. 10-year tanks should be emptied when they are two thirds full of sludge.

5.2.2. Anaerobic filters

No proper guidelines seem to exist on the design of anaerobic filters, for the sorts of applications under consideration in this study. The Sri Lanka code of practice for septic tanks recommends the use of 'biological filters' for disposal of septic tank effluent where the percolation rate of the soil exceeds 60 minutes for a 25 mm drop. It also recommends the effluent to be discharged to a drain or reused for gardening. The code is rather vague in this context, and defines the 'biological filter' as "a shallow chamber consisting of a bed of gravel, broken stones, clinker etc. through which the sewage is made to flow in order to promote biological oxidation by a zoologic film developed on the filter media" (SLS 745, 1986). It does not provide any guidelines, however, for the design of these 'biological filters' merely stating that they may be either aerobic or anaerobic, and that the filter media, which should be clean and insoluble in sewage, "should be graded from 75 mm to 40 mm with the coarser ones at the bottom". The code also specifies that the filters should be provided with 'underdrains', but does not go on to explain their specific nature or purpose.

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[35] The lower limit is to guard against solids carry -over during peak flows and the upper limit is for ease of construction.

[36] This value could be increased as required to suit specific situations.

Based on the results of this study, it could be recommended that anaerobic filters, which are to be used for secondary treatment of septic tank effluents, be designed according to the basis of nominal hydraulic retention time[37], with the following recommendations.

a) Nominal HRT should be between 0.7 and 1.5 days. For filters discharging directly to surface drains, a value of 1.5 days should be used[38].
b) Surface loading rate should be limited to a maximum of 2.8 m/d.
c) Filters should be designed in upflow mode, with a clear space of at least 0.3 metres between the filter floor and the bottom of the tank to facilitate cleaning if required.
d) Filter media should be of crushed rock, washed free of fines while immersed in water[39], and ranging from 12 to 50 mm nominal size, laid in two or three layers of equal height, with the largest size at the bottom and the smallest on top.
e) The recommended depth of the filter bed is 1.2 metres. This could be reduced to accommodate local site restrictions, provided the total volume is conserved.
f) A minimum headspace of 0.3 metres should be provided above the water level in the filter, from which a vent pipe of minimum 50 mm diameter should be led off.
g) The end of the vent pipe should be covered with fine mesh, and the filter unit sealed, to prevent mosquitoes from entering and breeding in the filter units.

Anaerobic filters designed according to these recommendations could be expected to give a consistent effluent, which is of good aesthetic quality, as well as having BOD_5 and suspended solids concentrations less than 30 mg/l. Biological nitrification cannot

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[37] Nominal HRT, in this instance, means HRT calculated based on the overall volume of the filter bed inclusive of volume occupied by the media.

[38] HRT values as low as 0.3 days could probably be used in particular circumstances, which are discussed later.

[39] Washing filter media by spraying with a pressure hose was found to be ineffective in practice.

reasonably be expected to take place in anaerobic filters, since the process is essentially an aerobic one.

5.2.3. Reed beds

The following recommendations could be made for reed beds for secondary and tertiary treatment of septic tank effluents in Sri Lanka, based on the findings of this study.

a) Reeds beds could be designed on the basis of specific area, with 0.3 m^2/p.e for secondary beds and 0.1 m^2/p.e for tertiary beds.
b) Construction metal of 12 mm nominal size, or stone chips could be used for bed media.
c) Beds should comprise channels of 1 to 1.5 metres width and 0.6 metres depth. And be at least partially below ground.
d) Vegetation could be non-specific, and virtually any species of plant, or a combination of species, could be used provided they have a good root structure with sufficient penetration. Broad-leafed plants with high rates of evapo-transpiration should be avoided where all the effluent is to be recovered for reuse, and should be selected for systems where a reduction in effluent flow would be desirable.
e) Large-scale secondary reed beds should be avoided where possible, due to potential problems of mosquito breeding.
f) Where used, secondary beds should be drained periodically, typically once a fortnight to once a month, to reduce mosquito breeding.

5.2.4. Percolation beds

The following guidelines are proposed, based on this study, for the use of percolation beds as tertiary treatment units for the polishing of effluents for on-site reuse or surface discharge in Sri Lanka.

a) The design specific area could be between 0.1 and 0.5 m^2/p.e depending on the level of pre-treatment. A value of 0.2 m^2/p.e is recommended as a minimum for reuse applications where disinfection is a requirement.
b) Bed media could be either sand retained on a 2mm sieve, or stone chips. The media should be washed free of fines by immersion in water prior to placing.
c) The recommended bed depth is 0.6 metres, with a larger depth of 0.9 metres for stone beds requiring disinfection of effluent.
d) Beds to be lined with two layers of HDPE liner (type 1000 polyethylene).

5.2.5. VFPGF's

The following guidelines could be proposed for the application of VFPGF's in Sri Lanka.

a) Secondary units to be designed for a specific area of 0.4 - 0.6 m^2/p.e, tertiary units for 0.15 - 0.2 m^2/p.e and units treating only kitchen wastewater from hotels for 0.7 m^2/p.e.as tertiary units. Secondary units are not recommended for the latter.
b) Recommended bed depth is 0.9 metres for beds filled with stone chips, and 0.6 metres for sand beds. A 0.3 metre layer of limestone is recommended for systems handling wastewater from hotel kitchens.
c) Pressurised influent dosing is recommended for larger beds of more than 25 p.e, as well as those handling kitchen wastewater from hotels, to ensure better influent distribution.

The performance in terms of treatment of VFPGF's designed according to these specifications would be similar to those of percolation beds, except that nitrification would be significantly better than either horizontal flow beds, or percolation beds[40].

5.3. Treatment systems

In the light of the experience gained from this study, some general conclusions and recommendations could be made as regards, selection and design of unit processes in order to synthesize treatment systems for specific objectives and applications. Septic tanks would be the unit process of choice for primary treatment and they should be designed according to the guidelines specified in section 5.2.1 above.

Anaerobic filters would be the obvious unit process of choice for secondary treatment, if capital cost were not a significant factor. Reed beds and VFPGF's are significantly cheaper than anaerobic filters, though they are more land and maintenance intensive. However, these drawbacks, as well as the anaerobic filter's excellent reliability and nuisance free operation under almost 'zero-maintenance' conditions, would still make it the process of choice except in the case of very small systems or those with severe financial constraints. Also, though reed beds and VFPGF's appear significantly cheaper, they need more land, together with a sufficiently favourable gradient, to allow gravity flow from the septic tank outlet to these units which are surface features.

The cost differentials between the anaerobic filters and the other unit processes decrease with increasing p.e. This is evident from Figure 5-1, which shows a graphical comparison of costs for secondary treatment unit processes with land valued at SLR $2000/m^2$, which is a representative average of land values across the systems implemented. The anaerobic filters are of 1-day HRT. All the units conform to the guidelines proposed previously.

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[40] This is a commonly accepted fact supported by most current literature (Cooper et al, 1999, Schonerklee et al, 1997)

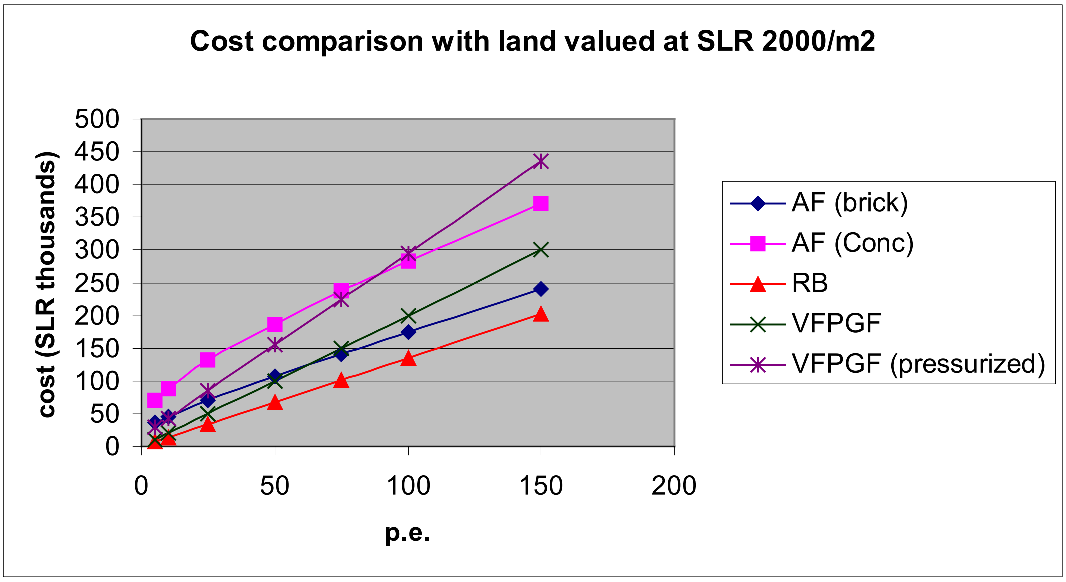

Figure 5-1. Comparison of costs for secondary treatment units with land valued at SLR 2000/m^2

As can be seen in the figure, the cost of pressurized VFPGF's as secondary processes exceeds that of brick anaerobic filters even at 10 p.e, while they exceed concrete anaerobic filters beyond 80 p.e. Non-pressurized VFPGF's exceed the cost of brick anaerobic filters beyond 50 p.e. Reed beds remain cheaper than anaerobic filters at this land value. However, if no favourable gradient exists, they become expensive, and lose the financial advantage to anaerobic filters.

As land values increase, the case for anaerobic filters increases. This is evident in Figure 5-2, which shows a similar comparison with land valued at SLR 4000/m^2. This value is more representative of the more central suburbs, and for hotels.

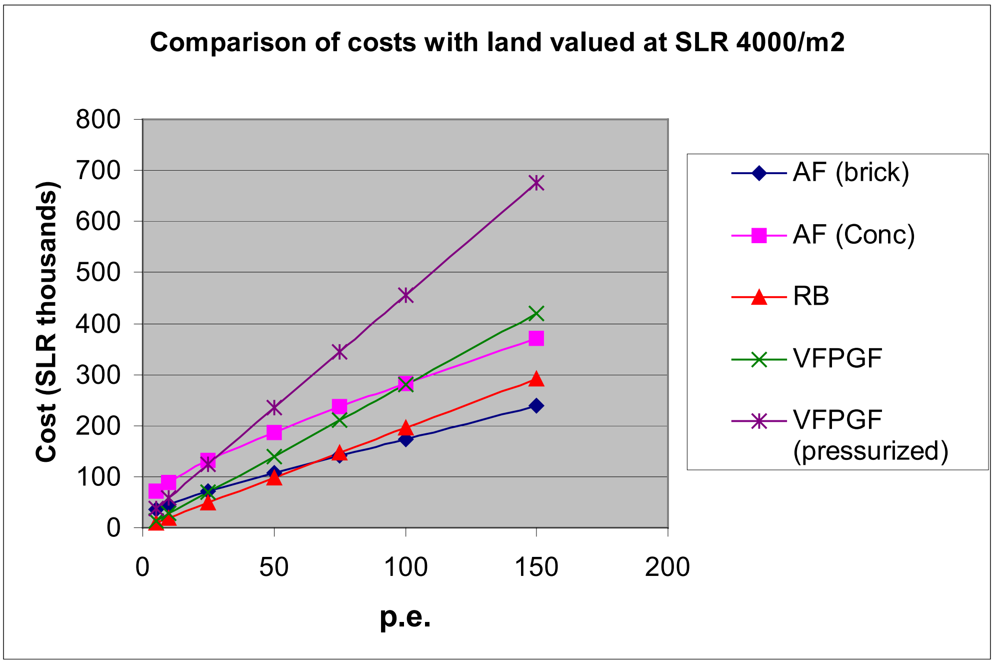

Figure 5-2. Cost comparison of secondary treatment units with land valued at SLR 4000/ m^2

As can be seen in the figure, the case for anaerobic filters at these land values is compelling.

Consequently, it could be recommended that anaerobic filters be the unit process of choice for secondary treatment, unless special circumstances preclude their implementation. Even in such special cases, smaller anaerobic filters of hydraulic retention times as low as 0.3 days should be considered, with one of the other processes to follow in series. Only if even this option cannot be implemented, such as in the case of very steep terrain, which precludes safe siting of the structure, or in the face of severe financial constraints, should the other units be used exclusively, as secondary treatment processes. They are definitely not recommended for applications where they would not be likely to receive basic attention to maintenance. Combined septic tank - anaerobic filter units are almost always cheaper than separate units and should be used wherever possible.

As far as tertiary treatment is concerned, the preferred choice would rest between percolation beds and VFPGF's. The selection would rest upon the availability, and opportunity cost of land. In cases where there is a restriction on space, for whatever reason, percolation beds would be preferred, due to their ability to be buried under parking areas, driveways etc. VFPGF's provide better treatment, particularly nitrification, and are easier to maintain when maintenance is required, as they are open, surface units. They do require more regular, though minor, maintenance activity in comparison to percolation beds, which are essentially 'zero maintenance' unless there is an unusual problem, such as clogging. Pressurized distribution of inflow is preferred in the case of VFPGF's, which would, however, drive up their cost, both capital and operational, particularly for small systems. In cases where land is a restriction, percolation beds and VFPGF's could be considered in series, as in the case of King's Park. In such systems, the specific areas of each unit could be reduced to 0.1 m^2/p.e.

The advantage of VFPGF's over reed beds lies in them being less land intensive, as well as their ability to be configured into virtually any shape to fit into available space or blend into the landscape. Also, they are not susceptible to breeding of mosquitoes. Reed beds, due to their horizontal flow, need to be configured in the form of channels, and tend to breed mosquitoes if they are not drained regularly. However, they could be considered in certain situations, particularly where the organic loading is high, or in non-pressurized systems. Also, their maintenance requirements are slightly less than VFPGF's, which need occasional cleaning of the influent distributors. This is a necessary, though minor activity, which if neglected, could lead to more serious problems.

5.3.1. Hotel systems

In addition to the general guidelines outlined in the preceding section, some specific guidelines could be recommended for hotel systems based on this study as follows.

a) Kitchen wastewater from hotels should always be pre-treated in a grease trap, which should be designed for daily cleaning. Daily-cleaned traps were found to perform better, and be maintained better than larger grease traps.
b) Hotel septic tanks should be designed for larger proportion of scum to sludge, when allocating storage volumes. A value of 0.5 or more of the required sludge storage volume is recommended instead of the usual value of 0.4.
c) The design sludge storage period should be 1 - 5 years.

d) The additional flow from functions is an important factor in the performance of hotel systems. This should be calculated based on the average number of functions per season for the hotel and the average number of pax/function. The total number of pax per season for functions should then be divided by the number of months per season to arrive at a value in terms of pax/month.

e) The design wastewater flow for the hotel should include the components estimated as shown in Table 5-1 below.

Table 5-1. Basis for estimating design flow for hotel systems.

Flow contribution	Recommended basis for estimation
Rooms	(No. of rooms) x (No. of guests per room) x (160 litres/guest/day)
Staff (residential)	(No. of staff) x (160 litres/person/day)
Staff (non-residential)	(No. of staff) x (40 litres/person/day)
Kitchen	(No. of meals/day) x (12 litres/meal)
Shops	(No. of employees) x (30 litres/employee/day)
Functions	(No. of pax/month) x (12 litres/pax) / (28 days/month)
Laundry	(No. of machines) x (1600 litres/machine/day)
Swimming pools	(No. of users/day) x (10 litres/user)

f) Kitchen and laundry wastewater should be treated together with the black water wherever possible.

g) Where kitchen wastewater is treated on its own, an anaerobic filter of 1.5 day HRT should be considered mandatory followed by a VFPGF with a minimum specific area of 0.7 m^2/p.e and a 0.3 metre layer of limestone included in the bed.

h) VFPGF units for hotels should have pressurised influent dosing. This could be either with pumps, or with dosing siphons where a net static head of over 3 metres is available.

Figure 5-3 shows the recommended treatment process for typical hotel systems. A tertiary treatment unit process should be considered essential for all surface discharge or reuse systems. GT denotes grease trap, ST denotes septic tank, AF denotes anaerobic filter and PB denotes percolation bed.

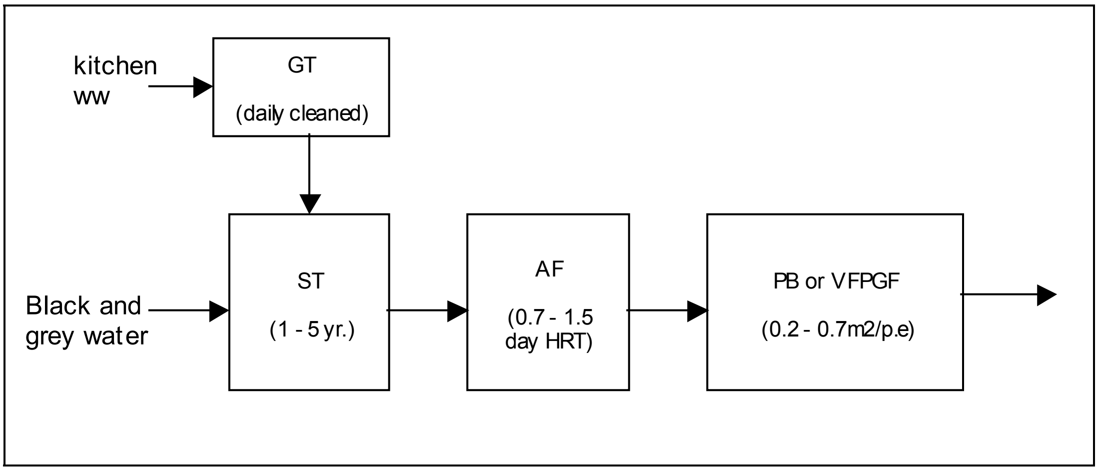

Figure 5-3. Recommended flow process for hotel systems

As far as effluent disposal for hotels is concerned, on-site reuse should always be the preferred option, as in this case the incremental cost for treatment up to reuse standards is minimal. Hotels consume large quantities of water for vehicle washing, with the common practice of drivers washing vehicles visiting the hotel on a daily basis. If there is significant garden area, reuse for gardening and vehicle-washing, would bring about significant savings in fresh water demand. New developments should be encouraged to reuse for toilet flushing as well, which could save up to 60 percent of fresh water demand of the hotel. At current national water rates, hotels and commercial institutions are charged at a flat rate of SLR 30/m^3. Figure 5-4 shows the computed annual value of effluent available for reuse, assuming 20 percent loss through the recovery system.

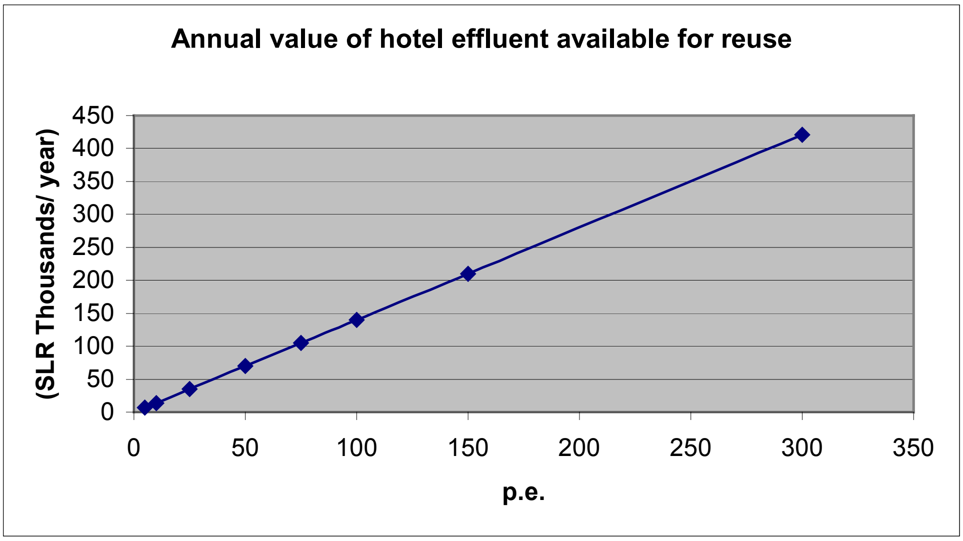

Figure 5-4. Annual value of hotel effluent available for reuse vs. p.e.

The slope of the graph indicates a treated effluent value of 1400 SLR/p.e/year available for recovery in hotel systems. Based on the average implementation cost for hotel systems of SLR 10481.00 inclusive of septic tanks, from section 4.9.1, this would mean that 13.3 percent of the total capital cost of implementation would be available annually for recovery through effluent reuse. The operational cost of pumping the effluent for reuse has not been included in these computations, as nearly all hotels pump their water for use from sumps anyway. The figures presented here are only indicative of the potential cost recovery, and the actual recovery should be evaluated on a case-by-case basis.

5.3.2. Individual houses

Given the general guidelines discussed in section 5.3 above, the following additional guidelines could be recommended for individual house systems based on this study.

The basis of flow estimation for houses should be a minimum of 160 l/person/d for black and grey water and 36 l/person/day for black water only. The former figure should be increased to 200 l/person/d in the case of more affluent housing with water consuming appliances such as washing machines, dishwashers etc.

In the case of surface discharge of effluent, a septic tank followed by either an anaerobic filter of 1.5 day HRT, or a secondary reed bed or VFPGF should be sufficient, provided there is reasonable surface drainage for the discharged effluent to flow without stagnation. If the effluent is to be reused, or if the discharge conditions are in a very densely populated area, without proper surface drainage, a tertiary treatment step is recommended. Tertiary treatment could be either by a percolation bed, VFPGF or reed bed. The selection should be based on the general guidelines outlined in section 5.3. If a tertiary treatment unit is included, the design HRT of the anaerobic filter could be reduced in accordance with the general guidelines.

Given the current national water tariff structure, a case for cost recovery through effluent reuse cannot be made for individual houses. This is because a block tariff of SLR 35.00/ month for the first 10 m^3 consumed per month is levied, irrespective of consumption. Therefore reducing consumption by effluent reuse would not bring about a saving in water bills. However, from a national standpoint, it simply does not make either environmental or economic sense to use drinking water for toilet flushing, gardening etc., particularly when reuse quality effluent can be produced relatively inexpensively through such systems. However, until tariff structures are revised to include incentives for water conservation through on-site reuse, the option of reuse would have to be based on environmental or civic consciousness, except in cases where water supply is unavailable or intermittent.

5.3.3. Housing schemes

The recommended guidelines for housing schemes would be much the same as for individual houses, except that the option of semi-collective or regional treatment should be explored by combining the treatment units with simplified and settled sewerage schemes, which could significantly reduce the overall cost of sewage disposal. Also, care should be taken to establish who would be responsible for operation and maintenance of the systems in the medium to long-term and their maintenance culture carefully reviewed before implementing reed beds or VFPGF units.

5.3.4. Schools and Halls of Residence

The guidelines for schools and residential halls would be much the same as those for housing schemes. Design flows should include any potential excess flow due to leaking toilet fixtures, which are a common occurrence in such institutions. Excess flow should be estimated by inspecting the condition of the buildings to be served, if they are operational at the time of design, or by inspecting similar buildings in the same institution or in other equivalent institutions. Stipulating that fixtures should be adequately maintained would serve no useful purpose in such cases, and would result in failure of treatment systems as in the case of Akbar-Nell.

5.3.5. Day-time occupancy buildings

Design flows for daytime occupancy buildings should be estimated on the basis of 50 l/person/day for daytime occupants, and a minimum of 160 l/person/day for overnight occupants. Potential excess flows should be estimated and included in the design flow as in the case of schools and halls of residence, particularly in public buildings where maintenance of fixtures is often poor. The preferred secondary treatment unit process would be an anaerobic filter. Secondary treatment by a 1.5-day anaerobic filter would suffice in many cases for surface discharge to drain, particularly in smaller systems of 30 p.e. or less. Larger systems, or those located in sensitive areas should include a tertiary treatment step. Where buildings contain restaurant kitchens, grease traps should be included for pre-treatment of the kitchen effluent. Where a significant proportion of the wastewater discharge comprises kitchen wastewater, tertiary treatment units should be considered mandatory.

5.4. Appurtenances

5.4.1. Access manholes

In most field situations manhole covers were found to be in a poor state of repair, and could often lead to malfunctioning of systems. This could be either due to routine inspection and maintenance of units being neglected due to difficulty in opening heavy manhole covers, particularly those which are designed to withstand vehicle loads, or due to the ingress of surface water and debris to the units, through manhole covers which are damaged, ill fitting, improperly sealed, or simply missing. During the course of this study, it was found that in general, unless one person can conveniently open access covers on his own, they are usually not opened for inspection or routine maintenance. As a result, it is recommended that large access manhole covers are left permanently sealed with lean cement/sand mixture, and small diameter inspection ports built into them which can be opened for regular inspection, sampling and minor maintenance activities such as rodding of inlet tees and checking sludge depth. These openings should be approximately 15 centimetres in diameter, with well fitting sheet metal covers. Plate 5-1 shows a view of such an inspection port. The port in the foreground is open, with the cover beside it, and a closed port is visible in the background.

Plate 5-1. A typical inspection port.

The manhole cover slabs are well sealed with cement / sand, which can be broken open in the event of larger scale maintenance activity. Similar small ports could be provided for desludging as well, which could accommodate the suction pipe of vacuum trucks during desludging, without the need for opening the large access manholes.

5.4.2. Dosing siphons

Where dosing siphons are used for VFPGF units, which are pressurised by gravity head, they could be very simply fabricated on-site with once-used plastic barrels, which are freely available in Sri Lanka, and a PVC outlet pipe with a simple inverted 'U' bend within the barrel. The length of the internal leg of the 'U' would determine the volume of each dose. A simple gate valve controls the outlet flow. Plate 5-2 shows three such dosing siphons used to dose three parallel VFPGF units in the

Thilanka system. The PVC outlet pipe extends down inside the barrel to form an inverted ‘U’ arrangement.

Plate 5-2. Dosing siphons fabricated with plastic barrels

5.4.3. Foot valves.

Foot valves of pumps which are used to pump septic tank effluents, particularly those handling kitchen wastewater, often get clogged with biomass growth on the valve, as do float switches. In such situations, it is recommended that foot valves be protected by a plastic mesh cover, and be left easily accessible and installed in such a manner as to facilitate removal from above the liquid level in the tank or sump. This could be done quite easily by incorporating a screw coupling in the suction pipe above the liquid level, which could be easily reached and unscrewed to lift the foot valve out for cleaning. Access should be made as easy as possible to enable one person to perform the entire operation.

5.5. Implementation

5.5.1. Materials

Appropriate materials should be used in implementation. Brick structures for anaerobic filters and septic tanks are not recommended if the units would be subject to prolonged periods of immersion below the ground water table. Exposed brick surfaces on the outside of such structures were found to deteriorate with time. Cement blocks, however, could be used in such situations without a significant difference in cost. All media used for reed beds, anaerobic filters, percolation beds and VFPGF's should be carefully washed, free of fines, while immersed in water prior to placing. This is important as fines, particularly quarry dust, in the case of metal beds, either wash out with the effluent as a thick unsightly black sludge, during the early stages of operation, or accumulate at the bottom of the beds and cause clogging. This sludge often disturbs neighbouring residents who mistake it for sewage solids. Spraying piles of media with high-pressure hoses was found to be ineffective in this study. Plate 5-3 shows bed media being washed in the recommended manner.

Plate 5-3. Bed media being washed by immersion in water.

5.5.2. Construction

The construction of these systems is relatively simple and could be handled by any reasonably good civil contractor. However, due care should be given to construction supervision, particularly during concreting of subsurface structures below the water table, as well as maintaining proper inlet and outlet levels, placing of HDPE liners and laying of beds. Two layers of type thousand polythene - which is freely available at hardware merchants nationwide, was found to be quite satisfactory for the lining of percolation beds, reed beds and VFPGF's. Where joining is required, simple joints should be made by placing the two edges of the sheets to be joined, together, and folding over three times in succession to form a 'hem' of approximately 3 - 4 centimetres width. These 'hems' should then be stapled in place at 5 centimetre intervals. This method was found to be quite effective provided due care was exercised during placing of the liner. Plate 5-4 shows a liner that has been joined in this manner being placed in position. Lengths of duct tape are visible, taped at regular intervals across the joins. This is to temporarily reinforce the joins while the liner is being laid.

Plate 5-4.The assembled liner being placed in the excavation for the bed

Care should be taken to prevent surface water and soil from washing into VFPGF units and reed beds. Plate 5-5 shows a simple retaining wall being built to protect a VFPGF unit from surface water and soil washing into the bed during wet weather.

Plate 5-5. A retaining wall being built to protect a VFPGF unit.

5.5.3. Commissioning

All units should be tested thoroughly for leaks prior to commissioning. This should be done by filling the units with water and allowing them to stand for two to three days while monitoring water level. Minor leaks in concrete tanks usually stop with time due to gradual hydration of the cement. However, major leaks in concrete tanks and all leaks in brick tanks should be attended to prior to commissioning. Anaerobic filter units should be checked for leaks before placing the filter bed, as repair is difficult once the bed is in place.

Septic tank and anaerobic filter units should be filled with water at start up, and commissioned with black water first, wherever possible. Kitchen and laundry wastewater should not be applied to the systems until the anaerobic filter units have matured well and show good signs of gas production. This could be easily confirmed by visual inspection, which would reveal active bubbling in a well-functioning filter. Plate 5-6 shows a view of an anaerobic filter through its access manhole with visible, active bubbling.

Plate 5-6. Visible bubbling of the water surface in an anaerobic filter

Kitchen and laundry effluent should be connected only after methanogenic activity has been established in the filter. This typically takes three to four weeks. For systems designed exclusively for kitchen wastewater or grey water only, the system could be commissioned by filling the septic tank with septage from another septic tank which is already in operation and receiving black water, either on its own, or in combination with grey water.

Influent distributors of VFPGF's and percolation beds should be tested with water prior to commissioning. Plants should be established as soon as possible upon commissioning. Shading should be provided for beds that are subjected to strong sunlight until vegetation is properly established.

5.5.4. Operation and maintenance

The routine operation and maintenance of these systems is simple and minimal, as this was one of the main criteria of selection. However, it was evident in this study that routine maintenance, though simple, is nevertheless important to the long-term functioning of the systems. The most important maintenance activities after commissioning of the systems, is desludging of septic tanks on time, cleaning of grease traps, and maintaining vegetation in reed beds and VFPGF's. In addition to these, pumps, foot valves and dosing siphons should be maintained properly to ensure proper functioning of pressurised systems. It was found, that these activities, though simple are not performed regularly unless access is made easy, and not more than one person is required to carry out regular maintenance activity.

5.6. Effluent standards

The effluent standards which are currently applicable, or applied in practice, to the systems under discussion in this study are the Sri Lanka Standard Nos. 652:1984, 721:1985 and 776:1987, which specify tolerance limits for industrial effluents discharged into inland surface waters, industrial and domestic effluents discharged into marine coastal areas, and industrial effluents discharged on land for irrigation purposes, respectively. Of these, only the marine discharge limits include domestic effluents. However, hotel wastewater, and wastewater from restaurants and other institutions are usually included into the other categories by regulators who are often empowered by vague municipal by-laws to “abate public nuisances”.
Table 5-2 shows the limits specified by the SLS standards for selected parameters, relevant to this discussion, in the three categories.

Table 5-2. Tolerance limits for selected quality parameters prescribed by Sri Lanka Standards

Quality parameter	Type of discharge		
	Inland surface waters	On land for irrigation	Marine coastal areas
Suspended solids (mg/l)	50	-	150
BOD_5 (mg/l)	30	250	100
COD (mg/l)	250	-	250
PH	6.0 - 8.5	5.5 - 9.0	6.0 - 8.5
Ammonia nitrogen (mg/l)	50.0	-	50.0

It should be noted that the only category, which specifically includes discharge of domestic effluents in the Sri Lanka standards, is for disposal into marine coastal areas. The other limits are specified for "Industrial" effluents, and it is not immediately clear whether institutions such as hotels, office buildings, schools etc., are considered 'industrial' for the purpose of effluent discharge. Limits prescribed for discharge on land for irrigation purposes do not include a limit for suspended solids, although a limit of 2100 mg/l is specified for total dissolved solids in this category. No limits are prescribed in any of the categories for pathogens or indicator organisms, nor for phosphates. The limits for irrigation have clearly been prescribed for crop irrigation purposes and on-site domestic reuse has not been considered at the time. The limits for discharge into inland surface waters also specify a minimum eight-fold dilution in "clean receiving water". If the dilution is less than eight times, the limits should be factored down accordingly. In practice however, this clause is often ignored. The code also does not specify how this dilution should be assessed in the case of impounded water bodies, such as for example, the Kandy Lake. Also, no allowance is made for the size of the facility discharging.

In the light of the above, the following recommendations could be made, based on this study, to update the effluent discharge standards in Sri Lanka, in order to facilitate regulation of disposal of sewage of a non-industrial nature, which overall, accounts for far more of the total effluent discharges in Sri Lanka than industrial sewage.

a) A specific category should be declared for 'domestic and commercial sewage', which includes hotels, shops, offices, schools, etc.
b) Specific standards should be prescribed for on-site reuse of such effluents for gardening, vehicle washing, and other outdoor uses as well as toilet flushing.
c) The standards for on-site reuse should be based on the World Health Organization guidelines for the re-use of effluents for unrestricted irrigation in terms of pathogens. This would include pathogen limits of less than one helminth egg per litre and less than 1000 cfu/100ml of faecal coliforms. The BOD limit should probably be 100 mg/l. Suspended solids should also be limited to 75 mg/l. The faecal coliform limit could be relaxed by an order of magnitude in the case of individual on-site reuse in private dwellings.
d) A separate discharge category should be specified for discharge into surface drains as this was found to be the commonest form of effluent disposal after soakage. This should not include a dilution clause, and should specify more relaxed standards in terms of BOD, Suspended solids and ammonia nitrogen. These standards should also be categorised based on the population equivalent of the discharging institution, with more relaxed standards for smaller population equivalents. The categories could probably be in the order of less than 30 p.e, 30 - 100 p.e, and over 100 p.e.
e) The limits for all discharges of commercial sewage into surface drains, should be relaxed to 50 mg/l BOD_5 and 75 mg/l suspended solids. No limit for ammonia nitrogen would be necessary in this category. These limits should be applicable provided a minimum flow length of one kilometre exists between the point of effluent discharge and the nearest perennial inland water body receiving the discharge from the drain. This distance could be reduced in the case of population equivalents less than 100, to perhaps, 500 metres for 30 - 100 p.e and 100 metres for less than 30 p.e.
f) The method of establishing violations should be based on a percentile of samples in the case of larger institutions, and the average of three consecutive samples at least one week apart in the case of smaller institutions, rather than on a single grab sample, as is currently the practice.

Implementing the above recommendations would ensure environmental and public health safety, while adopting pragmatic national standards for the disposal of sewage in the urban and suburban context in Sri Lanka. The systems evaluated in this study have proven to be capable of conforming to these standards in an affordable manner, which is sustainable in the medium to long-term within the constraints of the local situation. They can be implemented in a step-by-step approach, with minimum disruption to public services and convenience, and without the need for large-scale single-point funding. They would go a long way towards solving the huge national problem of urban sewage disposal in an environmentally and culturally sensitive manner.

5.7. Future work.

Continuous monitoring of the systems described in this study would be useful in order to assess their long-term performance and viability. In addition, as more and more systems are implemented and commissioned on the ground, the study should be expanded to include these new systems in order to improve the understanding of how such systems behave in practice, as well as to improve the cost estimation process. Further work needs to be done on evaluating the real factors which affect clogging of VFPGF systems and percolation beds in order to seek ways of overcoming them in design as well as in operation. The systems should also be evaluated in terms of nutrient removal capability, as eutrophication of inland waters and algal blooms become an increasing concern in Sri Lanka.