9

Monitoring and evaluation

Once a WSP system has been commissioned, a routine monitoring programme should be established so that the actual quality of its effluent can be determined.

Routine monitoring of the final effluent quality of a pond system permits a regular assessment to be made of whether the effluent is complying with the local discharge or reuse standards. Moreover, should a pond system suddenly fail or its effluent start to deteriorate, the results of such a monitoring programme often give some insight into the cause of the problem and generally indicate what remedial action is required.

The evaluation of pond performance and behaviour, although a much more complex procedure than the routine monitoring of effluent quality, is nonetheless extremely useful as it provides information on how underloaded or overloaded the system is, and thus by how much, if any, the loading on the system can be safely increased as the community it serves expands, or whether further ponds (in parallel or in series) are required (see Section 10.2). It also indicates how the design of future pond installations in the region might be improved to take account of local conditions.

9.1. EFFLUENT QUALITY MONITORING

Effluent quality monitoring programmes should be simple and the minimum required to provide reliable data. Two levels of effluent monitoring are recommended (reference should also be made to the routine pond maintenance record sheets to be completed by the pond supervisor – see Section 8.2 and Figure 8.1):

(a) *Level 1:* representative samples of the final effluent should be taken regularly and analysed for those parameters for which effluent discharge or reuse requirements exist; the EU Directive on urban wastewater treatment (Council of the European Communities, 1991*a*) requires samples to be taken as follows, depending on the size of the treatment plant (in population equivalents):

2,000 - 49,999 p.e.	12 samples per year
≥ 50,000 p.e.	24 samples per year

(although for plants ≤ 9,999 p.e. the number of samples can be reduced to 4 per year if the 12 samples collected in the previous year are satisfactory);

(b) *Level 2:* when level 1 monitoring shows that a pond effluent is failing to meet its discharge or reuse quality, a more detailed study is necessary. Table 9.1 gives a list of parameters whose values are required, together with directions on how they should be obtained.

Table 9.1 Parameters to be determined in a "Level 2" effluent quality monitoring programme

Parameter	Sample type [a]	Remarks
Flow	-	Measure both raw wastewater and final effluent flows
BOD	C	Unfiltered samples[b]
COD	C	Unfiltered samples[b]
Suspended solids	C	
Ammonia	C	
pH	G)	Take two samples, one at 08.00-10.00 h
Temperature	G)	and the other at 14.00-16.00 h
Faecal coliforms	G	Take sample between 08.00 and 10.00 h
Total nitrogen	C)	Only when effluent being used (or
Total phosphorus	C)	being assessed for use) for crop
Chloride	C)	irrigation. Ca, Mg and Na are
Electrical conductivity	C)	required to calculate the sodium
Ca, Mg, Na	C)	absorption ratio[d]
Boron	C)	
Helminth eggs[c]	C)	

[a] C = 24-hour flow-weighted composite sample; G = grab sample.

[b] Also on filtered samples if the discharge requirements are so expressed.

[c] *Ascaris lumbricoides, Trichuris trichiura, Ancylostoma duodenale* and *Necator americanus*.

[d] $SAR = (0.044Na)/[0.5(0.050Ca + 0.082Mg)]^{0.5}$ where Na, Ca and Mg are the concentrations in mg/l.

Since pond effluent quality shows a significant diurnal variation (although this is less pronounced in maturation ponds than in facultative ponds), 24-hour flow-weighted composite samples are preferable for most parameters, although grab samples are necessary for some (pH, temperature and faecal coliforms). Composite samples should be collected in one of the following ways:

a) in an automatic sampler, which takes grab samples every one or two hours, with subsequent manual flow-weighting if this is not done automatically by the sampler;
b) by taking grab samples every one to three hours with subsequent manual flow-weighting; or
c) by taking a column sample (see Section 9.2) near the outlet of the final pond; this can be done at any time of day and gives a good approximation to the mean daily effluent quality (Pearson *et al.*, 1987*b*)

9.2 EVALUATION OF POND PERFORMANCE

A full evaluation of the performance of a WSP system is a time-consuming and expensive process, and it requires experienced personnel to interpret the data obtained. However, it is the only means by which pond designs can be optimised for local conditions. It is often therefore a highly cost-effective exercise. The recommendations given below constitute a level 3 monitoring programme, and they are based on the guidelines for the minimum evaluation of pond performance given in Pearson *et al.* (1987*a*), which should be consulted for further details.

It is not intended that all pond installations be studied in this way, but only one or two representative systems in each major climatic region. This level of

investigation is most likely to be beyond the capabilities of local organizations, and it would need to be carried out by a state or national body, or by a university under contract to such a body. This type of study is also necessary when it is required to know how much additional loading a particular system can receive before it is necessary to extend it.

Samples should be taken and analysed on at least five days over a five-week period at both the hottest and coldest times of the year. Samples are required of the raw wastewater and of the effluent of each pond in the series and, so as to take into account most of the weekly variation in influent and effluent quality, samples should be collected on Monday in the first week, Tuesday in the second week and so on (local factors, such as a high influx of visitors at weekends, may influence the choice of days on which samples are collected). Table 9.2 lists the parameters whose values are required. Generally the analytical techniques described in the current edition of *Standard Methods* (APHA, 1995) are recommended, although the procedures detailed in Annex II should be followed for chlorophyll *a*, algal genera and sulphide. The modified Bailenger technique should be used for counting the number of helminth eggs (Ayres *et al.*, 1991; see also Ayres and Mara, 1996). Faecal coliforms should be counted by the methods detailed in *Report 71* (HMSO, 1994; see also Ayres and Mara, 1996).

Composite samples, collected as described in Section 9.1, are necessary for most parameters; grab samples are required for pH and faecal coliforms; and samples of the entire pond water column should be taken for algological analyses (chlorophyll *a* and algal genera determination), using the pond column sampler shown in Figure 9.1. Pond column samples should be taken from a boat or from a simple sampling platform (or the outlet structure) that extends beyond the embankment base. Data on at least maximum and minimum air temperatures, rainfall and evaporation should be obtained from the nearest meteorological station.

On each day that samples are taken, the mean mid-depth temperature of each pond, which closely approximates the mean daily pond temperature, should be determined by suspending a maximum-and-minimum thermometer at mid-depth of the pond at 08.00-09.00 h and reading it 24 hours later.

On one day during each sampling period, the depth of sludge in the anaerobic and facultative ponds should be determined, using the "white towel" test of Malan (1964). White towelling material is wrapped along one third of a sufficiently long pole, which is then lowered vertically into the pond until it reaches the pond bottom; it is then slowly withdrawn. The depth of the sludge layer is clearly visible since some sludge particles will have been entrapped in the towelling material (Figure 9.2). The sludge depth should be measured at various points throughout the pond, away from the embankment base, and the mean depth calculated.

It is also useful to measure on at least three occasions during each sampling season the diurnal variation in the vertical distribution of pH, dissolved oxygen and temperature. Profiles should be obtained at 08.00, 12.00 and 16.00 h. If submersible electrodes are not available, samples should be taken manually every 20 cm.

9.3 DATA STORAGE AND ANALYSIS

It is advisable to store all data in a microcomputer using a spreadsheet such as EXCEL, so that simple data manipulation can be performed. From the data

Table 9.2 Parameters to be determined for minimum evaluation of pond performance

Parameter	To be determined for [a]	Type of sample [b]	Remarks
Flow	RW, FE	-	
BOD	RW, all pond effluents [c]	C	Unfiltered and filtered samples
COD	RW, all pond effluents	C	Unfiltered and filtered samples
Suspended solids	RW, all pond effluents [c]	C	
Faecal coliforms	RW, all pond effluents	G	
Chlorophyll *a*	All F and M pond contents	P	
Algal genera	All F and M pond contents	P	
Ammonia	RW, all pond effluents [c]	C	
Nitrate	RW, FE	C	
Total phosphorus	RW, FE	C	
Sulphide	RW, A pond effluent, F pond contents or depth profile	G,P	Only if odour nuisance present or facultative pond effluent quality poor. A depth profile is preferable
pH	RW, all pond effluents	G	
Temperature (mean daily)	RW, all pond effluents	-	Use maximum-minimum thermometers suspended in RW flow and at mid-depth in ponds
Dissolved oxygen [d]	Depth profile in all F and M ponds	-	Measure at 08.00, 12.00 and 16.00 h on at least three occasions
Sludge depth	A and F ponds	-	Use "white towel" test (see text)
Electrical conductivity	FE	C)	
Chloride	RW, FE	C)	Only if effluent used or to be used for crop irrigation.
Ca, Mg and Na	FE	C)	Ca, Mg and Na required to calculate the sodium
Boron	FE	C)	absorption ratio [f]
Helminth eggs [e]	RW, all pond effluents	C)	

[a] RW = raw wastewater; FE = final effluent of pond series; A = anaerobic; F = facultative; M = maturation.
[b] C = 24-hour flow-weighted composite sample; G = grab sample taken when pond contents most homogeneous; P = pond column sample.
[c] Alternatively RW, A, F and final M pond effluents only, if there are more than two maturation ponds.
[d] Measure depth profiles of pH and temperature at same times, if possible.
[e] *Ascaris lumbricoides, Trichuris trichiura, Ancylostoma duodenale* and *Necator americanus*.
[f] SAR = (0.044 Na)/[0.5 (0.050 Ca + 0.082 Mg)]$^{0.5}$ where Na, Ca and Mg are the concentrations in mg/l.
Source: Pearson *et al.* (1987*a*).

collected in each sampling season (or month if sampling is done throughout the year), mean values should be calculated for each parameter. Values, based on these means, can then be calculated for:

(a) hydraulic retention times (= volume/ flow) in each pond;
(b) volumetric BOD and COD loadings on anaerobic ponds;
(c) surface BOD and COD loading on facultative ponds; and
(d) percentage removals of BOD, COD, suspended solids, ammonical nitrogen, total phosphorus, faecal coliforms and helminth eggs in each pond and in each series of ponds.

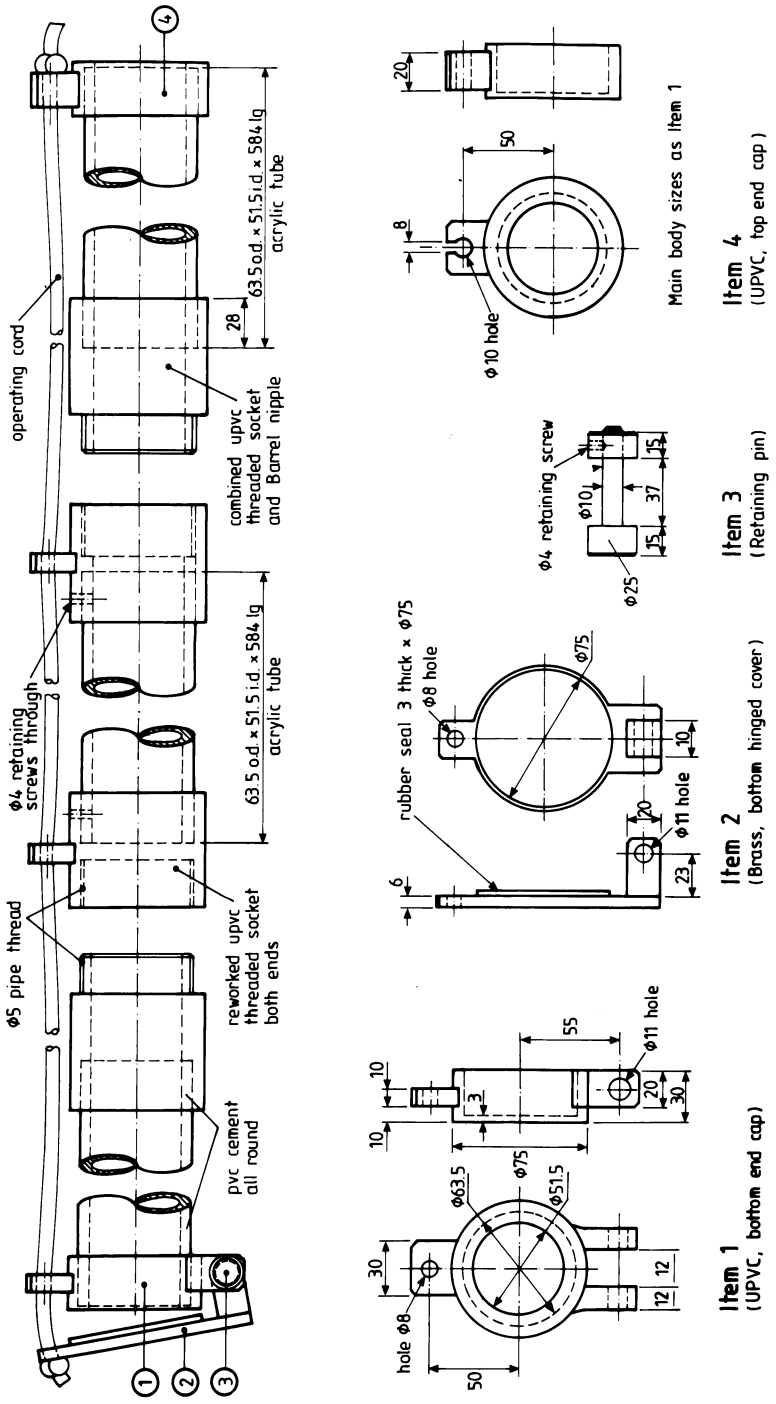

Figure 9.1 Details of pond column sampler (Pearson *et al.*, 1987*a*). The overall length (here 1.7 m) may be altered as required. The design shown here is a three-piece unit for ease of transportation, but this feature may be omitted. Alternative materials may be used (for example, PVC drainage pipe)

Figure 9.2 The "white towel" test for measuring sludge depth

A simple kinetic analysis, based on (for example) a first order reaction in a completely mixed or plug flow reactor (for length to breadth ratios less or greater than 4 respectively) may be attempted if desired (see Mara, 1976). The responsible local or central governmental agency should record and store all the information and data collected from each pond complex, together with an adequate description of precisely how they were obtained, in such a way that design engineers and research workers can have ready access to them.