11

Wastewater storage and treatment reservoirs

While it is true that waste stabilization ponds can more easily produce effluents suitable for agricultural reuse (principally crop irrigation – see Section 12) than other wastewater treatment processes, they share the same disadvantage with these other processes, namely that their effluent can only be used for crop irrigation during the irrigation season. During the other months of the year, the effluents are discharged, essentially to waste, to a surface watercourse.

Wastewater storage and treatment reservoirs (WSTR), also called effluent storage reservoirs, were originally developed in Israel to overcome this disadvantage and permit the whole year's treated wastewater to be used for crop irrigation during the irrigation season. WSTR are especially advantageous in arid and semi-arid areas where agricultural production is limited by the quantity of water (including treated wastewater) available for irrigation. Wastewater is too valuable to waste in arid and semi-arid areas, and the use of WSTR prevents such waste.

11.1 SINGLE WSTR SYSTEM

In Israel, where treated wastewater is extensively reused (see Section 4.3), the practice has been to treat the wastewater in an anaerobic pond and to discharge its effluent into a single WSTR which is 5-15 m deep (Figure 11.1a). The irrigation season in Israel is 4-6 months long, and so the single WSTR has a storage capacity equivalent to 6-8 months wastewater flow. It is full at the start of the irrigation season, and empty at the end of it. In this way 2-3 times as much land can be irrigated, and 2-3 times as much crops produced. Further details are given in Juanico and Shelef (1991, 1994) and Juanico (1995).

However, a disadvantage of this system is that the single WSTR is filled and drawn down simultaneously during the irrigation season. This means that the anaerobic pond effluent is discharged into a continuously decreasing volume of WSTR contents, such that towards the end of the irrigation season – i.e. closest to crop harvest – the irrigation water is of increasingly poorer quality (Liran *et al.*, 1994).

Design Example No. 4(a) in Annex I shows how a single WSTR system is designed for restricted irrigation.

11.2 SEQUENTIAL BATCH-FED WSTR

The Israeli system described above is for restricted irrigation (see Section 12.1), and the long retention time in the WSTR ensures that the effluent contains ≥ 1

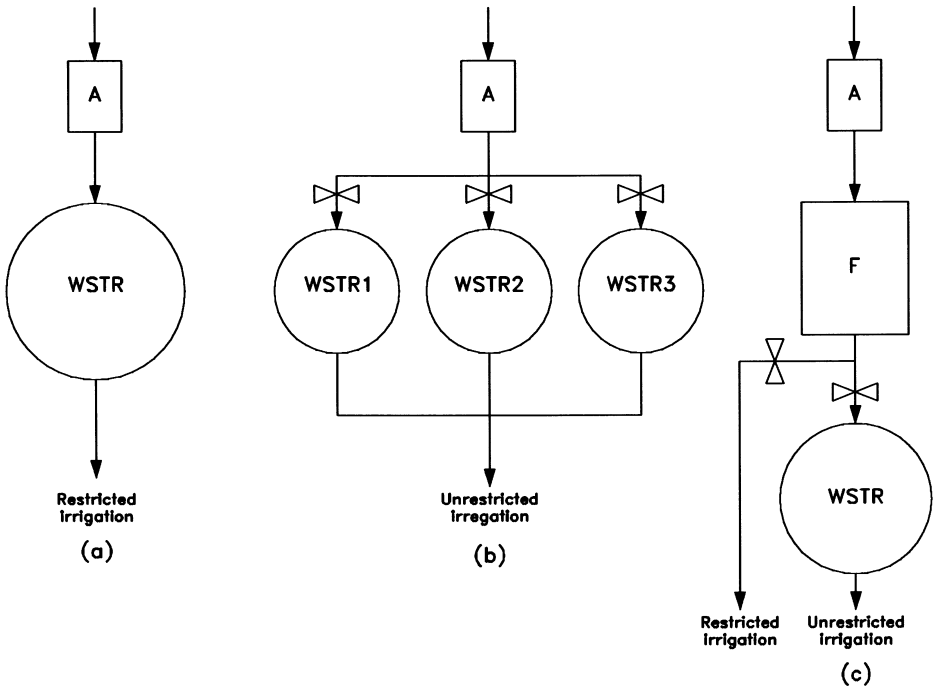

Figure 11.1 (a) single WSTR system for restricted irrigation, (b) sequential batch-fed WSTRs in parallel for unrestricted irrigation and (c) hybrid WSP - WSTR system for both restricted and unrestricted irrigation. A, anaerobic pond; F, facultative pond. In (c) a maturation pond may be necessary after the facultative pond (see text)

intestinal nematode egg per litre, which is the WHO (1989) guideline for restricted irrigation (Table 12.1). However, if farmers wish to practise unrestricted irrigation (i.e. the irrigation of food crops eaten raw), the above single-WSTR system is not suitable as the effluent will not contain ≤1,000 faecal coliform bacteria per 100 ml, which is the WHO (1989) guideline for unrestricted irrigation (Table 12.1).

For unrestricted irrigation, two WSTR options are available:

(a) three or four sequential batch-fed WSTR in parallel, and
(b) a "hybrid" WSP-WSTR system.

The sequential batch-fed WSTR system (Figure 11.1b) comprises an anaerobic pond and, depending on the length of the irrigation season, three or four WSTR in parallel (but usually only three) (Mara and Pearson, 1992; Mara *et al.*, 1997). Each WSTR is operated sequentially on a cycle of fill-rest-use (Table 11.1), and faecal coliform reduction to < 1000 per 100 ml occurs rapidly during the fill and rest phases (Pearson *et al.*, 1996). Thus the whole year's wastewater is available for unrestricted irrigation during the irrigation season. This system is, therefore, suitable in situations (a) where local farmers are engaged in essentially horticultural production, or (b) when local control is imperfect such that wastewater treated for restricted irrigation is in fact likely to be used for unrestricted irrigation.

Design Example No. 4 (b) in Annex I shows how a sequential batch-fed WSTR system is designed.

11.3 HYBRID WSP-WSTR SYSTEM

The hybrid WSP-WSTR system is shown in Figure 11.1c. The wastewater is treated in an anaerobic and facultative pond. During the months when effluent is not required for irrigation, the facultative pond effluent is discharged into a single WSTR; during this period the long retention time ensures that faecal

coliform numbers in the WSTR fall to below 1000 per 100 ml. During the irrigation season the facultative pond effluent is used for restricted irrigation, and the WSTR contents for unrestricted irrigation.

Table 11.1 Management strategy for three WSTR in parallel for an irrigation season of six months

Month[a]	WSTR 1	WSTR 2	WSTR 3
January	Rest	Fill (1)	Empty
February	Rest	Fill (1)	Empty
March	Rest	Rest [or Fill (1)]	Fill (1) [or Empty]
April	Rest	Rest	Fill (1)
May	**Use**	Rest	Fill (1)
June	**Use**	Rest	Fill (1)
July	Fill (1)[b]	**Use**	Rest
August	Fill (1)	**Use**	Rest
September	Fill ($^1/_2$)	Fill ($^1/_2$)	**Use**
October	Fill ($^1/_2$)	Fill ($^1/_2$)	**Use**
November	Fill ($^1/_2$)	Fill ($^1/_2$)	Empty
December	Fill ($^1/_2$)	Fill ($^1/_2$)	Empty
Volume[c]	4	4 [or 5]	4 [or 3]

[a] July and August are the hottest months, so WSTR No. 3 has the minimum rest period of two months at this time. The other two WSTR have rest periods of four months to ensure FC die-off to < 1000 per 100 ml during the cooler months.

[b] Proportion of monthly flow discharged into each WSTR.

[c] WSTR volume expressed as multiple of monthly wastewater flow. The WSTR need not have equal volumes as the volume of treated wastewater required for irrigation may vary throughout the irrigation season.

Depending on the retention times in the anaerobic and facultative ponds, and the number of intestinal nematode eggs in the raw wastewater, it may be necessary to have a single maturation pond between the facultative pond and the WSTR. This is to ensure that the effluent used for restricted irrigation contains ≤ 1 intestinal nematode egg per litre (see Section 6 and Design Example No. 2 in Annex I).

Thus if, for example, the irrigation season is six months long, the hybrid WSP-WSTR system permits twice the area of land to be irrigated – half for restricted irrigation and half for unrestricted irrigation. As noted in Section 12, discussions must be held with the local farmers to ensure that they are aware of these two irrigation water qualities. In order to protect public health the facultative (or maturation) pond effluent can *only* be used for restricted irrigation (unless the required number of maturation ponds are used to reduce the FC level to below 1000 per 100 ml during the irrigation season).

Design Example No. 4(c) in Annex I shows how a hybrid WSP-WSTR system is designed.