Ponds

Who's afraid of anaerobic ponds?

By D Duncan Mara and Stephen W Mills

Everybody has at least heard about waste stabilization ponds (WSP). They are an extremely efficient and highly cost-effective method of wastewater treatment, especially in developing countries wherever there is sufficient land for them. There are three types of WSP in common use—anaerobic, facultative and maturation, and these are arranged in series as each has different, but complementary, functions. Anaerobic and facultative ponds are designed principally for BOD removal, and maturation ponds for faecal pathogen removal, although some pathogen removal occurs in the former and some BOD removal in the latter.

BOD removal

In warm climates anaerobic ponds are *extremely* efficient in removing BOD. Table 1 shows the very high BOD removals obtained in anaerobic ponds treating municipal wastewater with a BOD_5 of 230–290 mg/l in northeast Brazil: in-pond temperatures were 25–27°C and retention times 0.8–6.8 days, and the BOD_5 removals were 68–80%. Table 1 shows that there is little advantage in loading anaerobic ponds lightly: the 0.8–day anaerobic pond achieved the same BOD removal as the 6.8–day pond, despite receiving a load nearly nine times higher.

Table 1 also shows BOD removal in primary facultative ponds receiving the same raw wastewater. Removals were high, 77–84%, but at much higher retention times, 9.5– 18.9 days. So, in terms of BOD removal, a ten–day primary facultative pond is only as good as a one–day anaerobic pond (or as shown in Table 1, a one–week anaerobic pond; anaerobic and facultative ponds are distinguished by absence of algae and oxygen in the former and an abundance of both in the latter: the applied BOD loading determines whether a pond operates as one or the other, but there is a 'grey' area in between which, for the ponds in the Table (right) is somewhere around 30g/m³.day).

This high efficiency of BOD removal means that anaerobic ponds actually reduce WSP land area requirements, as primary facultative ponds are much larger than anaerobic and secondary facultative ponds combined. This saving in land can be as high as 60% (Mara, 1976).

> Anaerobic ponds are a low-tech and highly efficient way of removing BOD, especially in warm climates. So why aren't they in more widespread use?

Pathogen removal

Due to the short retention times in anaerobic ponds, faecal bacterial and viral removals are not very high, generally a little less than one order of magnitude (Oragui *et al*, 1987). An exception is the removal of *Vibrio cholerae* O1: Oragui *et al* (1993) reported a 94% removal (from 485 per litre to 28 per litre) at a retention time of 1 day, and it seems that *V. cholerae* is very sensitive to the high levels of sulphide present (9–12 mg/l).

Anaerobic ponds are also good at removing helminth eggs: 90% are removed at a retention time of 1 day (Mara and Silva, 1986; Ayres *et al*, 1992), and the combination of a 1-day anaerobic pond and a 3-day secondary facultative pond reduced the egg count from 145 per litre in the raw wastewater to 1 per litre (Mara *et al.*, 1994), which is the WHO (1989) guideline value for crop irrigation.

Metal removal

There are few data on the removal of heavy metals in WSP. Moshe *et al.* (1972) showed that primary facultative ponds could cope with receiving up to 30 mg heavy metals per litre (6 mg/l of each of Cd, Cr, Cu, Ni and Zn) without reduction in performance, presumably by precipitation of the metals at around pH 8 or above as hydroxides and/or oxyhydroxides. Overcash *et al* (1978) found high removals of Cu (96%), Zn (92%) and Mn (87%) in an anaerobic pond treating piggery wastes; Parker (1979) also found high removals of Cu (75%), Zn (83%) and Pb (87%) but lower removal of Cr (47%); and Kaplan *et al* (1987) reported much lower removals (< 30 %) of Cd, Cu, Pb and Zn in the overloaded WSP at Beer Sheva, Israel (which are atypical in that the anaerobic ponds are preceded by 'settling ponds').

It is generally accepted that the principal mechanism of heavy metal removal in anaerobic reactors, including anaerobic ponds, is by precipitation as metal sulphides. Theoretical considerations (Cowling *et al*, 1992; Gupta *et al*, 1994) indicate that this is a highly efficient process, and Cowling *et al* reported high removals (> 90%) of Cd, Cr, Cu, Fe, Hg, Pb and Zn in a USAB reactor. Sulphide precipitation also occurs very efficiently in the anoxic zones of freshwater lakes (Frevert, 1987).

Pond code	Retention time (days)	BOD_5 loading (g/m³ day)	BOD removal (%)
Anaerobic ponds:			
A2	0.8	306	76
A4	1.0	215	76
A1/3	2.0	116	75
A1/2	4.0	72	68
A1/1	6.8	35	74
Primary facultative ponds:			
F4	9.5	27*	77
F5	18.9	14*	84

Table: BOD loadings and removals in anaerobic and primary facultative ponds in northeast Brazil

*Surface BOD_5 loadings were 322 and 162 kg/ha.day. Raw wastewater BOD: 230-290 mg/l; in-pond temperatures: 25-27°C.

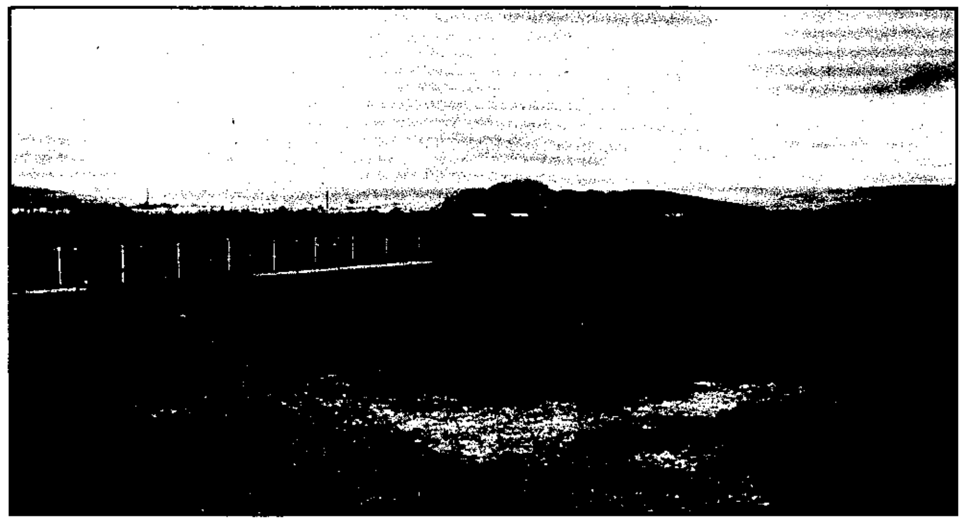
Sources: Silva (1982), Mara et al. (1983) and Oragui et al. (1987).

Industrial wastewaters

Apart from achieving high removals of heavy metals, anaerobic ponds are very efficient in treating high-strength industrial wastewaters, especially those from agro-industries (dairies, feed-lots, abattoirs, canneries), either separately or in combination with domestic wastewaters (Alabaster *et al*, 1991).

Many compounds in industrial wastewaters are toxic to algae, and pretreatment in anaerobic ponds ahead of facultative and maturation ponds is necessary to avoid this. Arthur (1983) particularly recommends this in the case of industrial wastewaters containing phenol-based hydrocarbons.

Floating materials (including oils) and scum also cause problems in facultative ponds by blocking out the light needed for algal photosynthesis, and this is again avoided by pretreatment in anaerobic ponds. A surface scum layer (see picture) is actually helpful in anaerobic ponds as it maintains anaerobiosis and helps to prevent odours.



Above: Anaerobic pond with solid surface crust at Nakuru, Kenya.

Desludging

The wastewater solids which settle in an anaerobic pond are digested anaerobically, so the rate of sludge accumulation (*S*) is quite low, around 0.04 m³ per person per year. Anaerobic ponds should be desludged regularly—usually when they are no more than half full of sludge; specialized lagoon desludging equipment is available (Brain and Meyerscough, 1993). The desludging interval (*n*, years) is simply calculated from (Mara, 1993):

$$n = B/2\lambda_v S$$

where *B* is the BOD_5 contribution in g/person day and λ_v the volumetric BOD_5 loading on the anaerobic pond in g/m³.day. So at 20°C and above (*ie*, λ_v = 300) and for *B* = 50 and *S*= 0.04, an anaerobic pond would become half full of sludge, and so require desludging, every two years. Sludge disposal is to landfill, drying beds or agricultural land: if to the latter, care has to be taken with respect to viable helminth eggs (storage for several months prior to land application, unless the sludge is well ploughed in, may be required) and heavy metals (but usually this is not a problem, except when the wastewater contains a high proportion of industrial effluent, since standards for land disposal are less stringent than those for effluents).

So, if anaerobic ponds are so good at removing BOD, *Vibrio cholerae*, helminth eggs and heavy metals, are not so problematic in their operation, and also save land, then why are so many people often so very hesitant to use them? The answer to this question is quite literally blowing in the wind – a fear of odour release. But, as we shall see, this fear is largely unsubstantiated.

Odour release

In anaerobic ponds sulphate ions and sulphur-containing amino acids are reduced to sulphides, and this is why there is a fear of odour release: some sulphide *may* leave the anaerobic pond surface in the form of hydrogen sulphide gas. But provided that the volumetric BOD_5 loading on an anaerobic pond is kept below 400 g/m³.day (Meiring *et al*, 1968)—and good design practice is to restrict it to a maximum of 300g/m³.day at temperatures ≥ 20°C (Mara *et al*, 1992), then odour release is not a problem.

The reason for this is because at pH 7.5–8, the normal pH in an anaerobic pond, most of the sulphide is present as the odourless bisulphide ion and only 22–9% as dissolved hydrogen sulphide gas (McCarty *et al.*, 1994). Some of this dissolved H_2S leaves the pond as the gas seeks to obey Henry's law, but at the sulphide levels normally found in anaerobic ponds, 10–15 mg/l, this does not give rise to any odour nuisance, and a properly designed anaerobic pond is no more odorous than any other well operated wastewater treatment works.

Odour from anaerobic ponds can thus be effectively eliminated at the design stage. They should not be allowed to become overloaded, however, as odour will then be a problem. Care has to be taken during the commissioning of anaerobic ponds: if they are commissioned before the secondary facultative ponds which receive their effluent, then odour release can be quite high as the anaerobic pond effluents are discharged into empty facultative ponds; but the solution is simple: commission the latter first. Similarly discharging an anaerobic pond effluent into the environment—on to land, for example, or to a river—can be problematic: odour release, or fish kills due to the high sulphide and ammonia levels. Again the solution is simple: treat the anaerobic pond effluent in at least a short retention (3–5 day) facultative pond prior to discharge.

Marais (1970) noted that '*pre-treatment in anaerobic ponds is so advantageous that the first consideration in the design of a series of ponds should always include the possibility of anaerobic pretreatment*'. We always seek to use them as standard. So, who's afraid of anaerobic ponds now?

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References

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