2.8 Desludging and pond closure

The reduction in concentrations of solids, BOD and particle-bound nutrients in ponds is due largely to sedimentation (see chapter 2.3 'Anaerobic, aerobic and facultative ponds'). Sedimentation can be problematic in ponds, as the accumulated sludge reduces the active pond volume and residence time and, consequently, treatment efficiency.

The choice of desludging option is an important consideration during the design stage. Options for desludging usually require batch removal:

- by excavator (standard or long-reach) or dragline with subsequent dewatering
- by vacuum tanker, with or without prior agitation
- by sludge agitation and pumping to a tanker, a big-gun irrigator or a drag-hose injector.

More frequent solids removal is offered by *in situ* sludge removal pipes and semi-continuous pumping to a dewatering bay.

Sludge measurement and characteristics

Sludge is a black, gritty, tar-like material that comprises a mix of inorganic material (sand etc.), slowly digestible organic material and dead microbial cell mass. It has a small particle size and is not readily separable in a solid–liquid separator. The sludge layer is a mobile fluid that forms peaks and valleys within the pond.

The basic principles of sludge management are adapted from Sheffield *et al.* (2000):

- Minimise sludge accumulation where possible by using a solids trap.
- Identify the trigger point for sludge removal—i.e. identify the depth where the volume of sludge begins to reduce required active volume (see chapter 2.3 'Anaerobic, aerobic and facultative ponds'). Record the trigger point permanently on a depth marker (for single ponds).
- Monitor sludge build-up. In a single pond system, the water level is regularly drawn down during irrigation, exposing the trigger level on the depth marker (see chapter 2.6 'Effluent storage requirement'). In a multiple pond system, water level in the primary (anaerobic) pond usually does not fluctuate, so take direct measurements (see below) before the end of the anticipated clean-out period.
- After the trigger point is reached, remove sludge (see 'Sludge removal' below), but leave a small residue (~150 mm or so) in the base to re-seed microbial activity upon refilling and to prevent the liner from drying out. Protecting the integrity of the liner during sludge removal is critical—aggressive agitation or over-enthusiastic excavator use may damage the liner and contaminate groundwater.
- Reuse nutrients via land application at agronomic rates (see chapter 3.1 'Nutrient budgeting').

The depth of the sludge is typically measured by probing from a boat (a slow, inaccurate and potentially dangerous task). A lightweight pole, sometimes fitted with a bottom plate, is lowered slowly into the lagoon until the liquid becomes denser; at that point the depth is recorded. The pole is then pushed lower until the bottom of the lagoon is reached, and the depth is again recorded. The difference between the two readings is the sludge depth. At least 10 depth measurements, including one at the marker, need to be made in a representative survey (Sheffield *et al.* 2000). Avoid locations with pipe inlets or pump intakes, where the sludge level is likely to be disturbed by localised flow patterns.

It is often very difficult to determine the interface between liquid and sludge, particularly in deeper ponds. Researchers sometimes use a nephelometer (light reflectance meter) to improve measurement accuracy. More recently, sonar has been used. The Queensland DPI (Duperouzel nd.) found that sonar in piggery effluent ponds offers rapid sludge measurement with an accuracy comparable to the nephelometer. Singh *et al*. (2007) reports on the development of a prototype that can map sludge profiles without requiring a person in a boat. At this stage, only a few commercial contractors can provide a sonar service.

Sludge samples for testing can be taken from a boat before agitation by using a length of 18-mm PVC tube:

- While wearing gloves, insert the tube to the base of the pond.
- Place your thumb over the open end and slowly withdraw the tube while maintaining the vacuum.
- Hold the lower end of the tube over a bucket and release your thumb, collecting only the black sludge.
- Repeat until 8 to 10 samples have been collected.
- Mix the samples and extract a subsample for analysis.

Procedures for sampling solids from a dewatering bay are given in Redding (2003). Also see chapter 7 ‘Monitoring and sampling’.

Typical characteristics of sludge are shown in Table 1. Note, however, that after surveying 30 piggery effluent lagoons, Sheffield (2000) concluded that owing to the variation in nutrient concentrations in sludge between farms, an analysis of the sludge in question was necessary for calculating application rates rather than using ‘typical’ values.

Table 1. Published sludge characteristics (standard deviation in parentheses).

Parameter	Units	Longhurst *et al.* (2000)	Barker *et al.* (2001)	pers. comm. G. Ward, 2007, QDPI.
Density	$kg{\cdot}m^{-3}$		994	
TS	%		7.3 (4.6)	6.5–8 [a]
VS	% (of TS)		57 (5.9)	
COD	$mg{\cdot}L^{-1}$		31206 (19002)	
pH			7.5 (0.55)	
Total N	$mg{\cdot}L^{-1}$	2450		1000–1400
TKN	$mg{\cdot}L^{-1}$		2276 (1042)	
NH_4-N	$mg{\cdot}L^{-1}$			210
NH_3-N	% TKN		32 (23)	55
P	$mg{\cdot}L^{-1}$	250	2197 (1726)	190–192
K	$mg{\cdot}L^{-1}$	500	918 (719)	620–625
S	$mg{\cdot}L^{-1}$			370
Na	$mg{\cdot}L^{-1}$		347 (192)	75
Ca	$mg{\cdot}L^{-1}$			2174
Mg	$mg{\cdot}L^{-1}$			872
Cu	$mg{\cdot}L^{-1}$		55 (44)	
Zn	$mg{\cdot}L^{-1}$		89 (49)	
EC	$\mu S{\cdot}cm^{-1}$		3649 (726)	

a: Generally, effluent with <8% solids can be pumped. The consistency of the sludge recovered by Ward (2007) was limited by the capacity of the vacuum tanker to extract the settled material without agitation.

US sources suggest that sludge has a lower N:P ratio than effluent, so application rates must be adjusted accordingly (see chapter 3.1 'Nutrient budgeting'). However, Australian (Ward 2007) and NZ (Longhurst *et al.* 2000) data show N:P ratios not dissimilar to those of effluent.

Sludge removal

Removal for reuse as a solid

- Pump liquid above sludge by usual distribution system.
- Using an excavator and mud bucket, remove sludge and place, via a sealed truck, into a bunded dewatering bay or one that drains back into the pond.
- After air-drying, solids can be hauled and spread with conventional solids-handling equipment.

Do not dump wet sludge directly onto paddocks: extremely high nutrient loading rates and the risk of leachate contaminating surface waters or groundwaters preclude this.

Removal for reuse as a slurry

- Pump liquid above sludge by usual distribution system, leaving sufficient behind to dilute sludge to a pumpable state following agitation.
- Agitate remaining contents and remove via a vacuum tanker (equipped with surface spray plates or soil injectors), or pump to a slurry spreader, big-gun irrigator or umbilical hose injector.

Agitation equipment can be either PTO-powered propeller-type mixers or hydraulic agitator/pumps that can also load slurry spreaders. Both types of agitators have a limited radius (~15 m; Jones *et al*. (2006)), so access points are required at least every 30 m.

Agitators can erode earthen liners, so propeller types must be kept at least 1 m from the liner. Hydraulic agitators must be monitored to ensure that the recirculation jet is not scouring the embankment. Check periodically for leaks from hoses and couplings to avoid spills and impairing vehicle traction or access.

Some contractors prefer to at least one of the long sides of the pond to be 6 m wide to allow for machinery access during desludging. Earthen ramps with a grade of 1:10 will allow safe approach to and departure from the embankment. It is also beneficial to provide a gravel-topped crest to maintain good traction while machinery is working beside the pond. Remember that such machinery can weigh in excess of 30 tonnes, and OH&S issues must be considered during the design.

In situ sludge removal—emerging technology

Some covered anaerobic ponds are equipped with a network of pipes across the base to:

- remove sludge without removal of the cover
- inoculate influent with microbes from the recovered sludge to enhance biogas production (see chapter 8.1 'Production and beneficial use of methane').

Such sludge harvesting techniques are also potentially useful for uncovered ponds, as they offer:

- the opportunity to minimise the required pond volume via a reduction in the sludge allowance (lower construction costs, lower total odour emissions)

- regular sludge removal with greater retention of nutrients for reuse
- avoidance of disruptive batch desludging.

In covered anaerobic ponds, a pump capable of handling high-solids material (up to 8%) is connected to the pipe network via a multi-valved manifold and operates semi-continuously, switching between laterals to remove sludge and return it to a mixing tank or solid–liquid separation system.

Typically the design of any such system is proprietary knowledge. However, the basic principles of pumping sludge require the following features:

- A minimum scour velocity of 1 $m \cdot s^{-1}$ (see chapter 1.6 'Pipes'), but typically not greater than 2 $m \cdot s^{-1}$, depending on pump characteristics (net positive suction head required).
- A pump that can handle solids and abrasive material (sand is more of a problem in dairy effluent than in piggery effluent) yet has reasonably good efficiency to minimise life-cycle operating costs.
- A compromise between the number of inlets and the numbers of laterals and valves to minimise installation costs without limiting the removal of sludge by 'rat-holing'. Rat-holing is the situation where one inlet on a lateral with many inlets may clear faster than the others, allowing effluent into the dewatering bay. Installing more laterals with one inlet each offers improved control, but the sludge's *in situ* angle of repose and therefore inlet spacing have not yet been documented.

The adoption of such systems is likely to be possible only where a drying bay is practical; that is: there is a sufficient area of flat or gently sloping land; the *in situ* soils allow construction of a pad with an impermeable clay liner; and the climate includes drying periods to allow evaporation to reduce the sludge moisture content from the 'slurry' range to the 'solid' range.

Sludge dewatering

Sludge dewatering bays

A sludge drying bay or pad may be simple or elaborate depending on the intended frequency of use. It has the following functional requirements:

- The pad must be able to drain any leachate or contaminated runoff back into the effluent collection system, or have a bunded volume that contains all leachate and any runoff.
- The base must be relatively impermeable and should be prepared with a compacted earthen liner (or have an artificial liner and a means of protection). Skerman (2005) provides a list of recommended construction procedures for earthen pads.
- Some form of bunding is required, as the moisture content of the removed sludge is too high for it to be stackable. This may be provided by earthen embankments, large bales of straw, or geotextile or shadecloth fences.

2.8 Desludging and pond closure

Figure 1. Empty drying bay with shadecloth fence (photo courtesy of Australian Pork Limited & QAF Meats).

Figure 2. Drying bay before clean-out (photo courtesy of Australian Pork Limited & QAF Meats).

A geotextile or shadecloth fence around a drying bay offers higher dewatering rates by virtue of its permeability. A simple shadecloth fence dewatering bay is shown in Figure 1. Note that the layer of sand on the pad indicates the base during clean-out.

Structures similar to separation and evaporation ponds (see chapter 2.1 'Solid–liquid separation systems') may be used to minimise costs. Design depths of approximately 500 mm for wet sludge will promote faster drying during the drier months.

Geotubes

Geotubes have also been used to dewater high-solids-content effluents and pond sludge. A large geotextile fabric tube is placed on an impermeable pad, filled with effluent, and then left to dewater for 2 to 5 days. After the tube dewaters sufficiently, additional effluent can be pumped in to refill it. This process of filling and dewatering may be repeated several times until the tube is full of solids. A final dewatering period of 10 to 14 days (or longer) can be used before the tube is opened and the solids are removed. Once opened, the tubes are discarded (or recycled for other uses such as laneway stabilisation or weed mats).

The tube retains a high percentage of the solids (95% TS, 80% TKN, 80% TP, 30% K), and the liquid returns to the effluent system. The solids can remain in the tube until spreading and do not need to be covered (rainfall will not enter the tube).

Chemical coagulants and flocculants can be added to the effluent to enhance nutrient removal and to speed the rate of liquid drainage from the geotube so as to shorten the time between refills (see chapter 5 'Odour emissions and control').

When used in pond desludging operations, the geotube system is limited by being batch-loaded: dewatering requires time during which specialist sludge agitation and pumping equipment (usually hired) sits idle. As sludge pumping costs may exceed the cost of the bag itself, ponds should be drawn down (by the usual irrigation procedures) to the sludge level before pumping sludge to maximise the solids content and reduce the number of refills. Two or more tubes may be warranted to maximise the use of specialist pumping equipment.

It is conceivable that a relatively large pair of geotubes (or more) could be used to separate solids continuously. However, the continuous drainage of effluent would probably necessitate construction of a concrete pad with drainage collection under the area. If earthen pads constructed with a compacted clay or membrane liner were used, bunding between tubes would be necessary to maintain access by isolating drainage from the working tube, and the liner would need to be protected from damage during tube removal and replacement.

The cost of a 14-m × 30.5-m geotube in 2005 was approximately US$10 m^{-3} (Texas Water Resources Institute nd.).

Pond closure

When a dairy ceases operation or a pond is to be replaced, existing ponds need to be closed properly so that they do not constitute a risk to surface water or groundwaters. Jones *et al.* (2006) suggest the following options as appropriate strategies for the permanent closure of ponds.

Option 1—Permanent elimination of earthen storage structure

1. Divert all surface water runoff away from the storage.
2. Remove any pipes and structures adding effluent to the storage.
3. Remove all liquid, pumpable sludge and solids.

4. Fill the structure with soil by pushing in existing embankments and bringing in additional fill as needed. The degree of compaction required for backfill material will depend on the anticipated future use of the site, but must be sufficient that settlement does not create a depression that collects rainwater. The backfill height should exceed the design finished grade by 5% to allow for settlement.

5. Establish a crop cover to minimise soil erosion. A crop with deep roots such as lucerne is preferred because of its ability to draw up any remaining nutrients.

Option 2—Permanent conversion to a freshwater pond

1. Add an overflow spillway (if one does not exist) or a standpipe to set a maximum water level at least 0.6 m below the lowest point in the embankment.

2. Remove any pipes and structures adding runoff or effluent to the storage.

3. Remove all liquid, pumpable sludge and solids.

4. Immediately after clean-out, refill the pond with fresh water to prevent the liner from drying out. When conditions suit irrigation, agitate the pond and completely empty it.

5. Refill the pond with water. If the resulting water quality meets the objectives for agricultural irrigation water given by ANZECC & ARMCANZ (2000), the structure can be managed as a farm pond. Otherwise, continue the cycle of emptying and refilling.

Note that regulatory controls on the establishment of farm dams may apply.

Option 3—Breaching the embankment

1. Divert all surface water runoff away from the storage.

2. Remove any pipes and structures adding runoff or effluent to the storage.

3. Remove all liquid, pumpable sludge and solids.

4. Breach the embankment low enough to allow any water that enters the pond to quickly drain away (this option may not be possible for below-ground structures).

5. Establish a growing crop or pasture. A crop with deep roots such as lucerne is preferred because of its ability to draw up any remaining nutrients.

Breaching the embankment before all contents are removed is not recommended: pollution incidents (and prosecution) have resulted from such an approach.

Option 4—Managing storages on temporarily de-stocked farms

Where a farm is temporarily de-stocked with the intent to restart later, a fourth option is appropriate.

1. Divert all surface water runoff away from the storage.

2. Remove all liquid, pumpable sludge and solids.

3. Refill the storage with water to limit damage to the liner from desiccation, weed growth, erosion and burrowing animals.

4. Manage the storage to prevent liquid overflow.

Under any of these options, it is important to protect the existing earthen (or geotextile) liner from damage. An intact liner minimises the risk of pollution of groundwater.

The cost of closing a pond is significant, and a lack of funds upon ceasing operations may be a deterrent to following the recommended procedure. However, if an improperly closed pond causes pollution, the costs in mitigating the damage and possible fines would exceed any avoided costs.

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