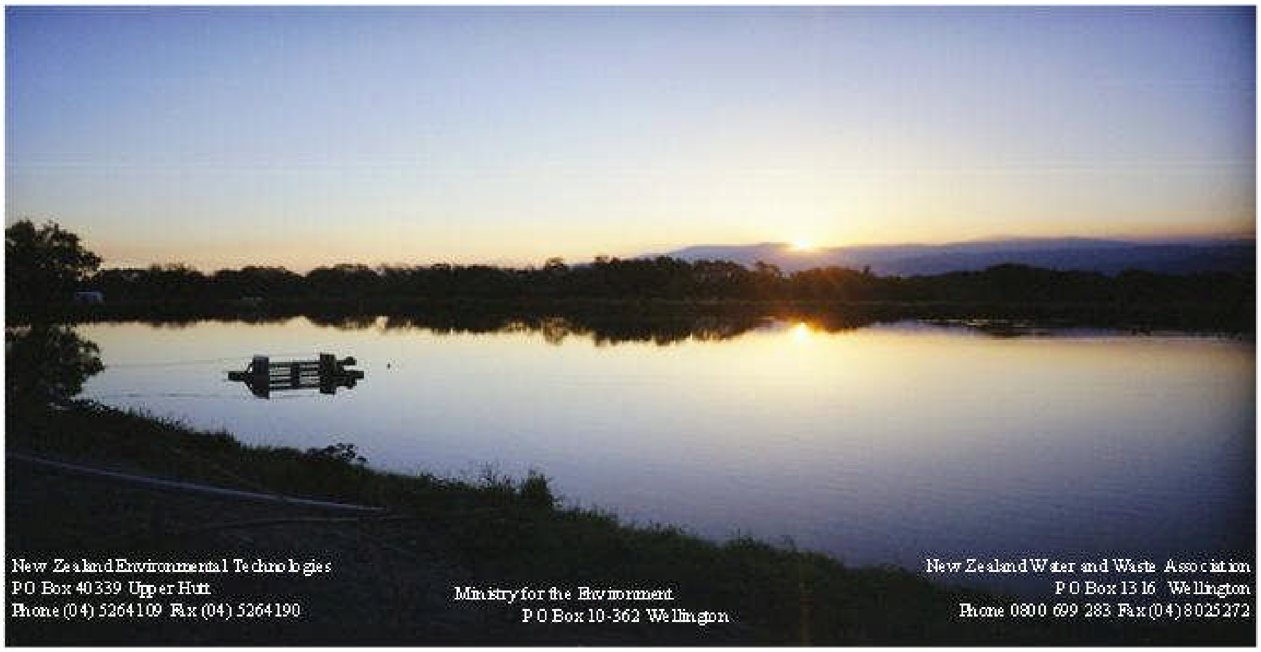
Oxidation Pond Guidelines 2005

NZET

Ministry for the Environment
Manatū Mō Te Taiao

nzwwa
New Zealand Water & Wastes Association
Waiora Aotearoa



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Status of This Draft:

This Guideline Document is in Draft form, we have termed this a "working draft", in that it has been checked for significant factual errors and serious omissions. It is undoubtedly not in "perfect" form, or arguably in anything approaching this. Nevertheless, it is being released as a document which should already serve its intended purpose, and, can be readily modified, updated and improved.

The proposed next stage in its development is to conduct a 1 day review workshop, under the auspices of the NZWWA, with input from representatives of the key stakeholders, TLA's, MfE, MoH, Researchers, Consultants, Designers, and Regional Councils. This step will be subject to available funding, and, in the interim, comments are welcomed at any time. Please provide comments and additional information, preferably by email to:

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1. Introduction

1.1 Overview

This document is an update of the Ministry of Works Guidelines for Oxidation Ponds 1974. It draws from recent research and modern practices. It is written for use by pond operators and designers, planners, regulators and other interested persons. It is however, not intended to be a primer on wastewater treatment, and assumes that the reader has a basic understanding of wastewater terms and practices.

These guidelines cover: how an oxidation pond works, how it differs from other types of ponds; how to operate oxidation ponds; what to do when things go wrong; and how to add to and modify existing ponds to improve their performance. They do not cover consent requirements that relate to individual ponds. Consents may include conditions that require specific actions that are not covered in this document.

The oxidation pond is one of the most commonly used methods for treating domestic sewage from small to medium-sized communities in New Zealand. Fitzmaurice (1987) reported that of 160 sewered communities with populations greater than 1,000, 100 used oxidation ponds as the main method of sewage treatment.

Ponds are less costly to construct and easier to operate than many other treatment systems. Modern ponds, with enhancements, have an important role to play in wastewater treatment in New Zealand. Ponds are robust, require low energy, are able to cope with hydraulic and organic loading peaks, and may provide buffer storage for land treatment systems.

In spite of their simplicity, however, they should not be ignored. A good understanding of how they work and attention to maintenance requirements will make sure the pond delivers the best effluent it can.

1.2 What is an oxidation pond?

Oxidation ponds are shallow earthen basins within which wastewater is treated biologically. Ponds are able to reduce the level of many contaminants in sewage including: Biochemical Oxygen Demand (BOD); suspended solids (SS); ammonia, and the number of microbes, including those which may cause disease (pathogens).

Oxidation ponds use algae and wind action to introduce oxygen to the pond liquid. The wind and inlet flows will also create currents within the pond which help to mix the wastewater over the full pond area.

The quality of outflow (effluent), from an oxidation pond, is very dependent on the action of these currents, and therefore how long the wastewater is held in the pond.

Microscopic animals in the pond graze on bacteria, reducing bacteria numbers considerably. Faecal coliform bacteria, indicators of the possible presence of pathogens, also die off naturally with time and exposure to sunlight. Therefore the longer the sewage stays in the pond, the more microbes are killed.

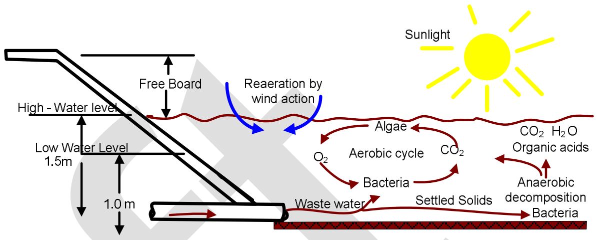


Fig 1: The processes at work in an oxidation pond

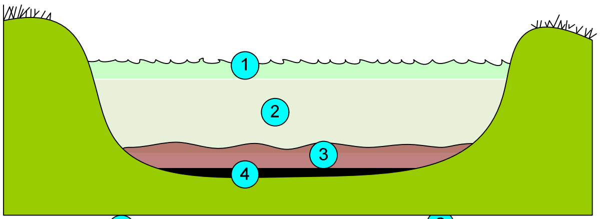
Dissolved nutrients in the sewage, such as nitrogen and phosphorus, feed green algae which are microscopic plants floating and living in the water. The algae also use carbon dioxide (CO_2) and bicarbonate as food much as land plants do. Like land plants, they release oxygen as a waste product. The oxygen is used by helpful bacteria to breakdown the incoming waste.

Algae produce oxygen from the process of photosynthesis, during the daytime. Pond oxygen levels, and some other characteristics, like pH, will therefore change throughout the day and from day to night time.

1.3 Pond classification – based on oxygen levels

These guidelines are about oxidation ponds, but there are other types of ponds. Three different pond systems are; oxidation (mechanically), aerated, and anaerobic; ponds. A term which covers all three types of ponds is "Waste Stabilisation Ponds". The following descriptions and diagrams show how they differ from each other.

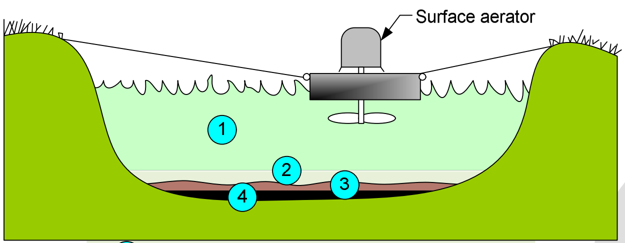
Oxidation ponds (including primary and secondary (facultative), and tertiary (maturation), ponds), have a bottom layer of sludge with no oxygen (anaerobic), a liquid anaerobic layer above that, then a middle layer with small amounts of oxygen (anoxic); and a top layer with oxygen (aerobic)



The top layer (1) is the aerobic zone, the second layer (2) is the anoxic zone, the third layer (3) is the anaerobic zone, and the fourth layer (4) is the sludge zone.

Fig 2: Oxidation pond

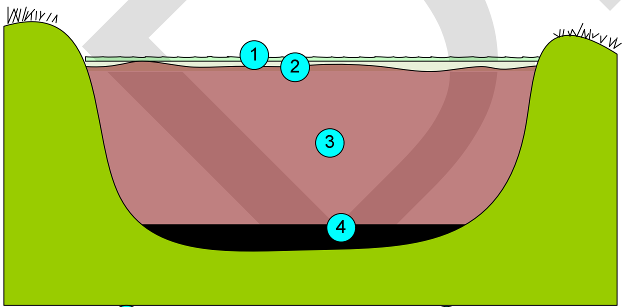
Some ponds have mechanical aerators on them. These range from facultative ponds with some extra aeration, to aerated lagoons that have so much mechanical aeration the aerobic zone increases to nearly the whole depth. In some aerated lagoons much of the sludge is also kept in suspension.



The top layer (1) is the aerobic zone, the second layer (2) is the anoxic zone, the third layer (3) is the anaerobic zone, and the fourth layer (4) is the sludge zone

Fig 3: Aerated pond

Anaerobic ponds are the opposite and have little, if any, oxygen present. They are usually deep and often are fed high strength dairy and meat wastes.



The top layer (1) is the aerobic zone, the second layer (2) is the anoxic zone, the third layer (3) is the anaerobic zone, and the fourth layer (4) is the sludge zone.

Fig 4: Anaerobic pond

1.4 Zones in oxidation ponds

Aerobic, anoxic, and anaerobic conditions exist in oxidation ponds. Different forms of wastewater treatment take place in the four zones, shown in Figs 2-4 above. The features are described in the following discussion:

The depth of the aerobic zone (the top zone) in an oxidation pond depends on: climate, the amount of sunlight and wind, loading, currents and how much algae is in the pond water. The wastewater in this part of the pond receives oxygen from the air, from the algae, and from the agitation of the water surface for example from wind and rain.

In the pond's aerobic zone, dissolved organic matter and oxygen are used by bacteria for normal growth, producing more bacteria, and treating the wastewater. Carbon dioxide is also released, which is used by the algae, (being a type of plant). The long retention period in the pond ensures that the new bacterial cells eventually pass into the "endogenous respiration" phase (a wasting process). The end products of this are inert matter and more carbon dioxide. The aerobic zone also treats the odours from gases produced in the lower layers.

Below the aerobic zone, the anoxic zone provides a transition to the anaerobic layers below.

The interface between the sludge and the pond anaerobic zone is an area of intense biological activity. Settled solids are washed around the pond floor but tend to accumulate to greater thicknesses near the inlet. Over the rest of the pond, there is a uniform depth of liquid between the pond surface and the top of the sludge layer, regardless of pond floor contours. Anaerobic decomposition reduces the quantity of organic matter converting it to carbon dioxide (CO_2), methane (CH_4) and residual matter. The bacteria derive their energy from the "food' they consume. The carbon dioxide and methane released can be observed as gassing and sludge belching.

1.5 Pond classification – relationship to other treatment

A pond receiving raw sewage may be regarded as a complete (primary and secondary) treatment unit. Primary treatment (physical sedimentation) secondary treatment (the biological conversion of unsettled organic matter which is responsible for the greater part of the Biochemical Oxygen Demand, into a settleable mass), and sludge digestion (the slow further break down of the settled solids) all take place in a natural manner. Some disinfection will also occur in such a pond. It should also be realised that some of the incoming degradable organic matter not used for biological energy within the pond, is passed out of the pond in a stable form as algae in the pond effluent.

Some typical combinations of ponds are shown in Figs 5 to 7. The terms primary, secondary, and tertiary oxidation ponds, are a New Zealand terminology. In other countries, primary and secondary ponds are usually called facultative and tertiary ponds are called maturation ponds.

A single pond that has raw sewage coming in is called a **primary pond**. In a primary pond, both primary and secondary treatment takes place.

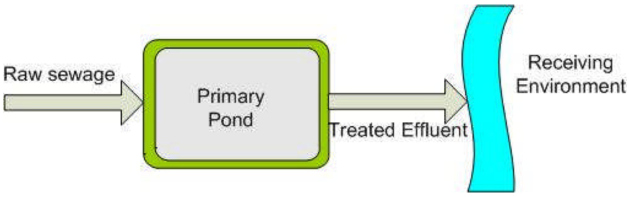


Fig 5: Primary (facultative) pond: provides primary and secondary treatment and sludge digestion.

A pond that follows primary treatment e.g. a primary clarifier or Imhoff tank is called a **secondary pond.** In it, mainly secondary treatment occurs.

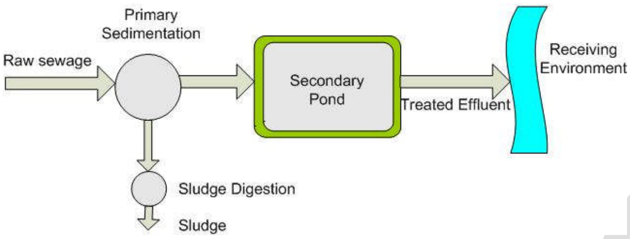


Fig 6: Secondary (facultative) pond: follows "conventional" primary treatment provides secondary treatment and sludge digestion.

A pond which follows another pond, either primary or secondary, or follows a secondary treatment plant, is called a tertiary pond. Such ponds are also called maturation ponds. In tertiary (maturation) ponds, further treatment occurs. This is mainly disinfection due to sunlight, cold, and predation by other organisms.

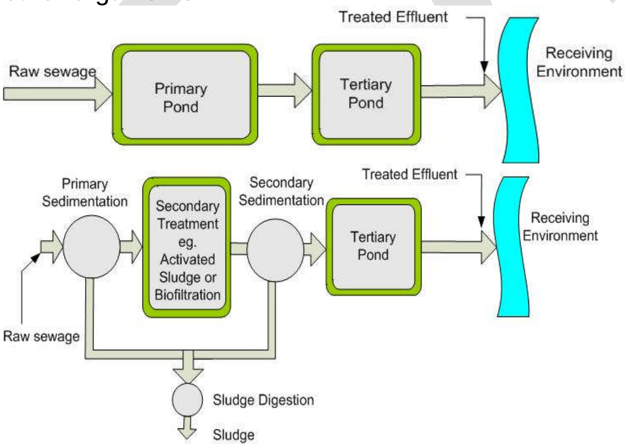


Fig 7: Tertiary (maturation) pond: following either a primary pond or "conventional" primary and secondary treatment

1.6 Oxidation pond effluent quality

Since the oxidation pond process is natural, and subject to influences which are random – weather, and predominant microbiological species, etc - a pond system cannot consistently produce effluent of a precise standard. Pond performance is influenced by variations of season and climate, for example ammonia removal is usually good in summer and poor in winter. Algal blooms are typically a summertime occurrence, and impact on BOD, SS and bacteria levels as well as clarity of the receiving water, and potentially presence and levels of algal toxins. Experience in New Zealand, has shown that as the load on a pond system increases, there is a deterioration of effluent quality.

Note that as most NZ wastewater systems experience high levels of inflow and infiltration of stormwater, pond effluent concentrations of contaminants may be quite low due to dilution rather than to particularly high levels of treatment. Typical results for primary ponds loaded up to the recommended rate of 84kg BOD/ha/day (1,200 people/ha), are shown below

Typical effluent quality for other pond systems and pond modifications are given in section 8.

Contaminant	Average	Maximum	Minimum
BOD_5 (g/m^3)	40	110	15
Suspended solids (g/m^3)	50	150	10
Faecal coliform bacteria (#/100 ml)	20 x 10^3	100 x 10^3	5 x 10^3
E coli bacteria (#/100 ml)	10 x 10^3	50 x 10^3	2 x 10^3
Total Phosphorus (g/m3)	8	16	4
Dissolved Reactive Phosphorus (g/m3)	6	12	2
Ammoniacal Nitrogen (g/m3–N) (winter time)	15	30	0.5
Ammoniacal Nitrogen (g/m3–N) (summer time)	5	10	0.1
Total Nitrogen (g/m3–N)	30	50	10

Table 1: Typical effluent results for a primary oxidation pond

2. Design and construction

2.1 Pond sizing

In NZ, facultative pond sizing has typically been based on a population or organic loading rate. The conventional design value for primary ponds has been 84 kg BOD/ha/day or 1,200 people/ha. These levels have been proven to be conservative, with almost all ponds loaded at these rates providing reasonable levels of treatment as long as the influent is from a mainly domestic source.

Secondary ponds (i.e. ponds which follow a suitable primary sedimentation process) are also sized on the basis of 84 kg BOD/ha day. However, allowing for a 33% reduction of BOD in the primary treatment unit, this equals 1,800 persons/ha. Ponds which are to treat septic tank effluent however, should be designed as primary ponds.

Tertiary pond design should be based on detention period at average flow. Historically, in New Zealand, a detention period of 20 days has been recommended. Modern design trends, however, are towards smaller multiple ponds in series, (Mara and Pearson 1998). For example, two 5 day detention ponds can theoretically achieve a similar performance to one 20 day pond, with half the footprint area. Ponds which follow a full conventional (primary and secondary) treatment plant are likely to increase the BOD and SS content of the plant effluent due to the production of algae within the pond.

Other methods of sizing ponds based on loading rates and desired effluent quality can be used, but it is not possible to be very precise in designing a system so influenced by uncontrollable factors.

A suggested limitation of primary pond area is 8-12 ha. In some larger ponds, wind action generates waves large enough to resuspend bottom sediments, which are then discharged in the pond effluent. Also, as pond size increases well above 12 ha, it is more difficult to distribute the inlet BOD loading over the whole area, which can lead to overloading in the inlet part of the pond.

2.2 Hydraulic design

Shilton (2001) presented an extensive study on the hydraulics of stabilization ponds. Twenty experimental configurations were tested in the laboratory and ten of these experimental cases were mathematically modelled and had good agreement with the experimental work. Shilton and Harrison (2003) then introduced guidelines for hydraulic design of oxidation ponds to "help fill the knowledge gap in the pond hydraulics area". They recommend:

- Short-circuiting should be avoided as it results in a large reduction in the discharge quality.
- Influent flows should be mixed into the main body of the pond to avoid localised overloading, making sure at the same time, not to create short-circuiting.
- The solids deposition within the pond occurs as a result of the flow, rather than the flow being redirected as a result of the solids.
- A pond should maintain a similar and reasonably well defined flow pattern through the range of possible flow rates.
- Baffles to shield the outlet.

Examples showing how to put some of these recommendations into practice are given in sections; 2.8, 2.10, and 4.2.3 of these Guidelines.

An important aspect of hydraulic design in ponds is the hydraulic retention time (HRT). This is the average time that the incoming wastewater stays in the pond. The HRT will affect the level of treatment the pond performs. Ideally, if there are no shortcuts – the pond can be considered a plug-flow system, that is the flow comes in at one end, travels round the pond and having been everywhere, passes through the outlet. The HRT can then be calculated by dividing the water volume of the pond by the flow.

If a primary pond serves 5000 people, and is loaded at 1200 people per hectare, then the pond will be 5000/1200 = 4.16 ha in area. If the pond is 1.5m deep, of which an average of 0.3m of the depth is taken up with sludge, then the pond volume is 4.16 x 10,000 (m^2/ha) x (1.5-0.3) = 49,920m^3. If the average incoming flow is 300 litres per person per day, or 0.3 x 5000 = 1,500m^3/d, then the HRT should be 49,920/1,500 = 33.3 days.

Now the actual pond HRT will not be 33.3 days. It will be a lot less. This is because of dead areas, where flow does not go, and currents, which cause short circuiting. Estimating HRT is important so that pond performance can be improved, using baffles and other methods. In order to find out what the actual HRT is, there are several methods, the most accurate of which is a tracer test.

Tracer test

A tracer test involves releasing a substance which can be measured in very small concentrations into the incoming sewage flow, and measuring how long it takes to reach the outlet. Since it will spread around in the pond, the outlet measurements will need to be taken over many days. The most commonly used tracer is Rhodamine WT, a fluorescing dye. Measuring the amount of the dye present in a sample requires analysis using a special spectrophotometer called a fluorometer.

Sampling will need to take place several times per day, so this means using an automatic sampler, and a lot of samples to analyse. Rhodamine WT is also sensitive to decay in sunlight, so a control sample next to the pond to measure the rate at which its strength changes is needed, i.e., reduction in concentration with time.

An alternative tracer is lithium, usually applied as the compound lithium chloride.

Although a tracer test involves a lot of time and expense. It still may be worthwhile, in that it will show very accurately how long the influent spends in the pond under the particular inflow, pond level, and wind and weather conditions which occurred at the time the test was run. But what about results under other conditions?

Other ways to estimate pond HRT are; computer modelling, physical modelling, use of drogues and floats, visual observation of currents, and the consent compliance test results.

2.3 Location and ground conditions

Ponds can be constructed in virtually any location; however it helps to reduce the cost if the site has suitable conditions and is located at a lower elevation from the area serviced, so the wastewater can flow to the pond by gravity. Ideally an area should be selected where the water table is deep and the soil is heavy and impermeable. Silt or clay soils are ideal for pond foundations and construction. Building ponds over coarse sands, gravels, fractured rock or other materials, that will allow effluent to seep out of the pond or allow groundwater to enter in, will require care and special engineering.

The siting of ponds is an issue which has received considerable attention, as various parties – designers and objectors for example, have tried to make the "rules" fit their needs for particular circumstances. Previously recommended distances have been *"300m from built-up areas or 150m from isolated dwellings. For populations of less than 1,000 persons these restrictions may be reduced provided that there is adequate natural screening and that the prevailing wind blows away from any housing area".*

In reality, however, there is no scientific basis for setting these distances, and each site should be evaluated on its own merits. Having aeration, for example will reduce the risk of odour problems, but the same aerators increase aerosols possibly carrying disease-causing organisms.

Conventional wisdom has been that siting in an open area will to take advantage of the sun and wind, will assist the efficient operation of the oxidation pond and improve the quality of the discharge. With more detailed consideration of, and attempts to control pond hydraulics, some designers prefer sheltered sites where high wind exposure is avoided.

Avoid sites that are likely to flood, have steep slopes that run towards a waterway, springs or water supply bore holes. The pond should be orientated with the longest diagonal dimension of the pond parallel to the direction of the prevailing wind, the inlet at the downwind end, and outlet at the upwind end. Ponds should not be located within 2 km of airports, as any birds attracted to the ponds may constitute a risk to aircraft.

The site should preferably be flat. Surface drainage should be away from the site or should be diverted away from the pond formation.

2.4 Shape

Wherever possible, and construction costs allow, ponds should be uniform in shape, preferably approaching square with rounded corners. Ponds must not be too narrow in relation to length (pond length should not exceed three times pond width), nor should they have sharp bays or re-entrants in which scum can lodge and weed growth develop.

2.5 Depth

Facultative, (primary and secondary), oxidation pond depths should usually be within the range 1.5m to 2.0m. Maturation (tertiary), pond depths can be less at 1.0-1.5m. The minimum acceptable depth stops aquatic plants becoming established. Such plants restrict natural flow patterns within ponds. Ponds used for buffer storage have successfully been operated at temporary depths of 0.8m without any problems occurring.

Modern design trends are to work to depths between 1.5 and 2.0m to allow for sludge storage and flow buffering capacity. No advantage is gained by making the pond any deeper. Greater depths can cause temperature stratification, which can result in the pond overturning when the surface water temperature cools rapidly and becomes colder than the temperature of the lower water. At this time (usually the first frost of winter) it is possible for the colder surface water to drop to the bottom of the pond, causing the warmer anaerobic and sludge layers at the bottom to rise to the surface.

Ponds which have adequate mechanical aeration, (often used for mixing as much as for aeration), generally avoid thermal stratification and turnover events.

Slight variations in pond depth do not affect pond operation. The natural movement of solids tends to give a uniform depth of liquid layers.

2.6 Embankments, wavebands and freeboard

Embankments form the sides of the pond. They must be well constructed to prevent seepage, settlement or erosion over time. Embankment slopes are commonly 1 (vertical) to 3 (horizontal) internally and 1 to 2.5 to 4.0 externally, (if they are to be mowed). External embankments should be protected from storm water erosion by providing adequate drainage. Internal embankments should be protected from wave action erosion by using concrete wavebands or rock rip-rap. Where a synthetic liner is used, a device must be provided to allow safe entry and exit for maintenance staff.

Embankment tops should be wide enough to permit vehicular access for maintenance purposes, a minimum width of 4 m is recommended. Tracks should be metalled to provide a good base for vehicle traction. Fill embankments should be constructed on good foundations and be compacted according to earthworks construction standards for the soils involved. Although a well constructed embankment as shown in Figure 8 will not be at risk from moving due to the weight of the pond water, good compaction will also minimise settlement, form a good base for wavebands, and reduce the risk of erosion damage from floodwaters, or seepage flows from within the pond.

Special care must be taken to locate any soft spots or filled areas on the pond site. These should be excavated and refilled with well compacted, good fill material.

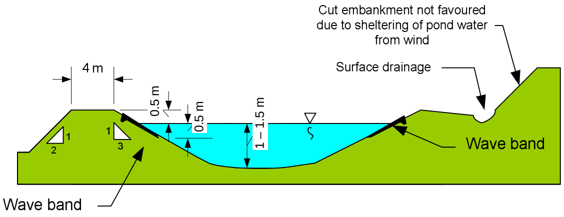


Fig 8: Typical embankment and waveband design

Where pipes are laid through embankments care must be taken with back filling around the pipe. If pipelines are to be laid through the base of the pond embankment it may be preferable to use PE or GRP pipes, laid at the same time that the embankment is built up. This will reduce the problems associated with differential settlement and avoid the need to dig up the embankment to repair damaged pipework.

A wave band forms a clean edge to a pond, preventing erosion and making the pond easier to maintain. Various materials have been used for wave band construction but to date, of the sheet materials, only concrete has been found completely satisfactory. Polythene sheeting, while a good option for small ponds, does not allow access onto the waveband for cleaning etc.; asbestos cement sheeting has broken up or moved; corrugated asbestos cement sheeting is generally too narrow, allowing waves to pass below the sheets and lift them, and debris collects on stone pitching making cleaning difficult.

Concrete wave slabs must also be keyed into the embankment. The use of small precast slabs is not recommended owing to the difficulty of providing an adequate key; unkeyed slabs have been known to slip. Joints between pre-cast slabs are also prone to weed growth.

If suitable larger rock sizes are available from nearby rivers or quarries, and the pond has inlet screening, then rock rip-rap placed on a medium to heavy grade of geotextile can provide bank protection at lower cost than concrete. Rock and geotextile has the advantages of not being effected by bank settlement and wave run-up is reduced.

Freeboard (the amount of waveband above the water surface) and waveband width, must be related to the size of waves which may form, which depends on the size and wind exposure of the pond. Typical wave band sizing for smaller ponds, (say up to 2 ha), is shown in Fig 8 above. For larger ponds specific design should be undertaken.

2.7 Construction

Certain site-related factors, such as the location of the water table and the composition of the soil, should always be considered when designing pond systems. Ideally, ponds should be constructed in areas with clay or other soils that won't allow the wastewater to quickly percolate down through the pond bottom to the groundwater. Otherwise, ponds in sensitive areas must be artificially lined with clay, bentonite, plastic, rubber, concrete, or other materials to prevent groundwater pollution. Imported linings will increase construction costs significantly.

When preparing a site for an oxidation pond all organic material should be stripped from the pond area. The subgrade is then compacted, any soft spots filled; embankments formed, along with inlet and outlet pipework; the base and sides sealed, if the soil used for construction is not fine enough to keep the rate of seepage suitably low, and the wavebands and tracks constructed.

In cases where the ground water table can rise above pond floor level the pond must be filled as quickly as is practicable and must be kept full to prevent the sealing layer from being lifted.

2.8 Inlet structures

The placement of the inlet pipe position, especially in relation to the outlet, predominant wind direction and pond baffling, will have a big impact on treatment efficiency in ponds.

Fig 9: Modifications to pond inlet – to provide jet attachment to the embankment wall

The recommended design for pond inlets used to involve taking the pipes well out from the embankments on piers. Shilton, (2003), discusses this and recommends for primary and secondary ponds, using a horizontal flow inlet where the inlet flow is directed along an embankment and is then deflected using stub baffles. Shilton argues the horizontal inlet provides momentum to move the solids deposits when the flow enters the pond, and the “attachment” of the flow to an embankment wall and subsequent deflection with stub baffles dissipates this energy in a controlled manner (which should be used to minimise short circuiting). For tertiary ponds with no settleable solids in the incoming flow, Shilton recommends more rapid dissipation of the inlet flow using a manifold or vertical jet in a corner with stub baffles each side.

Figure 9, shows how a primary pond inlet which previously discharged into the centre of the pond, has been modified to flow along the pond embankment. In this case, the flow then passes to a surface aerator rather than a baffle.

2.9 Transfer structures

Pond to pond transfer structures should be kept as simple as possible. In many cases a pipe through the pond embankment at mid-depth is all that is required. Where it is necessary to control the depths of each pond independently a weir box can be set in the pond embankment. If the transfer draw-off is at pond surface level it should be baffled to prevent floating debris from passing out of the pond.

With the growing use of pond buffer storage as part of a treatment and disposal system, transfer structures may also be restricted, to allow a fixed discharge rate between ponds. Fig 10 below shows such a system in use between a secondary and tertiary pond.

Here, the small slot in the outlet chamber allows only a constant flow to pass with any excess creating a build up in pond level. If storm flows occur, then the flow passes through the top of the chamber as it did prior to modification. At this plant, pond levels have been dropped to 800mm depth leading into the summer (no discharge) period, to allow for extra buffer storage. This depth reduction has not created any problems.

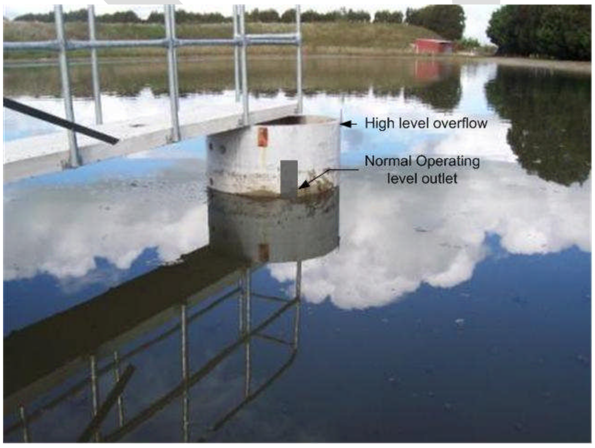


Fig 10: Transfer structure between secondary and tertiary ponds – allowing fixed outlet flows until pond is full

2.10 Outlet structures

Outlets should be placed out of the main flow path of the incoming wastewater. Final outlet positioning can be selected after the inlet position/type and pond baffling has been designed.

Typically outlets have been either been from top water level, surrounded by a scum baffle, or through a submerged pipe located approx 500mm below top water level, and feeding into a weir box. Outlet weir boxes for larger pond systems should have facilities to allow the ponds to be completely drained.

The use of screw-down penstocks should be avoided where possible. Ingress of grit to penstock seating has caused leakages. Where penstocks are used the screw threads should be covered with protective tape to minimize corrosion.

Outlet and transfer structures should always be sited on the upwind side of the ponds, in prevailing conditions, to keep them clear of floating debris and to reduce the likelihood of short-circuiting. Fig 11 shows a baffled outlet structure to prevent short circuiting currents passing along the embankments , from flowing straight into the outlet. In this case, gabion baskets were used to create the baffles.

Fig 11: Outlet baffling using gabion baskets – outlet is between two stub baffles

2.11 Filling

Ponds should be completely filled and maintained at operating level as soon after construction as is possible. Rapid filling prevents the establishment of weeds.

Ponds that are allowed to fill slowly generally suffer bank erosion until the liquid level rises above the wave band. Some slow filling ponds have become anaerobic, accumulating large areas of floating solids, because of the build-up of heavy concentrations of organic matter in limited volumes of liquid.

2.12 Flows

In most cases the ability to accurately measure pond inflow is important. It provides information on the condition of the sewerage system as well as information for future design purposes and consents. Flow measurement of raw sewage usually involves a control device, such as a flume, which causes the flow to act in such a way that measurement of upstream depth can be used to calculate the flow rate. The increased upstream depth created by the flume can also be used to advantage when screens are installed on the inlet flow channel.

Measurement of the pond effluent flow rate is easier and has more bearing on the effect of the discharge on receiving waters. Effluent measurements do not usually agree with influent measurements as seepage and evaporation losses occur. A simple V notch weir is often used for pond effluent flow rate measurement. As with a flume, the application of a formula to the upstream depth measurement allows calculation of the flow rate.

Any flow measuring device, however, should be regularly checked and calibrated. In far too many cases such checking has found that highly inaccurate measurements have been made, often due to; incorrect formulae being used , older control devices – (weirs or flumes), being too small for current flows, or poor or non calibration of depth measurement devices.

Fig 12: V notch weir with ultrasonic depth measurement on pond effluent

Terminal pumping stations should be fitted with "hours run" meters. This applies particularly to small pond systems where other means of flow measurement may not be necessary.

2.13 Recording

Most pond monitoring equipment comes with outputs for recording and data logging of critical information (like pond inflow rates and DO measurements). One option is for the data to be manually entered during a site visit or, alternatively, it can be automatically logged onto a data logger or sent electronically through a telemetry system to be logged at a base station.

Many discharge consents for pond systems now require automatic measurement and logging of key parameters such as; flow, temperature, and dissolved oxygen. Telemetry systems are also becoming more common for ponds. Both automatic measurement and telemetry are desirable if there is the possibility of the ponds requiring rapid intervention in response to low oxygen levels for example.

2.14 Seasonal variations

Oxidation ponds will experience seasonal loading variations due to local weather conditions, rainfall intensity and stormwater infiltration. Some ponds will also have to cope with variable loading from holiday populations or seasonal industry. Most ponds need more frequent checking in the spring and summer when grass and weeds grow quickly and when seasonal properties are occupied causing a higher loading.

In colder climates the rate of biological activity during winter will be slower and could cause a reduction in pond performance. The pond operating level may need to be increased to help increase the operating temperature for the pond organisms.

Pond life varies seasonally, with cyanobacteria, (commonly known as blue-green algal) blooms occurring in many ponds during peak summer temperatures. With the recently increased recognition of the possible impacts of blue-green algae and algal toxins on people, stock, and the environment. This is an important aspect of pond discharges to surface waters.

2.15 Fencing

Fences are essential to keep livestock out of pond areas and to deter public access. The large areas of land usually involved, tend to make climb-proof fencing expensive, although from a health and safety perspective, its use is desirable. In many cases, the "front entrance" to ponds is security fenced in this manner, with the "back door" being left at stock proof fencing. Normal 7 or 8 wire stock-proof fences are usually all that is provided.

Fencing can be erected on top of the pond embankment immediately above the wave slab. This approach lessens the amount of land to be kept tidy but makes maintenance work such as the removal of floating debris and repairing erosion more difficult.

A second approach is to erect the fence so as to leave an access way around the top of the pond embankment. Pasture growth between the edge of the pond and the fence must be controlled by mowing or by grazing. If grazing is practiced, a supply of drinking water must be supplied for the stock. Alternatively the area can be 'mob stocked' to clean off all pasture growth in a day or so.

2.16 Road access

The main access way to the ponds should be an all-weather vehicle track. The access way around the pond embankment need not be an all-weather track since maintenance work can be planned in relation to weather conditions, but it should ideally have a firm base.

2.17 Warning notices

Notices warning the public that access to the pond area is prohibited should be placed so that any person approaching from any direction can see at least one notice.

Signs should make it clear that no public access is allowed to pond areas and that there are water and disease hazards with ponds. Where pond discharges flow to a receiving water, it is also becoming common for signs to warn the public of disease risks from contact with affected zones of the receiving water. An example of the wording used in an outfall to river sign is shown in Figure 13 below.

Fig 13: Typical outfall signing

2.18 Operator accommodation

It is usually desirable to provide a building in which the operator can store equipment, carry out routine tests, keep plant records and wash after attending the ponds. The size of the building should be related to the size of the ponds and to the monitoring requirements. Provision of a suitable water supply is often a problem but this can be overcome by; collection, tank storage and treatment of roof runoff water.

2.19 Allowance for population growth

Ponds should not be designed for more than a 25% increase of the population at the time of construction, except where there is good evidence that a very high rate of growth or loading will occur.

In the past, a number of ponds have been oversized and, because of evaporation and seepage, have never filled. In some cases this problem has been accentuated by the use of temporary fences for dividing a raw sewage section from a tertiary section. This practice simply increases the pond areas to be filled simultaneously. Raw sewage and tertiary ponds should be completely separate units.

Measurements taken at several pond systems have shown that seepage and evaporation losses are of the order of 100-150 m3/ha day during the summer months. To illustrate the effect of this order of pond water loss, consider the following calculations:

Raw sewage pond area required for a design population of 5000 people.

Area = 5,000 people / 1,200 people/ha = 4.2 ha

Daily inflow from present population of 4,000 (at 250 litres/head day) = 1,000 m3/day.

Losses due to seepage and evaporation

= 4.2ha x 150m3/ha/day = 630 m3/day.

Therefore during the summer periods more than half the inflow to the raw sewage pond is lost by seepage and evaporation.

If a large, (20 day detention), tertiary treatment pond were included in the system a further 2 ha of pond surface area would be required to provide an additional 20 days' retention. Total loss due to evaporation and seepage would then be:

6.2ha x 150m3/ha/day = 930 m3/day.

Now the major portion of the pond daily inflow would be lost. Virtually a "nil discharge" condition would result.

It has been shown that the average open-water evaporation rate is between 650 and 800 mm per year in most areas where oxidation ponds are constructed in New Zealand. January monthly average open-water evaporation is generally between 100 and 225 mm in these areas (Finklestein, 1973). The effect of such losses must not be ignored when a pond system is designed.

The build-up of heavy concentrations of organic material and the lack of natural "flushing" of algae can result in the development of excessively large algal crops and in a reduction of the quantity of oxygen that can be dissolved into the pond liquid. Under these conditions night time algal respiration may absorb much of the pond's dissolved oxygen and the pond could become anaerobic. It is therefore important to ensure that ponds are not over-sized. It is also under such conditions that blue-green algal blooms often form with the resulting potential problem of algal toxins.

3. Operation and Maintenance

3.1 General

Frequency of inspection and maintenance work should be related to the size of the pond system and the requirements of the monitoring program for the discharge consent. Even the smallest of ponds should be visited at least once a week. Record sheets of pond operation must be filled in regularly to maintain a full summary of pond operational history. An example record sheet is given in section 9 of these Guidelines.

Systems with more than one pond operated in parallel or series may need operators to check and adjust flow levels or divert flows to and from certain ponds to optimize performance.

Most inspections/visits should include brief checks of the banks, channels, grounds around the ponds, inlet and outlet structures, pond appearance, level, monitoring for dissolved oxygen, pH, temperature and odour (if any). Records should be kept of every visit and all observations, including information about the weather or other factors that may be influencing pond conditions. More extended inspections and formal sampling and testing are also periodically necessary.

A simple and useful indicator of pond operation is the dissolved oxygen, (DO), level in the pond liquor. The system must remain aerobic during daylight hours, from 10 am say, until night time. Note that DO content varies through the day and even hourly; to obtain meaningful information, sampling times and locations must be standardised and any low values should be considered in the context of what has happened before and after, time of day etc. A good indication of daytime DO is gained from readings taken between 11:00 and 14:00 hours.

To maintain facultative conditions there must also be an algal community in the surface layer. A useful indicator of the number of algae present is the chlorophyll-a concentration. Pearson (1996) suggested that to ensure stable facultative conditions, a minimum in-pond chlorophyll-a concentration of 300 µg/l was required. To measure chlorophyll-a, take a fresh sample from the top waters (say 300mm below the surface), into a clean container and despatch to an analytical laboratory.

A simpler test for the level of algae present is the “stone test”. This involves picking up a rock, throwing it into the pond, and observing the colour of the resulting splashed water. Although hardly scientific, this is easy to do, and is often a very good rough indicator of pond conditions. A bright rich green colour indicates that the pond is in good condition and that there are plenty of algae present. A dull green, turquoise blue or yellowish colour could mean that a less desirable type of algae is becoming dominant in the pond. A grey, brown or black colour often indicates there are not enough algae present. In calm weather and high loadings, the test may reveal a green layer over black depths. This is a bad sign and can mean the pond is about to crash. Red colouring can com from extensive growths of Daphnia or Moina, especially on under loaded ponds. These will generally recede to normal levels in a matter of days and do not seem to cause any problems.

With regular inspections, testing, and record keeping, operators become familiar with the natural cycles and in particular requirements of the system, as well as what factors tend to influence its performance.

Floating debris should be periodically removed from the pond surface (This work is best carried out when wind action concentrates floating material into a corner of the pond). Sump suckers, (vacuum trucks), are often used for this purpose. All pond structures, including inlet, outlet and transfer boxes, should be kept clean and free from growths.

Debris washed up onto the wave band must be removed. The wave bands should be brushed or water blasted regularly to discourage slime growths. Pond banks must be checked regularly and any erosion must be repaired immediately. Perimeter fences must be checked and kept in good repair. Warning signs must be maintained in good condition.

Floating weeds can become a nuisance for oxidation ponds as they have the potential to block out sunlight which is needed for algal photosynthesis. Removal should be in early summer before these weeds become too well established. It is very important to ensure that pond embankments are kept free of excess weed growth. Clumps of weeds can harbour insect life and may dangle into the pond, trapping floating debris and causing odour problems. Spraying of weeds should be with appropriate sprays approved for use around water courses.

Buildings at the pond site should be maintained at a good standard.

The point of discharge of pond effluent to the receiving water must be inspected and cleared of weed growth to ensure free flow and rapid mixing of the discharge.

Electrical and mechanical equipment such as aerators and flow recorders need to be checked and serviced as per the manufacturer’s recommendations. Aerators require daily greasing if not provided with an automatic greaser. In any case, it is advisable to check aerators daily.

3.2 Sampling and analysis

Samples should always be collected from the same point or location. Raw wastewater samples for pond influent tests may be collected either at the wet well of the influent pumping station or at the inlet control structure. Samples of pond effluent should be collected from the outlet control structure or from a well mixed point in the outfall channel. When outlet pipes are not accessible, effluent samples can be taken from within the pond, near the outlet. These, should be collected from a point 2 meters out from the pond edge and 300mm below the surface. When sampling, care should be taken not to stir up sludge from the pond bottom. Try to avoid collecting samples during or immediately after high winds or storm events because solids will be stirred up after such activity.

Probably the most important sampling that can be accomplished easily by an operator is routine pH, temperature, and dissolved oxygen (DO) tests several times a week, and occasionally during the night. These values should be recorded because they will serve as a valuable record of performance. The time of day should be varied occasionally for the tests so that the operator becomes familiar with the pond's characteristics at various times of the day. Usually the pH and DO will be the lowest at sunrise. Both will get progressively higher as the day goes on, reaching their highest level in late afternoon.

A record of samples collected should be kept and include location, time, date, person sampling and a unique code number. This information should also be included on the label of each bottle (there may be more than one bottle needed for each sampling site).

The laboratory will usually provide the correct bottles (with any necessary preservatives), chain of custody sheets and sometimes an outer pack (e.g. chilli bin). It is usual to pack chilli pads or ice around the samples when transporting samples either locally or to a remote laboratory via courier. Samples must arrive at the laboratory as soon as possible so the quickest transport method should be used which may be overnight courier.

Generally consent conditions that require laboratory testing, specify that this be done at an accredited laboratory.

A useful sampling tool is the "sludge judge". This is a clear tube, with a non return valve in the base, which allows a stratified sample to be taken through the water and sludge layer.

3.3 Plants and vermin

Plant and vermin control is an important part of good house keeping for oxidation ponds. Weeds around the edge of the pond are the most objectionable because they allow a sheltered area for mosquito breeding and scum accumulation. Weeds can also hinder air circulation on a pond. Some weeds will grow in depths shallower than 1 metre so an operating level of at least this depth is necessary. Weeds (including roots) are best pulled out by hand or sprayed as soon as they emerge and before any germinate, become established and damage the embankments.

Any rat and rabbit infestation must be controlled, (rat and rabbit burrows can damage pond embankments). These vermin can be removed by a number of methods including poisoning and trapping. Care should be taken not to leave raw screenings lying around so as not to create a food source for vermin.

3.4 Odour control

Many NZ ponds will experience odour problems at some stage during their life. Odours are usually caused by overloading the pond, a temporary biological imbalance, such as an algal bloom, or poor housekeeping practices and can be remedied by taking corrective measures. During high loading, when the entire dissolved oxygen has been used up, odours are produced because the aerobic layer no longer exists at the top of the pond.

Oxygen levels in ponds are affected by water temperature. This is for several reasons; colder water is able to hold more dissolved oxygen before it is saturated, but warmer water temperatures will speed up the rate of decomposition of waste and promote the growth of organisms in the pond, including algae, which add oxygen by photosynthesis. Figure 14 below shows how oxygen levels and temperature relate for a specific (non-mechanically aerated) oxidation pond.

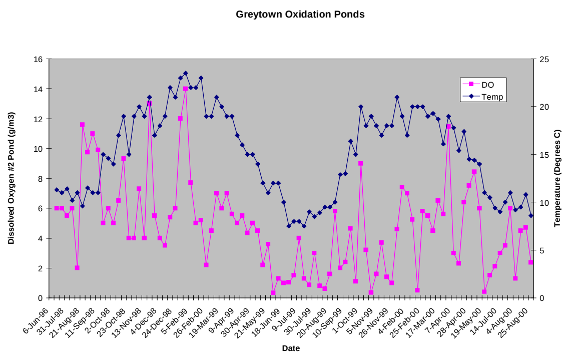


Fig 14: Seasonal dissolved oxygen and temperature variability

There are several ways to reduce odours in ponds. These include; recirculation of supernatant from aerobic ponds, the use of floating aerators, a rake or long poles can be used to break up floating mats, a boat with outboard motor can be used to add oxygen, as can a land based air compressor with a drilled pipe to produce air bubbles within the pond.

3.5 Crash prevention

Ponds develop their own unique biological community which varies with time. Apparently identical adjacent ponds receiving the same influent in the same volume often have a different pH and a different dissolved oxygen content at any given time. One pond may generate considerable scum while the neighbour doesn't have any scum. For this reason, each pond should be routinely tested for pH and DO. Such testing may indicate an unequal loading because of the internal clogging of influent or transfer pipes that might not be apparent from visual inspections.

Tests may also indicate differences or problems that are being created by buildup of solids or solids recycling. pH and DO samples are usually collected at the outlet side of the pond unless a complete profile is being done.

If it is suspected that the pond is going to "crash" ie, go anaerobic throughout it's full depth, or this has already occurred, then a full inspection of the pond should be immediately undertaken to assess the pond's condition and suspected reasons for the pond's deterioration.

Some of the most common reasons for the pond "crashing" are:

Event	Cause	Remedial Action
Low Oxygen	High strength waste	Remove waste, reduce waste influent strength by pre-treatment, or add aeration
	Aerator failure	Reinstate aeration
	Poor mixing	Modify inlet and baffling, possibly install mixers
	Decay of algal bloom	Temporarily aerate with outboard motor
Sludge Belching	Excessive sludge depth	Spread or remove sludge
Overturn	Anaerobic and sludge layers move to surface	Aeration or sodium nitrate dosing, (note there are concerns about the effectiveness and health and safety issues with sodium nitrate dosing).
Death of Pond Biomass	Toxin in influent	Identify and neutralize toxin, identify source and remove

Table 2: Remedies for pond crashing

3.6 Desludging

When oxidation ponds were first introduced in New Zealand, it was thought by many that they would never have to be desludged. This has proved incorrect. Even though some ponds have been operating for 25 years or more without having to be desludged, many of these are now suffering from excessive sludge depths. These ponds are producing poor effluent quality partly due to excessive sludge being resuspended and then washed towards the outlet. The increased sludge volume will also reduce the pond's working depth and retention time, causing a further reduction of effluent quality.

Sludge storage in ponds is continuous with small amounts being stored during warm weather and large amounts when it is cold. At colder temperatures, below about 15 degrees C, the bacteria are not active enough to break down the stored sludge. As a general rule, sludge depth in a pond should not be deeper than 600 mm in isolated pockets or 500 mm, or one third of the ponds depth, which ever is greater, as an average depth in the pond.

Ideally, the pond's sludge profile should be measured annually to gain an appreciation of the fill rate and pond's projected life expectancy before desludging is required. If this is done, the cost of desludging required can be budgeted for in advance. In some cases, desludging can be delayed by directing unnecessary solids loads, such as septic tank clean out wastes, to other points of disposal such as dedicated septage dewatering facilities. Sludge depth measurement to the top of the sludge layer can be made with a simple tool as shown below.

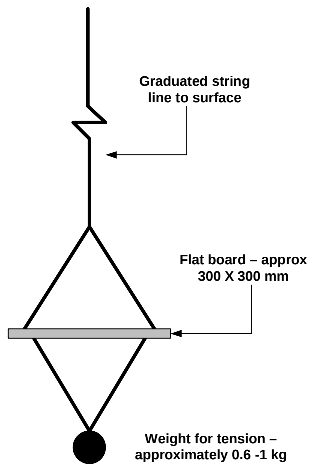


Fig 15: Sludge depth measuring tool

Measurement of the bottom of the sludge layer can be made with a rod with graduations on it. Accessing the pond is best by boat (as opposed to wading), however, health and safety issues need to be well addressed.

There are a number of proven methods to remove the sludge from an oxidation pond. In NZ the most commonly used methods are;

- If the pond can be taken "off line" an option is to drain the pond level down to the sludge layer. Then dewater the sludge using wind and sunlight. (This is best done in the summer time). It is possible to dry the sludge to 50% dry solids content. At this level, the sludge can be removed by excavators and trucks.

- A temporary partition can also be made and the pond desludged into this, as was done at Inglewood. Once dewatered, the sludge can be removed using a digger or bobcat (care should be taken not to damage the pond floor or embankment with heavy machinery).

-Install a dredge on the pond to suck up the sludge and pump it to either a dewatering vessel (like a Geotube), an evaporation tank/pond, or dewater on site using a mechanical plant such as a centrifuge or press.

Because the mechanical dewatering methods involve equipment hire, polymer and power, and the dewatered sludge may be 15-25% dry solids, (meaning higher cartage costs), it can be more cost effective to construct a new pond if space allows, and dewater the pond by drainage and evaporation.

Fig 16: Sludge dredge at work on oxidation pond

The Geotube works by filling a permeable geotextile bag with sludge which allows filtered water to drain through small pores in the geotextile. This filtered water can be redirected back into the oxidation pond for further treatment. The remaining sludge is trapped in the Geotube bladder and over time the sludge volume is reduced. This system allows repeated 'topping up' of the Geotube (so that one tube can be used over an extended period). When the final cycle of filling and dewatering has been completed, the bag is left for consolidation. Dewatering levels reported are up to the mid 20 % dry solids for initial fast cycles, and up to high 30% for final consolidation.

The advantages of this product are that you can dewater onsite without interrupting the oxidation pond process, and all decanted water is trapped and returned to the pond. The bags are relatively small and light (when empty) and take up a small footprint while on site.

Fig 16: Geotube pod being filled with pond sludge

Oxidation pond sludges, because they contain a small proportion of fresh settled material, represent a bio hazard. They also normally contain significant levels of heavy metals which may influence their disposal. They cannot be classified as Biosolids under the Biosolids Guidelines (NZWWAssn 2003), without testing, evaluation and usually, further processing.

When ponds are being desludged, care must be taken that any lining on the base is not removed or damaged.

3.7 Blue green algae

Blue-green algae, (more correctly known as cyanobacteria), are naturally occurring organisms in most freshwater environments. They occur as single microscopic cells or in colonies that form slimy strands visible to the naked eye. Blue green algae are of concern both in the oxidation pond and in any water body which receives the pond effluent.

Nutrients from oxidation pond effluent can also encourage the growth of blue-green algae in the receiving water. The process of nutrient enrichment in a waterway is called eutrophication. The main nutrients contributing to eutrophication are phosphorus and nitrogen. When conditions are favourable, blue-green algae populations can 'bloom', multiplying at such a rate that they dominate the local aquatic environment. At this point, problems for other organisms start to occur. The water becomes malodorous and a bright green scum may appear on the surface. Some species of blue-green algae produce toxins which are dangerous, sometimes fatal to livestock, wildlife, marine animals and humans.

The decomposition of dead blue-green algal cells by bacteria consumes oxygen. When billions of such cells die during a bloom, the water becomes oxygen-depleted. This can lead to the death of other marine organisms, including fish, which need oxygen to survive.

In ponds, blue green algal control is sometimes possible by; modifying pond loading, use of temporary mixers and aerators, or dosing an algaecide such as copper sulphate. Often however, a rampant bloom will remain until colder weather conditions occur. Care must be taken when considering the use of an algaecide as death of the cyanobacteria can result in high levels of toxin release.

Under bloom conditions, it may be necessary to test for algal species and the presence of toxins, especially where the pond discharges into sensitive receiving waters.

3.8 Embankment erosion

The action of waves, especially in larger ponds with high levels of wind exposure, can, over time, cause significant erosion to the internal pond embankments, even when they are protected by wave bands. Waves can overtop wave bands saturating the soil behind and the pounding action can then weaken the saturated soil, causing it to slump. This problem has been addressed by using cast in-situ wave bands, with the footing located at the top rather than at the bottom, refer figure 18.

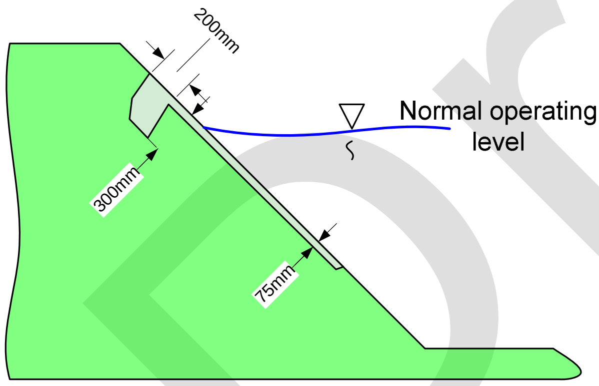


Fig 18: Recommended concrete wave band construction details

Alternatively, rock on geotextile can be used, preferably over the full slope with a toe of rock at the base.

3.9 Livestock

Cattle should not be permitted to graze around pond embankments. The cysts of the beef tapeworm (taenia saginata), which is parasitic to man and causes beef measles in cattle, can be transferred to cattle from domestic sewage. Grazing by cattle can also result in erosion of pond embankments through hoof damage.

There are no restrictions on grazing by sheep and goats, although it would be prudent to place these animals onto clean pasture for several weeks before culling.

3.10 Saltwater entry to ponds

Saltwater must be prevented from entering ponds and sewerage systems serving ponds. Combinations of sewage and saltwater which contain more than 5% saltwater cause sulphates to break down to sulphides, releasing hydrogen sulphide. Where ponds are constructed in salty areas on coastal land the top layers of salty soil should be stripped from the pond site.

Salt water can also be contained in some industrial discharges such as from ion exchange water treatment systems and may occur in wastewater reticulated in coastal areas due to infiltration.

3.11 Flies, fish and birds

There is a popular theory that pond insects are a source of nuisance and that insect-eating fish should be introduced to control their numbers. In fact, properly loaded ponds do not have insect problems. Such problems have only been experienced in the early lives of one or two initially under loaded ponds, or following pond decommissioning. Fish have no effect on controlling nuisance levels of midge and should not be introduced without prior consultation with DOC, because of the possibility of them spreading to the receiving environment. Birds on the other hand, especially swallows, can keep fly and midge numbers down.

4. Upgrades and Improvements

4.1 Screening

Manually cleaned bar screens with 20-50mm gaps used to be the standard screening arrangements. These however, required regular cleaning and still allowed a lot of solids to pass. There are now a number of different automatic screens available for removing solids from raw sewage. These include step screens, drum screens and bar screens.

Fig 19: Step screen and press.

Modern screens are also becoming much finer, typically with apertures around 3-6mm and with jets to break up faecal material from the screenings. They also typically incorporate automatic presses which dewater the screenings and discharge them to sealed plastic bags; figure 19 shows a step screen and press, a popular screening option for raw wastewater.

4.2 In Pond

4.2.1 Retention times

Any pond treatment system works best with even flow to encourage the rapid and continuous growth of bacteria involved in the biological breakdown of the wastewater. It is essential that the daily loading into the ponds is kept to the design standards of the pond system. A very large load may flush out important bacteria, eventually leading to system failure. Variation in loads will alter the retention time. Any extension of the time that the wastewater remains within the pond system will increase the disease-causing microorganism die-off. The concentration of microorganisms within the effluent will be reduced and the effluent will be of higher quality before discharge into a waterway.

4.2.2 Recirculation

Whilst mechanical recirculation of pond liquor has been attempted in this country and overseas, the limited amount of reliable data available gives little theoretical or practical support to the process. Only in one case in New Zealand where a strong sewage is treated in very large ponds has the process proved beneficial in rapidly diluting and distributing the sewage into the body of ponds. Recirculation by simple pumping has proved successful in alleviating odour and weed growth problems in small badly sited ponds, where there is insufficient wind action to provide natural mixing.

Some aerators, however, provide a strong directional current, and these can be used to improve pond mixing.

4.2.3 Baffling

Shilton and Harrison (2003) have undertaken extensive research into pond hydraulics. In this work they suggest that baffling of oxidation ponds can produce significant improvements in effluent quality and make the following recommendations:

- A minimum of 2 baffles and maximum of 4 is recommended.
- Even baffle spacing across the pond is the most effective configuration.
- Short stub baffles can be as effective as much longer baffles.
- Baffles are useful as an outlet shield.

Baffles can be made from a variety of materials; tipped rock, gabion baskets, or plastic sheets with weights and floats fitted. To be effective they do not have to be totally impermeable, just sufficient to stop high speed currents.

4.2.4 Rock filters

A rock filter operates by allowing the wastewater to travel through a submerged porous rock bed, causing algae to settle out on the rock surfaces as the liquid flows through the void spaces. The accumulated algae are then biologically degraded. The principal advantages of rock filters are their relatively low construction cost and simple operation. Odour problems can occur and the design life for the filters and the cleaning procedures have not been firmly established. However, several units have operated successfully for years.

Rock filters have shown to be a low cost method that can be added to pond systems with good results.

4.2.5 Rock groynes

Rock groynes have become a very quick and simple option to baffle one pond into multiple compartments in series. The compartments use a rock filter as a baffle which helps to filter out algae and may promote nitrification and de-nitrification to remove nitrogen. There is limited but growing experience with this system in NZ to date. Plants which have been upgraded in this way have almost all achieved reductions in pathogens and some have achieved more stable suspended solids and nitrogen removal. However ammonia removal (nitrification) in winter is still unreliable. Some rock groynes have also clogged.

One to two years operation is required to achieve full performance.

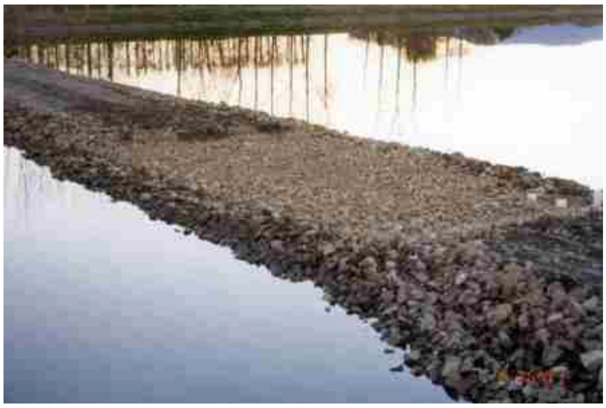


Fig 20: Rock groyne, partitioning tertiary (maturation), oxidation pond

4.3 Aerators (types and positioning)

Oxidation ponds rely on wind action to introduce much of the required oxygen to the pond liquid and to develop flow patterns and mixing within the pond. Artificial aeration may be necessary when the pond is overloaded or during long calm wind periods. Care with aerator location can also help to improve mixing and reduce short-circuiting.

Mixing is important as non-motile algae tend to sink to the pond floor, and it is important that they are returned to the surface to be in the effective zone of light penetration.

4.3.1 Mechanical aerators

Motor driven, mechanical aerators provide a combination of liquid aeration and mixing.

Mechanical aerators can be classified as; impellor type aerators, which disturb the water and bring it into contact with air, and aspirator type aerators which pass air through the water. Mechanical aerators can be further classified based on whether the axis for the impellor is horizontal or vertical and whether the impellor is geared or rotates at the motor speed.

Figure 21 shows a typical vertical shaft surface aerator. The impellor sucks water up through the draft tube and sprays it out in a circular pattern radiating out from the aerator. These are usually direct drive from the motor to the impellor, and are therefore less expensive than aerators involving gearboxes. Some designers prefer caged rotor or aspirator type aerators to the vertical shaft type, as they are reported to give better oxygen transfer rates for the power used, are able to provide directional currents which can be directed to enhance mixing and reduce short circuiting, and do not entrain as much bottom sludge.

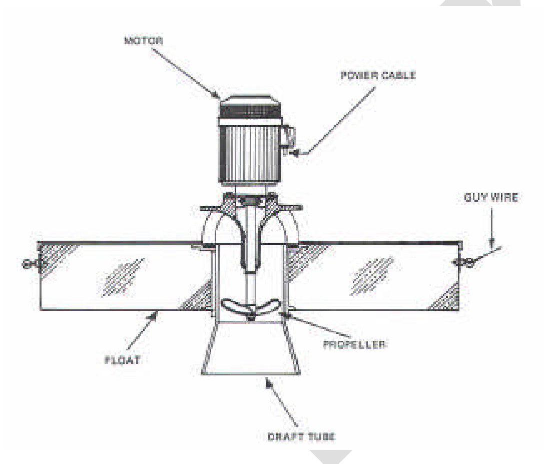


Fig 21: Vertical axis surface aerator

A very rough rule of thumb for aerator sizing is that 1 kW of installed aerator capacity will add 1 kg of oxygen per hour to be pond water. For example, a 1 Ha pond is loaded at 150kg/day BOD. The additional aeration required is therefore approximately (150-84)/24 or 3kW.

Aerators can be operated on timers, manually controlled, or automatically controlled utilising DO meters to switch them on and off. Continuous aeration can assist with pond nitrification, (the oxidation of ammonia to nitrate), thus reducing the impact of the pond effluent on aquatic organisms in the receiving waters.

Fig 22: Horizontal axis caged rotor aerator

4.3.2 Diffused aeration

Coarse bubble systems are useful for providing short term aeration in pond systems, especially in small ponds. Such systems use an air blower located on the pond embankment or within a building, feeding air into a drilled pipe placed into the pond.

The aeration pipe may be located on piers used to carry the inlet pipeline, or weighted and suspended from floats or cables. They should be placed below the surface but kept high enough so as not to disturb the lower layers.

There is also some limited use of fine bubble aeration. Figure 23 shows a multi celled pond system with fine bubble aeration and suspended sessil media.

Fig 23: Membrane fine bubble aeration.

4.4 Post treatment

4.4.1 Wetlands

The use of constructed wetlands in NZ has increased steadily since the 1980's and currently there are more than 80 non-agricultural wetland wastewater treatment systems in NZ, (Tanner C 2002). Constructed wetlands can supplement pond treatment systems, providing advanced secondary/tertiary treatment and polishing. Wetlands are also considered to be a practical means of addressing cultural issues and spiritual values for Maori.

Constructed wetlands in NZ can be most simply subdivided into two categories: Surface flow where wastewater flows through a shallow bed planted with emergent aquatic plants, and subsurface-flow wetlands where wastewater flows through planted gravel-filled beds.

Figure 24 shows a surface flow wetland treating oxidation pond effluent at Kaiwaka, Northland, (photo courtesy C Tanner, NIWA).

Figure 24: Surface flow wetland

Constructed wetlands can effectively reduce and stabilise SS and BOD concentrations in pond discharges. Faecal bacteria levels can commonly be reduced by around 1 log unit or more, but inputs from wildlife generally preclude achievement of E. coli levels below ~300-500 cfu/100 mls. Properly designed and sized wetlands can also reduce nitrogen levels in pond discharges.

4.4.2 Disinfection

Multiple tertiary ponds in series are able to provide good reduction in pathogens and indicator organisms down to levels often associated with disinfection processes.

Disinfection of effluents which are treated through pond systems is quite common and could theoretically be achieved using chlorine, UV light, or ozone. In practice, however, only multiple ponds in series with and without UV are used in NZ.

Chlorination has been used historically in wastewater disinfection in NZ due to its simplicity and long term history of effectiveness. It has however, fallen into disuse because of concerns with environmental effects of chlorinated organics and residual chlorine, and operational costs compared to alternatives such as UV. Because residual chlorine is toxic to aquatic species, an effluent dosed with adequate chlorine concentration to kill most microbes should be chemically de-chlorinated, adding to the complexity and cost of treatment.

UV Light is becoming the most common means of disinfection of wastewater effluents in NZ. UV treatment systems use high intensity lamps that are submerged in the wastewater or have lamps that are surrounded by tubes that carry the wastewater. Disinfection occurs when the ultraviolet light damages the genetic material of the bacterial or viral cell walls so that replication can no longer occur. Care must be taken to keep the surface of the lamps clean because surface deposits can shield the microbes from the radiation, thus reducing the performance of the system. Lamp fouling can be addressed by auto wiping mechanisms, but the transmittance of the wastewater must be above 20% for UV to be an effective disinfectant. Although there is some correlation between transmittance and suspended solids, this has been found to be quite variable between different ponds and specific monitoring for transmittance or pilot trailing of UV plants is recommended. As a general rule, pond effluents require additional treatment, (multiple tertiary ponds, wetlands, etc), before UV light becomes effective. Such a system is shown in figure 25.

Fig 25: Pressure UV system treating effluent with two stage ponds, surface flow wetlands, and irrigation filter pre-treatment.

Ozone is generated by passing oxygen (O_2) through a high voltage potential resulting in a third oxygen atom becoming attached and forming O_3. Ozone is very unstable and reactive and oxidizes any organic material it comes in contact with, destroying many disease-causing microorganisms, with the added bonus of removing other wastewater components such as colour. As with chlorination, there is currently no use of ozonation for pond effluents in NZ.

4.4.3 Land treatment

Land treatment of the pond effluent is becoming more and more common in NZ, especially in areas where discharging effluent directly to water bodies has become environmentally and culturally unacceptable. Most land treatment systems take the pond effluent, and then treat it to a better quality. Pre-treatment options usually include some sort of filtration (to remove or reduce the algal levels) and sometimes disinfection (to reduce the pathogen levels), before the effluent is discharged to land by; surface sprinklers, surface irrigation or subsurface irrigation.

All of the above land application options have been used with success but performance of land treatment systems depends greatly on the quantity and quality of effluent, and the amount and the type of land used. A good guide for further information and design of land treatment systems is the NZ Guidelines for Utilisation of Sewage Effluent on Land, (NZ Land Treatment Collective, 2000). As operational experience with different systems increases, issues such as long term performance in fine grained soils are becoming better evaluated.

Land treatment of pond effluent during summer low flow periods in the receiving water, can be a good option. This provides land treatment when the land is best able to receive the effluent, and discharge to river during the higher flow periods, when dilution and lower temperatures reduces the impact. Ponds are particularly suited for pre-treatment for land treatment systems because they can provide buffer storage to accommodate short term high inflows or periods when the land treatment system is not able to operate.

A test pit dug next to a subsurface drip line is shown in figure 26.

Fig 26: Subsurface drip line

4.4.4 Micro-filtration

Micro-filtration of oxidation pond effluent involves passing the flow through very fine holes in synthetic membranes which physically remove most particles and microbes. Currently only one pond system, at Dannevirke is being treated by micro-filtration. The Dannevirke system was installed in 2004 and is still undergoing commissioning. It is preceded by three oxidation ponds in series with the final pond divided in two parts to provide buffer storage. Although the effluent quality is very good, the installed cost of micro-filtration systems are at the top end for upgrade options.

Fig 27: Wastewater micro-filtration plant

4.4.5 Advanced pond systems

Advanced pond systems comprise 3-5 ponds in series, with each one specifically designed for a particular function. The different ponds typically comprise; a fermentation pond, a high rate algal pond, algal settling ponds, and a maturation pond.

NZ installations to date of high rate ponds for Municipal Wastewater treatment have been limited to pilot scale, but the concept appears to show promise of achieving high quality results.

Fig 28: Advanced pond system pond layout

4.4.6 Coagulation – sand filtration

Sand filtration, using filters and processes similar to water treatment plants is another effluent upgrade option. Sand filters without coagulant addition, (plain filtration), are not very effective on pond effluents. With coagulant addition, however, high quality results can be obtained, (refer section 8 for typical values). The filter backwash is discharged back to the pond system. NZ has such filtration plants at: Pauanui, Coromandel, and Omaha, in the Thames – Coromandel area. One of these uses a clarifier and sand filter, one a subsurface gravel wetland, and the third a tertiary pond, prior to the sand filters. Significant operating costs are involved due to the cost of coagulant.

Fig 29: Sand filtration plant. Tanks are flocculation, backwash storage, and filters.

5. Frequently Asked Questions

If you are using an electronic copy of these guidelines, holding down the control key plus a left mouse button click on any of the questions below will take you to the relevant section.

How often should I measure the sludge depth ?
My ponds have an odour problem !
Is the colour of the pond important ?
What are Blue-Green Algae?
How do I design a pond?
How do I build a pond?
What operational records should I keep?
What effluent quality should a pond produce ?
What effluent quality can an upgraded pond produce ?
How can I improve the discharge quality?
Can I treat the pond effluent with UV light?
I'm confused by the different names used to describe ponds.

6. References and Further Reading

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7. Web Sites

http://www.lagoonsonline.com

http://www.epa.gov

http://www.usace.army.mil

http://encyclopedia.laborlawtalk.com

8. Indicative Effluent Quality from Improved Pond Systems

Contaminant	BOD_5	SS	TN	NH3-N	TP	DRP	FC	E Coli
	g/m^3	g/m^3	g/m^3	g/m^3	g/m^3	g/m^3	cfu/100 ml	cfu/100 ml
Facultative (Primary) Pond	40	50	40	15	8	6	$20x\ 10^3$	$10x10^3$
Maturation (Tertiary), Pond	30	40	35	13	8	6	$10x10^3$	$5x10^3$
Multiple Maturation (Tertiary), Ponds in Series	30	40	25	10	8	6	2×10^3	1×10^3
Micro-Filtration	5	1	5	10	4	2	1	1
Rock Groynes	30	35	30	10	8	6	$5x10^3$	$2x10^3$
Coagulation and Sand Filtration	5	5	20	10	5	3	50	10
Wetlands	15	15	25	5	6	4	$5x10^3$	$2x10^3$
Wetlands and UV Light	15	15	25	5	6	4	200	100

Table 1: Typical effluent quality from pond improvements (median values)

9. Pond Record Sheet

		Pumps		Sewage Flow		Oxidation Ponds												
Day of month	Plant inspected	Meter Reading (Hr or KwH)		Pump Hours	Daily Flow (M3)	Time of Test	pH		Dissolved Oxygen		Temp of Ponds (°C)		Appearance of Ponds		Odour		Weather	Comments
		No. 1	No. 2				No. 1	No. 2	No. 1	No. 2	No. 1	No. 2	No. 1	No. 2	No. 1	No. 2		
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