CAN WASTE STABILISATION PONDS CHALLENGE ADVANCED BIOLOGICAL WASTEWATER TREATMENT PROCESES

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ABSTRACT

Waste stabilisation ponds are the most common wastewater treatment system in New Zealand. Pond systems for treating wastewater have existed for centuries

Wastewater treatment is coming under increasing scrutiny and pressure to improve water quality of the receiving water.

Coupled with the need for better disinfection and nutrient attenuation is the requirement for technologies to be sustainable.

Although considered old hat, pond systems still have much to offer in terms of modern day thinking about wastewater treatment and nutrient removal. They are cost effective to build, simple to operate and use little or no energy in their operation. They are an environmentally sustainable technology compared with other wastewater technologies, such as advanced biological wastewater treatment processes i.e. activated sludge.

Instead of investing in higher technology treatment, pond systems upgraded with floating treatment media (FTM commonly referred to as Floating Treatment Wetlands) technology can save hundreds of thousands of dollars in capital and operational costs, minimising the burden on ratepayers, yet still achieve high quality effluent normally associated with the advanced treatment processes.

FTM technology offers a unique alternative and environmentally sound process representing a highly technical development that uses and improves on, a naturally occurring phenomenon.

This technology enables us to ensure we can meet the business requirement for sustainable solutions.

KEYWORDS

Waste Stabilisation Pond, FTM Technology, Water Quality, Receiving Water, Better Disinfection, Nutrient Attenuation, Sustainable.

1 INTRODUCTION

Hunterville is a small town in the Rangitikei District located on SH1 about 40 kilometres north of Bulls. The town has a population of 450 people and is mainly a support town for the rural community in the area. The wastewater network comprises largely earthenware pipe installed around 1910.

Sewage from Hunterville is treated in primary and secondary oxidation ponds located between State Highway 1 and the Porewa Stream approximately 500 metres south of Hunterville. The ponds were commissioned in March 1978. Design and Constructional requirements of these ponds at the time were as per the Ministry of Works and Development, Guideline for the Design, Construction and operation of Oxidation Ponds. Raw sewage ponds were sized on a design loading of 84 kg BOD_5/ha day (i.e. 1,200 persons/ha). Secondary ponds (i.e. ponds which follow a suitable primary sedimentation process) were also be sized on a basis of 84 kg BOD_5/ha day

1.1 CONSENT STATUS

The Rangitikei District Council applied for a Discharge Permit to continue discharge treated sewage from the Hunterville oxidation ponds into the Porewa Stream for a term of 15 years at a rate of up to 175 cubic metres per day. On 25 November 1999 the Director, pursuant to delegated authority under Section 34 of the Resource Management Act 1991, granted Discharge Permit 7079, pursuant to Section 105 of the Act, to the Rangitikei District Council to discharge treated sewage from the Hunterville oxidation ponds into the Porewa Stream for a term expiring on 30 April 2007.

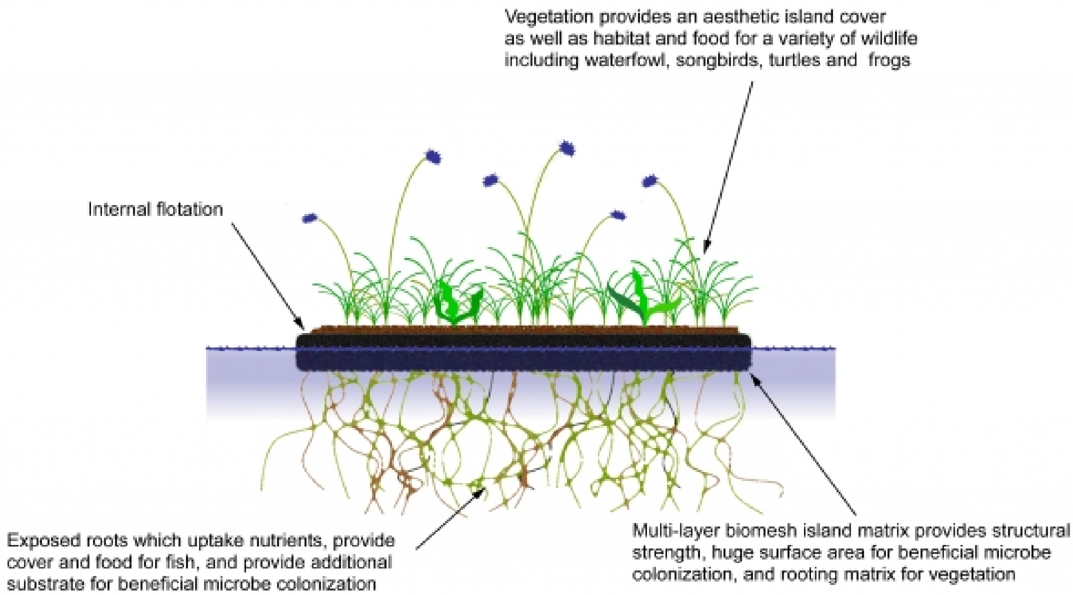
Horizons Regional Council's Investigation Officer(s) identified both localised and cumulative effects of the discharge and considered that adverse effects may be masked by the low upstream water quality. These Officers reported that the discharge causes a conspicuous change in the colour and clarity of the receiving water and significant increases in suspended solids, BOD_5 and dissolved reactive phosphorous at a distance of 50 metres downstream from the discharge point under low flow conditions.

The Investigation Officer(s) reported that the discharge does not presently comply with the water quality criteria in Section 107(1) of the Act.

2 FLOATING TREATMENT WETLANDS

2.1 OVERVIEW

Constructed wetlands are commonly used to cleanse water of pollutants. They work by exposing water to natural processes - microbial processes - facilitated by plants and organic matter. In order to expose as much water as possible to the beneficial activity of the wetland, they are created wide and shallow. This approach is natural and effective, but very costly in terms of the land required to create this shallow, wide tract. BioHavens act like a constructed wetland but with none of the land requirements. They represent a concentrated wetland effect. With the huge surface area presented by the individual matrix fibres, every 250 sq ft island equates to 1 acre of wetland surface. Whenever you launch a BioHaven you effectively launch a floating wetland. The water doesn't have to be shallow for the benefits to be realised - solar-powered pumps can be used to circulate water through the island to increase exposure to microbial activity. Floating Treatment Wetlands (FTWs) are a relatively new development. In a recent review of all the offerings on the market today, NIWA (the National Institute of Water and Atmospheric research, of New Zealand) identified BioHaven floating islands as the most innovative and advanced of all.



2.2 HOW A FLOATING TREATMENT WETLAND WORKS

This paper examines the potential of developing and applying a novel "floating treatment wetland" concept for the provision of enhanced wastewater treatment, particularly with regards to fine particulate removal. Constructed treatment wetlands have traditionally involved the use of free-floating aquatic plants, or sediment-rooted emergent wetland plants, either with water flowing through the root zone (subsurface flow) or amongst the stems (surface flow). Floating treatment wetlands (FTWs) are an innovative variant on these systems that employ rooted, emergent plants (similar to those used in surface and subsurface flow applications) growing as a floating mat on the surface of the water rather than rooted in the sediments. Because of this feature, floating treatment wetlands offer great promise for infiltration-driven wastewater treatment applications as they are little-affected by fluctuations in water levels that may submerse and adversely stress bottom-rooted plants.

Although not a very common type of wetland ecosystem, floating wetlands occur naturally in many parts of the world and offer some useful insights into the long-term function and operation of artificially created floating treatment wetlands. Natural floating wetlands typically consist of a 40- 60cm deep floating organic mat supporting plant growth, the upper portion of which is comprised of densely intertwined live, dead and decaying roots with some litter collection on the surface. Below the active root zone a layer of low-density decomposed peat and decaying plant detritus develops, the depth of which is usually dictated by the rooting depth of the plants. Beneath the peat layer a zone of relatively clear free-water exists, that varies in depth (0 – 2m) with the wetland water level. On the base of the wetland basin, beneath the free-water zone, a layer of organic sludge develops over the native subsurface material. Whereas attached wetlands can experience alternate periods of flooding and drying, the water level with respect to the vegetation in a floating wetland is effectively constant. The boundary between saturated and unsaturated soil remains constant, which minimises hydrologic factors as a source of variation in plant growth and other biogeochemical processes.

Since floating wetlands rarely experience inundation or flooding of the wetland surface, the natural floating substrates are typically characterised by being predominantly organic in origin, with very little mineral content. Self-buoyancy in natural floating wetlands is achieved via two main processes:

- Entrapment within the matrix of gases generated during anaerobic metabolism of organic deposits.
- Occurrence of air spaces within the living biomass, particularly the rhizomes, of particular vegetation.

Over the past two decades, artificially created floating wetlands have been studied in various parts of the world for a range of applications, such as water quality improvement, habitat creation, and aesthetic enhancement. Systems created for water quality improvement, termed Floating Treatment Wetlands (FTWs), have been used for the treatment of:

- Combined stormwater-sewer overflow
- Sewage
- Acid mine drainage
- Piggery effluent
- Poultry processing wastewater
- Water supply reservoirs.

Numerous techniques have been used for the creation of floating wetlands and a number of commercially available systems are available throughout Europe and North America. The most common approach to constructing floating wetlands is through the creation of a floating raft or frame supporting a mesh on which plants are grown. Coconut fibre or peat is often used as a growth medium. Buoyancy in such systems is generally achieved through the use of sealed sections of plastic pipe or tubing (PVC, PE, PP), sealed drums or polystyrene foam pontoons. A low cost method has been developed in India using naturally buoyant bamboo. A number of companies (e.g., Bestmann Green Systems, AGA Group) produce modular rafts (triangular or square) that can be readily joined together to form floating wetlands of various shapes and sizes. On a relatively large scale, Oceans Ark International have developed an approach (the "Restorer") for treating wastewater in lagoons that involves the use of multiple linear floating wetlands with synthetic textile curtains hanging beneath to provide additional substrate for biofilm attachment and to create a lengthy serpentine flow path. Fine bubble aerators are used throughout to increase dissolved oxygen concentrations and enhance mixing.

A second, rather elegant and well-developed approach to the construction of floating wetlands involves the use of a matrix with intrinsic buoyancy which itself serves to support the growth of the plants. Examples include the spun polyester matrix with injected buoyant polystyrene manufactured by Floating Islands International (USA) and the floating plastic netting materials produced by the Huck Group (Germany). Published data on the treatment performance of the various FTW applications are limited. In general, it seems that FTWs have been effective at removing suspended solids and nutrients, although reported phosphorous removal efficiencies are somewhat variable.

Compared to conventional pond and wetland systems, FTWs are considered to possess a number of advantages that may enhance certain contaminant removal processes. The cover and shelter provided by the floating mat promotes conditions conducive to settling by reducing turbulence and mixing induced by wind, waves and thermal mixing. Compared to conventional sediment-rooted wetlands that are predominantly restricted to water depths of less than 0.5m, FTWs can be constructed deeper to provide extra water volume, reduce flow velocities and enhance settling. Plant roots are believed to play a key role in treatment processes within FTWs by virtue of the contact that is afforded as the water passes directly through the network of hanging roots that develops beneath the floating mat. Plant roots provide a living surface area for development of biofilms containing communities of attached-growth micro-organisms responsible for a number of important treatment processes. The thick network of roots and associated biofilms are effective at physically trapping particulates within the water column, which subsequently slough off the roots as heavy particles that are more amenable to settling.

A number of factors are likely to promote the development of reducing conditions within the sediments (and water column) underlying a floating wetland. These include:

- Regular supply of organic matter from the floating plant material;
- Presence of inundated, waterlogged conditions which limits gaseous oxygen diffusion into the sediments
- Elimination of re-oxygenation of the water column via photosynthetic algae; and
- Obstruction of diffusion of oxygen across the air water interface and reduced wind and wave induced aeration due to the protection provided by the floating mat.

Some form of re-oxygenation of the water leaving the FTW will generally be required prior to discharge into a natural waterway. Re-aeration may be achieved by incorporating an open-water pond section after the FTW, through the use of active aerators or the use of a passive cascade outlet structure. Overall, the level of oxygen depletion in the water column beneath a FTW system may be partially manipulated by controlling the proportion of pond surface that is covered by floating wetland.

Potentially suitable plant species for FTWs in New Zealand include emergent sedges from the genera Carex, Cyperus, Schoenoplectus and Baumea and rushes from the genus Juncus. Taller-growing native species such as the larger sedges (e.g., Baumea articulate and Schoenoplectus tabernaemontani) and raupo (Typha orientalis) are likely to develop extensive root systems and be particularly good at trapping suspended particles, but will experience greater wind resistance and will render small islands vulnerable to over-turning during higher winds. Thus, the use of taller species may be limited to larger FTW systems that are securely anchored. Open textured coarse peat or coconut fiber materials that do not become too heavy or anaerobic once saturated are likely to be the most suitable media for plant establishment on floating wetlands.

2.3 HISTORICAL BACKGROUND

Waste stabilisation ponds (WSPs) are the most common wastewater treatment system in New Zealand. Pond systems for treating wastewater have existed for centuries with use of the first constructed WSPs beginning in the 1920s. New Zealand has a considerable investment on WSPs, which make up over 60 % of wastewater treatment plants (WWTPs) – most are located in small- and medium- sized communities.

In the Rangitikei District Council (RDC) WSPs make up over 90 % of WWTPs.

However, wastewater treatment is coming under increasing scrutiny and pressure to improve as concerns are raised about the risks that microbial pathogens (bacteria, protozoa, viruses) in wastewater pose to aquaculture, tourism, mahinga kai and recreational water, if they are not adequately removed. Also critical nutrients frequently observed at elevated levels within the effluent of municipal sewage include nitrogen and phosphorus contributing to poor water quality of the receiving water.

Impacts of eutrophication (highly nitrified water) can include toxicity to humans and animals via ingestion, dramatic and unsightly algal growth; oxygen deficiencies that vitiate support of aquatic life, and odours generated from decaying organic matter.

Coupled with the need for better disinfection and nutrient attenuation is the requirement for technologies to be sustainable.

Although considered old hat, WSPs still have much to offer in terms of modern day thinking about wastewater removal. For example, WSPs are cheap to build and simple to operate, they use little or no energy in their operation so they could be considered environmentally sustainable compared with other wastewater technologies, they provide havens for birdlife, and they produce low volumes of bio solids (sludge) that require disposal.

Two possible solutions to the eutrophication of lakes, rivers, streams etc. are: (1) prevention through a radical change in lifestyles; and (2) water/wastewater treatment to remove existing contaminants, including microbial pathogens and excess nutrients.

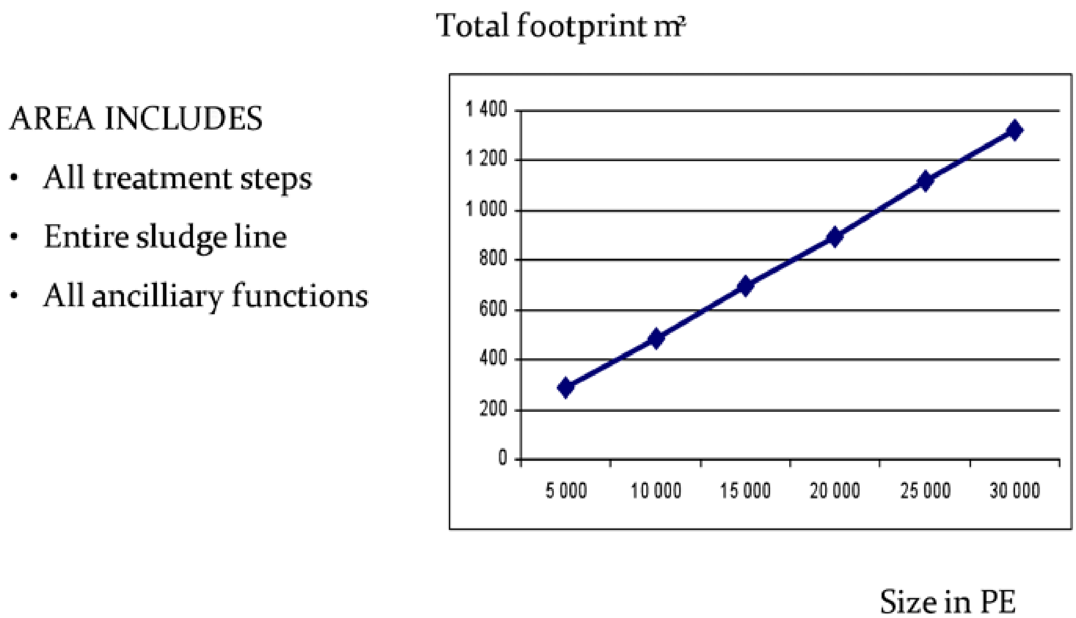
Radical lifestyle changes are a worthy pursuit; however, the scope and significance necessary to reverse the damage would make it a challenging option. Treatment, as an alternative in many forms, is more within our reach.

Most industrialized countries currently rely heavily upon mechanical treatment to improve the quality of the water emitted from their wastewater facilities. While those techniques generate high-quality water, they can be expensive to maintain and they require costly upgrades when populations expand.

An alternative to the mechanical treatment of wastewater is the implementation of floating treatment wetlands (FTWs). Instead of investing in higher technology treatment, WSPs can save hundreds of thousands of dollars in capital and operational costs, minimising the burden on ratepayers; and ensuring that WSPs remain a fundamental part of RDC wastewater infrastructure.

FTWs offer a unique ability with a zero land space approach with high treatment and bio-sequestering abilities. These plants are very compact and because of the botanical garden appearance they don’t have a negative effect on the value of the neighbouring properties.

See total foot print m^2 graph below.



Strategically placed islands or clusters of islands will sequester nutrients and remove suspended solids by providing the ideal habitat and huge surface area for the base of the food chain. Bio films and microbial activity that supports water life and all associated water quality begins on the root zones and amongst the matrix itself. These extremely important microbes convert nutrients and what is regarded as pollutants, to an available food source for plants and invertebrates.

FTWs are unique in their properties of being able to support aerobic and anaerobic zones in the same surrounding area. These zones are essential for the de-nitrifying and nitrifying of wastewater.

Attenuation of nutrients and the removal of total suspended solids using Floating Treatment Wetlands technology have been well studied and documented by the National Institute of Water & Atmospheric Research.

2.4 WHAT ARE FLOATING TREATMENT WETLANDS (FTM)

Constructed treatment wetlands are engineered systems designed to enhance the processes and interactions that occur in natural wetlands between water, plants, microorganisms, soils and the atmosphere in order to remove contaminants from polluted waters in a relatively passive and natural manner.

Constructed treatment wetlands typically involve flow of contaminated water through the shoots (surface-flow or free-water surface); or root-zone (subsurface-flow or submerged bed; of emergent species of sedges, rushes and reeds.

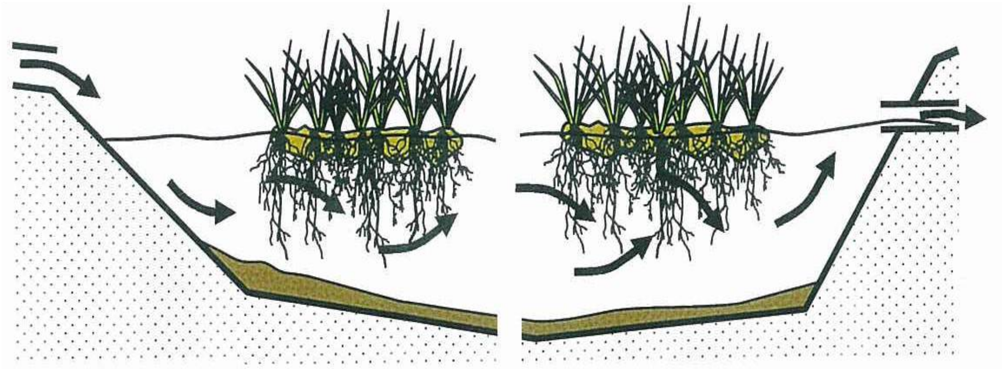
A third approach has also been used for wastewater treatment involving the use of free-floating aquatic plants which float either as thin layer on the water surface (e.g., duckweed and azolla) or have speciallyadapted buoyant leaf-bases (e.g., water hyacinth, water lettuce and salvinia).

Floating treatment wetlands (FTWs) are a variant on these systems that employ rooted, emergent plants (similar to those used in surface and subsurface flow applications) growing as a floating mat on the surface of the water rather than rooted in the sediments

See stylised longitudinal cross-section through a typical floating treatment wetland system with partial cover of pond surface with floating wetlands on the next page.

Note: the water depth can vary in such a system.

Floating treatment wetlands are distinguished from free-floating aquatic plant systems by the fact that they utilize larger emergent wetland plants growing on a somewhat consolidated floating mat, as opposed to an unconsolidated mass of small, individual buoyant plants lacking any significant mat.



In floating treatment wetlands, plants may either be supported on a floating raft structure and rooted in some sort of matrix or soil media, or (as in many natural floating marshes) self-supported on intertwined mats of their own buoyant roots and rhizomes, and accumulated plant litter and organic matter. Because they float on the water surface, floating treatment wetlands are little-affected by fluctuations in water levels that may submerse and adversely stress bottom-rooted plants.

Floating treatment wetlands may be likened to a hydroponic system, as the plants acquire their nutrition directly from the water column in which their roots are suspended, rather than from the soil. They also share some similarities with subsurface flow treatment wetlands, in that treatment occurs as water flows through the root zone of the plants, rather than amongst the stems.

The terminology used in naming floating wetland systems, both natural and artificial, is extremely varied. Virtually all of the major natural floating wetland ecotypes around the world have been given a different name, typically of local origin. Because of the relatively novel status of artificial floating wetlands used for water or wastewater treatment, there is still no consistent terminology that has been broadly applied. As artificially created floating wetlands become increasingly used for water or wastewater treatment there is a need to derive a commonly applicable and somewhat generic term for such systems. The term: “Floating Treatment Wetland” seems most broadly useful. However, such floating marshes employing emergent plants should be differentiated from treatment systems utilising free-floating aquatic plants (e.g., duckweed or water hyacinth) which, although sharing a number of similarities, are structurally and functionally different to the systems discussed here.

Floating treatment wetlands are distinguished from free-floating aquatic plant systems by the fact that they utilize larger emergent wetland plants growing on a somewhat consolidated floating mat, as opposed to an unconsolidated mass of small, individual buoyant plants lacking any significant mat. Despite the differences, free-floating aquatic plants systems, particularly those using larger species such as water hyacinth, can provide a useful insight into how a floating treatment wetland might function and perform.

Free-floating aquatic plant systems have been used to reduce particulate and organic loads in sewage and industrial wastewaters. The prevention of algal growth via shading and the reduction of wind and thermal mixing can tend to make these systems more effective at removing suspended solids and organic matter than regular facultative pond systems (Reed et al. 1995; Vymazal et al. 1998). The extensive roots system hanging below water hyacinth plants provides a large surface area for attached growth microorganisms. The high growth and uptake rates of many free-floating plants can also result in significant removal of nutrients and metals if there is enough land area available and the plants are regularly harvested. Metal removal also occurs through the chemical precipitation and adsorption on substrate and plant surfaces, with mature plants sloughing root material which becomes bound in the benthic sludge (Reed et al. 1995). Many of these processes are also likely to be important in floating treatment wetlands using emergent macrophytes.

Whilst free-floating aquatic plant systems show a lot of promise, many of plants suitable for such systems are not native species to New Zealand and have been identified as serious weeds. Species such as water hyacinth originate from more tropical climates, rendering them particularly susceptible to frost. There may be some potential for the use of native species such as Lemna minor and Azolla filiculoides. However, these small species do not develop extensive root systems for biofilm development and would require specific structures to counteract wind-driven movement and prevent them from being washed out of the system during rainfall events.

The requirement for regular harvesting for nutrient and metal removal renders free-floating aquatic plant systems a rather labour-intensive approach. Thus, the use of treatment systems reliant on free-floating aquatic plants is considered inappropriate for wastewater treatment in New Zealand. They tend to have limited application outside tropical and subtropical climate zones.

2.5 WHY THE PROPOSAL OF A FLOATING TREATMENT WETLAND SYSTEM FOR HUNTERVILLE

The Hunterville WWTP project's purpose of a constructed FTW is to improve nitrogen and other pollutant removal, reduce heating, increase habitat availability, and reduce land requirements and maintenance costs. Addition of floating islands has been reported to significantly improve nutrient and other pollutant removal, and to reduce heating that is a common problem in constructed wetlands program.

It also reflects and embraces the RMA definition which recognises the financial implications to the community of various otherwise technically and environmentally acceptable options.

2.6 RANGITIKEI'S CHOICE

2.6.1 WASTE STABILISATION PONDS

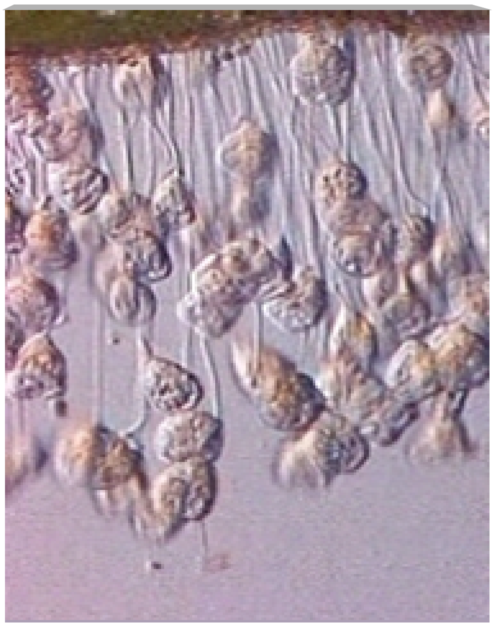
- Savings in Capital and Operational costs
- Minimum burden on ratepayers
- No need for sophisticated mechanical technology
- Remain a fundamental part of our Wastewater Infrastructure

2.7 MECHANISMS

While naturally-occurring floating wetland islands have been known for many centuries (see Van Duzer, 2004 for an extensive review, their use as a treatment technology is relative recent.
Artificial floating wetlands consists of rooted emergent wetlands plants growing on a geo-textile mat floating on the water surface - combine the beneficial elements of pond and wetlands within a single system

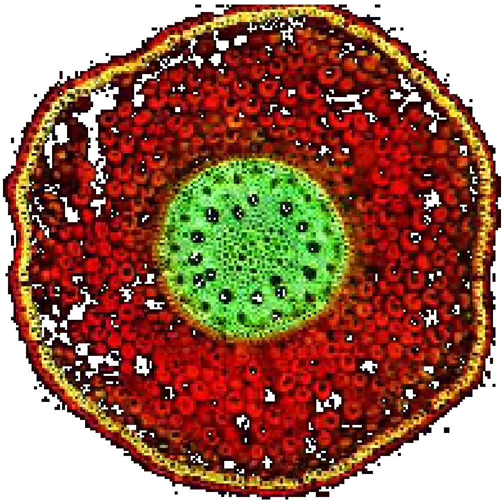
The dense hanging root mat that forms beneath the FTW provides close interaction between the plant roots (and attached biofilm) and nutrients in the water column.
As the plants are forced to meet their nutrient requirements from the water column rather than the soil, they are likely to experience greater uptake of nutrient and other contaminants from the water than conventional sediment-rooted wetlands.
In addition, the large root area provides a surface for the development if biofilms (predominantly bacterial) which can contribute to nitrogen and phosphorous attenuation
Organic exudates released from the plant roots have the potential to provide organic carbon to de-nitrifying bacterial organisms promoting transformation of oxidized nitrogen to nitrite gas under anoxic conditions.

The "Root-Dwellers"



There are more than 3,000 species present as root-dwellers.
This is a growth substrate that is alive, and as enzymes come and go metabolic processes take place through and near the root surface. This provides for a healthier and better "sticking" biofilm.

Root Cross Section



The roots are actually a truly special kind of fixed film substrate. They are alive, grow on their own and produce an **enourmous surface area: over 10 000 m2/m3** of reactor space!
An important note: while the plants are the most visible parts of the system, it's not the plants that treat the water!! Instead, the plants with their **extensive root system provide the habitat for a complex ecosystem** that is thriving on the waste stream

2.7.1 SUSPENDED SOLIDS

Smith and Kalin (2000) measured the mass of solids trapped amongst roots of a two year old floating Typha vegetation mat on an acid mine drainage pond. They reported that 0.29 kg of solids were trapped per 15 m^2 of root surface area per m^2 of FTW during the second growth year. This equates to 0.02 kg of solids trapped per m^2 of root surface area. Using root surface area data from a seven year old system (114 m^2 root surface area per m^2 FTW), the authors estimated that a mature system would capture approximately 2.2 kg of solids per m^2 of floating vegetation. This would account for 37% of the annual load of SS received by the pond under investigation, assuming complete coverage of the pond with floating vegetation mats. They postulate that the actual long term trapping of suspended solids would be substantially higher than that estimated from a single measurement, given that trapped solids would be periodically sloughed from the roots and settle to the bottom of the pond, thereby opening up more root surfaces for entrapment.

2.7.2 NUTRIENTS

The Heathrow Airport pilot-scale floating wetlands did not perform as well as adjacent subsurface and surface flow wetlands in terms of NH_4, NO_3 and PO_4 removal during the first year of operation (Revitt et al., 1997). The poorer P removal performance of the floating wetlands (relative to the other wetland systems) may be partly due to the lack of a substrate for sorption of PO_4. It is unclear from the paper of Revitt et al. (1997) whether the different wetland technologies being trialled were receiving equivalent loading rates, which makes it difficult to derive clear conclusions from the comparative performance. Kansiime et al. (2005) conducted a mesocosm study of the nutrient removal performance of floating papyrus plants receiving secondary treated sewage in Uganda. The plants were grown in 30 L buckets and batch fed effluent every seven days. TN and NH_4-N concentration reductions stabilised at approximately 80-90% after 15 weeks of growth, whereas the mean percentage reduction of TP and ortho-phosphate stabilised at approximately 70-80% after 21 weeks of growth. The nutrient removal performance of floating papyrus generally exceeded that of papyrus rooted in gravel substrate. Floating plants displayed greater root development than the same plants grown in gravel, with the authors estimating that floating plants developed a larger root surface area (ca. 422,000 cm^2) than the plants rooted in gravel (ca. 207,000 cm^2). Sekiranda and Kiwanuka (1998) conducted a similar mesocosm study to that of Kansiime et al. (2005), except they examined the nutrient removal performance of floating and gravel-rooted Phragmites mauritianus in 40 L buckets receiving daily pulses of anaerobic sewage treatment pond effluent to achieve an average residence time of 5 days. An operating water depth of 0.3 m was maintained and the flow regime was operated in a vertical up-flow configuration. There was generally very little difference between the gravel-rooted and floating mesocosms in terms of nitrogen removal, with both systems achieving greater than 97% reduction in the concentration of NH_4-N. However, control buckets without plants or gravel also achieved high removal of

NH_4-N (92.5%). In contrast to Kansiime et al. (2005), Sekiranda and Kiwanuka (1998) found that the gravel rooted systems achieved a significantly greater reduction in TP and PO_4-P concentrations than the floating P. mauritianus mesocosms. This difference was reportedly due to a greater amount of P associated with plant biomass in the gravel-rooted plants. Application of Floating Wetlands for Enhanced Stormwater Treatment: A Review of 37 Floating treatment wetlands (termed Artificial Floating Meadows) have been trialed in Hungary for removal of nutrients from lake water (Gulyas and Mayer; 1993 cited in: Lakatos, 1998). A pilot experiment was conducted using water from the Danube River with additions of 5 mg/l of NO_3 --N and 2 mg/l of reactive phosphorus. The retention time in the artificial floating meadow was two weeks. Final results indicated that the floating meadow removed 85% of the total nitrogen content. However, phosphorus removal was poorer at 40%. In addition, with the onset of winter and colder temperatures, the efficiency of both nitrate and phosphate removal was reported to decrease.

2.7.3 PATHOGENS

Kansiime and van Bruggen (2001) estimated that a papyrus zone of the floating marshes of Nakivubo wetland (Uganda) were achieving a two log reduction in faecal coliform concentrations, whereas a Miscanthidium zone achieved a one log reduction. These authors concluded that morphological differences between the two species and their associated mats accounted for differences in pathogen die-off. They found that the finer, more roughly textured roots of papyrus resulted in a much greater number of faecal coliforms being attached to these root surfaces. The papyrus mat also had greater amounts of organic debris falling from the underside of the mat through the free-water column, providing additional surface areas for the attachment of faecal coliforms and subsequent sedimentation.

2.7.4 PHOSPHOROUS

Phosphorous is present in wastewater as orthophosphate (PO^{3-}_4, HPO^{2-}_4, $H_2PO^-_4$ and H_3PO_4), polyphosphates and organic phosphate. The average phosphorous concentration in sewage is between 5 – 20 mg P l^{-1} as total phosphorous of which 1 – 5 mg P l^{-1} is organic, the rest inorganic. Normal secondary treatment can only remove 1 – 2 mg P l^{-1} and so there is a large excess of phosphorous that is discharged in the final effluent that gives rise to eutrophication in surface waters.

The efficiency of phosphorous removal is usually no more than 10 to 20 % for a root zone plant. However, this efficiency can be increased to 80 % or more with the addition of a metal- or iron salt for example an iron chloride which allows the precipitation of iron phosphate. At Hunterville's wastewater plant chemical precipitation will be used to remove the inorganic forms of phosphate by the addition of a coagulant.
Seed flow schematic on page 15.

2.8 METALS

2.8.1 ZINC

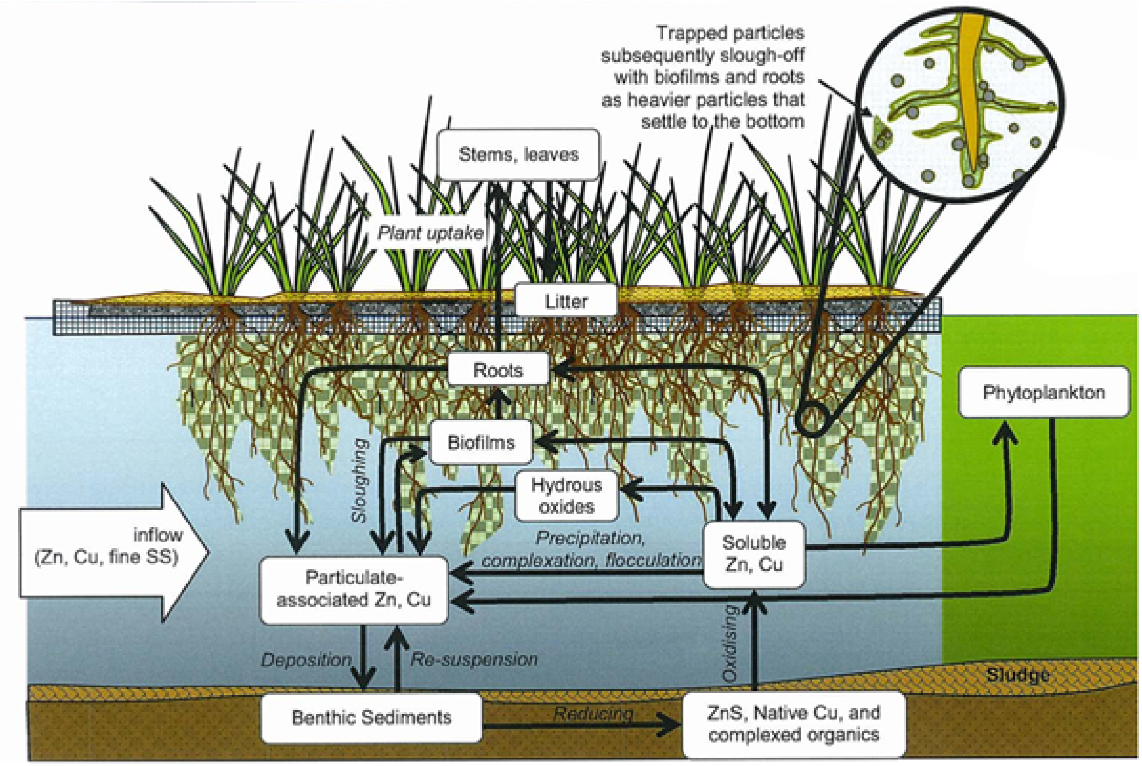
In the study of Revitt et al. (1997), the average concentration of zinc (Zn) in the effluent from the pilot scale floating treatment wetlands at Heathrow Airport was greater than that of the influent during the first year of operation. The authors did not comment on why the floating wetlands acted as a source of zinc. One possible explanation may be the release of zinc from galvanised metals if significant amounts of these materials were used in the floating structures.

2.8.2 COPPER

The mean copper (Cu) removal efficiency achieved by the Heathrow Airport pilot scale floating treatment wetlands was 20-30% during the first year, which was comparable to the adjacent surface and subsurface flow wetlands (Revitt et al. 1997).

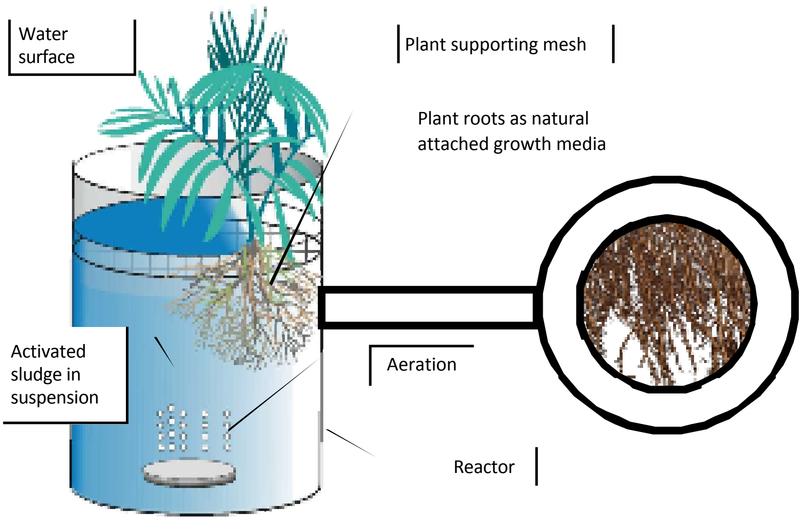
NOTE: Hunterville's domestic wastewater is not a metal rich wastewater.

See conceptual model below of copper and zinc pathways and interactions within a floating wetland wastewater treatment system.



<u>Hunterville Conveyance Wastewater Treatment Scheme</u> (See flow diagram page 15).

Mode of operation:



The primary and secondary oxidation ponds will function as open aerobic reactors and are arranged in series and act as a continous flow design. The first reactor will have fine fine bubble aeration at the bottom and have suspended 'activated sludge'as in traditional solutions. On the watertable of both reactors there is a matrix (grid) on which plants are placed. The root system of these plants dangle into the water 1 – 1.5 m. Several thousands of plants are placed into the reactors.

As the water flows through the various reactors different ecologies will develop in each reactor. In the begining of the treatment line those species will thrive which are accustomed to high nutrient and ammonia concentrations and towards the end of the treatment line those which „don't mind" if food is much harder to find.

The reactors are followed by a moving bed sand filtration plant or continuous backwash filter and a UV reactor for final effluent polishing (See flow diagram on page 15). All the other traditional components of a treatment plant such as blowers, pumps, mixers etc. are also present.

The application of sand filters to raw wastewater is rarely appropriate and is more applicable as tertiary treatment following a biological wastewater-treatment process. The resultant final effluent from a sand filtration system can have low levels of residual solids (See Table Filtration performance below), and the application is particularly useful for final polishing before discharge to a river or stream.

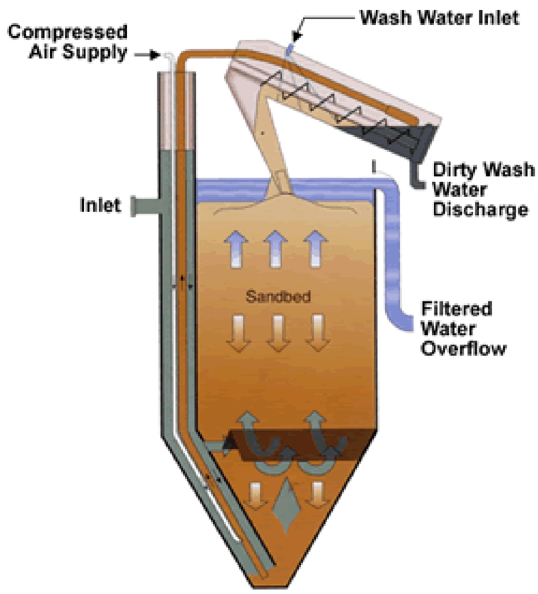
Filtration performance

Filter type	Wastewater	Filter depth, ft	Hydraulic loading, gal/(min · ft^2)	Percent removal		Effluent, mg/l	
				SS	BOD	SS	BOD
Gravity downflow	TF effluent	2–3	3	67	58	—	2.5
Pressure upflow	AS effluent	5	2.2	50	62	7.0	6.4
Dual media	AS effluent	2.5	5.0	74	88	4.6	2.5
Gravity downflow	AS effluent	1.0	5.3	62	78	5	4
Dynasand	Metal finishing	3.3	4–6	90	—	2 5	—
	AS effluent	3.3	3–10	75–90	—	5–10	—
	Oily wastewater	3.3	2–6	80–90†	—	5–10†	—
Hydroclear	Poultry	[illegible]	2–5	88	—	19	—
	Oil refinery	[illegible]	2–5	68	—	11	—
	Unbleached kraft	1	2–5	74	—	17	—

† Free oil.
Note:
ft = 0.305 m
gal/(min · ft^2) = 4.07 × 10^{-2} m^3/(min · m^2)

The interception of solids can also be a useful technique for the removal of substances capable of bioaccumulation, which may be present in biological solids, or in some colloids.

The type of sand filter proposed for this project is the moving bed, or continues backwash filter, which has been developed into several forms, the most well –known being the proprietary TOVEKO Filter system (see picture and diagram below).



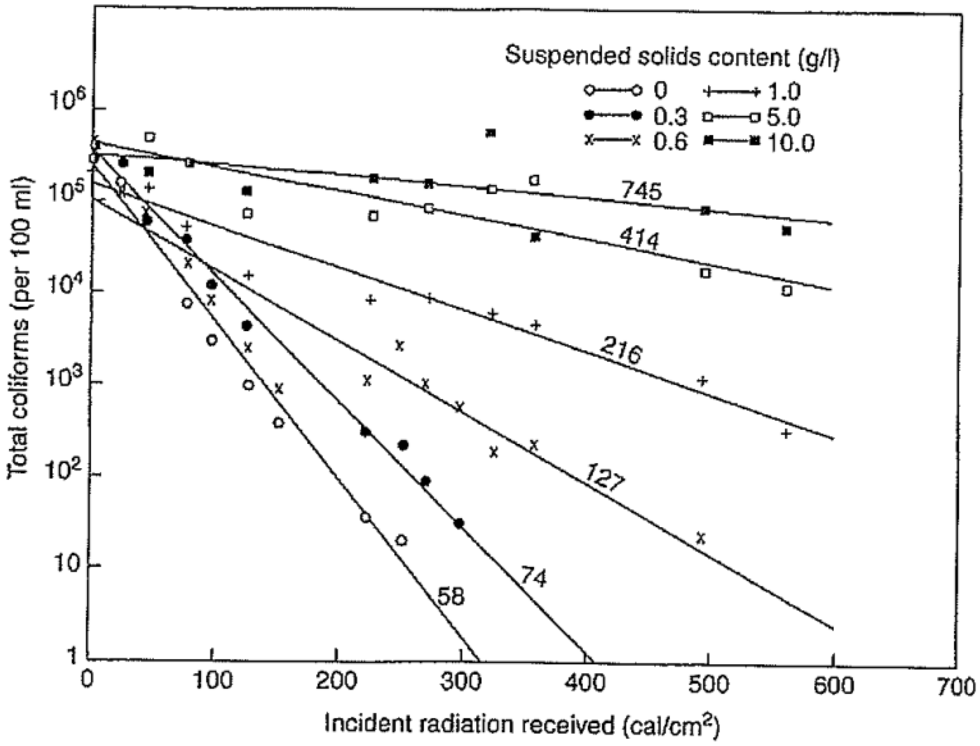
The moving bed sand filter operates continuously, avoiding the need for periodic shutdowns to allow the sand to be backwashed, as sand is cleaned continuously by means of an internal washing system.

In operation, the dirty water enters the inlet launder that runs along the entire length of the filter and is then directed into the bottom of the filter bed. As the water rises to the surface, the suspended solids are left behind, so the water gets gradually cleaner as it rises up through the filter sand. Once the water is above the sand bed, it overflows along the length of the filter.

Here sand is separated from the removed suspended particles by turbulent action, the heavier grains of cleaned sand falling back into the top of the filter, and the lighter solid particles flowing over a weir to waste. As a result, the sand bed is in slow, constant downward motion through the unit, wastewater purification and sand washing take place continuously.

This makes TOVEKO filters especially suitable for un-manned sites, or those where the quality of the feed water varies regularly, since the filter automatically adjusts itself.

A chemical flocculant (e.g. $FeCl_3$) will be added to precipitate the phosphorous and to improve the performance of suspended solids removal, thus enhancing the UV disinfection process. See effect of suspended solids on the amount of radiation required to inactivate coliform bacteria in the figure below. Both UV radiation and short-wave visible light are lethal to bacteria, with the rate of death related to light intensity, clarity of the water, and depth. The lethal radiation is rapidly absorbed by suspended and colloidal solids, which rapidly reduce its effect.



The effect of suspended solids concentration on the amount of radiation required to inactivate coliform bacteria in 1 litre beakers. The amount of radiation required to inactivate 90% of the coliforms originally inoculated (S_{90}) in cal cm^{-2} is shown against the plotted regression (Irving 1977).

The removed solids will be returned to the treatment process. See flow diagram on page 15. This will be particularly useful for maintaining nitrifying bacteria in the treatment process.

2.9 OUTCOME

It is expected to achieve an effluent of <10 mg BOD_5/l; < 10 mg TSS/l; < 10 mg NH_4-N/l.

Note: Legislation (One Plan) requires effluents discharged into sensitive waters to incorporate phosphate removal. Satisfactory phosphorous removal of less than 1 mg P l^{-1} can only be achieved by the addition of a coagulant to allow chemical precipitation.

Monitoring by the District Council and Horizons shows that the water quality of the Porewa stream is degraded upstream of the oxidation ponds effluent discharge. Nutrient enrichment and bacterial contamination are evident.

Macroinvertebrate surveys confirm the low water quality of the stream. The Macroinvertebrate Community Index upstream and downstream of the effluent discharge is less than 100, which indicates a high level of pollution.

A Water Quality of the Porewa Stream at the Sewage Treatment Ponds in Hunterville report by Pohangina Environmental Consulting Ltd, concluded the following:

- Taxonomic composition of invertebrate communities was similar upstream and downstream of the discharge point in the Porewa Stream from the sewage treatment ponds at Hunterville.
- The biotic indices indicate that this discharge was having no adverse effect on the stream's ecology.
- Biotic indices show poor water quality in this part of the Porewa Stream.
- Periphyton biomass was not significantly different upstream and downstream of the discharge, however there was a significant increase in the percentage of stream substrate covered by filamentous algae downstream of the discharge.

From the above it is quite obvious that intensive agricultural practices have had direct negative impacts on many aquatic environments. One result has been the introduction of chemical nutrients at concentrations that have contributed to poor water quality. Critical nutrients frequently observed at elevated levels within our water systems include nitrogen and phosphorus. Sources of these nutrients include the Hunterville WWTP, livestock waste and crop fertilizers. Impacts of eutrophication (highly nitrified water) can include toxicity to humans and animals via ingestion, dramatic and unsightly algal growth; oxygen deficiencies that vitiate support of aquatic life, and odours generated from decaying organic matter.

2.9.1 STORM FLOWS

The lagoons/reactors will act as balancing ponds to store inflow/infiltration flows during storm events. As previously mentioned the water depth can vary in such a system.

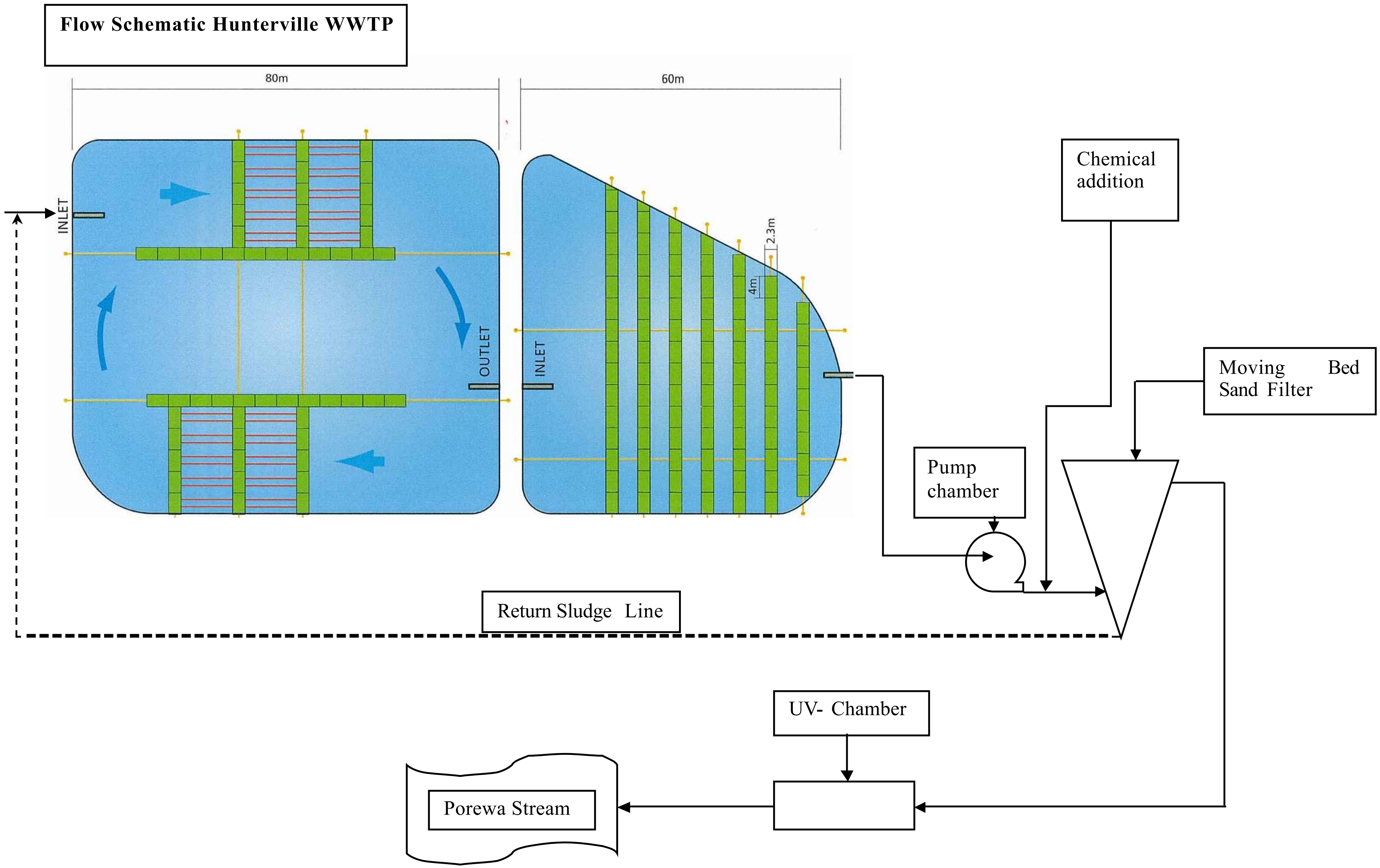
2.9.2 ADVANCED WASTEWATER TREATMENT

The term tertiary treatment is often used as a synonym for advanced wastewater treatment (AWT). Adn while similarities exist, the two are not precisely the same. Whereas tertiary treatment is an additional step applied after secondary treatment to reduce the suspended solids and, to some extent the BOD_5. AWT is any process or system used after conventional treatment, or to modify or replace one or more conventional steps. AWT systems remove refractory and mainly soluble pollutants which are not readily removed by conventional biological treatment. Several of these pollutants can affect aquatic life. For example, unionised ammonia (NH_3) is highly toxic to fish and can cause deoxygenation as it is oxidised; nitrogen and phosphorous promote eutrophication in rivers and lakes respectively; while nitrogen compounds, trace organics and pathogens can hinder the reuse of surface water for supply. The main treatment methods proposed for this project include the removal of ammonia by nitrification; the removal of inorganic nitrogen by denitrification; phosphate removal by algal synthesis and chemical precipitation using iron or aluminium coagulants; reduction of dissolved organics (residual organic matter) using chemical treatment and finally disinfection of effluent to control pathogens, especially viruses by Ultraviolet (UV) radiation.

2.9.3 PROCESS FLOW DIAGRAM

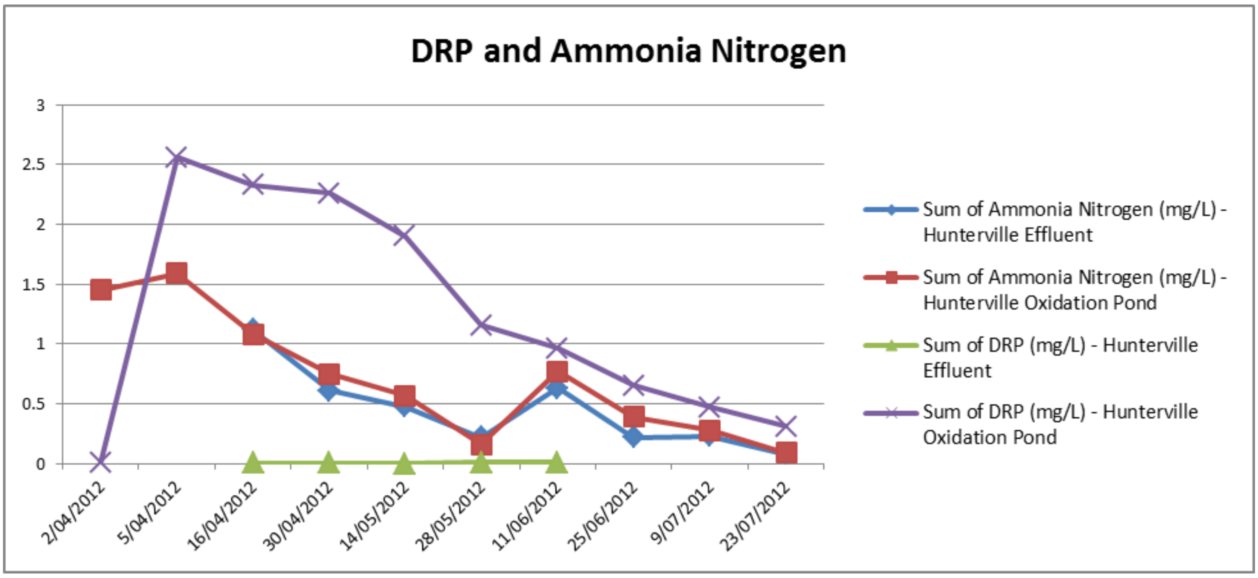
It is convenient to look at the wastewater treatment plant as an enclosed system with inputs and outputs. As mentioned before it is a continuous system and, therefore, the outputs, in the form of sludge and a final effluent, will also be continuous.

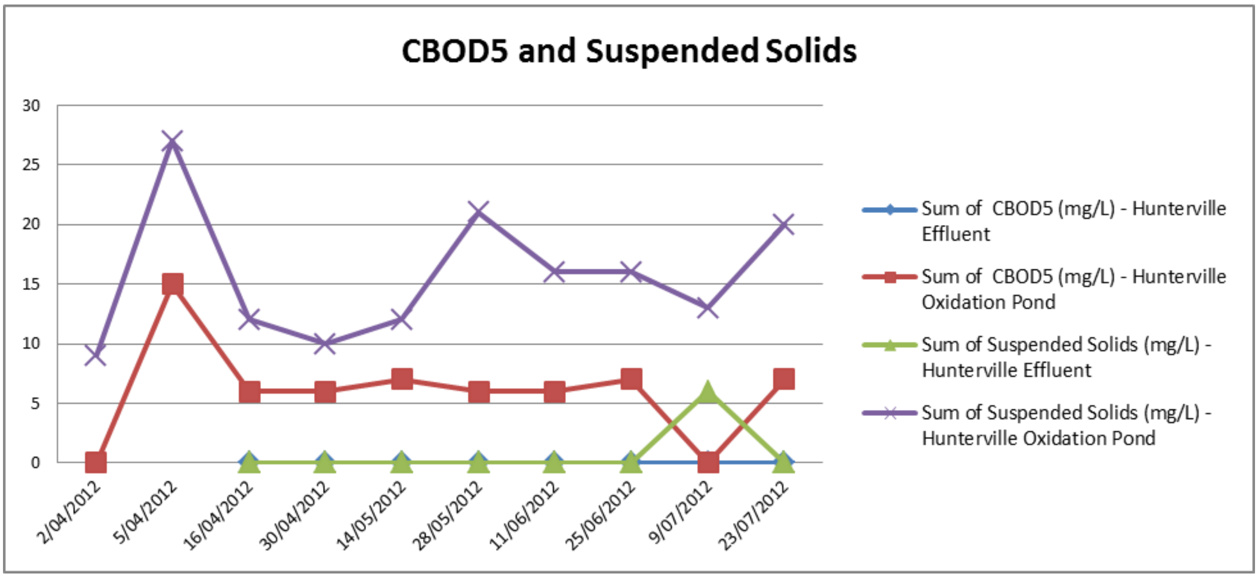
See flow diagram next page.

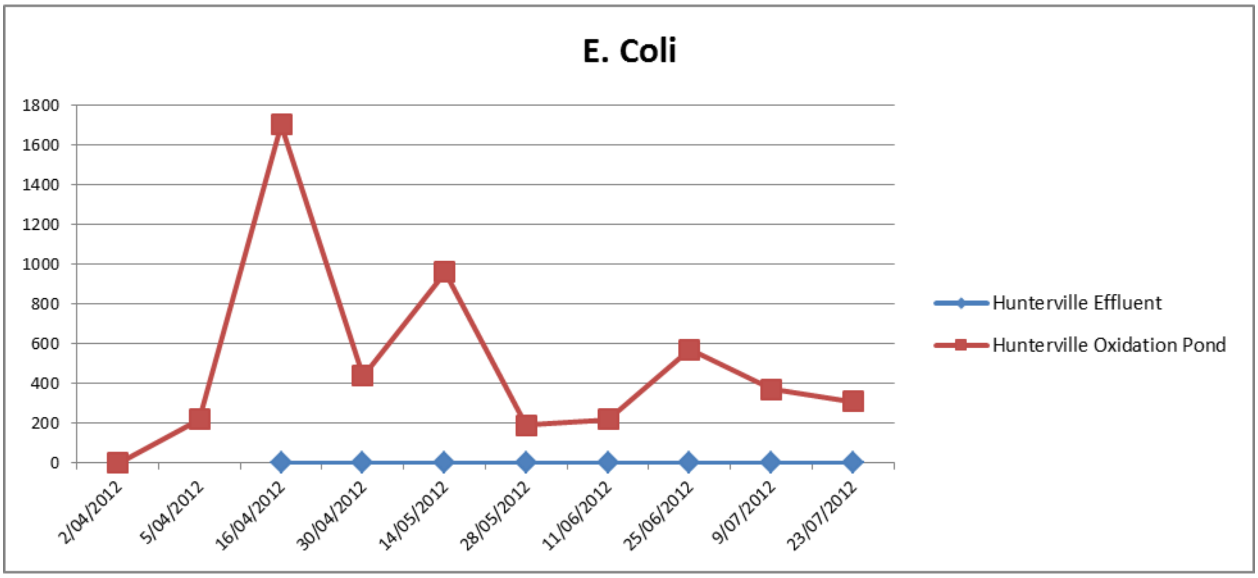


Flow Schematic Hunterville WWTP
80m
60m
INLET
OUTLET
INLET
2.3m
4m
Chemical addition
Moving Bed Sand Filter
Pump chamber
Return Sludge Line
UV- Chamber
Porewa Stream

2.10 RESULTS AND DISCUSSION







A recent World Bank Report (Shuval *et al.* 1986) came out strongly in favour of stabilization ponds as the most suitable wastewater treatment system where land is often available at reasonable opportunity cost and skilled labour is in short supply.

Bacteria and higher organisms live in an attached form on fixed bed media inside the reactors (i.e. no 1 and 2 pond). Providing a stationary habitat allows an incredibly diverse and robust biofilm to grow and thrive, ultimately offering significantly improved nutrient removal, energy efficiency, and resiliency, all in much less space than conventional technologies.

Floating Treatment Media plants are designed to enhance the natural process of complex ecosystems by creating considerably more diverse biology than those already in use in the industry. In addition to the bacteria found in traditional activated sludge systems, FTM plants are populated by over 3,000 species of microbes.

A series of distinct ecosystems within the reactors contain species ranging from bacteria, protozoa, to plants, snails and other invertebrates.

As can be seen from the results above, combining the use of waste stabilization ponds and root zone plants (i.e.FTM technology) with a system or technology added downstream of this process in the form of a simple filtration device is an attractive wastewater treatment method.

The reasons for this are:

- Filtration treatment devices can provide, through the use of filter media, a significant reduction of suspended matter from FTM pond technology effluent.

- Effluents from FTM pond technology most often need a post treatment polishing step and the use of a simple filtration system offers an excellent cost-effective solution to this problem.

- The use of waste stabilization ponds with FTM technology and a filtration device, in combination, offers a higher level of certainty as an effective pollution abatement and aquatic ecosystems management strategy.

3.0 CONCLUSIONS

Floating Treatment Media (FTM) leverages the use of various natural and artificial media to provide a fixed habitat for a diverse fixed-film bacterial culture which metabolizes the contaminants in wastewater. These populations of organisms live in an attached form on fixed bed media inside the reactors, as opposed to being in constant motion as is the case with conventional technologies such as Activated Sludge or MBBR. Providing a stationary habitat allows an incredibly diverse and robust biofilm to grow and thrive inside the reactors, ultimately offering significantly improved nutrient removal, energy efficiency, and resiliency, all in much less space than conventional technologies.

FTM systems are exceptionally robust: in case of a dramatic change in flow rate of influent characteristics the systems performs much better due to its diversity. These diverse ecologies are much less prone to collapse than the limited diversity traditional systems.

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Robert Gunn – Managing Director, The Downs Group

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