“Ecologically informed Sanitation Systems with Water recycling, for Sustainable Development”

The Way of the future.

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1 Introduction

The global environmental crisis does not recognise any country’s sovereign rights nor geographical boundaries. The environmental issues facing humanity now and in the future cannot be solved by others. Our survival as citizens, as communities and as notions will depend on the strategies we adopt to actively participate in our local bioregion.

Increasing global populations and the demand for economic growth further strain the limited resources available. The most fundamental of these resources and the greatest limiting factor to our survival and growth is the availability of clean water. The systems we design to deal with our wastewater and sanitation in the future will be one of the most significant challenges for engineers, architects and town planners.

As developed and emerging economies around the world grapple with the concepts and implications of Ecologically Sustainable Development (ESD) it is becoming universally accepted that centralised water and sewerage systems are no longer viable medium or long-term options (Priestly, Burns, Davis, 1998).

2 Population Growth and Sustainable Development

In many parts of the world, the orderly development of urban and near urban areas is dependent on the availability of water. Many countries around the world within the last five to ten years have experienced sever water shortages of such magnitude that water rationing has been necessary. In areas where the available sources of water are limited or unreliable, it is now recognised that wastewater represents a very reliable water source. If wastewater from urban and near urban areas were reused locally for a variety of nonpotable uses, the demand on the potable supply would be reduced and population growth could be sustained. As a result, the focus of the field of wastewater management is beginning to change from the construction and management of regional sewerage systems to the construction and management of decentralised wastewater treatment facilities.

Decentralised wastewater management (DWM) may be defined as the collection, treatment and reuse/disposal of wastewater from individual homes, clusters of homes, or isolated communities, industries, or institutional facilities at or near the point of waste generation (Tchobanoglous, 1995; Crites and Tchobanoglous, 1998). In some cases the liquid portion could be transported to a central point for further treatment and reuse, if the quality is not sufficiently high enough for reuse. Given the increasing demands on freshwater supplies, it is clear that DWM is of great importance in developing long-term strategies for the management of our environment. Therefore, in addition to the implementation of large scale reuse projects, it will become important, in the future, to develop appropriate strategies and operating agencies for the management of localised reuse projects.

3 The Challenge for Environment Equipment.

Since 1974 Environment Equipment Pty Ltd has dedicated itself to the pursuit of environmentally sound wastewater and sanitation systems. In the early year the main focus was in the development of sanitation systems, which did not need water for flushing and ancillary to this an appropriate means of disposing of household wastewater on-site.

The Rota-Loo range of products was developed and proved very successful for residential homes in rural areas where water was in short supply and also for domestic and commercial applications in environmentally sensitive areas where development was limited and where mains infrastructure was not possible. National Parks and Ecotourism Developments have been the greatest proponents of these technologies for the last 27 years.

In the middle to the late nineties we realised that whilst the Rota-Loo products definitely had their place, they were not going to be universally accepted by the mainstream and were not appropriate for high density urban applications. The significant increase in urban developments caused by population growths in the cities was starting to impact on;

1. the demand for water supply,
2. effects to the ecological environments around traditional sewerage outfalls,
3. the potential and cost for urban water authorities to upgrade their infrastructure to meet the every increasing demand,
4. the potential for higher risks to human health as the centralised reticulated sewerage treatment systems became old and incapable of operating at optimum efficiency,

5. as well as entrenching an outdated engineering solution to the problem of providing adequate wastewater and sanitation facilities to a generation of people who were demanding that governments and corporations adopt thinking and strategies that would lead toward Ecologically Sustainable Development.

We recognised that this is where the work needed to be done, we had to develop a system that was;

1. Appropriate for urban developments,
2. Easy to use,
3. Easy to maintain,
4. Easy to scale up
5. Little to no impact on the environment
6. Sustainable, and
7. Cost effective.

3.1.1 Composting Toilets and Greywater Systems

i. Rota-Loo Composting Toilets (see appendix I)

The current range and design of the Rota-loo waterless composting toilet system is possibly the most efficient of its type anywhere in the world.

The unit comprises a rotationally moulded cylindrically shaped outer tank, which has a door opening moulded into its side the full height of the tank. Inside the tank is housed a steel reinforced rotationally moulded turn-table or carousel on to which are positioned either six or eight (domestic or commercial models) wedge shaped removable composting bins, in the base of each bin are moulded a series of air holes and drain holes which allow the liquid waste to pass through and also allows air to penetrate in. On top of the two sets of hole is placed a geo-textile liner, which acts as a filter medium. The geo-textile liner has a flow rate of approximately 300 l/s/m2 and a density of 175 microns thus allowing all liquids and air to flow through yet retain all solids inside the bin.

On the lid of the outer tank, two flanges are moulded in to allow for up to two waste chutes to be connected to the system. The waste chute once connected to the lid of the Rota-Loo passes vertically up through the floor of the toilet room and is connected directly into the base of the toilet pedestal.

Around the outside of the outer tank two pods are positioned each diagonally opposite each other. One becomes the air inlet and is placed close to the bottom of the outer tank and the other is attached to the vent pipe and is placed approximately 75% of the way up the side of the tank. In most installations a fan is mounted in the vent pipe and runs continually. The air inlet is connected and led off to an area of warm air, this is most important for an efficiently operating system (Burrows, 2000).

Correctly installed, the toilet pedestal will be positioned directly above a compost bin, when in operation the toilet waste drops directly into a bin where liquids such as urine filters through the pile passes from the base of the bin in to the bottom of the outer chamber. In effect the liquids have been separated from the solids thus creating a completely aerobic environment in the bin. This is especially important for an efficient rate of decomposition and minimisation of odour. The air being pulled through the system by the operation of the fan directs warm air into the base of the Rota-Loo where the liquid is stored thus;

1. Evaporating the liquid as is passes over it,
2. Increasing the internal temperature of the system, thus increasing the rate of decomposition,
3. Increasing the rate of pathogen kill over time.

Once a bin becomes full access is made into the unit via the door, the handle of the full bin is grasped and the entire turntable is rotated one position to the left. This brings into position an empty bin whist the first or newly filled bin is removed from the filling position yet remains inside the system to continue the composting process. This procedure is repeated several times until all the bins have been filled by which time the first bin has passed though all the six or eight positions inside the Rota-loo and when it comes to the filling position again will have been inside the system for one to two years and will have fully composted its contents. The bin is then simply taken out the compost emptied and dug into the soil the bin returned for filling and the process starts again without any water ever having been wasted, no pollution generated and a reusable, soils rejuvenating end product (humus) generated.
The use of composting toilets saves on average between 19% and 25% of domestic freshwater supply.

3.1.2 Greywater Treatment Systems (see appendix II)

Ancillary to the composting toilet a system for dealing with the household wastewater is needed. As the faecal material has been eliminated from the household waste stream the quality of the water is more easily dealt with.
The most common passive greywater system are the;

1. Niimi trench system,
2. Reed-Bed or Rock plant filter system

Both these system have in common a baffled holding tank, which allows for primary and secondary sedimentation processes to occur before the water is displaced from the tank. These two systems also have in common an impermeable layer at the base of the trenching, thus not allowing water to penetrate into the subsoils and ultimately the water table.

The Niimi trench system has its impermeable membrane in a parabolic shape beneath layers of topsoils (200mm), sand (200mm) and screenings (200mm) the wastewater line is placed in the middle of the screenings layer. The total depth of the trench is 600mm. The top of the 450mm wide trench is mounded above ground level to negate infiltration from ground water and planted out. The wastewater is stored in the base of the trench and is accessed by the plants roots, water is also delivered into the active zone of the trench via capillary action along the membrane's walls. The Niimi trench systems relies predominately on transpiration to account for water uptake.

The Reed-bed system is more efficient that the Niimi trench as it relies not solely on transpiration as it is also aided by evaporation to take up the water generated by the household. The Reed-bed system consists of a series of troughs 1.5m in length 450mm wide and 600mm deep joined together. Each trough has an inlet at one end and an outlet positioned at the other end approximately 50mm below the height of the inlet. Each trough is filled with washed aggregate between 20mm – 40mm and planted out with reeds, the most efficient reeds for water and nutrient uptake are Phragmatis Australis. The top of each trench is built above ground level similarly to the Niimi trench system to negate infiltration from groundwater run off.

The effectiveness of composting toilets and greywater treatment system as on-site wastewater and sanitation systems is well known with systems operating in many countries around the world.

The limiting factors to these systems from becoming more widespread are;

1. The need for high set houses or houses with cellars,
2. Favourable climatic conditions for efficient operation,
3. Cultural taboos on issues of human excrement,
4. The amount of land needed for effective disposal of wastewater,

3.1.3 **Wormfarm Waste Systems** (see appendix III)

The development of the Wormfarm Waste System came following the limited success of another Australian system that used Vermiculture to process the organics generated from a domestic household. The for-runner to the current Wormfarm Waste System was fraught with design flaws, which ultimately caused the product to fail but which in hindsight helped inform some of the design aspects of the current model.

The systems operation was primarily informed from observations of natural ecological systems and is analogous in part to the function of the floor of a rain forest. A thick and heavy litter receives waste from the forest animals and plants and through Vermiculture and microbial activity the organic materials are reduced to minute particles, soils, CO_2 and water, soil pH is stabilised and nutrients recycled. Worm activity specifically for processing animal, human and agricultural wastes is well documented (Edwards C.A, Bohlem P.J). The process of filtering water through the organic pile too provides some primary filtration.

The Wormfarm Waste system is designed for domestic use by a population equivalent of 25 persons and a hydraulic load not exceeding 5000l/day.
The system consists of a tank with a capacity of 2500 litres buried in the ground with a composting bin on top at ground level.

Inside the tank and suspended approximately 450mm from the base is the filter medium which sits on a specially designed concave filter cradle capable of with standing several tonnes of weight. The filter medium, seeded with worms is the processing bed onto which all the household organic waste is deposited, wastewater from the house, which is used primarily as a transportation mechanism only carries the waste a short distance before depositing its load and filtering through the organic layer. The quality of water in the base of the wormfarm waste system at this point is relatively clear with a Biochemical Oxygen Demand (B.O.D) concentration of 20 mg/l and Suspended Solids (SS) of 30 mg/l. The wastewater however is of a quality, which must be discharged for subsurface irrigation. During the Vermiculture processing as stated above the organic waste is transformed from its initial state into smaller particles, of the SS discharged the majority are in the form of worm castings and worm eggs. This fact provided for one of the benefits of this system in areas with poor soils condition. The expulsion of worm casting into the subsurface trenches provides for vigorous Vermiculture activity, aeration of the soil and ultimately improved soil conditioning.

The domestic Wormfarm Waste System is suitable for sloping sites, where a gravity feed unit can be utilised or a pump unit when used in an area with flat or level landscape. The pump unit operates with a double float switch mechanism pumping water from the base of the unit into the trenches once a certain level has been achieved, the activation of the pump may be as little as once a day for a few minutes and will depend on the amount of wastewater generated.

As an on-site waste system the Wormfarm unit is exceptionally suited as it is also capable of transforming most of the household putrescible waste, scrap paper, cardboard and any other organic material the household may produce simply by depositing this waste through the composting bin situated at ground level directly over the filter medium and processing area. A grate in the top of the tank restricts any material larger than 180mm in diameter from entering the processing area, (this in accordance with the soon to be published Australian Standards for Composting Toilet Systems).

Whilst the Wormfarm Waste System is very efficient in processing the organic waste load from domestic residence the quality of the wastewater from the system still needs to be disposed of subsurfacely.

3.2 Electroflocculation (Robinson, 2000)

3.2.1 INTRODUCTION

Wastewater is the largest disposal problem associated with waste and by product production, being typically many tonnes of water per person per year in industrialised countries. Yet the total amount of pollutant in the water is often much less than 0.1% (1,000 ppm). Great quantities of water are used to remove small amounts of pollutant. The magnitude of the waste problem could be considerably reduced if techniques were used which concentrated or removed the small amount of pollutant and left the majority of water in a condition suitable for reuse. Many different techniques are available, including a variety of filters, chemical dosing, reverse osmosis and similar. Many of these are either very pollutant specific or more expensive than dumping and using more water. These latter options are fast disappearing and new methods need to be sought.

For a technique to be successful it needs to satisfy a number of criterion, including;

i) It must be cost effective, producing results, which are cheaper than dumping and purchasing more water. With water costs in Australia of ≈ $0.70 k/L for purchasing water and a similar price for disposing to sewer, both the capital and operating costs must be low and the results as good as tap water for the technique to be successful.

ii) It must remove the contaminants producing water, which can be reused in the same application, or as a replacement for water in another application.

iii) It must not in itself produce great amounts of waste.

iv) It must operate reliably and have low downtimes.

Electrolytically based processes appear offer some of these advantages. These involve the passage of an electric current via sacrificial electrodes. Their operating costs are low because of the low cost of electricity and the element materials used. Many attempts have been made in the literature to take advantage of the potential associated with these capabilities, with limited success. The process, usually known as electrocoagulation (Stuart, 1946; Bonilla, 1947, Matteson et al., 1995), involves the passage of an electric current, usually using aluminium electrodes. Aluminium goes into solution at the anode and hydrogen gas is released at the cathode. The aluminium coagulates with the pollutants, which can then be removed, usually by either settling or filtration. Some of the problems encountered with this technique have been associated with element lifetimes (see for example Osipenko and Pogorelyi, 1977; Nikolaev et al., 1982). This has resulted in high operating costs and made the process uneconomic and the potential benefits were lost. Recently these problems appear to have been overcome and at least one commercial electrocoagulation unit is available. A variation of the electrocoagulation process is one in which the gas generated by the process captures the coagulated pollutants and floats them to the surface. Known as electroflocculation, it offers the possibility of a one step process, in which polluted water is pumped into a processing reactor, the pollutants are floated to the surface and the cleaned water is pumped out at the end of the process. Theoretically there are no chemicals to be added and no filters which need cleaning, enabling this process to have the potential to achieve the above goals. Laboratory prototype reactors had been constructed in which preliminary work was undertaken to check the feasibility of the process and determine its viability to treat different types of wastewater. These results also enabled an understanding of the processes involved to be gained. Based upon the success of laboratory experiments, industrial scale units were field trailed in a number of different applications. Our results have indicated our ability to treat a variety of different types of water. Fats, oils and greases (FOGs) removal rates in excess of 99.95% have been achieved. Turbidity of rural clay water has been reduced to below 1 NTU, from values starting at greater than 500 NTUs. Bacteria removal rates in excess of 99% have been achieved from single stage reactors. The process appears to hold significant advantages for the treatment of wastewaters.

3.2.2 THEORY OF ELECTROFLOCCULATION

Electroflocculation provides an alternative technique for the removal of pollutants from wastewater. The process involves the application of an electric current to sacrificial electrodes, usually aluminium, inside a processing tank. The reactions at the anode and cathode respectively are typically

$$Al - 3\,e^- \rightarrow Al^{3+} \qquad (1)$$

and

$$2H_2O + 2e^- \rightarrow 2OH^- + H_2 \qquad (2)$$

generating aluminium ions as a coagulating agent as well as gas bubbles. The well-known properties of the aluminium ions as a coagulating agent causes them to combine with the pollutants. The gas bubbles generated can capture the coagulated agglomerates, similar to the application in a dissolved air flotation (DAF) unit, resulting in most of the pollutant being floated to the surface. In theory, this electroflocculation process can be used as an alternative to DAF processing, with the added advantage that there are no chemicals to be added. As is the case with DAF, there are no filters to be used for final pollutant removal. In addition to the use of aluminium, other metals also have coagulating properties and can be used in place of aluminium. The use of these in conjunction with or independently of the use of aluminium, offers several potential advantages associated with the electroflocculation process. Not the least of these is that the aluminium/metal coagulating cation is added without the addition of an anion. This means that the whole process is carried out without any substantial effect upon the salinity of the water. Additionally, the sludge produced by electrocoagulation is reduced by a factor of 2 or 3 over the use of chemical coagulants(Musquere et al., 1983). Also, experiments suggested that electrolytically added aluminium ions were much more active than chemically added aluminium ions (Donini et al., 1994), meaning that less aluminium was required and that this process could be used to treat a number of different pollutants which could not be handled by chemical flocculants such as alum (aluminium sulphate).

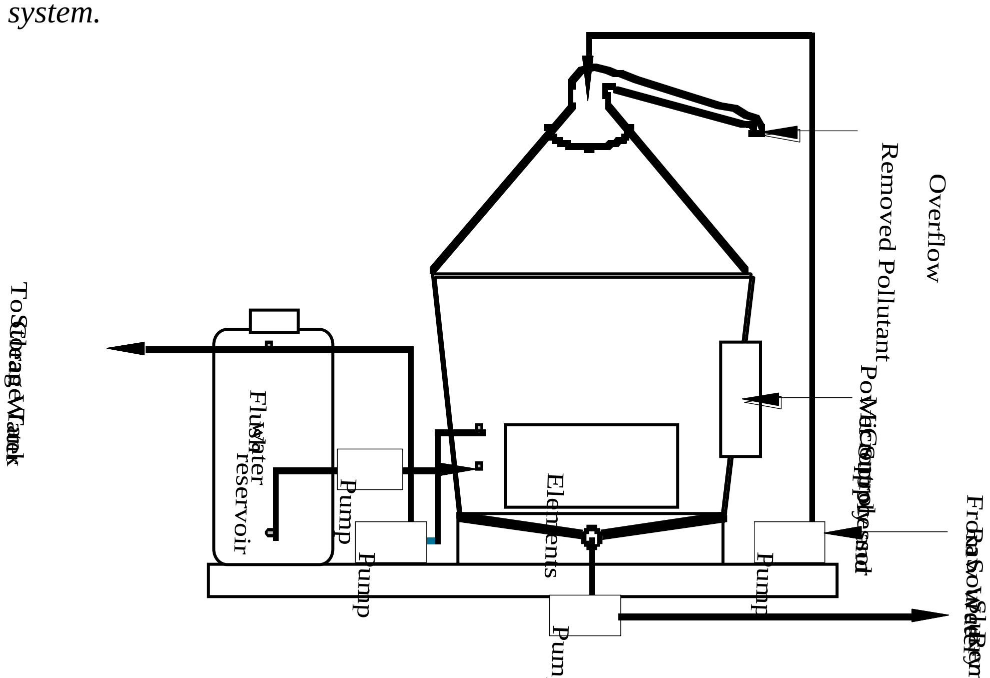
Based upon these and other perceived advantages, considerable development work was undertaken with the objective of determining if the above-mentioned potential advantages could be converted into a practical system.

3.3.4 AN ELECTROFLOCCULATION BASED WATER TREATMENT SYSTEM.

In order to take advantage of the capabilities of the system, a number of different features had to be incorporated into the operation. Perhaps the most obvious of these is element lifetime. Considerable development work was undertaken to determine the causes of element failure and take steps to prevent said problems. This was done in a multi pronged approach. Firstly, by evaluating the causes of element failure, we were able to take steps to prevent the problems from occurring. Secondly, should the problem occur, we were able to produce a design in which the elements were easily cleaned and replaced, with low operating down times. By a combination of these processes we were able to minimise the problems associated with the element lifetimes, to the extent that these no longer represented the limiting factor in a number of tested applications. In order to use the produced hydrogen gas as a flotation medium, we needed to design the elements such that this could be achieved effectively. This has been done and the system now operates effectively as a flotation system, with most of the pollutants floating to the surface, from where they need to be removed. In our system, we have used a conical shaped top. The pollutants float to the surface, where they are concentrated. From there they are floated out the top by simply raising the water level by the injection of further water to the bottom of the tank. Provided this is done in a suitable manner, the water floats the pollutants from the surface causing them to overflow into a suitable container.

Having developed a suitable system, the next step was to automate the process so that it would operate continuously. In this regard, we decided to operate under the batch process, involving the processing of the water one batch at a time. This was primarily due to the different reactions, which occur at different times in the clarification of the water. It was determined that there were far too many variables associated with the treatment of water in a continuous process. During our development work, it was found to be much easier if we retained control of the process, with the water being treated for the total reaction. We were also able to develop a system in which any changes in the quality of the water would be automatically compensated for by the electronics, throughout the whole of the process. Figure 1 illustrates an electroflocculation based water treatment system reaction tank. Water is pumped into the tank until it reached the pre-determined level. The electrodes are activated, generating the coagulating agent at the anode and hydrogen gas at the cathode. The coagulating agent captures the pollutants and combines them into larger assemblies, the same as occurs with electrocoagulation. But there the similarity ends. In our electroflocculation reactors, the hydrogen gas captures the coagulated pollutants and floats them to the surface. There the conditions in the tank assure that they remain at the surface. At appropriate times, the water level is raised and the pollutants are forced out of the top of the tank. Processing times depend upon the nature of the pollutant to be removed and how quickly it is required to remove them. Typical processing times are between 1 and 3 hours. The water is pumped in and processed. The pollutants are removed from the top by periodically adding water from the flush water reservoir, the amount of water added being about 5% of the volume of the water being processed. The cleaned water is then pumped out via the flush water reservoir, refilling it every time it is emptied. In this manner, the process is completely self contained and will repeat itself for as long as there is contaminated water to be processed and the cleaned water reservoir has space to take more water. The only difference between this and a continuous process is the existence of water storage tanks before and after the processing tank. If these are provided, the combination can receive water at a given rate, process it and pass it on again at the same rate. This automated operation feature gives it the properties of a continuous system. The process adds aluminium to the water as well as raising the pH slightly due to the generation of hydroxide radicals through reaction 2. The amount of aluminium added depends upon the nature of the water being treated. However typical amounts added, as determined from calculations based upon the passage of current and the reaction at the anode, reaction 1, suggest that amounts of between 10 and 50 mg/L are used. Beyond that amount, the process starts to be too expensive for many applications. The insolubility of aluminium and the nature of the coagulating reaction mean that most of the aluminium is used in the coagulating process and the aluminium levels in solution are not often beyond the 2 mg/L level.

***Figure1**. Schematic illustration of a commercially sized electroflocculation Based water treatment system.*



After the water has reacted fully it is pumped out of the reactors. Aluminium levels at this stage are typically less than 1 mg/L. Measurements have shown that this level of aluminium drops as the water is allowed to stand further. Typically values of less than 0.1 mg/L are reached after 12 - 24 hours standing, that being less than the levels of aluminium often found in drinking water.

3.3 Case Studies

3.4.1 Applications for Electroflocculation are many and varied, ranging from cleaning;

1. Dirty dam and river waters, which represent conditions typical of processing fresh water found in inland dams and rivers in Australia and many other countries. This water would otherwise be suitable for domestic use, were it not for the presence of the clay and sometimes other contaminants such as bacteria and algae, etc. The process works on suspended solids, down to the size of and including large dissolved molecules. Included in suspended solids are bacteria, algae, clay (from dam/river water), spores and some BODs. Included in large dissolved molecules are decayed organic matter (humus), dye molecules, some detergent molecules and a whole range of other materials. Typical removal rates are 98% + of what the process can remove.

2. Wastewaters from grease traps and oil traps have provided the most successful results with the removal of fats, oils and/or greases (FOGs) from emulsion in the water. Removal rates of greater than 99% have been achieved from a single stage process. When combined with a two-stage process, removal rates of greater than 99.95% have been consistently achieved in industrial applications treating up to 10,000 litres per day. As well as reductions in the FOG concentrations, the COD level has been reduced by over 96%.

Encouraged by these results it was determined to set up a pilot plant to ascertain the viability over time on societies worst quality water.

3.4.2 Sewerage Treatment Plant (STP) Effluent Aeration Treatment (EAT) Unit

Water in an EAT unit at a sewerage treatment plant was passed through one of these systems to determine the effects achievable using an electroflocculation treatment. Table 2 summarise some of the results obtained. Typically turbidity was reduced to below 2 NTUs, which, after settling, was further reduced. Bacteria counts were reduced by ≈ 98 - 99% in the primary treatment tank. This reduced the count sufficiently that only minor antiseptic treatment was required to further reduce the levels to zero. This could be done by the use of ultra violet light, or the electrolytic addition of silver, or both. This could eliminate the need for chlorination of the water. It should also be noted that the removal of the suspended solids was achieved without the addition of alum or other traditional coagulating agents.

In previous applications, this type of water has often been clarified by the addition of alum. As a result of this, the treated water has too high a salinity to be reused for agricultural purposes. However at the end of this treatment, it is seen that there has been no increase in salinity and as such, provided the other criterion are met, the water appears to be suitable for agricultural reuse. An indication of the removal rates of several parameters involved in the treatment of STP's EAT unit water is given in Table 2. Please note that these figures are a compilation of measurements made at different times and do not relate to individual sets of measurements. However, they serve to indicate the types of results, which have been achieved. The addition of silver as a disinfectant, typically 0.2 - 0.4 mg/L can considerably enhance the ability of the system to remove all faecal coliforms and the 0 faecal coliforms per 100 ml results were obtained after either ultra violet light or the addition of silver. Residual silver was 0.11 mg/L. The pH of the treated water was typically in the range 8 - 9. The low turbidities were achieved with the conductivity remaining well below 1,000 µS. Tests for pH, conductivity, turbidity and faecal coliforms were performed according to EL12, EL5, EL2 and EL28A respectively, Standard Methods for the Examination of Water and Wastewater, 19th Edition, 1995, APHA. Cryptosporidium and Giardia were tested according to G.C.W. 13.

Table 2.
Summary of some measured values obtained after treating EAT unit water using the electroflocculation based system.

	EAT	Electropure Treatment Plus Ultra Violet Light		
Faecal Coliforms	300,000 per [illegible]	[illegible]	[illegible]	0/ [illegible]
[illegible]	00/50L	[illegible]	[illegible]	[illegible]
Cryptosporidium	[illegible]	[illegible]	[illegible]	[illegible]

3.4 On-Zite (Environmental Sanitation System)

The On-Zite Wastewater and Sanitation System is a hybrid of the two technologies mentioned above.

The Wormfarm waste system is the primary processing area for the household organic waste material. Once the wastewater has been used for its primary purpose as a transportation medium, it is filtered through the organic layer and stored in the bottom of the Wormfarm waiting for processing.

The Elements of the 200Lt domestic Electroflocculation unit have been adapted to deal with a wide range of contaminants that may be present in raw domestic wastewater. Once the 200Lt of the wastewater has been stored in the base of the unit the microprocessors in the electroflocculation unit turns on the submersible pump and fills the processing tank. Processing time varies depending on the quality of the raw water and its conductivity is monitored regularly by the system to determine how clean it is, some settling time during processing is included to settle any heavy metals that aren't able to be raised in the flocculant, these are automatically flushed out after approximately 10,000 litres of processing, these are deposited with the flocculant into a small geotextile dewatering bag, (similar to the material used in the base of the Rota-Loo bins as filter). The water used to flush the flocculant and the heavier metals is returned to the system whilst the geotextile bag continues collecting waste until it is full, it is then simply removed, emptied and replaced. The average processing time is approximately 90 minutes. Once the

Electroflocculation unit has determined that its volume of processed water is clean the discharge pump is activated and the now clean water is pumped from the processing tank through a Sliver Colloidal disinfection unit into a “clean-water” storage tank ready for reuse at a “Class A” quality.

3.5.1 Effluent Reuse potential

“The key to any effective On-site wastewater treatment and sanitation system is the ability to produce a relatively high quality of reusable water”.

In the Australian Wastewater Industry it has long been recognised that the reuse potential is the key. The implications for water conservation are relatively self evident but the extents to which reusing water can have a compounding effect on reuse potential has been little explored. Some of the implications to the design of urban developments will be outlined a little later.

Worldwide, however, the most common use of reclaimed wastewater has been for agricultural and landscape irrigation. Recently, recharge and indirect and direct potable reuse have received consideration in places such as the United States. A repurification project in San Diego, California for example have proposed to blend repurified wastewater with local runoff and imported water in the local water supply storage reservoir (ZCPH, 1996). For individual decentralised systems, landscape irrigation will continue to be the principal reuse option. For small flows, landscape irrigation and similar applications will continue as the major reuse options. In isolated commercial and industrial facilities, toilet flushing in buildings with dual plumbing systems, and reuse for water features and landscape irrigation will continue. To maximise the reuse of treated wastewater at or near the point of generation, satellite reclamation plants will continue to increase in number (Tchobanoglous 1999) Satellite plants, may in fact be a larger version on an On-Zite system with a common Electroflocculation unit.

Categories of municipal wastewater reuse and typical applications (Tchobanoglous & Burton, 1991)

Wastewater reuse categories	Typical Application
Agricultural irrigation	Crop irrigation, commercial nurseries.
Landscape irrigation	Parks, Schoolyards, freeway median strips, golf courses, cemeteries, greenbelts, residential.
Industrial recycling and reuse	Cooling water, boiler feed, process water, heavy construction.
Groundwater recharge	Ground water replenishment, saltwater intrusion control, subsidence control.
Recreational/Environmental uses	Lakes and ponds, march enhancement, streamflow augmentation fisheries, snowmaking
Non potable urban uses	Toilet Flushing, clothes washing, car washing, fire protection, air conditioning, etc.
Potable reuse	Blending highly repurified water with existing water supply, pipe to pipe water supply

Potential applications for reuse will ultimately be governed by the quality of the water, in the state of Victoria, Australia the Environment Protection Authority (EPA) have classified three categories for wastewater reuse.

Performance Objectives for Wastewater reuse (EPA, 1996)

TREATMENT	**WATER QUALITY**	**OPTIONS FOR WATER REUSE**
"CLASS A" No restriction on public access	PH 6.5 – 8.0 (1) BOD < 10mg/L Turbidity ≤ 2 NTU (2) Coliforms < 1 org/100mL Viruses < 2 in 50 L Parasites < 1 in 50 L CL2 residual > 1 mg/L after 30 minutes contact or equivalent disinfection Nutrient, toxicant and salinity controls**	· Urban use (garden watering and toilets) · Agriculture (direct contact with crops)* · Aquaculture (human food chain) · Other uses subject to written EPA approval Any of the options listed in the classes below subject to satisfying the applicable precautions*
"CLASS B" Limited restrictions apply	PH 6.5 – 8.0 (1) BOD < 10mg/L SS < 15 mg/L Turbidity ≤ 2 NTU (2) Coliforms < 10 org/100mL 80th percentile < 40 orgs CL2 residual > 1 mg/L eg UV system Nutrient, toxicant and salinity controls**	· Aquaculture (Non human food chain) · Municipal use (uncontrolled access)* · Agricultural (contact with some crops)* · Pasture and fodder for milking cows and other animals* · Fire protection systems · Industrial but NOT for cooling towers
"CLASS C" Restricted access applies	PH 6.5 – 8.0 (1) BOD < 20mg/L SS < 30 mg/L Coliforms < 1000 org/100mL 80th percentile < 4000 orgs or equivalent level of disinfection, eg 30 day pond detention Nutrient, toxicant and salinity controls**	· Silviculture, fibre or fodder for grazing animals but NOT pigs · Horticulture and non human food crops* · Pasture (Not for pigs or milking animals)* · Municipal (controlled public access)* · Agriculture (no direct contact with crops)* · Ornamental water (restricted access) · Construction and mining industries*

Notes: All wastewater reuse projects shall be adequately signed, conforming with AS1319, (1) 90th percentile compliance, (2) 5 NTU maximum value, * A withholding period will be required between cessation of wastewater application and the site or product being accessible to the general public ie generally, dry pasture r 1 hour for Class A and B, 4 hours for Class C reuse.

Given the "Class A" water quality achieved with an On-Zite system and the size of a standard domestic residential block it is easy to see that the reuse potential will significantly impact on the overall amount of water used. Reuse can account for 70% of the household demand.

Domestic Customer Water Use Profile (WSAA, 2000)

Domestic Consumption Component	**Domestic Compliance or Task**	**Annual Consumption per average household (kL/year)**	**Percentage of average annual domestic consumption**	**Possible Savings with water efficient devices**
Kitchen	Dishwashing Sink	8.8 3.7	4 1	20%
Laundry	Washing Machine Trough	30.3 8.0	12 3	35%
Toilet	Cistern	48.6	20	50%
Bathroom	Shower Bath Basin	50.4 8.0 6.6	20 3 3	50%
Garden	Outdoor Use	86.0	34	
TOTAL		250.4	100	

Notes: Figures taken from Melbourne Water Corporation study on household consumption.

Thus reducing potable supply demand to 30% of current usage or the equivalent of increasing catchment size by 230%

3.5.2 Costs

3.5.2.1 INFRASTRUCTURE

The CSIRO in Australia have commenced a study independently of the water authorities to identify and generalise on the cost drivers associated with providing sewerage infrastructure for urban developments. As this information has as yet not been published we are unable to provide full details at this point, however a generalisation of the findings shows that on average the cost to provide sewerage reticulation over the last three years in the outer suburbs of Melbourne in fairly sandy/loamy soils has been in the vicinity of $5,300.00 per lot, however this has ranged from $3,000.00 to $10,000.00, thee costs have been for the provision of the reticulation with a connection point for each property and does not include the cost of the main transfer or treatment plant, nor the internal plumbing costs for each property owner.

Some additional costs which are relevant are the multiplying factors for different soils conditions, again, these figure have not yet been published are and therefore expressed as estimates, however, they do fairly well reflect the statistics gathered thus far. The multiplying factors for the following soil conditions are averages over standard trench widths from 300mm to 1200mm

Material	Multiplying factor
Sand	1
Light soil	1.15
Clay	1.28
Soft Rock	4.4
Hard Rock	7.25

These costs are fairly general and won't reflect the real cost of any particular development as they do not take into account other cost drivers, for example, that may be applicable in undulating terrain where more pump stations would be required than in a flat area. Cluster sizes, density, flow design etc are examples of other drivers which will effect the over all cost.

3.5.2.2 WATER, GLOBALLY

The cost of water according to Watertech Online in the beginning of September 2001 rated Australia's water as the third cheapest in a snapshot of world published prices. At US 48 cents per cubic metre, it topped only Canada and South Africa. Water in Europe was the most expensive. Of the 14 countries polled, European countries filled the top nine places, lead by Germany at $2 a cubic metre. The US ranked 10th at $1 per cubic metre. Average price in the 14 countries polled increased 3.8 per cent over the past year to US 76.4 cents per cubic metre. Only the Netherlands reported a fall with a decrease of 0.8 per cent, but it was still the fourth most expensive.

3.5.2.3 COMPARISON

Comparing the cost of reticulated sewerage infrastructure to that of an On-Zite system at first glance may not seem very favourable, as the cost of the On-Zite system is around $10,000.00 per house site, however as mentioned above the infrastructure costs given only accounts for around 75% of all the cost drivers, and the total infrastructure costs, only account for 60% of the total capital expenditure with a further 40% of total capital expenditure needed for treatment (The Australian Urban Water Industry, 1998). The On-Zite system is in fact considerably cheaper to install than reticulated sewerage when one considers the systems potential as a decentralised system. The final design of the OnZite system will have the capacity for modularisation where the primary treatment tank and electroflocculation component can be removed and separated, therefore allowing each individual household to have only the primary treatment on-site. As mentioned previously the quality of the wastewater from the primary treatment system can yield a 20mg/l BOD and 30mg/l of SS making its transportation from the primary tank relatively easily. In fact, a 25mm poly irrigation

pipe is all that is needed to convey the wastewater to a site where a larger Electroflocculation unit is installed, capable of processing the wastewater from several houses. With the current sizing of Electroflocculation unit available a development or decentralised community of up to 50 houses can benefit from this type of system with a capital outlay of only $4,000.00 per household including the trenching and pipe-work.

The operating cost of the On-Zite system is also considerably less expansive than the cost of the supply of mains reticulated water. Whilst, using the Australian example above of US 48 cents per cubic metre, an On-Zite system can produce a "Class A" quality reusable water for around US 20 cents per cubic metre, whilst at the same time reducing the demand from the external reticulated supply by some 70% and their overall cost of water by almost 60%

Other cost advantages of advanced decentralised technologies like the On-Zite system are currently being compiled by the Rocky Mountain Institute in the USA. The U.S. Environment Protection Agency funded project entitled "Valuing Decentralised Technologies for Water Quality Protection: A Catalogue of Benefits and Economic Analysis Techniques" will be available for release in June 2002

The possibility for completely autonomous communities now can be seriously considered when potable water catchments from collective rooves are designed into residential development plans.

3.5.3 Implications for urban development

The most significant implication for urban developments is the understanding that any development with a residential block size not large enough to utilise the entire recycled water generated for reuse will in fact produce a net export from the site. Under normal conditions using conventional on-site systems which are unable to generate a high quality of recycled water this can be a significant and limiting factor, however as the On-Zite system is capable of achieving a "Class A" which in effect is of a quality equal to or better than stormwater, any discharge from a residential block should be able to be discharged to the stormwater or equivalent (such as swales) infrastructure. In medium or higher density developments this means that the entire sewerage infrastructure can be negated, saving significant costs for the overall development.

The potential then for further reuse of water can be made available for such things as irrigation of parklands in areas around clusters of houses, irrigation for communal market gardens, or Permaculture designed edible landscapes, for artificial larks, aquaculture or for fire fighting.

These cluster reuse potentials can also be combined into larger scale projects where more significant amounts of reusable water can be made available for recreational

purposes, for commercial use as in light industry or even sold back to the nearest water authority.

4.0 Small Scale to Large Scale Projects.

4.1 Ballarat Grammar School

A prototype of the On-Zite system was installed at Ballarat Grammar School in central Victoria in early 2001 after we entered and won the tender for the "Wastewater Reuse Scheme for the Year Nine Centre."

The following is an extract from "The Specifications for Wastewater Reuse Scheme for the Year Nine Centre at Ballarat Grammar School."

Overview

A wastewater reuse scheme has been proposed that is consistent with the philosophy of sustainability that underlies Ballarat Grammar School's new Year Nine Centre. Potable water servicing basins, sinks and the hot water system will be collected from the roof runoff and stored in a rainwater tank . Water for toilet flushing will be recycled from the combined basin sink and toilet wastewater. Wastewater will be treated to comply with the health and environment standards and sterilised prior to use within the toilets.

These water supply approaches illustrate the principles of ecologically sustainable development. The State Environment Protection Policies (SEPPs) encourage the recycling and reuse of wastewater and the irrigation of effluent on land (EPA 1996b). By capturing, using and recycling rainwater within the Year Nine Centre, the school will be reducing the catchment wide environmental impacts of stormwater and wastewater. In addition , the use of biological technologies such as wormfarms and wetlands ensure educational opportunities are maximised. Students and staff can safely interact with many aspects of such systems and be involved in day-to-day management activities, for example flushing of downpipes to keep potable water quality high, harvesting or reeds and worm castings to recycle nutrients and testing of water quality parameters in the laboratory.

The wastewater reuse system described in this document achieves the dual aims of avoiding degradation of the environment and risk to public health (EPA1996b). Best Practice Management guidelines (EPA 1996b) have been followed in the design and documentation of the system.

The Year Nine Centre will be the classroom base for 150 students and 6 staff…

Year 9 Building, Ballarat Grammar School
Unplanted Reed-Bed in the foreground, Wormfarm Waste System and Electroflocculation Unit against building.

Partially Installed System.
(Top of Wormfarm exposed beneath compost bin, Electroflocculation Unit against wall under window line, MIMIC panel under facing window.)

4.2 Environmental Suburb (Appendix IV)

On Thursday, April 26th 2001 the Victorian State Minister for Planning, Mr Thwaites unveiled a proposal for a major new urban development project to be undertaken by the Urban Land Corporation (ULC) in Melbourne's northern suburbs.
The Media Release from the Ministers Department explained that Mr Thwaites described the project as the largest ever undertaken by the ULC and that it will set new standards for environmentally friendly development.
"The project will create a new suburb at Epping North for 8000 households, ultimately accommodating 25,000 people," Mr Thwiates said.
"The development will embrace "new urbanist" design principles that seek to improve the quality and sustainability of urban development while creating more liveable communities.
"The Epping North development will be a model of environmentally friendly design, including:
§ Energy efficiency
§ Reusing and recycling water
§ Reducing waste
§ Reducing car dependence.

"The development will be designed so people can walk through it rather relying on a car.
"The activities of the Urban Land Corporation are being directed to the Government's commitment to promoting high quality and more sustainable growth of Melbourne's suburbs.
"The new development will provide a practical demonstration of the improvements in urban and environmental design that the Bracks government believes should become the norm for urban developments in Victoria.
"For too long, councils and the community have been prepared to accept developments which fell short of satisfying the crucial tests of environmental sustainability and of developing communities with a strong sense of place and not just housing estates. The time has come to "lift the bar" and take a more demanding and longer term view of our investments in new urban development," Mr Thwiates said.
The media release went on to say that the project would be undertaken progressively over 15 years and would have an end value of approximately $1.8 Billion.
"People said that environmentally sensitive design, community building and support for sustainable transport systems are all seen as critical to a sustainable city."

Coomes Consulting Group of Melbourne are the engineers responsible for the engineering, surveying, town planning & design as well as the project management, landscape architecture and environmental science aspects of the overall project. We are currently liasing with Coomes on the design implications of On-Zite systems and for which we have received a letter of interest from them for pursuing the application of this system for this and other projects on individual or neighbourhood basis's.

5 Summary

Increasing global populations and the demand for economic growth are straining the limited global resources available. The most fundamental of these resources and the greatest limiting factor to our survival and growth is the availability of clean water. The systems we design to deal with our wastewater and sanitation in the future will be the most significant challenges for engineers, architects and town planners.

"The key to any effective On-site wastewater treatment and sanitation system is the ability to produce a relatively high quality of reusable water".

Given the "Class A" water quality achieved with an On-Zite system and the size of a standard domestic residential block it is easy to see that the reuse potential will significantly impact on the overall amount of water used. Reuse can account for 70% of the household demand. ***Thus reducing potable supply demand to 30% of current usage or the equivalent of increasing catchment size by 230%***

The most significant implication for urban developments is the understanding that any development with a residential block size not large enough to utilise the entire recycled water generated for reuse will in fact produce a net export from the site. Under normal conditions using conventional on-site systems which are unable to generate a high quality of recycled water this can be a significant and limiting factor, however as the On-Zite system is capable of achieving a "Class A" which in effect is of a quality equal to or better than stormwater, any discharge from a residential block will be able to be discharged to the stormwater infrastructure. In medium or higher density developments this means that the entire sewerage infrastructure can be negated, saving massive costs for the overall development.

The operating cost of the On-Zite system is also considerably less expansive than the cost of the supply of mains reticulated water. Whilst, using the Australian example given earlier of US 48 cents per cubic metre, an On-Zite system can produce a "Class A" quality reusable water for around US 20 cents per cubic metre, whilst at the same time reducing the ***overall cost of water by almost 60%***

"Ecologically informed Sanitation Systems with Water recycling is The Way of the future.

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