WASTEWATER TREATMENT, TECHNOLOGIES AND RESOURCE RECOVERY – M8

Eco-efficiency opportunities for Queensland manufacturers

Choosing the right treatment

Most manufacturers produce wastewater, whether it is generated as part of the production process or cleaning equipment after use. It is often regarded as just an unavoidable expense. However, often savings can be found if time is taken to consider how and why wastewater is generated. Savings can come from actions such as:

- minimising the production of wastewater
- reduction in disposal costs
- product recovery
- water reuse on or off site
- energy recovery.

This fact sheet is targeted at those manufacturers who are starting to understand their wastewater costs and investigating treatment options.

Reduce wastewater production with water efficiency

When wastewater is disposed of to the sewer manufacturers generally pay for both the quantity and the quality of the water. Therefore before investing money into treatment systems, reducing the amount of wastewater generated and the amount of pollutants going to the sewer can have an immediate impact on costs for very little capital.

Dry cleaning is a great way to reduce the amount of wastewater generated and can also help reduce the amount of pollutants entering the wastewater stream. Use a broom, squeegee or mop and bucket instead of a hose to clean up spills reducing wastewater generation.

Other options to reduce water consumption can also be investigated such as reusing relatively clean water such as final rinse water for first wash, reduce flow of hoses and optimising sprays and nozzles.

Dry cleaning will reduce wastewater generation.

REDUCING WATER USE BY 52 PER CENT THROUGH CHANGES IN PRACTICES

Food processing company, Australian Food Corporation, reduced their water consumption from 3.10 kL per tonne of product to 1.49 kL per tonne of product over three years through a series of changes to water practices in the factory, including:

- replacing all inefficient taps saving 296 kL/year
- reducing the defrosting cycle of freezers saving 5500 kL/ year
- turning off sprays when the conveyor was not running saving 13 kL/year
- replacing interlocking belts with flat belts saving cleaning time and 788 kL/year
- retraining staff to operate hoses more effectively and to preferably dry clean or use buckets to wash spills on floors during manufacturing.

(Australian Food Corporation is an ecoBiz participant)

For more information on more efficient cleaning methods view the cleaning methods and practices (M9) fact sheet in this series.

Selecting a wastewater treatment system

When choosing a wastewater treatment system, consider the quantity and quality of the wastewater stream. Testing the wastewater during periods of typical operation is a good way to obtain an understanding of the composition of the wastewater stream and which contaminants need to be removed. Obtaining a list of tradewaste categories can help manufactures determine if their wastewater is being charged correctly and if an improvement in quality will reduce costs.

If water is to be reused, the quality and quantity of wastewater produced and that required for reuse should be considered. For example, the quality of water produced by energy intensive reverse osmosis would not usually be necessary (or cost effective) for irrigation. However, it may be cost effective if the water can be used within the process.

Future changes to operating conditions should also be considered. If wastewater quantity or quality fluctuates during the year then any treatment system need to be robust enough to handle these fluctuations. Similarly, building in flexibility will avoid system duplication. Carrying out an eco-efficiency program can minimise the total effluent loads on a system, saving capital and operational costs.

Additional factors to consider include:

- where the water can be used
- what quality is needed to allow reuse
- operating costs
- mains water charges
- energy use or potential to generate energy
- potential to recycle wastewater
- potential to recover product
- chemical costs
- space availability
- infrastructure requirements
- labour requirements including skills
- maintenance requirements.

Wastewater technologies

Generally wastewater treatment is run as a system (or treatment train) using several steps each with a function to improve one or more aspect of the wastewater. A treatment train approach of two or more treatment systems may provide a better solution than a single system. Treatment generally runs through several steps which can include:

1. pre-treatment such as large object removal, balancing flows and pH adjustment
2. primary and secondary treatment – bulk removal of contaminants
3. tertiary treatment – polishing water to meet requirements (excluding membranes)
4. membranes – removal of contaminants to higher levels
5. sludge management – treatment of sludge produced by the wastewater treatment to reduce disposal costs.

Many companies simply undertake pre-treatment in conjunction with water efficiency measures such as flow reduction and pollutant prevention and discharge to sewer. However for those companies that want to undertake more extensive onsite treatment, the following tables provide an indication of what is available.

Table 1 - Common pre-treatment techniques

Treatment	Description	Contaminant removal	Advantages	Disadvantages
Screens	Floating booms or static screens are used to remove bulk items such as plastics or wood.	Large solids, sometimes oils.	Good removal of bulk material. Low operating and capital costs.	Can become clogged if the opening size is too small for the types of contaminants or not properly maintained.
Filtration	Using media such as sand or crushed glass, filtration captures contaminants as the wastewater passes through the filter media.	Medium size particles removed. Organic matter.	Low capital and operating costs compared with membranes. Can be used as trickling filter bed with microorganisms removing organic matter.	Can become clogged and may need pre-treatment.
Balancing tank	One or more storage tanks to regulate fluctuations in flow quantities or qualities.	Damping fluctuations in water quantity and quality.	Low capital and operating costs. Can assist in improving performance of other components of the wastewater system.	Requires a significant amount of space which may not be available if not built into the original design.
pH adjustment	Addition of chemicals to adjust the pH to acceptable limits for either further treatment or disposal to sewer.	Adjusts acidic or alkaline wastewaters.	Low operating and capital costs. Can be automated. Can be sufficient to meet tradewaste licence conditions.	Does require the addition of chemicals to a waste stream.
Flocculation	Addition of chemicals to remove particles.	Suspended solids.	Low operating and capital costs. Can be automated.	Does require the addition of chemicals to a waste stream.
Grease trap	Uses physical means to remove floating fats oils and grease from wastewater as well as sludge.	Fats oils and greases.	Low capital and operating costs.	May not handle fluctuations in flow quantity. Needs pumping out regularly.
Pre-settling tank	Physical removal of particles from the water using gravity and time.	Sediment, small particles.	Low capital and operating costs.	May not handle fluctuations of flow and if not sized correctly will not settle properly. Needs pumping out regularly.

Table 2 - Common treatment techniques

Treatment	Description	Contaminant removal	Advantages	Disadvantages
Clarifier	Clarifiers can be a combination of both settling and/or flotation mechanisms to remove contaminants. They can be used in both the front and back ends of wastewater treatment systems. Similar to settling tanks, clarifiers use gravity to form a sludge from settled contaminants.	Suspended solids and grit.	Can handle larger quantities.	Requires a significant amount of space which may not be available if not built into the original design. Can become unstable if flocculent dosage is incorrect or wastewater characteristics change. Needs vigilance to ensure good operation.
Dissolved Air Flotation (DAF)	Uses high pressure air pumped into the stream to entrain insoluble material particularly fats, oils and greases (FOGs). Bubbles float to the surface with the FOGs which are then skimmed off. Sludge falls to the bottom and is then removed.	Insoluble material FOGs, reduces total suspended solids, biochemical oxygen demand (BOD) and chemical oxygen demand (COD).	Can be useful as pre-treatment prior to discharge to sewer to reduce tradewaste charges. Easy to install and operate. Can deal with high rates of operation and variation in flow quality if well designed with balancing tanks.[1]	Does not remove soluble material for example sugars. Can have high capital and operating costs. Can have high energy and chemical requirements.
Anaerobic Digestion	An oxygen-free environment digests organic component in the wastewater to generate biogas. The gas can be captured and used as a fuel source.	Organic matter (BOD and COD reduction), organic suspended solids.	Conversion of up to 90% of potential energy in carbon from wastewater into retrievable biogas. Low energy requirement. Small amount of biomass produced, therefore low sludge disposal costs. Smaller space requirements and lower requirements for nutrient dosing compared with aerobic treatment options. Good for treating wastewater streams with high organic content.	Long start-up periods. Does not manage fluctuations in flow rate or strength well. Limited use for dilute waste streams. Effluent output slightly higher organic content than aerobically treated waste. May produce odours. May contain methane dissolved in effluent.
Aerobic digestion	Removal of organic matter in the presence of oxygen. Generally air or oxygen is added. Activated sludge plants are examples of aerobic digestion.	Organic matter (BOD and COD reduction), organic suspended solids.	Robust, flexible, quick. Adaptable for dilute waste streams. Good for polishing of anaerobic effluent streams.	High energy requirements for aeration. Large amounts of biomass generated so therefore high sludge disposal costs. Higher costs for nutrient dosing. Larger space requirement than anaerobic digestion.
Biological Nutrient removal (BNR)	BNR comprises of two processes: Biological nitrogen removal and biological phosphorous removal. The nitrogen removal phase is an aerobic step while the phosphorous is an anaerobic phase.	Nutrients, some BOD/COD reduction. Depending on the design, removal of Total Nitrogen to 2mg/L [2] and Phosphorous of ›2 mg/L if BNR in conjunction with depth filtration and disinfection.[3]	Enhanced nutrient removal, reduced sludge production, (also better settlement and dewatering of sludge).[4]	High technical and operational expertise required. High capital and operational (energy) costs. Complicated system configuration.[5]

1 Envirowise, Dissolved-air flotation (DAF) application and design. **www.envirowise.gov.uk/166728**.
2 Daigger, Glen T., John A. Buttz, 1998, Upgrading Wastewater Treatment Plants, CRC Press.
3 Asano, Takashi, Metcalf & Eddy, Franklin L. Burton, Harold L. Leverenz, Ryujiro Tsuchihashi, George Tchobanoglous, 2007, Water Reuse: Issues, Technologies, and Applications, McGraw-Hill Professional.
4 Makaya, E., Z. Hoko, W. Parawira and E. Svotwa.2007, An Assessment Of The Effectiveness Of Biological Nutrient Removal From Wastewater: A Case For Hatcliffe Sewage Treatment Works In Zimbabwe. EJEAFChe, 6 (10),.2409-2419.
5 Makaya et al, 2007, An Assessment Of The Effectiveness Of Biological Nutrient Removal From Wastewater (as per 4).

Table 3 - Common tertiary treatment techniques

Treatment	Description	Contaminant removal	Advantages	Disadvantages
Ion exchange	Water is passed through resin beads which contain fixed sodium ions. When contaminants such as salts in the water pass past these beads they replace the sodium on the beads and are removed from the water.[6]	Salts including hardness. Other chemical contaminants including organic residues.	Low maintenance and long life of resins if operated correctly.[7] No addition of chemicals to the water. Can be used to accumulate substance for product recovery. Applications include demineralisation and water softening.	Spent brine product may be difficult to dispose of. Fouling of resins may occur due to contaminants in the wastewater such as organic matter.[8] Resins need to be regenerated after approximately 12-48 hours.[9]
Chlorination	Addition of chemicals as a sanitiser. Can be automated.	Bacteria, viruses, protozoa.	Provides residual sanitisation.	Adds chlorine to the water.
Ozonation	Application of ozone can reduce organic compounds.	Bacteria, viruses and protozoa.	No residuals in the water. Ozone degrades to oxygen which is non-toxic.	Does not provide residual sanitisation. Can have high operating costs due to the amount of energy required.
UV radiation	Chemical free method of disinfecting water. Ultraviolet radiation passes through the water killing microorganisms.	Microorganisms such as protozoa, bacteria, moulds and yeasts.	Effectiveness increased if used in conjunction with ozone.[10]	Needs frequent maintenance and replacement of lamps which can be costly. Water quality characteristics such as high turbidity, organic components and flowrate can reduce efficacy. Does not provide any residual sanitisation.
Activated carbon	Generally used after biological or physical-chemical treatment. Adsorbs both organic and inorganic compounds.	Organic and inorganic compounds. Heavy metals, algae bloom (toxin).	Used prior to a disinfection phase can reduce the amount of disinfection required. If used as part of the cooling tower or boiler water treatment can lead to better water efficiencies and reduced bleed.	Although the carbon can be regenerated, it will eventually have to be disposed of.
Sonication	Uses vibrations to emulsify fats making them easier to remove by methods such as DAF.	Fats.	If used in conjunction with anaerobic digestion can potentially increase biogas yields.	Needs to be used in conjunction with other treatment measures.
Electrocoagulation	Electric current passed through water to initiate a range of electrochemical reactions which destabilise, suspend, emulsify and dissolve contaminants forcing them to precipitate.	Suspended and colloidal solids, fats, oils grease and complex organics. Removes colour and odour.	Large size flocs can be easily separated using filters. Increased reduction in total suspended solids compared with chemical means. No moving parts so low maintenance. Simple equipment and easy to operate.[11]	Sacrificial electrodes need to be replaced frequently.[12] Operating costs can be high with electricity use and electrode replacement or fouling. High capital costs as they are not widely sold.
Hydrocavitation	Chemical free system accelerates two streams to high velocities and collides them producing hydrodynamic cavitation and mechanical sheer forces to kill bacteria and reduce corrosion activity.	Bacteria. Reduced corrosion.	Beneficial for cooling towers. Studies investigating efficiency of removing heavy metals, phosphorous and trichloroethylene (TCE) from water.	Not good for applications where next to zero micro-organism counts are required, e.g. food, pharmaceuticals. Not yet widely used.

6 Stevenson, D. G., 1997, Water Treatment Unit Processes, Imperial College Press, 26.
7 New Zealand Institute of Chemistry, Ion exchange resins, **nzic.org.nz/ChemProcesses/water/13D.pdf**
8 New Zealand Institute of Chemistry, Ion exchange resins (as per 7).
9 New Zealand Institute of Chemistry, Ion exchange resins (as per 7).
10 EHEDG Update, 2005. "Safe and hygienic water treatment in food factories" Trends in Food Science & Technology 16, 568-573.
11 Yousuf M., A. Mollah, Robert Schennach, Jose R. Parga and David L. Cocke, 2001, Electrocoagulation (EC) — science and applications, Journal of Hazardous Materials Volume 84, Issue 1, 1 June 2001, Pages 29-41.
12 Yousuf et al., 2001, Electrocoagulation (as per 11).

Table 4 - Membrane techniques

Treatment	Description	Contaminant removal	Advantages	Disadvantages
Microfiltration (MF)	Physical barrier uses pressure (created using energy) to force the "permeate" through pores of the membrane and the concentrated "retentate" retains the contaminants. Filtration down to 0.45 microns.	Bacteria and suspended solids. Typical uses include clarification of fruit juice, wine and beer.	Costs of the membranes continue to decrease as they become more widely used. Removal of contaminants that pass through other treatment systems. Good for pre-treatment for NF or RO.	High capital costs. High operating costs in terms of energy use and membrane replacement. Disposal of retentate can be difficult as municipal sewage treatment plants may not accept it due to the high contaminant concentrations.
Ultrafiltration (UF)	Physical barrier uses pressure (created using energy) to force the "permeate" through pores of the membrane and the concentrated "retentate" retains the contaminants. Filtration down to 0.01 microns.	Bacteria and protein. Typical uses include separation of protein in milk.	Costs of the membranes continue to decrease as they become more widely used. Removal of contaminants that pass through other treatment systems. Good for pre-treatment for NF or RO.	High capital costs. High operating costs in terms of energy use and membrane replacement. Disposal of retentate can be difficult as municipal sewage treatment plants may not accept it due to the high contaminant concentrations.
Nanofiltration (NF)	Physical barrier using pressure (created using energy) to force the "permeate" through pores of the membrane and the concentrated "retentate" retains the contaminants. Filtration down to 0.001 microns.	Bacteria, protein, sugars, large salts and caustic from clean-in-place systems.	Costs of the membranes continue to decrease as they become more widely used. Removal of contaminants that pass through other treatment systems. Good for desalting gelatine, sugar decolourisation, concentration of food, dairy and beverage products or by-products.	High capital costs. High operating costs in terms of energy use and membrane replacement. Disposal of retentate can be difficult as municipal sewage treatment plants may not accept it due to the high contaminant concentrations.
Reverse Osmosis (RO)	Physical barrier uses pressure (created using energy) to force the "permeate" through pores of the membrane and the concentrated "retentate" retains the contaminants. Filtration down to 0.0001 microns.	Generates extremely pure water. Bacteria protein, sugars, large salts, caustic from clean-in-place systems	Costs of the membranes continue to decrease as they become more widely used. Removal of contaminants that pass through other treatment systems. Application for processes that require extremely pure water such as beverage products such as beer, feed water for boiler and cooling tower.	High capital costs. High operating costs in terms of energy use and membrane replacement. Disposal of retentate can be difficult as municipal sewage treatment plants may not accept it due to the high contaminant concentrations. Requires pretreatment (generally at least to MF level) otherwise membranes have to be replaced too frequently.
Electrodialysis	Dissolved salts form ions with a positive or negative charge. An electrical charge is placed on two end electrodes forming a potential gradient. The membranes are positively and negatively charged repelling or attracting the salt ions making concentrated streams.	Contaminants that can be charged, particularly salts.	Most economic at low salinity levels.[13] Applications include: demineralisation of whey, wine stabilisation.	Upper limit of salinity of inflow at 1500-2000 mg/L. High capital costs. High operating costs in terms of energy use and membrane replacement. Disposal of retentate can be difficult to dispose of as municipal sewage treatment plants may not accept it due to the high contaminant concentrations.
Membrane Bioreactors	A combination of membrane and biological treatment of effluent. Generally a two tank process. The membranes are either UF or MF.	Organics, bacteria and proteins.	Can reduce space requirement by 50%.[14] Suitable for retrofit and upgrade of existing plants. Hydraulic retention time (function of flow rate) is independent of sludge retention and so the system is able to cope with inflow fluctuations of both quantity and quality. Provides excelled pre-treatment to RO or NF.	Uses more air and energy than conventional treatment.[15] Installation costs are relatively low, however, equipment costs are high – due mostly to the membranes.[16]

13 Stevenson, D. G., 1997, Water Treatment Unit Processes, Imperial College Press, 30.
14 Layson, A. and L. Sorgini, November 2007, "Low-pressure membranes help solve water scarcity", Water, Australian Water Association, Volume 34, No.7. 34-36.
15 Pearce, Graeme, 2008, An introduction to membrane bioreactors Filtration and Separation January/February 2008, 32.
16 Pearce, 2008, An introduction to membrane bioreactors (as per 15).

Table 5 - Common sludge management techniques

Treatment	Description	Contaminant removal	Advantages	Disadvantages
Filter Press	In this batch process, the liquid sludge is pumped through a filter and retained on a filter cloth that may need the addition of a filter aid. Polymer can be added to improve dewatering.	Compacts sludge to reduce storage, transport and disposal costs. Particularly good if cake is considered a hazardous material due to contaminants such as heavy metals.	Produces the highest cake concentrations. Operating costs can be lower than other methods especially when storage and transport are considered. Filtrate (liquid) quality can be better (lower in contaminants) than other dewatering methods.[17]	Initial costs can be high. Requires maintenance to ensure all cake is removed from the filter cloth after each load. Some systems are not automated and manual labour is required to remove the cake.
Belt filter press	Liquid sludge is applied between two belts which are pressed together to remove the water to produce "cake". This is a continuous process. Polymer can be added to improve dewatering.	Compacts sludge to reduce storage, transport and disposal costs.	Reduced costs of the disposal of sludge. Reduced footprint compared with large dewatering ponds. Reduces storage and transportation costs of cake. Cake can be composted if not contaminated by substances such as heavy metals or plastics. Labour requirements low and maintenance simple.[18] Quick start up and shut down. Less noise than centrifuge.[19]	May not be economical at low flowrates as equipment costs are high. May cause odour problems but can be controlled.[20] Oils and greases can cause problems with the filters. Sharp objects may damage the filter belt. Belt washing can be time consuming. Self-cleaning belt filter presses are available.[21]
Vacuum filters	A vacuum is applied to a filter pulling wastewater through and retaining the solids in a cake on the media.	Compacts sludge to reduce storage, transport and disposal costs.	More compact than drying beds. Continuous process.	Not appropriate for dilute sludge due to the high amount of energy required to remove the water.
Centrifuge	A rotating cylinder with a conical end allows solids to fall to the end and water discharge from the other end. Polymer can be added to improve dewatering.	Compacts sludge to reduce storage, transport and disposal costs.	Low space requirements. Can handle both dilute and thick sludge.[22] Many different types are available.	Unsuitable for high flowrates.
Drying beds	Drying beds are large areas onto which liquid sludge is discharged. Solar drying beds are shallow concrete beds exposed to the sun which evaporates the water from the sludge to produce cake for disposal. Alternatively, the beds can be sand drying beds with the sludge applied on a bed of sand and the liquid filtering through the sand to a drain.[23] Dry sludge can be removed manually or mechanically.	Solar beds appropriate for alum and ferric sludges.[24] Compacts sludge to reduce storage, transport and disposal costs.	Low operating costs. Yields can be improved through the addition of polymer.	Require large areas. Retention time within the beds can be significant especially for dilute sludge and during periods of wet weather. Contaminated run-off during wet weather can be difficult to contain.
Landspreading	Application of the biosolids component of sludge onto land. Biosolids can be further processed into granulated product for application as a fertiliser.	Removes the need for disposal of sludge to landfill.	Low disposal costs. Returning nutrients to the soil.	Requires dewatering first. Contaminants in the sludge may prevent landspreading, such as heavy metals. Transport costs to the area for landspreading may be high.
Compost	Composting converts biosolids from sludge to a microbiologically stable and less odorous soil additive through a decomposition process using oxygen, water and bacteria.	Removes the need for disposal of sludge to landfill.	Low disposal costs. Returning nutrients to the soil.	Requires dewatering first. Contaminants in the sludge may prevent landspreading, such as heavy metals. Onsite composting may not be possible due to space restrictions and transport of waste to composting facility may be costly.

17 Bratby, John, 2006, Coagulation and Flocculation in Water and Wastewater Treatment, IWA Publishing.
18 United States Environmental Protection Agency, 2000, Biosolids Technology Fact Sheet: Belt Filter Press, EPA 832-F-00-057, September 2000.
19 United States Environmental Protection Agency, 2000, Biosolids Technology Fact Sheet: Belt Filter Press (as per 18).
20 United States Environmental Protection Agency, 2000, Biosolids Technology Fact Sheet: Belt Filter Press (as per 18).
21 United States Environmental Protection Agency, 2000, Biosolids Technology Fact Sheet: Belt Filter Press (as per 18).
22 Bratby, John, 2006, Coagulation and Flocculation in Water and Wastewater Treatment, IWA Publishing, 375.
23 Bratby, John, 2006, Coagulation and Flocculation, 360 (as per 22).
24 Bratby, John, 2006, Coagulation and Flocculation, 361 (as per 22).

The Golden Circle hydrocavitation system

HYDROCAVITATION SAVES MONEY AND WATER

Golden Circle saves thousands of litres of water and dollars per year through the installation of a hydrocavitation system on cooling tower water. Cycles of concentration in the cooling towers has been increased from 3 to more than 7, saving approximately 8 ML/year and chemical use has significantly dropped. The reduction in chemical usage had an additional bonus of reducing wastewater treatment requirements. The hydrocavitation system is leased by Golden Circle at a rate considerably less than the savings, providing a cost effect option.
(Golden Circle is an ecoBiz participant.)

Resource Recovery

Product recovery

Often it is possible to recapture raw materials lost to wastewater. This not only recovers a valuable resource but also reduces the pollutant load and tradewaste costs. Recovery through physical or chemical means is becoming increasingly more popular as raw material costs increase. Membranes mentioned in Table 4 above can be used to extract product without physically or chemically changing it. Chemicals can often be used to precipitate wastewater components such as dissolved metals.

Energy recovery

Wastewaters high in organic matter, such as those from food processing factories, may be suitable for biogas extraction through methods such as anaerobic digestion. Methane (biogas) can be used as an energy source.

UASB at Foster's Australia

BENEFITS OF UASB

A brewery, Foster's Australia, uses an upflow anaerobic sludge blanket (UASB) process to reduce chemical oxygen demand in its wastewater stream from approximately 5500 mg/L to 200 mg/L. Once in operation, the UASB is quite robust, responding quickly to start-up and shut down periods. In addition, biogas produced by the process is collected and used in the boiler providing 20 per cent of the site's energy use or approximately $750,000 in energy savings per year.

Wastewater recycling

Water recycling should only be considered once potential water reuse options and process optimisation has occurred. Government regulations and approvals must be gained before using recycled water especially in industries such as health and food.

While there has been some hesitation to embrace the use of recycled water in the past, changes in water management policy may help to increase acceptance.

For more information visit: The Queensland Water Recycling Guidelines
www.derm.qld.gov.au/services_resources/item_details.php?item_id=204566&topic_id=23

and the Australian Guidelines for Water Recycling Phases 1 and 2.
www.ephc.gov.au/search/node/water%20recycling

These documents focus on water recycled through municipal treatment plants but can provide some guidance for internal recycling. A risk based approach has been adopted and should be applied to any on-site water recycling.

Third party install and operate

There are several water treatment companies that offer to install and operate wastewater treatment systems on site, providing water back to the manufacturer for a fixed price. The third party can operate the whole system or just part of the treatment train. The benefit for the manufacturer is the supply of an alternative and secure water source at a reduced rate without the expense or problems of maintaining a complex treatment system. The third party operator benefits from the fixed income of the treatment system for a set period of time.

This series of fact sheets provides examples and suggestions to the modern manufacturer on how to achieve both economic and environmental benefits from eco-efficiency. Visit the project website **www.ecoefficiency.com.au** for more ideas and case studies.

The eco-efficiency for the Queensland manufacturers project is an initiative of the Department of Employment, Economic Development and Innovation and the Department of Environment and Resource Management with technical information provided by UniQuest through the Working Group for Cleaner Production. For further information visit the project website www.ecoefficiency.com.au

00976