Technology Overview (Public Distribution)

Aquamill® water purification technology

For further information please contact:

David Aizenstros (0407 320 836)

Peter Vudrag (0430 080 353)

Aquamill® Five Star Pty Ltd
ACN 118 563 956
18 Natalia Av
Oakleigh South
Victoria 3167
Australia

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1 The Industry

1.1. Water Treatment and Purification

In order to appreciate the many benefits of the Aquamill® technology it is useful to have a general understanding of water treatment and purification so as to put our process into context.

Water quality is generally measured in terms of its physical, chemical and biological characteristics. The treatment of water depends on the water quality required for its end-use and the types of impurities in the incoming water. These range from the removal of contaminants to allow the discharge of water back into the natural environment through to purifying water for both human consumption and industrial purposes. The impurities in water may be present as insoluble particles of varying sizes or dissolved substances of biological or chemical origin.

Water can contain particles or dissolved substances such as:

- Large foreign particles e.g. soil, sand
- Minerals e.g. heavy metals, nitrates, iron, sulphur, salts
- Pathogens e.g. bacteria, viruses, fungi, parasites
- Chemicals e.g. volatile organic compounds (VOC's)

Accounting for water due to its increased cost and reduced availability has begun to exert pressure on industry for more of it to be re-cycled and for it to change the way it is used. In addition governments and the public in the future will expect industry to use water that has been recycled from waste water treatment plants as well as recycling more of its own.

There are four main issues associated with purifying water:

1. **Cost** of the equipment and its operation over the lifecycle of the plant from manufacture and installation through operation (including maintenance and waste disposal) to disposal at the end of its life.
2. **Environmental impact** includes the energy used, efficiency of water conversion and handling of the waste by-products from the water treatment process.
3. **Human health impact** takes into account the level of water purity and possible side-effects of chemical additives.

4. **Technical issues** includes the presence in water of visible particles that can affect the functioning of machinery; bacteria and viruses that pose occupational health and safety (OH&S) problems; salts that can negatively impact industrial processes; and organics (such as tannin from wood) hormones and antibiotics that may pose OH&S or maintenance issues.

Aquamill®'s technology addresses each of these issues:

1. **Cost -** It has a small footprint, and modular design with few moving parts which make it easy to manufacture, assemble and maintain. Furthermore as the system operates at atmospheric pressure, it is a cost effective, energy efficient solution for purifying water and concentrating the contaminants in the concentrate stream.

2. **Environmental impact -** It is environmentally friendly on three fronts (i) supplies purified water for reuse (ii) has significantly lower energy consumption when compared with competitive evaporator systems (iii) effectively deals with industrial and mining waste remediation and recovery.

3. **Human impact -** It addresses major health issues (i) removes water soluble chemical compounds (including theoretically those of arsenic) (ii) sterilizes most pathogens such as bacteria, viruses and fungi (iii) produces near-zero liquid discharge which simplifies, and lowers the cost of handling, and disposal of the concentrate.

1.2. Current Water Treatment Processes

In discussing water treatment processes it is necessary understand the types of contaminants existing in waste water streams. These fall into one of the following classes:

1. Insoluble particulate solids

2. Immiscible liquids

3. Dissolved organic compounds

4. Pathogens

5. Sparingly soluble salts

6. Highly soluble salts

Classes 1 to 5 are in the main amenable to treatment by low-energy methods which are usually carried out in the pre-treatment stage (Fig.1). Such processes are widely available from a multitude of vendors. In many municipal water systems only the above contaminant classes are present in significant amounts while the Class 6 contaminant TDS level is well within the potable water range. Where this is not the case and the Class 6 TDS level is above acceptable levels, either set by potable water standards, or by regulatory standards for release to the environment, action must be taken to lower this level. Generally the removal of highly soluble salts (Class 6) is the most challenging and energy intensive step in the water purification process.

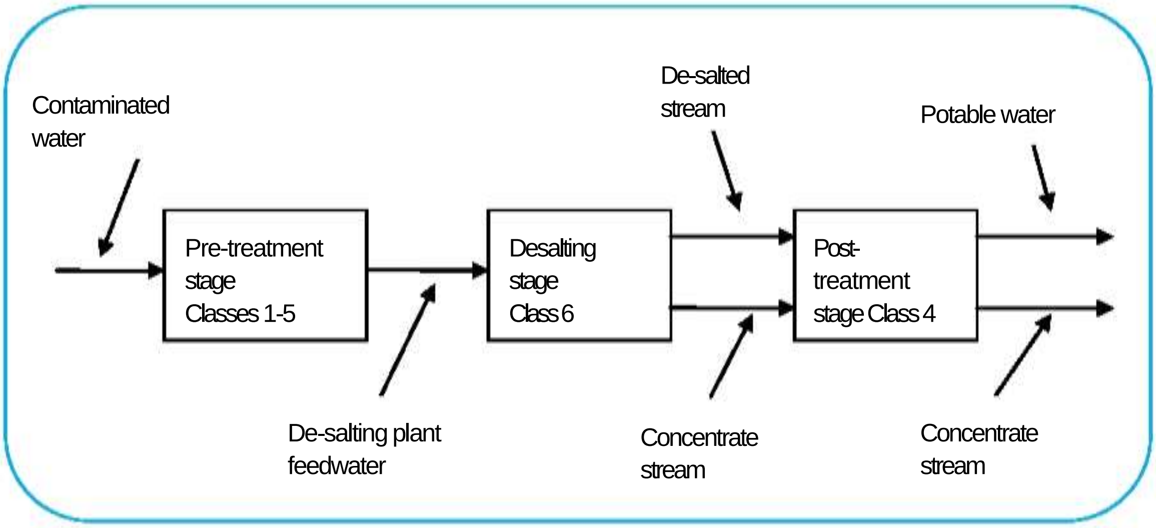

Figure 1: Water treatment process and classes of contaminants

There are many approaches to desalting water and these can be categorized into one of the following groups:[1]

- Membrane
- Thermal
- Ion exchange

The advantages and disadvantages of each of these processes are summarized in the following table. Each of these processes suffers a deficiency either in terms of its energy efficiency or in terms of its potable water recovery rate or in terms of maintenance requirements. Often these processes also require chemical additives to ensure output water meets minimum quality levels and to minimize maintenance requirements. Energy efficiency is of particular concern, and each of these processes operates best for certain ranges of total dissolved salts (TDS) as shown in Fig.2.[2]

[1] Desalting Handbook for Planners, Desalination Research and Development Program Report No. 72, US Dept of the Interior, Bureau of Reclamation, Third Edition, July 2003

[2] Water Desalination Technical Manual TM 5-813-8, U.S. Department of Army, September 1986

Current Water Purification Processes

Processes	Advantages	Disadvantages
Membrane		
Reverse Osmosis	• Cheap and simple designs, widely available • Less energy intensive than thermal methods • Lower cost per unit volume of fresh water	• Can only operate with TDS feed concentrations of less than 50,000 ppm • Ineffective at removing many unwanted solutes, including non-ionic salts (e.g. Boron) and organic materials • Generally needs high cost electrical energy for operation • Membranes prone to scaling and fouling, and replacement rate depends on the quality of the feedwater • Membranes can be fouled by any number of organic or inorganic materials, including microbial biomass • Feed water often requires intensive pre-treatment meaning that overall system cost is dependent on feedwater quality • Harsh cleaning agents decrease life of membrane elements increasing system operating costs • Does not benefit as greatly as thermal processes from economies of scale
Electro-dialysis	• Higher feed recovery • Most cost-effective for low TDS feed concentrations of less than 3,000 ppm	• Less cost-effective than Reverse Osmosis if TDS is greater than 3,000 ppm • Not effective at removing non-ionic high molecular weight species • Feed water generally requires pre-treatment to remove species or particles that may coat or foul membranes
Thermal		
Multi-Stage Flash Distillation	• Relatively low initial investment cost for large scale plants • Benefits from economies of scale • Regarded as a mature and reliable process • Electrical energy requirements lower than reverse osmosis if thermal energy readily available e.g. hybrid electrical power station • Multi stage process (up to 40 stages) needed for highest efficiency • Large footprint required	• Overall cost of producing fresh water can be twice as high as reverse osmosis unless cheap thermal energy is available • Suffers from serious scaling problems necessitating regular maintenance
Multi-Effect Distillation	• Similar characteristics to MSFD • Generally considered to give lower cost per unit volume of freshwater than MSFD	• Operating costs per unit volume of fresh-water are greater than reverse osmosis unless cheap thermal energy is available • Suffers from serious scaling problems
Vapour Compression	• Similar to MED except that it generally has only one effect • Gives lower cost per unit freshwater than MED, which can approach performance of RO for higher salinity feedwater • Generally only built as moderate sized plants	• Greater complexity than MSFD and MED • Suffers from serious scaling problems necessitating regular maintenance
Ion Exchange		
	• Resins can be designed to exchange strong and weak anions and cations • Can be used for removing sparingly soluble salts which cause scaling • Can be used for desalination especially for low to moderate TDS feed concentrations • Best available method for de-ionization of water (produces ultra-pure water) • Very low energy requirements for low TDS feed concentrations	• Volume of water treated inversely proportional to TDS feed concentration • Does not work well with soluble non-ionic compounds • Regenerant volume can be high and increases with high TDS feed concentrations • Overall cost of producing fresh water can be very high for high TDS feed concentrations

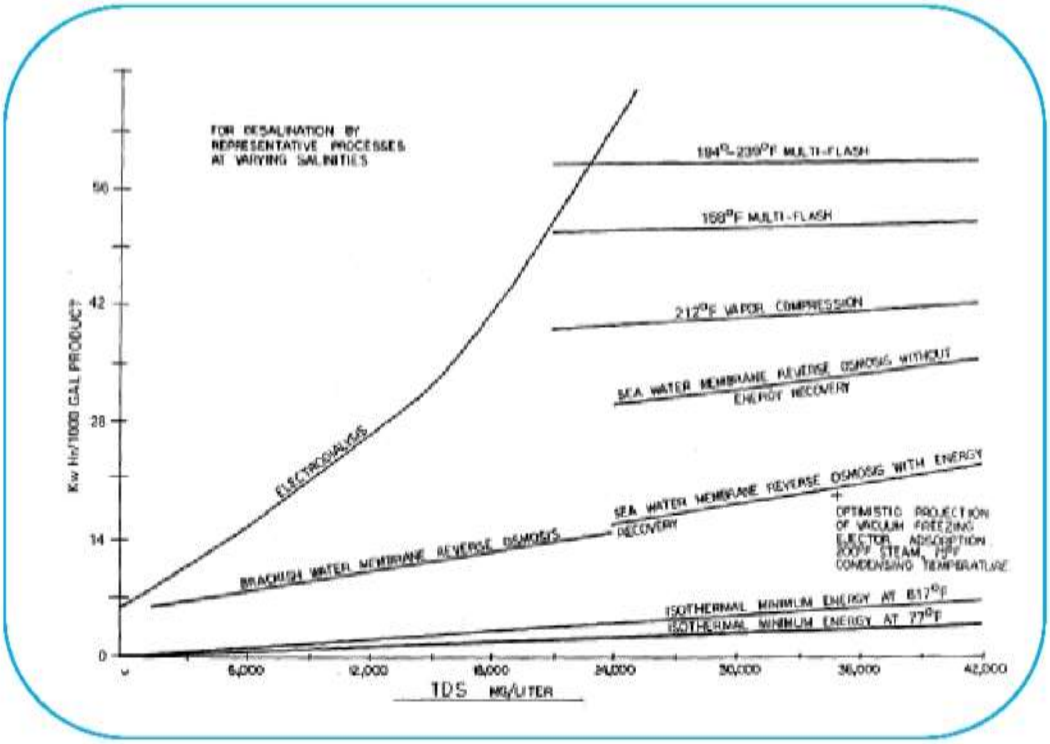

Figure 2: Energy efficiency (kWh/1000 gal) of representative desalination technologies as a function of total dissolved salts (mg/L)

1.2.1. Membrane Technologies

Membrane technologies desalinate and purify water by using semi-permeable membranes to preferentially allow certain species to move through the membrane in preference to others. Thus if a high concentration solution (contaminated water) lies on one side of the membrane and a pure solvent (pure water) lies on the other then the solvent will preferentially move across the membrane to dilute the solution concentration. If however a high pressure is applied on the solution side then the net flow of solvent will reverse direction and flow to the solute side. This is known as *reverse osmosis* (RO) and can be visualized as a process for removing the water solvent from the contaminated solution. RO should not be confused with other methods of filtration which mechanically separate water from contaminants by what is essentially a mechanical sieving process.

Reverse osmosis is the most commonly used membrane technique for desalination as its main advantage is that it is generally less energy intensive than for example thermal processes. However it often requires multiple pre-treatment stages, has higher maintenance and replacement costs due to membrane fouling, and is quite sensitive to the initial quality of the feed water. Reverse osmosis is largely ineffective in removing soluble non-ionic compounds such as boron. This has proved to be a major headache with RO desalination plants as the accepted safe level of boron is often well below what is found in seawater and brackish waters. Generally commercial RO membranes can only handle TDS level up to 50,000 ppm.

Another membrane process is *electro-dialysis* where an electric field is applied to the contaminated solution. Here the charged ions are steered to selective membranes which allow the ions to pass without allowing any water to pass. In this case the process can be visualized as one for removing the contaminants from the water. This process works best for feeds where the total TDS levels are quite low (less than 3,000 ppm) at the outset as the pressure drop, resisting water flow across the electro-dialysis cell, is quite small.

For further reading on desalination refer to O.K. Buros, "The ABCs of Desalting."[3]

1.2.2. Thermal Technologies

Thermal technologies rely on boiling or freezing water and capturing the purified water while the contaminant remains behind.

The most common and easily understood of this group is *distillation*, which involves the evaporation of water, using heat to remove the water from the source and then condensation of the water vapour back into a liquid.

The main advantages of distillation technologies are that they are generally insensitive to the quality of the initial feed water solution and produce high quality water output, although current technologies do require greater energy input than many other methods.

Another thermal technology is *thermal oxidization* which breaks down waste water into hydrogen, oxygen and the contaminants using extreme heat. Unlike most separation technologies, thermal oxidization leaves nothing to dispose of but a dry ash. This is a possible method for dealing with polluted waste water with very small levels of insoluble suspended contaminants but it does not produce clean water for further use.

1.2.3. Aquamill® Process

While the Aquamill® technology is also a thermal process it is unique, and offers great benefits, especially for industrial waste water treatment where it offers the following **combined** features:

- Can treat water having super-saline concentrations (c.f. RO)
- Produces much lower concentrate volumes (typically less than 20%) than other known processes for input water having 3.5% salt concentrations.
- Potable quality water yield much higher than other known processes
- Can treat water with high levels of sparingly soluble salts without requiring long maintenance down-times due to scale build-up
- It has lower energy requirements than other competitive systems.

[3] www.idadesal.org/pdf/ABCs1.pdf

1.2.4. Ion Exchange

In ion exchange processes specially developed acidic synthetic resins exchange proton or sodium ions for calcium and magnesium ions, while basic resins exchange OH or bicarbonate ions for other anions. The result is that the undesirable ions are immobilized as the water passes through exchange resin cells and the treated water is contaminant free. Once the capacity of resins to absorb the relevant ions is exhausted they can be restored to their original ionic states by treating them with suitable acid or base solutions.

Ion exchange processes have been used to produce the best de-ionized water for many industrial and pharmaceutical applications over many decades. However these processes have not proved capable of being scaled up to large industrial scale processes for water desalination.

2 The Aquamill® Technology

Aquamill® uses a proprietary thermal process (patents pending) in a novel way which gives rapid evaporation and avoids scale build-up, especially on the important heat transfer surfaces. Many of the beneficial attributes of the Aquamill® process can be traced back to these two features. A key outcome of the process is that it allows separation of the water from contaminated industrial waste water on-site.

Aquamill® has made a world-first advance in water purification technology which, in a highly efficient manner, removes purified water from polluted water originating from a wide range of sources. As a result the process is equally suited for purifying contaminated water, for concentrating industrial waste water and for use in industrial evaporator processes. In concept, it is based on a modular platform which has been shown to be scalable up to industrial plant sizes, is easy to maintain, and has a compact physical footprint.

There are four key benefits which flow from the unique Aquamill® process:

(1) **Waste volume reduction**: The waste product to be transported is reduced by more than 80% resulting in reduced handling costs.

(2) **Water purification**: The recovered water which makes up 80% of the waste product volume is of potable quality.

(3) **Product recapture**: In many processes valuable minerals are dumped with the waste water, thus polluting the environment. The Aquamill® process recaptures and concentrates these minerals, so reducing pollution and in many instances allows recovery of highly valuable minerals.

(4) **Energy Conservation**: The Aquamill® process uses energy recovery to greatly increase the operating efficiency of the water treatment process. In this case the latent heat of the steam is recovered and re-used many (more than 10) times. As a result the cost of operation of the Aquamill® process is considerably reduced when compared with traditional distillation.

Aquamill® is expected to meet the burgeoning demand for containing the increasing costs of treating and managing contaminated waste water streams in the manufacturing and mining industries.

An added benefit is the ability to recycle or sell the clean water. It is important to note that the Aquamill® process is ***not*** a recycling solution in these applications, but is a contaminated water treatment process which produces clean water as a by-product. As such the clean water produced is valued at its marginal cost of production.

The unit has a simple, robust design which is low cost, easy to maintain, and highly efficient with few moving parts. The unit also includes a number of inbuilt sensors to record the energy input and internal temperatures of the components and pressure sensors to ensure that the steam-loaded components of the Aquamill® machine are operating within specified limits.

Aquamill® developed a 3,000L/day in-house prototype unit which provided data for the development of an in-field pilot plant designed to treat a nominal 15,000 L/day of contaminated waste water. The Company plans to develop designs for a larger range of systems during 2014/15, which will be capable of processing between 15kL/day and 1,000kL/day of water leveraging the scalability feature of the technology and utilizing modular design.

Positive results from early tests have demonstrated the scalability of the daily volume output by employing cellular configuration. The daily volume capability for the Aquamill® concept is essentially unlimited and will be determined largely by economic considerations.

2.1. The Aquamill® Prototype Machine

A view of the early Aquamill® prototype 3000 L/day machine installed and operated at the Aquamill® factory in Clayton South, Victoria, Australia is shown in Fig. 3, where the elements of the machine are illustrated. The key elements of the system are the evaporator unit and the energy recovery vapour compressor. The separation of the contaminated feedwater into steam and concentrate takes place in the evaporator.

To date Aquamill® has successfully processed contaminated waste water (with contaminants in Category I described in the table below) during trials at its facilities in Clayton South. The results of the processing were subjected to independent analysis and audit by ALS, Environmental Division, Water Resources Group. ALS validated that feed water, considered unfit for human consumption and domestic use, was successfully processed by Aquamill® and met key criteria in the Australian Drinking Water Guidelines.

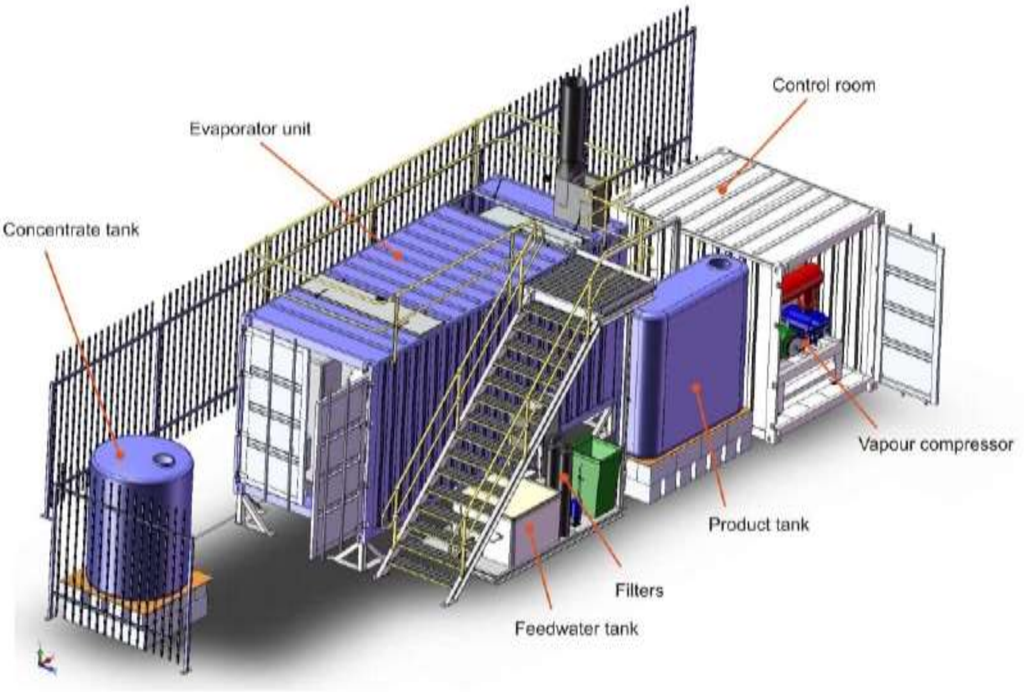

Figure 3: Aquamill® prototype 3000 L/day machine

In order to process more highly contaminated waste (Category II and higher), the Company's new pilot plant will serve to do this on trial sites approved by the EPA for the handling of such hazardous materials.

Aquamill® Purifier Contaminant Categories

Contaminant Category	Description of contaminant
I	Brackish Saltwater Carwash Laundry Truck/train Stormwater Yarra water Heavy metal
II	Mercury Cadmium Arsenic Paper (waste water from production) Bio-contamination
II	Grey water Legionnaire E coli Hospital liquid waste Organic
IV	Cyanide Wax Oils Polychlorinated biphenyls (PCB)
V	Pesticides Nerve gas Dioxin Carcinogens

2.2. The Benefits of Aquamill® Process

- Cost-effective solution for purifying water and extracting solids from contaminated waste water
- Water extraction efficiency greater than 80% compared with typical RO efficiencies of less than 50%
- Near-zero liquid discharge simplifies the handling and disposal of concentrate and lowers their costs
- Can process water with super-saline contaminant concentrations, is insensitive to contaminant composition, and can remove dissolved contaminants
- Prototype system has demonstrated low salinity TDS levels of 60 parts per million (ppm) which is comparable to conventional distillation systems. RO systems typically have TDS levels in excess of 200 ppm
- Removes many types of chemical compounds including those of arsenic and boron which are difficult to remove using other processes
- Sterilizes most pathogens in water including bacteria, viruses and fungi
- Process is innately insensitive to boiler scale build-up on heat transfer surfaces due to its unique process architecture
- Energy efficient and can be modified to use heat from a number of alternative sources thus reducing electricity usage
- Process can be scaled up to very large volumetric throughputs
- Process benefits from economies of scale as volumetric throughput is a function of evaporator chamber volume
- System designed to be modular with standard modules fitting inside a 20 foot container envelope. Plant capacity can be increased by linking multiple units
- Simple, robust and low-maintenance design

3 Outline Specification

- Capacity
  - Our mobile field trial unit has a nominal capacity of 15,000L/day.
  - Our process allows for capacities of several 1,000 L/day

- Input Stream
    - Can handle feed water having up to 70,000 ppm TDS compared with RO which is generally limited to 50,000 ppm TDS
    - For higher TDS levels refer to factory
    - Suspended solids less than 5 μm
    - Can handle sparingly soluble Mg^{++} and Ca^{++} salts
- Coefficient of Performance
    - Proven operation at COP ≈15
    - Performance road-map indicates COP increasing to more than 30
- Concentrate Stream Concentration Ratio
    - Depends upon feed water TDS
    - Demonstrated concentration ratio of 4:1 with 70,000 ppm saline feed water
- Boiler Scale Build-Up
    - Operational experience indicates minimal build-up of boiler scale on heat transfer surfaces
- Plant Output
    - Condensate stream (< 60 ppm TDS) shown to meet Australian Drinking Water Guidelines with regard to dissolved salts
    - Near ZLD concentrate stream
    - Planned energy efficient ZLD add-on stage is part of system development road-map
- Aquamill® Plant Operating System
    - Computer based control system uses multi-level optimizer architecture for optimizing operating performance and minimizing energy consumption
    - Operating system is wireless/internet enabled for remote machine performance and health monitoring
    - Remote monitoring of system operation for improving system availability ratio and reducing maintenance down-time
    - Operating system roadmap includes a number of additional features