

final report

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Indirect potable reuse – Learnings from the Singapore NEWater Scheme

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Executive Summary

The island Republic of Singapore historically obtained approximately 50 % of its water supply from outside its national borders. In 1999, the Singapore Government launched a strategic initiative to develop alternative and renewable sources of water, in an effort to ensure reliability of supply and consistency of quality and this gave rise to the so-called “Four Taps of Singapore” strategy. The four taps cover the four sources of water that will be available to Singapore in the future – *local stormwater collection and use, imported water, seawater desalination and water reuse.*

The focus of the *water reuse* component of this strategy was the production of a high quality of reclaimed water that could be supplied to the high-tech semi-conductor manufacturing sector as well as augmenting the raw water storage reservoirs. The first stage of this programme was the decision in 1999 to develop a NEWater Demonstration Plant that was used to prove the feasibility of reliably reclaiming a high quality of water from municipal effluents.

The success of this Demonstration project gave the Government of Singapore’s Public Utilities Board (PUB) confidence to proceed with the development of the wider NEWater Programme; the construction of NEWater Factories at Bedok, Kranji and Seletar, the introduction of NEWater to the surface water reservoirs, the supply of NEWater to the semi-conductor manufacturing sector and planning to further expand the production of NEWater to cater for anticipated increase in demand through NEWater Factories at Ulu Pandan and Changi.

The NEWater Scheme

The development of the NEWater Scheme in Singapore started with a Demonstration Plant, the findings from which served as the basis for the PUB embarking on the wider NEWater Scheme that is in place today.

The Demonstration Plant

The feedwater to the Demonstration Plant was drawn from the secondary effluent produced at the adjacent Bedok Wastewater Treatment Plant (WWTP); a WWTP that receives a raw sewage that contains some 5-10% of mixed industrial effluent.

The Plant was a membrane-based advanced water reclamation plant consisting of Microfiltration (MF) followed by Reverse Osmosis (RO) and Ultraviolet (UV) Disinfection with a capacity of 10 ML/d and the purpose of this study was to:

- Establish performance and operational reliability of the dual-membrane and UV disinfection processes;
- Assess the physical/chemical and microbiological quality of the high-grade reclaimed water through a rigorous 24-month sampling, analytical testing and monitoring programme (SAMP), and
- Compare the long-term chronic toxicity of NEWater with an existing raw water source through a comprehensive Health Effects study that included the use of both fish and mice – the first such study in the World.

Design of the Plant commenced in February 1999 and it was commissioned in April 2000. Its operation and overall performance was overviewed by an External Panel of Experts who concluded in July 2002 that “*The Singapore Government should consider the application of indirect potable reuse as NEWater is a safe and valuable supplement to the existing Singapore water supply*”. A copy of this report can be found on the website www.pub.gov.sg/NEWater.

As a result of this finding, full-scale NEWater Factories were constructed at the Bedok and Kranji WWTP sites and NEWater was introduced into reservoirs on 21st February 2003; it was already being supplied to the computer semi-conductor industry at this stage.

The Full-Scale NEWater Factories

The first two full-scale NEWater Factories were those at Bedok and Kranji that were officially opened in February 2003. These were followed by the Seletar NEWater Factory in April 2004 and the Ulu Pandan facility in March 2007. The location of these four Factories on the island is shown in Figure 1 below.

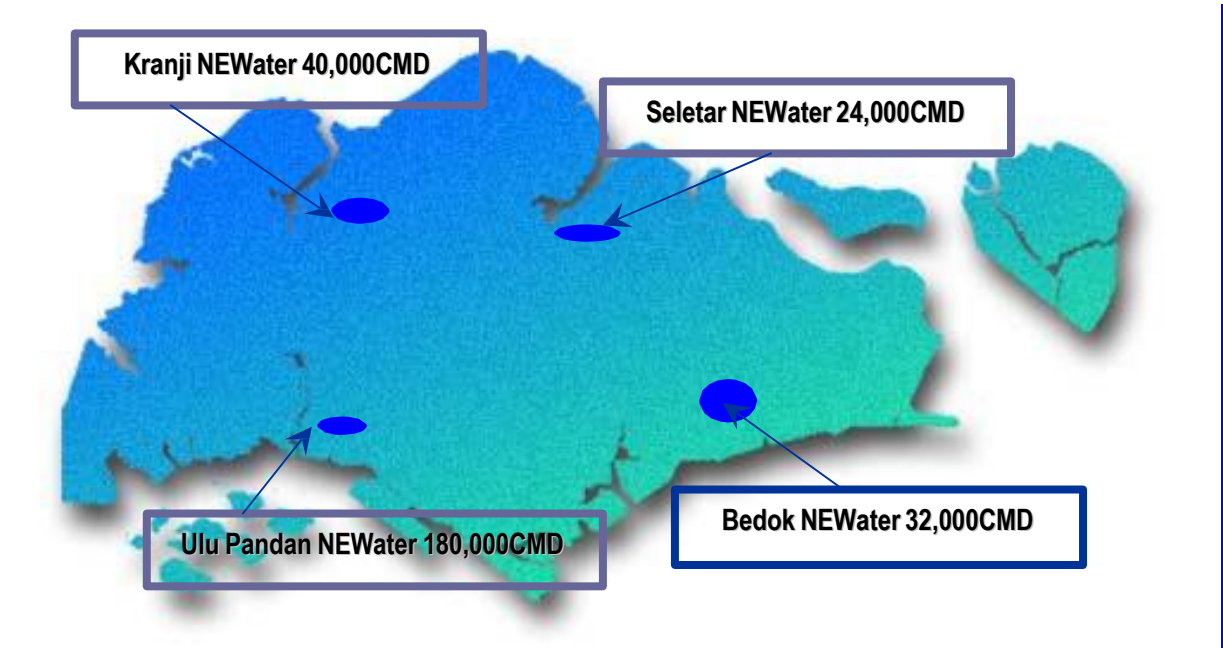


Figure 1: Location of NEWater Factories in Singapore

NEWater from each of these NEWater Factories is pumped to local industrial areas – referred to as ‘clusters’ – where the semi-conductor companies are located. Each of them, other than that at Ulu Pandan, has the ability to also discharge into local raw water storage reservoirs as part of the country’s Indirect Potable Reuse (IPR) scheme.

Current plans are for the contribution of NEWater to the drinking water supply to be some 3% by 2011; equivalent to 45 ML/d but it is likely that as more NEWater is produced in the future and the demand by industry is met, there will be more NEWater to be discharged to the reservoirs.

The current NEWater production stands at some 300 ML/day, representing 21% of the daily consumption of water in Singapore. This figure will increase substantially in 2008 when the expansions at Kranji and Bedok are commissioned and again in 2010 when the large Changi NEWater Factory is commissioned with a flow of some 400 ML/d.

Technologies Used

The feedwater to each of the NEWater Factories is drawn from effluent produced at the adjacent Wastewater Treatment Plants (WWTPs). These feedwaters would be classed as ‘secondary effluents’ in Australia as there is no further treatment, such as sand filtration or disinfection, after the biological treatment stage before they are transferred to the NEWater Factories.

The treatment trains in each of the NEWater Factories incorporate the ‘multiple-barrier concept’ that was incorporated in the Demonstration Plant and are all membrane-based, consisting of either Microfiltration or Ultrafiltration ahead of Reverse Osmosis, and followed by Ultraviolet disinfection, pH correction and residual chlorine dosing prior to being transferred to the distribution pipelines. In addition, the level of equipment redundancy and on-line instrumentation was carefully evaluated to ensure reliability of supply of NEWater on a 24/7 basis. A simplified flow schematic is shown in Figure 2 below.

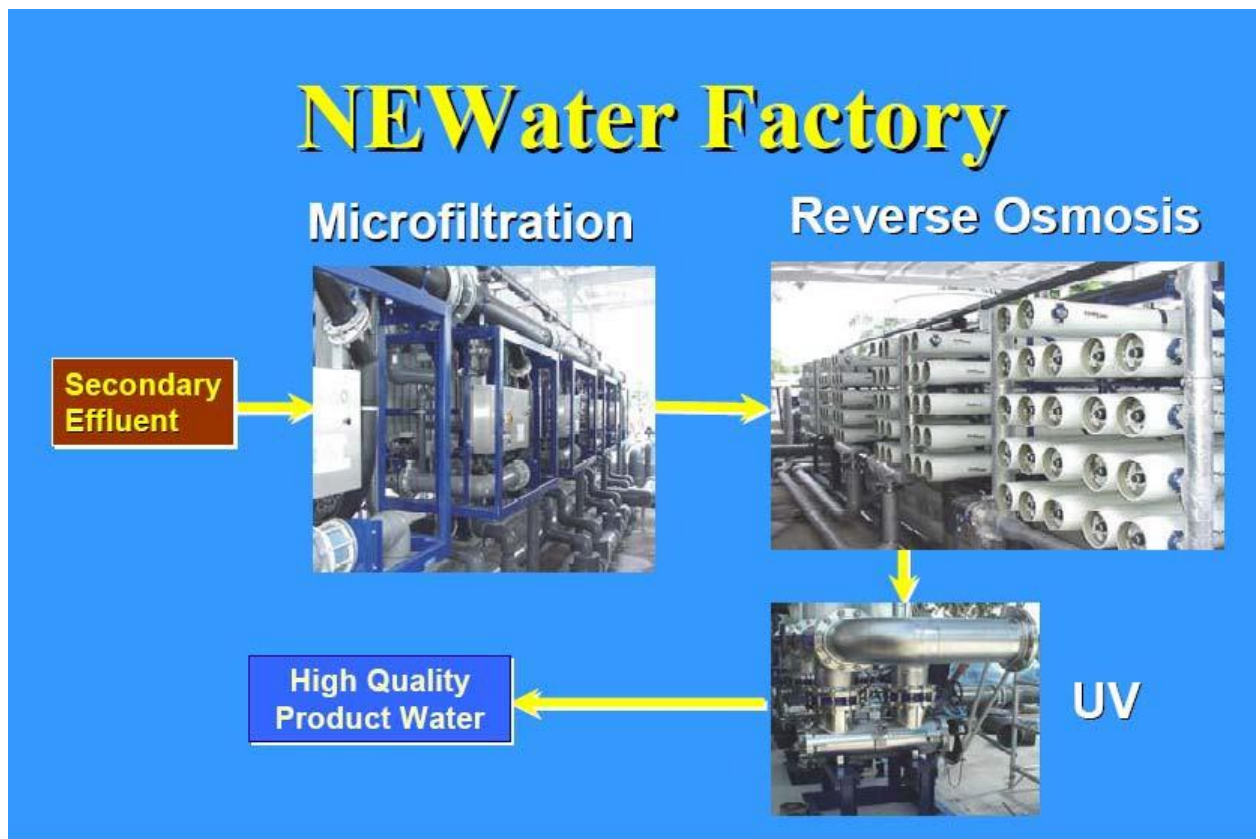


Figure 2: Flow Schematic of Technologies at NEWater Factories

NEWater Quality

Both the feedwater and the product water (NEWater) at each of the NEWater Factories are monitored for the following parameters as part of a Sampling & Monitoring Programme (SAMP) - a total of 292 different parameters.

- Physical Characteristics (9)
- Inorganic Chemical Agent & Disinfection By-Products (6)
- Other Inorganic Chemicals (44)
- Organic Disinfection By-Product (26)
- Other Organic Compounds (36)
- Organic Indicators (7)
- Pesticides (57)
- Radiological Quality (6)
- Microbiological (17)
- Wastewater 'Signature' Compounds (4)
- Synthetic and Natural Hormones (4)
- Persistent Organic Pollutants (27)
- Chemical Contaminants Lists (49 parameters)

The quality of NEWater is consistently superior to both the World Health Guideline (WHO) guideline values (2004 3rd Edition & 1st Addendum 2006) as well as the US EPA Standards (updated in August 2006) – the two benchmarks selected by the Singapore Government's Public Utilities Board (PUB) for NEWater to be measured against.

Cost Implications

The overall capital cost of the NEWater Factories in 2002 was approximately *S\$1.1million/ML of NEWater produced*, inclusive of all components. In transferring this cost factor to Australia, consideration must be given to not only the date (i.e. 2002) and flow range (i.e. 24 to 40 ML/d) but also the difference in labour and material costs in the two countries.

Quality Assurance and Monitoring

The Sampling & Monitoring Programme (SAMP) in Singapore

As mentioned above, a total of 292 different parameters are monitored for in the Feedwater and NEWater at each of the NEWater Factories as part of the overall NEWater Sampling & Monitoring Programme (SAMP). In addition, the quality of NEWater is monitored near the end of the distribution system at the semi-conductor industries to identify if the quality changes as it is transferred from the production facility to the point of use, a distance of some 6-8 kms.

The frequency of testing varies for each group of parameters and in some cases for each parameter within a group. The frequency of sampling can be:

- Continuous (i.e. on-line)
- Weekly
- Monthly
- Quarterly
- Six-monthly
- Annually

The frequency is determined through a regular review of the results to-date and the relevance of the parameter to the control of the product water quality.

Independent Audits

Overlaying the procedures for the collection and reporting of quality data are two *Audit Panels*.

The *Internal Audit Panel (IAP)* meets quarterly and it reviews/audits the quality of NEWater, the quality of Potable Water, the adequacy of the water quality and sampling programme (the 'SAMP'), the O&M procedures at the NEWater Factories and Water Treatment Plants as well as the adequacy of staff competency and training.

A report is submitted at the end of each audit that summarises the findings and recommendations for changes to either the SAMP or the plant operation or both. This report is submitted to the Chairman and the Chief executive Officer of the PUB.

The *External Audit Panel (EAP)* meets every 6 months and takes a high level view of the activities undertaken in the context of Singapore's long-term water management planning and implementation. It also reviews and signs off on the Internal Panel's recommendations – in particular those that involve changes to the scope of the SAMP.

As with the Internal Panel, the External Panel also submits a report to the Chairman and Chief Executive of the PUB at the end of each audit.

Operational Monitoring & HACCP

While the discussion above relates to *Verification Monitoring*, considerable attention has also been given to *Operational Monitoring* over the entire treatment train at each NEWater Factory. To this end all NEWater Plants started planning for HACCP accreditation in 2004 and achieved certification for HACCP

and ISO 9001 in September 2006. All are aiming for certification for ISO 14001 and OHSAS 18001 in late 2007.

All NEWater plants now operate to HACCP principles with appropriate Critical Control Points (CCPs) identified at stages within the treatment trains and with all CCPs being measured with on-line instruments.

Public Consultation and Participation

Background

After some 3-4 months of operation of the Demonstration Plant, it was obvious to the PUB/ENV team at this early stage in the project that the quality of water produced by the Demonstration Plant was consistently higher than the targeted US EPA and WHO Guidelines and that operating costs were trending in the expected region.

It was also at this stage that the full realisation of the significance of having a source of high quality reclaimed water available for high-end industrial reuse and, if necessary, for indirect potable reuse came to the fore and a decision was taken by the PUB/ENV to start an information programme for the Members of the Cabinet.

Briefing of each Cabinet Minister occurred over the latter half of 2000 and culminated in a further summary briefing for the entire Cabinet in November 2000. It was also at this stage that PUB and that part of ENV associated with water and wastewater merged into a 'new' PUB.

The continuing good operation of the Demonstration Plant over the rest of 2000 and the early part of 2001 prompted PUB to decide to move to fullscale production of 'high grade water' as it was known at that time. Tenders were called in February 2001 for two new reclamation plants as well as a Visitor Centre that was to provide "*..education to grassroot organisations, schools from primary to tertiary levels and general members of the public who are interested to know about the Product Water, the technology involved in its production, its quality and its uses*".

Design of these facilities commenced in June 2001, with the two plants being commissioned in December 2002 and the Visitor Centre officially opened to the public in February 2003.

It was in late 2001 that the brand name of "NEWater" was developed and from then on used in all promotional material relating to the development of the alternative water source.

Public Education – the methodology

The NEWater Public Education Programme was formalised in April 2002 and outlined a pathway for reaching out to the Community/Public and included activities such as:

- The production of White Papers on Indirect Potable Reuse applications and Frequently Asked Questions;
- Production of information packages on the production and quality of NEWater;
- Development of a Crisis Communication Plan that identified a strategy for addressing any issue that might be raised by the Public during the operation and development of the NEWater scheme;
- Planning tours for the local media to the NEWater Demonstration Plant as well as operational IPR schemes in the US;
- Providing input to the design of the 'experience' and 'messaging' that would be incorporated in the Visitor Centre;
- Promotion of the Visitor Centre as the cornerstone of the overall Education Programme.

It was also agreed at this time that the PUB would focus on liaising/informing all Members of Parliament (the Cabinet having already been informed), the local media and community leaders including those of the various religious groups in the Island Republic. The Chairman of the PUB carried out the liaison with

the MPs while designated senior PUB staff carried out the liaison with local media and community leaders.

The PUB staff developed a programme for the local media (both electronic and printed) to learn about NEWater – its production, its quality and the uses that it can be put to – as well as a tour to operational IPR plants in the US. An opportunity to meet and interview the Expert Panel was also programmed.

A decision was taken in early 2003 to bottle NEWater and make bottles available to the general public – free-of-charge. They were also promoted at Singapore's National Day celebrations in August 2003 when 60,000 bottles were distributed, and maximum exposure for this initiative was achieved when the full Cabinet all publicly drank from their bottles during the celebrations.

The Visitor Centre

The Visitor Centre is located at the Bedok NEWater Factory and was officially opened by the Prime Minister of Singapore in February 2003. The Centre offers a 'state-of-the-art' multi-media experience with carefully crafted messages in each of its five zones or areas and it caters for the full range of visitors – from school children to international experts in the water industry. Regular visits to the Centre are included in the Singapore Schools' curriculum.

The Centre has another unique feature and that is that it is constructed 'around' an operational NEWater Factory to ensure that visitors can follow and see the actual technology in operation and producing NEWater.

An indication of the scale and appearance of the Visitor Centre can be gleaned from Figure 3 below.



Figure 3: Entrance to the Visitor Centre at the Bedok NEWater Factory

The 'messaging' incorporated into the Visitor Centre was considered critical to the success of the Centre and the overall message adopted is:

"The Bedok NEWater Factory creates NEWater, which is a critical resource in Singapore's effort to provide water for industry, for living, for life"

This overall message is reinforced by the sub-messages developed in each of the areas within the Centre.

Community/Religious Leaders

Meetings were held with local community groups and with leaders of the various minority religious groups, e.g. Jews, Moslems and Hindus, at which PUB outlined how NEWater is produced, its quality, its potential uses and its plans to introduce NEWater into the raw water storages were discussed. The individual groups were then taken on a personalised tour of the Visitor Centre to see just how NEWater is produced and to reinforce the message that NEWater is a safe and reliable alternative source of water.

Feedback from the various religious group leaders was positive – with the simple message being that there would be general acceptance provided the NEWater is *clear, odourless and complies with the relevant quality standards*.

Media Tour to the US

A media tour to visit operational Indirect Potable Reuse plants in the US was carried out in September 2002 for members of the printed and electronic media in Singapore. The tour was led by a senior PUB person and supported by a consultant who made all the necessary arrangements and obtained all the clearances required for media interviews.

The aim of this tour was to inform/educate the media in Singapore so as to ensure balanced reporting when they returned – an aim to a large extent achieved. Both newspaper articles and documentaries produced for TV did not have the emotion often seen in Australia and the US and for the most part were factual and reinforced the fact that NEWater was of such a high quality as to offer minimal risk to consumers – both industry and public.

The Computer Semi-Conductor Manufacturing Industry

Singapore has a number of multi-national computer semi-conductor manufacturers in operation and prior to early 2003 these were all drawing on the PUB's drinking water as the raw water source for their ultra-pure water (UPW) production plants. These semi-conductor manufacturing operations consume large quantities of water and PUB was keen to persuade them to change to NEWater in lieu of drinking water as their raw water source.

Discussions started with the companies in mid 2001 and given that the manufacturing operation is for 24 hours a day and 7 days a week (24/7), the discussion very quickly focussed on not only quality but also reliability of supply at the nominated quality. These issues were resolved and the companies agreed to consider changing to NEWater in lieu of drinking water. Uptake of NEWater was initially slow, being only some 25% when the full-scale plants were commissioned in February 2003 but the present day situation is that 100% of all semi-conductor manufacturers draw only NEWater and not only do they now pay slightly less for their water but its high quality has resulted in a 10-20% reduction in the operating costs in their own UPW plants.

This impact of quality on operating costs is due mainly to the fact that the Total Organic Carbon (TOC) and Turbidity of NEWater are significantly less than the corresponding values for drinking water – refer to the Section on NEWater Quality above.

There are currently new computer semi-conductor manufacturing companies starting up in Singapore and they are automatically planning for a NEWater intake. This increased demand, together with the uptake by other industries – see following Section – has necessitated the PUB planning for, and constructing, additional NEWater Plants to cater for future demands.

General Industrial Use

Another significant use of water in Singapore is that of 'make-up' for commercial building air-conditioners and once the computer industry had accepted the use of NEWater, the PUB started to promote its use in this 'make-up' duty – constructing a separate pipeline to take the water in to the CBD from the NEWater Factories.

Some pharmaceutical companies have recently approached PUB with the view of switching to NEWater for use in their manufacturing process; this approach only coming after the pharmaceutical companies were satisfied on the quality and reliability of supply of NEWater.

There are to-date no food industries using 100% NEWater although they do accept drinking water from the IPR scheme.