Multiple Barriers Ensure Safe Potable Water From Reclaimed Sewage – Windhoek, Namibia

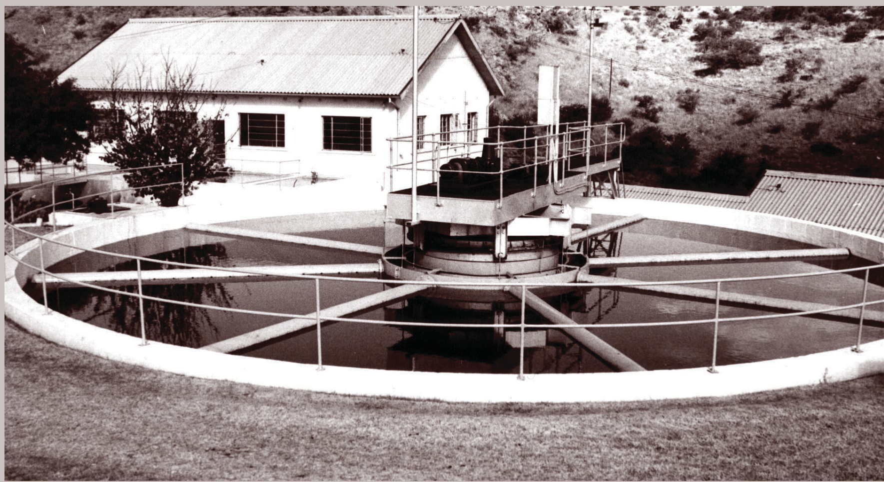
The Goreangab Water Reclamation Plant in Windhoek is internationally renowned as the first and only plant in the world to reclaim domestic sewage for potable use as a supplement to Windhoek's very scarce raw water resources.

Leading edge process technology was integrated into the design of the new 21 Mℓ/d Goreangab Water Reclamation Plant, which was completed in 2002. It is internationally renowned as the first plant in the world to reclaim domestic sewage for drinking water purposes. After 32 years it continues to be the only plant in the world to do so.

SCARCE RAW WATER RESOURCES

Namibia is the most arid country in Southern Africa and continuously faces serious water challenges. The initial Goreangab Water Reclamation Plant was built by the City of Windhoek in 1968 to reclaim water directly from domestic sewage effluent as a supplement to Windhoek's very scarce raw water resources. The plant can be fed from two sources, these being the Gammams Sewage Treatment Plant and the Goreangab Dam. The raw waters are blended and treated as a single stream. In general, the objective is to utilise a larger portion of the effluent from the sewage treatment plant than water from the Goreangab Dam.

LOOKING BACK AT THE BEGINNING…



The original water reclamation plant in Windhoek was developed by the National Institute for Water Research (NIWR) of the Council for Scientific and Industrial Research (CSIR) during the 1960s. The design and operation was based on the results of a pilot plant operated by the NIWR in Windhoek over the period 1964 to 1968.

After the Water Research Commission (WRC) was established in 1971 it immediately embarked on an ambitious research programme to expedite the development of the technology of water reclamation and to study the health effects of such water.

A research facility was constructed by the CSIR at Daspoort water treatment works in Pretoria and the Windhoek plant was modified from time to time to incorporate advantages gained from the latest research results with financial assistance from the Water Research Commission.

In 1976 the Windhoek plant was upgraded and extended, again with financial support by the WRC. At the inauguration ceremony Dr GJ Stander, the then chairman of the WRC, stressed the significance and the value of the ground-breaking research at Windhoek with a quotation from an American scientist who (at a conference in 1969) said: "*Windhoek will become famous as the first city in the world to reclaim wastewater on a regular basis for direct domestic reuse. This plant has been in operation since spring 1969 and the peoples of the world have taken little notice of its existence*.

"*Yet, in this same year that saw science and engineering land a human on the face of the moon, science and engineering also brought direct water reuse into reality. The question is, which event will have more intimate impact on our lives and those of our children?*"

HEALTH CONCERNS

Due to pollution in the catchment area of the dam, the quality of the water had deteriorated over the years to such an extent that conventional treatment methods could no longer be applied. The two sources had to be combined and treated in a single extended and upgraded new Goreangab Water Reclamation Plant.

During the early nineties, the need arose to augment the plant significantly and to upgrade its treatment train with the latest technology to address the most recent health concerns.

GFJ, South African consulting engineers, formed a consortium with Fichtner in Germany and Multi-Consult in Namibia and the *FMG Goreangab Joint Venture* was awarded the technical responsibility for this challenging project.

NEW TECHNOLOGY

Since the commissioning of the first reclamation plant in 1968 a huge amount of new information on various aspects of water treatment became known. Experience obtained from the old plant, information from pilot plant studies and

The High Lift Pumping Station consists of two pumpsets.The pumping station further houses the raw waterpumps with the raw water inlet works to the right of the pumps, just below the clear water reservoir. Several on-line instruments are situated in the building for quality control purposes.

knowledge of current technologies had to be integrated into a process design which eventually lead to a reclamation Plant producing water of a final quality which is sustainably fit for human consumption.

RESEARCH AND DEVELOPMENT

The new treatment plant was designed using data from 400 days of pilot testing and a comprehensive review of international practices.

This research and development part of the project played an important role in eventually determining the process train and establishing important design parameters. In this regard, research was focused on the optimal removal of organics and harmful pathogens from the water. This was achieved by operating an ozone/activated carbon pilot plant, a membrane pilot plant and performing some full-scale studies on the old plant with regard to the precipitation of organics at various pH levels.

Following the research part of the project, water quality concerns were categorised into the following:

- Physical and Organoleptic
- Macro Elements
- Microbiological
- Disinfection By-products

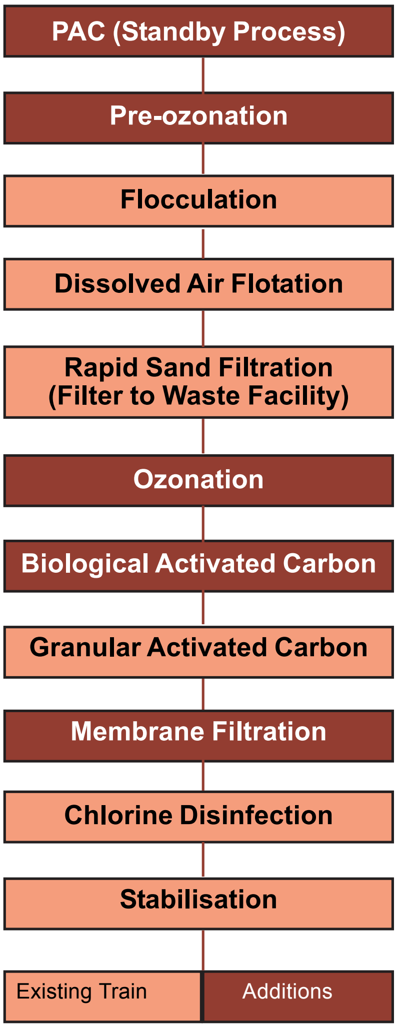
BARRIERS

The process design was one of a 'multiple barrier' process where individual barriers were established for each of the groups mentioned above. With a major emphasis being placed on a safe final product, three barriers were set for pathogens like *Cryptosporidium* and *Giardia*. The reduction in organic content before chlorination to reduce the formation of trihalomethanes (potentially carcinogenic) also necessitated three barriers. Employing this approach for each concern would ensure a final water complying with the stringent standards required.

Following the establishment of a design philosophy, the processes required to create the multiple barriers had to be identified and sequenced into a final process design. The old plant was taken as a starting point for processes currently employed and a detailed evaluation of the existing plant indicated that the old treatment train comfortably provided one treatment barrier against physical and organoleptic parameters through Dissolved Air Flotation (DAF), settling, and filtration and two barriers against most microbiological and biological parameters (two chlorination steps).

To enhance the multiple barrier concept further, the following specific adaptations and additions to the original process were implemented:

- Powdered Activated Carbon (PAC) dosing, should one of the



Note: Sedimentation and secondary chlorination were omitted from the existing train

The ultrafiltration unit process, which acts as a final barrier against harmful pathogens

key processes such as ozone, membrane or Granular Activated Carbon (GAC) filtration fail. This process will only be an operational barrier.

- The settling step was shown to add very little benefit to the phase separation already achieved by DAF and could be excluded without any compromise to the overall plant performance.
- Ozone was added as an additional step before GAC for its ability to destroy cysts, particularly *Giardia* and *Cryptosporidium*; further to oxidise organics, iron and manganese.
- Biological Activated Carbon (BAC) to enhance dissolved organics removal without the regular high cost of regeneration of GAC.
- Membrane filtration provided an additional barrier for both the biological parameters and the physical parameters.
- The removal of iron and manganese was specifically addressed, especially in view of its fouling effect on the membrane process.

This philosophy resulted in the process train as shown in the diagram and described hereafter.

PROCESS TRAIN

The major features of the plant are:

- PAC dosing as a standby barrier for dissolved organics removal.
- The provision of pre-ozonation for oxidation of iron and manganese. To achieve this, some of the ozonation capacity is available at the inlet box.
- An acid dosing system (experimental) for flexibility when the pH needs to be adjusted for better organic precipitation.
- A ferric chloride dosing system as well as a polymer dosing system for flocculation.
- Two flocculation units with flexibility to vary the mixing intensity.
- A DAF system for removal of algae and other suspended particles.
- Sand filtration with upstream dosing of potassium permanganate and caustic soda to facilitate manganese oxidation and removal in the filters.
- An ozone facility, including the ozone injection units, the ozone contact tank, and a Pressure Switch Adsorption (PSA) plant for oxygen production. This is a barrier to *Cryptosporidium* and *Giardia* and also oxidises organics and makes it more susceptible for adsorption onto the activated carbon.
- A granular activated carbon facility following ozone consisting of three separate steps – the first step to be used as a biological carbon facility and two GAC units to be used as an adsorption facility. The lowering of organic content is a priority as this has further implications during final chlorination.
- An ultrafiltration unit process as a final barrier against cysts and the further lowering of organic content and turbidity.

- A chlorine dosing step with a contact time of one hour, and a residual of at least 1 mg/ℓ free chlorine when leaving the plant.
- Final stabilisation to obtain a calcium carbonate precipitation potential of 4 mg/ℓ is achieved using caustic soda.

AUTOMATION

Automated processes, which require limited operator intervention and a monitoring Supervisory Control and Data Acquisition (SCADA) system, which stores a number of critical parameters for control purposes are important features of the plant.

QUALITY CONTROL

Due to the sensitive and multi-disciplinary nature of this Turnkey Project, the Consultant employed site personnel on a full time basis. Personnel from FMG supervised construction and ensured that all quality control documents were completed. Specialist personnel were utilised for each discipline namely civil, mechanical, electrical and instrumentation/control. Inspections were done on the membranes in Holland and on the PSA Plant in Italy. The Client and Consultant in Johannesburg witnessed a factory acceptance test on the SCADA.

The Contractor had to prove all intermediate and final guarantee values during a four week trial period. These guarantee values dealt with all aspects of the project, from process related values such as water quality constituents to engineering issues such as the correct backwash rates and final water production rates. During this period the Consultant's personnel checked that all guarantee values were met. The reclamation plant was accepted as fully functional towards the end of 2002 and the Plant was officially inaugurated on 2 December 2002.

WATER QUALITY

The water quality produced meets the quality guidelines of the World Health Organisation, Rand Water (South Africa) and the Water Quality Guidelines for Namibia. Water samples are taken on a four hourly basis after each treatment process for analysis to ensure compliance with the stringent standards required. Health standards in Windhoek have been monitored closely since the inception of direct reclamation in 1968. No known water related outbreak of disease has been experienced.

COSTS

The cost of providing water from the Goreangab Plant is less than the alternative of developing further dams, conveyance and treatment systems in distant catchments. The environmental impact of dam construction and inter catchment transfer systems are also avoided.

The project was awarded at a value of N$92 million (R92 million) and the client made provision for contingencies of just over N$5 million. The project was completed for N$95 million resulting in a saving of more than N$2 million (N$1 = R1). The project was financed by the Kreditanstalt für Wiederaufbau (KfW) in Germany, the European Investment Bank (EIB) and the City of Windhoek.

Potable reuse is an indispensable element of the Windhoek water system and has proven to be a reliable and sustainable option. Water of exceptional quality can consistently be produced from treated domestic sewage.

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