BEAUFORT WEST WATER RECLAMATION PLANT: FIRST DIRECT (TOILET-TO-TAP) WATER RECLAMATION PLANT IN SOUTH AFRICA

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Abstract
Historically final effluent from a wastewater treatment works would either flow to the river or be used for irrigation. As a result of the topographical conditions in Beaufort West the Municipality decided to implement the first "direct" water reclamation plant in South Africa. The term "direct" is used because treated effluent from the wastewater treatment works is further treated and pumped directly back into the town's water supply system. The project was initiated and awarded to Water & Wastewater Engineering under a 20 year design, build and operate concession. The water reclamation plant has been completed and is fully operational, delivering water which is complying with the SANS 241-1: 2011 (Edition 1) standard. It is a ground breaking project in that it unlocks a significant water source that has historically either been over looked or under utilised.

Keywords: Beaufort West, direct water reclamation, advanced oxidation, constituents of emerging concern (CEC's), multiple barrier.

INTRODUCTION
Beaufort West is situated in the heart of the Great Karoo and is renowned for its vast landscapes, beautiful wild life and rich history. Beaufort West was the first town in South Africa to be proclaimed a Municipality, is the birth place of the world renowned heart surgeon Chris Barnard and now has the first direct water reclamation plant in South Africa. The Beaufort West Water Reclamation Plant (WRP) is only the second of its kind in the world. The other direct WRP is situated in Windhoek, Namibia. The term "direct" is used because treated effluent from the wastewater treatment works is further treated and pumped directly back into the town's water supply system.

WATER DEMAND HISTORY
What makes the Beaufort West water supply difficult is that it has no perennial rivers in the surrounding area. Water supply is heavily reliant on rainfall and drought is inevitable. The Municipality has two main sources of water i.e. surface runoff that is captured in the Gamka and Springfontein Dams and borehole water. During the recent drought both dams and approximately 50% of the boreholes dried up. Given this background the Municipality identified water supply as a key strategic resource and embarked on a short, medium and long term strategy to secure the water supply.

The short term strategy focussed on water demand management. This included detecting and managing water losses, installing pre-paid water meters, redeveloping existing boreholes, developing additional boreholes and implementing water restrictions. The medium term strategy focused on further groundwater exploration, water reclamation and desalination of existing saline boreholes. The long term strategy is to develop a field of boreholes 30 kilometres out of town.

After completion of the short term strategy and groundwater exploration, the Municipality embarked on implementing the water reclamation plant. Beaufort West Municipality asked tenders for the design, build and operation of the plant under a 20 year concession. After reviewing the various tenders received, the tender was awarded to Water & Wastewater Engineering.

Water & Wastewater Engineering used leading technology and applied innovative design in order to ensure optimal removal of organics and harmful pathogens. The design applies the "Multiple Barrier" principle to ensure the removal of:
• Macro elements;
• Physical and aesthetic determinands;
• Chemical determinands (macro and micro);
• Organic determinands;
• Contaminants of emerging concern (CEC)

IMPLEMENTATION OF THE PROJECT
The project was completed in three stages i.e. the EIA/planning stage, construction stage and the current operational stage. During the EIA process a lot of emphases were placed on informing all the communities of the proposed plant. From the outset it was clearly stated that treated effluent will be further treated and used for potable water. News paper articles were published and leaflets were handed out from door to door. During community meetings the proposed water reclamation plant was placed on the agenda and questions around the water quality was answered as transparent as possible. No major objections were received from the public and the EIA process was completed.

Construction of the plant commenced at the height of the drought. A decision was made to fast track the construction works. This implied civil and mechanical contractors being on site at the same time. Despite these challenges the project team managed to complete the project in six months and delivered the first reclaimed water on 15 January 2011.

Currently the project is in its operational stage and the plant is delivering reclaimed water of exceptional quality. Table 1 and Table 2 provide a summarised list of determinands being tested.

Determinand	Risk	Unit	SANS 241-1: 2011	Final Water	Compliance
Physical and aesthetic determinands					
Colour	Aesthetic	mg/L Pt	≤ 15	5	Passed
Conductivity	Aesthetic	mS/m	≤ 170	4	Passed
Total Dissolved Solids (Calculated)	Aesthetic	mg/L	≤ 1200	28	Passed
Total Dissolved Solids (Measured)	Aesthetic	mg/L	≤ 1200	34	Passed
pH value	Operational	pH units	≥5 to ≤ 9,7	6.5	Passed
Turbidity (Operational)	Operational	NTU	≤ 1	0.2	Passed

Table 1: Analysis of Physical and Chemical Determinands of the Reclaimed Water

Determinand	Risk	Unit	SANS 241-1: 2011	Final Water	Compliance
Chemical Requirements – macro determinand					
Ammonia as N	Aesthetic	mg/L	≤ 1.5	< 0.1	Passed
Chloride as Cl^-	Aesthetic	mg/L	≤ 300	8.0	Passed
Fluoride as F^-	Chronic Health	mg/L	≤ 1.5	< 0.1	Passed
Nitrate plus Nitrite as N	Acute Health	mg/L	≤ 11.9	1.4	Passed
Sodium as Na	Aesthetic	mg/L	≤ 200	7.4	Passed
Sulfate as SO_4	Aesthetic	mg/L	≤ 250	0.2	Passed
Zinc as ZN	Aesthetic	mg/L	≤ 5	< 0.01	Passed
Chemical Requirements – organic determinand					
Dissolved Organic Carbon	Chronic Health	mg/L	≤ 10	< 1	Passed

Table 1: Analysis of Physical and Chemical Determinands of the Reclaimed Water

Determinand	Risk	Unit	SANS 241-1: 2011	Final Water	Compliance
Microbiological Determinands					
Faecal Coliforms	Acute Health	Count per 100ml	Not Detected	0	Passed
E. Coli	Acute Health	Count per 100ml	Not Detected	0	Passed

Table 2: Analysis of Microbiological Determinands of the Reclaimed Water

MULTIPLE BARRIER TREATMENT
From the outset of the project a very conservative design philosophy was adopted. The project team knew that it was the first project of its kind in South Africa and that there could be no compromise on water quality. The design focussed on pre-treatment with multiple removal of determinants.

Pierre Marais from Water & Wastewater Engineering says: "From the outset the Municipality focused on proper pre-treatment. Mr Louw

Smit (Director of Engineering) was aware of the sensitivity of the project. The design had to incorporate safety measures with automatic shut down if there is deterioration in unit processes." Marais explains the treatment processes:

1. Phosphate Removal
Ferric-Chloride is dosed into the existing activated sludge plant to remove Ortho-Phosphates from the final effluent. The Ferric-Chloride also acts as flocculent for better settling of suspended solids in the secondary settling tank;

2. Settling
After the final effluent leaves the existing wastewater treatment works it flows to a settling tank. The settling tank settles the remaining suspended solids and acts as a buffer between the existing works and the new water reclamation plant;

3. Pre-disinfection
After settling of the suspended solids the feed water is disinfected with chlorine;

4. Filtration
The pre-disinfection is followed by gravity sand filtration. The sand filters remove all macro organic matter and any remaining suspended solids. This barrier also protects the down stream membranes from fouling as a result of shock organic loads or excess flocculent dosing;

5. Ultra Filtration
Ultra filtration is a membrane process where water is pumped through membrane straws. As a result of the nature of the feed water, outside-in flow direction membranes were selected. Ultra filtration membranes remove among other things Giardia, Cryptosporidium, bacteria and most viruses.

6. Reverse Osmosis
High pressure reverse osmosis membranes follow the ultra filtration membranes. The reverse osmosis membranes remove most remaining organics in the water, pesticides, hormones, CEC's, aqueous salts and metal ions.

7. Advanced Oxidation
An advanced oxidation step follows the reverse osmosis membranes. This process entails the dosing of peroxide followed by UV lights. The UV light catalyses chemical oxidation of organic contaminants in water by its combined effect upon the organic substances and reaction with hydrogen peroxide. First, many organic contaminants that absorb UV light may undergo a change in their chemical structure or may become more reactive with chemical oxidants. Second and more importantly, UV light catalyses the breakdown of hydrogen peroxide to produce hydroxyl radicals, which are powerful chemical oxidants. Hydroxyl radicals react with organic contaminants destroying them and producing harmless carbon dioxide, halides and water by-products. The process produces no hazardous by-products or air emissions. In short, this process is designed to destroy any remaining dissolved organic contaminants in the water.

8. Post Stabilization and Disinfection
Following the advanced oxidation the pH is elevated and a small amount of chlorine is added to protect the water until it reaches the end user.

9. Blending of Water
The reclaimed water is pumped up to a service reservoir and blended with the other water sources i.e. the treated dam water and borehole water. The mixing ratio is 1:4. The towns water is therefore made up of 20% reclaimed water. This ratio can be increased to 25%.

PERFORMANCE BASED CONTRACT
The asset (water reclamation plant) belongs to Beaufort West Municipality and Water & Wastewater Engineering operates and maintains the works under a 20 year concession. The contract is performance based and should the final water not meet the required standard, the plant is automatically shut down. A shut down results in lower volumes of reclaimed water produced, which in turn converts to a financial penalty. This ensures that Water & Wastewater Engineering continuously apply astute principles in the operation and maintenance of the plant.

CONTINUOUS EDUCATION
Despite the comprehensive planning and EIA process the initial public perception was negative. A comprehensive awareness campaign was launched with various groups and scholars visiting the plant. Today the people of Beaufort West are proud of their plant and very few objections are received from the community.

Continuous education campaigns, mainly for scholars, are underway. This is done by taking them through the plant and letting them taste, smell and touch 100% reclaimed water. This has been very successful and is planned to take place year to year.

In addition to the above the test results of the final water are made available to the public and these results are published in the local news paper.

FUTURE TESTING
Umgeni Water is currently in the process of determining selected steroid estrogens in treated sewage effluent in the Umsunduzi (Duzi) River water catchment area [1]. Part of the study is to determine the levels of Estradiol, Estriol, Estrone and 17-α-ethinyl-estradiol in a pilot plant membrane bioreactor followed by advance treatment. It is envisaged to embark on a series of similar tests at the Beaufort West WRP in order to compare the results of the Beaufort West WRP with that of the Umgeni Water study.

CONCLUSION
The Beaufort West water reclamation plant is fully operational and is delivering water that is complying with the SANS 241-1: 2011 (Edition 1) standard. It is a ground breaking project and unlocks a significant water source that has historically either been over looked or under utilised.

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References
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