

**THE EFFECT OF BIOFOULING ON A REVERSE OSMOSIS MEMBRANE
PURIFICATION SYSTEM AT SASOL, SASOLBURG**

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DECLARATION

This work has not previously been accepted in substance for any degree and is not concurrently submitted in candidature for any degree.

Signed.....

Date.....

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DEDICATION

This dissertation is dedicated to my family and friends who have been very supportive throughout my study.

ABSTRACT

Reverse osmosis (RO) membranes are widely used in water purification. The presence of biofilms in water and industrial water purification systems is prevalent. As a result, biofouling which is a biofilm problem causes adverse effects on reverse osmosis process, which include flux decline, shorter membrane lifetime and an increase in energy consumption. The effect of biofouling on RO membranes was investigated at a water treatment facility at Sasol, Sasolburg by investigating the quality of water purified by the RO system and the extent of fouling that is attributed to biofouling. Chemical and microbiological data was averaged based on the results obtained from water analysis and samples from a fouled membrane. Bacteriological plate counts ranged between log 1.5 to 4 cfu/ml in water samples and log 3.9 to 4.5 cfu/cm² on biofilm from the membrane surface. Water analysis indicated a high conductivity of 121 μ S/cm in the feed and 81 ppm of the TDS, whereas in the permeate conductivity was found to be around 6 μ S/cm and 3.8 ppm of the TDS. This indicated that components present in the feed were retained by the membrane. This was supported by membrane autopsy which showed that the bacteria and elements found in the feedwater were also present on the membrane surface, hence contributing to fouling. An average of 33% of cellular ATP was measured on the biofilm from membrane sample, showing that the fouling bacteria are metabolically active *in situ*. The results clearly indicated that an important biological activity occurred at the membrane surface.

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GLOSSARY OF TERMS

Adsorption - the process by which carbon filters trap chemicals.

Autopsy - a standard procedure for assessing loss of membrane performance.

Biofilm - is a complex aggregation of microorganisms growing on a solid substrate. Biofilms are characterized by structural heterogeneity, genetic diversity, complex community interactions and an extracellular matrix of polymeric substances.

Biofouling – accumulation of microorganisms-biofilms- on a surface of membranes at such a level that it causes operational problems.

Brackish Water – Water with salt concentrations of between 5,000 and 20,000 parts per million (ppm). Seawater generally has salt concentrations of greater than 20 000 ppm.

Chlorine - a chemical used to disinfect water.

Colloid - a tiny particle that remains in suspension in a liquid.

Concentration Polarization - refers to the concentration gradient of salts on the high pressure side of the membrane surface created by the less than immediate re-dilution of salts left behind as water permeates through the membrane. The salt concentration in this boundary layer exceeds the concentration of the bulk water. This phenomenon impacts the performance of the process by increasing the osmotic pressure at the membrane's surface, reducing flux, increasing salt leakage and increasing the probability of scale development. Increasing the velocity (turbulence) of the brine stream helps to reduce concentration polarization.

Conductivity – a measure of the ability to conduct an electric current. Since ionized impurities increase the conductivity of water, it is also an accurate measure of ionic purity. Conductivity is normally expressed as microSiemens/cm ($\mu\text{S}/\text{cm}$).

Desalination – the removal of salt from wastewater.

Disinfection - the process of killing bacteria and other microorganisms in water.

Extracellular polymeric substance (EPS) - is a complex mixture of macromolecules including polysaccharides, proteins and nucleic acid, each comprising variable molecular mass and structural properties. EPS firmly anchor cells to the surfaces and stimulate additional microbial colonization.

Feed, feedwater - a solution that enters a device or system for a specific purpose, as in a chlorine feeder.

Fouling – is the undesirable deposition of material on a surface.

Flocculent - a substance that is added to water to make particles clump together in order to achieve better filtration.

Flux – water volume flowing through the membrane per unit area and time

Hardness - the amount of calcium and magnesium in water, which causes the membrane to clean inefficiently.

Ion - an electrically charged atom.

Membrane - a thin material that is porous enough to reject pollutants while allowing pure water to pass through.

mg/L- milligrams per litre, a measure of the amount of a substance in water. It is the equivalent to parts per million.

Particulate - particles in water.

Permeate - that portion of the water that passes through an RO membrane.

pH - the measure of alkalinity/acidity in water. A pH of 1 to 7 is acidic, 7 to 14 is alkaline, and exactly 7 is neutral.

Pore size - refers to the smallest substance that an RO membrane will reject most of. For example, a 0.001 micron membrane might reject approximately 90 percent of all substances 0.001 microns and larger.

RO Membrane - a semi-permeable material, that is, a material through which water passes relatively quickly, while other substances cannot (or do so relatively slowly). Membranes provide the barrier layer or interface for cross flow separation. Membranes are thin, porous material constructed of organic polymer (e.g., cellulose acetate, polyamide and charged polysulfone). RO membranes will typically reject contaminants with molecular weights greater than 200.

Scale - a hard, whitish buildup of mineral deposits on surfaces that contact water, such as the inside of water pipes or the boiling chamber of a distiller.

Turbidity - a measure of the opacity or cloudiness of water that is caused by particulates.

Total Dissolved Solids (TDS) – total salt and calcium carbonate concentration in a sample of water, usually expressed in milligrams per litre (mg/l) or parts per million (ppm). The state recommended Maximum Contaminant Level (MCL) drinking water standard for total dissolved solids is 500 mg/l, the upper MCL is 1,000 mg/l, and the short-term permitted level is 1,500 mg/l.

Reverse Osmosis (RO) – a process of desalination where high pressure is applied continuously to the feed water, forcing water molecules through a semi-permeable membrane. Water that passes through the membrane leaves the unit as product water. Most of the dissolved impurities remain behind and are discharged in a waste stream.

Scaling – salt deposits on the interior surfaces of a desalination plant deposited during the treatment process.

Reverse osmosis system pressure drop -The pressure difference between the inlet to the initial RO membrane elements and the concentrate stream pressure coming off the tail end elements is what pushes the water across the membrane surface of all the elements. This is called the pressure drop or the hydraulic differential pressure (P).As long as the flows are constant, the hydraulic differential pressure will not change unless something physically blocks the passage of flow between the membrane envelopes of the elements (fouling). Therefore it is important to monitor the hydraulic differential pressure across each stage of the system. An increase in the hydraulic differential pressure can then be isolated as lead end, tail end or both to indicate the possible cause of any problems.