

# EVALUATION OF NANOFILTRATION FOR THE TREATMENT OF RURAL GROUNDWATER FOR POTABLE WATER USE

## EXECUTIVE SUMMARY

Clean drinking water and sanitation, effective wastewater or industrial effluent treatment and management, and safe and efficient health care facilities and awareness are vital services to all communities around the world and in particular, South Africa. The South African government has embarked on the provision of adequate and safe water to all. This has led to a more intensive water research than ever before to ensure increasing and continued supply of drinkable and other survival related water. As a result, a new Water Services Act evolved to ensure access to water by the many families that never had one before. Coupled to this Act, is the National Water Act 36 of 1998, which guarantees safe water. The Act guards against pollution and intends to conserve and protect water.

### **Characterization of rural water**

South African rural areas are characterized by underground water abstraction, and largely depend on this for a living. Apart from this, some areas get their water from streams, rivers, and springs. Although groundwater is normally "clean", some areas experience high levels, than is acceptable, of nitrate, fluoride and in some instances, high sulfate in their water. Salinity is also of major concern but will however not be dealt with in this study. These pollutants have their levels higher than the SABS specifications for human consumption, livestock watering and irrigation. High fluoride concentrations are experienced in borehole waters in the Mankwe (about 14ppm), Moretele (4 to 5ppm) and Taung districts (approximately 5ppm). The waters are not fit for human consumption. Nitrate concentrations are as high as 173ppm in Moretele and 130ppm in Kudumane districts <sup>(1)</sup>.

High levels of nitrate (>10ppm as N) is known to easily convert the nitrite in the stomach which in turn get adsorbed in the blood stream. Nitrite hinders or defects oxygen adsorption and as a result causes oxygen depletion in the blood. Fluoride (>1ppm) causes

skeletal and dental fluorosis, and teeth mottling. It has crippling effects. Areas with high levels are usually characterized with consumers having yellow to brown-coloured or stained teeth. Sulfate in general is not known to have adverse health effects except at concentrations above 200ppm when diarrhea starts to develop. It can be a problem in areas that depend on water downstream the gold and coal mines that normally have acid mine drainage problems. This water from mines can also contaminate underground water via seepage into aquifers, subsequent health effects on consumers using groundwater. It is necessary to keep these pollutants to permissible levels and for that reason, an economic and easy to operate technology is sought to remove or keep nitrate, fluoride and sulfate to acceptable levels.

Membrane processes are gaining popularity in South Africa, especially for industrial use. It is expected that municipal use will soon become inevitable. Nanofiltration is a relatively new technique, which is looser in its polymer membrane structure than the Reverse Osmosis membrane which has dense top layer. These membranes usually having molecular weight cut-offs of 100 – 1000 Dalton, have a surface charge which can be influenced by the solution in contact with the membrane. This enable them to be discriminatory in rejecting or retaining ionic species (like water pollutants) based on weight and charge (mono- or divalent).

### **Aim and objectives of the study**

Noting high concentrations in the North and North West Provinces, it will be worthwhile to investigate affordable and easy to use and maintain techniques that will be used in these rural areas. The aim of this study is:

1. to gain an understanding of pollution in the rural areas by sampling for pollutants for the life of this study,
2. to investigate if nanofiltration is the process suitable for application in removal of nitrate, fluoride and sulphate,
3. to construct a laboratory scale unit for ground water treatment,
4. to build and develop cross-flow nanofiltration pilot plant for study in rural areas,
5. to capacitate and empower people from the community to operate and maintain the unit.

During sampling, the areas of the greater Rustenburg region showed high levels of fluoride and to some extent of nitrate. For the other three regions (Klerksdorp, Mafikeng and Koster), the levels of these two pollutants were within the limits. The study was continued on the cross-flow unit using sampled water from selected sites.

Nine commercial NF-membranes (D11, D12, CTC1, NF70, NF90, TFC-S, TFC-SR, TFC-HR and TFC-ULP) were evaluated in this and another <sup>[2]</sup> study for their efficiency (flux and retention) using pure water, non-charged solutes, single and mixed salts as well as numerous water samples from North West rural areas. All membranes had a negative surface charge density. While D11, D12 and TFC-SR had the highest flux for all systems tested, they had the lowest retention in terms of non-charged solutes as well as single salts. NF70, NF90 and TFC-S displayed reverse osmosis (RO) properties with high reflection coefficients ( $\sigma$ ) but low permeabilities for non-charged solutes and single salts. Membrane performance varied greatly when using mixed salts (depending on the salt combinations) and no correlation could be found.

A small laboratory scale NF unit was built to do preliminary studies in terms of screening and characterising the NF membranes. The NF unit, which could be operated up to 25bar, was built with the courtesy of Henk Veldhuis (Twente University, Holland).

For rural water treatment and testing of the high-pressure cross-flow NF unit, the best retention for fluoride and nitrate. All membranes efficiently removed sulfate due to their negative surface charge. While it was not possible to correlate membrane performance for different sample sites, TFC-S, TFC-SR, NF70 and NF90 had the best retentions on a dead-end module, and are recommended for further investigations.

The built high-pressure cross-flow unit was tested for performance by rejecting prepared solutions of sulfate, nitrate and fluoride. The results were comparable to those of the dead-end mode studies. In treating rural water, the membrane performance varied slightly from those observed during dead-end studies. Although the divalent ion (e.g.sulfate) levels were reduced greatly, monovalent ions were poorly rejected by all membranes, including the NF70 which showed promising results during the dead-end mode studies.

The backlog of the study was the failure to train and empower community people to operate the unit. This was because it was difficult to transport the unit to various sites of interest. The sampled water was instead brought on-site to where the unit was built. The ease of operation of the unit is recommended for further study.