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Fluoride removal from groundwater by nanofiltration

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Abstract

The fluoride content in many regions of Morocco greatly exceeds the acceptable standards. The beneficial or harmful effects of fluorides on teeth and skeleton depending on their concentration have been widely studied. Fluoride removal operations were conduced on underground water using a nanofiltration pilot plant with two modules. The performances of two commercial spiral membranes were proved. The influence of various experimental parameters such as initial fluoride content, pressure and volume reduction factor were studied.

Keywords: Defluoridation; Nanofiltration; Recovery rates; Pressure; Membrane

1. Introduction

An excess amount of fluoride ions in drinking water has been known to cause adverse effects on human health. To prevent these adverse effects, especially tooth and bone fluorosis, the World Health Organization fixed the maximum acceptable concentration of fluoride ions in drinking water to 1.5 mg/l [1,2]. The same standards were adopted in Morocco.

The fluoride content in many regions of Morocco greatly exceeds the acceptable standards. In the plateau of Benguerir (centre of Morocco), where the work was conduced, the dental fluorosis as a harmful effect is widespread among the population. The water in this region usually exceeds the standards for fluoride and is sometimes brackish. The fluoride contamination in this region is attributed essentially to the phosphate deposit.

Until today, the National Office of Drinking Water (ONEP) in Morocco has proceeded to a dilution to avoid the frequent seasonal excesses. With the decrease in water resources, especially

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underground water and with frequent excesses observed during the last decades, the dilution solution becomes unattainable in a short term. So to prevent this situation, ONEP has initiated studies in collaboration with Ibn Tofail University to investigate remedial options.

Different water defluoridation methods have been investigated: addition of chemicals to cause precipitation [3,4], ion exchange [5,6], adsorption [7,8] and membrane processes [9–12].

Among the membrane processes nanofiltration (NF) is the more recent technology. It is an innovative process having many applications especially for drinking water and wastewater treatment. Nanofiltration is a process with the properties between reverse osmosis (RO) and ultrafiltration (UF). The required pressures for NF are lower than those for RO making energy costs lower. Also the permeability of the nanofiltration membranes is higher than those of the RO one, making the NF performance in desalination preferable for some brackish waters. Because they carry charge in aqueous solution, nanofiltration membranes have a high retention of charged particles, especially bivalent ions, making this technology suitable to remove hardness.

For their high and specific membrane selectivity, nanofiltration and electrodialysis (ED) appear to be the best membrane processes to remove fluoride from equilibrated underground water.

In a previous paper [9], the study was carried out on a fluoride removal from underground water by electrodialysis using a pilot plant with a capacity of 1 m^3/h. In this work fluoride removal operations were conduced for underground water by nanofiltration using a pilot plant having a high pressure pump with a maximal flow rate of 3 m^3/h. The aim of this work is, on the one hand, to compare the performances of two commercial membranes with different pore radii (90 and 400 Da) and, on the other hand, to observe the influence of some operational parameters on the defluoridation performance.

2. Experimental

The experiments were performed on an NF/RO pilot plant (E 3039) supplied by TIA Company (Technologies Industrielles Appliquées, France). The operations were conduced in a semi-batch mode as is shown in Fig. 1. The applied pressure over the membrane can be varied from 5 to 70 bar with manual valves.

The pilot plant is equipped with two identical modules operating in series. Each module contains one element. The pressure loss is about 2 bar corresponding to 1 bar of each module.

The two spiral wound modules are equipped with two commercial nanofiltration membranes of one type. Table 1 gives the characteristics of the membranes used.

Table 1
Characteristics of the membranes used

Membrane	Cut off (Da)	Surface (m^2)	Material
NF90	90	7.6	Polyamide
NF400	400	7.6	Polyamide

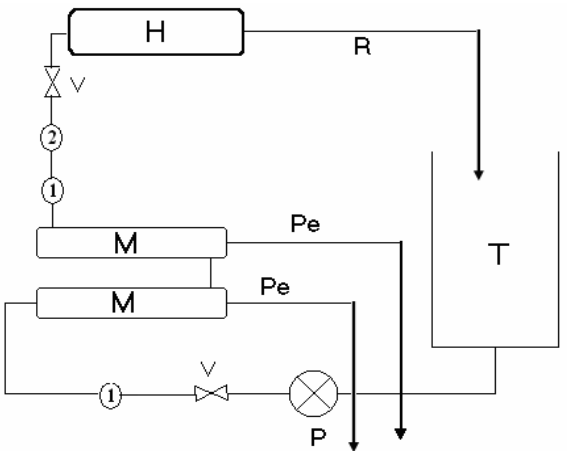

Fig. 1. Diagram of the nanofiltration pilot plant. T: tank; P: feed pump; V: pressure regulation valves; M: nanofiltration module; Pe: permeate recirculation; R: retentate recirculation; H: heat exchanger; 1: pressure sensor; 2: temperature sensor.