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AQUAPOT: Study of the causes in reduction of permeate flow in spiral wound UF membrane. Simulation of a non-rigorous cleaning protocol in a drinkable water treatment facility

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Abstract

In the last two years, international AQUAPOT project has carried out the installation of three drinking water treatment plants based on ultrafiltration (UF), in rural areas of the Andean region of Ecuador without access to drinking water. In addition, the project has carried out an applied parallel investigation in the Naquera Research Centre (CIN) in Valencia that has by objective the anticipation to the problems that can arise in the operation of the drinking water facilities already installed, as a consequence of a non-rigorous cleaning protocol. For the investigation, analogous drinking water treatment plants to the ones installed in Ecuador have been used, working continuously in long-term operation assay and using as feed superficial water with a high microbiological contamination. Cleaning protocol was applied every 7 days using a cleaning solution an basic and acid agent followed by a disinfectant reagent. Results after 6 months of test, showed a progressive decrease of the permeate flow and presence of microbiological contamination. This work exposes main results and conclusions from real assays, and recommendations to achieve a correct operation of the UF plant.

Keywords: AQUAPOT; Potable water; Ultrafiltration; Membranes; CIN

1. Introduction

Since 2004, the AQUAPOT international project has carried out a technical support by using membrane technology to provide with drinking water supply to poor rural regions with no access to safe water [1].

After applying location protocol [2] in Pucara, Santa Isabel and Giron (province of Azuay, Ecuador), drinkable water facilities based on ultrafiltration (UF) [3] were located in the best suitable emplacement. Assembly of the drinkable water

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facilities was completed with an specific training of local technicians based on cleaning and maintenance protocols in order to assure suitable procedures in their operation.

Control and periodic supervision of the drinking water facilities allowed to detect deficiencies in the systems installed that could be caused by the non-rigorous maintenance of them.

After studying causes and reviewing defined protocols of maintenance for each installation, was determined that were adequate. Observed deficiencies seemed to be explained by over long-term operation without cleaning.

Due to the significance of this fact and the impact that a non-proper working could have in population supplied with drinking water produced, it was proposed to simulate working conditions and deficient maintenance operation in an analogue drinking water treatment plant built in the Naquera Research Center (CIN), in order to achieve a practicable solution. Research done in CIN implemented by AQUAPOT project in Valencia (Spain) [4] basically consists in doing long-term assays in which membrane filtration was continuously carried out with a non-adequate cleaning. Operation and research with these facilities will allow to explain and detect prematurely problems that can come up in Ecuador and look for a suitable solution.

For the experiments, feed water with similar physical-chemical characteristics to the superficial water from Ecuador has been used. Moreover, to accelerate the fouling of the membrane active layer, feed water used contains high microbial concentration.

2. Methodology

Methodology followed to study the effect of a non-rigorous installation's maintenance, consisted in simulate cleaning conditions followed in the real water treatment plants, with the aim

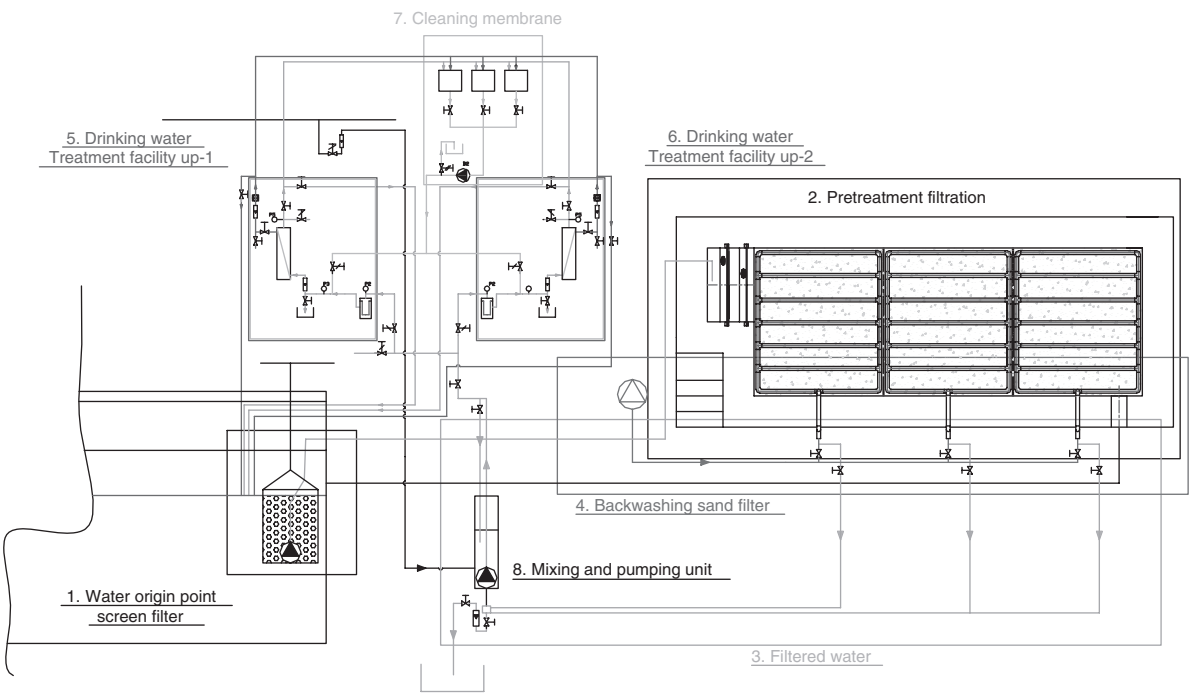

Fig. 1. Flow diagram of the installation in Naquera Research Centre (Valencia, Spain).

Table 1
Surface water analysis

	Method	Feed (CIN)	Feed (Ecuador)
pH (units)	SM* 4500 HB	7.25	7.84
Conductivity (μS/cm)	SM* 2510 B	803	118
Suspended solids (mg/L)	ISO 11923	1.5	–
Total coliforms (CFU/100 mL)	SM* 9221 E	>1000	500

*Standard methods for the examination of water and wastewater, 20th edition.

of forcing an irreversible membrane fouling and study the adverse effects that can arise and affect the quality of water produced.

2.1. Drinking water treatment plant

Drinking water treatment facility's feed comes from a nearby irrigation pond with 5000 m^3 capacity. Feed water is first filtered through a screen filter in the origin point, followed by a sand filtration before UF plant.

Fig. 1 shows the flow diagram of the drinking water facility installed in the Naquera Research Centre (Valencia, Spain).

2.1.1. Water origin point

Superficial water is collected from an irrigation pond and filtered through a cylindrical screen filter made of stainless steel with 6 mm pore size.

2.1.2. Filtration

Pretreatment is composed of a prefilter and sandfilter. Prefilter is made of stainless steel mesh with pore size between 3 and 0.8 mm. These metal grids are easy to remove for its periodic cleaning.

Sand filter has 9 m^2 of filtration surface area and is able to reach a filtration of about 200 microns. Granular media filter is composed by sand layer (0.5 mm particle size) and gravel layer (5–15 mm particle size). For cleaning, backwashing is used with compressed air (0.5 bar), clarified water or both.

2.1.3. UF facility

Drinking water treatment unit contains a 10-micron filter to remove suspended solids and two UF spiral wound modules in series, with polysulfone membranes, with a cut off (MWCO) of 100 K Dalton.

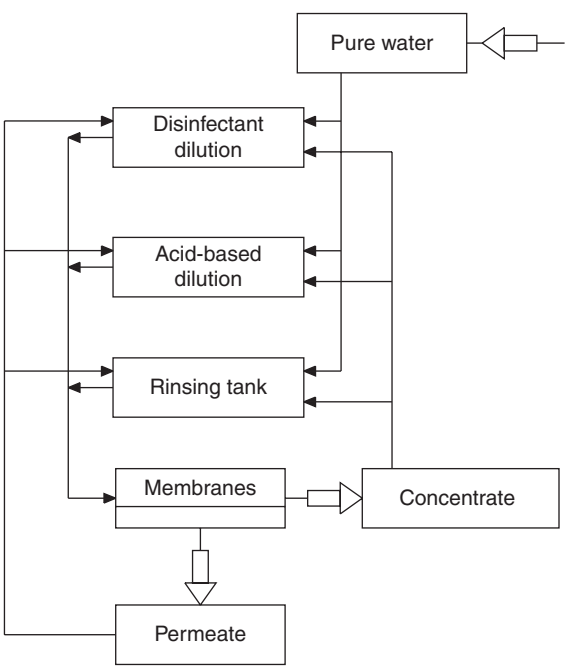

Fig. 2. Washing cycles during cleaning protocol.

2.2. Working conditions

Working conditions of the system installed are

- Feed flow: 1200 L/h
- Working pressure: 4 kg/cm^2
- Permeate flow: 800–1000 L/h
- Feed water temperature: depending on weather conditions (8–25°C)
- Operational period: 24 h/day

2.3. Feed water characteristics

Feed water for the assays comes from an open-air irrigation pond and has a microbial content higher than superficial water that is feeding drinking water facilities installed in Ecuador. Table 1 shows analytical results from both sources.

2.4. Cleaning protocol

When permeate flow values decrease over 50% of the initial flow, membranes are cleaned to recover its performance.

Washing cycles with recirculation are shown on Fig. 2.

Cleaning protocol for membranes is described in Fig. 3.

- Washing cycle: every seven days
- Cleaning steps (cleaning times: 20 min for each solution)
  - flushing with ultrafiltrated water from rinsing tank for 10 min
  - acid solution: citric acid reagent 1–3% (20 min)
  - flushing with ultrafiltrated water from rinsing tank for 10 min

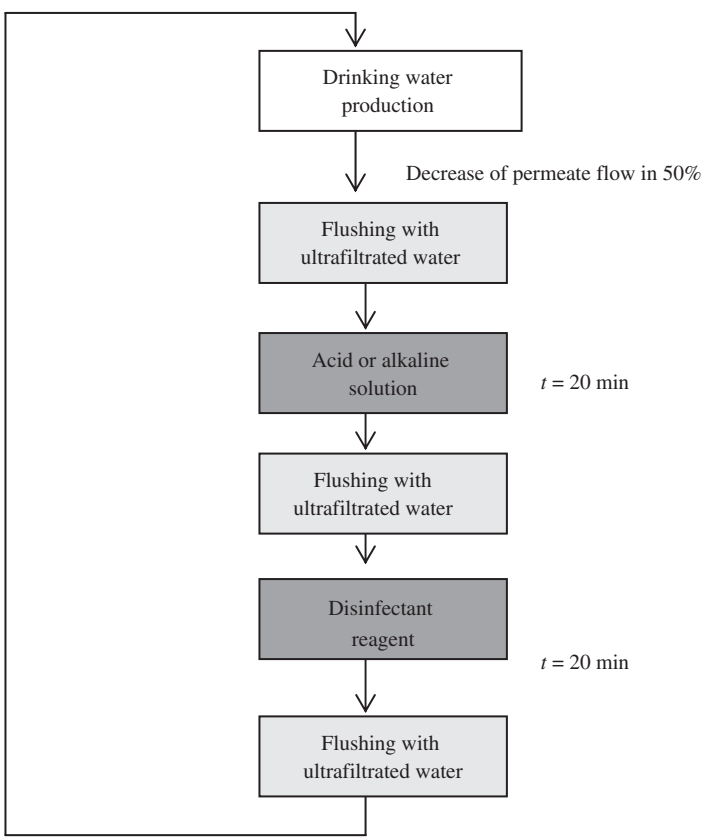

Fig. 3. Cleaning protocol.

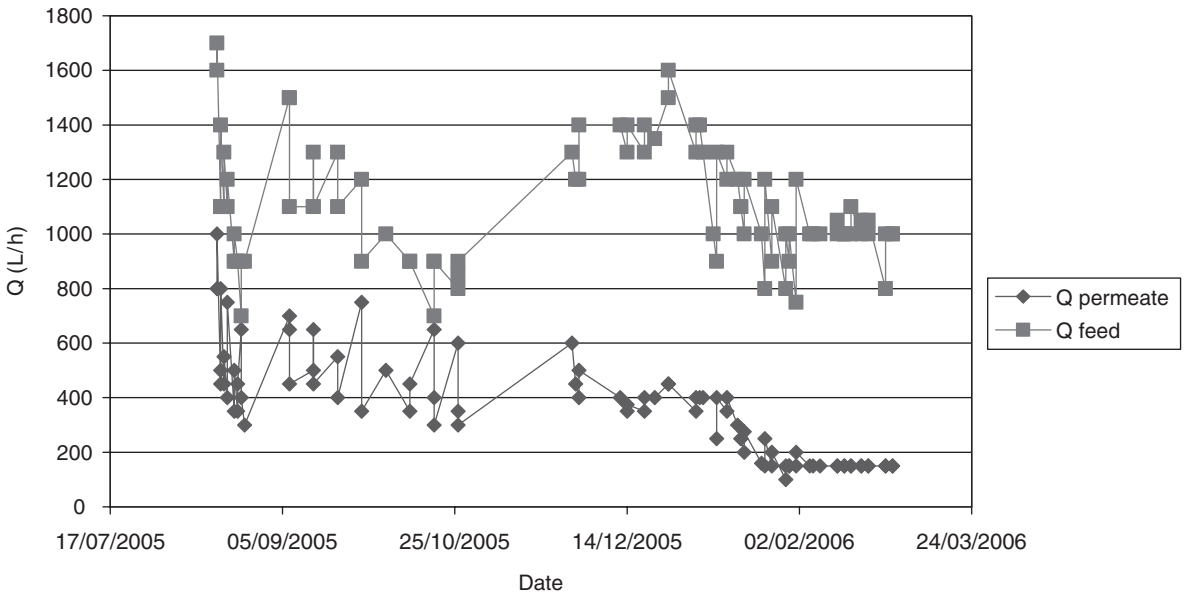

Fig. 4. Feed and permeate flows versus time during 6 months.

  - alkaline solution: NaOH pH 11 (20 min)
  - flushing with ultrafiltrated water from rinsing tank for 10 min
  - disinfectant solution: NaHClO 100 ppm (20 min)
  - flushing with ultrafiltrated water from rinsing tank for 10 min
- Cleaning temperature: between 11–25°C.

After cleaning, recirculation pump is stopped and starts drinking water production.

2.5. Microbiological analysis

Before each cleaning, samples from feed and permeate were taken for microbiological analysis (total coliform and fecal coliform test) in order to verify the correct operation of the installation.

3. Results and discussion

The experiments carried out during 6 months have permitted obtaining the following results:

- In the Fig. 4 can be observed a progressive decrease of the permeate flow with time and a moderated recovery of this one after each cleaning until reaching an irreversible fouling. After 6 months of tests, the flow of permeate decreased in a 85% in respect of the initial value.
- In each experiment, microbiological analysis indicated absence of contamination due to coliforms in the permeate flow, until the phase of irreversible fouling was achieved. In this case, Fig. 5 shows presence of microbiological contamination as result of total coliforms test

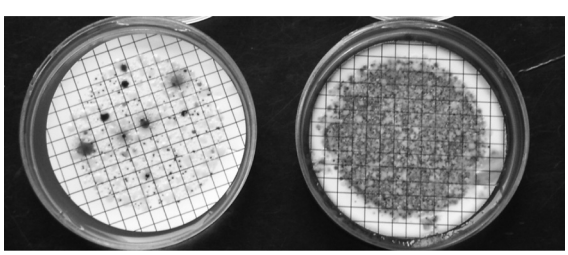

Fig. 5. Results of total coliforms test for permeate and feed water samples.

for feed water (right side) and permeate (left side) samples. Red dots indicate presence of contamination due to total coliforms and the blue dots contamination of fecal origin corresponding to *Escherichia coli*.

4. Conclusions

From the analysis of results the following conclusions can be consider:

- The applied protocol of cleaning has not been effective, which is noted by the progressive decrease of the permeate flow with time as consequence of an irreversible fouling of membranes.
- The behavior of membranes has been excellent during the 6 months of long time testing.
- For more time the right performance of membranes is not recoverable with the protocols of cleaning applied, because the irreversible fouling of the membrane active layer.

5. Applications to the UF-facilities in service

After the accomplishment of long-term tests, the following points will be considered:

- Increasing the frequency of membrane washing as minimum once a day. So it will be possible to obtain to a good maintenance and cleaning of membranes.
- Checking the recovery ratio of the permeate flow produced after each washing.
- Studying alternative cleansing products for the polysulphone membranes used, which be able to eliminate the bio-layer formed by low frequency of cleaning.

These recommendations will be applied in the facilities that are working in Ecuador, with the purpose of maintaining the water flow produced and to be able to assure their microbiological quality for human consumption.

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