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Degrémont's largest nanofiltration plant: NOM removal at the Vegi 2000

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ABSTRACT

Nanofiltration (NF) is an alternative for micropollutant and organic matter removal. Some important aspects must be taken into account in the design and the operation (e.g., biofouling). The Vegi 2000 plant with a total production capacity of 110,000 m^3/d is the largest NF plant built by Degrémont. Commissioning was scheduled for end of 2008. The first feedback of the plant commissioning of the plant is presented. The choice of the treatment line was linked to pilot tests carried out from 2000 to 2005. The aim was to better understand water quality problems and to compare several alternatives for the treatment; the best dissolved organic carbon (DOC) and especially biodegradable DOC reduction was targeted. Pilots were installed at the Eupen drinking water treatment plant. Ozonation coupled with granular activated carbon (GAC) absorption was tested, and different membrane alternatives were also considered (microfiltration/ultrafiltration) (MF/UF), UF + powdered-activated carbon (PAC), NF). NF was tested with Toray, Hydranautics and Dow membranes and focused on Dow membranes. The first feedback of NF will be presented in the future.

Keywords: Nanofiltration; NOM; Membranes; Brackish surface water; Desalination

1. Introduction

Belgium is increasingly meeting drinking water problems due to a lack of resource and degraded surface water. Natural organic matter (NOM) occurs in raw water, among others as humic substances, giving the water a color [1] as total organic carbon. Organics in the distribution network can lead to bacteria regrowth. Chlorination can partly help to prevent from biofilm development but increases THM concentration by oxidizing organics, as NOM acts as the precursors to disinfection by-products. [2]. Nanofiltration (NF) is an alternative method for organic matter removal with a removal efficiency sometimes higher than 90%, being in some cases more effective than "conventional" activated carbon adsorption [3]. Therefore, this technology was selected to upgrade the Vegi 2000 (Belgium) drinking water treatment plants in Eupen and La Gileppe. Both plants treat surface water and are equipped with conventional clarification, which is maintained as NF pre-treatment. Moreover, the energy requirements for NF is much lower than reverse osmosis (RO). NF allows performance of both ultrafiltration (UF) and RO; however, NF operates at lower pressure, usually in the range of 50–150 psi.[1]

The NF plants are located in the eastern part of Belgium, close to the German border (Fig. 1), with a total production capacity of 110,000 m^3/d.

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Fig. 1. Plant location.

2. Raw water

The La Gileppe and Eupen plants are both fed by dam water from from the Stembert and La Vesdre dam waters, respectively. Daily and complete raw water analyses are made on both plants; as a consequence, TOC values are well known, as are their variations. There are seasonal peaks between September and December of organic matter. The La Gileppe TOC analyses are found to be 7–8 mgC/L. For Eupen, the TOC is 11–14 mgC/L.

3. Pilot tests

Due to the problems of bad water resources and in order to improve treatment, some pilot tests were performed by the Wallon Water Society (SWDE) in collaboration with membrane and process suppliers. Preliminary laboratory tests consisted of studying the conditions for biofilm development: TOC of 0.8–1.2 mgC/L was considered as the objective of treatment.

As a consequence, different treatment lines were operated on the raw waters to compare their performances in terms of organic matter reduction. The following treatment lines were studied:

- replacement of pre-chlorination by pre-ozonation
- ozonation + granular activated carbon
- UF/MF
- powdered activated carbon + UF
- NF with Toray Hydranautics and Dow membranes

The main conclusion was that only the NF process could produce water with TOC values below 1 mgC/L (Table 1). These results confirm other data from the literature [3,5].

Pilot tests ran for 5 years from 2000 to 2005, and as we can see in Fig. 2, recovery remained stable between 80 and 90%. Moreover, TOC concentration in the NF permeate was around 0.2–0.3 mg/L (see Fig. 3), allowing a possible blending between permeate and NF feed water allowing a reduction of the NF membrane surface.

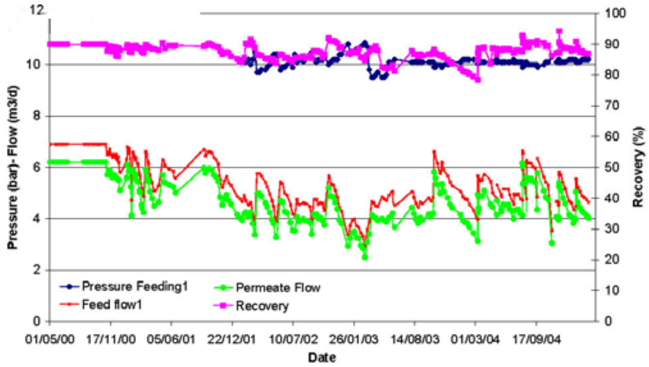

Fig. 2. Pilot hydraulic conditions: pressure and flow from 2000 to 2005.

Table 1
Treated water quality

TOC (mg/L)	Pre-treated water	Permeate
Minimum	1.7	ND
Maximum	3	0.2
Average	2	0.02

In terms of the calco-carbonic equilibrium, Eupen and La Gileppe raw water was poorly mineralized and the historical plants were already equipped with remineralization treatment based on CO_2 + lime and CO_2 + calcium carbonate.

4. Plant design

4.1. NF feed water quality for design of La Gileppe

The following water characteristics have been taken into account for the design of the La Gileppe plant (Fig. 4). Water characteristics after flotation are:

- pH: 6.5
- low turbidity (< 10 NTU)
- low water temperature (4–10°C)
- low hardness and alkalinity (respectively 20 mgCaCO$_3$ and 5 mg CaCO$_3$)
- high metal concentration (aluminium, 0.4 mg/L, Fe 0.65 mg/L and Mn 0.58 mg/L)
- quite high TOC, on average 3 mg/L (between 2.5 and 3.8 mgC/L).

4.2. NF feed water quality for design of Eupen

The following water characteristics have been taken into account for the design of the Eupen plant. Water characteristics after clarification and filtration are:

- pH: 6.8
- low turbidity (<0.1 NTU)
- low water temperature (4–10°C)

- low hardness and alkalinity (respectively 9 mg $CaCO_3$ and below 5 mg $CaCO_3$)
- low high metal concentration (no aluminium, Fe at 0.01 mg/L and Mn 0.03 mg/L)
- quite high TOC, 2–4 mg/L

These values are from the original project specifications.

4.3. Filtration tests

La Gileppe results measured after existing $CaCO_3$ filters give relatively high SDI values (3.8) while laboratory sand filters give better results (2.6), more compatible with a long-term NF operation.

4.4. Process line

Based on the pilot study results and the historical design, the process line is as follows:

- prechlorination (shock, as necessary) and oxidation ($KMnO_4$)
- coagulation/flocculation with an aluminium-based coagulant, pH correction (NaOH to control the pH)
- clarification with flotation on La Gileppe and conventional settling tank at Eupen
- RO protection using cartridge filters
- NF (recovery 90%)
- blending of permeate with NF pre-treated water
- remineralization with CO_2 + calcite filters
- final disinfection

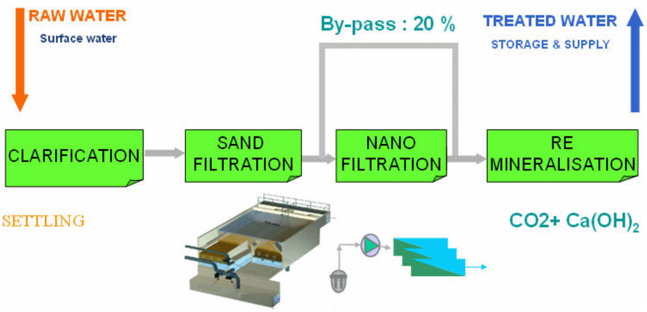

Fig. 3. Eupen treatment line. Capacity: 65,000 m^3/d.

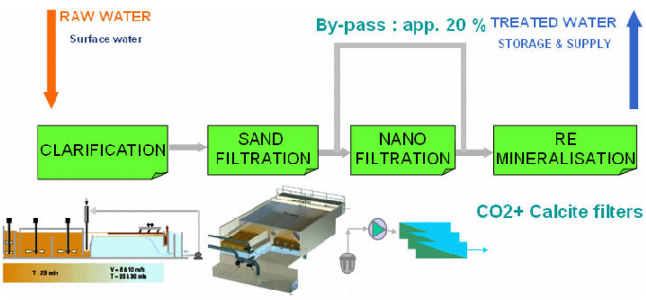

Fig. 4. La Gileppe treatment line: Capacity: 45,000 m^3/d.

The La Gileppe plant has three NF racks (five racks for Eupen) with all three stages to obtain a 90% conversion rate. A by-pass of NF (approximately 20% regulated according to TOC concentrations) enables reducing equipment and operation costs since NF is the most expensive process in terms of OPEX and CAPEX. Permeate is blended with NF by-pass for a downstream remineralization on $CaCO_3$ filters after CO_2 injection (Figs. 5–7).

Fig. 5. Eupen sand filter washing.

Fig. 6. La Gileppe RO plant under commissioning.

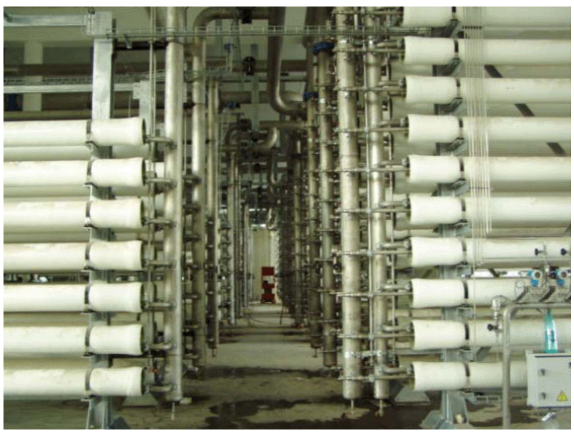

Fig. 7. Eupen RO plant under commissioning.

The overall process design was based on the following key objectives:

- Achievement of the produced water quality in terms of organic matter and mineralization
- Maximum reliability of the overall process
- Optimized capital and operating cost
- Maximum water recovery and minimum wastewater discharge
- Flexibility in terms of process adaptability to widely varying influent conditions and in terms of potential future plant expansion

4.4.1. Prechlorination/oxidation

To oxidize manganese and iron, $KMnO_4$ is injected into raw water (1 mg/L); then, chlorination is applied (0.5–0.8 mgCl_2/L) to oxidize organic matter. This pre-oxidation treatment, not recommended for upstream RO membranes [6], is planned to be reduced step by step.

4.4.2. Clarification

At La Gileppe a conventional flotation is used for clarification on three parallel lines while a settling tank was installed at Eupen. Both use the same aluminium-based coagulant (Sachtoklar); pH regulation (between 6.4 and 6.7) is made with caustic soda. Flotation velocity is 10 m/h.

4.4.3. Filtration

Twenty-three filters (ES 0.95 mm) are available at the Eupen plant but only 14 are operated at the same time. Filtration velocity is 5 m/h. The three actual calcite remineralization filters have been rehabilitated to sand filters (ES 0.95 mm). Filtration velocity is 5.4 m/h.

4.4.4. Chlorine neutralization

Neutralization of any chlorine residual from pre-chlorination (using sodium bisulfite) is included in the design. Different online analyzers (Redox, chlorine) are installed upstream RO membrane to prevent any RO membrane oxidation.

4.5. RO design

4.5.1. Variable RO feedwater quality

The key sizing (limiting) parameters for the RO design is organic matter. Both RO plants are designed for a recovery rate of 90%. Upstream NF membranes are used with an anti-scaling agent (Genesys) injected to prevent $CaCO_3$ scaling.

4.5.2. La Gileppe general design

The RO feedwater flow from pretreatment is designed at 40,000 m^3/j. The RO system includes three trains (Fig. 6). Each train includes three stages with 68/34/15 pressure vessels with six membranes. Filmtec NF 270-400 mem-branes are used. Reject from the NF system is discharged to the wastewater treatment plant.

Fig. 8. Eupen calcite filter under construction.

4.5.3. Eupen general design

The RO feedwater flow from pretreatment is designed at 57,800 m^3/j. The RO system includes five trains (Fig. 7). Each train includes three stages with 60/28/12 pressure vessels with six membranes. Filmtec NF 270-400 membranes are used. Reject from the NF system is discharged to the wastewater treatment plant

4.5.4. Post-treatment

The RO permeate is blended with a variable portion of pretreated water (20% on average), and the aim is to get a TOC concentration below 1 mgC/L. Remineralization is done by CO_2 injection (already in operation on the historical plant after flotation for La Gileppe) and filtration on calcite filters. There are three calcite filters at La Gileppe and five at Eupen (Fig. 8) (filtration velocity 5 m/h and between 15–20 min contact time). After remineralization for both plants, treated water alkalinity will be between 50–70 mg$CaCO_3$/L and hardness 80–100 mg$CaCO_3$.

4.5.5. Final disinfection

Before the use of nanofiltration, a 2 mg/L chlorine dosage for final disinfection was used to get 0.25 mg/L of maximum residual in free chlorine. It is expected to be reduced to 0.5–1 mg/L with NF treatment in operation.

4.6. Wastewater

Sand filter and calcite filter backwash water is directly recycled upstream pre-treatment to reduce water losses. Sludge from clarification is sent for dehydrating treatment by centrifugation.

5. Conclusions

The 5-year pilot study reached to the main conclusion was that only the nanofiltration process could produce water with TOC values below 1 mgC/L. NF performances were more efficient than conventional pre-treatment like CAG filtration or membrane treatment in TOC removal.

The Vegi 2000 water treatment plants is Degrémont's largest NF plant. The project is based on strict treated water requirements. Selection of the process, as well as membrane design, was based on long-term pilot tests.

This is accomplished in conjunction with satisfying the other key project objectives:

- Achievement of the produced water quality in terms of organic matter and mineralization
- Maximum reliability of the overall process
- Optimized capital and operating cost
- Maximum water recovery and minimum wastewater discharge
- Flexibility in terms of process adaptability to widely varying influent conditions and in terms of potential future plant expansion

The system will have to prove that it is well designed during the first months of operation. NF will require the lowest filtered water SDI with the most optimized pre-treatment. However, preventive non-oxidizing biocides might be necessary [6]. Raw water characteristics change will have to be taken into consideration for pre-treatment optimization to get the best SDI values for an upstream membrane. This plant is nevertheless challenging with very high raw water variability.

An extension to 60,000 m^3/d at La Gileppe and 65,000 m^3/d at Eupen is planned in the next few years and is considered in this upgrading.

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