Reverse Osmosis Technology to Reduce Fresh Water Consumption – Case Study, Agnico Eagle Finland, Kittilä Mine

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Abstract Mines require large volumes of water in their processes. Therefore, the recycling of process waters is desirable. With improved water recycling, freshwater intake can be reduced while simultaneously decreasing water discharge.
Reverse osmosis (RO) is acknowledged as the key technology for the recycling of process waters. In this study, the RO pilot operated in Agnico Eagle Finland Kittilä Mine with a slightly over-saturated gypsum solution with the silt density index permanently near or above 5.0.
Based on this near full-scale pilot operated for more than a year, we recommend RO technology for process water recycling.

Key words IMWA 2017, Agnico Eagle, Mine Water Treatment, Water Recycling, Reverse Osmosis

Introduction

Agnico Eagle Finland Kittilä Mine is a gold mine situated in Northern Finland. The objective of Kittilä Mine is to increase water recycling per ton of ore processed. In addition to increasing the water recycling efficiency of the mine, it may be possible to decrease fresh water intake.

Reverse osmosis (RO) is typically used in desalination processes, and the technique is applied in the major number of the world's desalination plants (Greenlee *et al.*. 2009). Furthermore, RO is a key technology in the recycling of process waters.

Although RO is widely used in other industries, the harsh conditions in mining environments result in specific challenges for RO operation. Pretreatment is extremely important for the reliable functioning of the RO, as various compounds may cause fouling or scaling of the membranes (Andes *et al.*. 2013). Typical RO membrane fouling and/or scaling factors include total suspended solids (TSS), iron, manganese, organic compounds, hardness, and microbiological growth (Vidqvist 2005). The main objective for this pilot is to gain knowledge about the technical usability of RO technology in Kittilä mine.

Methods

The water recycling pilot was begun at the end of 2015 and has since been operating at Kittilä mine. The feed water for the pilot is neutralizing pond water that is slightly over-saturated with gypsum solution with a silt density index, a typical fouling indicator for RO membranes, permanently near or above 5.0. The RO has the capacity to produce approximately 20 m^3/h of low salinity permeate with a recovery rate of 50 %. The RO permeate is used as the process water.

The water recycling pilot includes pumps, a heat exchanger, chemical dosing units, sand filtration, mechanical bag filtering, and two parallel RO units. A model of the process can be seen in figure 1. The four sand filtration tanks (figure 1, units on the left) consist of iron and manganese oxidising sand media together with traditional sand filtering media. The main function of the sand filtration is to reduce TSS, microbiological load, and other potential fouling factors of the RO membranes. The bag filter unit (not shown in figure 1) is used to reduce residue particles after the sand filtration. Subsequent to bag filtration the flow is divided into two RO units (figure 1, two units on the right), which contain different membrane types.

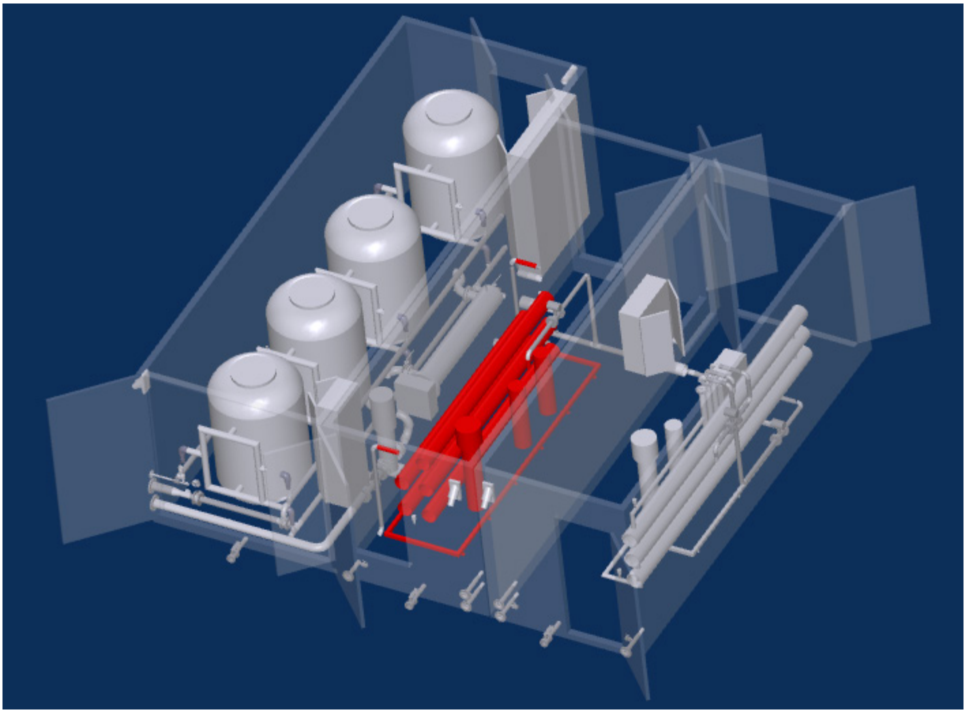

Figure 1. *A model of the water recycling pilot.*

Results

The reliable functioning of the presented water recycling system during feed water changes was investigated in this study by examining the performance and life cycles of different RO membrane types, fouling and scaling factors, as well as benefits and disadvantages of different chemical additions and various membrane cleaning procedures. A process data summary is presented in figures 2 and 3.

Sand filtration decreases TSS approximately to 1 mg/l. However, it is not efficient at reducing organic matter, as seen in figure 4. The levels of organic matter were measured using biological oxygen demand (BOD), chemical oxygen demand (COD), and total organic carbon (TOC).

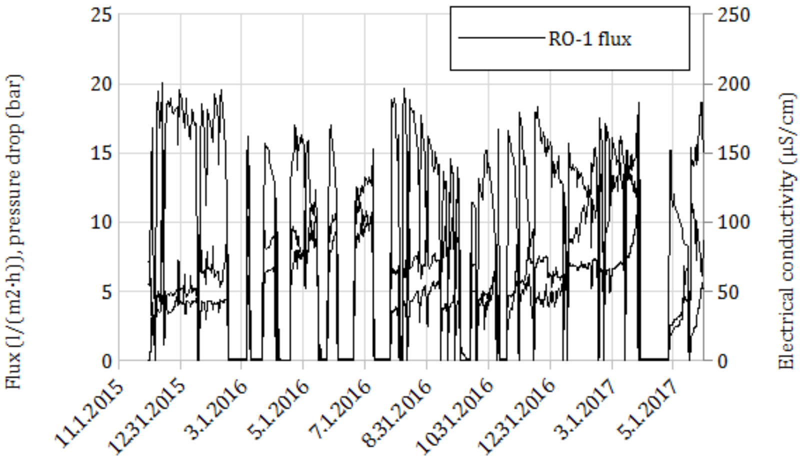

Figure 2. *A summary of the process data of RO-1.*

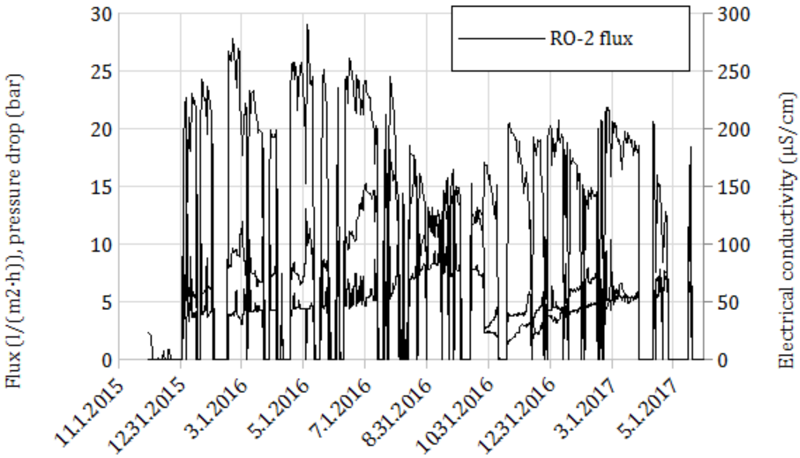

Figure 3. *A summary of the process data of RO-2.*

When operating with a 50 % recovery, the concentrations of the compounds from the RO feed ("Bag filtered" in figure 4) to the RO concentrate ("RO-1 cons" and "RO-2 cons" in figure 4) should be multiplied by factor 2. The differences between the RO membrane types can be seen in figure 4. After three months of operation (figure 4a), the concentration factors of TSS, BOD_7-ATU, COD_{Cr}, and TOC for RO-2 were 1.55, 1.63, 1.68, and 1.58, respectively. Eight months later (figure 4b) the values were 1.63, 1.95, 1.81, and 1.89, respectively. For RO-1, however, the concentration factors three months after the beginning of the pilot (figure 4a) were 1.35, 1.25, 1.76, and 1.58, and eight months later with different membranes (figure 4b) 0.89, 1.20, 1.10, and 1.11, respectively. The data shows a clear difference between the membrane types, where the second set of membranes of RO-1 accumulate more solids and organic matter than the membranes of RO-2. Furthermore, the divergence in the performance of the membranes was seen as faster permeate flow decrease, and in the increment of pressure and permeate conductivity of RO-1 compared to RO-2. In addition, the difference in the membrane characteristics was seen in practise during RO cleaning operations.

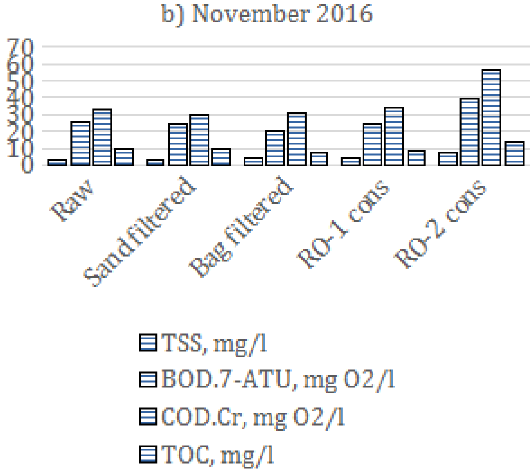

Figure 4. *TSS and the indicators of organic matter.*

Feed water changes affect the performance of the water recycling system. For example, TSS varied from 0.5 mg/l to above 30 mg/l directly affecting the performance of the sand filtration. The microbiological quality of the feed water further contributes to membrane fouling. Figure 5 shows microbiological levels of raw water and sand filtered water. Microbiological fouling is estimated to be one of the most significant fouling factors of the RO membranes in this water recycling pilot. In addition, clay and organic matter are known to foul the membranes.

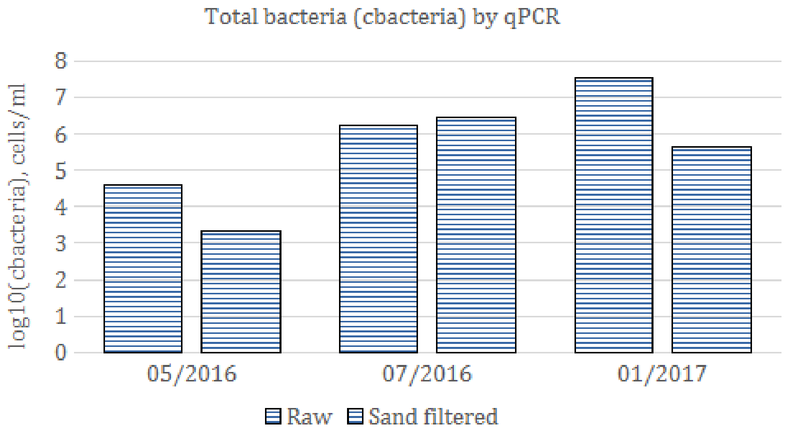

Figure 5. *The bacterial concentrations in raw water and sand filtered water. Measurements were done with a quantitative polymerase chain reaction (qPCR) by Industrial Water Ltd.*

Conclusions

The Agnico Eagle Finland Kittilä Mine case study showed the RO technology to be an efficient system for mine water treatment, as the water recycling within the mine was increased and the permeate quality was shown to be consistent.
The most challenging factor in the use of RO technology is membrane fouling. Therefore, different membrane types and enhanced pretreatment methods need to be studied to increase the RO production cycle time between RO membrane cleaning operations.

In this study, regular process observation alongside RO cleaning procedure development were done to ensure the functioning of the water recycling pilot. Due to the importance of microbiological fouling, systematic and regular microbial monitoring was additionally conducted.

Improved water recycling is not only technically useful for the mining industry, but is also capable of decreasing environmental impact of any industrial branch. Water recycling is also a prerequisite for the goal of zero liquid discharge in any process.

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