Pall Corporation

Mine Water Treatment Solutions for Discharge and Re-Use

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Summary

This paper focusses on the description of reliable, safe and economical treatment of mine water from different types of mines and applications by advanced membrane systems. The applications include mine drainage water from underground mines, intrusion water in open pit mines and excess water from tailing storage facilities. The illustrated references confirm the existence of robust, reliable, and economical technologies that ensure that, even under varying conditions, environmental discharge requirements can typically be met by providing appropriate quality waste water for disposal. As the spectrum of harmful components vary from mine effluent to mine effluent, and defined discharge requirements by local environmental authorities become even more stringent, an in-depth review of water analysis data and operating conditions must be conducted to determine the appropriate mine water treatment system design. Broad experience in treating landfill leachate has helped Pall to design sustainable and dependable systems for mining.

1. Introduction

Environmental concerns, stringent regulations, resource management, and access to water (along with general acceptance by the respective local community mine for the operation of the mine) have become major issues for mining companies worldwide during the last couple of years.

While the major wastes generated by mines are waste rock, tailings and overburden, the majority of emissions can be found in discharged mine water.

As mine water accumulates when the water level overflows the depth of an open pit surface mine or an underground mine, the water must be pumped or drained out of the mine to ensure safety and stability. Depending on the water availability and quality, it may be re-used for process applications on site such as make-up water, dust suppression or mill operations, grinding, leaching, and steam generation .

Since more than 70% of all pollutants from the mining industry are emitted into water, the removal of these contaminants prior to discharge is receiving significant attention. It is critical to avoid a discharge of toxic components into the environment and subsequently back to the food-chain. Because of this, regional discharge requirements are becoming more stringent, while non-compliance is being penalized more frequently and more heavily.

Water and wastewater treatment is thus becoming a major focus of mine operations, which is changing the landscape of site water management and treatment.

2. Fundamentals of the System Design and Requirements

Recent developments in reliable and economical membrane technology have allowed Pall Corporation to design robust, cost-effective systems that produce a good quality of water in a broad range of mine wastewater treatment applications.

Applications include the removal of oxidized components and other particulate matter as well as the removal of dissolved components by using integrated systems. These incorporate unique, high-crystalline polyvinylidene fluoride (HC-PVDF) hollow fibre membranes, followed by Reverse Osmosis (RO) or Nanofiltration systems, based on spiral-wound or Disc-Tube™ technologies.

Pall's advanced membrane systems ensure that the critical water management needs of mining customers are met by addressing the broad spectrum of water contaminants even at remote sites. In addition, these environmentally responsible technologies outperform conventional treatment methods by far and allow customers to meet their goals for both nature protection and health improvement. In some cases, treated mine waters are even re-used for potable purposes.

Furthermore, Pall's innovative products enable process optimization, thus minimizing emissions and waste.

With several hundred Pall Aria™ installations worldwide, (including mining, landfill leachate and other non-mining water installations), Pall has gained tremendous experience in helping mining companies with their environmental or health improvement programs.

Water balance and contamination levels can sometimes be very difficult to predict as site-specific factors such as fluctuations, variability in TSS, and acid generation potentials have a significant impact on the amount of dissolved components in the water.

In order to minimize water management problems due to excess water at a mine site, or to address changing constituents or contaminant levels over time, Pall has designed its water treatment system to be highly "modular" and offers it in a multi-rack-based configuration. Its design allows variable operation of hydraulic load changes throughout the day, and can also handle changing levels of fluid properties (e.g. turbidity) by adjusting the trans-membrane-pressure. In addition, the system's capacity can be easily upscaled to meet future demands. Additional pre- or post-treatment stages can also be added to reflect changes in regulatory requirements.

In order to minimize the use of chemicals, Pall has developed an "Air-scrub" operating protocol for the membranes. This process provides a highly efficient removal of solids and fines from the membranes during the standard operation sequence and gives the hollow-fibre-membrane the highest possible recovery rates. A large ecological benefit of the Pall membrane technology is the fact that no chemical injection is necessary during standard operation of the system.

Membrane recovery with appropriate cleaning protocols is ensured, which consistently brings the permeability back to nearly that of "new membranes". This has been demonstrated in numerous installations over the years.

The extremely robust nature of the HC-PVDF hollow fibre membranes gives them a superb lifetime expectancy.

3. Operation Conditions

Changes in water volume and the amount of suspended and dissolved solids that need to be removed are not untypical for mine wastewater/drainage applications, especially in coal mining or tailing effluents. Accordingly, the system needs to be flexible enough to cope with these varying conditions while consistently meeting defined effluent characteristics in the membrane permeate.

A typical example of the rapid changes that occur in mine water is shown in the following chart:

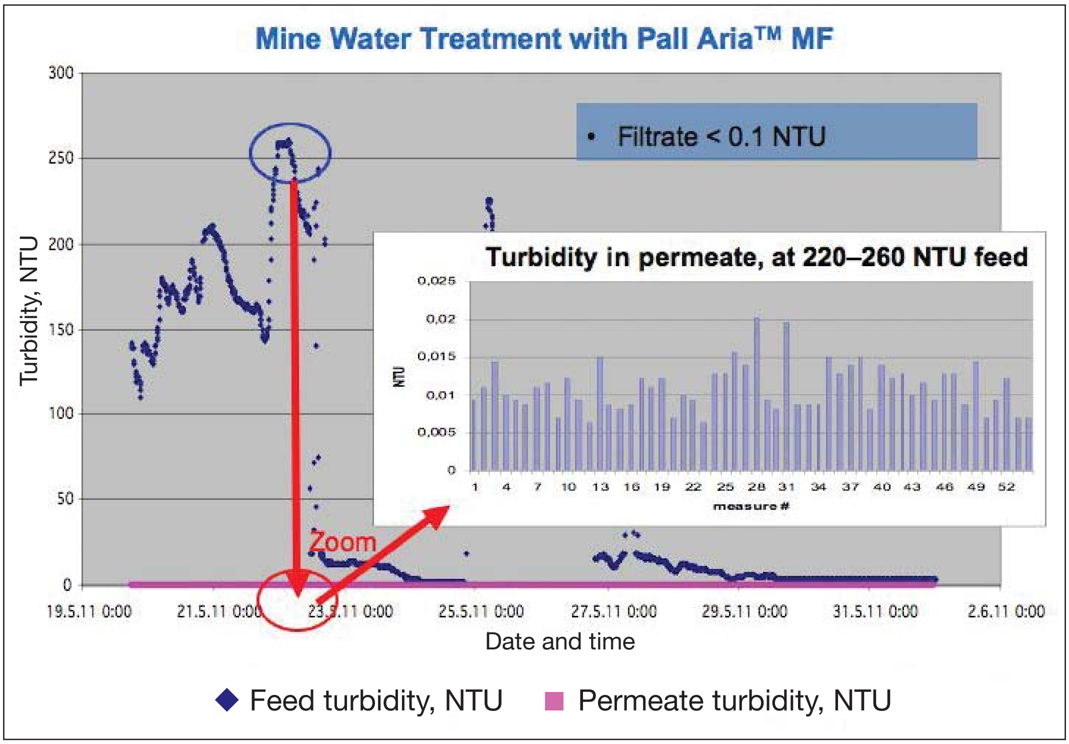

Figure 1: *Turbidity in mine effluent*

It should be noted that the measuring point of the water turbidity is downstream of a settling pond where coagulation agents were added which caused the bulk solids to settle.

Independent of the huge variability of the feed turbidity, the Pall hollow-fibre system showed a stable and reliable operation.

One reason for this is that the "out-in" flow direction across the selected membrane type eliminates any "clogging". Increased loading of solids led to an increase of debris on the membrane, thus raising the transmembrane pressure while maintaining a constant output of filtrate. An automatic adjustment ensured proper operation of the Pall Aria™ Membrane System even under highly variable conditions. Most importantly, despite the peak-load of contaminants (raising turbidity to around 250 NTU), the permeate quality remained far below 0.1 NTU. This provided maximum protection of the technology installed downstream (e.g. reverse osmosis), ensured low effluent discharge values for total suspended solids (TSS), and ensured that oxidized components such as iron, manganese or arsenic were removed continuously, safely and reliably. The data in the chart above was measured at a pilot plant in Russia/ Siberia in spring 2011.

To remove multiple contaminants with different chemical properties from mine water, a microfiltration step followed by reverse osmosis or nanofiltration is typically the best solution in order to avoid extensive and cost-intensive pre-treatment of the water.

4. Examples and Results

The following treatment example of a fairly difficult water quality that accumulated during the treatment of excess tailing circuit water from tailing storage facilities (TSF) at a gold mine in the US shows the proven capabilities of the Pall technologies:

The key contaminants of concern were metals, nitrate, sulphate, arsenic and the TDS-value. The solution to these hazardous materials was a reverse osmosis system, protected by a Pall HC-PVDF microfiltration system. Pre-treatment was conducted by means of oxidation, coagulant addition, and settling.

To assess the system performance, two parameters were measured online and documented for the environmental authorities:

- the turbidity value, measured as Nephelometric Turbidity Unit (NTU),
- and the conductivity (µs/cm).

Contaminant	Total (mg/l)	Local discharge limit (mg/l)
Ni	0,4	0,05
Fe	2,2	1
As	0,1 – 0,2	0,1
NO_3 -	320	220
SO_4^{2} -	1400	600
TDS	1900 – 2200	2000

Figure 2: *TSF water feed values and discharge limits*

The Pall system was able to fulfill the local requirements regarding discharge values right from the start, e.g. sulphate effluent values were below 10 mg, showing a consistent sulphate removal efficiency of more than 99%. Its extraordinary performance was not inhibited by the complex mix of contaminants in the mine water.

Another example relating to treatment of intrusion water from a copper mine is shown below.

This example shows the reduction of contaminants from dam water entering the mine's water treatment plant. The water was first treated by MF-RO and the concentrate was subsequently treated by a Disc- Tube™ RO system with the following results:

- Sulphate was reduced from 100 mg/l to < 5 mg/l
- Copper was reduced from 0.5 mg/l to < 10 µg/l
- Manganese was reduced from 0.6 mg/l to < 50 µg/l
- Zinc was reduced from 0.2 mg/l to < 5 µg/l

The performance of a Disc Tube™ system regarding the parameters raw water feed and permeate can be seen in the following diagram:

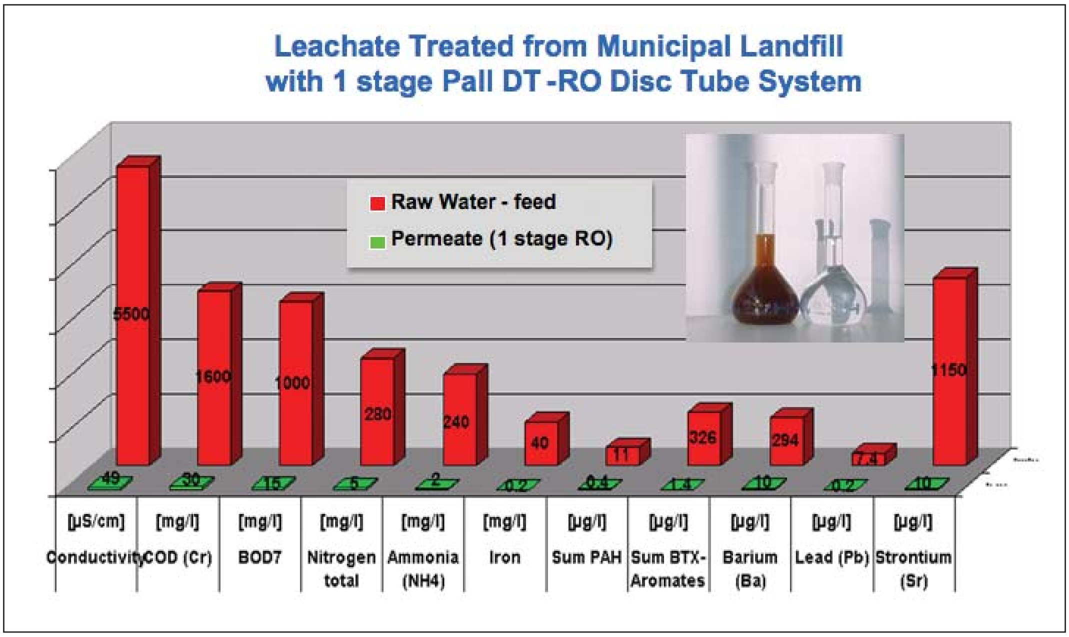

Figure 3: *Leachate and permeate values*

The results of wastewater treatment from a hazardous waste site using the same DT-technology are illustrated in the following chart:

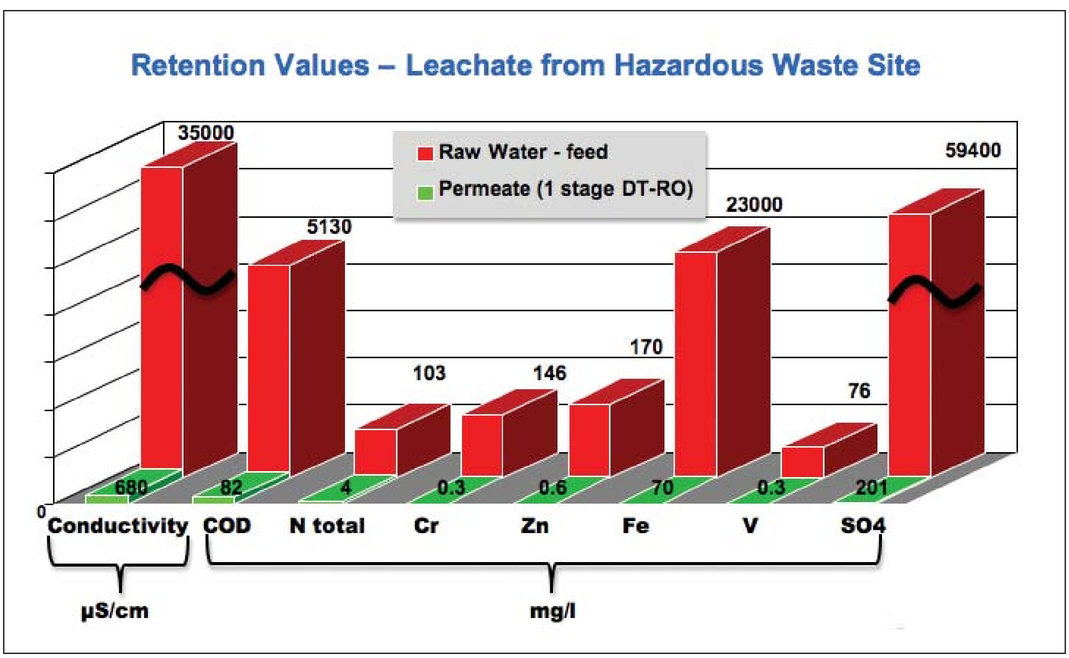

Figure 4: *hazardous waste water treatment*

The cases described above underline the importance of a state-of-the-art treatment system design that is capable of operating in varying mine water quality and quantities.

Recent developments in robust and economical microfiltration membrane technology combined with the leveraging of its experience in landfill leachate treatment have allowed Pall to design and install systems with outstanding performance in mining waste waters.

Depending on the quality and nature of contaminants, microfiltration systems have been installed directly in mine drainage water (to remove manganese, iron, arsenic, colloids, or diverse solids), or in combination with reverse osmosis systems (where RO is used to purify the fluid by removing dissolved solids).

Additionally, Disc-Tube systems have been used to minimize the volumes of remaining brines.

Their track of records is based on numerous installations and experiences from treating leachates from landfills or hazardous waste sites.

Effluent water from with these technologies can be discharged into surface waters or re-injected into aquifers. Several installations re-use that water for process applications or even for potable purposes in arid regions.

5. Conclusions

Membrane technology has a long track record of excellent performance in desalination for drinking water, surface and well waters and MBR wastewater treatment. Recent developments in membrane polymer chemistry combined with unique regeneration capabilities have enabled Pall to provide made-to-measure water treatment solutions. These solutions utilize high-crystalline-PVDF hollow-fibres with airscrub regeneration as the key separation step for the treatment of mining water and wastewater/leachate. The system's robust fibres demonstrated consistent performance in several challenging mine water applications over the last few years. The implementation of this latest technology has helped mining companies to reduce costs, improve their processes and protect the natural environment of the communities in which they operate.

A number of water treatment systems are in place, mainly in the gold, coal, nickel, and copper industries. The systems are installed at operational, industrial scale plants, where mine drainage or pit water, waste water from tailing storage facilities, and even "produced water" from coal seam methane production are treated.

The use of treated wastewater varies based on geographic region, treatment method, local discharge requirements, and re-use requirements. Properly treated water has even been used for potable applications at mine sites.

The production of potable and process water from ground water by removing contaminants such as heavy metals and pathogens is part of the system capabilities.

The highly sophisticated Pall membrane systems have proven to work extremely reliably with a wide range of very complex and hazardous mine water contaminants over a long period of time without any downtimes.

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