Pall Corporation

Scientific & Technical Report

Upgrade of Nuclear Power Plant Laundry Waste and Floor Drain Water Treatment System Utilizing Microfiltration

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*Filtration. Separation. Solution.*SM

Abstract

Conventional nuclear power plant laundry waste and floor drain treatment systems are based on decanting, followed by centrifuge separators and evaporators. They have limited removal efficiency for fine particles, resulting in poor reduction in radioactivity levels in the treated water. Separators suffer from foaming issues due to the presence of detergents and require frequent maintenance, exposing the workers to radiation. The 1468 MW Pressurized Water Reactor (PWR) nuclear power plant at KKP Phillipsburg, Germany evaluated a hollow-fiber membrane based Microfiltration (MF) technology for the concentration of the waste before it was sent to the evaporator. Following an 18-month long pilot test, the plant decided to purchase the totally automated, turn-key MF system based on a Pall Aria™ platform. The MF system, with flow capacity of 3-6 m^3/hr, consists of 3 MF modules, associated pumps, tanks, valves and controls, all mounted on a compact skid.

Over the 18-month long pilot testing, the MF technology amply demonstrated its capability for consistently high particulate removal efficiency, safe and reliable operation and high availability with an average recovery rate of 95%. Filtrate flux rates of up to 50 Liters/m^2/hr (LMH) were achieved during the trial, with only one chemical cleaning required during the period. The plant reported an average activity in the filtrate of 17,900 Bq/m^3, which meets the local requirement of 40,000 Bq/m^3 (as reported by the plant) for its release into the environment. The 20X concentrate stream from the MF system was processed by the evaporator. This paper discusses the details of the MF system and its performance during the pilot test.

Introduction

The Phillipsburg nuclear power plant (NPP) in Germany has two units — one 926 MW (gross) Boiling Water Reactor (BWR) that was commissioned in 1979, and one 1468 MW (gross) Pressurized Water Reactor (PWR) that was commissioned in 1984. Since its inception, the plant was using a system that consisted of a decanter followed by a centrifugal type separator, and then a drum evaporator to treat the low level radioactive waste generated by the laundry and the ground drains. The treatment system performance was less than satisfactory, as it suffered from poor solid particulate removal, achieved low reduction in activity and no reduction in Chemical Oxygen Demand (COD) of the treated water. The drum evaporator experienced foaming and required frequent maintenance, resulting in higher radiation exposure to the workers.

Pall proposed its hollow-fiber membrane based Microfiltration (MF) system as a replacement for the decanter and the centrifugal separator in the existing plant. Since this was a new concept for the plant, they requested a long, rigorous pilot test to prove the technology under the various operating conditions in the plant. A pilot trial was conducted for over 18 months, using Pall's (MF) technology at the PWR plant. The feed for the trial was from the laundry washing operation and the floor drains. Based on the successful conclusion of the trial, the plant purchased and installed a pre-engineered, turnkey, skid-mounted, Pall Aria MF system on July 1, 2010.

Pall Hollow Fiber Microfiltration Technology

Hollow fiber microfilter membranes are offered by many vendors. However, the feature that distinguishes the Pall membranes is the highly crystalline PVDF material used in their construction. This gives the membranes a highly homogenous structure that imparts exceptional strength and a wide range of chemical compatibilities (making it suitable for aggressive chemical cleaning, if needed). The overall result is a robust product that has proven itself in many challenging applications.

The individual MF hollow fibers have 0.7 mm ID and 1.3 mm OD. The modules selected for the application were 15.2 cm dia, x 2 m long, each containing 6300 individual hollow fibers with a total surface area of 50 m^2. Each module is rated to produce 18 m^3/h water flow rate, giving it a flux of 360 LMH. Figure 1 shows the cutaway view of the module.

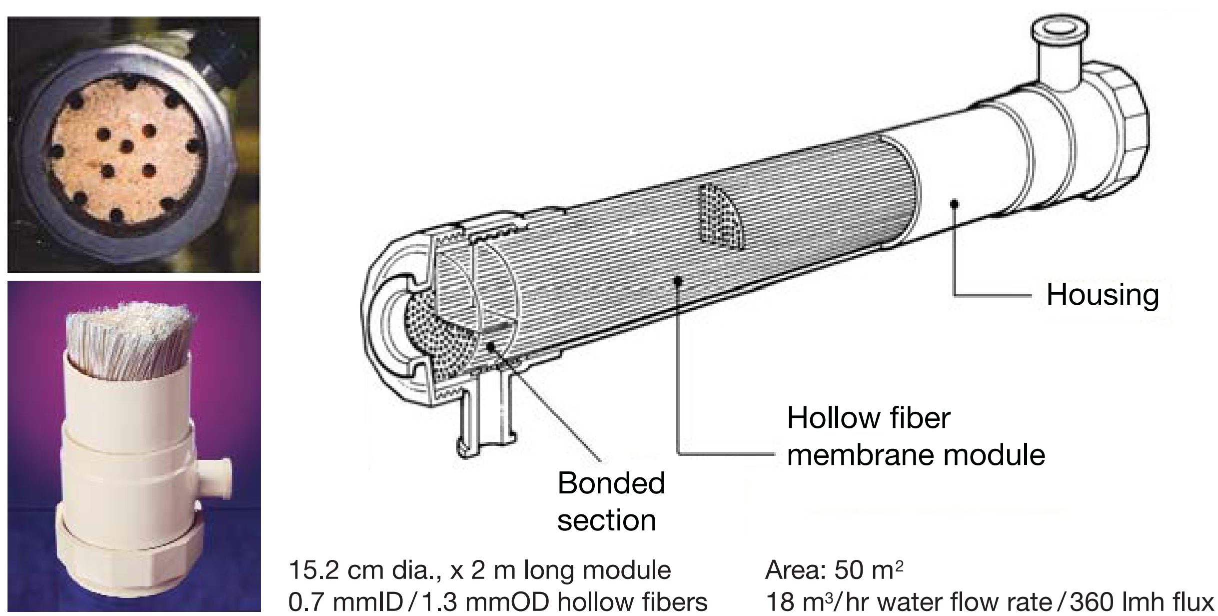

Figure 1: Hollow fiber microfiltration module

The hollow fiber modules are offered as part of a system, the Pall Aria skid, which is a pre-engineered, fully automated system. The feed water is processed in the dead end mode (i.e., the water is forced under pressure through the membrane on the outside diameter — retaining the contaminant on the surface), with periodic cleaning of the membrane to maintain the desired flux. During normal use, as the contaminants build up on the membrane surface, the Trans Membrane Pressure (TMP) increases, as illustrated in Figure 2. The cleaning process, called "Flux Maintenance", consists of: a) air scrub and reverse flow (ASRF), done every 20 to 30 minutes, to dislodge contaminants accumulated on the surface; b) enhanced Flux Maintenance (EFM) using hot water and a chemical solution — typically hypochlorite — is usually done once a day; and c) chemical clean-in-place (CIP) to restore the membrane permeability — is recommended once per month. All Flux Maintenance operations on the Pall Aria skid are automated and controlled by a Programmable Logic Controller (PLC).

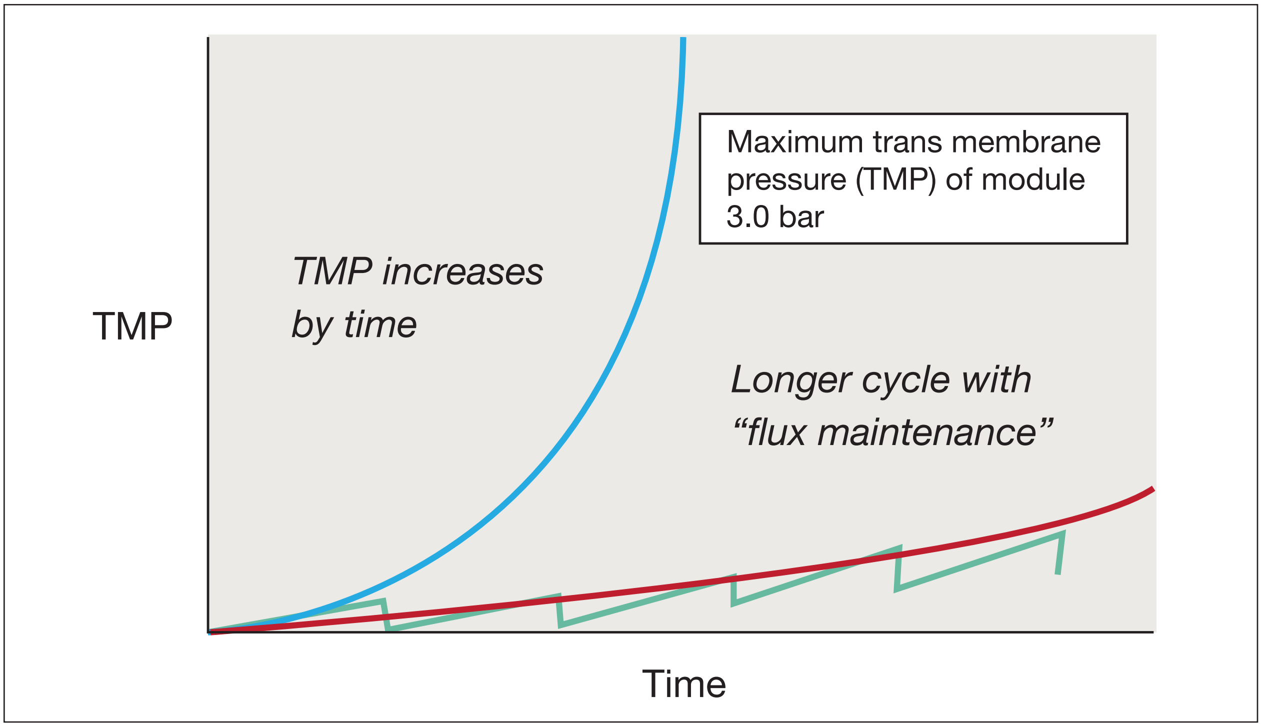

Figure 2: Typical membrane operation

Pilot Testing at Phillipsburg NPP

The objective of the test was to demonstrate that the Pall hollow fiber MF technology is stable, consistent and that the membrane integrity remains intact over an extended period of time with no permanent membrane fouling. The test was also intended to demonstrate: a) the effectiveness of Pall's standard flux maintenance protocol in achieving filtrate quantity and quality targets; b) that a concentration factor of 20X (95% recovery) can be achieved; c) that the system can handle varying feed water quality and system upsets; d) that a filtrate turbidity of < 0.1 NTU is achieved; and e) that a 30-day CIP interval or better is achieved.

The pilot test skid used at Phillipsburg NPP consisted of one full size, 15.2 cm dia, x 2 m long MF module, a raw feed water tank, a feed water pump, a filtrate tank, a backwash pump and a PLC with data collection via PC. The unit was tested in a range of filtrate flux, starting with <40 LMH to 60 LMH. With filtrate flux of up to 50 LMH, the TMP increase was moderate; however at flux >50 LMH, the TMP increase was more severe. Hence, 50 LMH was selected as the target for further testing. In June, the TMP increase was traced to the change of the laundry detergent to a phosphate-free type. Reverting back to the phosphates-containing detergent solved the problem. Chemical cleaning (CIP) on June 19 (using 1% detergent solution) reduced the TMP successfully. The TMP recovery was > 94%. This CIP was undertaken 18 months after the start-up.

Key parameters of feed water turbidity, flux, temperature and TMP were recorded throughout the test. Figure 3 shows the data recorded during the week of May 5th. The filtrate turbidity during the 18 month long test was in the 0.002 to 0.004 NTU range, whereas the feed water turbidity was as high as 100 NTU. On June 9th, an unusually high activity value (~220,000 Bq/m^3) of raw feed water was observed; however, the filtrate activity remained low — consistent with prior performance when the feed activity was low. The average reduction in activity between the feed and the filtrate was 62%. The filtrate activity (absolute measured value) was consistent throughout the trial.

Figure 4 shows the activity of the feed and the filtrate and the % reduction for the samples obtained during the pilot testing. The average activity of the filtrate was 17,900 Bq/m^3. Local regulations allowed release of the filtrate with up to 40,000 Bq/m^3 to the river, as reported by the plant. The target of 95% recovery of the feed was achieved. The concentrate, which comprised 5% of the total feed volume, was sent to a drum evaporator for conversion to a low volume, solid radioactive waste for storage.

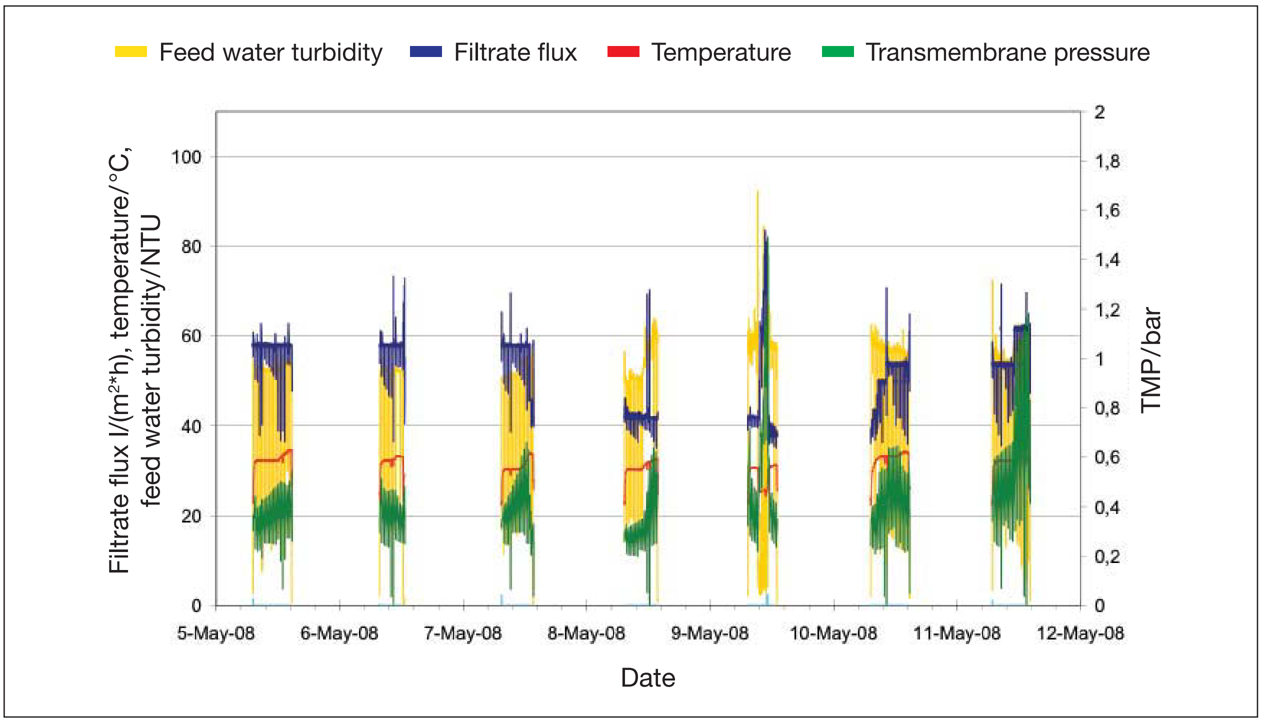

Figure 3: Pilot trial — parameters from May 5-12

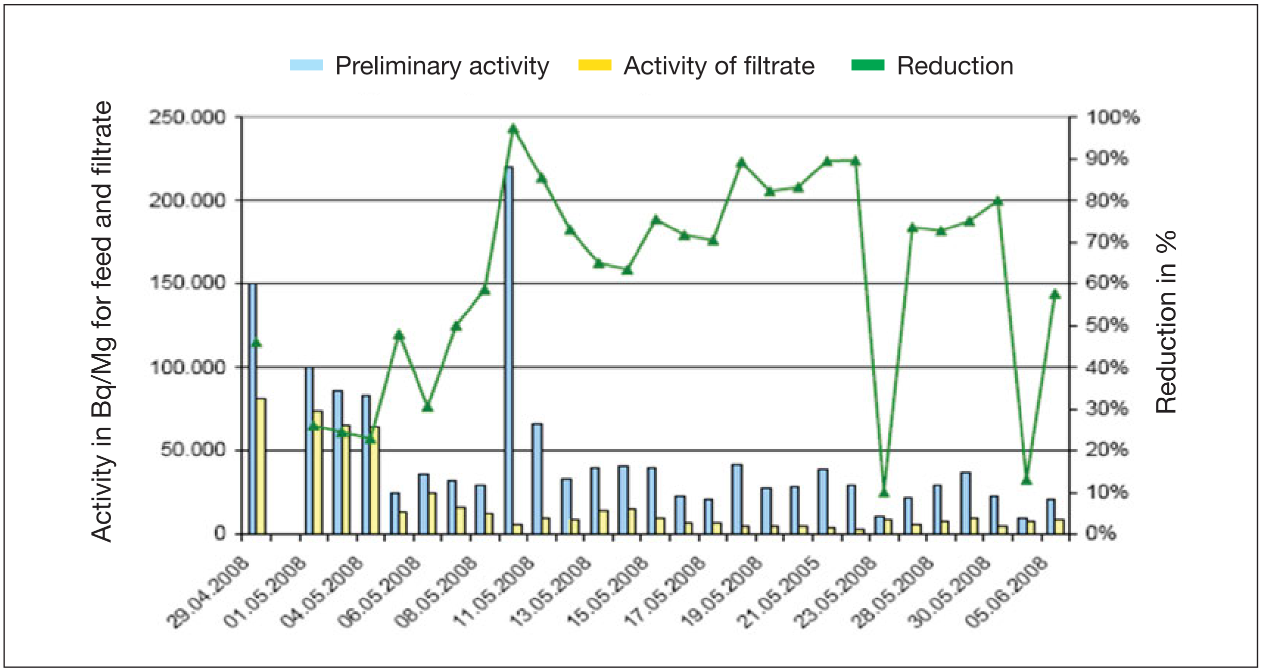

Figure 4: Radioactive material reduction

The Chemical Oxygen Demand (COD), an important consideration for the water released to the environment, was also monitored during the pilot test. The data presented in Figure 5, shows the COD data for the feed and the filtrate as well as the % reduction. The filtrate COD levels were acceptable for release of the filtrate to the river. The acceptable limit according to the plant is < 250 mg/L.

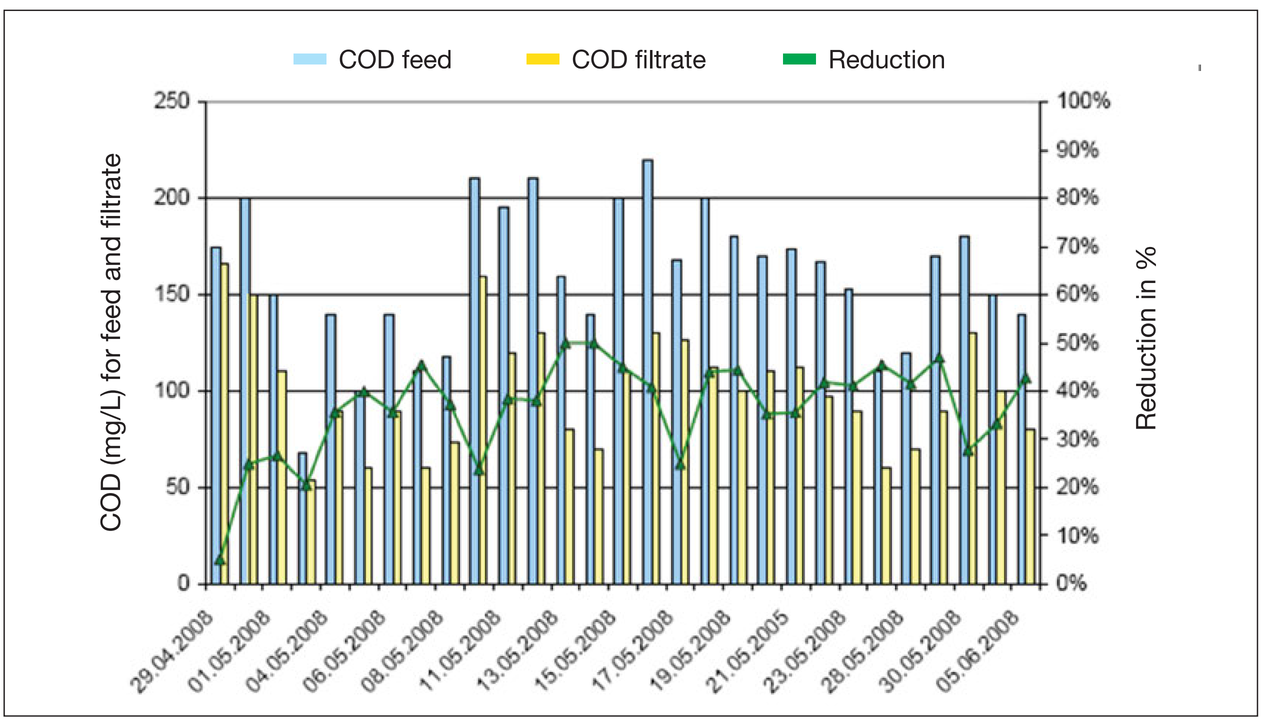

Figure 5: Chemical oxygen demand (COD) reduction

Conclusion

In summary, the Pall Microfiltration pilot test ran flawlessly for over 18 months, with minimal operator interface and maintenance. The filtrate turbidity, activity and COD targets were achieved. The standard air scrubbing / backwash and weekly EMF were effective in cleaning the fiber surface, showing good recovery. Only one chemical cleaning was necessary during the 18-month trial period, due to the high TMP caused by the change of the laundry detergent to the non-phosphate containing type. The chemical cleaning was effective in restoring the permeability of the membrane to near the value for new membranes. During the trial, the membrane system was operated in filtrate flux range of 30 LMH — 62 LMH. Based on the trial data, 50 LMH was recommended with a slightly increased trans-membrane pressure. The overall recovery (depending on operating parameters) was between 92% and 96%.

Following the 18-month trial, the used module was pressure tested to identify any possible defects or damage as a result of the use. The integrity testing, which was quite simple, safe and fast, showed no damage or degradation of the membranes. Based on the successful conclusion of the pilot testing, the plant purchased and installed a pre-engineered, turn-key, skid mounted Pall Aria system.

The Pall Aria A1 Membrane system, supplied to the Phillipsburg NPP (see Figure 6), consisted of three modules, a feed water pump, raw water pump, back wash pump, and manual valves to operate the 300 micron rated pre-filters. The raw water tank was made of Polypropylene (PP), with electrical heating for use as a cleaning (CIP) tank (after manual filling with a 1% NaOH solution). The filtrate tank was also made of PP. Low cost and excellent compatibility were the main reasons for the use of PP. The system was commissioned on July 1, 2010. The plant is very satisfied with the performance of the Pall Aria system for the treatment of laundry and floor drain water. As of the last report, the skid was operating for about 8 hours each day and at times 20 hours, when needed. Although the skid has room for three MF modules, only two were needed to achieve the throughput required. The modular nature of the skid allowed the operation to run with two modules, with the option of installing the third module when needed.

In light of the success of the Pall MF technology, the Phillipsburg NPP is considering using the MF system for treating the secondary loop IX resin bed regeneration water. A nuclear power plant in France has also purchased a similar unit and has reported satisfactory performance for the treatment of its laundry and floor drain waste water.

Figure 6: Pall Aria™ A1 Membrane system

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