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RECOVERY AND RECYCLING OF INDUSTRIAL SIDE-STREAM WASTEWATER

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ABSTRACT

Most industrial operations generate a substantial quantity of "side-stream" wastes. These streams are characterized by their high concentrations and difficult-to-treat property. Recent studies have identified side-stream wastes as a major cause of performance problem to treatment operations. As the national water scarcity crisis escalates, industries have started looking into recycling of the less desirable water sources as a long-term sustainable solution to the problem. This presentation shall explore the technical challenges associated with side-streams management.

INTRODUCTION

It is well documented that water is a scarce resource in many parts of the world including in the U.S. In some areas water availability is the key issue while in others, water quality is the major problem. Some locations, unfortunately, have to cope with both quality and quantity issues. In response to these growing concerns, industry has been challenged to find ways to utilize poorer quality water, such as the side-stream wastes, which in general is not being considered a viable source in the past.

For most industrial water and wastewater treatment operations, a substantial quantity of side-stream wastes is generated from the manufacturing and water/wastewater treatment processes as by-products of the operations. These streams are characterized by high concentrations in total dissolved solids (TDS), suspended particles, difficult-to-treat chemicals and organic substances.

SIDESTREAM SOURCES

As shown in Figure 1, side-stream wastes are generated from three primary sources: (1) Manufacturing operations, (2) Process water supply treatment operations, and (3) Wastewater treatment or recycling operations. The types of side-streams from these sources vary according to the industry, production processes, technology employed and method of operation. As a general characteristic, side-streams have high instantaneously flow rate but small average volume relative to the main stream, and they contain high concentrations of various contaminants as indicated in Table 1.

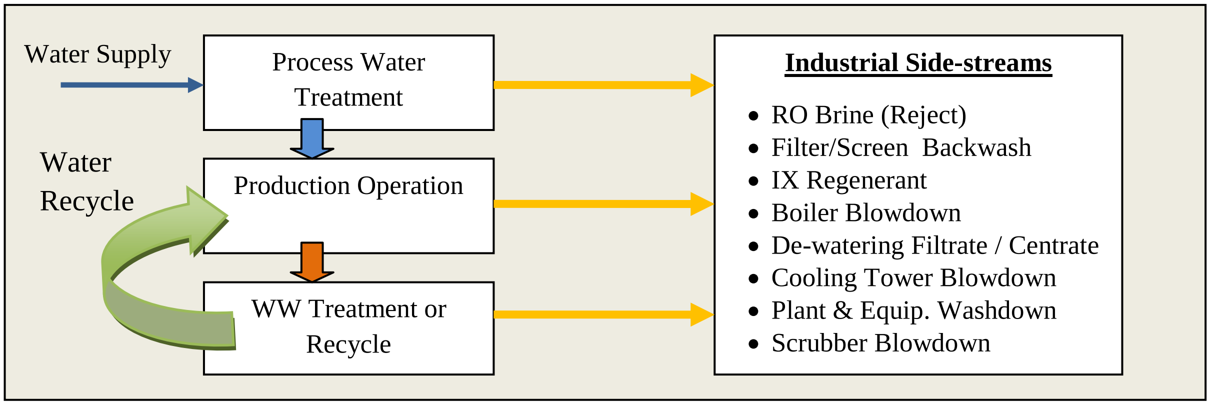

Figure 1 – Industrial Side-stream Sources

Table 1 – Side-stream Contaminants

Side-stream	Contaminants
Reverse Osmosis Brine	High TDS, hardness, silica, and metals
Filter/Screen Backwash	High TSS
Cooling Tower Blowdown	High TDS, TSS, hardness, silica, and organic
Equipment Wash-down	Complex cleaning chemicals, and trace heavy metals
Scrubber Blow-down	High chloride, sulfate, heavy metals and organic
Ion Exchange Regeneration Wastes	High TDS, TSS, hardness
Boiler Blowdown	High TDS, metals and complex chemicals

IMPACT ON WWTP

Most of the traditional wastewater treatment plant (WWTP) combines the side-stream wastes with the main wastewater stream for treatment. It was reported that the side-stream wastes cause significant interferences, malfunctions and damages, in many cases, to the treatment operation. The degree of impact on the WWTP will depend largely on factors such as the flow volume, surge frequency, chemical characteristic, TSS concentration, and mixing ratio and blending method for the side-streams. The following examples were documented for some of the major impacts observed and reported.

- Foul the RO membrane pre-maturely and cleaning the membrane is difficult.
- Foul or bind the activated carbon and sand filter medium, and increase the backwash frequency and volume.
- Interfere with the coagulation reaction and cause discharge compliance issues.
- Cause settling difficulties in clarifier resulting in carry-over of pin flocs in the overflow.
- Induce watery sludge cake generated from the de-watering process.

SIDE-STREAM RECYCLING TECHNOLOGY

Reverse Osmosis (RO) - RO membranes are designed for removal of dissolved solids with high efficiency, but adversely affected or fouled by suspended solids, colloidal material or scale. Common examples of such foulants are calcium precipitates, metal oxides, colloidal silica and various organics. Industrial side-stream wastewater typically contains most, if not all, of these fouling substances. Once fouled, limited by its membrane material properties, only mild cleaning chemicals such as citric acid and detergent can be used to restore the flux. Stronger or more effective cleaning chemicals, such as sulfuric acid, hydrochloric acid, bleach, and peroxide cannot be applied as they will cause irreversible damages to the RO membranes. In wastewater recycling applications, RO can rarely function independently without any protection from the fouling materials. Appropriate pretreatment must be provided to achieve stable performance of RO membranes.

Microfiltration (MF) – Certain MF products have demonstrated the ability to handle concentrated wastewater and significantly reduce membrane fouling to provide stable, predictable RO performance. The success of MF for this application can be attributed to the following key reasons:

- MF membrane is designed to remove suspended solids and colloidal particles (RO foulants). Some of the MF products, such as the one with tubular configuration, can handle very high TSS of >5,000 mg/L in the influent.
- MF membrane can be made of a variety of polymeric materials, including PVDF, which exhibit strong resistance to concentrated chemicals. As a result, the membrane can be cleaned with mineral acids, oxidizers (bleach, peroxide), caustic and selected organic solvents for removal of different persistent fouling elements, both inorganic and organic, which are difficult to be removed with weak cleaning chemicals.
- MF filtration produces a quality product water stream with NTU (<1.0) and SDI (<3.0) values in full compliance with the feed water criteria specified by all RO manufacturers.
- The chemical or physical characteristic of the foulants in the wastewater can be converted into particles suitable for removal by MF filtration.
- The MF can be designed to remove regulated contaminants in the side-stream wastes and make the RO reject more manageable for recovery or discharge.

Chemical pre-treatment plays a key role in membrane-based treatment or recycle. Properly designed and controlled chemistry mitigates the effects of the fouling components on membrane because it induced a change in the characteristics of the foulants. The principle pre-treatment chemistries for different contaminants are presented in Table 2.

Table 2 – Pre-treatment Chemistry Examples

Contaminants	MF Pre-treatment Chemistry
Hardness (Ca & Mg)	• Chemical softening - Lime & soda ash
Heavy Metals	• Hydroxide precipitation – Caustic/lime • Sulfide precipitation – Sodium sulfide • Organo-sulfur precipitation – Sodium Dithiocarbamate (DTC)
Fluoride	• De-fluoridation – Calcium/aluminum salts
Sulfate	• Sulfate precipitation - lime and aluminum salt.
Silica	• Chemical adsorption – Magnesium salt
Oil & Grease	• Adsorption – Lime / activated carbon • Acid Cracking – Sulfuric acid
Organic	• Adsorption – Lime / activated carbon • Coagulation – Aluminum/iron salts • Oxidation destruction – Bleach / Peroxide

CASE STUDY
SIDE-STREAMS RECYCLING

Project Data

Plant Type/Location

An automotive components manufacturers located in Mexico.

Background

(1) There was severe shortage of quality water around the plant site.

(2) Performance of the main WWPT plant was unstable and subject to frequent upsets due to high variation of the influent characteristic.

Project Objective

Segregate the difficult-to-treat side-streams, specifically the cooling tower blowdown and RO brine, for water recycling and improvement of the central WWTP operation.

Years of Operation

Over 8 years.

Side-stream Flow

100 to 150 GPM.

Recycle Concept

Selected side-streams, RO brine, cooling tower blowdown and others from the production processes and main wastewater treatment plant are directed to an equalization tank. The process starts with chemical softening / coagulation and followed by microfiltration and RO. The RO permeate is returned to the cooling tower for reuse, and the reject stream is discharge to an on-site evaporation pond for de-watering.

Design Considerations

The side-streams contain a variety of membrane foulants including hardness (Calcium and Magnesium), silica, organic (Anti-scalant & Dispersants) and total suspended solids (TSS). Fouling control plays a critical role in the success of operating a membrane-based recycling system. The Fouling Mitigation Technique (FMT) employed consists of Chemical Softening for converting all foulants into compatible forms followed by MF for separation of the resulting suspended solids.

The MF membranes employed in this installation are manufactured in a tubular configuration designed to handle high solid concentration. The membranes, made of PVDF, are cast on the surface of porous polymeric tubes to produce a nominal pore size of 0.1 micron. Figure 2 illustrates the MF membrane modules installed in the system. Bleach and hydrochloric acid are typically used for membrane cleaning.

Figure 2
MF Module End View

Figure 3
MF System Configuration

The chemically pre-treated wastewater is processed through the MF membrane modules designed for separation of the precipitates from water. The wastewater is pumped at a velocity of 12 – 15 ft/sec through the membrane modules connected in series as shown in Figure 3. The turbulent flow, parallel to the membrane surface, produces a high-shear scrubbing action which minimizes deposition of solids on the membrane surface. During operation, filtrate permeates through the membrane, while the suspended solids retained in the re-circulation loop are periodically purged for further de-watering. An automatic back-pulse mechanism provides surface cleaning by periodically reversing the filtrate flow direction. The MF has been operated with an average flux of 300 GFD. The entire treatment process is depicted in Figure 4.

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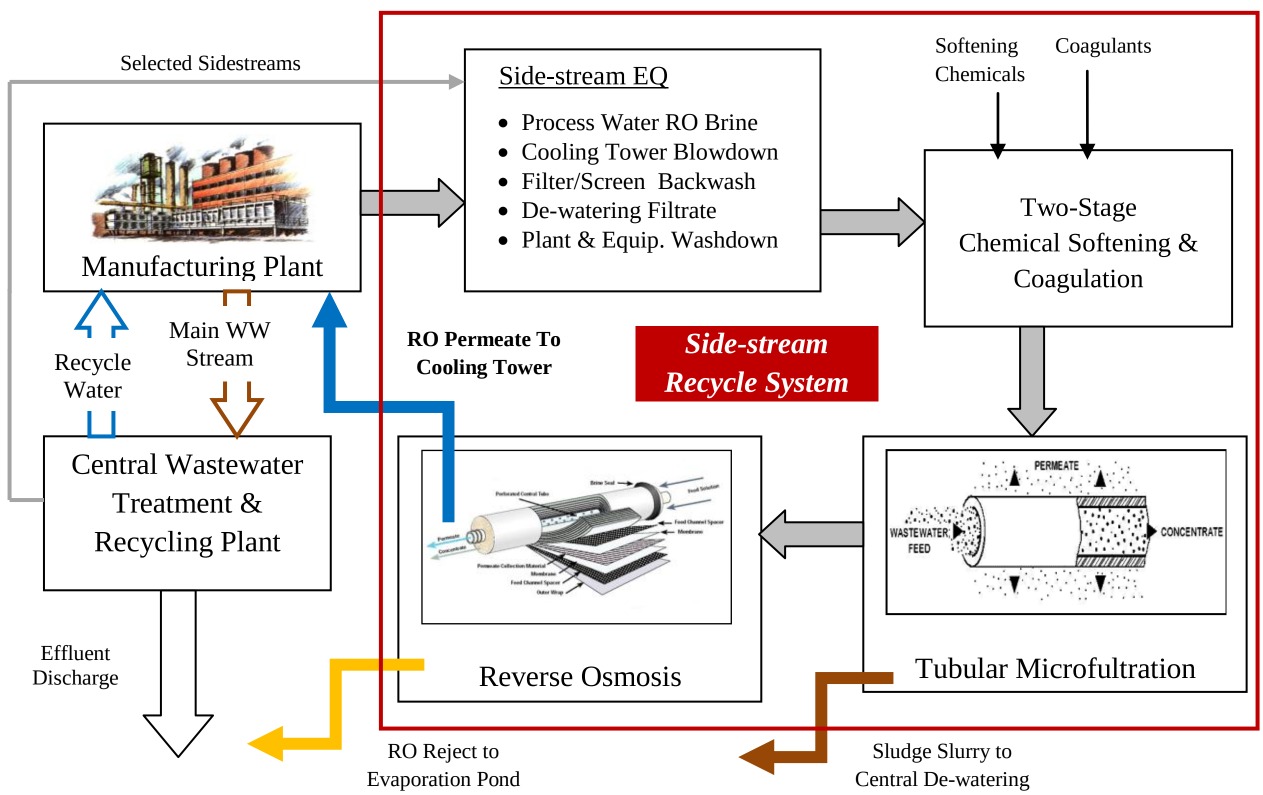
Membrane Process Performance Data
The removal efficiency for selected elements in the MF filtrate and RO permeate is presented in Table 3.

Table 3 – Selected Membrane Process Performance Data

Selected Elements	**Influent (mg/L as ion)**	**MF Filtrate (mg/L as ion)**	**RO Permeate (mg/L as ion)**
Ca	150 – 300	<35.0	<1.0
Mg	100 – 250	<5.0	<0.5
SiO_2	100 - 200	<10.0	<4.0
Na	900 – 1,200	<1200	<60
SO_4	1,000 – 1,500	<1500	<40
Cl	500 - 900	<900	<45
TSS	250 – 1,500	<1.0	ND
TDS	3,000 – 4,000	<4,000	<200
SDI	----	<2.0	----

Figure 4 – Simplified Side-stream Wastewater Recycling Process Flow Diagram



CONCLUSION

Side-stream wastewater is known to cause adverse impact to the operation and performance of a conventional wastewater treatment system. Most of the side-streams can be clearly defined, but for large industrial plant operations, some of them will require thorough site survey to track and identify. The removal of side-stream wastes from the main wastewater stream has a two-fold advantage: (1) Improve and optimize the performance of the main treatment system, and (2) maximize the in-house resource available for recycle and reuse. Membrane based technology (MF/RO) is proven as a technically viable approach. Chemical pre-treatment that transforms wastewater into membrane-compatible form provides the needed flexibility to cope with the complicated and fast-changing side-streams chemistry. To assure a successful side-stream control project from initial design to final operation, careful evaluation of potential sources of reuse water is needed and detailed treatment processes must be tailored to the site specific needs of a particular plant.

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