

Ask Tom! Column

Concentrating RO Reject Streams with VSEP

Guest article by Dr. Brad Culkin, New Logic Research, Inc



Introduction

The problem of dealing with the concentrate streams from reverse osmosis (RO) membrane processes is well known. Spiral wound membrane systems are limited in the overall recovery attainable with thin film composite membranes. The reason recoveries are limited to between 50% and 90% is the fact that spiral membrane systems cannot tolerate any suspended solids, whether they are already present in the feed or they are appearing by chemical precipitation inside the modules.

Elaborate pretreatment is used to eliminate particulate solids from RO spiral feeds. The removal of suspended solids must be absolute. Even trace amounts of suspended solids will kill a spiral module application. Anti-scalants are added to suppress the kinetics of crystal nucleation thus delaying formation of suspended colloids inside the modules.

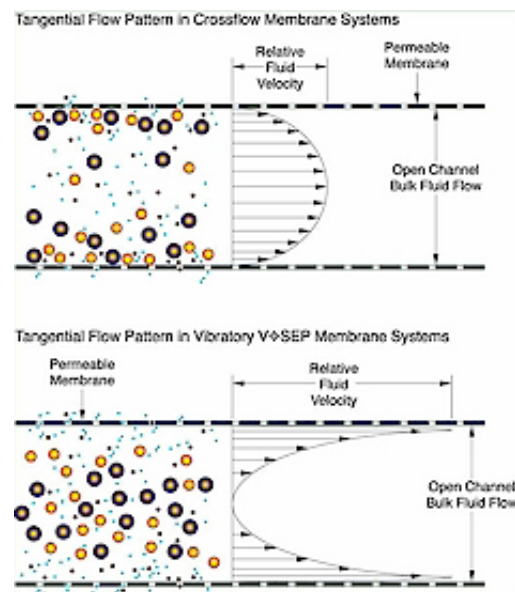
The current model assumes that mineral fouling, whether by colloids in the feed landing on the membrane surface, or by precipitates forming on and in the outer thin film layer, is capable of reducing flux to near zero. Many minerals can be periodically dissolved away in acid but in the case of salts whose solubility is independent of pH, like gypsum, or those which are nearly insoluble such as silica, this fouling is deemed intractable. This explains the current practical limits to recovery in RO systems.

The inability to dispose of this high solids product from reverse osmosis systems leads to the need for huge evaporation ponds, high capacity injection wells, and energy intensive crystallizers, each with its own set of problems. Without such two step methods, however, it is often impossible to get the required operating permits because discharge of the liquid reject stream of membrane systems is often not allowed. What is needed is a membrane technology capable of functioning as a crystallizer or evaporator.

A New Technology - VSEP

A new type of membrane separator which used vibration rather than cross flow to keep the membranes from caking up with solids was developed in the late 1980's. Originally the idea was to use the technique, called Vibratory Shear Enhanced Processing, or VSEP, to dewater viscous slurries like paints and pigments. A great number of systems used this technology for micro filtration and ultra filtration of latex polymer, oily water wastes, kaolin clay, precipitated calcium carbonate, ground calcium carbonate, colloidal silica, and many other ultra fine colloidal or "white water" suspended solids streams.

The extension of this VSEP technique to doing direct crystallization using RO membranes was delayed for two reasons. First, the machinery had to be modified to take the high pressures associated with RO. Second,



the accepted model for fouling of thin film composite membrane by mineral precipitation suggested that even the high shear of the VSEP process might not remove the tenacious scale thought to be formed on and within the membrane. By 2001, conditions were ripe for testing both a new high pressure design and this theory of mineral fouling.

It turns out that, given enough shear, the process of crystal formation at the membrane surface does not form a tenacious continuous film of scale. To the contrary, the minerals precipitate as a colloidal particle which is roughly spherical and which is attached only at the point of tangency between each particle and the membrane surface.

In other words, the particles forming by precipitation are similar to those which are already present in the feed. Since spiral wound membrane modules cannot handle particulate solids in the feed, it should be no surprise they cannot handle identical particles appearing by precipitation either. It is not necessary to invoke a separate model involving super tenacious scale forming models to explain fouling of spirals by precipitation. Indeed, such models are apparently wrong.

Continuous Crystallization

Since VSEP is inherently good at handling colloidal separations by design, it should be no surprise that we now are routinely using this technique for continuous crystallization of dissolved minerals as part of a continuous reverse osmosis system. The typical process uses conventional spirals to reach the point of saturation with respect to calcium, silica, barium, or some other mineral, and to feed the concentrate from the spirals directly to a VSEP module which runs as a continuous crystallizer.

The VSEP process runs to an end point determined by the rheology of the suspended solids sludge reaching a "pumpability" limit, or the osmotic pressure due to sodium salts reaching the design pressure limit of the machine (as much as 2,000 psi). For typical applications this corresponds to volume reductions of 1000 to 1 from spiral feed to VSEP concentrate.

To be clear, the VSEP membrane module is fitted with RO membranes. As the on-spec permeate passes through the membrane, dissolved solids precipitate as ultra fine suspended solids. These solids join other suspended solids which may be present in the feed. All suspended solids are then swept away from the membrane surface by the high shear VSEP process.

Once a given ionic species begins to drop from solution, its solution concentration remains constant at the saturation concentration of that salt. For this reason, the permeate does not deteriorate as it would in the case of infinitely soluble materials, and so permeate quality with respect to hardness is excellent. Only highly soluble sodium salts climb in concentration, and the recovery eventually becomes comparable to the rejection of the membrane; permeate becomes higher in sodium salts only.

Applications

Since 2001, dozens of high pressure applications using VSEP modules fitted with RO and nanofiltration membranes have been successfully deployed. Applications include:

- VSEP is being used at full scale to dewater raw pig manure lagoon water through RO membranes. There is no pretreatment ahead of the VSEP process other than coarse screening.
- VSEP is used to remove BOD from pulp mill end of pipe waste using a 50% salt reject nanofiltration membrane.
- VSEP is used for organics removal from a chemical plant waste stream with RO membranes.

- In the largest refinery in the world, VSEP is used to remove selenium from stripped sour water at a design flow rate of 700 gpm. The concentrate from VSEP is 5 gpm of concentrated black water which goes to an evaporator.
- A very large VSEP reverse osmosis system will be delivered to an oil field customer. Eventually 3,000 gpm of high pressure boiler feed will be produced at 95 percent recovery.
- The VSEP has been piloted for crystallization of hardness from municipal RO reject.

For the engineering community this is great news. There is a proven, mature machine technology which has been successfully adapted to solving the recently topical problem of RO reject. Moreover, this new process allows membranes to function as a crystallizer, opening the door to many new and exciting applications for process engineers working in the chemical, environmental and water treatment industries.

About our author

Dr. Brad Culkin is the Chief Technical Officer of New Logic Research, Inc. In addition to founding New Logic and inventing VSEP, he holds numerous patents in diverse areas including filtration, loudspeakers and flat panel displays.

Before joining New Logic, Dr. Culkin worked as chief engineer for Dorr-Oliver, Inc., where he developed several new separation technologies. Culkin earned his bachelors degree in chemical engineering from the University of Pennsylvania, master's degree in theoretical mathematics from Johns Hopkins and a PhD in chemical engineering from Northwestern.

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Welcome to Ask Tom!, a monthly column by our resident water treatment guru, Tom Keenan of National Environmental Services Agency (NESA). Tom addresses the issues that bug you the most. And Tom knows!! With 35 years experience in providing environmental support services to public and private sector clients on a wide range of environmental issues.

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Guest articles for the **Ask Tom!** Column are always welcome, for more information please contact Tom Keenan directly at his email address: info@nesa.ie