INTRODUCTION

Waste sugar is most often the greatest contributor to the BOD (Biochemical Oxidation Demand) discharge from a typical soft drink manufacturing facility. Most of these wastes are attributable to spillage and wash-down procedures in the canning, bottling and blending inherent to the production of soft drinks.

Sugar, such as sucrose (cane or beet sugar) or fructose (corn sugar), is readily digestible by microorganism and thus develops a relatively high BOD/mass ratio. Typically, one hundred pounds of fructose will result in seventy pounds of BOD with the discharge from a plant being anywhere from 5000 to 20,000 mg/L of BOD.

These high BOD levels will have a relatively pronounced impact on municipal biological-type wastewater systems; hence, it is not uncommon for the municipality to assess a surcharge for high BOD wastes to cove the added cost of treatment.

The fact that many municipal wastewater treatment plants in the USA are overloaded when it comes to BOI capacity has only compounded the problem.

Beyond the obvious option of water conservation and/or simply contending with the surcharges, treatment may be needed at the plant level. Conversion of these sugar products to gaseous by-products via a biologic digestion or oxidation-type wastewater system, or off-site disposal are some of the few methods of dealing with such wastes.

Concentration of the BOD compounds can prove to be economically attractive by either increasing the efficiency of the process (e.g. biological) or reducing the costs to move these wastes to another location.

MEMBRANE SYSTEMS

One approach to concentration is to employ a membrane system, which separates water from the sugar solution. Unlike "normal" filtration, a membrane system operates in a "crossflow" mode, meaning the feed flow is parallel to the membrane surface. Only a portion of the water found in the feed stock passes througl the membrane, while the sugar becomes increasingly concentrated in the remaining stream.

Using this approach, the volume of waste for disposal can often be cut by a factor of 5 to 10, depending on the original sugar concentration.

The process of concentrating sugars with a membrane is known as reverse osmosis because it uses a very f pored membrane to separate the sugar from the water, working in the opposite direction of "osmosis".

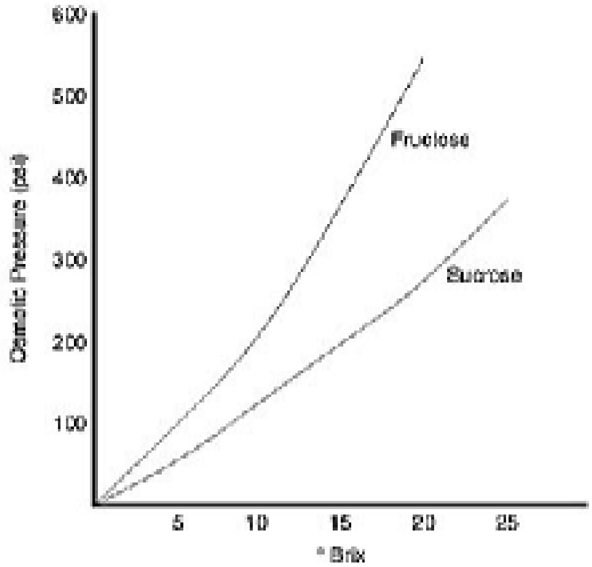
Osmosis is the phenomenon that occurs when a solute (e.g. sugar) is separated from solvent (water) by means of a semipermeable membrane, with the solvent flow through the membrane in the direction of the sugar solution - resulting in diluting the sugar concentration. Reversing this flow by means of applying an external pressure to the more concentrated side, creates the phenomenon of "reverse" osmosis which allow the further concentration of the sugar in the solution by "removing" more water.

While it takes on the appearance of simple filtration, RO utilizes the external force (in the form of a high pressure pump) working against the "osmotic pressure" created by the different concentrations of sugars or each side of the membrane (feed water versus purified water side).

Specific osmotic pressures generated by the different sugars are relatively easy to calculate and they are ve repeatable empirically. Since these methods use pressure/flow as a means of assessing the energy levels, osmotic pressure is represented in terms of pounds per square inch (psi).

Examples of osmotic pressure for different compounds at different concentrations are shown in Figure I.

FIGURE I



All solutes exhibit osmotic pressure, the extent of which is dependent on their molecular size and concentration. Osmotic pressure is greater for smaller molecules and increases as concentration increases. I sucrose (MW 342) and fructose (MW 180), the osmotic pressures are approximately 120 and 240 psi (8.3 a 16.6 bar) per 10 Brix concentration, respectively.

The degree of water removal is limited by the maximum osmotic pressure that can be practically overcome pressure created by the high pressure pump, or the resistance to compaction (densification) of the porous membrane. Maximum practical pump pressures tend to be in the neighborhood of 800 psi (55.2 bar). Thus, practical operation tends to be in the realm of sugar concentrations representing around 400 to 600 psi (27 to 41.4 bar) osmotic pressure (leaving enough additional force to drive a reasonable amount of water flow)

As more water is removed the osmotic pressure climbs, decreasing the amount of flow through the membra as a result of the reduced "effective pressure" (difference between the pump pressure and the osmotic pressure).

The relationship between water removal and concentration of the sugar tends to be exponential as exhibite in Figure II.

FIGURE II

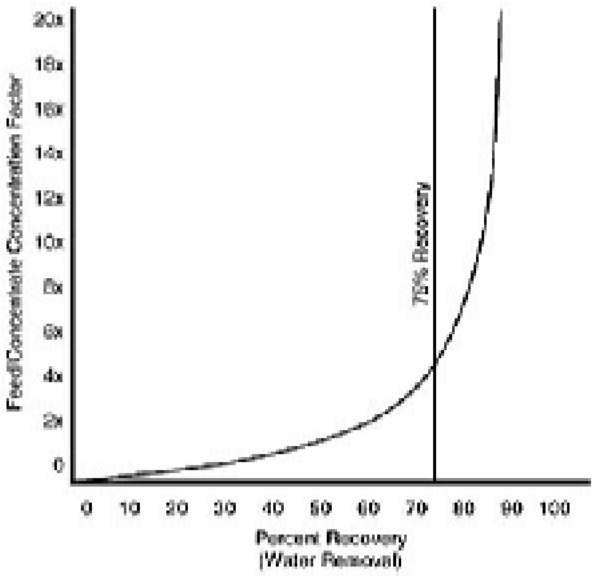


Figure II shows that as one goes beyond 75-80% water removal, the rate of concentration begins to accelerate dramatically.

As a result, the practical application of a membrane system is in the neighborhood of 75-80% water remova with up to 90 or 95% water removal feasible only in cases where the feed water stock is very dilute.

SOFT DRINK PLANT APPLICATIONS

A typical soft drink facility will generate a waste stream of 1 to 2 Brix sugar, which translates into a BOD of around 7000 to 14,000 mg/L. This varies to quite some degree depending on the products being produced and the way water is used in
the plant. Typically, most of the sugar comes from the rinse of blending containers and spillage in the canni or bottling production lines.

As soft drinks have moved more toward using fructose as a sweetener, the resulting osmotic pressure level found in a typical wastewater stream are, in fact, doubled versus when cane or beet sugar was used. This h affected the application of membranes somewhat, nevertheless RO continues to be one of the more economical methods of concentrating sugars.

For example, in a case where we start with 2 Brix fructose [47 psi (3.2 bar)], we can remove about 92% of the water before we reach an osmotic pressure of 600 psi [41.4 bar (25 Brix)]. In the case of sucrose, we c remove 96% of the water before reaching 600 psi (41.4 bar) in the concentrate stream.

Hence, the transition from sucrose to fructose has changed the ability of RO to remove 96 gal (363 L) of wa from 100 gal (379 L) of sucrose wastewater to 92 gal (348 L) of water from fructose wastewater.

MEMBRANE TYPES

The two most widely used membrane types, CA (cellulosic type) and PA (polyamide type) have both been applied successfully to concentrate waste sugars.

PA membrane has the advantage of providing high flow and excellent rejection of fructose. For example, at 1.8 Brix, PA membrane has been shown to produce a water discharge containing as little as 43 mg/L BOD (about 99.7% rejection), with a feed of 14,000 mg/L.

CA membrane, on the other hand, will reject fructose at approximately 98.5%, which translates into a permeate product of about 200 mg/L BOD from a feed stream of 14,000 mg/L. At concentrations of 11-12 Brix, the permeate will be in the 450-500 mg/L range; thus, the rejection improves somewhat as the concentrations increase, meaning that the passage of sugar to the permeate is not necessarily directly proportional to the feed concentration.

A key advantage of using the CA membrane, despite its lower permeate quality is its ability to withstand oxidizing agents, such as chlorine. This often comes into play when cleaning these systems of organics buil up and bacterial growth.

SYSTEM DESIGN

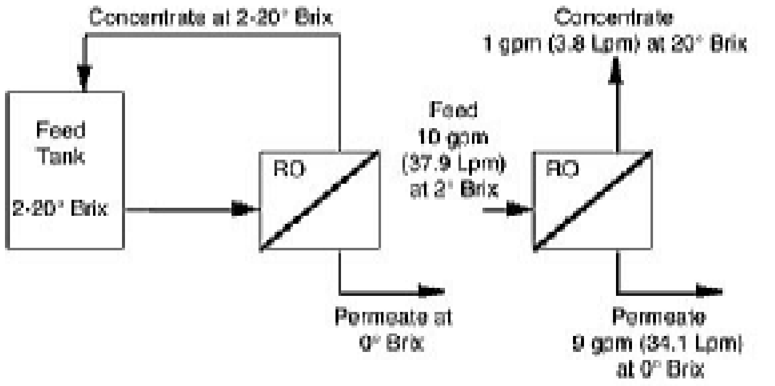
Prefiltration is one of the more important factors of system design for sugar concentration. Since it is not uncommon to encounter various forms of dirt and debris mixed with the sugar wastes, it is important to filt the solution adequately prior to entering the RO in an effort to reduce the insoluble solids loading on the R

This prefiltration may be in the form of a multimedia backwashable sand-type filter. Or, it may be a diatomaceous earth "pre-coat" type filter or several other forms of filtration. Any of these systems should b followed by
5 micron cartridge filtration. In any case, it is important to filter the stream to the five micron level in order optimize membrane element life.

Even with proper filtration, the membrane element itself should be designed specifically to handle the potential for some degree of dirt and debris loading. Using a spiral-wound configuration (which typically is t most economical), a design using thicker membrane spacer materials and an "unbound" type of element th traps less in the way of organic materials, is advisable.

The system can be designed to operate in a batch or continuous mode with examples of both shown in Figu III.

FIGURE III



There have been cases where multiple RO systems have been installed to achieve the highest concentratior sugar, while discharging the lowest level of BOD. A soft drink facility on Long Island, New York, for example installed a system that used three machines, with the primary feeding its permeate to a secondary RO for further polishing, and another secondary RO applied to the concentrate stream to further concentrate the sugar.

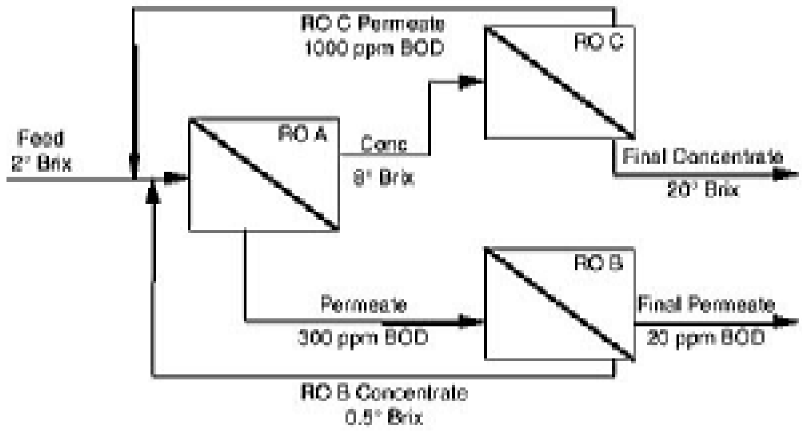
The reasoning for applying the second machine to the concentrate has to do with the concept of subjecting only a small amount of membrane surface area to the highest concentration and pressures. Thus, one can r the "first stage" at relatively low pressures [400 to 500 psi (27.6 to 34.5 bar)], concentrating the sugar to 1 12 Brix and then passing the now small stream of "concentrate" to the second
RO for further concentration at higher pressures [800 to 1000 psi (55.2 to 69.0 bar)].

Since higher pressures and more frequent cleaning is required for this second stage, it is wise to keep the amount of membrane subjected to this rigorous environment to a minimum; thus keeping the membrane replacement costs low.

Meanwhile, further processing of the permeate allows one to achieve the lowest BOD figures possible, particularly if one chooses PA membrane for this stage of the system.

A system lay-out using this design is shown in Figure IV.

FIGURE IV



CONCLUSION

The most appropriate type of system design is dependent on the unique requirements of each particular application. If one wishes to merely concentrate sugar wastes by a factor of ten, decreasing the volume of liquid requiring disposal by a factor of ten, while achieving BOD figures in the "less than 500 mg/L" range, t system can be extremely simple and the results very predictable.

Meeting higher objectives are also very achievable using somewhat more complex designs.