CAI 334 IRRIGATION WATER QUALITY AND WASTE WATER MANAGEMENT

UNIT IV NOTES

Desalination by reverse osmosis

Desalination is a separation process used to reduce the dissolved salt content of saline water to a usable level. All desalination processes involve three liquid streams: the saline feedwater (brackish water or seawater), low-salinity product water, and very saline concentrate (brine or reject water).

The saline feedwater is drawn from oceanic or underground sources. It is separated by the desalination process into the two output streams: the low-salinity product water and very saline concentrate streams. The use of desalination overcomes the paradox faced by many coastal communities, that of having access to a practically inexhaustible supply of saline water but having no way to use it. Although some substances dissolved in water, such as calcium carbonate, can be removed by chemical treatment, other common constituents, like sodium chloride, require more technically sophisticated methods, collectively known as desalination. In the past, the difficulty and expense of removing various dissolved salts from water made saline waters an impractical source of potable water. However, starting in the 1950s, desalination began to appear to be economically practical for ordinary use, under certain circumstances.

The product water of the desalination process is generally water with less than 500 mg/1 dissolved solids, which is suitable for most domestic, industrial, and agricultural uses.

A by-product of desalination is brine. Brine is a concentrated salt solution (with more than 35 000 mg/1 dissolved solids) that must be disposed of, generally by discharge into deep saline aquifers or surface waters with a higher salt content. Brine can also be diluted with treated effluent and disposed of by spraying on golf courses and/or other open space areas.

Technical Description

There are two types of membrane process used for desalination: reverse osmosis (RO) and electrodialysis (ED). The latter is not generally used in Latin America and the Caribbean. In the RO process, water from a pressurized saline solution is separated from the dissolved salts by flowing through a water-permeable membrane. The permeate (the liquid flowing through the membrane) is encouraged to flow through the membrane by the pressure differential created between the pressurized feedwater and the product water, which is at near-atmospheric pressure. The remaining feedwater continues through the pressurized side of the reactor as brine. No heating or phase change takes place. The major energy requirement is for the initial pressurization of the feedwater. For brackish water desalination the operating pressures range from 250 to 400 psi, and for seawater desalination from 800 to 1 000 psi.

In practice, the feedwater is pumped into a closed container, against the membrane, to pressurize it. As the product water passes through the membrane, the remaining feedwater and brine solution becomes more and more concentrated. To reduce the concentration of dissolved salts remaining, a portion of this concentrated feedwater-brine solution is withdrawn from the container. Without this discharge, the concentration of dissolved salts in the feedwater would continue to increase, requiring ever-increasing energy inputs to overcome the naturally increased osmotic pressure.

A reverse osmosis system consists of four major components/processes: (1) pretreatment, (2) pressurization, (3) membrane separation, and (4) post-treatment stabilization. Figure 16 illustrates the basic components of a reverse osmosis system.

Pretreatment: The incoming feedwater is pretreated to be compatible with the membranes by removing suspended solids, adjusting the pH, and adding a threshold inhibitor to control scaling caused by constituents such as calcium sulphate.

Pressurization: The pump raises the pressure of the pretreated feedwater to an operating pressure appropriate for the membrane and the salinity of the feedwater.

Separation: The permeable membranes inhibit the passage of dissolved salts while permitting the desalinated product water to pass through. Applying feedwater to the membrane assembly results in a freshwater product stream and a concentrated brine reject stream. Because no membrane is perfect in its rejection of dissolved salts, a small percentage of salt passes through the membrane and remains in the product water. Reverse osmosis membranes come in a variety of configurations. Two of the most popular are spiral wound and hollow fine fiber membranes (see Figure 17). They are generally made of cellulose acetate, aromatic polyamides, or, nowadays, thin film polymer composites. Both types are used for brackish water and seawater desalination, although the specific membrane and the construction of the pressure vessel vary according to the different operating pressures used for the two types of feedwater.

Stabilization: The product water from the membrane assembly usually requires pH adjustment and degasification before being transferred to the distribution system for use as drinking water. The product passes through an aeration column in which the pH is elevated from a value of approximately 5 to a value close to 7. In many cases, this water is discharged to a storage cistern for later use.

Extent of Use

The capacity of reverse osmosis desalination plants sold or installed during the 20-year period between 1960 and 1980 was 1 050 600 m3/day. During the last 15 years, this capacity has continued to increase as a result of cost reductions and technological advances. RO-desalinated water has been used as potable water and for industrial and agricultural purposes.

Potable Water Use: RO technology is currently being used in Argentina and the northeast region of Brazil to desalinate groundwater. New membranes are being designed to operate at higher pressures (7 to 8.5 atm) and with greater efficiencies (removing 60% to 75% of the salt plus nearly all organics, viruses, bacteria, and other chemical pollutants).

Industrial Use: Industrial applications that require pure water, such as the manufacture of electronic parts, speciality foods, and pharmaceuticals, use reverse osmosis as an element of the production process, where the concentration and/or fractionating of a wet process stream is needed.

Agricultural Use: Greenhouse and hydroponic farmers are beginning to use reverse osmosis to desalinate and purify irrigation water for greenhouse use (the RO product water tends to be lower in bacteria and nematodes, which also helps to control plant diseases). Reverse osmosis technology has been used for this type of application by a farmer in the State of Florida, U.S.A., whose production of European cucumbers in a 22 ac. greenhouse increased from about 4 000 dozen cucumbers/day to 7 000 dozen when the farmer changed the irrigation water supply from a contaminated surface water canal source to an RO-desalinated brackish groundwater source. A 300 l/d reverse osmosis system, producing water with less than 15 mg/1 of sodium, was used.

Advantages

· The processing system is simple; the only complicating factor is finding or producing a clean supply of feedwater to minimize the need for frequent cleaning of the membrane.

· Systems may be assembled from prepackaged modules to produce a supply of product water ranging from a few liters per day to 750 000 l/day for brackish water, and to 400 000 l/day for seawater; the modular system allows for high mobility, making RO plants ideal for emergency water supply use.

· Installation costs are low.

· RO plants have a very high space/production capacity ratio, ranging from 25 000 to 60 000 l/day/m2.

· Low maintenance, nonmetallic materials are used in construction.

· Energy use to process brackish water ranges from 1 to 3 kWh per 1 0001 of product water.

· RO technologies can make use of use an almost unlimited and reliable water source, the sea.

· RO technologies can be used to remove organic and inorganic contaminants.

· Aside from the need to dispose of the brine, RO has a negligible environmental impact.

· The technology makes minimal use of chemicals.

Disadvantages

· The membranes are sensitive to abuse.

· The feedwater usually needs to be pretreated to remove particulates (in order to prolong membrane life

· There may be interruptions of service during stormy weather (which may increase particulate resuspension and the amount of suspended solids in the feedwater) for plants that use seawater.

· Operation of a RO plant requires a high quality standard for materials and equipment.

· There is often a need for foreign assistance to design, construct, and operate plants.

· An extensive spare parts inventory must be maintained, especially if the plants are of foreign manufacture.

· Brine must be carefully disposed of to avoid deleterious environmental impacts.

· There is a risk of bacterial contamination of the membranes; while bacteria are retained in the brine stream, bacterial growth on the membrane itself can introduce tastes and odors into the product water.

· RO technologies require a reliable energy source.