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Reverse Osmosis

Grace Lin
AEssense Applications Scientist

What is reverse osmosis?

Reverse osmosis, which we commonly refer to as RO, is a water purification technology that moves ions, chemical molecules, and large particles from water solutions. The technology was developed in the 1950s, and has been extensively used in many fields to obtain clean water; especially in drinking water purification.

The principle of reverse osmosis is applying pressure to push water through a semi-permeable membrane. At the end of the process, the solutes (chemical molecules and particles solved in water) retain on one side of the membrane where pressure is applied, and the solvent (in this case, pure water) is allowed to pass to the other side and be collected.

What is osmosis?

To understand exactly how this process works, we should first understand what osmosis means. Osmosis is a phenomenon that occurs in nature, where solvent molecules (in most cases, water molecules) continues to move through a semi-permeable membrane towards the region with higher solute concentration. This process continues until the solute concentrations at both sides of the membrane are equal (Figure 1).

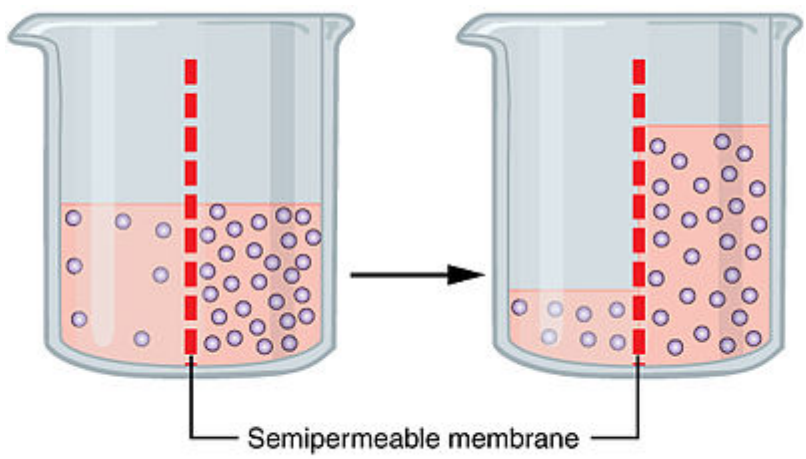

Figure 1. The process of osmosis. The blue dots represent the particles (solutes) in the pink solution (solvent). (Wikipedia: osmosis)

Osmosis occurs in all the biological systems, as biological membranes are semi-permeable. All living organisms are composed by cells, and cell membranes are typically semi-permeable membranes that are impermeable to large molecules (such as proteins and sugars) while water passes through. If we throw a cell in water, the water molecules will move from the side with lower solute concentration to the side with higher solute concentration.

For example, if we throw a cell in pure water, the water molecules will move into the cell and the cell will swell to become turgid. If we throw a cell in seawater, which has very high solute concentration, the water molecules will move out of the cell and the cell will shrink. This is why most plants tend to die if we water the plant with seawater: water will move *out* of the plant root cells instead of moving in.

Plant roots absorb water by osmosis. This is also the reason why it's really important that we understand the solute concentration in the nutrient solution in hydroponics. We can obtain this information by measuring the electric conductivity of the nutrient solution.

Different from diffusion, which has no membrane involved, osmosis requires a force to occur. This force comes from the solute's interaction with the membrane. Therefore, in order to reverse the osmosis process, we need to apply pressure to "push" the water molecules against their naturally moving tendency. The higher concentration the water solution is, the more pressure is required to overcome the osmosis force.

Reverse osmosis systems: design and performance

In general, an RO system can remove about 95%-99% of dissolved ions, organic chemicals, particles, colloids, and bacteria from the original solution (feed water). Note that there is no RO system that can completely remove 100% of the solutes, bacteria, and viruses, so RO is *not* the system that produces sterile water. Whether a molecule can pass RO membrane or not is mostly depending on its molecular weight and ionic charge. The greater the molecular weight and the ionic charge, the more likely it is to be rejected by the membrane.

A simplified RO system can be described as figure 2. The "feed water" is pressurized to pass through the semi-permeable membrane to produce the "permeate water", where 95%-99% of solutes are removed, and the "concentrate water", which is highly concentrated with all the rejected molecules. The concentrate water then goes to drain or can be recycled to pass through RO system again to save water in some circumstances.

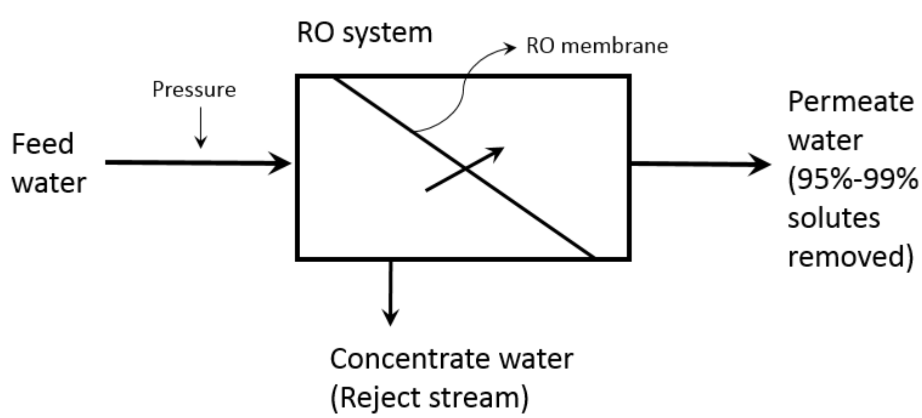

Figure 2. The process of RO

Different from standard filtration (dead-end filtration), which all the water flow passes in one direction and all the solutes are collected in the filtration membrane or media, RO systems uses crossflow filtration. The feed water crosses the filter with two outlets: the permeate water goes one way and the concentrate water goes the other way. Such methods allows water flow to take away the solutes accumulated on the membrane surface and lower the frequency of necessary membrane replacement.

When determining the performance of an RO system, we usually considered these factors:

- **Rejection rate (%):** this number tells us how much solutes can be removed from the RO system. We obtain this number by comparing the electric conductivity of the feed water and the permeate water. The higher the rejection rate, the better performance the RO system is. For example, if the rejection rate for one RO system is 95%, it means 95% of the solutes in the feed water are removed.

- **Recovery rate (%):** water recovery rate is the percentage of permeate water being "recovered" from the feed water. The higher the recovery rate is, the less waste water is sent to the drain and the more permeate water we collect. However, if the recovery rate is too high, it comes with its own problems such as solutes building up and plugging the RO membrane (fouling) or solute precipitation (scaling), when the concentrate water flow is too low. An industrial RO system has recovery rate ranging from 50% to 85% depending on the design and the quality of feed water.
- **Mass balance:** the mass balance can be presented as the equation below:

  Feed water flow x Feed water EC = (Concentrate water flow x Concentrate water EC) + (Permeate water flow x Permeate water EC)

  If the left side of the equation is more than 10% different from the right side of the equation, it's time to check the sensors for the water and recalibrate them.

Pretreatment for reverse osmosis

Before installing an RO system, it is suggested to conduct a water quality test to understand the chemical characteristics of the irrigation water. Water quality differs dramatically depending on the areas and the sources. In many cases, water pretreatment is necessary to remove particular matters to increase the lifespan and the efficiency of the RO system.

Pretreatment often includes filtering of larger matter such as sand, silt, and clay to prevent clogging the RO system. Some dissolved ions such as ferric (iron) oxide, calcium, and magnesium in water, can quickly precipitate within the system when exceeding a certain concentration. This can be prevented by pretreatment methods such as adding anti-scaling dispersant chemicals (dispersing these ions so they cannot combine into a precipitate) or softening the water by ion exchange. In addition, if algae and pathogens are present, the water should be pasteurized by pretreatment such as UV, ozone, or hydrogen peroxide dosing.

Is it necessary to use reverse osmosis water in cultivation?

The main reason to use RO water is to precisely control how much plant nutrients are present in the irrigation water and being delivered to the plant roots. In general, RO water is not required when growing plants in the field or in the greenhouse with soil. In fact, the nutrient delivery (or fertilization) for growing with soil is relatively indistinct, as the fertilizers need to be broken down by the microorganisms in the soil and it's difficult to measure exactly how much nutrients remain in the soil or substrate particles when watering the plants.

However, when growing with hydroponics, using RO water ensures that we can precisely estimate how much nutrients we put in the water and how much nutrients were absorbed by the plants since we start with water that's almost 0 ppm. With aeroponics, using RO water adds great benefit in controlling and maintaining the cultivation system.

Reference

Paul V. Nelson. 2012 Greenhouse Operation and Management, 7th edition. Pearson Education Inc.

Puretech: http://puretecwater.com/what-is-reverse-osmosis.html