Chapter 11

Reverse Osmosis

11.1 Introduction

A longstanding problem facing mankind has been how to create freshwater from saltwater. There are two main methods of doing this. The first is to distill the water - *i.e.* to boil the water into steam (leaving the salt behind), and then collect the steam and cool it back into fresh water. The second method is to use what is known as reverse osmosis.

11.2 Osmosis

We described osmosis when discussing bacteria and algae (section **??**). We shall recap here.

Osmosis occurs whenever a region of salt water and a region of fresh water are separated by a semi-permeable membrane. This is a membrane that allows water to pass but not the salt ions. What happens in this situation is that water will flow from the region of fresh water, towards the region of salty water. There are several different ways of explaining why this happens, but perhaps the most comprehensive is to say that osmosis occurs because the universe gets more "messy" over time (this is the second law of thermodynamics). This means that water likes to become more mixed up, and the only way it can do that is by the water passing from the fresh to the salty side of the membrane.

This process sounds counterintuitive, but leads to a real physical pressure or force - see figure 5.1. The more salty the water is on the salt side (*i.e.* the greater the concentration), the higher the osmotic pressure.

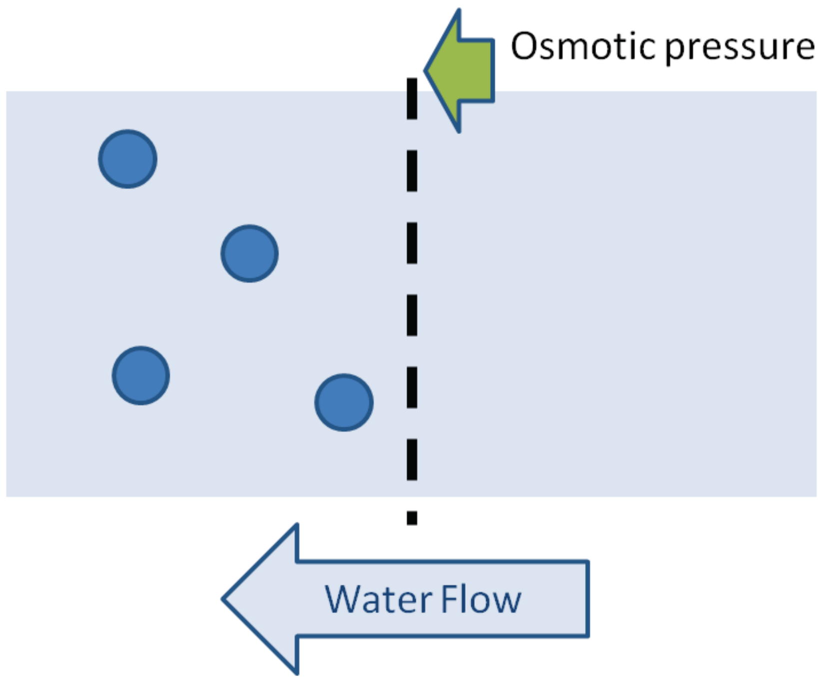

Figure 11.1: When fresh and salty water are separated by a semi-permeable membrane (which lets water through but not salt ions), the water will flow from the fresh side to the salty side. In this picture, the light blue background is supposed to represent the water and the blue circles indicate the salt ions.

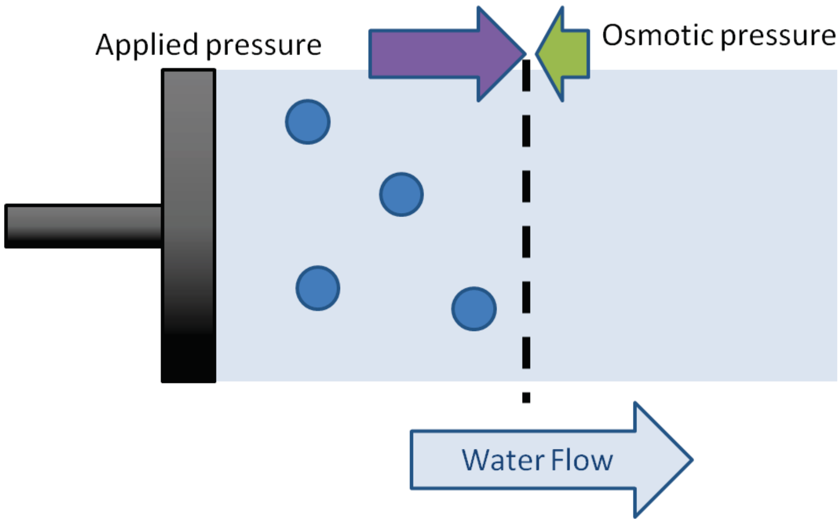

Figure 11.2: If the pressure on the salty side is increased enough then water can be forced in the reverse direction, from the salty side to the fresh side. The ions cannot pass through the membrane, so the water that has been passed through is made salt-free.

11.3 Reversing Osmosis

In figure 11.1 we have depicted the semi-permeable membrane as something like a sieve, and indeed these membranes are sometimes referred to as 'molecular sieves'. The question may occur: "If these membranes act like sieves, why can't we just use them to sieve the salt out of the water?" This is essentially what happens in reverse osmosis, or 'RO'. In RO, a pressure is applied to the water on the salty side of the membrane. If this pressure is high enough, it can overcome the osmotic pressure and go in the opposite direction, *i.e.* water moves from the salty side to the fresh side. We have created new fresh water! We see that we can overcome the tendency of the water to mix up, but at a price - we have to exert a force and expend energy[1]. It is called reverse osmosis because we are going in the *reverse* direction to the way the water would naturally flow. As the water is forced through the membrane, it will of course leave the salt ions behind. These will build up near the membrane and increase the concentration of the water (figure 11.3). We have already noted that the osmotic pressure increases as

[1]We can only increase order by expending energy. In order to get this energy we will have to have increased the disorder *somewhere else*. Thus, the total amount of disorder in the universe is always increasing - the second law of thermodynamics can't be beaten!

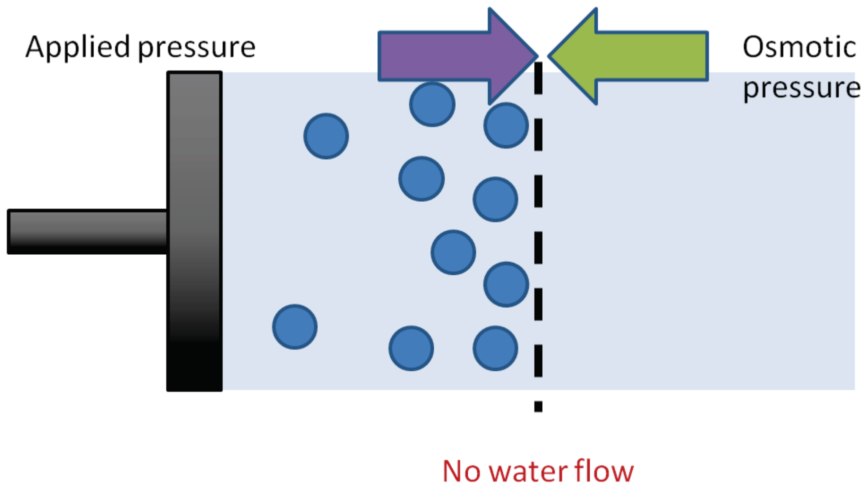

Figure 11.3: As the water is forced through, the ions get left behind on the salty side. This means that there will be layer of water with a high concentration of salt next to the membrane. The osmotic pressure depends on concentration, so as the layer gets more and more concentrated, the osmotic pressure builds up and up until eventually the flow of water stops. To get the water flowing again, either the pressure must be increased or the concentration decreased.

the concentration increases. This means that as we push water through the membrane, the concentration builds up and up and eventually the osmotic pressure will be so great that that it matches the pressure we are applying. At this point we will not be able to force the water through any further.

11.4 Cross flow and removing the concentration layer

As can be seen in figure 11.4, the concentration is only increased in a narrow layer around the membrane. If we can flush this layer away and replace it with water with a lower salt concentration, then the osmotic pressure will drop again and we can continue to create fresh water. In order to do this new water is fed into the system across from (*i.e.* parallel to) the membrane rather than 'head on'. This means that the flow of water has the effect of 'washing away' the concentration layer on the surface of the membrane. This method is a way to try to reduce the osmotic pressure that is opposing the reverse osmosis.

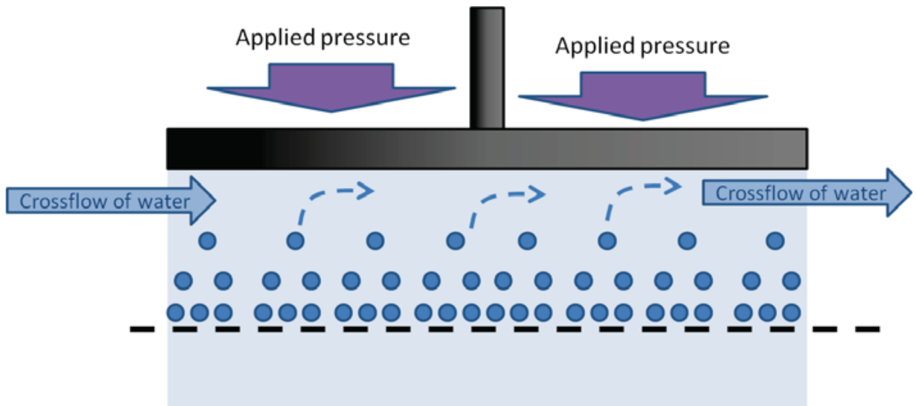

Figure 11.4: By introducing water across the membrane, *i.e.* parallel to it, some of the concentration layer can be washed away, thus keeping the osmotic pressure down.

11.5 Problems in reverse osmosis and how Hydropath can help

There are several problems that commonly occur with reverse osmosis. First is that the membranes have a tendency to scale up. As the water is pushed through the membrane, the concentration in the water near the membrane increases - we can think of this as in increase in the hardness of the water! This increase in concentration means that the water becomes supersaturated and therefor starts to form scale on the membrane.

Another problem is that bacterial and algae can grow on the membrane. The scale that forms there can make bacterial growth problems worse as it gives the bacteria a place to hide!

Both of these problems lead to blocking of the membrane. As can be imagined, semi-permeable membranes are rather prone to blocking, either by scale or by fouling from bacteria and algae. Blocking the membrane will make it even harder to force water through it, and therefore lead to a further decrease in the flow and the amount of fresh water produced.

11.5.1 Prevention of scale

By treating the water coming into the system, we can create clusters which form crystals when they hit the concentration layer. These crystals will then be washed away by the crossflow.

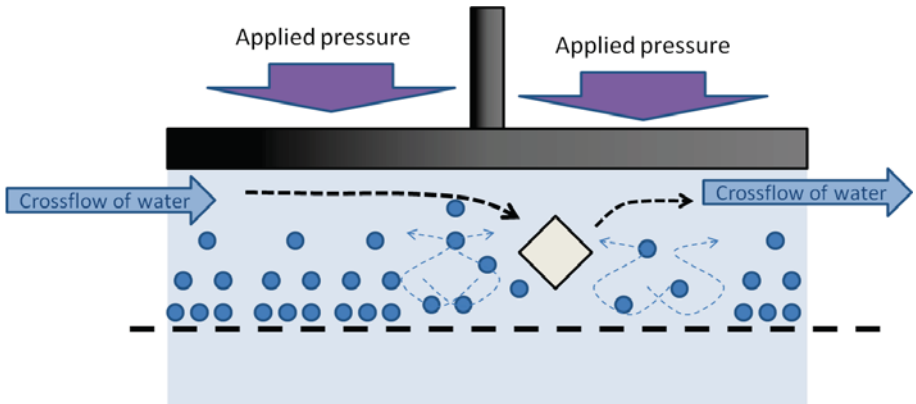

Figure 11.5: The crystals of limescale formed will disturb the concentration layer so that more of the ions that have built up are washed away, the concentration near the membrane is reduced and the flow rate is increased.

11.5.2 Prevention of biofouling

We have discussed how Hydropath technology can eliminate bacteria and algae. By treating the incoming water, we can prevent buildup of biofouling on the membrane. Note that we cannot clean up a membrane that has been already fouled with bacteria!

11.5.3 Reduction of osmotic pressure

Another advantage that Hydroflow has is to reduce the osmotic pressure and thereby increase the flow rate. It does this by disrupting the concentration layer. Basically, when limescale crystals are formed in the concentration layer, their motion as they are moved in the crossflow will disturb the concentration layer, essentially stirring it up. This will reduce the concentration in the water next to the membrane and hence increase the flow rate (for a given pressure).