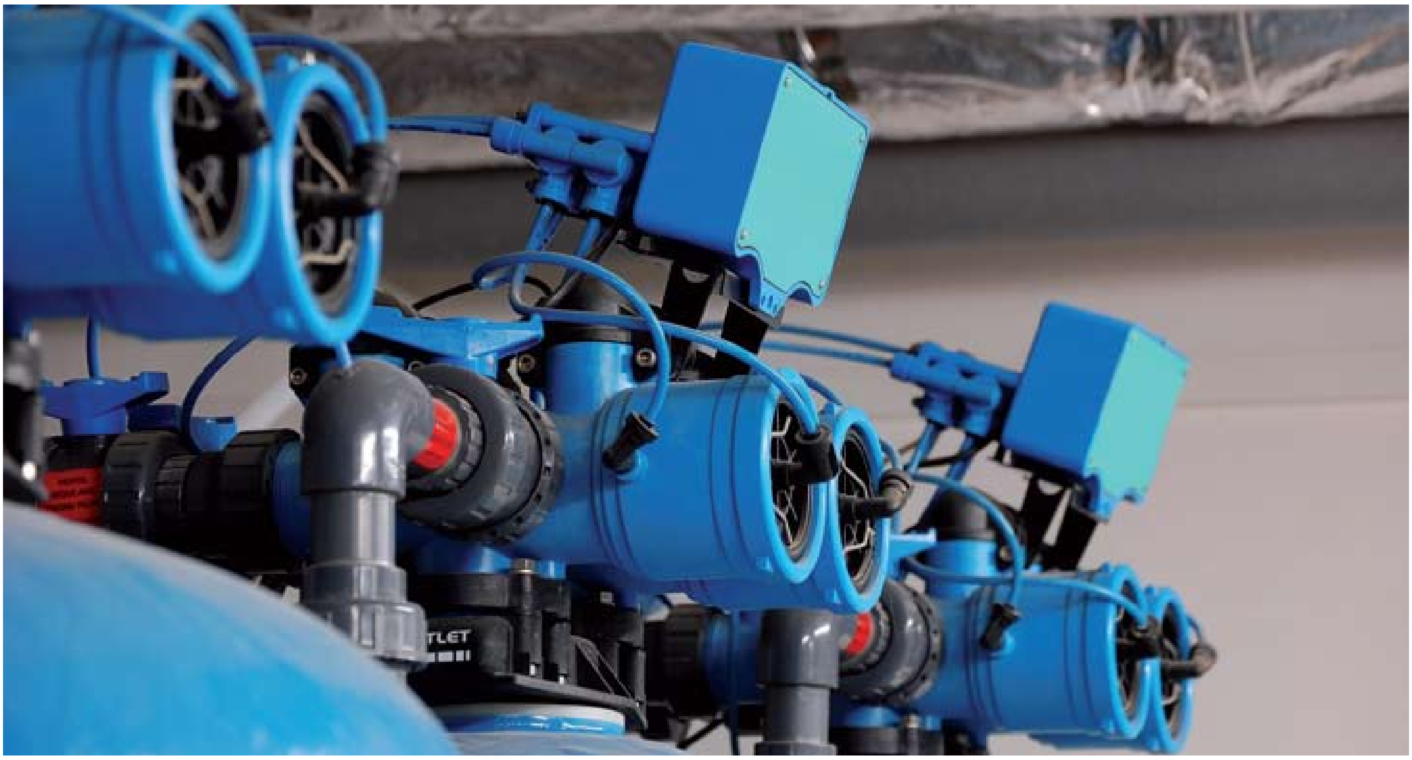
Guidance Leaflet

the Rippleffect
Water efficiency for business

Reducing water use – **softeners and reverse osmosis**



Most water supplies contain dissolved solids (e.g. salts and other minerals, particularly calcium and magnesium). The type and level of the dissolved solids contribute to the overall 'hardness' of the water which, in certain parts of the UK, such as the east and south-east, can be very high. If not treated, these can impair process efficiency and cause equipment to fail.

Businesses abstracting water directly from a groundwater source or receiving water supplied by their water company in hard water areas may need to take action to prevent scale forming through the precipitation of these minerals during use.

Hardness or scale formation can impair the efficiency of some equipment (e.g. boilers and heat exchange units) or, simply, the operation of valves. Just 1.6 mm (1/16") of scale in heating systems will cause a 12% loss in heating efficiency[1].

To remove the dissolved solids, water softeners, based on ion exchange, are often used. In situations where high-quality water is required or is beneficial (e.g. for renal dialysis or cooling tower 'make-up' water), further treatment by reverse osmosis to remove the total dissolved solids (TDS) may be required. In each of these treatment processes there are opportunities to save water.

[1] British Water 'A Consumers' Guide to Water Softening', available at www.britishwater.co.uk/Document/Download.aspx?uid=ee36c54e-925e-4b64-b732-b7b13aa6a638

Ion exchange softeners

Ion exchange water softeners comprise a resin or 'bed' contained in a large cylinder through which the water flows. The calcium and magnesium ions in the water (which cause hardness) are exchanged for sodium ions from the resin.

Once all the sodium ions have been exchanged for calcium and magnesium ions, the resin will need to be regenerated. This is undertaken by backflushing a strong salt solution (brine) through the unit allowing the calcium and magnesium ions to be exchanged for sodium. The used brine solution, which now contains calcium and magnesium, is discharged to drain.

Water softeners may be installed on the main water supply (but excluding wholesome (potable) water) to a whole building or dedicated to a specific area such as:

- boiler 'make-up' water;
- laundries;
- kitchens (dishwashers);
- process waters in high hardness areas;
- dyeing; and
- cooling tower 'make-up' water.

Water softeners should not be installed on the wholesome water supply because the elevated concentration of sodium in softened water has potential health risks.

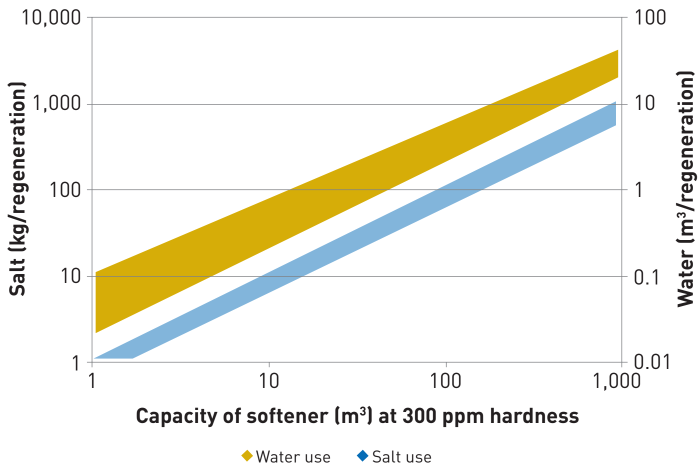
Water companies should be able to provide information on the water hardness in their area. Alternatively, a map that shows the water hardness in England and Wales is available from the Drinking Water Inspectorate (DWI)[2].

Hidden costs of water softening

The softening process will consume chemicals (such as salt), water and electricity, so the cost of softened water is greater than the incoming mains or abstracted water.

The amount of salt and water required for the softening process will depend on the hardness of your water. If you do not know the amount of salt and water your softener uses, you can estimate what it should use from Figure 1.

Figure 1: Salt and water use by softeners during a regeneration cycle



Note, this graph assumes a water hardness of 300 ppm of calcium carbonate, which is for very hard water. If the water hardness is significantly different from 300 ppm, then the capacity of the softener will be different from that shown. For example, if your water hardness is 150 ppm, the effective capacity of the softener will be about double that calculated from the graph.

Salt typically costs between £5 and £8 per 25 kg (bulk delivery tends to be cheaper) and, using your water supply costs, you should be able to estimate the 'value' of each cubic metre of softened water.

Typical values of mains and softened water are:

UK mains supply[3]	£0.59 – £1.75/m^3
Softened water	£1.00 - £2.16/m^3

Remember that additional costs will be incurred for disposal of any water (e.g. regeneration liquors) to sewer, typically between £0.54 and £2.67/m^3.

Actions

1. Identify the location and number of water softeners used on your site.
2. Calculate how much softened water you are using and its cost.

[2] www.dwi.gov.uk/consumers/advice-leaflets/hardness_map.pdf

[3] UK mains supply based on standard 2010/11 tariffs.

Understanding where water is used in a softening plant

To identify the water saving opportunities, you first need to consider:

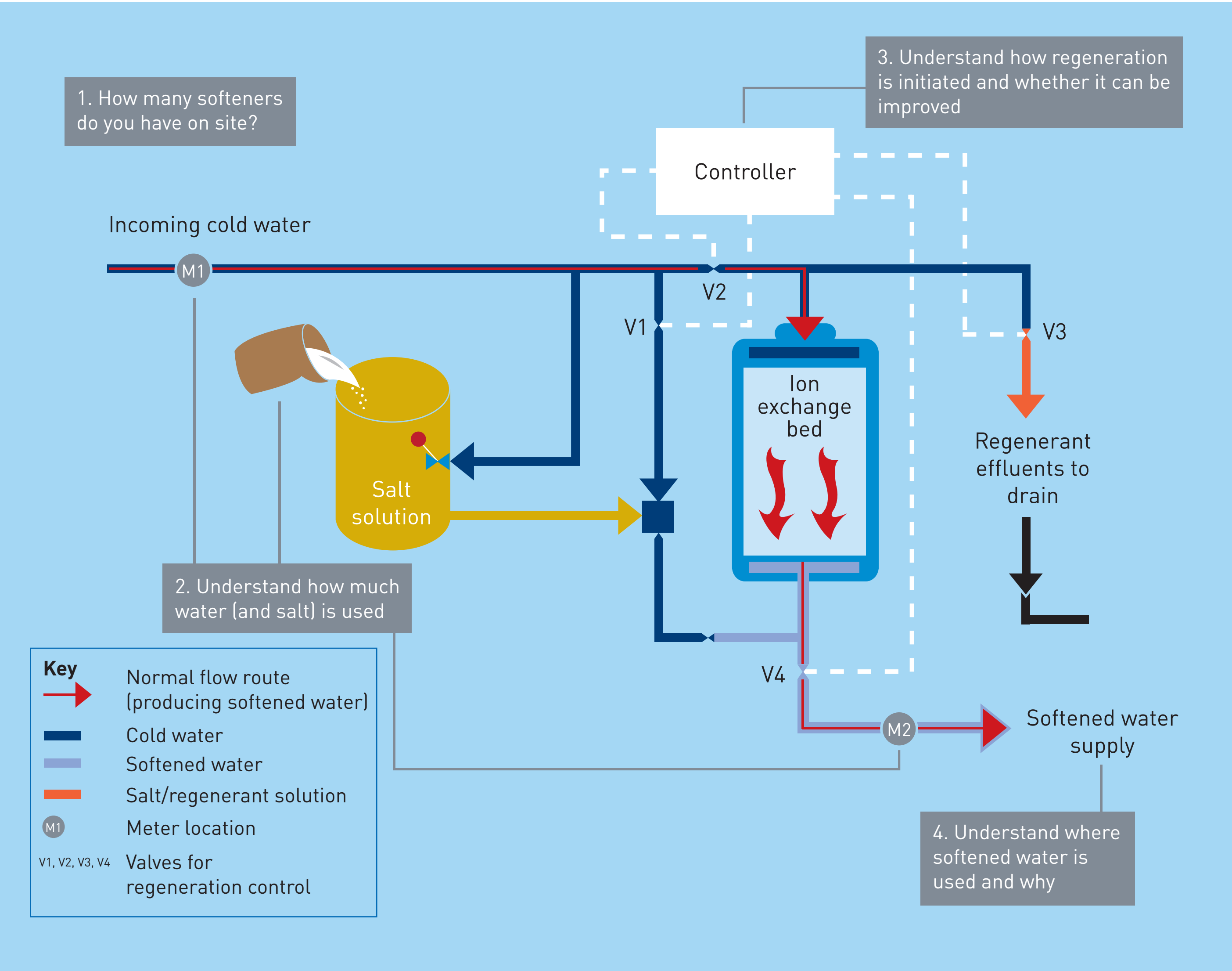
- **how much water the softening process uses; and**
- **how much and where softened water is being used.**

Water used for regenerating ion exchange beds can be easily monitored. Meters M1 and M2 installed in the locations shown in Figure 2 enable the water volume to be calculated:

M1 – M2 = water used by softening unit for regeneration and brine make-up

This measured volume can then be used to check the plant's actual performance against the manufacturer's specification.

Figure 2: A typical softening plant and potential water efficiency improvements



By looking at your site's water distribution plan, you should be able to identify the various points where softened water is used and, if you have meters installed, you can assess the amount of softened water issued, as shown by M2 in Figure 2. Develop a water balance for your regeneration process to check that the actual volume of mains water used is similar to the theoretical water consumption value calculated from your water balance. For guidance on developing a water balance see EN895 'A guide to developing a water balance', which is available on the WRAP website[4].

Each point of use should be reviewed to determine whether it requires softened water or whether mains water could be used instead. The use of a blend of mains and softened water may be appropriate in some instances. Meters should also be installed where appropriate to measure and monitor the use of softened water. Water meters are inexpensive to install; a simple 30 mm water meter with a pulsed output costs between £75 and £95, excluding fitting. Meters are included on the Water Technology List[5], as part of the Enhanced Capital Allowance scheme.

Well-labelled pipework is key to understanding where water is being used around your site. There are often many pipes around a softening installation and, unless they are easy to follow, it can be difficult to understand what flows where, making water management more difficult. Labelling pipework to show its contents and flow direction will make this much easier. This is also true for the softened water distribution system.

Actions

1. If necessary, install meters to monitor your softened water use.
2. Check your actual regeneration water use against the theoretical value and investigate any discrepancies.
3. Check that softened water is necessary for each point of use and whether any could be replaced with mains water.
4. Label pipework to indicate contents and flow direction.

Opportunities for saving water during regeneration

The amount of salt and water used during a regeneration cycle depends on the capacity of the softener rather than the degree of exhaustion of the ion exchange bed because very few softeners are equipped with sensors to detect when the ion exchange bed is exhausted (see Figure 1). This means that, however much the softener has been used, the regeneration cycle will consume the same amount of salt and water.

Consequently, how often the regeneration cycle is triggered will determine the overall use of salt and water by the softener. With salt costs ranging from £5 to £8/25 kg (bulk delivery is cheaper) and raw water from £0.59 to £1.75/m^3, costs for regeneration can soon mount up.

Salt and water will be used unnecessarily if the softener is regenerated before the full capacity of the ion exchange bed has been used. This is more likely if regeneration is undertaken manually or on a timed basis. In some softeners, the volume throughput will be monitored and, at the appropriate time, a controller will activate the regeneration cycle by opening the regeneration valves (V1 – V4 in Figure 2). This is the most efficient and cost-effective method of controlling regeneration cycles.

The volume of water that can be softened by an ion exchange bed depends on the water's hardness, and this varies from location to location (although it is usually consistent for any single water supply). Therefore, the maximum volume of water that can be softened before the bed capacity is exhausted needs to be established before setting the controller to the volume at which regeneration is to start, known as the breakthrough point.

The breakthrough point can usually be calculated by using the softener specification/hardness of water or it can be determined by undertaking simple tablet/colorimetric testing[6] on the softened water to detect where the hardness breaks through.

[4] http://envirowise.wrap.org.uk

[5] www.businesslink.gov.uk/wtl

[6] Tablet/colorimetric testing uses proprietary tablets that react with the 'hardness' in a water sample to produce a colour. This is measured in a colorimeter, which then indicates the level of hardness in the sample.

Actions

1. Establish how your softener is set to regenerate – manually, by timer or by volume.
2. Consider setting regeneration to start based on volume throughput.
3. Check the volume throughput is set to the maximum so that regeneration occurs just before bed exhaustion (i.e. hardness breakthrough).

Reverse osmosis

Reverse osmosis (RO) works by forcing water molecules through a semi-permeable membrane at high pressure, typically between 400 kPa and 1,200 kPa (4 bar and 12 bar), producing two water streams. One stream is very pure water and is known as the permeate. The other stream retains the dissolved solids and particulate matter, and is known as the reject water (or concentrate). Reject water is usually disposed of to drain. A typical membrane treatment plant is shown in Figure 3.

RO removes a high proportion of TDS, typically between 90% and 98%, and virtually all particulates. This means RO is suitable for many applications where high-quality water is required or is beneficial (e.g. boiler or cooling tower feedwater).

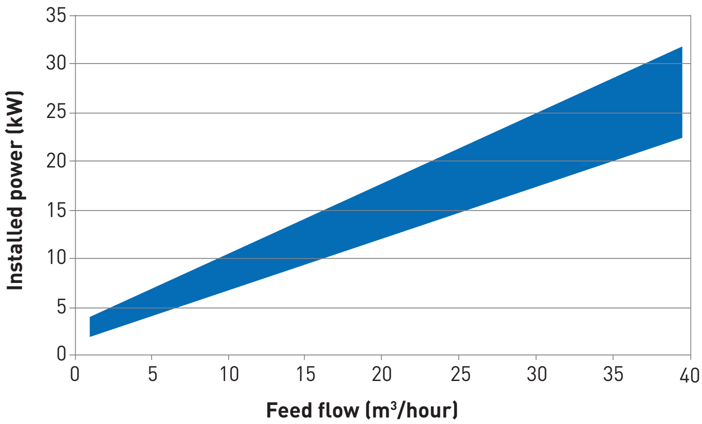
Mains water has a relatively high TDS content. Therefore it is often softened before it enters the RO unit to prevent scale build-up and membrane fouling, which reduce performance.

Figure 3: Membrane treatment plant recovering evaporative condensate for reuse (courtesy United Milk, now Westbury Dairies)

Hidden costs of reverse osmosis

Electricity used by the high-pressure feed pump is the main operating cost of RO plant. Typically, the installed power requirement increases as the capacity of the RO unit increases. The range of installed power requirements for various capacities of RO units is shown in Figure 4.

Figure 4: Range of installed power requirements for RO units



Additional costs may be incurred for the disposal of the reject water as trade effluent, any necessary pre-treatment (such as softening) and membrane cleaning. Periodic replacement of the membranes will also be required, but this depends on the operational life of the RO plant. Typical costs for water treated by RO[7] range between £1.51 and £3.83/m^3.

Action

1. Using your own costs, calculate the cost of the treated water produced by your RO plant to see how it compares with the 'typical costs'.

[7] Note this does not include capital and maintenance costs (e.g. including membrane replacement) which can be significant for RO plant.

Understanding where water is used during reverse osmosis

To identify the water saving opportunities on RO installations you first need to consider:

- **how much water is being used by the RO process;**
- **the volume of reject water that is produced; and**
- **how much permeate is being produced and where it is being used.**

Potential areas for water efficiency improvements in a typical RO plant are shown in Figure 5.

The recovery efficiency of RO units can be monitored since most RO installations have meters (or rotameters) on the permeate and reject water flows. The recovery efficiency of an RO unit can be calculated using the following formula:

$$\text{Recovery efficiency (\%)} = \frac{\text{Volume of permeate}}{\text{Volume of feedwater}} \times 100$$

Installing meters in the locations shown in Figure 5 would allow this to be measured and expressed as:

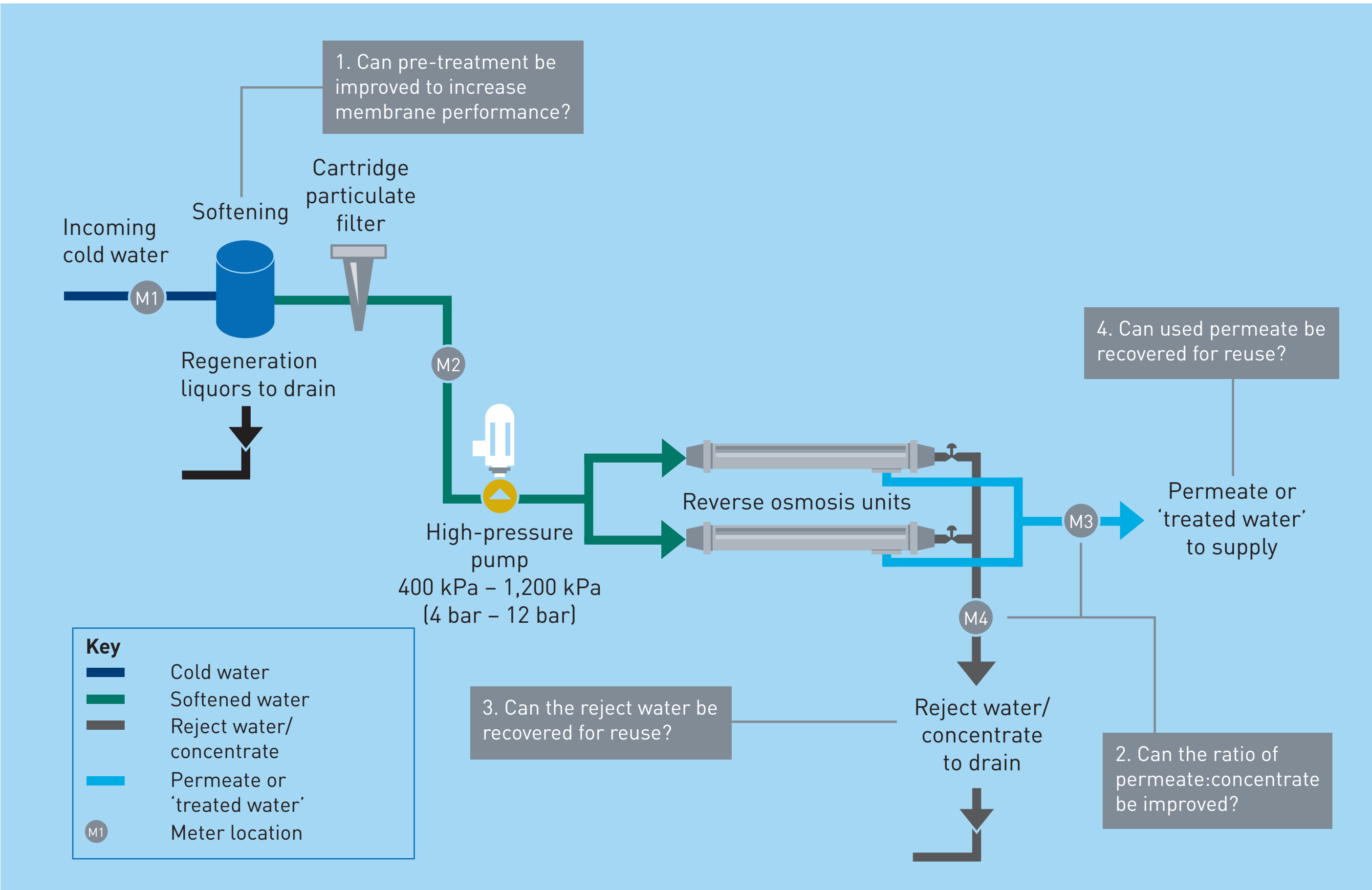
$$\text{Recovery efficiency (\%)} = \frac{M3}{M2} \times 100$$

Typical recovery efficiencies are between 70% and 80%, but will depend on operating parameters as well as the feedwater quality, membrane type and membrane condition.

The main loss of water will be due to the flow of reject water; a lower reject water volume will give a higher recovery efficiency.

Additional water will be used for the periodic cleaning of the membrane units. However, this is usually insignificant compared with the flow of reject water.

Figure 5: A typical RO plant and potential water efficiency improvements



Actions

1. Calculate the recovery efficiency of your RO unit.
2. Quantify the monthly or annual flow of reject water to identify whether it can be recovered for reuse.
3. Identify where permeate is being used, assess whether required and reduce if possible.

Opportunities for saving water during reverse osmosis

There are three key aspects to consider when evaluating the water efficiency of RO plant:

- **increasing the recovery efficiency;**
- **reusing the reject water; and**
- **reusing used permeate.**

RECOVERY EFFICIENCY

The recovery efficiency can be increased by improving the pre-treatment, for example, by installing softeners to reduce membrane fouling or cartridge filters to reduce fine solids in the feedwater.

Sometimes, solids can limit the recovery efficiency. Having a high concentration of these solids in the feedwater may result in the membrane being fouled. To prevent salts precipitating out, the concentration needs to be reduced by continual dilution to keep the salts in solution.

The addition of chemicals may help to mitigate this effect (e.g. the addition of an acid can help to limit bicarbonate ion concentration). Your RO supplier should be able to advise further.

REUSE OF REJECT WATER

The flow of reject water can be high, between 20% and 30% of the feedwater flow. Therefore, recovering and reusing this water offers considerable scope for water savings. Often, this water is very similar to the initial feedwater, but contains an elevated concentration of TDS, typically between 3 and 5 times the concentration in the feedwater. This water can usually be recovered and reused directly where water quality is not important (e.g. for toilet flushing).

If the water has been softened prior to use in the RO unit and the site uses large volumes of softened water elsewhere, it may well be possible to recover the reject water (which is essentially 'concentrated' softened water) and add it to other softened water in a storage tank. The concentrated TDS in the reject water will be diluted and is unlikely to significantly affect the hardness of the water. This reduces the amount of softened water you may need to generate and helps to reduce costs.

REUSE OF USED PERMEATE

Permeate from RO units is high-quality water. Very often, when this water is used, the wastewater generated (i.e. used permeate) is also high quality when compared with 'raw' mains water. As such, it may be possible to collect it and reuse it (e.g. for final high-quality rinse water).

Actions

1. Establish whether any changes to the plant operation could improve the recovery efficiency.
2. Review the opportunities to recover reject water and possibly blend with other water for reuse.
3. Review uses of permeate and establish whether any used permeate could be recovered for reuse elsewhere on site.

Waste & Resources Action Programme

January 2011

The Old Academy
21 Horse Fair
Banbury, Oxon
OX16 0AH

Tel: 01295 819 900
Fax: 01295 819 911
E-mail: info@wrap.org.uk

Resource Efficiency helpline
0808 100 2040

www.wrap.org.uk/rippleffect