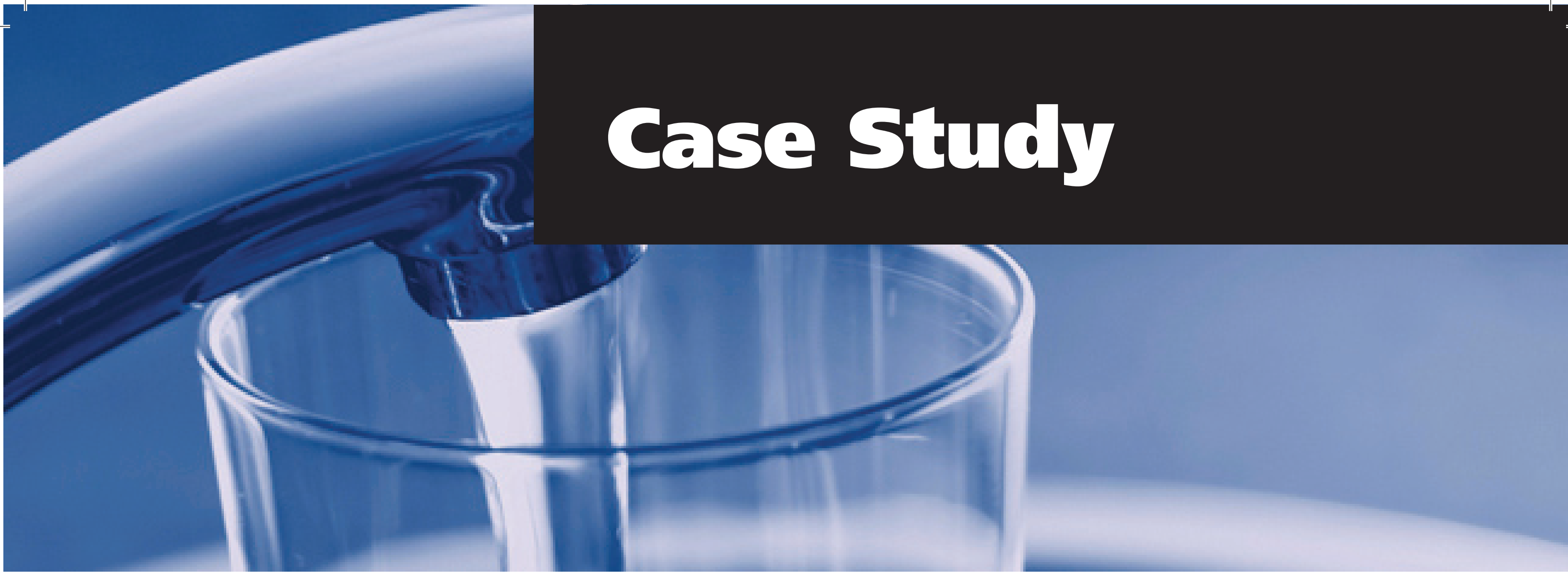


Case Study

K.A.U.S.T. project: CO_2 for potable water

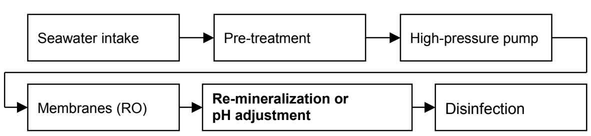
Application: CO_2 injection for pH correction at a SWRO desalination plant.

Carbon Dioxide (CO_2) is used in many industrial applications. In the beverage industry it is used to carbonate beer, soft drinks and mineral water. Mostly within the Norit Group this is where the application of CO_2 ends - however there is another application outside the beverage industry where Norit Haffmans can add its CO_2 expertise.

At this moment Norit Haffmans is working on a project for the King Abdullah University of Science and Technology (K.A.U.S.T) in Saudi Arabia. K.A.U.S.T will be located in a small town called Thuwel near to Jeddah. The students and townspeople living on the campus will source potable water from a newly built 40,000 m^3/d desalination plant which uses a reverse osmosis process to turn seawater into potable water.

Reverse osmosis (RO) is a membrane separation process that uses pressure to force a solvent, in this case water, through a membrane that retains the solute, in this case "salt", on one side and allows permeate (purified water) to pass to the other side.

The general process steps of this sea water purification are:



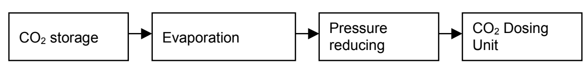
When we focus on the CO_2 application, we look at the RO (membrane filtration) and re-mineralization process.

Traditional seawater desalination requires the addition of mineral acids to the pre-treated seawater prior to the membranes for scale control and to maintain performance. The application of mineral acids also led to the generation of CO_2, which, as a gas, passed through the membrane and lowered the pH of the produced permeate to pH 5.5-6.2.

With the increased use of thin film composite membranes, which can operate across a wide pH range from pH 2-11, the application of acid has been phased out and this has led to an increase of the permeate pH. This has also meant an inability of the now neutral pH permeate to dissolve the limestone (or milk of lime) required for the re-hardening of the potable water to meet WHO or SASO water quality standards.

The purpose of adding the CO_2 is to adjust (increase) the pH value and to allow the calcium (Ca+) ion to re-create some hardness and alkalinity as required by the WHO and SASO standards. This also reduces the corrosive and aggressive nature of the desalinated water received from the seawater RO Plant.

A CO_2 injection unit consists of the following parts:



CO_2 storage

CO_2 in a liquid phase at approximate 17 bar and –24°C is held in CO_2 storage tanks. Depending on the consumption rate of CO_2 and the environment either cryogenic or conventionally insulated tanks are used. Tank sizing will depend on the consumption and the time in between refilling. Trucks transporting liquid CO_2 in portable tanks ("road tankers") are typically used to refill the CO_2 storage tank.

CO_2 evaporation

CO_2 will be added to the RO-water in a gas phase. Therefore the liquid CO_2 must first be converted into gas. The CO_2 vaporizing process requires the input of energy. This energy input is typically

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done using ambient air, electric or steam energy. When the ambient temperature is above 10°C an air heated vaporizer is the most economical solution, as electrical or steam based vaporizing systems have significantly higher operating costs. After the evaporator the CO_2 will be in the gas phase but still at approximately 17 bar and hence the need to first reduce the pressure prior to injecting into the water.

Pressure reducing

In the pressure reducing step the CO_2 pressure is reduced to approximately 2 bar above the RO water pressure. As safety mechanism an additional valve is installed upstream of the pressure reducing valve to ensure the CO_2 tank pressure cannot drop too quickly and cause potential safety related issues. After the pressure reducing step the gas pressure will be typically below 10 bar.

CO_2 dosing unit

With the dosing unit a mass flow meter and a automatic dosing valve will control the amount of CO_2 gas injected into the water. The amount of CO_2 injected will depending on the water flow rate, the inlet water pH and the end desired outlet water pH. Control of the pH value is executed in two possible ways:

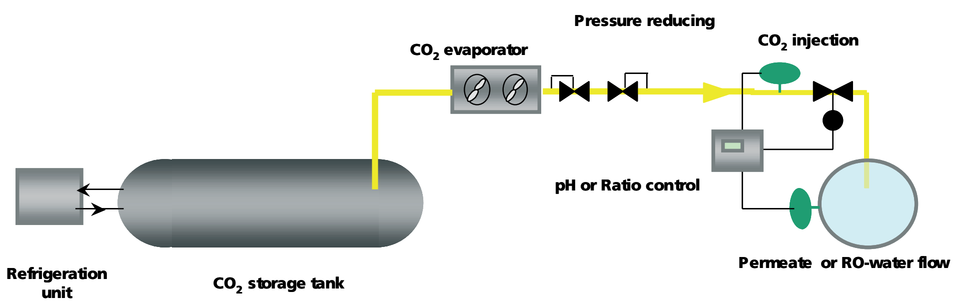
a. Dosing based on direct outlet pH measurement in the RO-water
b. Dosing based on ratio (flow) control (applicable with a stable inlet water pH)

The amount of CO_2 present in the RO water will normally be in the order of 40 to 60 ppm.

After the actual injection Norit Haffmans recommends to use a static mixer for a proper distribution and absorption of the CO_2 in the water. In many cases additional lime dosing (addition of Hydrated Lime to the RO water) will be combined with the CO_2 dosing and uses only one static mixer. Another solution is the use of a limestone-filter whereby the dissolved CO_2 in the RO-water will pass trough this filter and in so doing so absorb the required minerals. The chosen lime dosing process has a big influence on the selection and sizing of the static mixer.

After the CO_2 and lime dosing the RO-water is re-mineralized, pH adjusted and will be transferred to the disinfection unit and thereafter is ready for consumption as potable water.

Flow sheet K.A.U.S.T. project



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