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Seawater collection by means of borehole

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ABSTRACT

The article discusses the process of seawater collection through boreholes for the operation of desalination plants. Seawater collection is essential for desalination, and it must have a specific electrical conductivity of around 50,000 $\mu\Omega$/cm, with an appropriate temperature of 25 ºC. The article describes the characteristics of the borehole, such as the diameter, suction surface, and casing, as well as the depth at which the seawater is collected. The drilling techniques for boreholes are also mentioned, which include percussion and rotopercussion machinery. Finally, the article explains the Ghyben-Herzberg formula for determining the hydrostatic equilibrium between freshwater and saltwater, which is used to determine the depth of the interface with respect to sea level.

1. Introduction.

The world population in 2022 reached 8,000 billion people, with a growth forecast to reach 10,000 million by 2050 (UN, 2022). This growth leads to an increase in the need for drinking water to supply not only the population but also to irrigate crops.

The scarcity of fresh water, the increase in consumption due to population growth, as well as climate change, means that the problem of fresh water supply is increasing day by day.

Seawater desalination is a viable alternative to supply the planet's increasing freshwater needs, as it is a practically inexhaustible source (Schiffier, M. 2004), Cipollina A. et al.2009).

2. Boreholes for sea water collection.

Seawater collection is a fundamental aspect for the proper operation of the desalination plant. When collecting seawater, it must be guaranteed that the water collected is seawater with an electrical conductivity of around 50,000 $\mu\Omega$/cm, at a temperature of 25ºC (Electrical Conductivity of Seawater A. L. BRADSHAW AND KARL E. SCHLHCHEX).

Electrical conductivity is the ability of water to conduct an electric current through dissolved ions.

The most positive ions are sodium (Na^+), calcium (Ca^{2+}), potassium (K^+) and magnesium (Mg^{2+}). The most negative ions are chloride (Cl^-), sulfate ($SO_4{}^{2-}$), carbonate, bicarbonate.

Seawater can be collected in two ways:

1. Direct seawater intake.
2. Boreholes for seawater collection.

3. Characteristics of the borehole.

Seawater collection by means of boreholes consists of drilling wells with a borehole diameter of between 350 millimeters and 600 millimeters, which is the diameter required for the installation of a seawater pump inside the borehole to feed the desalination plant. Seawater wells are usually located at a distance of less than 100 meters.

In seawater wells, the suction surface of the pump will be installed inside the well, at a level lower than - 40 meters over sea level (m.o.s.l.).

To avoid possible collapse of the borehole walls, causing entrapment inside the borehole, the borehole will be cased with Polyvinyl Chloride (PVC) pipe with nominal diameters between 300 millimeters and 500 millimeters.

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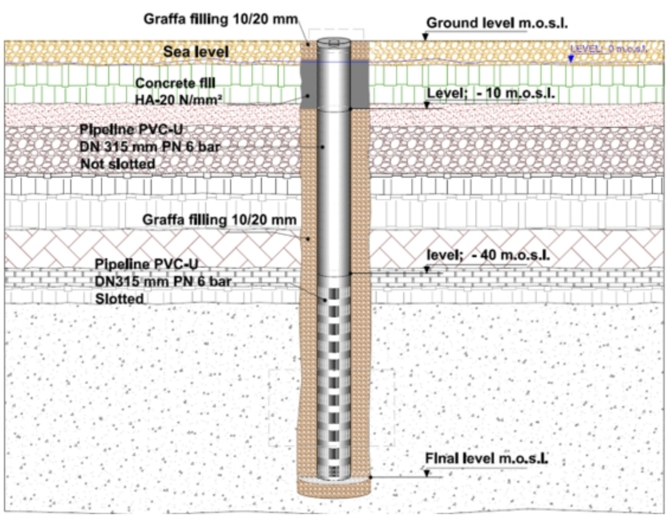
The pipe is slotted from -40 m.o.s.l., in order to allow the entry of seawater for its impulsion. The free space between the casing and the borehole walls is filled with gravel, as a filtering element, from the lower level of the borehole to the -10 m.o.s.l. level. The maximum size of the aggregate must be 76 millimeters. The granulometric composition will be determined according to the characteristics of the land to be drained and the drainage system.

From this level to the ground level, the space between the pipe and the borehole walls will be filled with concrete, in order to prevent the possible contributions of surface water from runoff, altering the conditions of the seawater to be desalinated and, therefore, varying the initial design parameters of the seawater captured. Figure 1 shows a construction detail of a seawater collection borehole.

Figure 1: Construction detail of a seawater collection borehole.



Source: Author.

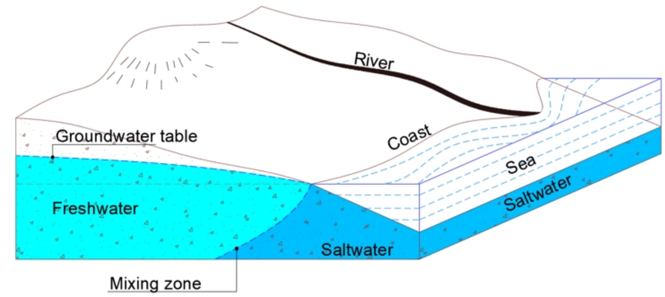
4. Depth of boreholes.

In order to ensure that the water catchment is salt water, the depth with respect to the water table at which the water is to be collected must be taken into account.

If we consider in a first approximation fresh water and salt water as two immiscible fluids, then they will be separated by an interface in the form of a bevel whose slope is defined by mathematical formulas.

Because of the slope of the interface, the saltwater front can be likened to a tongue that advances inland during periods of lower aquifer recharge and retreats towards the sea when recharge is higher. However, seawater and freshwater are not immiscible, but mix in a zone known as the mixing zone, and the transition from one fluid to the other is gradual. This zone is also known as the diffusion or transition zone. All these processes are shown in Figure 2.

Figure 2: Freshwater, mixing zone and saltwater.



Source: Author.

The Ghyben-Herzberg formula (Verrjuit Arnold et al. A note on the Ghyben-Herzberg formula. Bulletin of the International Association of Scientific Hydrology. Volume 13, number 4. pp. 43-46. Technological University, Delft, The Netherlands) determines the hydrostatic equilibrium between freshwater and saltwater by considering them as two immiscible, i.e., non-mixing, fluids separated by an interface.

Based on these assumptions, equilibrium occurs when:

γ_d (H+Z) = γ_s Z

γ_d: density of fresh water (gr/cm^3)

γ_s: density of seawater (gr/cm^3)

Z: depth of the interface with respect to sea level.

5. Drilling techniques for boreholes.

The drilling of these wells can be carried out by means of percussion or rotopercussion machinery.

5.1. Percussion drilling.

The drilling of percussion wells is carried out by means of a percussion bit. The bit will have a diameter that can vary between 350 mm to 600 mm and an estimated mass of 5 tons to 6 tons.

Percussion drilling consists of dropping the bit at a certain height, from 5 centimeters to 15 centimeters vertically, and with a certain frequency, which will depend on the characteristics of the ground to be drilled. The bit hits the ground fracturing it, water is introduced into the borehole, so that the fractured ground together with the water introduced creates a drilling mud.

The drilling progress follows the following sequence, once approximately 2.0 m deep has been drilled, the bit is withdrawn to introduce a mud removal valve. The mud removal valve consists of a metal pipe about 4 m long with a non-return valve. The valve is introduced into the sludge by weight, introducing the sludge inside the pipe. With the valve full, the valve is removed from inside the borehole, emptying the sludge into a sludge pond.

5.2. Rotopercussive drilling.

In rotary percussive drilling, rotation of the drilling head is combined with percussion. Drilling diameters are smaller than percussion drilling, with rotopercussive diameters ranging from 180 millimeters to 450 millimeters.

Drilling mud is extracted by introducing a fluid through the inside of the drillstring, which then rises up the borehole walls dragging the crushed material with it.

The advantage of roto-percussion drilling over percussion drilling is that the drilling yields are higher with roto-percussion, however, it requires more specialized machinery with smaller drilling diameters than with percussion. As a great disadvantage, this type of drilling is not advisable for very fractured terrains.

Conclusions.

The method of seawater collection through boreholes is simple, cheap and the least harmful to the environment (Environmental impact of seawater distillation and reverse osmosis processes, A.J. Morton, I.K. Callister, N.M. Wade, DOI10.1016/s0-011-9164(97)00002-7).

The disadvantage of drilling boreholes for seawater abstraction is that the abstraction flow is conditioned by the permeability of the land through which the borehole is drilled. In the case of land with low permeability, it will be necessary to drill several boreholes to meet the flow demand of the desalination plant.

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