22nd Australasian Fluid Mechanics Conference AFMC2020
Brisbane, Australia, 7-10 December 2020
https://doi.org/10.14264/5577c91

Desalination Using Simple Materials

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Abstract

Water is the main source of life for humans as our body is made up of over 60% of water. We require water that is clean and safe for mandatory purposes such as food production, consumption and sanitary purposes. In many regions of the world water scarcity is a serious concern. These regions, rely heavily on water purification methods such as desalination which purifies saline water from rivers and oceans, removing minerals and salts to give fresh water. The problem with current desalination methods is that they are overly costly and requiring sophisticated equipment, and thus not well suitable for undeveloped regions which often need desalination most.

This experimental work reports on a more affordable and simpler (not requiring sophisticated equipment) desalination method through the use of simple materials as it would reduce significantly the cost of production and operation. The process of the prototype will be reverse osmosis which uses pressure to force water through a filter, trapping minerals and salts to give fresh water. The materials used will be sand and clay for the filter; and steel is used for the prototype's structure. The composition of sand and clay that can act as the filter will be the challenge, as well as the amount of pressure required to force the water through the filter.

The resultant product is an affordable and simple desalination method that can produce fresh water from saline water. This product will be easy to manufacture and use which would be suitable to most people of any skill and knowledge, especially in undeveloped regions, for obtaining fresh water.

Keywords

Desalination; Simple materials; Clay; Sand.

Introduction

This work originates from an observation that, while clay is virtually impermeable to water, sand is on the other hand very permeable. Thus perhaps a right mixture of sand and clay would just let fresh water through, but not salt. The result of such belief, if it holds true, would then be a simple, effective, and cheap method for desalination.

Water shortage is a major problem worldwide and over 35% of the world's population do not have access to fresh water supply, so they will rely heavily on water filtration methods such as desalination. Also, as these regions are mainly undeveloped, they will require a desalination product that is affordable and simple to use.

Desalination refers to various methods of eliminating excess salts or minerals from saline water to acquire fresh water which is used for sanitary purposes, consumption and food production. These methods include thermal distillation, electric desalination and reverse osmosis. The method that the project will be mainly focusing on is reverse osmosis which uses pressure to force the water through a semi permeable filter leaving excess salts and minerals behind.

Water from rivers, oceans and lakes all flow through land or ground and dissolve minerals and contaminants along the way. So, by removing these contaminants, it may be possible for the water to be drinkable and used for food production.

Overall, the main aim of this work is to create a simple, effective and cheat desalination method capable of removing inorganic contaminants from water sources. This work thus investigates the design and construction of a reverse osmosis desalination process using simple materials that are abundant worldwide such as sand, clay. Generally, the filter will be a type of membrane but in this design, the filter will consist of a mixture of sand and clay. The reason for using sand and clay as a mixture is because sand is highly permeable whereas clay has low permeability, thus it's believed it's possible to mix them to create a filter that allows fresh water to pass through, leaving impurities behind.

The process of reverse osmosis desalination is shown below in Figure 1.

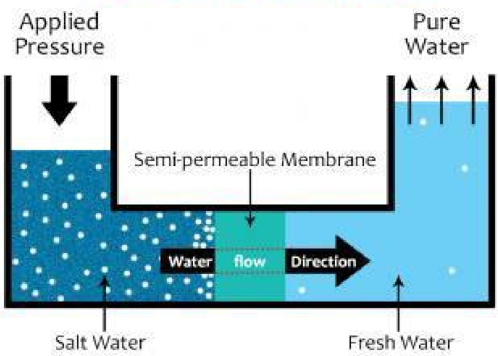

Figure 1. Reverse Osmosis Desalination [2].

This work focuses on finding experimentally the right sand-clay mixture for a filter and pressure to drive saline water through it to give fresh water. Residual salinity in the filtered water is measured with a TDS meter for TDS (Total Dissolved Solids [including Salts]) level as well as the electrical conductivity.

Two main types of desalination technology are currently applied worldwide, namely thermal evaporation and membrane separation [3]. The reverse osmosis method used in this work belongs to membrane separation. Thermal evaporation on the other hand uses heat to purify water through evaporation and condensation. In the last 10 years, SWRO (Sea Water Reverse Osmosis) has been the dominant method of desalination in regions outside the Middle East. Conversely, thermal evaporation is the dominant method used there.

Commercially, various companies have been innovating portable desalination kits which makes purifying water more convenient. An example is the "Universal Water Desalinator" from "Prime Water Purifiers". The product can operate without using electricity and is capable of purifying from 2 to 3 quarts (1.9 l to 2.8 l) of water a day. The process is conducted through thermal evaporation which uses a boiling pot to evaporate and condense the water into two water bottles. The only drawback from using this product is that the process is long and is only able to produce small amounts of water. A photo of the 'Universal Water Desalinator' is shown below in Figure 2.

Figure 2. Universal Water Desalinator [1].

There is currently ongoing research on reducing the cost of desalination processes as well as innovating new products to make desalination an efficient solution to the worldwide water shortages; and it can be foreseen that technology advances are expected to reduce the cost of desalination water by 20% in the next five years, and by up to 60% in the next 20 years [4].

Experiments

A desalination equipment is constructed. This is shown in Figures 3 and 4. Thus saline water is collected in the upper part of a steel chamber-and-piston assembly. Below the saline water is the clay-and-sand mixture that acts as a filter. A weight is placed on a platform on top the piston to create pressure on the saline water. Two drip holes below the clay-sand mix (filter) to let desalinated water to pass through, to be collected by a container below (Figure 3). Cotton and coffee-paper (coffee filter) are also placed below the clay-sand mix as strainers to prevent the clay and sand particles to pass through the drip holes.

"White Brickies" sand and Kaolin clay have been used for the clay-sand mix (filter). In a typical experiment, the cotton-and-paper strainers would take up the lowest 5 mm of the chamber. Next and above them is the clay-sand mix of about 10 mm height (thus of volume 2.6×10^{-5} m^3). Next and above the clay-sand mix will be the saline water with a depth of about 69 mm (thus of volume 1.8×10^{-4} m^3)

Figure 4 shows the steel parts in a SolidWorks drawing of the desalination equipment. Chamber size is Ø58 ID×84 mm, supported on two legs of 70 mm height. Total height of the chamber-leg assembly is 160 mm, including the 6 mm thick plate at chamber's bottom. Diameter if the trip holes is 4 mm. Piston consists of a square top plate 80×80×10 mm to act as platform for a weight to create pressure, a circular bottom plate ØD×10 mm (to press on the clay-sand mixture), where diameter D (just below 58 mm) is for close-fit with the chamber's inside wall, and a cylindrical rod Ø30×80 mm connecting the two plates.

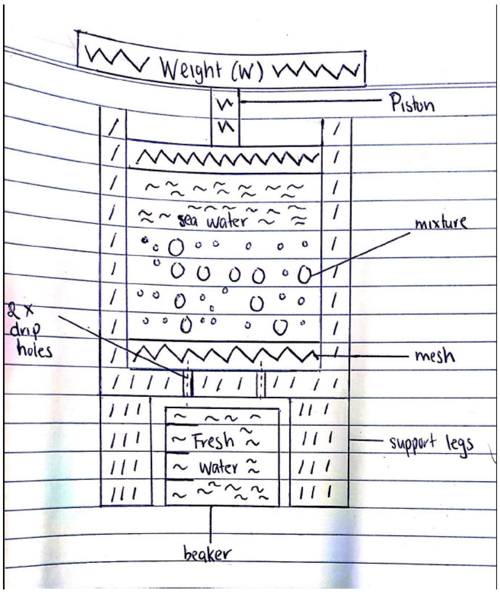

Figure 3. Components of the desalination equipment.

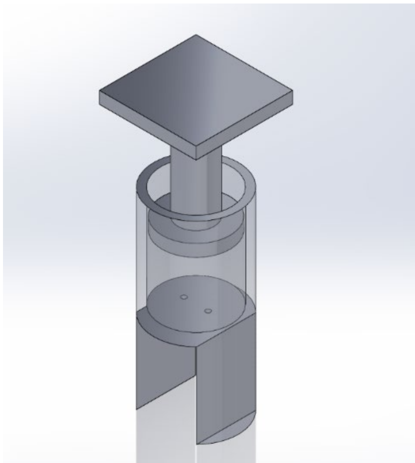

Figure 4. SolidWorks drawing of the desalination equipment, showing steel parts.

Saline water

The saline water was constructed using tap water, which was measured to have a TDS of 215 ppm, and by adding table salt to increase the TDS to 974 ppm. This was suitable for the experiment as the required TDS for drinking water is less than 500 ppm, and less than 800 ppm for growing plants.

Pressure

Two mass of 20 kg and 35 kg were used, to create pressure of 74.3 kPa and 130.0 kPa respectively on the saline water. The lower pressure has simply resulted in a longer time for a same amount of saline water to be desalinated.

Clay-sand mix (filter)

The difference between the clay-sand-mix filter samples will be the composition of sand and clay in the mixture. 6

compositions have been tested, with the following clay-sand ratios: 0%-100%, 10%-90%, 40%-60%, 60%-40%, 90%-10%, and 100%-0%. Each composition was tested 3 times to increase the reliability of the experiment. After the composition is repeated 3 times the results will be compared to make sure that they are similar, which therefore shows that the results are reliable. If the results do not come out similar, the composition will be repeated another 3 times and the results will be compared again. The clay-sand-mix filter was constructed based on 100g of total mass. For example, for 60% sand and 40% clay, the sand will be measured at 60g whilst the clay at 40g. Figure 5 shows a view of the 60%_Clay-40%_Sand mixture.

Figure 5. A 60%_clay-40%_sand mixture.

Measuring water's salinity

Water's salinity is measured with a hand-held TDS Meter 3 Water Quality Tester. This meter measures both TDS (Total Dissolved Solids [including Salts]) in ppm, and EC (Electrical Conductivity) in µS/cm. TDS and EC are related, and both indicate water's salinity. As readings of TDS and EC are sensitive to temperature change, a constant temperature of 25ºC is maintained for the measurements. Figure 6 shows the TDS Meter being used.

Results

Saline water was constructed from tap water and table salt to give a TDS reading of 974 ppm. This saline water is then desalinated using the equipment and method described above. Each test was repeated 3 times, and Figure 7 shows the TDS readings of the water after it has passed through the sand-clay mixture.

Figure 6. The TDS Meter 3 Water Quality Tester is being used.

Figure 7 shows that a clay-sand ratio of 60%-40% gives the largest reduction in water salinity (from 974 ppm down to an average of 550 ppm). But 550 ppm is still above the 500 ppm which is the highest value suitable for drinking.

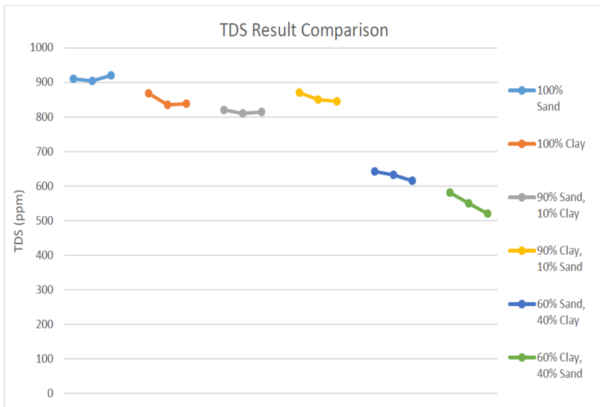

Figure 7. TDS readings for different clay-sand-mix ratios. Test for each ratio is repeated 3 time.

On the other hand, after a saline water sample has been passed through a clay-sand mix of 60%-40%, resulting in a TDS reading of 572 ppm (down from the original 974 ppm), it is again repeatedly passed through the same 60%-40% clay-sand mix. This repeating process results in the gradual reduction in water salinity as shown in Figure 8.

Figure 8 shows that a saline water sample of TDS 974 ppm has been passed repeatedly 5 times through a 60%-40% clay-sand mix using the equipment of this work, the salinity TDS reading has been reduced to a mere 194 ppm, well within the ideal TDS for drinking water of 150 – 250 ppm.

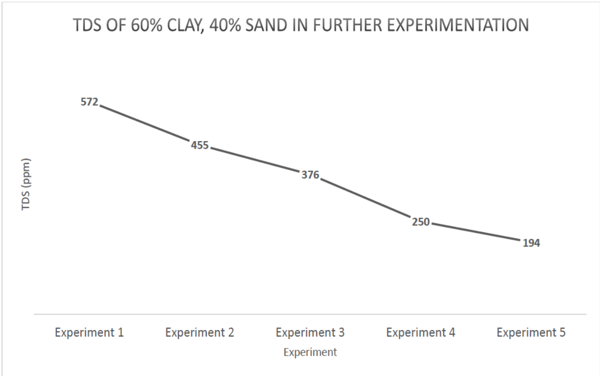

Figure 8. TDS readings of a same saline water sample when it is repeatedly desalinated using the clay-sand mix of 60%-40%.

Because the thickness of the clay-sand mix used in this work is only about 10 mm, from the results in Figure 6, it could thus be expected that thicker layers of the clay-sand mix would reduce the salinity more markedly. In other words, if a layer of 60%-40% clay-sand mix of 30 mm thick had been used, TDS would have been reduced from 974 ppm to well below 500 ppm, suitable for drinking.

On the other hand, from results of Figures 7 and 8, other mix ratios of clay and sand could also be used for desalination; it's only that they are not as effective as the 60%_clay-40%_sand mixture, and thus needing more repeats, or as discussed, thicker layers of the mixtures.

Conclusions

Overall, the theory of using simple materials such as sand and clay to act as a filter for desalination has been shown to be possible, which means that a clay-sand mixture has the capabilities of removing salts and minerals from saline water, thus creating water that is within the drinking and food production range. The range for drinking water is a TDS level of 0 – 500 ppm, whilst the range for food production is 0 – 800 ppm.

This theory has been proved workable by using a composition of 60%_clay-40%sand which produced water which has a TDS level of 194 ppm at the end of a series of 5 repeated desalination passes. This is acceptable for both drinking water as well as water used for food production.

Ultimately, all compositions of sand and clay are capable of filtering salt and minerals from saline water as shown from the results of our experimentation, but the best composition will produce the largest reduction in TDS. In this case it was 60% clay and 40% sand.

References

[1] All About Water Filters (2019). *5 of the Best Portable Desalination Kits You Need to Own.* Available at: <http://all-about-water-filters.com/best-portable-desalination-kits/> [Accessed 23 Sep 2019]

[2] Barth, B. (2019). *How Desalination Plants Work*. Available at: <https://greenliving.lovetoknow.com/environmental-issues/how-desalination-plants-work> [Accessed 23 Sep 2019]

[3] Boulianna, C. (2017). *Methods for Desalination*. Available at: <https://sciencing.com/methods-desalination-5038235.html> [Accessed 23 Sep 2019]

[4] Voutchkov, N. (2016). *Desalination - Past, Present and Future*. Available at: <http://iwa-network.org/desalination-past-present-future/> [Accessed 23 Sep 2019]