REVERSE OSMOSIS: A POSSIBLE SOLUTION TO WATER SCARCITY

Amanda Zelnis (ajz32@pitt.edu)

OVERVIEW

People are faced with problems every day. One could even argue that problems are part of the nature of life. Some people are faced with the problem of what shoes to wear that day or what restaurant to go to. However, other less fortunate people are faced with problems that hold much more weight and are of greater magnitude. Such problems can be a matter of life or death. Currently, many developing countries are facing the complex problem of water scarcity. People in these countries either drink contaminated water or decide to drink little to no water at all. If they drink the contaminated water, they will run the risk of becoming deathly ill. If they do not drink the water, they will likely become deathly dehydrated. Regardless, the people in these communities are suffering, and they need help.

This problem matters for me as an engineer because I refuse sit on the sideline and watch people suffer. I believe that because engineers have the means and knowledge to relieve suffering, it is their duty to help. In fact, some engineers of the same mindset have already developed a few technologies that have the potential to help the water crisis. The technology of reverse osmosis is currently the most promising. Reverse osmosis turns undrinkable water to drinkable water by removing any contaminants that are unsafe for consumption. This technology has already been implemented in a few developing communities. However, this does not mean the work for engineers is complete. The technology needs to be revised and modified to make it a more practical and viable option for developing countries.

WATER SCARCITY LEADS TO SUFFERING

Water sustains human life. Water is vital to human health. Water is necessary for proper sanitation and hygiene. Although there is abundant water for everyone on Earth, according to the United Nation's Water for Aid effort, "it is distributed unevenly and too much of it is wasted, polluted and unsustainably managed" [1]. In result, the UN estimates that "water scarcity affects nearly 40% of the global population and is projected to rise" [2]. Fluence, a corporation that supplies water reuse solutions, defines water scarcity as "a lack of sufficient water, or not having access to safe water supplies" [3]. Although water scarcity does occur in westernized nations, it is most prevalent in developing countries. UNICEF, an internationally respected organization that strives to improve the lives of children and families, reports that "eight out of ten people without access to safe drinking water live in rural areas and nearly half of them live in sub-Saharan Africa" [4]. Without aid, these people are left to drink and use contaminated water that is detrimental to their health. According to the World Health Organization (WHO), the leading international agency concerned with public health, "contaminated water and poor sanitation are linked to transmission of diseases such as cholera, diarrhea, dysentery, hepatitis A, typhoid, and polio" [5]. In fact, the nonprofit organization Water Aid estimates that "289,000 children under 5 die each year due to diarrheal diseases cause by poor water" [6]. Additionally, the WHO reports that a newborn baby dies every minute from infection due to lack of clean water [5]. These numbers may seem too shocking to be true, but they represent a very real problem that is directly affecting many real people.

A POSSIBLE SOLUTION

Desalination, as its name implies, is the process of extracting minerals and salts from a substance. Desalination as a technique to attain drinkable water from seawater has been used for centuries. In the fourth century B.C, Aristotle told of sailors desalinating ocean water by utilizing evaporation techniques. Since then, desalinations techniques have significantly advanced. Modern desalination techniques are now regarded by many professionals as the answer to the clean water crisis.

The most used desalination technique is reverse osmosis. According the paper titled "State-of-the-art of reverse osmosis desalination" published in the ScienceDirect journal, this technique "is capable of rejecting nearly all colloidal or dissolved matter from an aqueous solution, producing a concentrate brine and a permeate which consists of almost pure water" [7]. Essentially, reverse osmosis can remove not only salts but also other contaminants from undrinkable water and transform it into safe, consumable water.

To understand reverse osmosis, one must first understand the naturally occurring process of osmosis. The most basic setup for osmosis requires a container that separates contaminated water and pure water with a semipermeable membrane. It is important to note that the term contaminated water, which can also be referred to as feed water, encompasses water that has high concentrations of salt, pyrogens, organics, and bacteria. The semi-membrane allows water to pass through but does not the contaminants to pass through. The feed water has a high concentration of contaminants while the pure water has a low to no concentration of contaminants. As experiments and observations have shown, nature desires and works toward equilibrium. In this case, the desired equilibrium is equal concentrations of contaminants in both types of water. Therefore, to decrease the concentration of contaminants in the feed water, the pure water will cross over the membrane and mix with the feed water until the number of contaminants per unit volume of water is equal in the both sides of the container. In other words, the concentrations in both sides of the container will be equal.

Reverse osmosis is simply the reverse of osmosis. As Puretec, an established company that specialized in reverse osmosis water purification, notes, "whereas osmosis occurs naturally without energy required, to reverse the process of osmosis you need to apply energy to the more saline solution" [8]. In other words, pressure must be applied to the feed water which contains the higher concentration of contaminants. When pressure difference is applied across the membrane, the water molecules from the feed water are forced to permeate through the membrane. The semi-permeable membrane prevents the salt and other molecules from crossing to the other side. Finally, the process is complete when one side simply contains isolated contaminants and the other side contains nearly pure and certainly drinkable water.

REVERSE OSMOSIS IN ACTION

Desalination plants use the reverse osmosis technique to transform large volumes of contaminated water into safe, drinking water. To account for such large volumes of water, the basic reverse osmosis setup is modified. Instead of a container with two sections, there is essentially a tube surrounded by many layers. The inner tube has a steady flow of pure water. Then, layers of the semi-permeable membrane are wrapped around this tube. The contaminated water is pumped through the layers of membrane while a pressure is applied to the outside of the tubes. Consistent with basic reverse osmosis, this pressure forces only water molecules into the center tube. This design has proven to be efficient and sustainable in producing large quantities of drinkable water.

In Developing Communities

In the 1990s, eleven reverse osmosis plants were installed in villages in India in the hopes of supplying the population with clean drinking water. These villages, located in the Ramanathapuram district, are situated on the coast of India. Because of the villages' proximity to the ocean, the groundwater, a primary source of drinking water, is too saline for consumption. According to the National Environmental Engineering Research Institute (NEERI), an Indian government organization, the reverse osmosis plants were designed and installed to "use brackish/saline ground water as feed water and produce product water" [9].

Regardless of whether the reverse osmosis plant is in a developing or already developed nation, the heart of the plant is the semi-permeable membrane. As noted by the NEERI, the "vital function of the RO membrane is to allow only pure water to pass through it and not the dissolved solute" [9]. Therefore, the Indian government imported a polyamide membrane from FilmTec Corporation, a company in the United States, to ensure quality performance. This membrane was then incorporated by professional engineers into the basic design of a reverse osmosis plant. Within a relatively short period of time, the reverse osmosis plant was up and working.

According to the NEERI "detailed information on plant design and engineering, water quality, plant personnel, and cost of O&M [operation and maintenance] was collected for a period of three years after commissioning of the two plants" [9]. The NEERI reported that "The salt rejection was 99% in Melasirupodhu plant and 98% in Sikkal plant immediately after commissioning" [9]. In other words, the reverse osmosis technology utilized by these plants successfully removed nearly all the salt in the originally undrinkable water. Thus, the resulting water was safe for consumption. The reverse osmosis technology was a significant source hope for a future in which the villages would not have to be concerned about contaminated water.

A CRITICAL LOOK AT REVERSE OSMOSIS IN ACTION

Many experts and professionals have expressed concerns about using reverse osmosis technology in developing countries. Specifically, Sunil J. Wimalawansa, a well-respected former professor of the sciences, points out that "potentially high start-up costs, necessity of electricity, handling of effluent water and the need for frequent back-flushing and/or replacement of filters and membranes remain obstacles to this technology" [10].

These obstacles are not merely hypothetical problems. In fact, the reverse osmosis plants located in India experienced some of these problems. For one, according to the NEERI, "both plants showed gradual decline in product water quality…[which] indicates the deterioration of RO membranes with time" [9]. Additionally, the NEERI reported that "both plants have been underutilized due to inadequate power supply and plant breakdown" [9]. In other words, the plant was not used for a period because of technical issues that could not be solved quickly by those that operated the plants. Finally, the NEERI concluded that "water from RO plants is costly ($ 2.2/m3) and not affordable by local population and state governments" [9].

Some professionals, amid all the concerns and criticisms, still retain a hopeful outlook on the future of reverse osmosis plants in developing countries. For example, Enas R. Shouman from the National Research Center in Egypt believes that "The prospective for cost reduction in reverse osmosis systems is promising in view of progressive development of RO systems" [11]. In other words, economic analysis has shown that the cost of reverse osmosis should decrease in the future possibly making the technology affordable to even developing communities. Additionally, according to the United Nations Environment Program, professionals foresee "development of more energy-efficient technologies that are simpler to operate than the existing technology… [or] development of energy recovery methodologies that will make better use of the energy inputs to the systems" [12]. In result, reverse osmosis technologies will become more viable options for the developing world.

CONCLUSION

I believe water scarcity is one of the most pressing problems of this century. If one cannot be convinced by any other reason, they will be convinced by the fact that water scarcity is literally a matter of life and death. Moreover, people are suffering daily due to a fixable problem. Based on expert opinion, I am not convinced reverse osmosis is the perfect technology to solve the water scarcity problem in developing countries. It has proved to be more harm than help when these plants have been installed in developing countries. Although reverse osmosis appears to not be the exact answer to the problem, I believe engineers must continue to either modify the technology or look for other technologies. Nevertheless, engineers must continue this work until the societies are no longer plagued by water scarcity, and I am prepared to further my education to a point where I can contribute to the solution.

SOURCES

[1] "Water Scarcity." United Nations Department of Economic and Social Affairs. 11.24.2014. Accessed 10.29.2017 http://www.un.org/waterforlifedecade/scarcity.shtml

[2] "Water." United Nations. Accessed 10.29.2017 http://www.un.org/en/sections/issues-depth/water/

[3] "What is Water Scarcity." Fluence. 10.06.2017. Accessed 10.29.2017. https://www.unicef.org/wash/3942_4456.html

[4] "Water, Sanitation, and Hydration." UNICEF. 04.05.2016. Accessed 10.29.2017. https://www.unicef.org/wash/3942_4456.html

[5] "Drinking Water." World Health Organization. 07.2017. Accessed 10.29.2017. http://www.who.int/mediacentre/factsheets/fs391/en/

[6] "Statistics." WaterAid. Accessed 10.29.2017. http://www.wateraid.org/what-we-do/the-crisis/statistics

[7] C. Fritzmann, J. Lowenberg, T. Wintgens, T. Melin. "State-of-the-art of reverse osmosis desalination." Elsevier. 10.2007. Accessed 10.29.2017. https://www.sciencedirect.com/science/article/pii/S0011916407004250

[8] "Reverse Osmosis Systems." PureTec Industrial Water. Accessed 10.29.2017. http://puretecwater.com/reverse-osmosis/reverse-osmosis-systems

[9] P. Kelkar, V. Joshi, M. Ansari, U. Manivel. "Performance Evaluation of Reverse Osmosis Desalination Plants for Rural Water Supply in A Developing Country – A Case Study." National Environmental Engineering Institute. 11.12.2002. Accessed 10.29.2017. https://link.springer.com/content/pdf/10.1023/A:1026147331266.pdf

[10] S. Wimalawansa. "Purification of Contaminated Water with Reverse Osmosis: Effective Solution of Providing Clean Water for Human Needs in Developing Countries." International Journal of Emerging

Technology and Advanced Engineering. 12.2013. Accessed 10.29.2017. https://www.researchgate.net/profile/Sunil_Wimalawansa/publication/284804889_Purification_of_Contaminated_Water_with_Reverse_Osmosis_Effective_Solution_of_Providing_Clean_Water_for_Human_Needs_in_Developing_Countries/links/565938d408aeafc2aac35f2c/Purification-of-Contaminated-Water-with-Reverse-Osmosis-Effective-Solution-of-Providing-Clean-Water-for-Human-Needs-in-Developing-Countries.pdf

[11] E. Shouman. "Economics of Renewable Energy for Water Desalination in Developing Countries." International Journal of Economics and Management Sciences. 12.04.2015. Accessed 10.29.2017. https://www.omicsonline.org/open-access/economics-of-renewable-energy-for-water-desalination-in-developing-countries-2162-6359-1000305.php?aid=66724

[12] "Desalination by Reverse Osmosis." United Nations Environment Program. Accessed 10.29.2017. https://www.oas.org/dsd/publications/Unit/oea59e/ch20.htm

ACKNOWLEDGMENTS

Thank you to the people in the Engineers Without Borders Club for showing me that you do not have to take the traditional engineering path to be successful. It is more important to follow your passions. Also, thank you to the writing center for helping me organize my thoughts and put them on paper.