Well Water in the Guarani Aquifer Region: Analysis of Water Purification by Reverse Osmosis Systems

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Abstract: The National Academy of Engineering defined the water scarcity as one of the modern problems that society is facing. Given the consequences that lack of water can bring to a community, finding ways to approach this problem is of utmost importance. The Guarani Aquifer region represents a good source to satisfy this need and guarantee water access to cities, towns or communities. However, groundwater carries some pollutants that come from different sources, which implies that the water must be purified to avoid health problems. The main objective of this work is to explore the main advantages of Reverse Osmosis (RO) systems and to propose it as an efficient method to purify water within each household.

Keywords: Desalination, reverse osmosis, energy, water treatment, well water, filters**.**

I. Introduction

One of the National Academy of Engineering (NAE) Grand Challenges is the development of effective methods for the purification of water to face the drinking water scarcity issue. The increasing demand for water in the last decades has triggered the search for new sources like groundwater, seawater and others. In the Littoral region of Argentina, which is over the Guarani Aquifer, the most common water source in small cities or towns is well water. This source, which people use every day, can contain solids, chemicals, pesticides, bacteria and many other contaminants that can cause damage to health. Household water usually gets some kind of treatment but some of the contaminants still remain in it.

To avoid harm to human health, the implementation of efficient methods to purify water is essential and RO becomes a great option to achieve this aim. RO systems are a good alternative to solve these problems due to their great ability to filter various contaminants, in addition to being less expensive than other methods.

The aim of this paper is to propose RO as an effective alternative to the treatment of groundwater, specifically applied in the Guaraní Aquifer zone to ensure a future with quality water in this region of the country. In order to achieve this aim, this paper contains four parts. First, it presents the current state of the Guarani Aquifer and its importance for the development of the region. Then, in the second section, the concept of RO is introduced and how it is a useful tool in potabilization processes. After that, an explanation of how RO can improve the quality of well water from the Guarani Aquifer is provided. Finally, an economic analysis of RO systems for domestic use and their advantages are presented.

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The present manuscript is part of the research activities in the Inglés II lesson at Universidad Tecnológica Nacional, Facultad Regional Paraná. Students are asked to research into a topic so as to shed light on a topic of their interest within the National Academy of Engineering's Grand Challenges or the United Nations' Sustainable Development Goals frameworks. If sources have not been well paraphrased or credited, it might be due to students' developing intercultural communicative competence rather than a conscious intention to plagiarize a text. Should the reader have any questions regarding this work, please contact Graciela Yugdar Tófalo, Senior Lecturer, at gyugdar@frp.utn.edu.ar

II. Guarani Aquifer: Economic Activity and Current State of Water

The Guarani Aquifer is one of the most important underground freshwater reservoirs in the world. It covers more than one million square kilometers and it is distributed in four countries: Brazil, Argentina, Paraguay and Uruguay. The amount of water in the aquifer is estimated at more than 35,000 cubic kilometers, and it is reported to recover around 150 cubic kilometer per year from rains. Because of its huge amount of water and its high rate of recovery, it is considered one of the most viable sources of water for the next generations. Figure 1 shows the distribution of the aquifer in the above-mentioned countries.

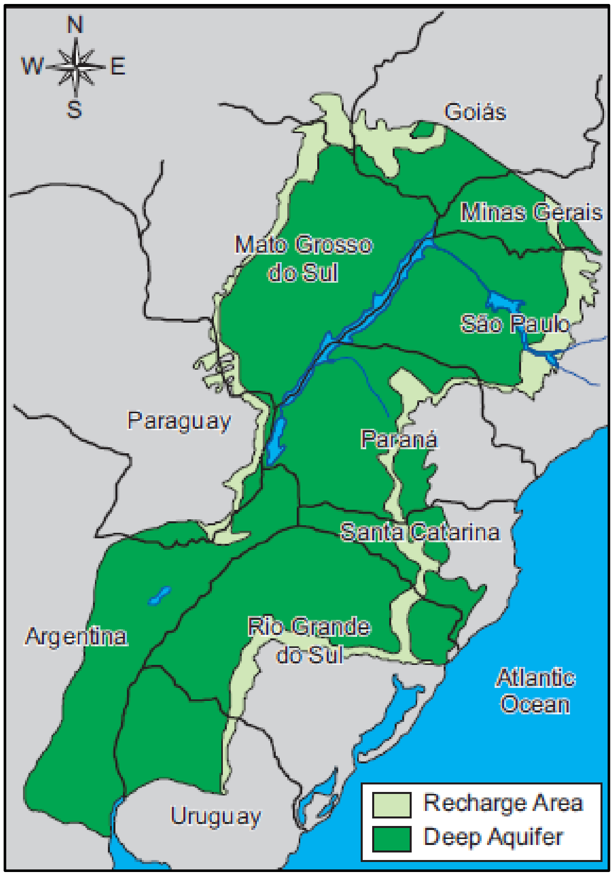

Fig. 1. *Guarani Aquifer: distribution of the aquifer between countries. Extracted from [1]*

The main activities in this region are agriculture and animal breeding due to the quality of the land and its warm temperatures across the year. The development of this region in the last decades has resulted in a higher demand for resources and, consequently, the expansion of the infrastructure. Thus, it is quite frequent to find that towns which cannot rely on a river nearby use well water to supply the demand.

Well water needs to get treatment to make it drinkable because it carries some minerals and microorganism from the soil. Currently, some other pollutants can be found in well water as well. These come from human action and particularly from the economic activities of the region.

To improve the efficiency of the farming industry most producers use agrochemicals and problems arise when these reach underground water. The purification systems across the region, in most of the cases, are not able to take these chemicals out of the water, entailing a high risk for the population that consumes the water.

Other components that affect the groundwater are the leaks from septic tanks and dung from animal farms. This waste has a large burden of microorganism that if it is not treated properly, they can produce serious diseases in human beings. Given all the reasons and the aforementioned pollutants, providing clean water is vital to keep a healthy population.

III. A Short Review of Reverse Osmosis

A. *Osmosis*

In order to better understand the central concept that underlies this paper and the contents that will be discussed later, it is important to discuss the operating principle of osmosis. This will help to understand how by causing the RO process a convenient way to filter water can be obtained.

RO is based on the principle of osmosis, by which a semipermeable membrane separates two solutions [2]. This membrane allows some compounds like water to pass through it, but it does not allow larger compounds through.

In osmosis, the natural tendency is for the water to move through the membrane from the dilute to the concentrated solution until concentrations are equal. Figure 2 shows the natural osmotic process.

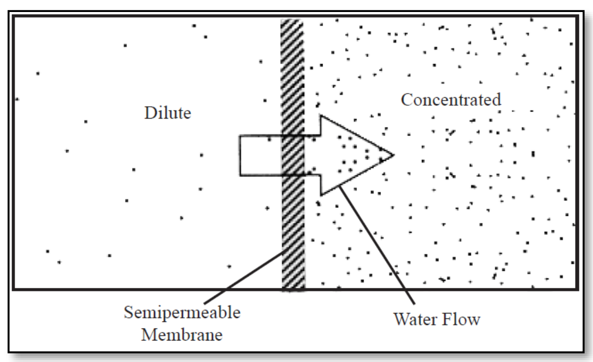

Fig. 2. *Natural behavior of osmosis: Concentrations stabilize when the ratio of the amount of water to the amount of particles on both sides of the membrane is the same. Extracted from [2]*

The following example best summarizes this process: two solutions of water and salt, which are separated by a semi-permeable-membrane, are in a container. One of the solutions (solution 1) has 100 grams of salt per liter of water, and the other (solution 2) has 50 grams of salt per liter. By osmosis, the water will move from the lower concentration solution to the higher concentration solution naturally, without external energy being supplied. That is, the water in solution 2 will begin to move into solution 1. This will cause the concentration of solution 2 to begin to increase at the same time that the concentration of solution 1 decreases. This movement will stop when both concentrations are equal, in this case it will happen when both solutions have a concentration of 75 grams of salt per liter of water.

B. *Reverse Osmosis and water collection*

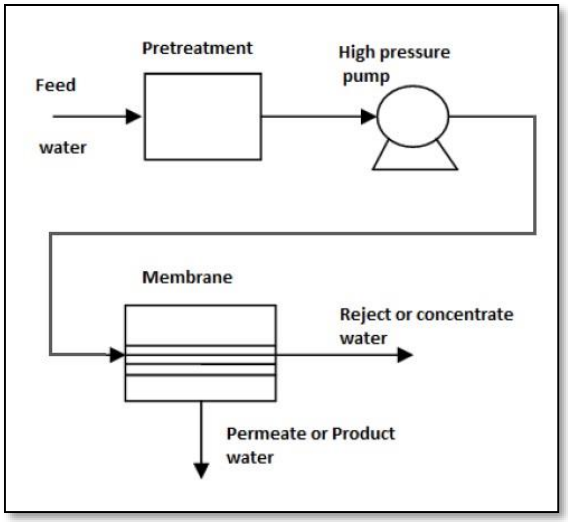

Fig. 4. *Stages of the Reverse Osmosis process. Adapted from [3]*

In RO, a pressure is applied on the contaminated side of the membrane, that is, where the residue concentration is highest [2]. This forces the osmotic process to reverse. With adequate pressure, contaminated water passes through the membrane without residue. This is possible owing to the fact that the semi-permeable membrane contains small pores that allow the passage of water but not waste. This process can be seen in the Figure 3.

After this, the treated water is collected in a storage tank and it is ready to be consumed or used. The contaminants are eliminated as wastewater and these residual waters can be used, for example, for the irrigation of farms or orchards.

Before RO can take place, water has to go through a pretreatment stage. This stage is important because if the feed water contains large particles and a lot of pressure is applied, the membrane will be damaged [3]. Therefore, when using a RO system to filter and purify water, it is important to know the components or contaminants that it contains in order to apply the necessary pressure. This pressure is given by a high-pressure pump that causes RO by pushing the water through the membrane while leaving the waste behind.

Figure 4 shows a high-pressure pump after the pretreatment process. This gives the necessary pressure for RO to happen

IV. Relationship between the Guarani Aquifer and reverse osmosis

Although RO systems have many applications like desalination of seawater or recovery of phenol compounds, this work focuses on groundwater treatment. RO systems are capable of filtering different types of biological agents and organic and inorganic compounds present in groundwater.

The São Paulo State University carried out a study on the different pollutants that are present in the water of the Guarani aquifer [1]. In this paper the investigators emphasized that there is a potential risk of contamination due to the large presence of herbicides and pesticides in the agriculture area that precisely coincide with the aquifer recharge zones. Through different tests the researchers concluded that there is a presence of diuron and hexazinone in the Guarani Aquifer, which have a high carcinogenic potential.

The Guarani Aquifer water also has a great presence of minerals like hydrochemicals and radionuclides. Hydrochemicals, such as calcium and magnesium, are not dangerous, and are even considered to provide health benefits in moderate amounts. However, concentration of radionuclides, especially radon, must be controlled because they may cause cancer [4].

Microorganisms that could come from diverse sources are a further kind of pollutant that can be found in well water. It has been demonstrated [5] that the RO membrane reduces significantly the presence of microorganisms, using active carbon filters in addition to the RO membrane to further improve the microbiological quality of well water.

Since it is not possible to purify water with only one filter, the combination of different methods results in an effective treatment of water. Activated Carbon filtration and sediment filtration are commonly used in conjunction with RO membranes. Whereas sediment filters help remove silt particles that may foul the RO membrane, activated carbon filters remove certain pesticides and microorganisms that the RO membrane is not as effective in removing. All these reasons support the use of RO systems as one of the best solutions to purify water.

V. Advantages of Reverse Osmosis systems in the Guarani Aquifer zone

RO systems have many advantages that make them a great alternative to water treatment in the Guarani Aquifer area. Some of the most important advantages are cost, simplicity and low power requirements.

A. *Cost*

The current state of the water drawn from the Guarani Aquifer has resulted in many people searching for an alternative to increase the quality of the water they consume. Some people have chosen to buy bottled water and others to filter well water with conventional filters. Both options have huge disadvantages: bottled water price is high (0.1U$D per liter) and the filter is expensive in relation to its performance. RO systems come to solve this.

RO systems can remove many types of impurities as explained above, in contrast to a filter that in general only removes dissolved minerals. Although a RO system doubles the price of a filter, around 300U$D, the price of treated water is around 0.003U$D per liter, thus saving money during use and making these systems highly convenient. Further, water produced by RO can not only be used for drinking, but also for cooking, irrigating and other applications which require quality water.

B. Simplicity

Regardless of size, all RO systems have few and simple parts: pretreatment filters, water pump, membrane and pressure tank. These systems are very reliable, owing to the fact that failure probability is really low. However, if any of the parts fail , there is a wide offer of spare parts.

Maintenance is another aspect that evidences the simplicity of RO systems. It is only necessary to change the pretreatment filter annually, replace the membrane every 2-3 years and drain the storage tank every 2 weeks. All these actions can be done by a user without special or technical knowledge.

C. Low power requirements

Residential RO systems require less energy to operate. Since only the water pump needs electricity to run, it might be powered by solar panels or any other renewable energy source. For this reason, RO systems are an excellent option to treat water in places without access to electricity. In the Guarani Aquifer zone, there are plenty of rural areas lacking connection to the power grid. In addition, water in these areas usually have a great amount of pesticides, thus a RO system combined with a solar panel is great alternative to treat well water.

VI. CONCLUSION

Throughout this paper we have focused on the use of RO in the Guarani Aquifer region, specifically in the Argentine littoral. In this area, due to agricultural activity, the use of pesticides is very frequent and this translates into the contamination of groundwater. This is very worrisome since well water is consumed by the inhabitants of rural areas.

RO is an effective alternative to groundwater treatment due to its high filtering performance and low operation cost. These advantages make these systems the best option for the purification of well water. However, in order to make the most out of the purification system is important to know which contaminants are present in the water.

Feed water generally contains suspended particles of both organic and inorganic matter. These pollutants can deposit on the membrane, fouling and damaging it due to the applied pressure and the size of the particles. Therefore, the priority is to eliminate them through a pretreatment, which often consists in activated carbon filtration, to increase the efficiency of RO systems.

Purifying water is essential for the development of a healthy life. Throughout this paper all the harmful pollutants which ground water could bring were presented. In the Guarani Aquifer region, a reliable method to purify water as the RO system is the best method to purify water, ensuring accessible safe water consumption for all.

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