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Home water treatment devices and their impact on depleting groundwater in the Gharyan region.

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Abstract:

There is no doubt that the contribution of reverse osmosis (RO) technology in desalination and providing safe drinking water at the national level is undeniable. However, the excessive and continuous expansion of its use at the household and small-scale level (small production capacities) may have negative effects on groundwater sources. This research aims to study this phenomenon and its impact on groundwater in the city of Gharyan as a model that can be generalized. The study includes field surveys and sampling of incoming, produced, and consumed water from some commercial establishments that purify and sell water at the municipal level, in addition to examining the sizes and types of units used. A similar household purification unit was installed and experiments were conducted on it using different sources of groundwater. Unfortunately, this study has shown that the percentage of clean, pure water obtained under the best conditions does not exceed 30% of the treated water quantity. Moreover, some cases even result in the wastage of water that is still suitable for drinking and can be reprocessed. The study also found that in many cases, the water treated does not exceed the internationally allowed maximum total dissolved solids (TDS) limit (between 500-1500 ppm), which in turn leads to wasting groundwater. Therefore, we recommend the following:

- Raise awareness among citizens about the seriousness of water scarcity in the region and encourage water conservation.
- Due to the amount of water wasted by using small-scale RO technology, we recommend reprocessing the water multiple times using this technology to provide larger quantities of usable water.
- Seek alternatives for water desalination that are more economical and waste less water.
- The responsible authorities should conduct necessary tests on the water to determine whether it requires treatment or can be used without treatment.

Keywords: RO devices, water desalination, groundwater, total dissolved solids (TDS)

1. Introduction:

The increase in population growth rates in the Arab Maghreb region in general and Libya in particular has led to increased water consumption, resulting in a decline in the main stock of groundwater and its inability to meet the necessary water needs (Ali Salem Bla'aw and Noufel El Masri). According to Al-Saadi and others, Libya suffers from a scarcity of water resources, making most of its areas semi-arid, with the percentage of these dry areas reaching approximately 99.8% of the total area, making them susceptible to drought and salinity. Libya's heavy reliance on groundwater makes it in dire need of it, as Libya depends on 95% of its groundwater (see Hamidan's study, 2012, and El-Faqi and Sowaid, 2016). It constitutes the main source of water used in various sectors and activities, including agriculture, irrigation, domestic, industrial, economic, and health uses. The total available quantities in these resources are about 3450 million cubic meters per year (El-Faqi and Sowaid, 2016). However, these quantities vary in distribution from one region to another, being significantly lower in the northern regions and along the densely populated coastal strip, where most of the land has high-quality soil for agricultural purposes, with 60% of it located in the Jafara Plain region. Meanwhile, in the southern regions amidst the desert, there is a surplus of this water stored in renewable and non-renewable aquifers. Renewable aquifers are mostly found in the northern basins, including the Jafara Plain, Al-Jabal Al-Akhdar, and Al-Hamada Al-Hamra, and they are replenished by rainfall and surface water flow, with quantities ranging from 500 to 600 million cubic meters per year, which is the amount necessary to compensate for the extracted water estimated at about 656 million cubic meters. As for the non-renewable groundwater reservoirs, they cover most of the lands in the southern half of the country, including the Murzuq Basin in the southwest, the Kufra Basin, and the Sirt Basin in the southeast, in addition to the Al-Hamada Al-Hamra Basin in the northwest. These reservoirs date back to ancient and modern eras according to the latest source (El-Faqi and Sowaid, 2016). The presence of groundwater basins in the south containing large quantities of water was discovered in the 1960s when oil exploration operations began, as the local population used to dig small traditional wells to meet their needs because the groundwater was close to the surface. Subsequently, the government started drilling deep wells using modern methods to extract and treat groundwater.

1.1. The Reality of the Sector in Libya:

Libya, with an area of 1,750,000 square kilometers, is located between latitudes 19° and 34° north, and longitudes 9° and 26° east. This places it within the dry desert climate region. The aridity and the need for fresh water are intensified by the fact that the country lacks permanent surface water streams. The continuous increase in population imposes an urgent need for fresh water to meet their needs, as well as for various economic activities. Furthermore, over 65% of Libya's population is concentrated along the northern coast, adjacent to the Mediterranean Sea. Most of the cities and other economic activities are located there, which has depleted the available groundwater resources. Libya is part of the Arab region, which is considered one of the poorest regions in terms of water resources worldwide. Libya, along with 12 other Arab countries, exceeds the threshold of extreme water poverty, with an estimated per capita share of about 120 cubic meters per year, according to the 2015 World Water Development Report. The global poverty line is estimated at 1,000 cubic meters per year per capita. Being situated within the desert and semi-desert climate, with low rainfall rates and limited surface water flow, except for some wadis during certain seasons, Libya primarily relies on non-renewable groundwater resources in the southern basins of Libya. The Great Man-Made River Project, which began operating in 1993, supplies water to densely populated cities along the Libyan coast (Hammidan, 2017). Table (1) illustrates the water needs according to reports issued by the Libyan Specifications Project for Bottled Drinking Water, 2004-2007, and 2009.

Type of use	1990year	2000year	2010year	2020year	2025year
Agriculture	4275	4800	5325	5850	6640
Drinking	408	647	1015	1512	1759
Industry	74	132	236	422	566
Total	4757	5579	6576	7784	8965

Table (1). Groundwater Production Requirements in Libya- million cubic meters per year

Several climate and environmental factors lead to water scarcity and displacement in Libya, and they can be summarized as follows, according to experts:

- Increased demand for water due to development activities.
- Depletion of natural water resources.
- Deterioration of water resource quality.

1.2. Problem Statement:

The research problem was selected based on the observed groundwater waste and mismanagement within small-scale reverse osmosis (RO) desalination units operating in the study area, which leads to depriving the region of an important and valuable resource without awareness.

1.3 . Research Methodology:

The research was conducted through an applied study inside the desalination units in the study area to assess the water waste situation. A sample survey questionnaire was distributed and analyzed within these plants. A domestic RO desalination unit was installed in the laboratory to determine the percentage of usable water from the wasted water. The percentage of dissolved salts in all samples was measured and compared to the Libyan standard specifications for drinking water.

1.4. Importance of the Research:

- Analyzing the water situation in the Gharyan region and evaluating its positive and negative aspects.
- Contributing to rationalizing water consumption and selecting successful methods for managing water resources.
- Predicting the future of water resources and understanding their ability to meet the needs of future generations.

1.5. Research Objectives:

- Maximizing the utilization of available water resources and using them efficiently and effectively.
- Encouraging citizens and various sectors to invest in water resources to enhance the capacity of the agricultural and industrial areas in Gharyan.
- Educating the public about responsible water consumption.
- Highlighting the importance of water monitoring, proper management, and continuous inspection of water facilities to ensure water quality, population health, and environmental preservation.

1.6. Concept of Desalination:

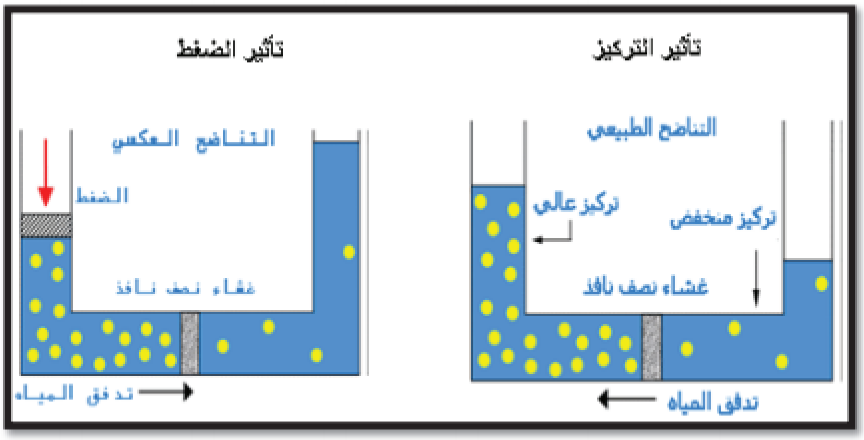
Many countries suffer from a shortage of potable water resources, which leads them to desalinate water. Water scarcity crises are expected to occur in many countries, and some statistics indicate that hundreds of thousands of people die annually due to the scarcity of clean water for human use. Desalination is a separation process used to reduce the concentration of dissolved salts in saline water to a level where it becomes suitable for drinking. Saline water contains a high percentage of dissolved salts such as chlorine, sodium, sulfates, magnesium, and calcium carbonates, which can alter the taste of water (See Shqeila, 2013).

1.7. Concept of Reverse Osmosis:

Reverse osmosis is a physical process in which water is transferred from a high-concentration medium to a low-concentration medium through a semi-permeable membrane by applying pressure to the concentrated solution, increasing the osmotic pressure. In a natural setting, when two solutions, one concentrated and the other diluted, are separated by a semi-permeable membrane, this system tends to reach equilibrium in the concentrations of the solutions. This occurs by the pure water crossing the membrane from the diluted solution to the concentrated solution. This process is also known as osmotic flow, and when the flow is equal to zero, it is said to have reached osmotic equilibrium (Jamal Khudair, Specialized Training Institute for Industries, Jordan).

It is easy to infer how to utilize this phenomenon in desalinating saline water at normal temperatures and without any chemical additives. The process simply involves passing the saline water through semi-permeable membranes by generating pressure on this water, allowing only pure water to pass through the membrane while retaining the saline water behind the membrane (Fuad Jwaid Al-Sharibi, Dr. Abdullah Mohammed Al-Abbas).

From an applied perspective, the feed water is pumped into a closed vessel where the membrane is pressurized. When a portion of the water passes through the membrane, the remaining water's salt content increases. At the same time, a portion of the feed water is discharged without passing through the membrane. Without this discharge, the increased salinity of the feed water causes various problems such as increased salinity, scaling, and increased osmotic pressure across the membranes. The amount of water discharged through this method ranges from 20% to 70% of the feed, depending on the salt content (Faten Shqeila, 2013).



Figure(1) showing the effect of concentration and pressure in the process of reverse osmosis

The reverse osmosis system consists of four main components according to Fouad Al-Sharibi, Abdullah Al-Abbas, and Faten Shaqila in 2013:

- Primary treatment.
- High-pressure pump.
- Membrane assembly.
- Final treatment.

1.8. Regarding the types of membranes used in reverse osmosis:-

There are several factors to consider, such as cost, risks, packing density, and cleaning opportunities. Membranes are not produced as flat layers without any modifications because that would require a very large surface area and high investment cost. Therefore, membrane systems are designed in a compact form to enable a large membrane surface to be placed within a smaller space. There are two main types of membrane systems: tubular membrane systems and frame-supported flat membrane systems. Tubular membrane systems include tubular, capillary, and hollow fiber membranes, while frame-supported flat membrane systems include spiral-wound and plate-and-frame membranes. It should be noted that fouling of membranes is inevitable in membrane filtration systems, even with sufficient pretreatment. The quantity and quality of the fouling are influenced by several factors, such as the quality of the feed water, membrane type and nature, system design and control mechanism. The main components that deposit on the membranes are organic matter, particles, and scaling. These materials cause additional obstacles to ensure continuous membrane operation. At a certain point, the pressure will increase significantly, leading to negative economic and technical consequences (Jamal Abdullah Thaib Khudair).

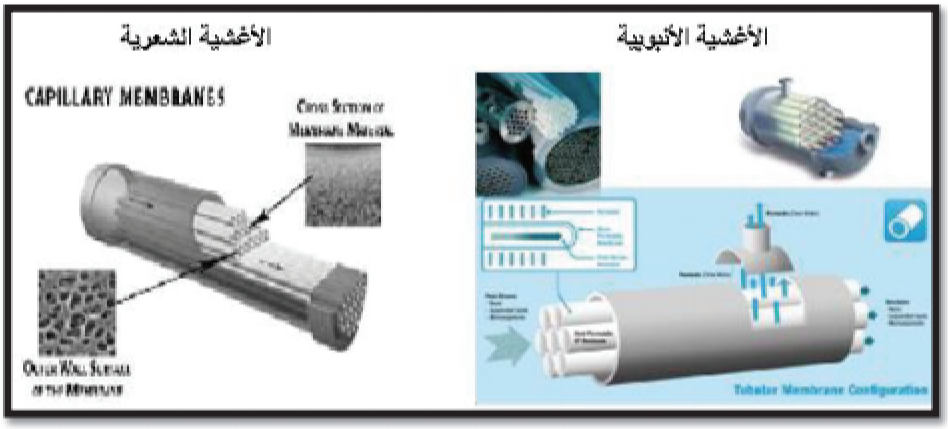


Figure (2) showing the type of tubular and capillary membranes.

1.9.The geographical location of the study area (Gharyan Municipality):

The study area is located along the northern edge extension of the central part of the western mountain known locally as "Jabal Gharyan." Its estimated area is approximately 7,695 square kilometers, and its average elevation reaches around 725 meters above sea level. The elevation increases south of Gharyan Municipality until reaching the Klipah area, which is about 25 kilometers away from Gharyan and has an elevation of approximately 870 meters (according to a study by Sharaf Abdulaziz Tarih, 1996).

The population density is about 160,000 inhabitants, distributed on the mountain slopes in the areas of Al-Qawasim, Gharyan Al-Markaz, Bani Naseer, and Al-Arban. These areas are among the regions that suffer from a significant shortage of water resources, similar to other regions in Libya. The water resources in the area are scarce and do not meet the daily water needs of the population or the requirements of public facilities, whether industrial or service-related. Additionally, there is a deficit in meeting agricultural needs.

1.10. Water Situation in the Study Area (Gharyan Municipality:

Rainfall varies from one place to another within the Western Mountain region, depending on the prevailing local conditions. The average rainfall in the area ranges from 250 to 350 millimeters per year. The amount decreases as we move west and south, where the mountain height decreases and its distance from the coast increases (Al-Jandil, Adnan Rashid, 1978). However, the actual value of this rainfall is influenced by several factors, including evaporation rate, soil type, and surface slope. The surface runoff in the study area ranges from approximately 10 to 100 cubic meters in most wadis, with an average permeability ranging from 0.4 to 0.5 meters per year (Nouri Al-Ayssawi, 1996).

To benefit from rainfall water, some dams have been constructed, such as Wadi Ghan Dam, which is the highest dam in Libya with a height of 48 meters. Its reservoir capacity reaches 30 million cubic meters annually, and it plays an important role in the integrated Gharyan project. There is also Wadi Zart Dams with a total length of 2.738 kilometers and a reservoir capacity of approximately 8.6 million cubic meters. In addition, there are earth dams that hold rainwater and collect it in the form of lakes and basins. These dams contribute to the reinforcement of the groundwater reservoir in the region. However, the amount of rainfall that can be reserved by the dams can only meet a very small percentage (1% to 2%) of the water needs. Rainwater is also collected through individual efforts by the citizens, often by connecting and collecting household surface water in tanks and underground reservoirs. However, this contributes only a very small percentage of the water supply to the region. The number of these tanks is approximately 4,446, with each tank having a capacity between 60 and 100 cubic meters annually, with a total capacity of about 355,680 cubic meters per year (Mohammed Aoun Shanna).

Therefore, surface water only contributes a very small amount and provides a very small percentage of the citizens' water requirements. It is used for limited purposes such as animal watering or domestic use without relying on it for complete drinking water. As a result, the region and its inhabitants rely on the limited groundwater reservoirs found in Wadi Ghan and Al-Kamishat, where several wells have been dug by the municipality, with a total number of about 39 wells. These are deep wells that flow their water into tanks distributed throughout the region via a network of pipes to the Hamada, Marwan, Sharifa, and Abu Zayan tanks. There are also agricultural wells dug by the citizens, which are shallow wells with a depth not exceeding 150 meters. All of these wells rely on non-renewable surface water lenses. Their water is marketed to the citizens through mobile tanks that roam the area in all directions and have become a distinctive feature of domestic use in Gharyan. However, they do not meet the needs of the population, and the cost of water use has become high, depleting the majority of the citizens' income (Sharaf Abdulaziz, 1996).

The study area also relies on the water of the Great Man-Made River, which flows from Al-Hassawnah Mountain (Fezzan) in southwestern Libya towards the cities and coastal areas in western Libya and the Western Mountain. It takes eight days to travel a distance of 610 kilometers before embarking on a different journey, ascending to the Western Mountain and reaching its peak at an elevation of 886 meters above sea level, through the Trehuna-Abu Zayan route. The aim is to transport 800,000 cubic meters of water per day to the Western Mountain region. In the first phase, 200,000 cubic meters per day will be allocated to supply Gharyan city and its surrounding areas with drinking water, and 400,000 cubic meters per day will be allocated to supply projects located in the vicinity of the region (refer to the report of the General Authority for Investment in the Second Phase of the Great Man-Made River System).

1.11. Detection of Total Dissolved Solids (TDS).

Groundwater does not exist in a pure state but contains varying proportions of suspended and dissolved substances that determine its quality. All the interactions that have affected the water from the moment of its condensation in the atmosphere until it emerges from the earth's subsurface are responsible for the physical, chemical, and biological characteristics of groundwater. Groundwater also contains different types of salts with varying concentrations and higher levels of dissolved components compared to surface water. This is due to the exposure of groundwater to soluble materials in the geological formation. The entry of sewage water and industrial waste into the aquifers is a clear source of deterioration and contamination of groundwater, posing a significant risk to public health. Refer to the study on the characteristics of groundwater in the Wadi Al-Shati region and the evaluation of the impacts of its quality deterioration by researcher Omar Asaad Ahmed.

2. Current Study:

2.1. Questionnaire Analysis Results:

Based on the information obtained from the questionnaire through the survey study, the number of units treating and supplying water to citizens was estimated to be more than 90 units. The ratio of water obtained from these units that is pure and suitable for drinking to the water that is disposed of is approximately 1/3:2/3. This means that about 70% of the water entering the treatment units ends up in sewage without being utilized. Consequently, this represents wastage and depletion of groundwater. Table (2) illustrates the percentage of Total Dissolved Solids (TDS) in samples taken from some commercial desalination plants in the Gharyan region, including the water entering the treatment process, the water produced for drinking, and the water discharged into the sewage. The results of the sample analysis clearly show that the water entering all the treatment units under study had a TDS concentration not exceeding 1000 ppm, and yet it was still treated to enhance its sweetness even though it was already suitable for drinking. Meanwhile, the analysis results of the water samples in the sewage showed that the TDS concentration was still within permissible limits and did not exceed 1500 ppm.

Table (2). illustrates the percentage of Total Dissolved Solids (TDS) for samples taken from commercial desalination plants.

Sample	Untreated water (Tank water)	Treated water (Drinkable Water)	Water after treatment (Loss)
1	874	53.8	1239
2	688	52.9	1430
3	814	94.4	1154
4	893	146	1465
5	842	62.1	1492
6	893	84.8	1477

As the survey analysis results showed, the quantity of water treated in each unit varies between summer and winter. The amount consumed in summer is double the amount consumed in winter. Therefore, the average quantity of water treated in each unit is approximately 18,000 liters per day (or 1,620,000 liters per day in all units), which is equivalent to 388,800,000 liters annually (388,800 cubic meters), assuming 20 working days per month. The amount of water produced (potable water) was approximately 129,600,000 liters annually, and the remaining quantity is discharged into the sewage system, which amounts to 259,200,000 liters per year (259,200 cubic meters). Not to mention the water treated in households using home purification units, which we were unable to quantify.

2.2. Results from the home unit:

Practically, the detection of total dissolved salt levels was conducted using this unit to determine water consumption and measure the salt content. The treatment process was repeated until reaching a salt percentage that exceeds the standard specifications for water in Libya. In the first round, 60 liters were introduced, and Table (3) shows the sequence of desalination results for each round in relation to the salt content.

First treatment		
Sample	**Quantity**	**Total dissolved Solids (TDS) Ration**
Before treatment (inflow)	**60 liter**	**834**
Treated Water (drinkable water)	**22 liter**	**104.7**
After treatment (outflow)	**38 liter**	**1242**

Second Treatment		
Sample	**Quantity**	**Total dissolved Solids (TDS) Ration**
Loss from first treatment (inflow)	**38 liter**	**1242**
Treated water (drinkable water)	**14.6 liter**	**194.8**
After treatment(outflow)	**23.4 liter**	**1524**
Third treatment		
Sample	**Quantity**	**Total dissolved Solids (TDS) Ration**
Loss from second treatment (inflow)	**23.4 liter**	**1524**
Treated water (drinkable water)	**10.2 liter**	**257**
After treatment(outflow)	**13.2 liter**	**1985**

Table 3. Soluble Salts Ratio of Samples during Experiments.

3. Results and Discussion:

Based on the previous processing percentages, the arithmetic mean of the total dissolved solids (TDS) is approximately 165.6 ppm. It is known that water treatment using reverse osmosis (RO) is a process for removing salts. The use of this technique initially requires identifying the quality of the water to be purified, and based on that, determining the need for using this technique or not. For example, water contaminated with high levels of suspended matter requires filtration methods, while it does not require reducing the salt content. On the other hand, water with high salt content requires reverse osmosis units. Therefore, the study guided us to the following conclusions:

- Large quantities of groundwater are being wasted in desalination plants in the study area without awareness of the future consequences. This applies to all Libyan cities and is therefore extremely dangerous. Not to mention the amount of water wasted in traditional irrigation methods and other uses.
- The percentage of total dissolved solids in the wasted water in some visited plants did not exceed the Libyan standards and specifications, making it suitable for drinking and only requiring filtration. It also complies with the European international standards (500-1500 ppm).
- The possibility of desalinating water multiple times instead of wasting it, as is currently the case, to preserve the maximum amount of groundwater.

4. Recommendations:

Based on the results obtained from the research, the following recommendations were reached:

- Raise awareness among citizens about the seriousness of water scarcity in the region and encourage responsible water consumption.
- All operating desalination plants within the study area and throughout the country should be placed under the supervision of a water institution established by the state to monitor them, keep track of all developments, and guide them on proper water consumption for this valuable resource.
- Install household meters to measure daily water consumption in order to reduce the quantities consumed.
- The responsible authorities should conduct necessary tests on water to determine whether it requires treatment or can be used without treatment.
- Seek alternatives for water desalination that are more cost-effective and minimize water waste.

- Intensify efforts to educate the public on the importance of conservation and avoiding wastage in water usage to reduce losses and waste.

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