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Water Resources and Desalination in Libya: A Review †

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Abstract: Due to the shortage of clean and fresh water, especially in the coastal regions there is an urgent need to look for alternative water sources to meet people needs and compensate the reduction in groundwater. Desalination is one of such alternative water sources that can solve water shortage problem in Libya and other countries where face the same conditions. Desalination is the main technology that has been developed globally over the past three decades to meet the increasing demand for fresh and clean water. The objective of this paper is to highlight the conventional and non conventional water resources in Libya. In this context, our paper intends to present an overview on seawater desalination technology in Libya and why it should be accommodated as a strategic and ultimate solution for water shortage.

Keywords: water resources; water shortage; man-made river; seawater desalination

1. Introduction

The state of Libya has an area of about 1.7 million km^2 with a total population of about 6.5 million. Ninety percent of the people live in less than 5% of the land, mostly along the coast. The population density in the central and southern parts of the country is below 1/km^2 [1].

North Africa is considered to be one of the driest regions in the world. Libya's annual rainfall ranges from 100 to 600 mm in the Northern areas. The coastal regions receive the largest amounts of precipitation, while the Southern areas receive as less as 10 mm. Only five percent of the entire area of Libya exceeds 100 mm annually. Some parts of the Libyan land are completely rainless [2,3].

Based on some data, the total water amount available in 2012 is estimated at 3890 mm^3 (3650 mm^3 groundwater, 170 mm^3 surface water and 70 mm^3 desalinated water). The total water withdrawal in 2012 is estimated at 5830 mm^3. This included 4850 mm^3 for agriculture (83%), 700 mm^3 for domestic use (12%) and 280 mm^3 for industrial sector (5%) [4,5]. The amount of water consumption in 2012 exceeds the amount of water available and the imbalance amounted for 1940 mm^3.

Water scarcity is one of the current greatest challenges in Libya, and will be the case in the future if no serious decisions are taken to solve this dilemma. According to some reports; Libya is one of the top countries facing water stress, with a baseline water stress score of 4.84. It has been constantly ranked as one of the most water-insecure places in the world [6,7].

Despite the fact that desalination is a proven alternative water supply technology that is growing in importance worldwide, the previous governmental regime in Libya has not seriously invested in the field of desalination, although establishment of desalination plants started in the sixties. The main focus of the former government to provide drinkable water for the Libyan people

living in the North was the man-made river project (MMRP). MMRP considered to be one of the biggest civil engineering projects, although, it has not terminated the water crises in Libya.

This paper attempts to reveal the reasons and consequences for the water shortage in the country. We first highlight the causes of water problem in Libya. Next we review the current status of water resources. We then briefly touch on the Libyan experience with the desalination technology. Finally, we attempt to consider desalination technology to be the first and ultimate alternative water resource to be adopted in Libya.

2. The Water Shortage Problem in Libya

Several countries in the world such as the Arab countries, West Asia, and Australia face severe water shortage issues today. Libya is considered to be one of the top 36 countries in the world facing water stress with a baseline water stress score of 4.84 [6]. The following reasons are believed to be the main causes of water problems in Libya:

a. Excessive groundwater exploitation
b. Decreased annual average of rainfall
c. Intensive agricultural activities in the coastal plains
d. Seawater intrusion
e. Low water tariffs
f. Lack of institutional framework
g. Lack of clear strategy related to the local water sector
h. Lack of awareness in the public of the need for the rational use and management of water resources
i. Poor management in the General Water Authority (GWA)

3. Water Resources in Libya

There are two types of water resources in Libya; conventional water resources (natural) including surface and ground water that represent about (97.3%) of the nation's water resources, and non-conventional water resources including seawater desalination and treated wastewater accounting for (2.7%) [8].

3.1. Conventional Water Resources

3.1.1. Surface Water

Libya has very limited surface water resources. Its contribution to the water resources in use is less than 3%. The country has no continuing river, very few of natural lakes and a number of natural springs, many of which are of good water quality, some springs are of high discharge rate such as Ayn Zayana (flow 5580 L/s), Ayn Kaam (flow 350 L/s), Ayn Dabbousia (flow 170–230 L/s) and Ayn Tawargha (flow 2000 L/s). There are about 185 springs of discharge rate less than 5 L/s such as Ayn Brada (flow 3.0 L/s), Ayn Al shershaar (flow 1.0 L/s), Ayn Shisa (flow 0.8 L/s), Ayn Tibah (flow 0.5 L/s) and Ayn Tanget (flow 0.1 L/s) [1,4,5].

It has to be mentioned that the available data concerning the natural springs are quite old and needs to be updated. This data was collected during the seventies and eighties and may no longer represent the conditions of these springs. Consequently one cannot state here the actual current conditions of such natural springs.

Around 16 major dams have been constructed in Libya in order to harvest rainwater with a total capacity of 385 mm^3 and an average annual storage capacity of 61 mm^3 (Table 1).

Table 1. Constructed dams in Libya.

No	Water Basin	Number of Dams	Total Capacity (mm^3)	Average Annual Storage (mm^3)
1	Al Jabal Al Akhdar	5	160.6	15.95
2	Kufra and Sarir	4	8.14	1.8
3	Jiffarah plain	3	96.6	25.5
4	Al Hamada	4	119.4	17.4
	Total		384.74	60.65

Water collected in these major dams is used for agricultural water supply, industrial projects, and, in some cases, for domestic use. The biggest three dams are: Wadi Quattara, Wadi Kaam, and Wadi El-Magineen with a design capacity of 135, 111, and 58 mm^3 respectively. Furthermore, a considerable number of new dams have been approved for construction. It is believed that the total amount of water will be captured annually by these new dams will increase to reach 120 mm^3 [4].

3.1.2. Groundwater

Groundwater is the main water source in Libya. It accounts for more than 98% of the total water consumption [9]. The total volume of groundwater in Libya is estimated to be 99,500 km^3 with a range in uncertainty of between 64,600 and 234,000 km^3 [10].

The groundwater resources in Libya are of two types; shallow aquifers that obtain water from rainfall and surface runoff and this type is renewable, and the second type is often called deep aquifers which are not renewable. Shallow aquifers are mainly found in the Northern underground basins such as Jiffarah Plain system, Al Jabal Al Akhdar system, and Al Hamada basin, while the deep aquifers (fossil water) are found in most of the Southern half of Libya such as Murzuq basin, Kufra basin, and Sarir basin (Table 2). It has to be stated that the second type (fossil water) was accidently discovered in the middle of the 20th century when oil exploration in the Libyan Southern desert was started. As a result of this discovery five main underground basins were formed [1].

Table 2. The main underground basins and their characteristics in Libya.

Basin Name	Area (km^2)	Basin Type	Estimated Groundwater Capacity (km^3)
Jiffarah plain	18,000	Renewable *	-
Al Hamada	215,000	Renewable	4000
Al Jabal Al Akhdar	145,000	Renewable	-
Murzuq	350,000	Non-renewable **	4800
Kufra and Sarir	700,000	Non-renewable	-

* Renewable groundwater is water that can be replenished annually through rain. ** Non-renewable groundwater basins are groundwater bodies (deep aquifers) that have a negligible rate of recharge on the human time-scale and thus can be considered non-renewable.

3.2. Non Conventional Water Resources

The non conventional water resources in Libya include mainly the man-made river, wastewater treatment and desalination technology. The detailed review of these resources are discussed and below summarized.

3.2.1. The Man-Made River Project (MMRP)

This project is considered to be the largest and most expensive groundwater pumping and conveyance project. According to the United Nations Environmental Program (UNEP), the MMRP is among the "largest civil engineering projects in the world."

This project was undertaken to meet the Libyan population's water needs by drawing water from aquifers beneath the Sahara—mainly the Nubian Sandstone Aquifer System—and conveying it along a network of huge underground pipes to the Northern coastal cities where most of the Libyan population live and fresh water is considered scarce.

At the time of deciding this project it was emerged that, MMRP would be five times more water cost-effective than any other alternative water supply option.

The project was designed in five stages and the optimum target of the project once its all five stages completed was to covey a large amount of water estimated to be 6 million cubic meter in a daily basis from their sources in the South to the North where there is an increase urgent need for clean and safe water. As this project considered to be one of the largest water conveyance systems it was classified as one of the non-conventional water resources, although the transported water is groundwater [4].

The construction work on this project began its first stage in the mid of 1980s. Consequently the management and the implementation authority of the MMRP was created to take responsibility of this big project. The construction of this project relied on funds from government collected taxes on gasoline and tobacco and travel, with no foreign or international support.

The water brought by the MMRP was decided to be used in the following activities; agricultural use (80%), domestic use (12%) and only 5% for the industrial use. The water usage cost was also estimated; 47 Dirham ($0.033) for one cubic meter for agricultural use, 80 Dirham ($0.057) for one cubic meter for domestic use, while 796 Dirham ($0.57) was estimated for one cubic meter for industrial use.

The first stage of the project was partially operated in 28th of August 1993, while the second staged was partially operated in 28th August 1996. Consequently around 400 million cubic meters of water was transferred from the first stage, and 230 million cubic meters was transferred from the second stage till the end of year 1998 mostly for domestic use. The third stage was an extended stage of the first stage in which added 1.68 million cubic meters of transferred water per day. The MMRP have not been totally completed as the fourth and fifth stages still to be accomplished.

Despite the fact that some coastal cities was supplied with water from MMRP, people feel skeptical about the quality of the water. Therefore a large percentage of the population in the big cities such as Tripoli, Benghazi, and Misurata do only use this water for washing, cleaning, industrial purposes and agriculture but never for drinking. The doubt of the quality of MMRP fresh water is being not good enough for drinking came up as people think that the water which is collected in big reservoirs is not analyzed or treated regularly which could make it does not meet the standards of drinking water [11].

Based on the above mentioned information concerning the quality of water and due to the current situation of MMRP, water shortage is still a continuing problem in most of the Libyan land.

3.2.2. Wastewater Treatment

According to data obtained from the General Company for water and wastewater (GCWW) there are around 23 wastewater treatment plants distributed all over the country. Only 10 plants out the total number are working and in operation, 8 plants are out of service and 5 plants are being maintained by the company's management teams.

Wastewater treatment plants were mostly designed for producing water suitable for agricultural use. The largest operating wastewater treatment plants are located in Tripoli, Misurata and Sirte with a design capacity of 110,000, 24,000 and 21,000 m^3/day respectively. Furthermore, most of the remaining wastewater facilities are medium and small sized plants (370–6700 m^3/day). The estimated amount of wastewater to be treated is 1,324,054 m^3/day, and the estimated amount of treated wastewater is about 145,800 m^3/day which accounts for only 11% and the remaining percentage of wastewater is being pumped into the sea, artificial lagoons and black wells without any treatment.

3.2.3. Desalination Technology

Desalination is considered to be the second important non-conventional water resource adapted in Libya. Desalination technology have been used in Libya since the early 1960s, although few desalination plants have been established since then. There are currently about 21 operating desalination plants, with a total capacity of 525.680 m^3/d. Thermal processes represent about 95% of

the operable desalination plants, while reverse osmosis membrane technology represent about 5%. The overall contribution of desalination in the overall local water supply represent 1.4% in the year 2002 [12].

Based on the documents obtained from the national co-operations and authorities there is some uncertainty regarding the real number of the current operating desalination plants in Libya. Careful comparison between all the obtained documents was done by the author in order to have a close idea to the real operating desalination plants. Table 3 presents the number of desalination plants as well as their production capacities in the Libyan coastline.

Table 3. The existing operating desalination plants in Libya.

Location	Desalination Type	Design Capacity m^3/d	No of Units	Operation Year
Tubrok	MED *-TVC **	40,000	-	1977–2002
Bomba	MSF ***	30,000	3	1988
Darna	MED-TVC	40,000	-	-
Sussa	MED-TVC	10,000	2	2000
Sussa ext.	MED-TVC	40,000	-	-
Abou Traba	MED-TVC	40,000	-	2006
Zliten	MSF	30,000	3	1992
Azawia	MED-TVC	80,000	-	-
Zwara	MED	40,000	-	2006
Zwara ext.	MED-TVC	40,000	-	-
Tubrok	MSF	24,000	4	1977
Tajoura	RO ****	10,000	2	1984
Misrata	MSF	30,000	3	1987
Sirt	MSF	10,000	1	1986
Azawia double	MED	2500 × 2	2	2006
Tripoli west	MED-TVC	5000 × 2	2	1999
Homes	MSF	10,560 × 3	4	1985
Benghazi North	MED-TVC	4800 × 1	1	2005
Benghazi North double	MED-TVC	2500 × 2	2	2007
Darna	MED-TVC	4700 × 1	1	1998
Hrawa	MSF	500 × 1	1	1989
Total design capacity				525,680

* MED is Multi-Effect Distillation. ** TVC is Thermal Vapour Compression. *** MSF is Multistage-Stage Flash. **** RO is Reverse osmosis.

Desalination plants presented in Table 3 belong to different authorities, although all of them are owned by the government. General Electricity Company of Libya, General Desalination Company (GDC) and General Company for water and wastewater (GCWW) are the responsible authorities for the desalination plants. According to the data obtained from the GDC the total amount of desalinated water produced in 2010 from desalination plants belonging to the company is 71 mm^3.

The Role of Desalination in Solution of Water Scarcity in Libya

Desalination is becoming a solution for water scarcity in most arid countries and yet not a strategic option adapted by Libyan government. Based on the detailed review presented on the previous sections including the current conditions of the manmade river project there is an urgent need to invest in the field of desalination. The following reasons are believed to make desalination the first and best solution for water crisis in Libya:

- Over-exploitation of groundwater
- The increasing demand of water
- The current unstable conditions of the MMRP make it unreliable water source in the future. Besides, continuing extracting groundwater from the Saharan aquifer and transport it by conduits up-north to the coastal cities makes it unfeasible taking into consideration the maintenance work involved

- The availability of seawater in high quantities and relatively free of industrial pollutants
- Libya has the longest Mediterranean coastline among African nations (around 1950 km)
- The biggest and the most populated Libyan cities are located along the coast
- Create opportunities for spatial development
- The availability of natural gas may contribute to lowering the cost of water production, especially when taking into consideration building joint power and desalination plants

In addition to the mentioned above reasons one can learn from the Arabian Gulf States experience in the field of desalination technology. Saudi Arabia is one of the Gulf countries, located in a dry region and is considered among the poorest countries in the world in terms of natural renewable water resources. However, Saudi Arabia has invested heavily in water desalination facilities and became the world largest producer of desalinated water with 28 operational plants providing 1.3 billion cubic meters/year of drinking water and 37.03 million MWH/year of electricity to major urban and industrial centers through a network of water pipes running for more than 7000 km in length [13]. The Saudi's remarkable experience with desalination can be a supportive reason to make the desalination technology an important source for providing water in the present and future time for the Libyan people especially those who are living along the coastline.

4. Conclusions

Based on the detailed review of conventional and unconventional water resources in Libya presented in this paper, Libya is heading toward severe shortage of fresh water if its government stands weak in front of this severe problem. The following conclusion and recommendation are extracted:

- The absence of good management in all water authorities caused many problems regarding documentation whatsoever. Therefore there must be a cooperation between the national authorities to solve the water shortage problem.
- Despite the fact that the manmade river has partly solved the water crisis in the northern parts of the country, yet it can not be reliable for all situations.
- Desalination of seawater should be strongly adopted in all coastal Libyan cities, while desalination of brackish water plants should be installed throughout the country.
- The responsible water authorities should urgently create professional inspection teams to investigate the out of service desalination plants and write reports describing the technical status of these plants, including the maintenance cost when its required. Based on these reports governments and private sector would be able to make the right decisions with regard to these plants. If these out of service plants stay as they are many technical, social and environmental problems should appear sooner or later.
- The government should take initiative in the direction of water reuse and recycling by encouraging research in water reuse field, this can be conducted by research centers and universities.

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