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Innovative Solution for Additional Water Resources at the Jordan Valley Area

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ABSTRACT

AL-Karama dam, the second largest dam in Jordan, was constructed in the Jordan valley area in the year 1979. Currently, the dam holds about 72% of its designed storage capacity with total dissolved solids concentration of 2.2%. The dam water was designed to irrigate 100 km^2 of new reclaimed areas and to provide drinking water for more than 30,000 residences. In this work, solar desalination system was suggested. The suggested innovative solution is designed to increase the dam efficiency and to increase water availability annually by 3.3 MCM in phase one to reach 9.2 MCM in the final plan. Furthermore to increase the irrigated areas by 20% in Jordan valley area. Considering the water availability, population and costs, small-scale solar desalination plant with reverse osmosis membrane is recommended.

***Keyword**:* Solar desalination; reverse osmosis; Al-Karama dam; irrigation; Jordan.

1. INTRODUCTION

Al- Karama Dam in the Jordan Valley has been built to store 55 MCM of water, mainly from the Yarmouk, and its yield will be used to help irrigate some 6000 hectares in the southern Jordan Valley. On the other hand, the effect of Al-karam dam on the surrounding environment (the effect of seepage from dam on groundwater salinity levels and soil salinity levels) does not appear to have caught researcher's attention so far.

The demand on clean water resources has been increased dramatically due to rapid growths in population and economy, causing catastrophic water shortage, especially in arid and water-stressed region areas like Middle East. According to Misdan et. al (2012) the current global water demand which is 4500 billion m^3, it would increase to 6900 billion m^3 by the year of 2030. Jordan has one of the lowest available water supplies in the world;

meanwhile Jordan has seen large increase in population and refugee's fluxes, leading to an increase in water demand (EUI, 2015). To address this unprecedented water scarcity, Jordan's water must be used where its social and economic value is highest. Jordan must treat and reuse virtually every drop of water (Aljaradin et al., 2017). The available water resources in Jordan are highly dependent on the amount of precipitation and groundwater. It is expected to have more than 430 MCM of water deficit by the year 2020 (MWI, 2014). As a result, the present surface water resources will no longer be sufficient to meet the future needs for humankind. Numerous researches were conducted in an effort to develop more sustainable technological solutions that would meet increasing water consumption.

1.1 Solar energy desalination potentials in Jordan

The solar energy potential in Jordan is enormous as it lays within the solar belt of the world with average solar radiation, 320 days of sunshine a year, ranging between 5 and 7 kWh/m^2, and 1000 GWh annually (Zafar, 2017). Solar energy in Jordan started to give attention locally and internationally for investments, encouraged by the government by tax subsidies and low interest loan rates and adapting build-operate-transfer (BOT) strategy. As an example, Ma'an development zone constructed the first solar energy plant for the production of 52.5 MW that counted about 1% of the country's energy capacity (Almadani, 2016).

Reverse osmosis membrane (RO) is one of the most used technologies among others in desalination of seawater using different energy input such as conventional and non-conventional. Since middle of last century many researches has been conducted to enhance the membrane technology, one of the innovative techniques in desalting water is membrane desalination that considered as cost effective. In order to utilize the solar radiation for desalination, it is necessary to know the energy falling on a unit area of the earth's surface per year; seasonal variations due to atmospheric conditions exist along with variations due to geographic location. Solar energy is divided into two components, direct radiation that received straight from the sun and diffuse radiation that has been scattered by clouds, earth and dust arriving from all directions (Goosen, et. al 2000).

In the recent time, the demand on safe water supply is relatively increasing, and the need to lower the cost of treatment process is required. The aim of this research is to design and develop a process, optimize the operation conditions to desalinate brackish and seawater with minimum power consumption. Minimizing the power demand will make the desalination techniques affordable for poorer countries (Khayet et al. 2010). Moreover, minimizing the chemicals usage for water pretreatment, hence the cost of the treatment will be reduced and the environment will be preserved.

1.2 Irrigation at the Jordan Valley area

About 80% of Jordan's water resources are used in agriculture that mainly depends on groundwater. Jordan valley is the most important cultivated area in Jordan where it produces the high proportion of the country's vegetables and fruits under irrigation. According to official data, Jordan exports 1 million tons of agricultural products in 2015 which is about $1.1 billion. Farming is a significant contributor to Jordan's overall export profile, accounting for around 20% of merchandise exports in 2013 according to the World Trade Organization data. Presently, Jordan's water is in danger because of the growing population and refugees reflux. Furthermore, the limited resources of water have enforced the use of saline low-quality irrigation water.

The limited resources of water have enforced the use of saline low-quality irrigation water (Shatanawi et al, 2011). Using low-quality irrigation water may reduce crop yields or irrecoverable damage to the environment, soils, and aquifers (annadale, 2008). Therefore, effective and wise use of all water resources in irrigation practices is the only way to cope with water scarcity and the likely problems associated with the reduction in water. In addition, reclaiming of new agricultural land is needed in order to face the steadily increase of population and establishing of new communities. In this regard, modern irrigation techniques accompanied with using alternate water sources (e.g., brackish water from Al-Karama dam) are considered appropriate solutions.

1.3 Purposes and objectives

In this study, we have to specify the existing problems and the effect of the dam and the surrounding environment to provide sustainable solutions for agricultural, environmental, and social perspective including women in the area. This solution contain small-scale desalination system primarily consists from vacuum tube heating system, passive water heating room, solar thermal collector solar and photovoltaic cells to generate power required by the system.

At present, the water cannot be used due its high salinity but in this innovation, we suggested to revive the dam by using sustainable solar technology. The dam has huge amounts of water that be used to supply long term high quality fresh water to secure food for all people living in the area plus development of small-scale farming (e.g. aquaculture) business.

Recovering the capital cost of the dam which was calculated approximately $80 million and saving about 200.000 - 300.000 JD of operating costs annually. Operation of desalination plants to desalinate 5 MCM of water annually to provide drinking water for residence about 30,000 people and refugees about 20,000 people including unexpected increase in the area.

2. STUDY AREA AND PARAMETERS

An overview

AL-Karama dam was constructed in the Jordan valley area in the year 1997, as part of the efforts to improve water harvesting, the dam considered the second largest in the Kingdom. Currently, the dam holds 40 MCM (million cubic meter) of its total storage capacity of 55 MCM (Mohsen, 2007). The dam water was designed to irrigate 100 km^2 of new reclaimed areas characterized by a high salinity and alkalinity soil in the Jordan valley area, but also to provide to provide fresh drinking water for 30,000 residence in the area. However, the high fraction of salinity in the captured water with total dissolved solids, TDS about 22,000 ppm, made it unfit for drinking or agricultural purposes.

The Dam is an earthfill embankment that was constructed in 1997 on Wadi Mallaha (Salt Pan) in the Jordan Valley area to store water for use in irrigation during the dry season (see Fig. 1). The dam catchment area measures about 61.2 km^2, receiving an annual average amount of rainfall of 150 mm in comparison, the annual potential evaporation is about 2,450 mm (NWMP, 1977; Department of Meteorology, 2004). Also, in the dams catchment area the total flood flow of 1 MCM annually and a base flow composed of saline water with an electric conductivity of 25,000 to 30,000 μS/cm (Salameha, 2004).

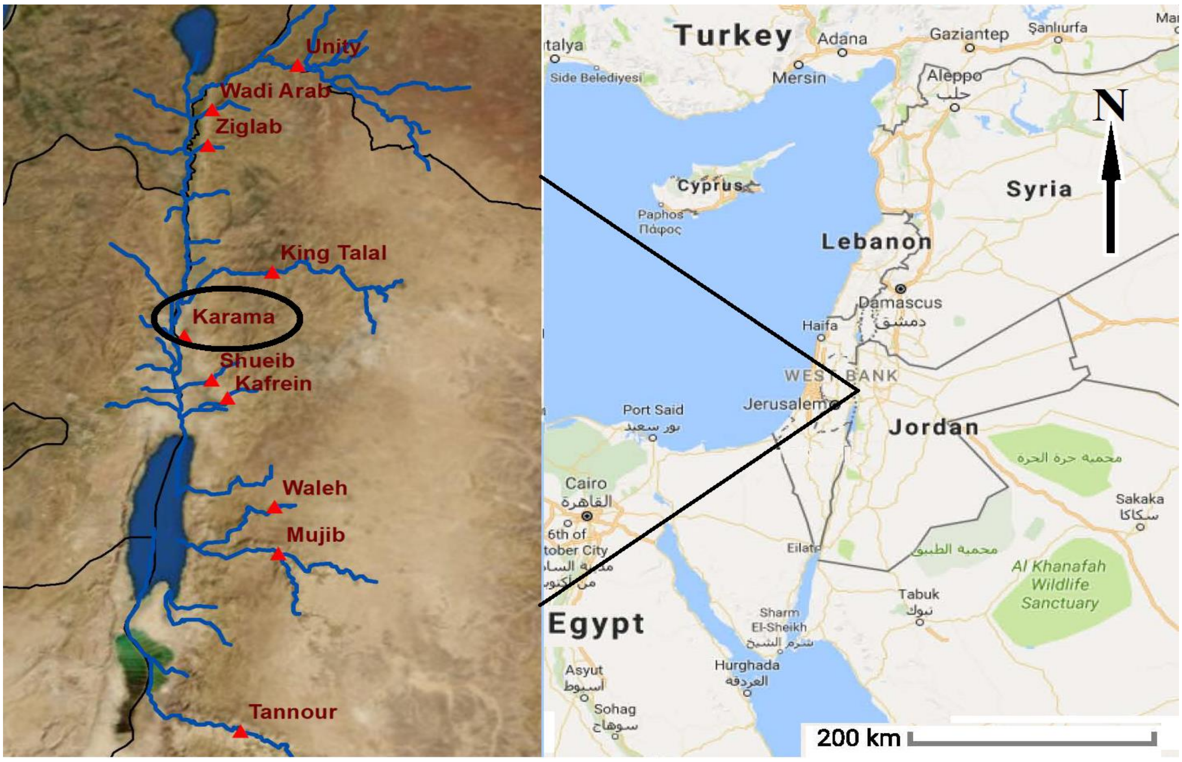

Figure 1: AL-Karama Dam - after Google map: https://www.google.se/maps/(2017) & (Altz-Stamm, 2012)

Figure 2: AL-Karama Dam overview (photo: The picture AL-Karama Dam was uploaded and shared by user sadpirate on panoramio.com)

The dam catchment area is relatively flat, possessing high porosity and permeability allowing rapid infiltration of rainwater resulting a very limited collected quantity of surface runoff, which has been estimated to an average 1 MCM annually. (Gibb, 1993). Also, farmers in the Jordan Valley have been deprived of fresh irrigation to be diverted to the dam to test it and to allow operational maintenance. However, this water became saline in the dam reservoir and that was discharged unused to the Jordan River (Salameha, 2004).

The surface area of the reservoir when filled is 5 km^2 and today reached to about 10 km^2 and the bottom of the reservoir is relatively flat full of a few million cubic meter of water that covers a bottom area of 2-3 km^2. Taking an average reservoir lake surface area of 4 km^2 then the expected annual amount of evaporation is about 9 MCM. Thus, the lasted amount of water from evaporation can increase the salinity of the reservoir (if no water is discharged) by around 20%, which means the great losses for Jordan that is afflicted by high water stresses and very limited water resources (Salameha, 2004).

As you can see in (Table 1), the characteristics and properties and uses of all dams in Jordan are presented in order to show the huge amount of available water that can be used for different purposes (FAO, excerpted Feb. 2017). These dams counts about 112 MCM, in which this amount is considered as an additional source of water and renewable water to feed many people and projects through some treatment such as solar desalination for drinking purposes etc. As mentioned before Karama dam will be considered as an example to start solar desalination to reuse the water for different purposes in a mini project system for the people living at the area.

Table 1: Characteristics and properties of dams in Jordan (FAO, excerpted Feb. 2017)

Name & Completion	Major basin	Height (m)	Capacity (MCM)	Irrigation	Water supply	Flood control
Shurabil Bin Hasna, 1967	North Rift Side Wadis	48	4.3	x	x	x
Shueib, 1969	South Rift Side Wadis	32	2.3	x		x
Wadi Arab, 1986	North Rift Side Wadis	83.5	20	x	x	x
King Talal, 1987	Zarqa	108	75	x		x
Kafrein, 1997	South Rift Side Wadis	37	8.5	x		x
Karama, 1997	Jordan Rift Valley	45	52.52	x		x
Tannour, 2001	Hasa	60	16.8	x		x
Wala, 2003	Mujib	52	9.3	x	x	x
Mujib, 2003	I Mujib	62	31.2	x	x	x
Wadha (Unity), 2007	Yarmouk	87	55	x	x	x

3. DESALINATION PLANT METHODOLOGY AND SOLUTION

3.1 Desalination Plant at Al Karama Dam

Al-Karama Dam Desalination Plant is a BOT project designed with reverse osmosis RO, where AquaTreat undertakes the design, build, supply, financing, operation and maintenance of the 10,000 m^3/day that was signed for a concession period of 15 years. At AL-Karama, RO plant with a TDS content of 18,000 is extracted from the surface water of the dam and water is treated by oxidation, sedimentation, pre-filtration in pressurized sand filters and carbon filters, a reverse osmosis plant with a recovery rate of 55 %. The treated water is conveyed to a storage tank from where it is pumped in several steps to Jordan's capital Amman. This water will be used as household drinking water and for irrigation. Unfortunately, the plant operated for a short time and due to technical problems the plant stop functioning; as a result of unclear agreements between partners; government, contractor and Jordan valley water authority. Re-operating the plants with minimal costs through solar desalination will provide locals with new affordable fresh water source.

3.2 RO Desalination Plant capacity and cost

Bashitialshaaer & Persson has calculated from more than 20 desalination projects from different countries in the MENA regions. The results presented here was calculated mostly for seawater reverse osmosis (SWRO) desalination plants, which means the better quality water is the cheaper production such as dam’s water and groundwater. It is obtained that the capital cost for desalination plant production is about $ 1 million for project capacity of 1000 m^3/d of desalinated water and unit cost is about $ 0.79/m^3 (approx. 4.5 kWh for 1 m^3). Also, they obtained capital cost for the power plant to produce 1 MW of energy is about $ 1 million and the average unit cost to produce 1 Watt from the power plant is about $ 1 approximately (Bashitialshaaer & Persson, 2010).

Multi-Stage Flash, MSF and Reverse Osmosis, RO processes dominate the market for both seawater and brackish water desalination, both counting today about 86% of the total installed capacity. In 1999 the installed capacity of RO processes was 31% and MSF was 65%, and in mid of 2014, RO was significantly increased and reached to 66% and MSF declined steadily to 20%, since it cost more energy (Bashitialshaaer and Persson, 2013).

Thus, it is good idea to use RO because this technology is the main deriving for desalination and must have more advantages over other technologies. Also, from the global distribution the total membrane systems reached to 93% while the total thermal processes are decreased to 7% (calculated from IDA latest book). Today, the downward trend in the cost of seawater desalination is clear, no matter what kind of used technology. From 2015 onward, the trend lines are all close to straight, with the average value tending to US $ 0.5. For different water sources before year 2001, the cost of RO desalination for brackish water was higher than that for pure and river. In general, from 2005 to 2010, the average cost tends to 0.3 $/m^3, while from 2015 onward it decreases to 0.2 $/m^3 for the same source of water (Bashitialshaaer and Persson, 2013).

From the all-aforementioned information about desalination plant, capital and unit cost will be useful in the current study and future plan for similar cases such as dams and brackish water as small-scale plants. Such information are considered as benchmark in which we can combined them with solar desalination system in order to improve the production capacity of the treated water to be greenery and sustainable as possible. Also, from both capital and unit cost results we can improve the cost of our plan when using solar desalination in the area and unit cost will be expected little lower than the usual desalination. In this study, we are trying to have solar desalination together with mobile desalination system that is functioning with RO membrane as seen in Figure 3. RO desalination mobile system is a full package with different capacity that can start from 500 to 5,000 m^3/day, which will be enough for the start of the treatment.

Figure 3: RO desalination plant in a mobile system (photo: Bashitialshaaer, 2015)

4. RESULT AND DISCUSSIONS

Currently, AL-Karama dam holds about 40 MCM with TDS concentration about 22,000 ppm in which for this quality of water the recovery ratio will be at least 55% and with nanotechnology might be better. Thus, from the current amount of water we can start one small-scale solar desalination plant e.g. 5,000 m^3/day (approx. 1.81 MCM annually) with the same recovery the input amount is about 3.3 MCM annually. So, we can plan upto 5 similar plants in order to desalinate 25,000 m^3/day (approx. 9.2 MCM annually) to feed more people in the area for drinking and the excess water can be used for other purposes. With simple calculation we can say just to run the desalination plants we need at least 25 workers and much more for the rest of the water. Similar idea can be applied to the other dams in Jordan and much more projects will be applied to desalination this amount (112 MCM) of water and employ more people from the same area.

In this plan, farmers and residence from AL-karama dam area are the targeted end users group. The Jordan Valley is divided into several distinct geographic sub-regions. Its northern part is known as the Gor, and it includes AL-karama area in which about 50,000 people lives in this area. The residential people (women, men and children) works now on farms larger than average (3 to 6 ha). Farms are small but yield an average $4,000/ha/yr and a good revenue per capita (about $5,000/ca/yr). Jordan Valley authorities is responsible for the water and agriculture in the area and they sell water in surplus of the normal allocations to farmers to increase revenues from water charges.

However, sudden increase in population, rising fuel prices and the decline in water availability had a destructive impact on these families economy. Thousands of square kilometers are dry today, abandoned, or sold. Many families are out of Jobs and the government is not doing so much to solve these problems. The area is characterized as having the highest rate of absolute poverty in Jordan. Agriculture has considered as important component of family income, more so than in any other part of the country. However, some of the current practices and behaviors needed to be changed. They need to use the latest technologies in agriculture that protect human and environment (e.g. irrigation water management, minimizing the water consumption, using the latest technology in agriculture, solar energy, and organic aquaculture).

4.1 Alternate partial root-zone irrigation (APRI)

Assessment of the environment impact of AL-karama dam and providing clear guidelines for proper design and management of different modern irrigation techniques are essential to create an integral evaluation for the project from the agricultural, environmental, and social perspective. In addition, the validation of such irrigation technique under field conditions is very important for the credibility of the outputs of this study. Useful numerical simulation previous studies of diverse irrigation methods by (e.g., Phogat et al., 2010; Simunek and Hopmans, 2009; Hanson et al., 2008; Ajdary et al., 2007; Lazarovitch et al., 2005; Gardenas et al., 2005; Skaggs et al., 2004) revealed that Hydrus-2D (Simunek et al., 1999) precisely simulates water and solute movement under different irrigation methods and soil types.

Alternate partial root-zone irrigation is an irrigation technique system that taking into account the volume of water for irrigation can be saved without significant yield reduction (e.g., Du et al., 2005). In this technique, part of the root system is subjected to drying soil while the remaining part is irrigated normally (e.g., McCarthy et al., 2002; Kang and Zhang, 2004). Switching of irrigation between the two parts depends on soil moisture content level in the drying soil, crop type, growing stage, soil texture, etc. (e.g., Saeed et al., 2008). By using available brackish water (i.e, AL-krama dam water), the overuse of freshwater resources in Jordan valley can be reduced. Few studies were conducted to address the influence of brackish water on soil salinity and crop water consumption by using a dynamic modeling technique. However, very few studies were carried out to simulate APRI with brackish saline water (Selim et al., 2011; 2012).

4.2 Addressable market and potential market

The innovation is designed to bring back life to the Jordan Valley area with the additional production and maintaining the cultivated land and to added about 100 km^2 (≈10,000 ha) as an additional land for new kind of crops that is in demand for the local and potential markets. For example, tomato, citrus, olives, chili and cucumber are needed all over the year locally and for the European Union markets. USA and some countries in the MENA region are also another target that is considered as the potential market for most of the crops from this area. Additional crops and fish are also planned for additional new markets. The basis of our claim is to restart the available desalination plant to its full capacity of one million cubic meters (MCM) (≈ 2,700 m^3/day) of drinking water annually plan to increase the total capacity to 5 MCM (≈ 13,700 m^3/day) annually. Thus, the additional water will increase the production of food, aquaculture and establishing more jobs (each small-small project can have at least 5 new jobs) to the locals.

4.3 The levels of participation

It is expected to have such gaps according to the structure of the society. Jordan and the area are characterized as male dominance. Many of the refugees have settled down in these areas and adapted the life style as they have the same cultural background and language.

Also, we think to work as a group together with the people in this innovation considering that all in the area can participate of equal amount of work and experiences for all levels which depending on their capacity in each work category. Through this equality system between all groups and collaborators, it will lead to a successful participation and then shrinking the available gaps. Also, the collaboration system between men and women can increase the chance of success of this innovation including the amount of production and decision-making in any future gap if it appears. The people in the area must work as a unit and family in order to avoid any kind of disturbance to run this work continuously and benefit from it for maximum production in drinking water, increasing cultivated area for more food production and securing the social system. In Jordan, most of the people having similar cultural system so we can easily communicate especially when the subject is directly touching their basic life conditions such as water and food. The social interconnection between the families living in the area is making gaps much smaller than the potential gaps.

5. CONCLUSION

Using latest technologies such as small-scale solar desalination and new irrigation methods will increase the productivity and reclamation of new land area first locally at AL-karama dam area and Jordan Valley area and might positively affected the whole region. Such innovation and idea probably is going to employ more people from the targeted area with the help of Jordanian government and international support. Improving water sector means everything to the people living in the area including all levels and genders.

With this idea, farmers can produce more than the normal amount and send their production to more countries over the world in which they can open new production lines from the revenue. The new production lines can be in the same field and/or change to another such as switching from agriculture to aquaculture mini projects.

It is good lesson to show the government and the people in the area how to use the water in AL-karama dam in proper and sustainable ways to provide fresh water and other purposes for the development of the area. Small-scale solar desalination is a cost effective while large scale plant is not affordable and/or accessible now. Also, this idea is applicable for the rest of the dams in Jordan (about 112 MCM) that is considered as additional source of water.

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