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Water Quality, Availability and Potential of Geothermal Energy Utilization, Afra Water, Jordan

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ABSTRACT

Reusing of 3.3 MCM (million cubic meter) of water every year from utilizing thermal water of the hot springs will boost the availability of water at the Dead Sea area. This water represent an additional sources of water for agribusiness in which all available springs and similar sources can follow the same way of successful. In this work the water quality of Afra hot springs was analysed at source and compared with the water at downstream at the Dead Sea area. Microbial analysis found no traces for faecal coliform and E.coli bacteria which lower the risk for contract diseases when the water is used for irrigation without any prior treatment. The water at upstream rich with high trace of metals with a significant content of bicarbonate, BOD_5 and COD but within Jordanian standards for irrigation purposes. Slight variations between physicochemical parameters and trace metal contents found between the water from the source and the water at the downstream because of surface runoff interactions at the way down. Afra spring water at the source is considered as low-enthalpy geothermal sources, as the temperature is range between 45-48 ^oC, therefore, power generation is unlikely to be possible. However, it can be used in curative water tourist. According to the water quality and availability, different suggestions for treatment and uses will be defined in this paper. Furthermore, to evaluate the potential uses at the downstream.

***Keywords*:** Afra hot spring; utilizing thermal water; chemical analysis; agribusiness.

1. INTRODUCTION

Jordan has one of the lowest available water supplies in the world; meanwhile Jordan has seen large increase in population (9.5 million people according to statistic 2016) and refugee's fluxes, leading to an increase in water demand. Water is projected toward deficiency of 56% of the national sector needs by 25% (Taha, 2016). It is expected to have more than 430 MCM of water deficit by the year 2020 (MWI, 2014). The most afflicted populations are those living in rural communities in which they are facing strict water shortages and are incapable to meet basic water needs (Aljaradin, 2017). 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. About 80% of Jordan's water resources are used in agriculture that mainly depends on ground water (Al-Kharabsheh and Ta'any, 2009).

Jordan is located in a semi-arid climatic zone and hence inherits a limited amount of rainfall recharging its surface and groundwater reservoirs. The consumption of groundwater is nevertheless far exceeding its renewable capacity and can reach over 50% of Jordan's total amount (Ammary, 2007; Mohsen, 2007). Groundwater resources are clearly vital for Jordan's population and economic wellbeing.

Therefore, managing the quality and the quantity of this water is essential in a sustainable way avoiding possible contaminations (Dina, 2004). Unfortunately, the groundwater quality is threatened by several factors including unsafe landfilling (Aljaradin and Persson, 2012, 2014 & 2016). Jordan valley is the most important cultivated area in Jordan where it produces the high portion of the country's vegetables and fruits under irrigation system (Hani and Shatanawi 2011). According to official data, Jordan exports about 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 world trade organization data. The need to adopt a more integrated approach to water management that will take into consideration the element of sustainability to adequate the use of available water resources (Sustainable Jordan, 2012; El-Ghadban, 1999).

1.1 Purposes

Many possible solutions for additional water resources and water management could be adapted in Jordan. Nowadays, Jordan needs to give the priority to water harvesting projects in different areas to accumulate the runoff water either in pools or in desert dams for irrigation, livestock, or artificial groundwater recharge. Sharing water resources with other neighbouring countries (active water cooperation) is considered very important to water supplies in the present and the future. In addition, the planned project for desalination and energy production from Red Sea Dead Sea canal project and desalinated brackish groundwater would be good solution to Jordan in order to minimize the available stress of fresh water (Bashitialshaaer et al., 2011; Malkawi, 2005; Mohsen, 2007).

2. RENEWABLE ENERGY AND THERMAL RESOURCES JORDAN

2.1 Renewable energy scenarios in Jordan

Developing renewable energy sources contributes to mitigate poverty, support production and protecting health while promoting sustainability and environmental quality (Hostettler, 2015). Energy in Jordan remains a top challenge for development (Aljaradin, 2017). The energy needs to be produced in a sustainable way, preferably from renewable sources which have a minimum environmental impact. Still, Jordan has been a pioneer in renewable energy promotion in the Middle East, with its first wind power pilot project in Al-Ibrahemiya as early as 1988 and recently Tafila wind power farm which is located at Tafila Governorate produce 117 MW. 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, 1000 GWh per year annually (Zafar, 2017). Solar energy in Jordan started to track attention locally and in international perspective for investments, encouraged by the government by tax subsidies and low interest loan rates provided by private banks supported by the kingdom central bank and adapting build- operate-transfer (BOT) strategy. Recent promising investment by private sector at Ma'an development zone constructed the first solar energy plant for the production of 52.5 MW which account for about 1% of the country's energy capacity (Almadani, 2016). Waste-to-energy been recognized as an effective approach to improve recycling rates, reduce the dependence on fossil fuels, and reduce the amount of materials sent to landfills and to avoid pollution. The estimated municipal waste generated in Jordan according to the last five years average production is around 3 million tons per year. The high organic waste (50% from the total waste generated) is suitable for methane gas capture technologies which is estimated at 170 m^3/ton waste.

Nowadays, there are many technologies available which makes it possible to utilize these energy potentials (Aljaradin, 2016). The major alternatives conventional technologies for large scale waste to energy solution are incineration, landfilling and anaerobic digestion. Construction of an incineration plant for electricity production is often a profitable system (as 50% are suitable for incineration e.g. garden and park waste, wood and textiles (1.5 million ton) with high calorific value and energy potential (8.1 MJ/Kg) that is capable to produce electricity 340 kWh/ton waste), even though the installation cost is high since production of electricity often leads to a large economic gain. Landfill gas utilization avoids the release of untreated landfill gases into the atmosphere, and produces electricity to sell commercially in an environmental friendly manner. Anaerobic digestion option is not only decreases greenhouse gas emission but also it is the best technology for treatment of high organic waste through converting the biodegradable fraction of the waste into high-quality renewable calorific gas (Aljaradin, 2016). However, all forms of renewable energy, remains largely untapped due to the high cost associated with non-conventional energy resources and relatively cheap availability of oil and natural gas. Consequently, the need for implementing energy efficiency measures and exploring renewable energy technologies has emerged as a national priority. Another emerging challenge will face Jordanian government's is the transition from conventional fuels to renewable energy resources will require capital investments, technology transfer and human resources development.

2.2 Thermal water resources in Jordan

Many investigations of the geothermal water resources have been recently taken place in several locations in Jordan, which was conducted regarding some parameters such as chemical properties, physical properties, heat source, therapeutic properties and their potential as a source of energy. Results concluded that the thermal water is heated by a crustal magma body or solidified hot pluton that represents the intrusive roots of the old lavas (about 1.8 ±0.1 million year old) while this lava are too small volume, less than 1 km^3 (Duffield, et al., 1987). Also, the chemistry of the thermal water suggests that it is probably equilibrated with crustal rocks of about 110°C (Truesdell et al., 1983). Therefore, a magmatic heat source for this thermal water seems unlikely. Thermal springs been used in bathing and in irrigation since ancient time and from then the rest of the water not used properly.

Recently, several hotels (spas) were constructed on the thermal spring’s sites that shows the ability of this water in treating several diseases (Lund, 2010; Salameh et al., 1991). Mazor et al., 1980 concluded that the temperatures might encourage further developments for spas and bathing installations and, to a limited extent, for space heating, but are not favourable for geothermal power generation. In 2010, Ajlouni et al., investigated out Afra hot springs, their new findings was recorded as high-radiation dose equivalents, known as impacts of exposure on public health in high levels of natural radiation areas. It was found that significant high dose rates in air were in the range of 10–18 000 nSv/h, and high-radiation zone due to gamma radiation was measured to be 4.0 mSv/h. The measured data was compared to the absorbed external dose rate outside the high levels of natural radiation in the Afra hot springs areas is less than 10 nSv/h (Ajlouni et al., 2010). In this study, the water quality of Afra hot springs will be analysed at source and compared with the water at downstream at the Dead

Sea area. According to the Afra water quality and availability, different suggestions for treatment and uses will be defined in this paper. Moreover, to evaluate the potential of geothermal energy uses in Afra area where the thermal water at above 45 °C.

3. METHODOLOGY

3.1 Study Area

Afra hot springs is located about 26 km north of Tafila city and about 160 km south of Amman-Jordan, as shown in Figure 1. Afra hot water flows from 15 different water springs, well-known for its mineral water baths, whose average temperatures range from 45 to 48 ºC. The collection of this water used for bath and medical purposes includes a centre for tourist services at the site. The total amount of water flow from Afra hot springs is estimated about 376 m^3/hour (about 9,000 m^3/day and 3.3 MCM annually, this water is used for swimming and bathing at source in the area of Afra and used again by hundreds of people in Alnaqueh area (downstream about 20 km away from the springs with a steep slope through the mountain) before it flows into the Dead Sea or used for other purposes (see Figure 2). This amount of water can benefit as an additional source of water in the region for drinking, agriculture and aquaculture purposes.

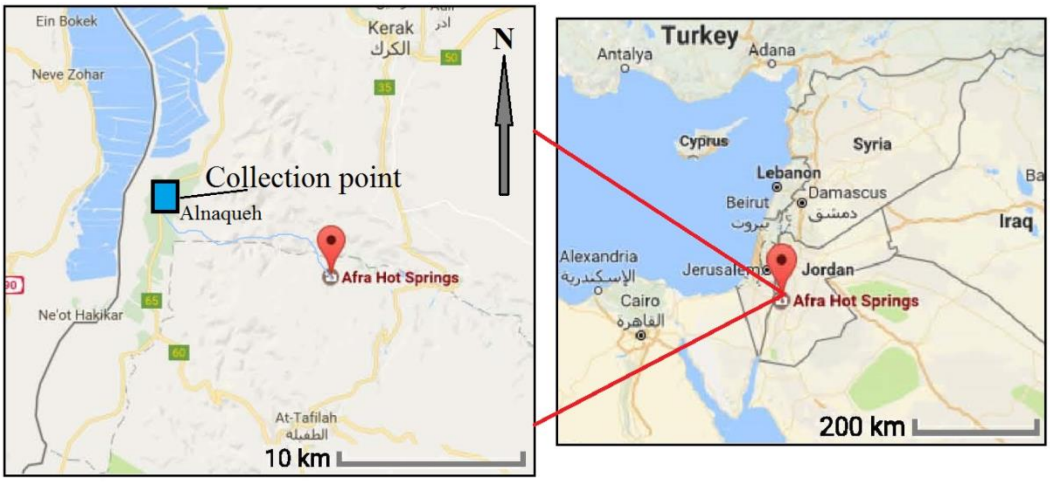

Figure 1: Afra hot springs - after Google map: https://www.google.se/maps/place/Afra+Hot+Springs/(2017)

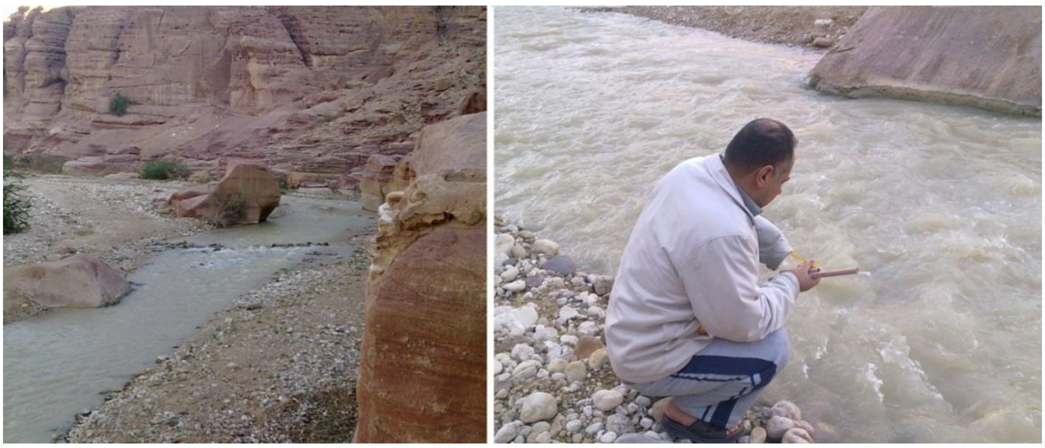

Figure 2: Afra hot springs water flow towards collection point (photo: Sep. 2013)

In general, available hot mineral springs in Jordan are very attractive to local and international people who seek physical healing in which Afra is one of the most important hot springs in Jordan. Afra site receives between 500-600 visitors every day and up to 2000-3000 during weekends, in other hand they generate almost 2000 kg of municipal solid waste with an average of 1.2 kg /capita /day which is relatively high. Since a huge amount of solid waste is dumped due to irresponsible behaviours at the source, this could be a major threaten to the water quality and could be a source for contamination at the Alnaqueh area which may affect the people reuse this water looking for healing. Physical and Chemical analysis will be conducted to the upstream and at downstream area, in order to compare the water quality so as to determine the level of contamination and its possible effect on human health.

3.2 Experiment analysis

Analysis for water quality on site was conducted. Samples from Afra hot spring upstream and from Alnaqueh at the downstream for further studies was collected. Afra hot water flows almost from a collection of 15 different water springs, whose average temperatures range from 45 to 48 ºC, with an estimated amount of water about 9,000 m^3/day (3.3 MCM annually). Most of this water is currently used for swimming and bathing at source in the area of Afra and reused again by hundreds of people in Alnaqueh area before it flows into the Dead Sea or reused for other purposes. Water samples were analysed immediately for their physiochemical parameters such as pH, electrical conductivity (EC), total dissolved solids (TDS) using portable pH-meter and EC-meter (WTW, Germany). Major anions Fe, Cl, NO_3, SO_4, Na, K, F, Mg and Ca were also analysed. Samples were collected in polyethylene bottles from the two locations Alnaqueh and the Afra spring were carefully handled and analysed. In this study, some chemical and physical parameters were analysed accordingly (see Table 1) in which the analysis was carried out at the Prince Faisal Centre for Dead Sea, Environmental and Energy Research.

Table 1: Results from the two locations, Afra source and Alnaqueh at the Dead Sea area

Parameters	Alnaqueh	Afra source	Water standard Jordan
pH	8.38	7.13	6.5 - 8.5*
Temperature, ºC	18	45	20-38
EC, µS/cm	951	1230	1000*
BOD_5, mg/L	62	1480	600 - 1500*
COD, mg/L	168	1250	1000 - 2500*
TDS, mg/L	580	440	< 500 - 1500*
SO_4, mg/L	56	68	< 200 - 500*
Cl, mg/L	25	48	< 200 - 500*
Na, mg/L	69	35	< 200 - 400*
Mg, mg/L	44	18	30**
Ca, mg/L	58	46	84**
Fe, mg/L	1.7	4.9	0,3-1**
NO_3, mg/L	0.1	0.1	50 - 70**
Br, mg/L	0.9	0.89	na
K, mg/L	2.1	2.4	11**
H_2S, mg/L	0.01	1.21	na
F, mg/L	0.1	0.01	2**
CO_2, mg/L	114	102	na
E. coli (MPN/ml)	0	0	0
Total coliforms (MPN/ml)	0	0	0
HCO_3, mg/L	168	138	0

*Water standard in Jordan (JS 286/2008). **Mufeed (2006).

The sampling bottles were rinsed in clear spring water several times and then filled to the top to minimize the entrainment of air in the samples. Three different samples were analysed in September 2013, in each location and then the average was calculated including onsite measurements for pH and EC. All glassware and polyethylene bottles were soaked in 20% HNO_3 for one day and rinsed several times with deionized water before use. The pH and redox potential (mg/l) was measured with PH meter Model 1100L. Conductivity and total dissolved solids (TDS, mg/l) was measured with Digital Conductivity meter Model CO301.

Calibration was always carried out before each measurement using standard buffer solutions of pH 4.00 and 7.00. Major anions (F^-, Cl^-, NO^{3-} and SO_4^{2-}) were analysed by 100 dionex ion chromatography instruments and major cations (Ca^{2+}, Mg^{2+}, Na^+, and K^+) were measured by a 800 varian flame atomic absorption spectrophotometer. The concentration of bicarbonate was determined by titration with 0.01 hydrochloric acid. Trace metals were analysed with a graphite furnace using GTA 100 instruments. The standard solutions of the anions, cations and trace metals as well as blank samples were prepared with different concentrations. After analyses, the accuracy of these standards was within ± 7%.

4. RESULT AND DISCUSSION

The quality of the water in the two locations are varied depending on many factors such as types of source, types of soil and rocks that the water travels, etc. The results are presented in Table 1, as mean values of the analysed for all selected parameters. The two locations downstream point called Alnaqueh and the upstream point called Afra spring were both compared with the current Jordanian water standard (JS 286/2008) for Drinking Water Quality. The water at upstream rich with high trace of metals with a significant content of bicarbonate, BOD_5 and COD but within Jordanian standards for irrigation purposes.

High TDS values were measured indicating high salinity at water downstream in comparison to source.
The high values analysed in Afra water at upstream may be due to the alteration of volcanic rocks and hydrothermal activity. Microbial analysis found no traces for faecal coliform and E.coli bacteria which lower the risk for contract diseases when the water is used for irrigation without any prior treatment. As Afra water is discharged onto the surface it subject to evaporative cooling, degassing, oxidation, and mineral deposition. The pH is higher at downstream in comparison with upstream probably because of the interaction with inorganic compounds during flow to downstream.

The water is rich with minerals (cations and anions) e.g. Fe, Mg and bicarbonate, however, some of these cations have increased (Na, Ma and Ca) due to the interaction with soil and rocks during flow. None of the major ions e.g. fluoride, chloride, nitrate and sulphate) exceeded the national and international guidelines. Hydrogen sulphide is present at much lower concentrations than carbon dioxide in Afra water. At pH values in the acidic range (<7) the predominant form of sulphide is H_2S, which can be subject either volatilization to the atmosphere or oxidation to thiosulfate and polysulphides. Formation of thiosulfate predominates over polysulfide formation because thiosulfate is more stable than polysulphides. Greater amounts of hydrogen sulphide were lost to volatilization and oxidation at lower pH values, and thiosulfate eventually is oxidized to sulfuric acid (Schoonen et al. 1998).

4.1 The upstream, Source (Afra hot Springs)

The chemical and physical measurements at source point of Afra spring water showed higher values than the other location downstream due to some reasons but still most of the results falls in the range of Jordanian standard. Afra spring water at the source is considered as low-enthalpy geothermal sources, as the temperature is range between 45-48 ^{o}C, therefore, power generation is unlikely to be possible. However, it can be used in curative water tourist.

4.2 The downstream, Alnaqueh (Dead Sea area/Jordan valley)

At the downstream area the water could be used after certain treatment for the agribusiness applications e.g. agriculture irrigation, mushroom culture and aquaculture (catfish, shrimp, tilapia, eels, and tropical fish) are particularly attractive because they require heating at minimum temperature range where there is a plenty of geothermal resources (Myslil, 1988). Many vegetable crops have been grown in geothermally heated greenhouses and has produced crops faster than by conventional solar heating e.g. cucumbers, chillies, and tomatoes, flowers plants, seedlings. Using geothermal energy for heating reduces operating costs up to 35% of the product cost and allows operation in colder climates where commercial greenhouses would not normally be economical (John, 2010).

Jordan valley is the most important cultivated area in Jordan where a high proportion of the country's vegetables and fruits is produced under irrigation. 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 kilometres 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 behaviours needed to be changed. They need to provide new sources of water and use the latest technologies in agriculture e.g. new irrigation techniques is highly demanding nowadays. Fish Farming is another usage, at present several farms producing tilapia exist in Jordan. For example the Arab Fish Company farm consists of some 40 basins, the company produce 20 -55 tons of tilapia per year. In winter, the temperature cannot be maintained at a sufficient level to ensure the survival of the fingerlings and allow the growth of the fish (Myslil, 1988).

5. CONCLUSION

This study concluded that the water of Afra springs at the two locations upstream and downstream according to the analysis conducted do not need any significant treatment and could be used in agribusiness applications at the downstream. This amount can reduces the tension in water scarce in the area because Jordan's water resources are in danger due to the population high growth ratio and refugees influx.

In addition, reclaiming of new agricultural land is needed in order to face the steadily increase of population and establishing of new communities. Providing new source of water will provide more food and create more jobs and social stability to the whole area and Jordan valley specifically. Slight variations between physicochemical parameters and trace metal contents found between the water from the source and the water at the downstream because of surface runoff interactions at the way down.

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