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WATER SCARCITY IN RELATION TO FOOD SECURITY AND SUSTAINABLE USE OF BIODIVERSITY IN JORDAN

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SUMMARY – Jordan is classified as a dry land country, which suffers from water scarcity similar to other counties in the region. Due to water scarcity the only fresh water ecosystem Azraq Wetland Oasis was destroyed. The destruction was a result of water over pumping from the greater basaltic Azraq basin, resulting in lowering water table to unprecedented levels. Hundreds of artesian wells have been drilled during the past two to three decades. The wells were drilled to fulfil the ever-increasing demand for water due to municipal and agriculture use to match the increase of human population. This excessive drainage of water has lead to total dryness of the Azraq Oasis except from two ponds where water is pumped daily into them. This drainage of water has lead to disappearance of the vegetation where 135 species have been recorded in that site; five of them are endemic and rare species. Most farms in the area have been destroyed and deserted. In addition, destruction of Azraq Oasis, which was, recognized as international Wetland Site, due to its importance as an immigration site for bird life. Again, due to dryness of the site birds have diverted from resting and nesting in the Azraq. In the past it was claimed that wild horses and a local brand of buffalos, have disappeared also. Azraq Oasis used to be an attractive site for tourism, which is lost now and in turn, affected the socioeconomic integrity of the people living in that area. Another sad case is that the use of the treated waste water in irrigation as about 50 million cubic meters are added to the water of the Zarqa River ending the King Talal Dam. Due to the bad quality of this water as a result of high contents of organic matter, various chemical compounds coming from the industry along the way, especially detergents dyes and so on, the fresh water vegetation along the river side has been almost altered with the disappearance of the majority of fresh water species. Worse than that is this water, is very unfortunate, is pumped along the course of the river and used for irrigation of crops and vegetables especially, leafy crops. Of course these practices are due to water shortages in Jordan. The government is trying hard to find solutions for this problem by finding new resources such as building new dams or water refinement. I am sure that these water ecosystems are able to rebuild themselves if water pumping is stopped and if the quality of the treated water has been enhanced or diverted to the desert for other purposes.

Keywords: Jordan, Azraq Oasis, Zarqa river, biodiversity, sustainable water use, treated water

1. INTRODUCTION

It is will known that water, is the most limiting factor to the survival and presence of the desert man and societies living in the dry ecosystem. Jordan is another example of those states, which are classified as a dry ecosystem, with almost more than 80% of its area is considered as a dry ecosystem (Allison, *et al*., 1998). The rainfall ratio is ranging from 200-50 mm, where almost 70% of Jordan is receiving less than 100 mm of annual rain (Al-Eisawi, 1985, 1996; Shehadeh, 1885).

Nevertheless, the majority of the Jordan Badia in the past was good enough to support wildlife, and used to be the place for old civilization palaces, and a hunting ground of various animals and birds, especially, in the Umayad period. Accordingly, many palaces and hunting loges were built such as: Qaser Amra, hunting lodge built in the period around 700 A.D. (Mountfort, 1965; Nelson, 1973). Other palaces can be dated at earlier or later periods especially Qaser Al-Hallabat, Qaser Al-Kharranah, Qaser Al-Azraq, Um Ajmal, Dair Al-Kahaf, Qaer Brqu'. These palaces were and still considered as a witness for the sustainable use of the dry land and wildlife by human through history.

The aim of this study is to highlight the importance of water as a major component in providing food and sustainable life for societies and human settlements as well as the wildlife in a dry

ecosystem such as the Jordan Badia. To demonstrate this fact, two examples are given; one is the status of Azraq Oasis known now as the Azraq Wetland Reserve; and the second is the new aspect of using treated sewerage water in agriculture resulting from Khirbit As Samra sewage station.

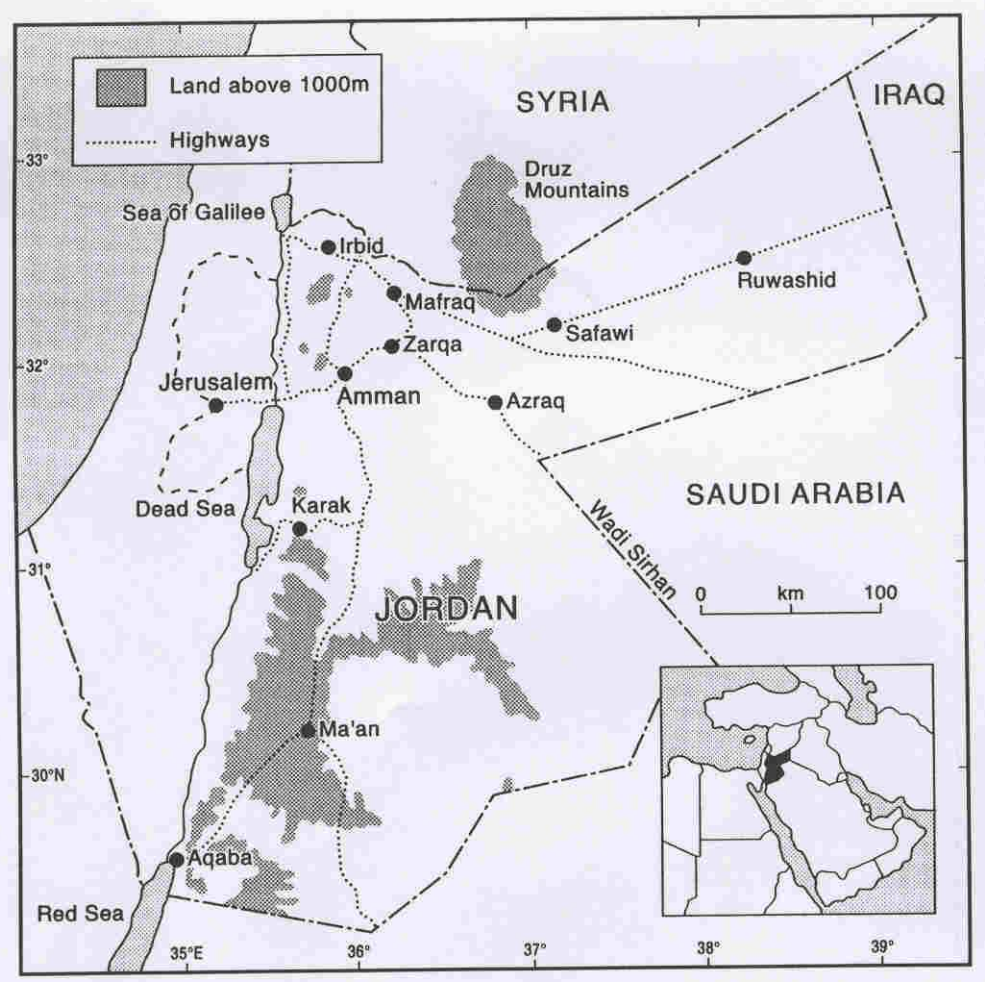

Figure 1. Showing Jordan and the locations of Azraq, Zarqa and Amman

1.1. History

Azraq Oasis is about 90 km E of Amman situated in the Eastern Desert (The Badia) in the territory classified as the Saharo-Arabian region (AL-Eisawi, 1985, 1996). This region is part of the larger Azraq Basin, characterized by hot long summer and cold winter with little rainfall (Map 1). Yet the occurrence of such a wetland in the heart of the desert have created very unusual lively ecosystem in an unexpected hostile environment.

The occurrence of Azraq Oasis was a miracle for the survival of many plant and animal species. It was found as a Gods creation to be in the heart of the desert to secure the travelling thirsty human or the helpless wild animal, and to rest the exhausted groups of flying migratory birds (Al-Eisawi, 1995). This site has been the bride of all those creatures who were in bad need for such a priceless habitat.

Azraq oasis has attracted scientists, tourists and explorers for its special position beauty and diversity. In fact few of British expedition were made to Azraq either on a voluntary bases or with prior arrangement with government of the Hashemite Kingdom of Jordan.

Nelson and others have called Azraq as an open laboratory for experimental biological work, since it provides all aspects of field research. In fact lots of suggestions were made to establish an institute

for a dry ecosystem studies in the Middle East.

2. PHYSICAL ASPECTS

2.1. Topography

Azraq oasis wet land is part of the larger Azraq basin. The whole area is more or less flattened forming a depression in the desert as extended into the Azraq Mud flat (Qa' AL-Azraq). Since it is more depressed than the surrounding places, it forms a structure like a huge concave plate. The altitude in the Eastern desert in general ranges from about 500 - 700. In some cases it exceeds the range limit where it becomes 480 m in Gublan Al-Hazeem and 1225 m the maximum limit as it is in the North-eastern part at the borders with Syria. In Azraq Oasis the altitude is about 520- 522 m, where it forms a low depression in comparison with the surroundings.

2.2. Rainfall

The rainfall of the Eastern desert (Badia) of Jordan ranges from 50- 100 mm / year and rarely exceeds such ratios. Azraq wetland reserve almost in the centre of the Jordan Badia, therefore, the rainfall in this area will be logically almost the mean between the two mentioned ranges.

During the period 1962- 1971 the mean rainfall was 73.5 (Nelson, 1973). The rain was mainly fallen within the period between the months of October and May.

The mean annual rainfall for Azraq during the period of 1966 - 1980 was 69.9 mm (AL-Eisawi, 1985).

In comparison to the above-mentioned numbers of rainfall the records of the Department of Meteorology, Amman, Jordan, give the mean annual rainfall for the period of 1981- 1992 as 67.8 mm. The months of rainfall were ranging from September to May.

2.3. Temperature

In general the temperature correlates with rainfall, therefore, if we consider the rainfall for the same period 1962 -1971, then the rainy months would have the least grades of temperature and visa versa. The maximum temperature recorded in the period 1962 - 1971 was 45.5 C° in July 1968, while, the minimal temperature was (-1.7 C°) in January 1966.

The mean maximum temperature recorded for the period 1966 - 1985 was 36.3 C°, while the minimum temperature recorded for the same period was 2.6 C° (AL-Eisawi, 1985).

Records obtained from the Department of Meteorology for the period 1981 - 1992, show that the mean maximum temperature was 26.4 C°, while the mean minimum temperature was 11.8 C°. The maximum temperature recorded for the same period was 45.0 C° in August, while the minimum temperature was (- 5.4 C°) in December and January (Al-Eisawi, 1995).

2.4. Evaporation

It is normal and expected that evaporation is correlated with increase in temperature and the hottest months of the year. Thus maximum amounts of evaporation were recorded in June - August following maximum temperature recorded during the same months. Similarly, the least amount of evaporation was recorded during the months of December - February where the minimal temperature is also recorded.

2.5. Humidity

In some hot dry places such as the Arab Gulf States often the humidity increases during the summer time when maximum temperature is recorded. Contrary to that is the Azraq Oasis and in general the Badia of Jordan is characterized by a dry climate during the summer time due to the little

amount of humidity. This has made the weather of Jordan especially the Badia very tolerable, even very pleasant. Relative humidity shows that the maximum humidity is correlated with rainy months and becoming less during the summer dry months. This behaviour is in contradiction with curves of evaporation, temperature and hours of sunshine duration (Al-Eisawi, 1995).

2.6. Soil

The Eastern desert of Jordan is characterized by having a dominant soil type called hammada. This soil type is mostly clayey and covered by gravels or pebbles. Azraq basin is characterized by having alluvial soil type transported by wind or water. The soil is mostly clayey loams or silty loams.

The parental rock is of limestone type withering into soil rich in calcium carbonates. Nevertheless, the whole basin is still rich in gypsum deposits which after withering adding to the texture of the soil component.

In addition to these major components, the soil of the basin and the wetland is highly rich in salt, dominated by sodium chloride. In flooding times, the soil becomes very sticky, grey in colour and becomes very difficult to move around.

The Eastern boarders of the Wetland Reserve is attached to the Qa' of Azraq, where the soil is dominantly silty loam which becomes very hard and solid during the dry season. It was clearly observed that salt crusts are covering the surface of the soil with a thickness varied from 5-10 mm after the water drying out in the flooded areas.

Soil around the water pools and water bodies is rather rich in organic matter due to decomposition of dead particles of biological components. Accordingly, often the soil colour looks very dark and the smell of methane gas can be detected.

2.7. Hydrology

The water of Azraq oasis is an accumulation of both surface water and deep subsurface water.

2.7.1. Surface water

The origin of the surface water is that Azraq wetland reserve and the attached Qa Al-Azraq are forming a low depression in comparison with surrounding areas. This depression is connected with inlet of *Wadi* (Valley) systems that charge their flooded water into the basin during the rainy season. It is well known in the desert areas that rain occurs in heavy floods in a very short of time. Sometime 80 % of the registered water can fall within few hours of one day. Such huge amounts of water will accumulate very fast in such depressions as Azraq, and thus have no time to be slowly absorbed by the soil surface.

2.7.2. Underground deep water

It is believed the major water body as an aquifer and accumulated in the water pools of Azraq wetland is gathered from the rainfall on the mountains of the Syrian desert. It is reported that mountain of *Jibal* (Mountains) *AL-Arab* South of Syria receives about 1200 mm of rain every year. Great amount of this rain is filtered to the underground layers where it accumulates in Azraq basin.

The quality of the water in Azraq wetland varies from potable to a brackish water. The total dissolved solids (TDS) range from 320 ppm to 1376 as recorded by Nelson (1973). Few Samples were taken during this study from flooded areas of the wetland have recorded a TDS number exceeding 5000 ppm. This is expected after a few years of total drought with no water floods at all and continuous accumulation of salts due to evaporation and no chance of leaching (Al-Eisawi, 1995).

2.8. Vegetation classification

Al-Eisawi (1995) classified the vegetation in the wetland reserve into the following major groups and subgroups with the dominant plant species in each group as follows:

1. Dry land vegetation
   (i) Silt Dunes,
   (ii) Rocky limestone vegetation,
   (iii) Qa border vegetation.

2. Wetland vegetation
   (i) i. Fresh water vegetation,
   (ii) ii. Brackish water vegetation.

3. Grass land vegetation

3. THE AZRAQ DILEMMA

During the past twenty years, and more clearly in the past ten years; and due to the population increase in Jordan coupled with the increased demand on water, huge amounts of water was pumped to the major cities of Amman and Irbid. In addition to that, a great number of borehole wells were drilled in North Eastern desert where fields of new vegetable and fruit orchard farms were initiated.

The result of that is an overall water abstraction from the Azraq Basin have reached 50-60 million m^3 (Nelson, 1973; Dottridge & Gibbs, 1998). Dutton (1998) claims, “that total volume of water mined to date from the upper aquifer is between 40 and 205 million m^3”.

The pumping of such huge amounts of water has exceeded the annual water recharge to the basin, which is estimated to be between 18-22 m^3/year (Nelson, 1973). The result of this over exploitation by human has led to the accumulative lowering of the water table and in turn the drying of Azraq Wetland Reserve and the surrounding area.

Based on the previously mentioned facts the whole ecosystem was threatened to be destroyed. In fact the water pools, the green vegetation, the water fish and other animals have almost disappeared. In addition carelessness has started to gain footsteps and peoples have made the wetland as a dumping place. On top of all of that fire have started to burn every thing even the deep roots and rhizomes of the shrubs, reeds, sedges and rushes, shrubs and other trees.

In 1994 an agreement with the international world bank through (R A M S A R) which is concerned with the conservation of wetland have given some financial support to Jordan to salvage the Wetland Reserve which was one day the most important desert stations for the rest of migratory birds travelling from Siberia to Africa and vice versa.

The Royal Society for the Conservation of Nature (RSCN) is the legal body to conserve this ecosystem. They have initiated a visiting site, with an exhibition showing with photographs the history of the ecosystem and how it should have been. They are trying to keep shallow, small pools as part of the wetland by pumping water to the site through an agreement with Jordan Water Authority. The rest of the pools are dry and the whole wetland reserve is in great danger.

3.1. Sequences of this dilemma

3.1.1. Drying of the water pools and the wetland reserve

The ecosystem is now totally dry for almost ten years. In the winter season of 1994/1995 Azraq wetland was last time observed covered by water and floods have filled the vast area of the Qa’ reaching the borders of the main road crossing between Azraq Druze (Azraq North) and Azraq Shishan (Azraq South). I made a survey the flora and vegetation of the wetland where I recoded 135 species with some new and rare species. Many species of migratory birds, insects and butterflies have been observed.

3.1.2. Alteration of the vegetation structure

Due to the continuous dry period over the past ten years the vegetation zonation, which was recognized, has been almost totally altered. Yes one can still observe the tamarisk shrubs and, silt dunes of *Nitraria retusa* the remnants of the sedge plant based which are totally dry, but nothing like the well identified zones which will be clearly apparent dung wet times. The Qa has never been covered by vegetation, it used be very dry and with compact hard soil that would not allow the germination and the survival of plants. At present the majority of the Qa is full saline halophytic vegetation dominated by the species *Halopeplis amplexicaulis*. This applies for other types of the wetland and the grassland have totally disappeared.

3.1.3. Loss of plant and animal diversity

Many species, which were listed during the survey in 1995, have disappeared as being water plants or wetland species. Accordingly, all the animal life associated has also disappeared, such as frogs, birds, and butterflies and in particular dragon flies. Some of the species that were growing in that site in Jordan have totally disappeared, such as the endemic and new species of *Centaurea postii*, *Nitraria schoberi, Ruppia chirrosa*, *R. maritim*a, *Zannichellia palustris*, *Riella americana, Cirsium alatum , Asparagus sp.* An endemic fish species called Sirhani (*Aphanis sirhani*) would have disappeared by now, unless it has been kept in water tanks and in the remnants of the water pools made by pumping of water. Other species of fish and animals have also disappeared.

3.1.4. Abandoning of agriculture fields and lowering of food productivity

Due to the water shortage and the salinity of the soil, farmers have started to abandon their fields, since soil became less productive. Farmers have accordingly started to abandon their fields and land investors have lost their money and dream to invest in crop production at various levels. Hopes of producing vegetables, leafy plants such as parsley, salary and lettuce, as well as, fruit crops such as dates, grapes, pomegranate and olives have disappeared. This has affected food production to support local population. The land was used over the past time as a grazing land for domestic animals, which were providing milk, meat, wool, leather and other by products have been lost.

3.1.5. Death of Ecotourism and nature attraction

All lovers of nature, bird watching people at the local and international level have abandoned the place due to the absence of migratory birds, which have changed their routs of migration. This internationally recognized RAMSAR site has lost most of its characteristics. Common and local people used to visit the site to enjoy the water pools scenery as well as the versatile green coves. Such people used to activate the local market, transport, restaurants, and reasonable small hotel investments. Accordingly, one or two small hotels have been closed which were used in the past to host and feed groups of nature's lover tourist. The idea that Azraq Oasis was close to the Desert Places and Shaumary reserve, which encloses one of the best Arabia Oryx herds in the word, used to complement each other and satisfy the appetite of the visitor, and used to be part of a desert tourist program.

3.1.6. Loss of the only wetland ecosystem in the desert of Jordan and an important international RAMSAR site

Azraq wetland was not an attraction for the nature lovers but also for the layman who used to find to visit Azraq as a salvation place from the crowded city. This demand was very important especially if no that there are no other water bodies of the same quality in Jordan. Even the two villages of Azraq where going to develop their business into that direction, but now a days they have alter the business to suit passing truck drives and other passengers of international passport. This of course has lower the quality of the serves, which would have been directed to serve a class and quality of customers. Azraq oasis was a vital source of water for the Bedouins and nomadic people as well as for their animals. Nowadays those people have to drive water tanks to carry water to their animals, which in turn increases the destruction of the ecosystem.

3.1.7. Socioeconomic structure and demography of the two villages

If the status of the wetland is still the same, ecotourism would have definitely thrived. As a result the demographic and the socioeconomic structure of the two villages would have been change into more modern, civilized and more stable society. People have stared to settle with their families to follow their business or start new ones, or to initiate new farms, fish aquaculture and others. At the time being, families either left or not increased and replaced by bachelor workers from neighbouring Arab citizens, which in some cases have inflected instability and unusual behaviour.

3.2. Solutions to this problem

The solutions to the problem can be summarized as follows:

1. Reducing pumping of water to the levels equivalent to the annual water recharge.
2. Increase water harvesting in the basin to replace the need for water in Agriculture.
3. Finding other resources of water especially, to subsidize the amounts pumped to Amman and Irbid as drinking water.
4. Using solar energy for water desalination.
5. Thinking of the revenues from conserving such wet ecosystem in terms of ecotourism and other socioeconomic values.

4. ZARQA RIVER AND KHIRBIT AS SAMARA SEWERAGE STATION

4.1. Preamble and site description

Amman old roman city Philadelphia was founded initially on a hill overlooking a river course and with beautiful downward extensions reaching the river, with formation, intact, gracious Amman Roman Amphitheatre; as well as the swimming pools and bath, known as the (Hamman Al-Huriate). This river was named Zarqa River, due to the fact that it was passing later on the city of Zarqa and continuing to Jerash bridge the continuing down to the Jordan Valley near the village of Dair Alla until it meets the River Jordan. It was passing from altitude around 800 m in Amman until reaching the Jordan River in point of about 300 m below sea level. Due to the increase of Amman populations after the floods of Palestinian immigrations at various stages, the river became highly polluted and dumping of uncontrolled sewage water.

To avoid this problem the government has forbidden any dumping of pollutants as much as possible and initiated a fresh water pumping station at the starting pint of the river springs. This has reduced the amount of water available in the river to its lower amount, to the extent that the river became almost dry in the summer time. Nevertheless, the river used to be call in Arabic *Sail Amman or Sail Az- Zarqa*, (means a water path with little water). The sail thus had been totally paved to become a main road in the old city centre, extending outside the city centre, in a place called Ain Gazal, near Mahatta in N.E. Amman. In that particular area *Ain Ghazal* sewage station was built. Later on this station was too small to treat wastewater coming from an ever-increasing city of Amman.

Accordingly, a new sewage station was established in Zarqa Governorate in a place called Khirbit As Samara, near Sukhna village. It was initially aimed at treating 20 m³/. But later on it was enlarged to treat up to 50 m³. The station often receives more water than can deal with. This occurs especially, during wintertime when flooded rainwater inters into the drainage sewage system and during summer time, when the population increases due to the return of Jordanian workers during the summer months, in addition other Arab visitors. During these periods the amount of untreated water reacting the station exceeds the treating capacity. Thus, untreated water would overflow directly to the Zarqa river or, the treatment will not be complete and also water is transferred to the Zarqa river.

4.2. Results

Along the course of Zarqa River one would observe brownish colored water with often dense foam covering the water (Al-Dwiri, 2004). This colour is due to the heavy loads of organic matter coming

with treated water; in addition to that, water is often added illegally to the course of the river from various industries, such as: textile, batteries and oils from garages and car wasting station. However, water samples along the river course, as well as plant biodiversity were studies.

Results have proved that water quality has moderately to high content of organic matter (BODs up to 180 mg/L), salinity (EC up to 2770 µS/cm), TDS (up to 1800 mg/L), Chlorides value (up to 430 mg/L). Al-Dwiri (2004) claims that the results of heavy metals fall within the accepted standards and do not form a threat to agriculture.

Samples of plant analyses taken from the same sites of water samples have shown similar correlation with the results of water analyses. Organic pollution was represented by the values of ammonium concentration was up to (416 mg/L); Nitrate concentration was up to (185 mg/L).

The most important thing is, that Zarqa River is identified as a fresh water ecosystem.

Usually fresh water ecosystems in Jordan are characterized by having an association of special group of water plant which was found to be missing in most of the time along the course of the river except in minor locations when unpolluted fresh water is joining the river course from the side wadies adding their water to the river.

4.3. Sequences of the problem

4.3.1. Water pollution

The quality of water coming from the sewage plant is polluted with high organic contents and minerals but previous microbiological studies have also proved the presence of other forms of infectious bacteria (Hashwa, 1985).

4.3.2. Altering and loss of plant biodiversity

Plant biodiversity along the river course was studies thoroughly, and staring enough most of fresh water plants were either absent or present in small numbers and very low density in comparison to other fresh water systems in the country. Usually dense growth of fresh water edible plants such as: *Nastortium officinale, Apium nodiflorum, A. graveolens, Rumex cassius*, *Mentha longifolia*, and *Lipidium latifolium*, are very rare or absent. These plants have been observed in case as scattered batches away from the water along the drier sides. In addition, even cattails, rushes and reeds where also absent. Oleander (*Nerium oleander*) is a common plant along the course of fresh water in Jordan was rarely observed and mostly observed at the joints where fresh water is mixing from a side pituitary.

4.3.3. Use of polluted water in agriculture of vegetables

It is very unfortunate that, the water along the course of Zarqa river is pumped directly and used to irrigate crops of leafy vegetables such as: parsley, spinach, cabbage, cauliflower, lettuce, and sometimes potatoes. This practice used to be forbidden in the past, but under the continuous complains of the farmers this practice was overlooked until it became a normal practice. These plants have caused in the past cases of severe diarrhoea and other symptoms of infection.

4.3.4. Mixing polluted water with fresh water of King Talal Dam

The water in the King Talal Dam is designed to be collected from the rainwater, with a capacity of about 80 m^3. But when 50 m^3 of polluted water coming from the station is mixed, then quality of the water in the dam will be definitely altered. This may be ok if we have a good rainy season, but if the season is not good then the quality of water becoming worse, especially, if we know that one of each five years is a good rainy season.

4.3.5. Bad smell effect and Mosquito problem

Khirbit As Samra Sewage plant was designed to serve almost 60 % of the population in Jordan. The station is forming a vast area of untreated of water pools, which produce serious air pollution from the smell, spreading tens of kilometres. In addition, mosquitoes and houseflies are making the situation beyond tolerance. People in the vicinity are always complaining, some have left their homes, and land prices has not increased as other parts around the major cities, which has doubled many folds.

4.3.6. Increasing pollutants in the fertile soil of Jordan valley

The water of the King Talal Dam is usually channelled and used for irrigation of various crops in the Jordan valley. This water has altered the soil characterizes in the irrigated areas especially, salt, nitrogen contents and pesticide concentration (Khatari, S. special communication).

4.4. Suggested solutions

4.4.1. Treatment of water to higher levels

The treatment of the water coming out of the station must be checked thoroughly to make sure the quality is good enough to match the water received from rain. The amounts of organic matter, salts and detergents must fit with the international standards without being able to make the colour of the water brownish and foamy.

4.4.2. Avoiding overflow of the station

Overflow of sewage water in the main station should be avoided to make sure no untreated water would reach the Zarqa River. This can be achieved by making sure that no mixing of rainwater with sewage drainage system, which causes the overflow during winter times. In summer times as a result of population increase part of the sewage water should be directed to other treatment stations near by.

4.4.3. Initiation of smaller stations to replace the central station

It is now believed that treatment of sewage water through a series of smaller stations in various parts of the major cities is much more efficient than having a central station. This will insure, better treatment and no overflow, it will insure also less smell and less insects. The draw back of this mechanism is the financial needs to establish such network of stations and secondly the 50 ^{3}m of treated wastewater was calculated as part of the agriculture water budget, will be partially or completely lost.

4.4.5. Avoiding mixing water with king Talal Dam

Some of the suggestion in the previous points would guarantee avoiding mixing treated sewage water with rainwater. Or channelling treated water for other purposes as in the following point.

4.4.6. Divert the water flow for the eastern desert

This method suggests to use treated water with its characteristics to the dry desert for the use of production of green built to avoid dust and to increase the chance for various elements of biodiversity. The water can also be used to star forest trees to act as a green built and timber production, provided that natural plant species should be used.

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