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Water issues in the Kingdom of Jordan: A brief review with reasons for declining quality

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Abstract
This paper examines the problems of water shortage and quality issues in the Kingdom of Jordan. Demand for water has led to a decimation of ground water supplies and a significant rise in salinity. This rise in salinity can be traced to increasing saline base flows, the reduction in natural flows, changing extent of agriculture, agricultural practices, contamination of irrigation systems with saline inflow and poor infrastructural planning. Water security in Jordan is a very serious issue due to the rapid increase in population growth. Jordan is faced with the need to tighten regulations in water treatment, address the issue of domestic supply losses and illegal drawdown of ground water in the short term to gain significant inroads into the water problem. However, in the longer term, there is a need for a review of current infrastructure and its functionality, changing agricultural practice and finding sustainable sources of water.

Key words: Water quality, water supply, water pollution, salinity, agricultural practice.

Introduction

Water resources available in Jordan have declined over the last half century; particularly as a consequence of increased population pressure, over-exploitation of aquifers for agriculture, and geopolitical impacts such as neighbouring countries restricting supply [1, 2]. Water in Jordan is also negatively and significantly impacted by highly variable climatic conditions, the significant mismanagement and loss of captured water resources, and by increasing pollution such as salinity [2]. Problems with, and access to, Middle Eastern water supplies and quality of that water are often touted as the historical cause for many of the regional conflicts [3-5]. Water is a key factor in the creation of a sustainable peace through increased cooperation and economic growth between neighbouring countries [4, 5]. Irrespective, the current use of water in Jordan is unsustainable and water strategies do not address this deficit in the long term [2].

Water management in Jordan becomes more complex due to an arid climate, maladministration of the nation's water resources and factors surrounding high population growth, particularly as the regions become more politically unstable in the near term. The importance of understanding water use and saving technology has been identified as one of the key future initiatives to reduce the pressure on Jordanian water supplies [2]. The economic issues fundamentally related to water in Jordan, such as the estimation of irrigation water demand and the complexities of the demand and supply functions for drinking water, have received little attention in the academic literature adding insecurity to future supply availability. The socio-economic impacts of the decline in water quality and availability are mostly felt within the agricultural sector including increased unemployment and poverty [2].

Jordan's past policies regarding water do not seem to have contributed to solving the shortage of water, primarily as a consequence of ineffectual implementation [2]. Problems contributing to not achieving implementation include the basic lack of financial and human resources to achieve goals, higher government policy priorities and a lack of ground level support for change based on personal perception [6]. This has led to a culture of inaction and as a result, the problem of water deficit persists and continues to deepen [7]. Decisions on the new development of land are often made without effective environmental considerations; if they exist, it is only in the context of the short term [2].

Irrigation practices are an example of short term-vision in water policy in Jordan and neighbouring countries, where increasing pollutants such as fertilisers and increased salinity are only now becoming critical to the survival of that sector [8]. Albaji *et al.* [9] noted that there is increasing pressure in the Middle Eastern region to increase production in order to meet population growth with ever more limited water resources. The experiences of Jordan and its neighbours has added focus to the clean up and regulation of current agricultural irrigation water use in this area [10]. The aim of this review was to examine the issues of water in the Middle East, but particularly Jordan, and then provide an overview of the issues under current discussion and action in Jordan.

Water in the Middle East

The Middle East is an area of low precipitation and high evapotranspiration, much of it with less than 200 mm precipitation a year and potential evapotranspiration of over 2000 mm. This defines the climate as 'arid' [1]. It has few rivers, arising in the mountains. Two of them, Euphrates and Tigris, are a major source of water in the region. Another river, the Jordan and its tributaries, is of significance to the west of the region. The limited water resources of the region have led to international disputes over water supplies; for example, between Syria and Turkey over the Euphrates and Tigris rivers [1].

Many of the countries in the Middle East have declining water supply issues in contrast to neighbouring countries, which has increased the regional political tensions [11]. Israel, for example, has about 300 m^3 of fresh water available per person per year and Kuwait about 1 m^3. Palestine, in the Gaza strip, is facing depleted supplies, increased salinity and pollution from boron [12]. It is estimated that 90% of available water in the Gaza strip is unfit for human consumption as a consequence of pollution [13]. This pollution has been identified as seawater intrusion, untreated urban waste as well as increasing natural salinity and quality decline [13]. These problems have been exacerbated by over pumping and low recharge rates. In recent years, large population increases into some areas resulting from immigration, refugees from the Palestine and Israeli conflict or high birth-rate have made agreement on equitable distribution of water imperative. This has been exacerbated by a series of historical Arab–Israeli conflicts and disputes between Arab countries in the region [1].

Secure water supplies have been a primary concern for Israel ever since the creation of the state in 1948. In the 1950s there were plans to share water of the Yarmouk River, a tributary of the Jordan River, and Lake Tiberias with Jordan and Syria [1]. However, Syria objected to Israel's plans to divert water from the Jordan above Lake Tiberias and Israel objected to a Syrian scheme to dam the Yarmouk as it would reduce flow into the Jordan [1]. The 1967 war resulted in Israeli occupation of the Golan Heights, southern Lebanon and the West Bank, which strengthened Israel's water supply position, as it controlled the headwaters of the Jordan and aquifers of the West Bank [1]. Drought and increased extraction during the late 20^{th} century reduced the levels of Lake Tiberias and increased its salinity to levels that threaten its aquatic life. Moreover, increasing groundwater exploitation above the safe yield has lowered aquifer levels, causing saline intrusion into the coastal aquifer, with potential to destabilise regional politics [1, 13, 14].

The other major area of water dispute in the Middle East involves the Euphrates and Tigris rivers, which rise in the mountains of Turkey and flow southwards into Syria and Iraq, which are dependent on these rivers for most of their water supply [14]. Turkey, as the upstream country, claims the right to control the water that originates within its border. Iraq claims historical rights to these rivers as its people depended on them for thousands of years, in what was Mesopotamia, using them for large-scale irrigation. Unfortunately, there is just not enough water for all the countries, leading to conflict and, at times, threats of war [14].

There has been a move in the Middle East to introduce an integrated approach to water demand management (WDM), which aims to optimise available water [15]. Effective WDM involves five key objectives to utilise existing water supplies rather than develop new ones [15]. These include economic efficiency, social development and social equity, environmental protection, sustainability of water supply and services, and political acceptability. In order to achieve these objectives, there are four strategic approaches through targeted action and planning [15]. Table 1 shows the four strategic approaches with recommended areas in which water savings can be achieved within the Middle Eastern Region.

There are four unifying factors that govern the water resource debate in the Middle East and North African regions, these are often the result of poor and improper management practices that limits water access [15]. Firstly, the available water resources in the Middle East are scarce and difficult to exploit. Secondly, there has been an increase in the demand for municipal and industrial water driven by population growth rates significantly above world averages. Thirdly, there is a lack of expertise in water management and a lack of initiative for a holistic approach to regional cooperation to resolve water issues. Finally, the structure of the water industry is significantly slanted towards supply and it is highly centralised.

Water Use in Jordan

There are three significant users of water in Jordan: municipal, industrial and agricultural; however, most concern has been with municipal water supplies at the cost of agricultural and industrial use [2]. This emphasis has meant little focus on the issues of pollution from fertilisers and other industrial and agricultural outputs; rather the focus has been targeted at illegal use of water[2]. Table 2 illustrates the current use of water and where that water has been appropriated in 2010, indicating that agriculture is the largest single user of water, both surface and aquifer one.

Agricultural extraction of water in Jordan has become a significant diversion of, and concern to, the national water supply [17]. The diversion of highland water by private irrigators, coupled with the use of water in the Jordan Valley for irrigation, has led to over-exploitation and degradation of the water system

Table 1. Strategic approach to WDM and the areas of water management that fall within that strategic sphere [15].

Economical	Institutional/Regulatory	Technical	Educational/Behavioural
Tariffs to mediate demand	Legislative controls and regulations	Accurate metering of measure consumption	Seminars and workshops
Financial rewards and incentives to save water	Regulated building and plumbing codes	Leak detection	Media campaigns
Enforcing polluter pays	Increasing capacity of supply institutions	Pressure monitoring and water saving devices	School curriculum
Market driven allocation	Land use regulation	Computerise water monitoring and distribution	Competitions and festivals
	Decentralisation of water at local level	The implementation of water saving devices	

Table 2. Water use in Jordan by sector and source (million m^3/year) [16].

Sector	Surface	Ground water source	Waste	Total
Municipal	46	170	-	216
Irrigation	350	313	52	715
Industrial	2.5	22	-	24.5
Others	515	3	-	54.5
Total	450	508	52	1010

as a whole [17, 18]. Molle *et al.*[18] argued that the best method of regulating the use of agricultural water leading to long-term sustainability for water use in agriculture was through the imposition of increased water taxation. The increase in the water tax on agricultural lands would lead to a shift from water intensive cropping of high water demand crops to those with reduced water dependence [18]. Increasing the price of water will lead to an increase in water efficiency; however, in the long term, it is only with a shift in farming practices that effective water use in the agricultural sector in Jordan can be achieved [19]. It is the role of government regulation and structural reform, while offering incentives for capital and risk minimisation, to assist farmers to move to alternative crops or exit high water intensive industries with compensation [10, 17, 18].

Jordan encounters considerable domestic water pressures with water rationing in Amman, having been implemented continuously since 1987, leaving many households with mains-water for as little as one day a week [20]. This lack of regular main supply has led to the illegal tapping into the water system with 30,000 prosecutions for water violations recorded in 2004 [20]. The Amman urban water system is in crisis with 54% of 105 million m^3 of water entering the system lost and unaccounted for in 2004 [20]. The urban population of Amman overwhelmingly (80%) considered the water supplied to their household as polluted with over chlorination, dirt, sediments and algae [20]. Table 3 illustrates the cost of water to each sector and associated consumption at current economically and environmentally sustainable levels [7].

Pollution and Water Supply

Water distribution systems, such as the Israeli National Water Carrier and the Jordanian King Abdullah Canal, distribute water from areas of water surplus to areas of water deficiency. However, there has been a growing issue with pollutants coming into the canal such as salts and other agricultural runoff, which has led to a rethink in agricultural water use [21]. The northern end of the King Abdullah Canal receives water diverted from the Yarmouk River via a 900-m long tunnel.

In 1994, the water use in Jordan, estimated at 3050 million m^3, was withdrawn from wells (56%), springs and surface-water sources (35%), and wastewater recycling and artificial recharge (9%) [7, 22]. Within this water use, non-renewable, estimated at 375 million m^3 per year, is derived from the aquifers without being replenished [7]. Desalination of brackish or sea water sources has been identified as one of the most significant ways to alleviate water issues in the short term. However, leak reduction in existing municipal infrastructure, increased water awareness and conservation measures, and the increased use of treated wastewater have been mooted also as possible water alleviating measures [22, 23]. Desalination and the transportation of seawater from Aqaba to the Dead Sea have been investigated as potential solutions for the growing water issues in Jordan and they offer the best long-term solution to the stability of Jordanian water supply [24].

The depth of ground water is highly variable in Jordan, ranging from 2 to 1000 m. The recommended safe yield is estimated at 276 million m^3 per year, indicating that the current use is 161% above safe yield [7]. The primary reserves of ground water are found in the south of the country with supply estimates of 90 million m^3 per year for 100 years [23]. One of the most significant problems with the use of ground water is salinity with salt levels varying between aquifers from 170 to 3000 parts per million. Natural salinity is a direct consequence of the surrounding geological formations [16, 25, 26]. Möller *et al.* [27] determined that the Jordan Rift Valley, that feeds the Dead Sea, had five geological formations which contribute a natural saline base-flow: recent Dead Sea and Lisan Lake water concentration due to evaporation with magnesium levels higher than calcium; the Neogene Sdom Sea evaporation, with a chemistry of magnesium levels higher than calcium in Ha'On for example; Zemah type sodium and calcium brines from secondary Neogene to recent ablation; the Tiberius Hot Spring and Tzofar [20], which are Neogene brines with higher calcium than magnesium; and Devora type deep water brines, with a high variability in chemistry.

The problems with salinity are often exacerbated by over draw-down and subsequent concentration and contamination of the aquifer, as demonstrated in the nearby Gaza region during the period 1994-2004 [28]. Many of the works constructed in the Jordan Valley to alleviate the water pressures have been based on unsound science [29]. Pitt and Alkhaddar [30] argue that suitability can only be achieved through pipes and desalination, such as the Red to Dead Sea pipe which would use the 500 m hydrologic difference to drive the desalination process.

The Karama Dam was constructed in 1995 on the Wadi Mallaha to provide irrigation water to farmers during the dry season. It is

Table 3. Household water consumption and associated costs [20].

Aspect of consumption	High-income households	Low-income households	Entire sample
Average consumption (m^3 per quarter)	70.24	32.68	51.68
Average water bill per quarter (JD)	55.8	14.84	36
Households buying bottled water (%)	44	20	32
Average spent on bottled water (JD per week)	10.45	8.2	9.75
Households buying water off private water tankers (%)	24	4	14
Average spent on water from tankers (JD per week)	20	17	19.57

situated atop the Lisan Mari salty formation, which has led to significant issues of salinity rendering the dam water unusable since construction [7]. There are three primary sources for the 503,000 tons per year of salt added to the Karama Dam each year: the catchment of the dam is estimated to carry 50,000 tons per year of surface salt from the King Abdullah Canal. The contributions to the dam from Wadi Mallaha and surrounding springs have also exacerbated the problem faced with salinity in the dam with these sources adding a further 137,000 tons per year of salt, the sedimentary base of the dam contains an estimated 6% soluble salts contributing 250,000 tons per year. The return of irrigation water also impacts flushing an estimated 66,000 tons per year into the system [29]. Infrastructure that supports the dam has been significantly damaged due to corrosion in the high salt environment leading to blow-outs in the maintenance costs with no benefit to the downstream agricultural systems [29]. The King Talal Dam is the largest resource in surface area, but it has suffered significant pollution as a consequence of industrial and domestic waste entering the catchment untreated, and while dissolved salts are deemed within safe limits for irrigation there are consequences for organic compounds [31].

Salinity in Water Sources in Jordan

Surface water: Surface water from Jordan ends in the Red or Dead Seas [32]. The Lower Jordan River base flow was in crisis during the 2001 drought, in which flows declined to 500 to 1100 Ls^{-1}, 2.5% of the average flow rate determined from historical records, with the drought leaving lasting environmental damage within the catchment [33]. There has been an increasing problem of agricultural contamination and environmental damage as a consequence of increasing draw-down. Increasing declines in agricultural production due to rising salinity are a consequence of accumulation of salts from saline surface water used to irrigate[2].

Groundwater: It constitutes the primary source for water in Jordan, with 80% of the country having access to this source and at current usage levels is unsustainable [2, 34]. There are 20 ground water basins in Jordan based solely on the basis of hydro-geological factors, these may differ from the administrative boundaries dictated by water-resources institutions [2]. Each basin may contain several aquifers of different ages and areal extent occurring at different depths. Although a rock formation may have properties favourable for the storage of water, it must be in contact with a source of water for recharge. It is the recharge which defines the type of ground water: renewable accounting for 5% of total ground water and fossil, which constitutes 96% of all ground water [16].

The most productive aquifers in Jordan are in the Quaternary sand and gravel in the Coastal Plains, the Cretaceous limestone in Belt Mountain region containing both the Jordan Rift Valley bordering ranges and regions of the Jordan Highlands, basalts of the Jordan Highland and Plateau, and finally sandstone of the South Jordan Desert, with each having a different susceptibility to salinity [7, 34, 35]. Springs flowing from aquifers in Jordan are often significantly contaminated with salts, the concentrations and chemistry of which are innate to the geological formation from which it sprang [7]. Each source of groundwater needs to be considered independently in order to achieve effective management of the risk of salinity associated with each formation's chemistry [29, 34]. This is in contrast to the national approach, which seeks to unite all aquifers under one policy set of guidelines for use [2].

Recharge to the ground water from anthropogenic activities such as seepage ponds, irrigation seepage and wastewater infiltration have the potential to further add to the contamination of the saline aquifers [36]. Contamination of fresh groundwater by saline water is a common problem in Jordan with extensive plans for management in place for over a decade having done little to alleviate the problems [37]. There has been a substantial rise in the level of salinity afflicting the entire Jordan water system. Natural sources of saline water in Jordan include the encroachment of sea water near the Mediterranean Sea and Red Sea, upward migration of highly pressurised brines in the Jordan Rift Valley and other areas, and subsurface dissolution of soluble salts originating in rocks throughout the region.

Mohsen and Al-Jayyouse [38] argue that effective desalination of brackish water is a viable option to reclaim a significant portion of the national water budget that is currently unavailable for use and often environmentally damaging. Heavy drawdown of ground-water levels has led to changes in the natural flow directions of the water contained within the aquifers. Consequently, the saline water has contaminated a previously freshwater aquifer [39]. The waste from agriculture has been identified as one of the single most important non-natural pollutants, particularly in the exacerbation of salinity issues, affecting the entire water system in Jordan. Some studies indicate that agricultural wastewater can increase the salinity levels of aquifers [40].

Dead Sea watersheds: During the last four decades, water resources in the Dead Sea watersheds have needed intensive development to meet growing demands for water with growing agricultural and industrial sectors [41, 42]. The current inflow into the Dead Sea is less than one half of that in 1964 after the agricultural and water infrastructural development in the upper catchments, particularly the Jordan, Yarmouk and Zarqa Rivers, leading to significant environmental concerns and damage [41].

Conclusions

Jordan is a country faced with a historical water problem that has the potential to get worse in the near future. At present, little is being done to address the problems of rising salinity, particularly in ground water. The lack of effective regulation has seen the over exploitation of water resource that has generated a significant degree of pollution. This pollution is a direct consequence of agricultural and industrial waste disposal and water use, coupled with an ineffective urban treatment system. Without the effective overhaul of the water management system, major structural work and a refocus on the utilisation and treatment of contaminated water, the future for water in Jordan is not promising, especially with the near neighbours having the same water issues. These issues have the potential to destabilise the region, a significant factor in the economic equation to resolve the regional water issue collectively.

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