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The Effect of Water Shortage on Water Quality of Different Resources in Jerash Governorate/Jordan, Based On New Water Quality Index

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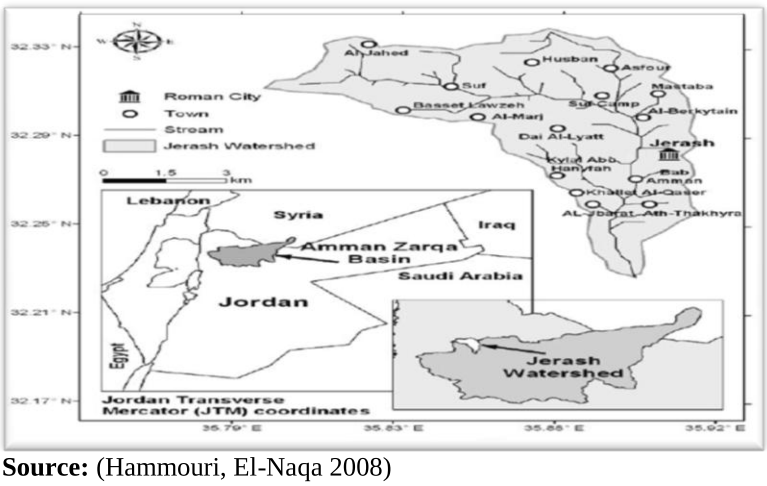
ABSTRACT
The individual average of water share In Jerash governorate is only 71 litres per day and that is the lowest allotment in Jordan. The aim of the study is to assess water quality of different resources in Jerash governorate, based on demographic, chemical and biological changes within a period of 11 years. Cluster survey method was applied and samples of drinking water were taken from different resources. Water of municipality and bottled groundwater resources were of acceptable quality; groundwater of tanker trucks and wells were also acceptable except that of high level of nitrate; spring water and harvested rainwater were potentially not safe and susceptible for biological contamination. At level of sub-districts, based on a new developed water quality index, it was chemically found that water in Mastaba sub-district was more complying with standards than Jerash and Burma sub-districts, but in biological respect both Jerash and Burma sub-districts were more compliance with the standards than Mastaba sub-district. In general, drinking water in Jerash governorate was chemically found of medium quality, and biologically of good quality.
Keywords: Falkenmark indicator, Gleick scarcity index, Jerash governorate, Water quality, Water shortage.

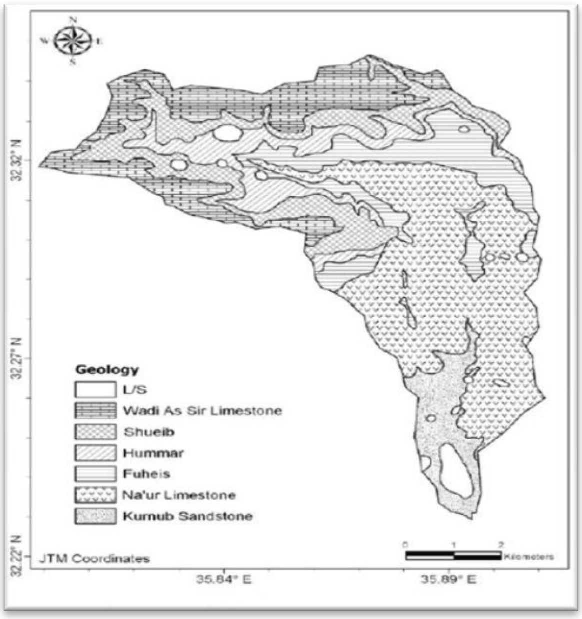
I. INTRODUCTION

Jordan is considered a good example of the countries suffering from shortage of water to meet the escalating needs. The consumption per capita does not exceed 54 cubic metres per capita per year [1]. Only 60% of water needs is met in Jerash governorate. The individual average share is less than 27 cubic metres per a year presenting the lowest percentage of water allocated in Jordan. Accordingly, Jerash imports water from neighbouring governorates as Mafraq, Irbid and Zarqa. Generally, Jerash governorate water requirements are mainly 35% for domestic use, and 65% for agricultural sectors use [2]. In addition, Jerash watershed comprises an area of 39 km^2 located in the north western part of Amman–Zarqa basin, as shown in Fig. (1).



Source: (Hammouri, El-Naqa 2008)
Figure (1): Jerash watershed location

Moreover, the groundwater resources in Jerash watershed are provided from Kurnub sandstone aquifer (K), Hummar dolomitic limestone aquifer (A4), and Nau'r limestone aquifer (A 1/2) (Fig. 2).Also, there are thirteen major springs of which five emerge from the A4aquifer, six springs from A1/2 aquifer and two springs from K aquifer.



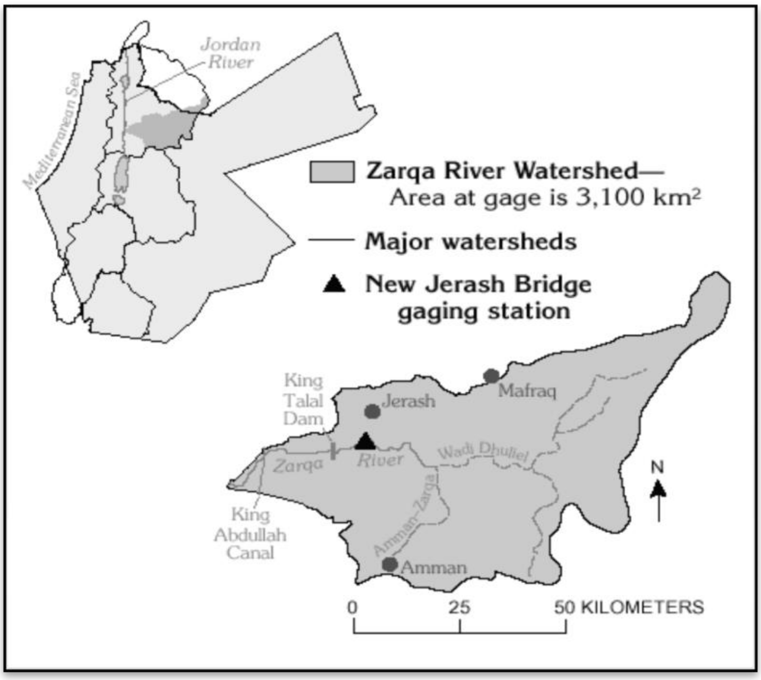
Source: (Hammouri , El-Naqa 2008)
Figure (2): geologic map of Jerash watershed

It was given by ministry of water and irrigation that the yield of wells in Jerash catchment was around 5 million cubic metres, while reached around 30 million cubic metres for the adjacent wells of Jerash catchment. However, the drawdown of total wells was about 36 million cubic metres. Furthermore, the discharge of springs was about 4.1 million cubic metres [3].

Water quality refers to the physical, chemical and biological characteristics of a water body. These characteristics determine how and for what water can be used and the species and ecosystem process it can support. From human health perspective, water shortage or scarcity will affect its quality. Thus, if the quality of water is improved, people with access to safer, cleaner and healthier water facilities shall become beyond many risks, health care burden shall be reduced and people shall also be able to lead more productive lives. However, there is no one answer to the question of 'what is water quality'. There are many different physical and chemical parameters that can be used to measure water quality [4]. Therefore, there is no single measure at global level that can describe overall water quality of any water source. Thus, a built-up index that quantifies deviation of water quality measures from normal/ 'ideal' concentrations could be more appropriate for summarizing quality conditions of water types, and over time [5].

Therefore, there is no single measure that can describe overall water quality for any water source, be alone at a global level. Thus, a composite index that quantifies deviation of water quality measures from normal, 'ideal' concentrations could be more appropriate for summarizing water quality conditions of water types and over time [5].

The team of An Integrated Watershed Management Project implemented in Jerash Governorate- reported that the natural base flowing in Zarqa River had become insignificant due to over abstraction. Thus, winter floods, As-Samra Wastewater Treatment Plant (in Zarqa governorate) and effluent constitute the major sources of the river flowing in summer months, which is finally stored in King Talal Dam [2] (Fig. 3). Moreover, it was found that water quality of King Talal dam is acceptable only for restricted irrigation purposes with slightly increases in TDS, BOD5, and NO_3 [6].



Source: http://exact-me.org

Figure (3): Location of Zarqa river and king Talal dam

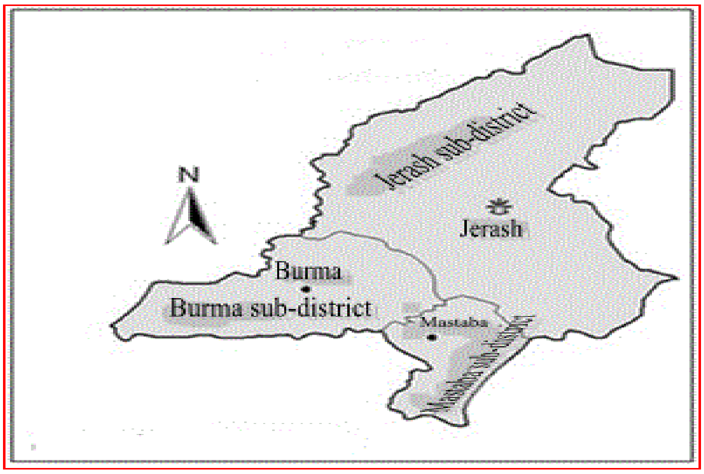
Another study performed on Amman-Zarqa basin based upon long-term data (1970–2005) of groundwater, samples collected from 538 wells across the basin, found that inefficient wastewater treatment of plants constitutes 91%, industrial activities 85%, and agricultural practices 25% of responsibility for salinization of wells. Also, it was found that Nitrate pollution reached values above threshold concentration of 50 mg/L in some wells [7].

The main objective of this study is to assess chemically and biologically drinking water quality of different water resources used in Jerash governorate in 2012/2013.

II. METHODS

The study was performed on two stages reviewing official records from 2000 to 2011 existed in General Statistical Department, Ministry of Water and Irrigations, and Ministry of Environment; in addition to collecting water samples from different water resources.

As shown in Fig. (4), Jerash governorate consists of three sub-districts: Mastaba, Burma and Jerash. Sub-districts were divided into clusters, each cluster contains 2500 persons. The total clusters were 65, and then seven clusters were selected appropriate to the size of the sub-district. Houses were drawn randomly within each cluster.



Source: (General Budget Department 2010)

Figure (4): Administrative Sub--districts of Jerash Governorate

Anumber of drinking water samples were drawn from different water resources to determine chemical and biological contamination (lead, nitrogen group, fluoride, E. coli, and total Coliform) [8; 9]. The number of houses included was 810, and water samples were 81 distributed as follows: Jerash sub-district, 5 clusters: 578 houses and 58 water samples; Mastaba sub-district, 1 cluster: 116 houses and12 water samples; Burma sub-district, 1 cluster: 116 houses and 10 water samples.

Attention was paid to water resources that are not controlled by Water Authority and Ministry of Water and Irrigation, like springs, rainwater and tanker trucks because there is more possibility to be exposed to contamination. So, the samples drew were10 samples of municipal piped water, 12 samples of spring water, 20 samples of tanker truck groundwater, 11 samples from bottled treated groundwater, and finally 20 samples of collected rainwater.

III. RESULTS AND DISCUSSION

3.1 Population growth

As shown in table (1) the population of Jerash governorate has normal increment (from 145700 to 187500). Also, the growth rate on the last six years was stable [10]; however the density of population was slightly increased (from 318.4 persons to 409.8 persons/1 km^2). The growth rate of Jerash governorate was similar to National growth rate (2.2) over the period 2007-2011.

Table 1: Population density and growth rate in Jerash governorate during 2000-2011

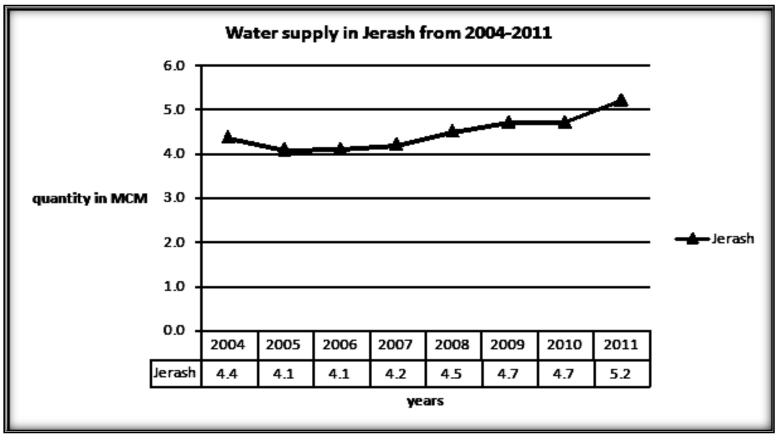
Year	Population	Population density (Person/Km^2)	Growth change	Population growth rate (%)
2000	145700	318.4	4,500	3.19
2001	149300	326.3	3,600	2.4
2002	152900	334.2	3,600	2.4
2003	156900	342.9	4,000	2.6
2004	161000	351.9	4,100	2.6
2005	164300	359.1	3,300	2.0
2006	168000	367.2	3,700	2.2
2007	171700	375.3	3,700	2.2
2008	175500	383.6	3,800	2.2
2009	179400	392.1	3,900	2.2
2010	183400	400.8	4,000	2.2
2011	187500	409.8	4,100	2.2

Source: General statistical department

Moreover, based on the latest population and housing census performed in 2004, 98.3% (19171 out of 19496) of non-Jordanians in Jerash governorate were Arabs. Only 0.3% of Iraqis lived in Jerash governorate. In addition, there are two Palestinian camps: Souf Camp which has 19,051 persons in 2003; and Jerash Camp, also called Gaza- camp, has 27,916 persons in 2003 [11]. Furthermore, Jerash ancient city attracts many non-Jordanian people annually to visit, especially at the time of the annual festival. For example, in 2010 and 2011 there were 354,608 and 179,700 visitors consequently.

3.2 Water supply

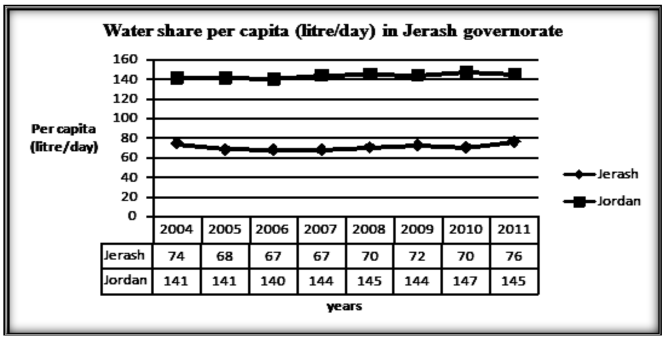
As shown in Fig. (5), quantity of water supply in Jerash governorate has started to increase since 2006. In general, quantity of water supply in Jerash governorate was small when compared with other governorates.



Source: Ministry of water and irrigation

Figure (5): Distribution of water supply in Jerash governorate during 2004-2011 (in million cubic metres (MCM))

In Fig. (6), it is shown that municipal water share per person was as half value of that of the whole Jordan. The highest share was 76 litres in 2011 versus 145 litres in other governorates of Jordan.



Source: Ministry of water and irrigation

Figure (6): Water share per capita (litre/day) in Jerash governorate and Jordan during 2004-2011

3.3 Water stress

According to the Falkenmark Indicator, there is absolute water scarcity when there is less than 500 cubic metres per person per year [12; 13; 14]. So Jordan as well as Jerash governorate suffers from absolute water scarcity (52.33 m^3/year/person in Jordan, 25.73 m^3/year/person in Jerash governorate). Therefore, living quality as well as health and water quality is expected to be low or dramatic. On contrast, according to Gleick scarcity index, Jerash water share per capita was exceeding 50 liters per day, and that is the basic daily amount for life needs (drinking, bathing, food, sanitation, and preparing food) [13].

Jerash governorate is among the top three governorates that have low average water share per capita (Jerash 71, Ajlouni 75.1, and Irbid 96.1 litres/day). Moreover, water share in Jerash governorate varied over the years, as shown in Fig. (6), and that can be explained by rainfall change, climate change, population growth, implementing projects and rainfall harvesting.

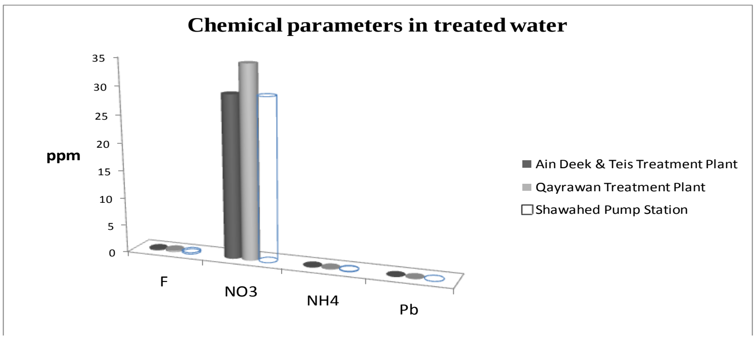
3.4 Data from official records

33.4.1 Raw ground water

According to official records of Ministry of Water and Irrigation concerning Jerash governorate over 2000-2011, all values of E. coli of raw water were highly above the Jordanian standard. Luckily most strains of E. coli are relatively harmless; and easily treated with chlorine [15].It was recorded that microbial contamination was the highest at Qayrawan treatment plant.This can be attributed to the location of Qayrawan plant which is near houses with cesspools. Also, all values of fluoride, lead, Ammonia, TDS, and pH were in compliance with national standards; while nitrate was above standards due to fertilizers and poor sanitation.

3.4.2 Treated ground water

At level of water treatment plants and pumping stations in Jerash governorate during 2000-2011, the pH and conductivity for both raw and treated water were in compliance with national standards of drinking water, which indicates that no chemical leaching is attributed to industries or solid wastes dumping [9; 16].Concentrations of TDS in water vary considerably in different geological regions owing to differences in the solubility of minerals. However, the presence of high levels of TDS may also be objectionable to consumers [15]. Moreover, values of fluoride, ammonium, and lead in treated water in Jerash governorate during 2000-2011 were below Jordan national standards of drinking water.



Source: Ministry of water and irrigation

Figure 7: Average values of fluoride, nitrate, ammonium and lead of treated water at treatment and pump stations in Jerash governorate during 2000-2011.

In Ain Deek and Ties, Qayrawan, and Shawahed locations, values of lead were zero, while ammonia values were 0.1 ppm; and nitrate values (29.26, 34.59, 29.22 consequently) were below WHO standards and nationals standards (Pb 0.01 mg/l, NH_4 0.2 mg/l, NO_3 $\leq$ 50 mg/l). However, Qayrawan treatment plant had higher average values than others.

World Bank revealed that the nitrate content in different wells was significant, and in some wells exceeded the limits for drinking water quality particularly in Amman-Zarqa basin, but was less alerting in the other basins. On the other hand, the number of E. coli and level of nitrate in some treated underground water was not within standards.

3.4.3 Surface water

Based on surface water tests performed by the Ministry of Environment in collaboration with Royal Scientific Society, water of King Talal Dam can be used for unrestricted agriculture, and according to FAO guidelines, physical and chemical results also revealed that water can be used for moderate and tolerable salinity, Boron and Sodium crops; and can be used for tolerable Chloride crops. Also, high level of Bicarbonate (337 mg/l), Sodium (286 mg/l), Chloride (444 mg/l), and drip irrigation can be used [17]. While Chemical and biological characteristics of water of Zarqa river/ Jerash security point suited restricted agriculture only, and that is due to deterioration of water quality due to wastewater discharged from factories and As-Samra wastewater treatment plant [17]. Furthermore, according to FAO guidelines, physical and chemical test results revealed that water of Zarqa river (at Jerash security point) can be used for moderate and tolerable salinity, Sodium, and Boron crops; and can be used for tolerable Chloride crops. In addition, high level of Bicarbonate (285 mg/l), Sodium (266 mg/l), Chloride (402 mg/l), and drip irrigation can be used; however cautious should be taken when using nitrogen fertilizers because of high level of nitrate (the average value was 52.6 ppm) [17].

Moreover, according to WHO guidelines, water of Zarqa river/ nurseries area can be used for restricted agriculture only. While according to FAO guidelines, physical and chemical test results revealed that water in this location can be used for tolerable salinity and chloride crops; for moderate and tolerable Sodium and Boron crops. Furthermore, high level of Bicarbonate (720 mg/l), Sodium (365mg/l), Chloride (569 mg/l), and drip irrigation can be used after water treatment. Also, because of the level of manganese (83 ppm) and iron (11.6 ppm), restriction of irrigation purposes was imposed [17].

3.4.4 Wastewater

For Jerash wastewater treatment plant, quality of effluent water did not comply with Jordanian Standard number (893/2006) / of discharge to valleys and streams. Levels of BOD (222 mg/l), COD (543 mg/l), phenol (0.06 mg/l), T-N (148 mg/l), PO_4 (56 mg/l), Cl (465 mg/l), HCO_3 (1039 mg/l), Na (312 mg/l), and E. coli (2.19E+05) exceeded the standards [17].

In summary, King Talal dam has good quality of water that suits unrestricted agriculture; while Zarqa river water has low quality of water, so it can be used for restricted agriculture only; and effluent of Jerash wastewater treatment had low water quality, so it is used for restricted non-eatable crops.

3.5 Drinking water resources within sub-districts

3.5.1 Municipal water

Table (2), about monthly schedule of municipal water in the study area, shows that 49.9% of houses got municipal water twice a month. During this period, it was found that residual chlorine solution in pipes had the ability to control biological contamination. Thus, those who got piped municipal water twice a month were potentially protected. While those who got it once a month or less were on more danger if they used municipal water for drinking. It was found that 9.38% of the sample were not connected to municipal water network or connected to other resources but did not get municipal water. Thus, this category was susceptible to biological and chemical contamination if unsafe substitute had to be used like springs and Zarqa River; in addition to financial burden if they have to buy water for drinking or for other domestic purposes. On contrast, 29.9% of the sample got municipal water three times a month or more. Among this category 12 houses (6 in Mastaba, and 6 in Jerash) got municipal water twice a week. Regarding sub-districts cases, there is high significant difference between them (χ^2 = 63.204, P =0.00). Burma had the highest percent of **no** municipal water supply, while Mastaba had the highest percent of getting municipal water supply three times a month or more.

Table 2: Monthly schedule of municipal water supply by administrative sub-district in 2012/2013

Administrative sub-district		Burma		Mastaba		Jerash		Total	
		No.	%	No.	%	No.	%	No.	%
Municipal water schedule per **month**	No water	22	19.0	6	5.2	48	8.30	76	9.38
	Less than 1	4	3.4	0	0.0	4	0.69	8	0.99
	1	14	12.1	16	13.8	50	8.65	80	9.88
	2	72	62.1	50	43.1	282	48.79	404	49.88
	3 or more	4	3.4	44	37.9	194	33.56	242	29.88
Total		116	100.0	116	100.0	578	100.0	810	100.0

111.5.2 Bottled water and tanker truck water

People in Burma sub-district bought more water (69% of houses) than both in Mastaba (53.4% of houses) and in Jerash (53.6% of houses). While people in Mastaba and Jerash sub-districts bought bottled treated water more than in Burma (25.9%, 30.8%, 10.3% consequently), citizens in Burma (50% of houses) bought more tanker truck water. It was found that there is high significant difference between the sub-districts (χ^2 = 45.406, P = 0.00).

3.5.3 Other water resources

It was found that inhabitants in Burma sub-district depended on other water resources (that are springs, Zarqa river and harvested rainwater by other people) more than two times of those in Mastaba, and five times than of those in jerash sub-districts (42%, 21%, and 8% respectively).This could be due to the fact that 77.6% of the houses receiving municipal water twice a month or less in addition to 19% are not connected to water network because of lower economic status; or more springs are existed in Burma than in Mastab sub-district. Although Jerash sub-district has lots of springs, not all of them are safe and protected from contamination. It was found that there is high significant difference between those administrative sub-districts (χ^2 = 125.160, P = 0.000).

3.6 Water sample test results

The overall chemical quality of water in Jerash governorate was medium, while the overall biological quality was good.

3.6.1 Municipal water

The overall chemical quality of water in Jerash governorate was medium, while the overall biological quality was good.

3.6.2 Municipal water

It was found that all municipal water samples were in compliance with Jordanian standards of drinking water – table (3).

Tables 3: Jordanian National Standards of drinking water supplies

Standard Values	Value	Unit
fluoride (F)	1.5	(ppm)[1]
ammonium (NH_4)	0.2	(ppm)
nitrate (NO_3)	50	(ppm)
Nitrite (NO_2)	2.0	(ppm)
lead (Pb)	0.01	(ppm)
Total dissolved solids (TDS) = electrical conductivity * 0.67	1000	(ppm)
E. coli	<1.1	MPN/100ml
Total coliform	<1.1	MPN/100ml
pH	6.5-8.5	-

Source: Ministry of water and irrigation

3.6.3 Spring water

Table (4) shows that 30% of spring water samples were contaminated with E. coli, and 55% of them had nitrate above the national standards. Some spring water was contaminated with E.Coli, Either because the spring site was exposed to animal and birds excreta, or due to septic tanks leaked from nearby houses, or fertilizers leakage.

Table 4: Results of spring water samples analysis in 2012/2013

Serial no.	Administrate sub-district	Total Coliforms	E.Coli	Nitrite	Nitrate	Ammonium	Fluoride	lead
		MPN/100ml	MPN/100ml	ppm	ppm	ppm	ppm	ppm
1	Burma	<1.1	ND[2]	<0.20	58.0	<0.10	<0.20	<0.01
2	Burma	<1.1	ND	<0.20	58.0	<0.10	0.23	<0.01
3	Burma	<1.1	ND	<0.20	58.0	<0.10	<0.20	<0.01
4	Mastaba	<1.8	ND	<0.20	65.55	<0.10	0.78	<0.01
5	Mastaba	<1.8	ND	<0.20	65.55	<0.10	0.78	<0.01
6	Jerash	7.8	ND	<0.20	19.07	<0.10	0.20	<0.01
7	Jerash	7.8	<1.8	<0.20	19.07	<0.10	<0.20	<0.01
8	Jerash	7.8	<1.8	<0.20	19.07	<0.10	<0.20	<0.01
9	Jerash	<1.1	ND	<0.20	58.11	<0.10	0.22	<0.01
10	Jerash	<1.1	ND	<0.20	58.11	<0.10	0.22	<0.01
11	Jerash	7.8	<1.8	<0.20	19.07	<0.10	<0.20	<0.01
12	Jerash	7.8	<1.8	<0.20	19.07	<0.10	<0.20	<0.01
13	Jerash	<1.1	ND	<0.20	60.11	<0.10	0.22	<0.01
14	Jerash	<1.1	ND	<0.20	60.11	<0.10	0.22	<0.01
15	Jerash	<1.1	ND	<0.20	53.22	<0.10	0.24	<0.01
16	Jerash	<1.1	ND	<0.20	53.22	<0.10	0.24	<0.01
17	Jerash	<1.1	ND	<0.20	47.12	<0.10	<0.20	<0.01
18	Jerash	<1.1	ND	<0.20	47.12	<0.10	0.20	<0.01
19	Jerash	7.8	<1.8	<0.20	20.35	<0.10	<0.20	<0.01
20	Jerash	7.8	<1.8	<0.20	20.35	<0.10	<0.20	<0.01

[1] ppm stands for parts for millions. It equals milligram per litre (mg / L)
[2] ND means not detectable

3.6.4 Tanker truck water

Also, 35% of tanker trunk water samples –table (5) - had high level of nitrate, whereas 65% of samples complied with the national standards with regard to all parameters.

Table 5: Results of truck water samples analysis in 2012/2013

Serial no.	Administrate sub-district	Total Coliforms	E.Coli	Nitrite	Nitrate	Ammonium	Fluoride	lead
		MPN/100ml	MPN/100ml	ppm	ppm	ppm	ppm	ppm
1	Burma	<1.1	ND[3]	<0.20	93.58	<0.10	0.44	<0.01
2	Burma	<1.1	ND	<0.20	93.85	<0.10	0.44	<0.01
3	Burma	<1.1	ND	<0.20	93.85	<0.10	0.44	<0.01
4	Mastaba	<1.1	ND	<0.20	44.0	<0.10	0.22	<0.01
5	Mastaba	<1.1	ND	<0.20	44.0	<0.10	0.22	<0.01
6	Jerash	<1.1	ND	<0.20	88.95	<0.10	0.35	<0.01
7	Jerash	<1.1	ND	<0.20	35.10	<0.10	0.35	<0.01
8	Jerash	<1.1	ND	<0.20	88.95	<0.10	0.28	<0.01
9	Jerash	<1.1	ND	<0.20	43.22	<0.10	0.28	<0.01
10	Jerash	<1.1	ND	<0.20	88.95	<0.10	0.37	<0.01
11	Jerash	<1.1	ND	<0.20	35.10	<0.10	<0.20	<0.01
12	Jerash	<1.1	ND	<0.20	88.95	<0.10	<0.20	<0.01
13	Jerash	<1.1	ND	<0.20	43.22	<0.10	0.30	<0.01
14	Jerash	<1.1	ND	<0.20	55.0	<0.10	0.23	<0.01
15	Jerash	<1.1	ND	<0.20	55.0	<0.10	0.23	<0.01
16	Jerash	<1.1	ND	<0.20	55.0	<0.10	0.23	<0.01
\17	Jerash	<1.1	ND	<0.20	47.00	<0.10	0.38	<0.01
18	Jerash	<1.1	ND	<0.20	47.00	<0.10	0.38	<0.01
19	Jerash	<1.1	ND	<0.20	34.22	<0.10	0.36	<0.01
20	Jerash	<1.1	ND	<0.20	34.22	<0.10	0.36	<0.01

3.6.5 Rainwater

For rainwater harvesting, people in Jerash governorate usually collect rainwater in January after many times of rain showers, but not from the first flush in order to get sure of clean roof. However, 25% of the rainwater samples (table 6) had been found bacteriologically contaminated, but not to a high level (less than 1.8 MPM/100 ml). It is quite common to find microbial contamination in collected rainwater indicated by E. coli, particularly if samples collected shortly after rainfall.

Table 6: Results of harvested rainwater samples analysis in 2012/2013

Serial no.	Administrate sub-district	Total Coliforms	E.Coli	Nitrite	Nitrate	Ammonium	Fluoride	lead
		MPN/100ml	MPN/100ml	ppm	ppm	ppm	ppm	ppm
1	Burma	23.0	<1.8	<0.20	2.58	<0.10	<0.20	<0.01
2	Burma	<1.1	ND	<0.20	3.00	<0.10	<0.20	<0.01
3	Mastaba	<1.1	ND	<0.20	2.55	<0.10	<0.20	<0.01
4	Mastaba	8.8	<1.1	<0.20	3.00	<0.10	<0.20	<0.01
5	Mastaba	21.0	<1.8	<0.20	2.00	<0.10	<0.20	<0.01
6	Jerash	<1.1	ND	<0.20	2.53	<0.10	<0.20	<0.01
7	Jerash	<1.1	ND	<0.20	3.11	<0.10	<0.20	<0.01
8	Jerash	<1.1	ND	<0.20	3.25	<0.10	<0.20	<0.01
9	Jerash	<1.1	ND	<0.20	2.00	<0.10	<0.20	<0.01
10	Jerash	20.0	<1.8	<0.20	2.40	<0.10	<0.20	<0.01
11	Jerash	<1.1	ND	<0.20	3.10	<0.10	<0.20	<0.01
12	Jerash	<1.1	ND	<0.20	3.15	<0.10	<0.20	<0.01

[3] ND means not detectable

13	Jerash	14.0	<1.1	<0.20	2.15	<0.10	<0.20	<0.01
14	Jerash	<1.1	ND	<0.20	4.00	<0.10	<0.20	<0.01
15	Jerash	<1.1	ND	<0.20	3.00	<0.10	<0.20	<0.01
16	Jerash	<1.1	ND	<0.20	3.11	<0.10	<0.20	<0.01
17	Jerash	<1.1	ND	<0.20	2.00	<0.10	<0.20	<0.01
18	Jerash	<1.1	ND	<0.20	2.25	<0.10	<0.20	<0.01
19	Jerash	<1.1	ND	<0.20	2.35	<0.10	<0.20	<0.01
20	Jerash	<1.1	ND	<0.20	3.25	<0.10	<0.20	<0.01

3.6.6 Bottled water

It was found that 27.2% of the studied houses bought bottled treated water for drinking from licensed water shops. Water shops bring water from tanker trucks; use filters, ozone, and ultra violet for treatment; then fill the final product of water in PET bottles. Surprisingly it has been found that 18.2% of the bottled water samples were slightly contaminated (less than 1.8 ppm Total Coliforms), but there was not E.Coli. This could be an indicator for inadequate treatment.

3.7 New water quality index

3.7.1 Overall water quality in Jerash governorate

Percent of compliance with national drinking water standards were used as water quality index, while classifications of water quality were derived from Canadian water quality designations –table 7 -.

Table 7: Water quality classifications

Percent of compliance with Jordanian standards	Classifications	Description
Less than 45%	Poor	Water quality is almost always impaired
45 – 64%	Marginal	Water quality is frequently impaired
65 – 79%	Medium	Water quality is usually protected but occasionally impaired
80 – 84%	Good	Water quality is protected with only a minor degree of impairment
85 – 94%	Very good	Water quality is protected with a slight presence of impairment
95 – 100%	Excellent	all measurements meet Jordanian standards virtually all of the time

So, with regard to chemical and biological tests, in overall, it was found that 74.07% of the analyzed water samples chemically comply with the Jordanian standards of drinking water, and 80.25% of them biologically comply with the standards -table (8)-.

Table 8: Percent of chemical and biological tests complying with Jordanian standards for drinking water, at Jerash governorate sub-districts, 2012/2013

Administrative sub-district	**Burma**		**Mastaba**		**Jerash**		**Compliance with standards**		
	No.	%	No.	%	No.	%	No.	%	**Classification**
Chemical tests									
Municipal	2	100.0%	2	100.0%	6	100.0%	10	100.0%	Excellent
Springs	0	00.0.%	0	0.0 %	9	60.0%	9	45.0 %	Marginal
Tanker Truck	0	00.0 %	2	100.0%	8	53.33%	10	50.0%	Marginal
Rainwater	2	100.0%	3	100.0%	15	100.0%	20	100.0%	Excellent
Treated water	2	100.0%	3	100.0%	6	100.0%	11	100.0%	Excellent
Overall compliance with standards	6	50.0%	10	83.33%	44	77.19%	60	74.07%	Medium
	Marginal		Good		Medium				
Biological tests									
Municipal	2	100.0%	2	100.0%	6	100.0%	10	100.0%	Excellent

Springs	3	00.0%	0	0.0%	8	53.33%	11	55.0%	Medium
Tanker Truck	3	100.0%	2	100.0%	15	100.0%	20	100.0%	Excellent
Rainwater	1	50.00%	1	66.67%	13	86.67%	15	75.00%	Good
Treated water	1	50.0%	2	66.67%	6	100.0%	9	81.82%	Verygood
Overall compliance with standards	10	83.33%	7	58.33%	48	84.21%	65	80.25%	Good
	Good		Marginal		Good				

3.7.2 Water quality of different resources

Municipal water, rainwater, and treated underground water were 100% chemically comply with the standards (Fig. 8). While spring water and tanker truck water were 45% , 50% respectively in compliance with the chemical standards due to the high level of nitrate in the raw ground water. On the other hand, municipal water and tanker truck water were 100% comply with the biological standards.

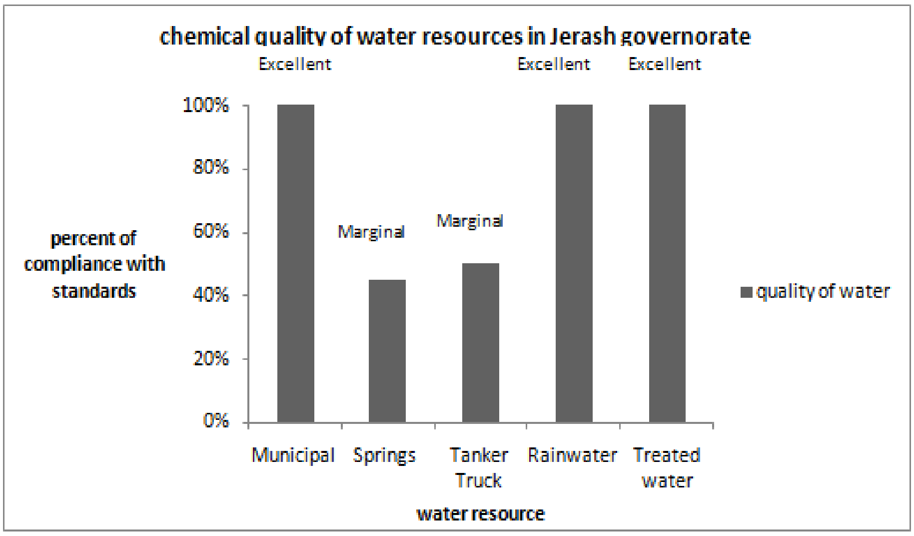


Figure 8: Chemical water quality of different water resources in Jerash governorate in 2012/2013

Quality of spring water, rainwater, and treated water was ranged from medium to very good, based on compliance with Jordanian biological standards (Fig. 9). This is logic since chlorine is added to both municipal and tanker truck water; while spring water and rainwater were neither treated nor disinfected with chlorine.

3.7.3 Water quality among sub-districts

At level of Jerash administrative sub-districts, the quality of water in Mastaba sub-district was chemically more complying with national standards than Jerash and Burma sub-districts . Biologically, it was found that both Jerash and Burma sub-districts were more in compliance with the standards than Mastaba.

The percent of safe water samples was less than that of ADWQ project in Jerash governorate (in 2005), in which the team found more than 99% of drinking water samples in compliance with National and WHO standards of drinking water. This is attributed to the fact that this study included samples of springs, collected rainwater, and bottled treated water, whereas RADWQ project did not include them.

Moreover, using the classifications of water quality shown in table (7), and with regards to chemical standards, marginal quality was dominant in Burma sub-district (50%) because 50% of dwellers used tanker truck water and 38% used spring water for drinking. It is well known that these water sources are potentially not safe.

3.7.4 Water quality at houses

Bottled water and municipal water: At level of houses in Jerash governorate (2012/2013), chemical parameters of water of municipal and bottled water, such as lead, fluoride, nitrite, and ammonium, were in compliance with both WHO and Jordan national standards of drinking water, which assure efficient water treatment at water treatment plant and water shops, and indicate freeness from chemical contamination. Related to municipal water, the previous findings are consistent with the results of a study performed by WHO and UNICEF. They found that there was high quality of drinking water in the distribution network, and found that the overall compliance with WHO guideline values and national standards was 97.8% [9].

Municipal water and bottled treated water in the three sub-districts (2012/2013) were free from E. coli which is a good sign of safe water. This is consistent with findings of USAID review team, who confirmed that municipal water supplies were treated effectively, and water quality at the household regard was within compliance levels. The team found 99.96% of municipal water samples were within international World Health Organization drinking water guidelines for microbiological water quality.

Tanker truck water: However, due to non-continuous supply, many inhabitants used tanker truck water, and purchased drinking water from water-treatment shops [16]. The latest Household Expenditure and Income Survey of 2008 estimated that around 19.2%, 4.7% and 2.3% of Jordan's household considered the mineral water (from water shops), wells and water tankers as the main source for drinking water; which was more expensive than that of public water network.

Tanker truck water in the three sub-districts (2012/2013) was free from E. coli which indicates efficient monitoring by Health ministry. Moreover, some tanker truck water in the three sub-districts of Jerash governorate had nitrate above national standards of drinking water due to high level of nitrate at the original source of that ground water.

Spring water and rainwater: On the other hand, spring water and collected rainwater in the three sub-districts sometimes had E. coli. This finding is consistent with project findings that found that natural springs suffered from pollution from cesspits or olive oil extraction mills [2]. Even protected spring water sometimes had high level of nitrate more than of national standards of drinking water due to leaching of fertilizers.

IV. CONCLUSIONS

Based on the new developed water quality index, the quality was found acceptable for municipal water and bottled groundwater resources; while groundwater of tanker trucks and wells were acceptable except of high level of nitrate; spring water and harvested rainwater were potentially not safe and susceptible for biological contamination. At level of sub-districts, it was found that, chemically, water in Mastaba sub-district was more complying with standards than Jerash and Burma sub-districts. While biologically both Jerash and Burma sub-districts were more compliance with the standards than Mastaba. In overall, drinking water quality in Jerash governorate was found chemically medium, and biologically good.

Findings of water quality were not dramatic as expected on the light of Falkenmark water stress indicator. This implies that Falkenmark indicator does not suit limited-water-resources countries like Jordan, while Gleick scarcity index is a very good substitute.

The new index of water quality is simple and can be easily used for both limited and non-limited water-resources countries.

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