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Filtered and Bottled Waters: Perception of its Quality against Tap Water in Selected Locations in Jordan

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Three different potable water types: tap water, purified/filtered water in private plants and stores, and sealed bottled water were collected from two governorates; Amman and Al Balqa and analyzed for various chemical parameters. The quality of bottled and filtered waters were assessed against the quality of treated municipal water system in terms of their suitability for human consumption. The bottled water samples were selected from ten brands (national and global), while filtered waters samples collected from a number of filtered water stores. The tap water samples have been collected from different locations in and around the two governorates. The results showed that quality of potable water varied depending on many factors such as: water quality at source, types of purification/filtration system, and the storage methods. None of the analyzed parameters exceeded the national and international guideline for potable water. Minor variations in chemical parameters were found between local and imported bottled water brands. All parameters tested were within both the national standards as well as the WHO guidelines, and the quality of tap water tested in all collected samples was in general good and is considered potable water with no health risk. The quality of water come from water purification shops contains medium ratios of chemical elements compared with tap water and bottled water. Quality of bottled water showed significant variation among the samples collected from different brands due to the diversity of methods of treatment and source of water from where these waters come from.

Key words: Bottled water, Purification, Filtered water, Consumption, Quality.

Management of water quantity is a key priority, nevertheless, water quality matters too: poor water quality is a significant social concern because of its effects on human health and productive activities; conversely, water of better quality means that more resources are available to help mitigate the scarcity problem.

Jordan is one of the most water scarce countries in the world (Figure 1) with a total renewable resources availability of 130 m^3/capita compared with i.e. 15% of the average water availability in Middle East and North Africa (MENA) countries, (MWI, 2012).

Jordan has several water and wastewater quality standards and undertakes three types of monitoring: (i) environmental monitoring of the quality of surface water and groundwater and of pollution sources; (ii) quality control monitoring of drinking water supply and sanitation; and (iii) environmental health monitoring.These are related mainly to the hygienic control of drinking water and wastewater as well as of other water uses such as bathing and recreation, (Ulimat, 2012).

Water scarcity remains a major challengedespite the high attention given to improving water management in Jordan. Moreover, rapid population growth is increasing water

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demand, putting additional pressure on the limited water resources. Overall, water resources are expected to decline to about 90 m3/capita by 2025, putting Jordan in the category of absolute water shortage (MoE, 2006). Water quantity and quality management in Jordan has been extensively researched, although the focus was mainly on "quantity" aspects, (Elaine*et al*, 2008).

Due to the water pollution crisis happened in 1998 and resulted from a generalized failure of drinking-water quality at Zai Water treatment plant, many Jordanians lost trust in the quality of drinking water (i.e. tap water) and turned to water purification plants and bottled water as an alternative. This new habit and concern over drinking tap water has continued up to our present time.Although the measures taken and applied by the concerned authorities to protect water resources including installing new treatment plants and the rehabilitation of the distribution network and despites the statements made by officials and experts that tap water is safe and that alternatives are not as perfect as they seem.

The present research intended to assess the quality of bottled and filtered waters in twogovernorates and to establish a general comparison with the current quality of tap waters, which is being very much less used by many Jordanians.

MATERIALS AND METHODS

Water Sample Collection and Analysis

Three different types of water samples have been collected. Tap water and filtered/ purified waters (from filtered water stores) have been collected randomly from different locations in two Governorates; Amman and Al Salt,Figure 2, while sealed bottled water have been selected from ten different brands, Table1.

All samples have been subjected to chemical analysis to determine the quality of these samples and if the quality complies with WHO guidelines and Jordanian national standards. The parameters tested werepH, EC, major cations (K, Na, Ca, and Mg) and major anions (Cl, NO_3, SO_4, HCO_3). The methods followed to perform the analysis is listed in Table 2.

RESULTS

The summary of the results on the water quality obtained for the three types of samples is shown in Table 3. These results and data were compared with both, the Jordan Drinking Water Standard (JS No.286/2008) as well as the WHO Guidelines, 2008,Table 4.

Physical Variables

EC values (Mean values in Tap water: 457.3; Bottled: 253 mean and Filtered 238.7 µS/ cm) for all samples from the three different types were below the permissible limit of the Jordan Drinking Water Standard (JS No.286/2008), i.e. 750 µS/cm and within the values of WHO guidelines (2011), i.e. 300-750 µS/cm. However, variation in EC values among the different types of waters is attributed to water quality at source, types of purification/filtration system, and the storage methods. The lowest value recorded for EC was for "ultra-brand" and this is because they use distillation technique in purification system.

Table 1. Different water bottled brands collected for analysis.

Brand code	Brand name	Source of Water
1	Abu-Rashid	Irbid well in Jordan
2	Ghadeer	Aquifer (Achara mountains in Jordan)
3	Ultra	Amman
4	Glitter pearl	Ain Al-Basha well
5	Arwa	Madaba well
6	Disi	Amman
7	Evian	Cachet spring French
8	Sannine	Aquifer (Sannine mountain in Lebanon)
9	Masafi	Masafi mountains in Ras Al Khaima UAE
10	Nestle	

Table 2. Different analytical methods used to determine selected parameters (APHA, 2000)

Parameter	Instrumentation	Method
Acidity (PH)	Electrometric Method	4500B/H^+
Electrical Conductivity (EC)	Conductivity	2510
Total Hardness (T.H)	EDTA Titrimetric Method	2340C
Calcium (Ca^{+2})	EDTA Titrimetric Method	3500D/Ca
Magnesium (Mg^{+2})	EDTA Titrimetric Method	3500E/Mg
Sodium (Na^+)	Flame Emission Photometric Method	3500D/Na
Potassium (k^+)	Flame Emission Photometric Method	3500D/K
Bicarbonate (HCO_3)	Titrimetric Method	2320B
Carbonate (CO_3^{-2})	Titrimetric Method	2320B
Chloride (cl^-)	Argentometric Method	4500B/Cl
Nitrate	Spectrophotometer	4500B/No_3
Sulfate	Terbidimetric Method	4500E/So_4

Table 3. Concentrations of the selected parameters

Sample	EC	K^+ mg/l	NO_3 mg/l	Mg mg/l	pH	Ca^{+2} mg/l	Na^+ mg/l	PO4 mg/l	Cl^- mg/l	T.H mg/l	HCO_3 mg/l	SO_4^{-2} mg/l
Tap water sample												
Al-Seru	892	9.31	8.11	22.08	7.91	67.2	109.28	0.22	147.95	264	88.45	84.98
Ira	563	5.02	34.99	12.42	8.38	88	29.99	0.0	67.98	274	95.77	34.20
Salalem	657	6.06	21.39	13.8	8.07	72	57.31	0.0	87.97	240	79.91	20.98
Batna	721	5.75	20.42	20.7	8.07	80	62.67	0.0	106.96	290	90.89	56.64
Baqi	729	5.85	19.49	18.86	8.16	76.8	68.56	0.39	117.96	274	89.67	12.66
Abdoun	322	4.39	2.09	11.5	8.05	27.2	35.78	0.0	57.98	118	42.09	20.98
Albnyat	257	4.70	0.92	13.8	7.92	20	36.42	0.0	47.98	60	25.01	47.57
Swefieh	278	4.08	0.91	1.38	8.02	20	37.49	0.0	62.98	56	21.35	20.98
Naour	320	3.97	3.01	3.68	8.16	28.8	37.49	0.16	59.98	88	29.89	21.98
Marj-Hamam	269	3.66	0.49	2.3	8.21	17.6	33.42	0.0	57.98	54	20.13	18.74
Filtered water sample												
Al-qala'a	327	1.77	1.75	2.76	8.05	10.4	26.03	0.0	57.98	38	44.53	4.073
Nice	226	1.4	17.89	22.08	8.02	60	35.46	0.0	22.99	76	42.09	7.360
Yasmen	207	1.04	4.74	0	7.84	0	1.499	0.0	37.98	36	25.01	6.48
Mohana	235	2.19	21.48	7.36	8.11	39.2	28.39	0.0	34.99	34	32.33	8.53
Sadeen	247	0.62	7.53	16.56	7.93	3.2	7.92	0.0	22.99	38	51.85	4.22
Wanderful	290	0.41	1.24	2.76	7.95	20	44.99	0.0	23.99	88	72.59	0
Tahany	219	1.25	3.76	17.94	7.81	76	10.28	0.0	29.99	38	33.55	7.62
Nima	184	1.36	0.75	5.06	7.62	38.4	5.78	0.0	17.99	86	37.21	10.57
Kholoud	346	1.25	13.55	15.64	8.16	4	22.07	0.0	61.98	0	46.97	4.13
Shahd	195	0.73	0.0	11.96	7.83	26.4	22.39	0.0	42.98	44	14.03	14.48
Bottled water sample												
Abu-Rashid	153	8.05	1.16	3.22	7.57	9.6	81.42	0.0	29.99	38	18.91	7.19
Ghadeer	181	0.83	9.13	12.42	7.89	8.8	52.49	0.0	55.98	246	98.21	23.23
Ultra	3.0	0.73	0.0	1.38	6.78	12	34.49	0.0	2.99	0	0.61	0
Glitter-pearl	312	1.046	1.24	1.84	7.82	10.4	49.07	0.0	32.98	130	62.84	22.73
Arwa	180	0.62	0.0	1.84	6.85	11.2	55.49	0.0	7.5	80	1.83	48.27
Disi	317	1.04	0.96	1.84	7.78	32	30.53	0.0	65.98	62	43.31	2.78
Evian	510	0.41	3.33	6.44	7.57	4	56.14	0.0	15.99	268	142.13	12.6
Sannine	239	2.61	0.0	5.52	7.11	24	18.32	0.0	16.99	118	59.17	35.95
Masafi	255	1.25	5.16	0.0	7.52	0	92.67	0.0	67.98	78	15.25	32.21
Nestle	284	2.40	5.16	3.22	7.08	12	27.99	0.0	37.98	118	54.29	9.9

Table 4. Jordan Drinking Water Standard (JS No.286/2008) and the WHO Guidelines

Parameter	Permissible limit	Max Allowable Concentration	WHO Guidelines (2011)
pH	6.5	8.5	6.5-8.5
EC (μ_S/cm)	750	2300	750-300
Ca^{+2} (mg/l)	100	500	100-300
Mg^{+2} (mg/l)	100	500	150
TH (mg/l) as $caco_3$	300	500	100-500
HCO_3^{-1} (mg/l)	100	500	125-350
Cl^- (mg/l)	200	250	200-300
NO_3^+(mg/l)	45	70	50
SO_4^{-2} (mg/l)	200	500	250
Na^+ (mg/l)	200	400	200
K^+ (mg/l)	10	50	10-50

Chemical Variables

Potassium has been tested because it is an essential element in humansand if ever, found in drinking water at elevated levels; it becomes a concern for healthy humans. In tap water sample Potassium, values were within the range 3.66–9.31mg/l with an average of 5.30mg/l. In filtered water samples values ranged between 0.42–2.20mg/l with an average of 1.21mg/l, while in bottled water ranged from 0.42– 8.06mg/l with an average of 1.90 mg/l. All of these values are withinboth; the Jordanian Standards and WHO Guidelines for drinking water, Figure2.

No sample had pH>8.4 among the three types of water. Figure 3, shows that all bottled water samples have pH below 8, while tap water and filtered water have almost similar pH values that ranged from 8-8.3. These values comply with the Jordanian Standards JS No.286/2008.

Wide range of nitrate content in tap water samples was recorded between 0.5 – 35mg/l with a geometric mean of about 11.19 mg/l , In filtered water samples values ranged between 0 – 21.5mg/l with an average of 7.27mg/l , and in bottled water ranged from 0 – 9.13mg /l the average of 2.10mg/l. None of these samples was found to surpass the limits for drinking water quality, however, the highest values in tap water were all found in samples collected from western part of Al Balqa Governorate.

Mg values in all collected sample have shown also a wide range between0-22.08mg/l, but are fully within the limits for drinking water quality (100 mg/l according to the Jordanian

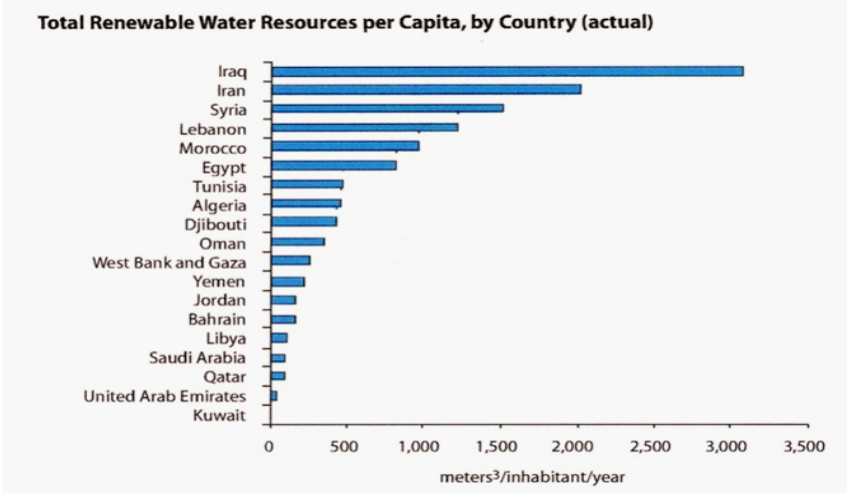

Fig. 1. Water availability in the MENA Region Source: World Bank, 2007

standard). Except a few samples in tap and filtered waters, the Mg content was almost around 10mg/l or less. The Ca and K values were within normal ranges for all samples tested and fit with the Jordanian Standards JS No.286/2008. Potassium contents particularly in filtered and bottled waters were almost around 3 mg/l while in tap water it has an average of 5mg/l.

Sulfate values in tap water sample were within the range 13 – 85mg/l with an average of 34 mg/l. In filtered water concentrations ranged between 0 – 14.5mg/l with an average of 7 mg/l, and these were lower than in bottled water which ranged from 0 to 48.3 mg /l the average of 19.40 mg/l, Figure 4.

High variance was recorded with regard to sulfate concentrations in bottled waters (0-48.8mg/l). Low values were recorded in Brands: Ultra and Disi. Ultra brand water is purified using distillation technique. No significant variance was recorded in sulfate concentrations in the water samples collected from filtering stores.

The PO_4 was only recorded in tap water sample with values ranged 0 – 0.397mg/l and an average of 0.08 mg/l. Higher values are attributed to three samples that exceeded the permissible limit of 0.1 mg/l. Two samples from Balqa Governorate and one from Amman Governorate.

HCO_3 concentrations show wide variance among samples from each type (20.13–96mg/

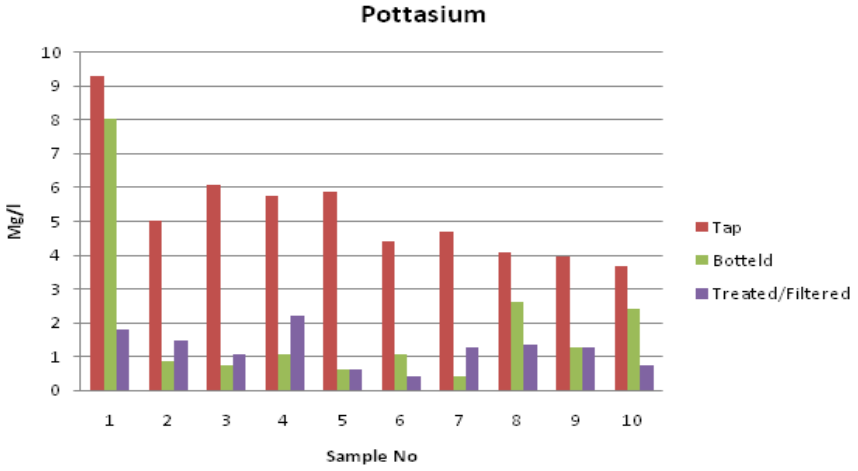

Fig. 2. Values of Potassium in the three types of water samples

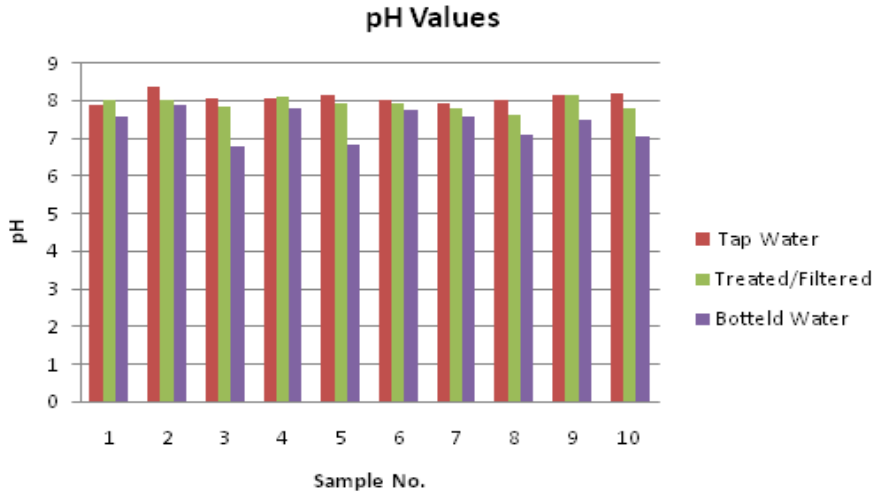

Fig. 3. Values of pH in the three types of water samples

l,Mean= 58.31mg/l in tap water, 0.61-142.13mg/l, Mean=49.33mg/l in bottled water and 25–72.60mg/l Mean=40mg/l in filtered water). Values in bottled water were in general higher than in filtered water samples, but they still within the Jordanian Standards (100mg/l).

Chloride concentrations in treated water were relatively lower than in bottled and tap water. The values in tap water sample were within the range between 48-147.95mg /l), while in filtered and in bottled water values were very close (filtered water: 2.99-61.98 mg/l, bottled water:2.99- 67.98 mg/l). Chloride content is known to be low; however, noticeable increase in its concentration may indicate pollution from sewage sources. According to the national standards and the WHO guidelines, all samples tested have an acceptable content of Cl.

The highest values of Total Hardness were recorded as expected in tap water samples,where they ranged between 54-290mg/l. In bottled water and filtered water values ranged between 0-268 and 0-88 mg/lrespectively.

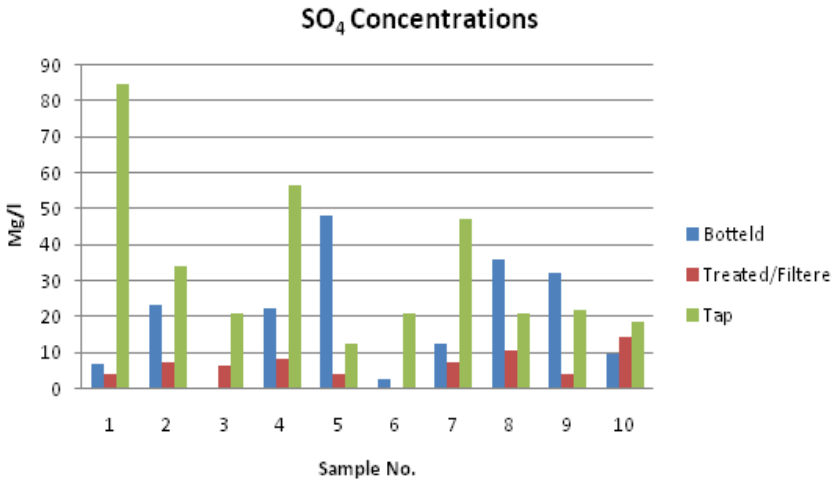

Fig. 4. Values of SO_4 in the three types of water samples

DISCUSSION

The issue of access to potable water is very important. In developed countries, people may not put a great deal of thought into the source of their water. In many First World nations, citizens can turn on a tap for fresh, potable water, which may also be enriched with elements like fluoride for health. In developing countries, however, a large proportion of the population does not have access to safe water.Yet 884 million people around the world live without improved drinking water and 2.5 billion people still lack access to improved sanitation, including 1.2 billion who do not have a simple latrine at all(WHO, 2008).

The World Health Organization (WHO) estimates that 88% of diarrheal disease is caused by unsafe water, inadequate sanitation and poor hygiene. As a result, more than 4,500 children die every day from diarrhea and other diseases. For every child that dies, countless others, including older children and adults, suffer from poor health (WHO, 2008).

In country like Jordan with very limited water resources, overuse of water leads to deteriorating quality as there is less resource to dilute the concentration of substances harmful to human health, to productive activities and to the environment in general. On the other hand, management of water quality might alleviate the quantity problem (for example through treatment practices that enable re-use of waste water); or it can exacerbate it, insofar as poor quality water creates incentives for increasing pressure on cleaner, but vulnerable water bodies such as fossil aquifers.

In 1998, there was a generalized failure of drinking-water quality in Jordan, The quality of the raw water sources and the warmer summer temperatures in early July 1998 initiated the taste

and odor problems. Algae in the raw water sources, with the conveyance systems promoting their further development, along with the inability of the Zai Water treatment plant management and operators to treat the water at full plant capacity, was due to inexperience, and caused primarily by insufficient Powdered Activated Carbon metering capacity, (Melkawi and Shiyyab, 1998; Abdel Khaleq, 2006).

The taste and odor problems were far greater than any experienced before, but the plant's staff failed to respond quickly enough to avoid the catastrophe that resulted. The plant had been running successfully for 10 years without an incident like this.

In one way, this incident did have the benefit of identifying nematodes as a future issue. Now that nematodes have been recognized as being present in the raw water and posing a potential health problem, immediately after which action was undertaken within the water sector to avoid a similar emergency in the future. Minimum requirements for water treatment were set, and an extensive programmed was started to protect water resources, to install new treatment plants and to rehabilitate the distribution network.

To avoid or reduce the impacts of inadequate water quality, many Jordanians purchase bottled water. The total quantity of bottled water annually purchased is estimated at 42 million liters. The net cost of bottled water is considered a conservative proxy for thedamage to health that would otherwise occur. It is assumed that only 75% of the bottled water is consumed to avoid such damage, while the rest is due to other preferences (Sarraf *et al*., 2004). Using the local market price of JOD0.2-0.3/liter, the annual expenses made to avoid health damages reach JOD11.2 million.

All parameters tested throughout the present research have been compared with the Jordanian drinking water standards as well as WHO guidelines as some of the bottled waters are imported (Table 2). Although fewer Jordanians are drinking tap water due to quality concerns, officials and experts stressed that tap water is safe and that alternatives are not as perfect as they seem. Therefore, since that time the people were not used the tap water.

In spite of the government tried to establish the credibility at the people, the people don'tbelieve that and they changed their habits to use bottle water instead of tap water. Accordingly, hundred companies were established for treated water for drinking water and they are available in the whole Kingdom. Currently, around 80 per cent of the central region's residents buy bottled water, according to a study conducted by the Jordanian-German Water Program.With 32 bottled water factories, 542 local water purification plants and five mineral water bottling plants in the Kingdom, citizens are not short of options when turning off the tap, according to the Ministry of Health.

CONCLUSION

According to the findings of the investigation, it is concluded that the quality of tap water tested in all collected samples was in general good and is considered potable water with no health risk. Quality of bottled water showed significant variation among the samples collected from different brands due to the diversity of methods of treatment and source of water from where these waters come from, but no concerns over its quality as all parameters content in this research are within the national standards.The quality of water come from water purification shops contains medium ratios of chemical elements compared with tap water and bottled water.This indicates that monitoring of water quality of tap water as well as filtered and bottled water is in general good.

Consequently, it is recommended that people to trust the quality of tap waters that is being treated and monitored by the concerned agencies, however people are advised to keep their household water tanks clean and closed well to avoid any contamination. Regular filters –to remove solids that may present in tap water due to corrosion of old networks- could also be installed and would be enough to secure a clean water.

Nevertheless, the variations in water quality among all tested samples are attributed to a number of factors, *inter alia*:

1) water quality at source
2) types of purification system, andthe storage methods
3) efficiency of filter and the membrane (at water filtering stores)

The present research highly recommends the replication of the present work on a larger

scale to cover the whole country.In addition, cover aspects related to the huge amount of water bottles being produced and used over the country, in terms of the "environmental cost" of generating more plastic wastes as well as the overuse of fossil fuel for manufacturing the plastic bottles in light of the lack of effective recycling industries in Jordan.

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