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Quality of Tank Water versus Treated Water in Greater Amman Municipality: A Pilot Study

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Abstract

Background: Waterborne diseases are some of the most common transmission methods of pathogenic bacteria to humans. This study aimed to assess the biological qualities of drinking water in Greater Amman Municipality's (GAM) 22 areas and investigates any significant differences in the microbiological content of tank and treated water through measuring risk indicator parameters in the period from 2015 to 2019. Treated water at private plants and tap water collected from tanks available at Food providing establishments (restaurants, café, and so forth) are included in this study.

Methods: Both tank water and treated water samples were collected from GAM's 22 areas, then analyzed for various microbiological parameters like; Total Coliform, Fecal coliform, Pseudomonas aeruginosa, Fungi, and Physical impurities.

Results: The findings obtained were matched with the Jordanian and U.S EPA standards for drinking water quality. The results of the microbiological analysis revealed that tank water samples were highly contaminated with Coliform and F. coliform. Furthermore, treated water samples showed very low contamination levels with Coliform, Pseudomonas aeruginosa, Fungi and physical impurities.

Conclusions: The results showed that the quality of potable water varied in microbial aspects, depending on many factors, for example, the water quality at the source and the type of purification system used. Findings recommend that the Water Authority of Jordan (WAJ), should increase water pumping frequency through the municipal pipes, GAM should increase awareness among owners of food-providing establishments with periodic cleaning of their tanks and encouraging them to provide their samples for testing to prevent potential water pollution.

Keywords

Contaminant, Microbiological, Public Health, Tap, Treated, Water.

1. Introduction

Water is one of the most essential components of life and without it, a human being can survive only for days. Water's importance arises from the fact that it is present in each cell of the human body, it makes up about 60% of our body's weight which can reach to 75% body weight in infants and decrease to 55% in the elderly. Moreover, it has an essential role in cellular homeostasis and in life in general (Jequier and Constant, 2010; Popkin et al., 2010). In 2015, about 4.5 billion people worldwide were not provided with adequate sanitation systems and about 2.1 billion lacked access to safe water; while there were about 51 million people in the Arab world who lacked access to safe drinking water (WHO /UNICEF, 2017). Even though the land area of Jordan is approximately 88.802 km2 in total, in 2017 it was ranked as the second water-poorest country in the world (Al-Khaza'leh, 2017). This water insufficiency is due to Jordan's arid and semi-arid climate, with only 100m3/capita/year, which appears to be diminishing each year, and is expected to reach almost 80m3 in the year 2020. Also, factors like high population growth rate, and economic development lead to an increase in the demand for the availability of water resources, which in turn affected both the quantity and the quality of water resources (Dougherty, 2006; Hadadin et al., 2010; and MWI, 2017). About 98% of the Jordanian total population (99% urban and 97% rural households) has access to safe drinking water. About 31% of all households use a filtration method to treat water domestically, while 62% of them use untreated water for drinking. The two most common sources of drinking water among both urban and rural households are bottled water and piped water provided by the related authorities. Piped water supply reaches only 50.3% of Jordanians through a piping system, where the pumping continues for 24 hours or less per week (MWI, 2017; DOS, 2017). According to a study conducted in 2018 (Mustafa and Talozi, 2018), Amman had been supplied with water for only 24 hours per week. Since the establishment of the Disi project, many districts in Amman are now supplied with water up to four days per week, and it was recorded that the peak of water supply in Amman for the month of August 2018 was about 36-hour /week. Potable water can be divided into the following categories: tap water (stored in the house tanks), potable water filtered domestically at homes using small filtration units, treated potable water in private plants (treated chemically, physically and microbiologically at the station site in order to produce desalinated water of distinctive quality to the consumer, its properties conform to the Jordanian standard) and finally locally and imported brands of bottled water (Batarseh, 2006). Although fresh and clean water is considered a necessity and an essential element for human health, it can also be a major source of microbial pathogens in developing regions. Poor sanitation, hygiene, and ultimately low water quality are responsible for 1.7 million deaths a year worldwide (Ashbolt, 2004). Unsafe sources of drinking water can be a significant source of enteric pathogens. These causative pathogens when present in consumed water, and then ingested, would be the source of many waterborne infectious diseases. (Bartram et al., 1996). The idea of this study arose to increase the consumer awareness regarding the microbiological content of potable water and increase global demand for treated water (Knox and McDermott, 2019). In Jordan, due to the lack of trust from the public in the sources of drinking water, people became more interested in securing themselves with other sources of potable water such as treated water (Batarseh, 2006). To protect public health, standards stating the Maximum Contaminant Level (MCL) had to be set. The MCL is defined as the highest level of contaminant allowable in potable drinking water. Both; the U.S. EPA's National Primary Drinking Water Regulations (NPDWRs) and Jordan standards and metrology organization (JSMO), have defined the MCL of various microorganisms such as Coliform, F. coliform, E. coli, and Pseudomonas aeruginosa (U.S. EPA, 2013) and (JSMO, 2010, 2015). For instance, the MCL for total Coliform in both tank and desalinated water is zero as shown in Table 1 and Table 2. According to the U.S. EPA regulations for testing of drinking water samples for total Coliform and E. coli., samples from drinking water systems are collected monthly, and no more than 5% of samples are allowed to test positive for total Coliform as shown in Table 2.

Table 1. Jordanian national standards for drinking-water, (Tap & Treated)

Parameter (Microbiological)	Acceptable level
Free-living organisms	Free
Fungi	Free
Total coliform count	<1.1/100 ml
Pseudomonas	<1.1/100 ml
Pathogenic enteric bacteria	<0/100 ml
F. coliform bacteria	<0/100 ml

SOURCS: JSMO, 2010, 2015

Table 2. EPA Primary Drinking Water Regulations.

Contaminant	MCLG[1] (mg/L)	MCL[2] (mg/L)	Sources of Contaminant in Drinking Water
Total Coliforms (Including F.coli-form and E. Coli)	Zero	5.0%	Coliforms are naturally present in the environment; as well as feces; F. coliforms and E. coli only come from human and animal fecal waste.

[1] Maximum Contaminant Level Goal.

[2] Maximum Contaminant Level.

SOURCS: U.S. EPA 2013.

Jiries et al. (2004) showed that drinking water originating from King Abdullah Canal (KAC) exhibited severe odor and taste problems, which were linked to technical problems in the operations conducted at Zei Water Treatment Plant and a pollution problem in the canal. Fandi et al. (2009) revealed that water samples obtained from different sites of King Talal Dam (KTD) had results that excessively exceeded the permissible limits set for F. coliform. The presence of F. coliform and E. coli indicates that the water was contaminated with human feces or animal wastes, while the total coliform counts indicate that the water is contaminated with both fecal waste and other bacteria from the soil (U.S. EPA, 2013). This study aims to provide an overview of the water tanks and treated water quality at private plants and food-providing establishments respectively, in Greater Amman municipality areas in terms of microbiological pollutants, and discusses the possibility of improving the water for drinking and food production purposes. To evaluate how polluted these waters are, the water quality standards for potable use established in HKJ, are provided and compared with the observed variability ranges of concentrations. Also, the paper provides recommendations that could improve the quality of water for drinking, and food needs.

2. Materials and Method

2.1 The study area

The study area includes all twenty-two areas which fall into the jurisdictions of Greater Amman Municipality (Figure 1). "Greater Amman Municipality is located geographically between latitudes 31°48′ N and 32°5′ N and longitudes 35°44′ E and 36°13′ E." It is the foremost important municipality in Jordan with an area of about 624 km2. It encapsulates the metropolitan region of Amman City – the capital of the Hashemite Kingdom of Jordan (Jaber, 2018). Consistent with the statistical data provided by the Jordanian Department of Population, and Social Statistics, Amman's resident population is estimated at around 4,440,978 million (DOS, 2019).

Figure 1. Location map of GAM's 22 administrative districts in **SOURCE: City Report Amman, Jordan (Cavoli, 2017).**

2.2 Sampling

Tap water samples were collected from water stored in food providing establishments tanks and treated water samples were collected from private plants during the period of 2015 to 2019 from twenty-two different areas of Greater Amman municipality as shown in Table 3. The sampling was conducted based on a schedule set by the Health Control sections distributed in all areas of GAM and these visits span all throughout the year. The number of visits depends on the number of various establishments in the area in a way that each one is visited once in each quarter. Furthermore, if a sample was reported as non-conforming, the related restaurant or water plant was notified to carry out disinfection and cleaning procedure. After that, a second sample was taken to make sure that the measurements taken were of fruitful results, otherwise legal actions would be done.

Samples were collected by well-trained inspection teams affiliated to the department of vocational and health control/ Greater Amman Municipality, in 250 ml, non- reactive borosilicated glass, non-leaking, wide mouth, capped bottles, which have been previously washed, rinsed with distilled water, and then, sodium thiosulfate was added as a neutralizing and dechlorinating agent which acts as a reducing agent and prevents any subsequent bactericidal effect on the microorganisms present in the sample. After that, it is autoclaved at (121°C for 15 minutes) in the preparatory laboratory, and then, sent to the sample collection site in cooler containers. A bottle containing glycerin was placed inside the cooler to monitor the sample's transport temperature that should not exceed 5°C. In case of Tank water, the inspector opened the cold-water faucet for two to three minutes to make sure that the system line was clear and flowing. Then, the cap of the bottle was opened carefully, while the inspector was wearing gloves and making sure not to touch the head of the bottle or the nozzle of the source of water. Once filled properly, the cap is returned to the bottle and closed right away. In the case of treated water, the same precautions were followed, and the sample was collected from the final point of the treatment system, making it in the exact same properties of that consumed by customers of these water treatment shops. The required volume needed to conduct microbiological tests was at least 250ml. Proper labeling and sample submission forms were filled correctly and delivered later to the coding unit of the department of Health and Vocational Control. The temperature of the container, any leakage in the bottles and any other mishandling practices that can affect the integrity of the sample were checked by the sample reception officer. Samples that were mishandled had been rejected immediately and had not been sent to the laboratory for testing, and later new sample had been ordered. The identity of samples was concealed and coded. Finally, the samples arrived at the Microbiology laboratory, the temperature of the container, as well as any signs of spillage, were checked by laboratory technicians, then the samples were submitted for testing directly. The first test conducted was the physical impurities test. The samples were mixed thoroughly for about 20 seconds at a 45° angle by hand. The mixing was facilitated by the head space of at least 2.5cm in the sampling bottles which originally have a volume larger than 250ml. Color, odor, turbidity and any kind of impurities were checked (SMEWW, 2017).

2.3. Microbiological examination

Microbiological tests were accomplished on water samples following the Most Probable Number method (MPN) according to the book of Standard Methods for the Examination of Water and Wastewater (SMEWW, 2017). This method is used to estimate the concentration of viable microorganisms in a sample by averages of replicating liquid broth growth in ten-fold dilutions. It is commonly used in estimating microbial populations in soils, waters, and agricultural products. The MPN method is performed in 2 steps (Presumptive test and Confirmatory test).

2.4. Most probable number tests

2.4.1 Presumptive test:

It is a screening test performed on water samples to check for the presence of Coliform organisms. The media used for this purpose is Lauryl tryptose broth (lactose fermentation) tubes, which come in two forms; single strength Lauryl broth and double -strength ones. The double strength tubes have double the quantity of the active material which is (Lauryl sulphate). A100 ml of water sample (tank and treated) are placed in 10 tubes of Lauryl: 10 ml each tube. Tubes are then incubated at 35°C for 24-48h. If the presumptive test is negative, no further testing is performed, and the water source is considered microbiologically safe. If Coliforms are present in water, they utilize the lactose present in the medium to produce acid and gas. Therefore, if any tube in the series shows gas, then the water sample is considered unsafe, and the confirmation test is performed on the tube displaying a positive reaction (Sulieman et al, 2009; SMEWW, 2017).

2.4.2 Confirmatory test

From each gas positive presumptive tube, a loopful inoculum is transferred into a tube containing 10 ml Brilliant green lactose broth medium. All tubes were incubated at 37°C and inspected for gas formation after 24 ± 2 hours. If no gas production was seen, further incubation was required for a maximum period of 48 ±3 hours. Again, tubes were checked for gas production which, if observed, demonstrated the presence of Gram negative and non-spore-forming bacilli. Hence, it indicated the presence of a member of the coliform group in the sample examined. A loopful from each positive Lauryl tryptose tube was also transferred into EC broth tubes which was then incubated at 44.5 ±0.2°C for 18-24 hours. EC broth is a selective medium used for the differentiation of Fecal coliforms, and it is the confirmatory test for Escherichia coli from food and environmental samples. EC-Mug however, is used as a confirmatory test for Escherichia coli from water samples. Any tube showing any amount of gas production in Durham tube, was considered positive for fecal coliforms, and the most probable number results was recorded. (Sulieman et al, 2009; SMEWW, 2017). Moreover, EC-Mug tubes showing positive gas production must be inspected under UV light to check for the presence of fluorescence. The number of fluorescent tubes is then referred to the MPN table provided by the SMEWW, as shown in table 4 (SMEWW, 2017).

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Table 3. No. of Tank & Treated water sample from each area in Greater Amman Municipality between (2015 – 2019).

DistrictF	Area	Tank water samples 2015	Tank water samples 2016	Tank water samples 2017	Tank water samples 2018	Tank water samples 2019	Treated water samples 2015	Treated water samples 2016	Treated water samples 2017	Treated water samples 2018	Treated water samples 2019
South	Qwaismeh	69	77	62	29	24	04	07	04	03	03
	Kuraibet al souq	39	36	63	40	34	05	04	05	07	05
	Muqabalian	39	26	48	18	13	04	07	05	08	03
	Uhud	08	18	13	16	11	01	02	03	04	02
	Bader nazal	38	28	34	31	26	01	04	06	04	02
North	Swieleh	60	61	64	21	09	06	12	12	10	01
	Abu nusair	17	23	21	41	12	13	18	17	12	01
	Shafa badran	27	42	54	35	13	14	25	24	09	02
	Tela alali	35	38	42	32	07	09	13	08	07	01
West	Wadi elseer	98	91	65	40	37	25	05	29	21	01
	Zahran	65	101	37	32	30	4	03	12	07	01
	New bader	18	14	17	22	20	6	12	13	10	00
	Marj elhamam	23	53	46	30	28	20	10	17	05	01
East	Naser	37	85	55	26	24	72	20	08	06	02
	Marka	68	44	70	35	32	21	35	23	11	05
	Yarmouk	86	55	51	26	23	03	02	11	04	01
	Tarek	38	14	45	33	30	10	04	08	03	03
	Basman	39	50	65	37	34	04	12	09	04	02
Middle	Madina	68	61	63	30	34	01	04	05	04	01
	Abdali	74	48	27	23	27	19	44	21	08	01
	Jubaiha	21	17	16	17	20	03	13	17	06	01
	Ras alain	38	25	31	26	29	01	06	18	05	01
	Inspection team	13	11	04	11	14	09	07	41	05	02
Total		1018	1018	993	651	531	255	269	316	163	42

Table 4. Most Probable Number for Water Coliforms

Positive tubes	MPN/100ml	Confidence limits (95%)	
		Low	High
0	<1.1	-	3.3
1	1.1	0.05	5.9
2	2.2	0.37	8.1
3	3.6	0.91	9.7
4	5.1	1.6	13
5	6.9	2.5	15
6	9.2	3.3	19
7	12	4.8	24
8	16	5.9	33
9	23	8.1	53
10	>23	12	--

SOURCE: SMEWW, 2017

On the other hand, the next most important microbiological parameter to look for is Pseudomonas aeruginosa. Through water treating systems, Pseudomonas aeruginosa can be transmitted into the water that is causing a waterborne disease. In these systems P. aeruginosa finds the perfect conditions of oxygen and humidity levels and a common bacterium included in water quality regulations for treated water and bottled water, as it is a common bacterium in water treatment systems and is considered an indicator of sanitation in the water treatment process. The MPN method was also performed on treated water samples for testing the presence of P aeruginosa. This time, the media used in the presumptive stage was Asparagine broth which was incubated at 35°C for 24-48h. Production of a green-fluorescent pigment under UV light constitutes a positive presumptive test and Acetamide medium was used as a confirmatory test. A subsequent color change in the Acetamide slant yellow-the orange media to purplish red one, constitutes a positive confirmatory test.

Negative results, which were represented by none of the tubes having any gas formation, were recorded as (<1.1MPN/100ml) and were considered as conforming to the Jordanian standards. On the other hand, positive results for Coliform, F.coliform, E.coli and Pseudomonas aeruginosa, obtained after confirmatory test with results between (1.1MPN/100ml) and (>23.01MPN/100ml), were reported as non-conforming to the standard.

2.5 Determination of Fungi

Using the pour plate technique, (Malt extract agar) was used for detection of Fungi. Two serial dilutions (10^{-1} and 10^{-2}) were made from each sample. 1.0 ml from each dilution was taken. Incubation was carried out at 25°C for (5-7 days), (Colony counter (Rocker-Galaxy 230) was used for the enumeration of colonies. according to the SMEWW (SMEWW, 2017), and plates with colonies ranging from 15-300 only were considered.) The number of Fungi/1ml were Calculated by multiplying the number of colonies by the dilution factor. Results are reported in terms of colony forming units per ml (cfu/ml). According to the Jordan standards and metrology organization (JSMO) for drinking water, Fungi must not be detectable in any 100 ml sample intended for drinking.

2.6 Statistical Analyses

Data is presented as mean and percentage using EXCEL 2019. The results were analyzed by analysis of variance (ANOVA). A p value of <0.05 was considered significant. Correlations were calculated by Pearson's correlation coefficients.

3. Results

3.1 Microbiological analysis for tank drinking water samples.

Results from Figure (2) and Table (5) show that total number of Tank samples during years 2015-2019 were 1018, 1018, 993, 651 and 531 respectively, with an average 842, the total number of conforming samples (complying with Jordanian standards for drinking water by having negative result in all tubes which were reported as <1.1MPN/100ml) were 741,727,716, 471 and 377 respectively, with an average 606 and average percentage 72%. While total numbers of non-conforming samples (not-complying with Jordanian standards for drinking water by having positive results in 1-10 tubes which were reported in values between 1.1MPN/100ml and >23.0MPN/100ml) were 277, 291, 277, 180 and 154) respectively, with an average 236 and average percentage (28%). Out of non-conforming samples, Coliform numbers were 149, 162, 167, 123 and 104 respectively, with an average percentage 17 %, Fecal coliform numbers were 108, 124, 96, 50 and 47 respectively, with an average percentage 10% and physical impurities numbers 20, 5, 14, 7 and 3 respectively, with an average percentage (1%). In comparison, the number of treated samples were less than the number of tap water samples due to the lower number of water plants in comparison with the number of other food-providing establishments.

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Figure 2. Microbiological analysis for tank drinking water samples., at Amman governorate sub-districts, 2015-2019

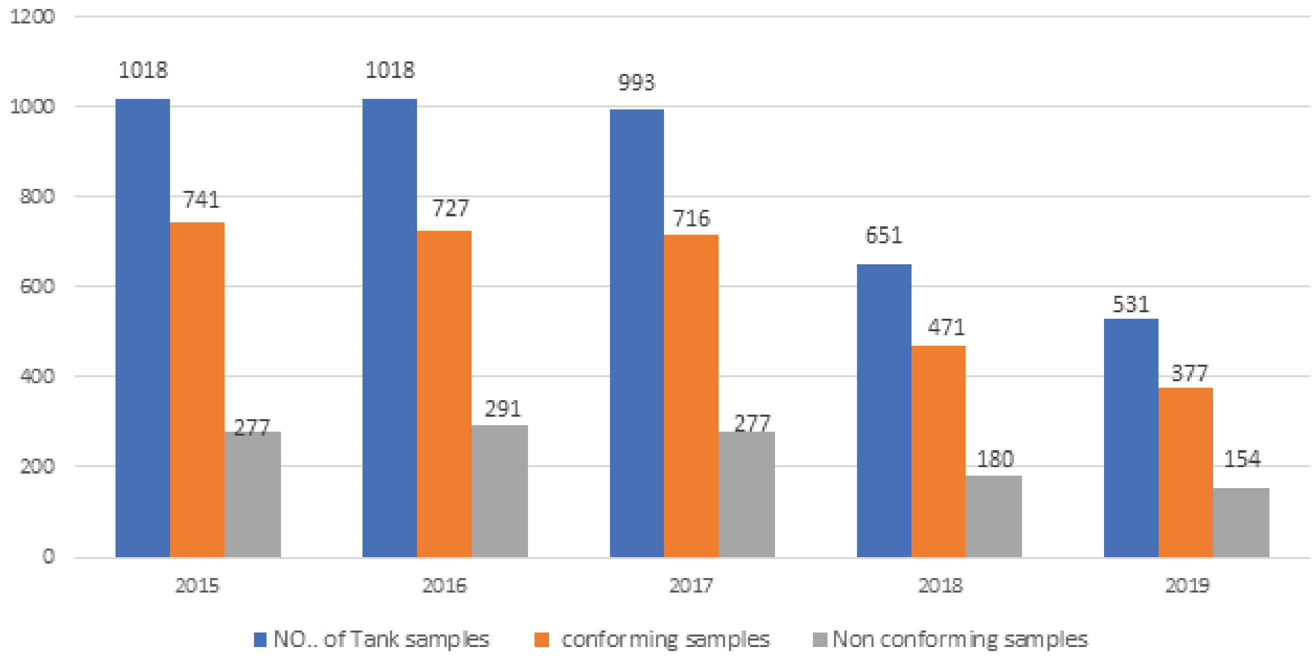

Table 5. Numbers & Percent of biological tests of Tank water samples Not-complying with Jordanian standards for drinking water, at Amman governorate sub-districts, 2015-2019.

Year	Compliance with standards (%)	Not Compliance with standards (%)	No. of +ve Coliform Samples	+ve Coliform samples (%)	No. of +ve F.coliform samples	F.coliform (%)	No. of +ve Physical Impurities samples	+ve Physical Impurities samples (%)
2015	73	27	149	14.6	108	10.6	20	2
2016	71	29	162	15.9	124	12.2	5	0.5
2017	72	28	167	16.8	96	9.7	14	1.4
2018	72	28	123	18.9	50	7.7	7	1.1
2019	71	29	104	19.6	47	7.4	3	0.5
Average	72	28	141	17	85	9.5	10	1

3.2 Microbiological analysis for treated drinking water samples.

Results from Figure (3) and Table (6) show that total number of treated samples during years 2015-2019 were 255, 269, 316, 163 and 42 respectively with an average 209, the total number of conforming samples (complying with Jordanian standards for drinking water by having negative result in all tubes which were reported as <1.1MPN/100ml)) were 227, 243, 279, 151 and 40 with an average 188 and average percentage 91.2%. While total number of non-conforming samples (non-complying with Jordanian standards for drinking water by having positive results in 1-10 tubes which were reported in values between (1.1MPN/100ml and >23.0MPN/100ml)were 28, 26, 37, 12 and 2 respectively with an average 21 and average percentage 8.8%. Out of non-conforming samples, coliform numbers were 11, 12, 14, 4 and 0 with average percentage 3%, Fungi numbers were 3, 1, 6, 1and 0 with average percentage 0.8%, Pseudomonas numbers were 9, 11, 13, 5 and 2 with an average percentage 4% and physical impurities numbers were 5, 2, 4, 2 and 0 respectively with an average percentage 1%.

Figure 3. Microbiological analysis for treated drinking water samples., at Amman governorate sub-districts, 2015-2019.

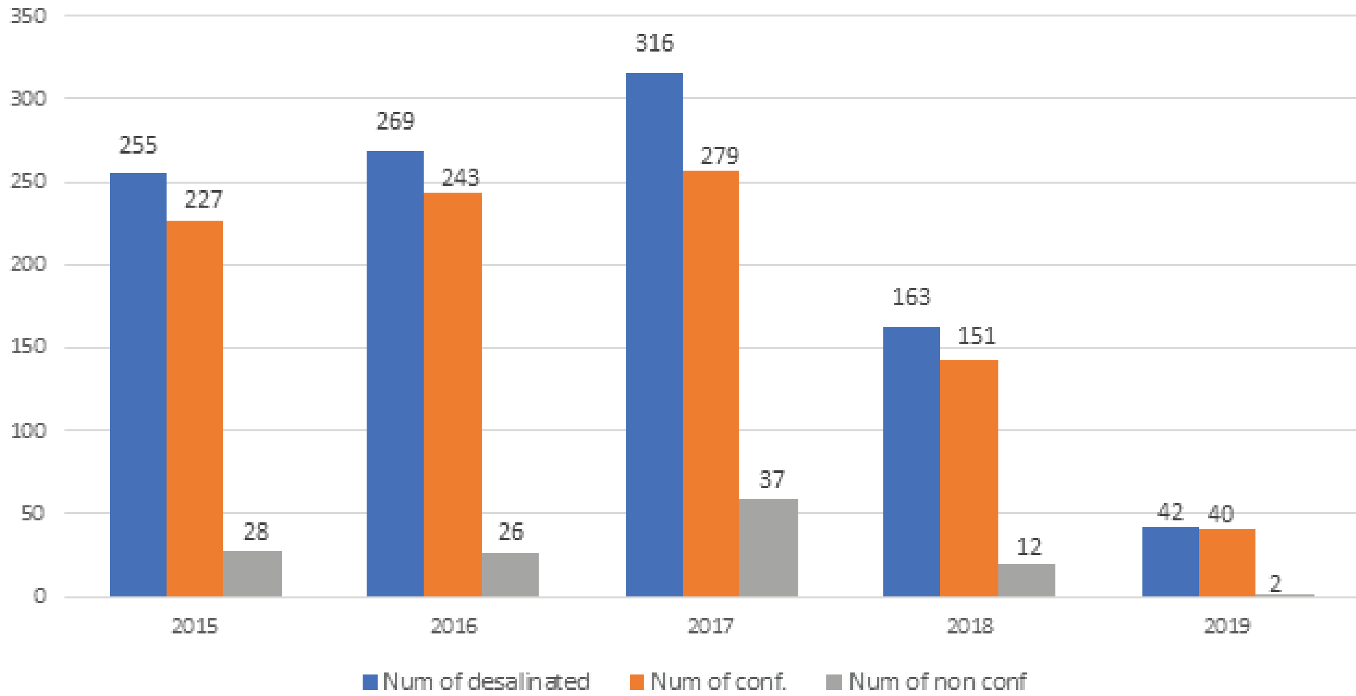

Table 6. Numbers & Percent of biological tests of Treated water samples Not-complying with Jordanian standards for drinking water, at Amman governorate sub-districts, 2015-2019

Year	Compliance with standards (%)	Not-Compliance with standards (%)	No. of +ve Coliform samples	+ve Coliform samples (%)	No. of +ve Fungi samples	+ve Fungi samples (%)	No. of +ve P. aeruginosa samples	+ve P. aeruginosa samples (%)	No. of +ve Physical Impurities samples	+ve Physical Impurities samples (%)
2015	89.1	10.9	11	4.3	3	1.2	9	3.5	5	1.9
2016	90.4	9.6	12	4.4	1	0.4	11	4.1	2	0.7
2017	88.3	11.7	14	4.1	6	1.9	13	4.4	4	1.3
2018	92.6	7.4	4	2.5	1	0.6	5	3.1	2	1.2
2019	95.2	4.8	0	0	0	0	2	4.8	0	0
Average	91.2	8.8	8	3	2	0.8	8	4	3	1

4. Discussion

Five years of Greater Amman Municipality/ Department of Health and vocational Control (DHVC) complete laboratories records of water microbiological testing was investigated. According to the Jordan standards and metrology organization (JSMO), and U.S. EPA's National Primary Drinking Water Regulations (NPDWRs), Coliform, and F. coliform bacteria must not be detectable in any 100 ml sample intended for drinking, and no more than 5% of samples are allowed to test positive for total Coliform as shown in Table 1 and Table 2 above. The information's analyzed from records, and compared with these standards showed that, Low percentage of physical impurities (1% of all tank samples) indicate that tank water samples were clear of impurities $p > 0.05$ and $r = 0.643$. High percentage of total coliform (17% of all tank samples), and Fecal coliform (10 % of all tank samples) indicates that tank water samples were contaminated with Coliform, and Fecal coliform bacteria $p < 0.05$, and $r = 0.96$ as shown in Table 5 above and Table 7.

Given that some of the tank water samples gave positive results for Coliform, and F. coliform at rates that exceeded the (JSMO and U.S. EPA's NPDWRs) permissible limits as shown in Table 8.

Table 7. Anova test of Tank water samples within 5 years.

Test parameters	Correlation	Sig.
Total no. of samples & Coliform	0.958	0.001*
Total no. of samples & F coliform	0.957	0.011*
Total no. of samples & Impurities	0.643	0.242

Table 8. Count category (MPN/100 ml) of non-conformed tank water samples compared with Jordanian standards for drinking water, at Amman governorate sub-districts, 2015-2020.

Count (MPN/100 ml)	Coliforms		F. Coliforms	
	Number	(%)	Number	(%)
<1.1	<1.1	0	<1.1	0
1.1	118	84.0	67	79
2.2	23	16.0	18	21
Average number of +ve samples assayed	141		85	

Therefore, tanks water is not suitable for both drinking and food production for many reasons, including:

- Non-frequent cleaning of storage tanks and leaving them open in some cases, may provide a chance for bird's residues, insects, and impurities to be present in the water and therefore, bacterial growth.

- Drinking water coming through the municipal pipes may not be contaminated; it contains chlorine which helps to prevent microbiological contamination. Yet, the limited pumping frequency which may be as low as once a week or less increases the possibility of contamination in the pipes. Whilst those who got piped by the municipal twice a week or more, were potentially protected as described by a previous study (Mustafa and Talozi, 2018).

- Moreover, due to non-continuous municipal water supply, many residents tend to use water provided by private water suppliers. Those mobile water truck tanks may be suffering from contaminants of their own. In turn, these contaminants would become inhabitants in the establishment's tanks, adding another source of pollution.

- Some water pipes are old and worn out, which leads to the presence of bacteria or their mixing with mud and Biofilm formation due to low pumping.

On the other hand, and according to the Jordanian standards and U.S. EPA's National Primary Drinking Water Regulations (NPDWRs), the treated water, Coliform, Pseudomonas aeruginosa, Fungi and physical impurities must not be detectable in any 100ml sample and no more than 5% of samples are allowed to test positive for total Coliform and F. coliform as shown in Table 1 and Table 2 above. Very low contamination (< 5%) of Coliforms or Pseudomonas aeruginosa risk indicators, Fungi and physical impurities were found within the tested treated water samples. Which indicate that treated water samples were not contaminated with any of these contaminants' bacteria $p > 0.05$ as shown in Table 9. According to the Jordanian standards and U.S. EPA's NPDWRs, the treated samples were fit for drinking. When comparing the results of our study with others, it was observed that our findings were consistent with a study that was conducted in 2022 (Keleb et al., 2022), which reported that municipal tap water samples from point of collection (MTPOC), and water samples from a household water storage container (HHSC) were positive for E. coli and total coliform respectively. Moreover, the MTPOC and HHSC had contamination levels higher than that of bottled water samples before packaging from manufacturing facilities (BPMF). However, another study conducted in 2021 (El-Naqa and Raei, 2021) that tested the microbiological parameters of potable water in GAM, such as total coliform, E. coli, Fungi and Pseudomonas, had results indicating it's high-quality for drinking purposes which in turn contradicted with our findings. Our study had some limitations due to the spread of COVID-19 pandemic, which narrowed the years of the study to be only between 2015-2019. Furthermore, it resulted in a limited collection sites which lead to a smaller number of treated water samples compared to tank water samples. In addition, it caused a delay in the publishing process or else it could have been more relevant.

Table 9. Anova test of Treated water samples within 5 years.

Test parameters	Correlation	Sig.
Total no. of samples & coliform	0.316	0.684
Total no. of samples & Fungi	0.551	0.336
Total no. of samples & P. aeruginosa	0.561	0.439
Total no. of samples & impurities	0.360	0.601

5. Conclusions

- Treated water is safe to be used for drinking purposes in terms of its free of any contaminants, since in all samples, no concentration reached the maximum level permitted by Jordan standards and (NPDWRs) for drinking water. Treated water samples were in compliance with these standards.

- Coliforms and F. coliform risk indicators were found in some tested Tank water samples at food providing establishments (> 5%) and failed to meet both Jordan standards and (NPDWRs) for drinking water.

Recommendations

-When it comes to the water we drink, governments have an important role to play in reviewing and maintaining potable water standards and in protecting consumers through transparent information.

- It is important for regulatory agencies to run routine checks on the piping systems distributed around GAM's twenty-two districts.

- Private water suppliers must undergo a certain form of censorship by a regulatory body, to ensure the sanitation of the water transported by their tanks.

- Increase awareness among owners of food-providing establishments with periodic cleaning of their tanks and encouraging them to provide their samples for testing.

- Ensure periodic cleaning of water tanks to prevent potential water pollution.

- It is highly recommended that the Water Authority of Jordan (WAJ), should increase water pumping frequency through the municipal pipes, which may be as twice a week or more.

Conflict of interests

We affirm that this submission represents work that has not been published previously and is not currently being considered by another journal. Also, I confirm that each author has seen and approved the contents of the submitted manuscript.

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- Mohammad Fawzi: conceptualization, methodology, writing-original draft, writing, reviewing & editing, project administration, approving the final.
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- Areej Hadadin: resources, data curation.
- Hana Frehat: data curation, formal analysis.
- Rasha ma'ayta: formal analysis, software.
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