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Source: Air, Soil and Water Research, 10(1)

Published By: SAGE Publishing

URL: https://doi.org/10.1177/1178622117733441

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Assessment of Potable Water Quality in Baghdad City, Iraq

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Air, Soil and Water Research
Volume 10: 1–5
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DOI: 10.1177/1178622117733441



ABSTRACT: Safe drinking water is crucial for the well-being of current and future generations. This study aims to evaluate the quality of potable water in Baghdad city. Furthermore, this study compares the quality of tap and bottled water. Baghdad city was divided into 4 districts based on the water source, and 40 water samples were collected from each district. Moreover, the most popular bottled water brands were sampled and compared with the tap water samples. The quality of the analyzed potable water samples varied based on the water source. The total dissolved solid (TDS) levels exceed the palatable (>600 ppm) water levels in some districts. In addition, the concentration of sulfate was relatively high in both tap and bottled water and ranged from 200 to 330 ppm. The bottled water quality was within the acceptable limits set by the World Health Organization, but the TDS levels were relatively high. The hardness, Cl^-, Pb^{2+}, and bacteria contents in both tap and bottled water were within the standard limits. Finally, it is important to conduct radiological analyses in the future to investigate the effect of wars on Iraqi water resources.

KEYWORDS: Bottled water, tap water, water quality analysis

RECEIVED: June 3, 2017. **ACCEPTED:** August 29, 2017.

PEER REVIEW: Two peer reviewers contributed to the peer review report. Reviewers' reports totaled 511 words, excluding any confidential comments to the academic editor.

TYPE: Original Research

FUNDING: The author(s) disclosed receipt of the following financial support for the research, authorship, and/or publication of this article: This study is supported by the Philadelphia University.

DECLARATION OF CONFLICTING INTERESTS: The author(s) declared no potential conflicts of interest with respect to the research, authorship, and/or publication of this article.

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Introduction

Freshwater is a precious resource essential for sustaining life, health, and ensuring the preservation of ecosystems. Due to the importance of water, the pattern of human settlement throughout history has often been determined by its availability. Good-quality potable water can be consumed in any desired amount without adverse health effects[1]; is free from harmful levels of impurities such as bacteria, viruses, minerals, and organic substances; and is aesthetically acceptable and free of unpleasant impurities, such as objectionable taste, color, turbidity, and odor.[2]

The most common problems in household water supplies are hardness, iron, sulfides, sodium chloride, acidity, and disease-producing pathogens, such as bacteria and viruses.[3] Thus, these are the most widely tested parameters to judge water quality.[2,4] However, several metal ions, such as sodium, potassium, magnesium, and calcium, are essential to sustain biological life. At least 6 additional metals, chiefly transition metals, are also essential for optimal growth, development, and reproduction. These metals are manganese, iron, cobalt, copper, zinc, and molybdenum, which are in small enough quantities to be considered trace elements. Trace metals function mostly as catalysts for enzymatic activity in the human body.[5] However, all essential trace metals are toxic at excessive concentrations.[6]

However, with lifestyle changes and population growth, the demand for water has increased dramatically, and its uses have become more varied. As a result, water quality has become of great concern.[4] There is evidence of an emerging global water crisis that will threaten lives, sustainable development, and even peace and security.[7] Currently, the demand for packaged drinking water is growing daily.[8] This creates new challenges for humanity to guarantee the quality and the required quantity of delivered water and to equalize access to drinking water.[9] There are different types of bottled water depending on the water source, additives added to the treated water, bottle size, and type.[10]

Tigris River is the main water supply for Baghdad city.[11] However, since April 2003, in Baghdad city, bottled water with 20-L capacity has gained a position in the market because of tap water pollution. The uncertainty of tap water quality after war has caused an increase in the number of local water treatment shops around Baghdad. A customer satisfaction survey conducted by the Directorate of Water in Baghdad showed that customers avoid drinking tap water, fearing that it is contaminated. However, the main concern of the bottled water industry is the absence of standards and specifications for water treatment processes in the shops; thus, treatment is usually based on one's own experience. As a result of an absence of standards, there is no monitoring or quality check over these shops. However, the problems associated with tap water supplied by the network may be classified into 2 main categories: problems in the treatment process and problem with the network distribution system.

As a result, an extensive analysis of potable water in Baghdad is urgently needed to elucidate the water quality. Thus, this study aims to evaluate the water supply from tap and bottled water in the city by conducting physical, chemical, biological, and trace elemental analyses. Then, the results are compared with the World Health Organization (WHO) guideline standards to assess the quality of drinking water collected from different sources and sample stations in Baghdad.



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Materials and Methods

Study area

Baghdad city is the most densely populated city in Iraq and has a high growth rate.[12] The population is approximately 4 million, according to the last residential census issued by the Ministry of Planning in 2015. Local immigration has played a main role in the population increase due to security circumstances around Baghdad city. This population increase has resulted in growing demand for potable water, and thus, potable water production will increase accordingly with low specification control.

Over the past few decades, the problem has been enormous due to high natural population growth, rural to urban migration, and major influxes of population in response to political and economic crises in the Middle East. These trends have resulted in increasing demand for both domestic and industrial users.

Water sampling and analysis

In this study, a total of 160 tap water samples were collected. All samples were taken from residential homes (tap water) from water obtained from the 4 main drinking water treatment plants (WTPs). The locations and names of these plants are as follows:

- AL-Karkh WTP, District No. (638);
- AL-Dora WTP, District No. (806);
- AL-Wahda WTP, District No. (733);
- East Tigris WTP, District No. (304).

The tap water sampling was performed using the same procedure used by Ahmad and Bajahlan.[13] The tap water samples were collected between the months of June and July 2015. Moreover, to properly monitor the tap water quality in Baghdad city, the whole city was divided into 4 sectors, as shown in Figure 1. Then, 10 samples from each sector were collected on a weekly basis. In this way, 40 water samples were collected from each sector during the sampling period. However, the tap water samples were kept in sealed glass bottles, refrigerated, and transferred to the laboratory. Then, the physiochemical parameters of the samples were analyzed. Finally, the results of each test were averaged and tabulated as the monthly average value.[13]

However, the quality of bottled water was investigated and compared with the quality of tap water. For this, water samples from the 9 most popular bottled water brands[2] were collected from the local markets and analyzed. The tested bottle brands were AL-Doualya, AL-Muthada, Sama, Safa, AL-Furat, Nabue, AL-Rayan, Mazi, and Rahyek. The bottles were 500 mL in size and composed of nonrecyclable polyethylene bottles. The standard methods described by Greenberg and Clesceri[14] were used for analysis of the physiochemical water quality parameters.

The tested water parameters were the pH, total dissolved solids (TDS), conductivity, turbidity, total hardness, magnesium, calcium, chloride, nitrate, nitrite, sulfate, sulfite, and trace element, such as lead and iron.[15] However, a full trace elemental analysis was not performed in this study due to (1) limitations in the epidemiologic data, such as that for mercury (Hg) and aluminum (Al); (2) the unlikely presence of elements, such as beryllium (Be) in drinking water; (3) the nontoxicity of elements such as zinc (Zn) in drinking water; and (4) sampling time and budget limitations.[16]

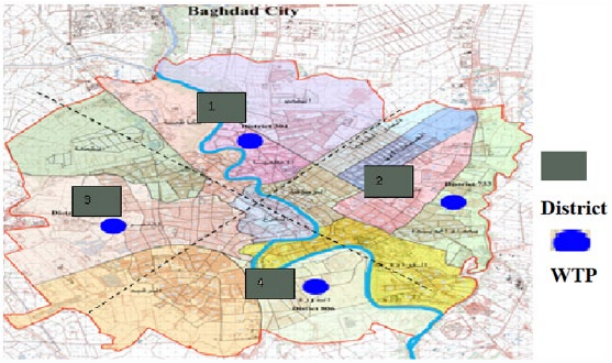


Figure 1. Baghdad city sampling locations. WTP indicates water treatment plant.

Bacteriological parameters

Microbiological analysis of drinking water is important to detect and control waterborne pathogenic diseases, such as typhoid fever, viral and bacterial gastroenteritis, and hepatitis A. Microbiological analysis of total and fecal coliforms was conducted to determine the bacteriological quality of the tested water samples. In addition, fecal coliform bacteria may occur in ambient water as a result of domestic sewage overflow or nonpoint sources of human and animal waste. A membrane filter method, which is a standard method for the enumeration of total and fecal coliforms in water and wastewater samples, was implemented. In this analysis, a 100-mL water sample was collected in a sterilized container containing sodium thiosulfate tablets to eliminate the effect of residual chlorine. Then, the sample was filtered through sterilized filters and incubated at 35 ± 0.5°C for total coliform analysis and at 44.5 ± 0.2°C for fecal coliform analysis.[13,17] After 1 day of incubation, colonies with a greenish-gold metallic sheen for total and blue for fecal coliforms were counted under a microscope with ×10 to ×15 magnification.

Drinking water guidelines

Guideline values for drinking water have been derived for many chemical constituents. The guideline or standard values represent the constituent concentrations that do not have any impact on human health over a lifetime of consumption. World Health Organization[18] guidelines were used to judge the quality of drinking water in Baghdad city due to its wide acceptance among various countries.

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Results and Discussion

The quality of potable water varies depending on many factors, such as the water source, treatment process, water storage method, and distribution network.[10] Table 1 shows the mean values of the analyzed physiochemical parameters and trace metals in tap water from Baghdad city. The water pH is one of the most important water quality indices. The obtained pH values ranged from 7.5 to 8.6, indicating that the tap water in Baghdad city is alkaline (pH >7). Furthermore, there are no remarkable variations in sampling sites, and thus, it can be concluded that the water treatment and purification methods had only a small effect on the hydronium ion concentration.

Moreover, the electrical conductivity (EC) and TDS concentration of tap water from the different sites did not show significant variation and ranged from 689 to 864 µS/cm and 567 to 683 mg/L, respectively. The TDS concentration considerably varied among various geological regions due to mineral solubility differences and local conditions, such as water resources and treatment process. Although the TDS concentrations in Baghdad city are within acceptable levels, that is, less than 1000 ppm, the tap water in districts 1 and 4 exceeded the palatable water level, that is, 600 ppm.[16] However, the differences in the EC and TDS level among the different sectors in Baghdad city may be attributed to variations in the tap water source and treatment techniques.

Water turbidity and hardness

Although the source of drinking water in Baghdad is surface water and is thus characterized by a relatively high suspended solid concentration, the implemented water treatment processes successfully eliminate these solids. The water turbidity is less than 1 NTU, which indicates the efficient removal of suspended solids. The water hardness is indicated by precipitation of soap scum and scale deposition when heating water, resulting in economic losses. The hardness of water from Baghdad city is approximately 90 ppm $CaCO_3$. However, according to WHO (2011), a water hardness less than 100 ppm should be monitored to reduce the risk of network corrosion due to low buffering capacity.

According to WHO (2011), there is evidence of human health impacts associated with a few chemicals. However, the obtained results indicate that the tap water in Baghdad city does not represent a toxicity problem. The tested nitrate, chloride, manganese, iron, sulfate, and lead levels were within the accepted WHO limits.

Bacteriological studies

The presence of total coliform in drinking water indicates the possibility of water contamination by pathogens or disease-causing bacteria or viruses that exist in fecal matter.[20] The obtained results show the presence of total coliform bacteria. This highlights the demand for further investigation of the type

Table 1. Mean values of the physiochemical parameters of tap water from different districts in Baghdad city and the WHO limits.

WATER SOURCE	DISTRICT 1	DISTRICT 2	DISTRICT 3	DISTRICT 4	WHO GUIDELINES[a]
pH	7.5	8.3	8.2	8.6	6.6-8.5
EC, µS/cm	864	689	764	803	—
TDS, mg/L	625	567	587	683	—
Turbidity, NTU	0.56	0.62	0.58	0.67	—
Chloride, mg/L	74	64	55	57	250
Total hardness, mg/L	94	88	73.4	91.3	500 ppm as $CaCO_3$
Nitrite, mg/L	<0.025	<0.025	<0.025	<0.025	3
Nitrate, mg/L	2.4	2.78	2.45	2	50
Sulfite, mg/L	20.4	26.2	25.6	23.8	—
Sulfate, mg/L	338	230	280	215	500
Calcium, mg/L	56	64	92	83	—
Magnesium, mg/L	34	36	41	33	—
Iron, µg/L	83	91	83	78	300
Lead, µg/L	0.003	0.003	0.004	0.002	0.1
Fecal coliform, CFU/100 mL	0	0	0	0	—
Total coliform, CFU/100 mL	7	5	2	2	—

Abbreviations: EC, electrical conductivity; TDS, total dissolved solids; WHO, World Health Organization.
[a]Adapted from WHO and Water, Sanitation and Health Team.[19]

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Table 2. Physiochemical parameters of the main bottled water brands in Baghdad city.

WATER SOURCE	AL-DOUALYA	AL-MUTHADA	SAMA	SAFA	AL-FURAT	NABUE	AL-RAYAN	MAZI	AL-RAHYEK
pH	8.4	8.2	7.9	7.4	8.4	8.0	8.4	8.2	8.2
EC, µS/cm	716	773	606	721	682	660	662	667	666
TDS, mg/L	472	510	400	474	450	434	436	440	448
Turbidity, NTU	0.22	0.26	0.41	0.28	0.35	0.18	0.32	0.23	0.17
Chloride, mg/L	12.2	13.4	22	11	14	12.4	17.6	34	19
Total hardness, mg/L	85.7	77.6	85	48	75	65	75	67	81
Nitrite, mg/L	<0.025	<0.025	<0.025	<0.025	<0.025	<0.025	<0.025	<0.025	<0.025
Nitrate, mg/L	2.4	3.6	3.4	1.6	6.7	4.3	3.7	4.7	5.8
Sulfite, mg/L	11.4	16.7	20.2	6.4	10.4	18.3	14.7	18.3	12.5
Sulfate, mg/L	204	175	240	255	267	294	340	286	346
Calcium, mg/L	25	36	45	13.4	27	37	46	57	48
Magnesium, mg/L	2.5	3.6	4.1	1.2	7.3	3.4	5.6	8.6	4.2
Iron, µg/L	30	23	40	12	22	24	15	20	17
Lead, µg/L	3	4	2	0	0	0	1	0	4
Fecal coliform, CFU/100 mL	<1	0	0	0	0	0	<1	0	0
Total coliform, CFU/100 mL	0	0	0	0	0	0	0	0	0

Abbreviations: EC, electrical conductivity; TDS, total dissolved solids.

and source of these microorganisms. District 1 has the highest total coliform presence, with an average of 7 CFU/100 mL, which may be attributed to the large population in this district and extensive industrial activities.

Furthermore, a specific subgroup of total coliform collection is fecal coliform bacteria, of which the most common member is *Escherichia coli*. The presence of fecal coliform bacteria in aquatic environments is a sign of either human or animal fecal contamination. The presence of fecal contamination is an indicator of a potential health risk for individuals exposed to this water. However, the performed tests show that the tap water in Baghdad city is free from fecal coliform.

Bottled water quality

Bottled water consumption is steadily growing almost all over the world. This can be attributed to concern, dissatisfaction, and uncertainty in the quality of tap water.[21] The obtained results shown in Table 2 indicate that most of the tested bottled water samples are alkaline with a pH above 8. Moreover, the TDS concentration in most of the tested bottled water samples is relatively high, ranging from 420 to 470 ppm. This indicates that either none of the bottled water was treated by reverse osmosis (RO) filtration or the water was from a mineral source. However, none of the bottled water samples were designated mineral water, and the bottled water was supposed to be treated by RO. Thus, it can be concluded that the high TDS concentration is due to a low level of treatment and lack of monitoring and control over the process.

Moreover, the sulfate concentration is relatively high in the tested bottled water samples. However, water carbonation is usually performed to improve the taste of bottled water that contains high concentrations of TDS and sulfate. However, carbonated beverages are suspected to enhance tooth enamel wear.[22] The remaining tests show good performance, and the quality of bottled water is within the international standards.

Comparison of tap water vs bottled water

Recently, comparisons between tap and bottled water have been made in various studie.[21] However, bottled water, which is more expensive, does not necessarily have better quality than tap water.[23] In some cases, tap water has better quality due to the implementation of more strict and frequent tests. Although both tap and bottled waters are alkaline with pH values higher than 7, generally bottled water has a higher pH, as shown in Figure 2. This may be a result of additional water treatment

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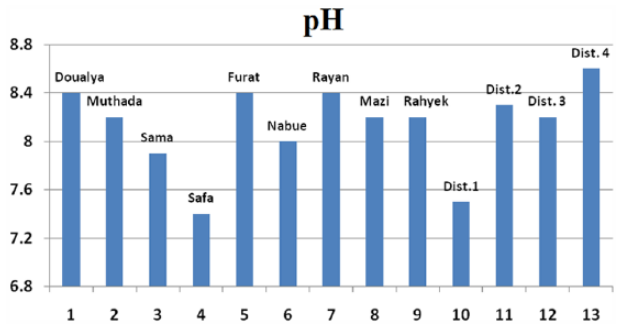


Figure 2. Comparison of the pH values of the tap and bottled water samples.

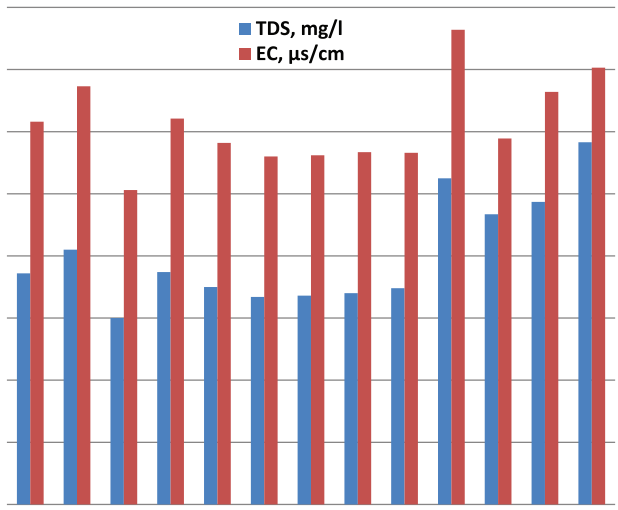


Figure 3. Comparison of the TDS and EC values of the tap and bottled water samples. EC indicates electrical conductivity; TDS, total dissolved solids.

methods that are practiced in water bottling industry. However, water from district 4 had the highest pH value.

Figure 3 shows that bottled water of all water brands has lower TDS levels and EC values. However, the differences in the TDS and EC values between tap and bottled water are not significant. The TDS levels for tap water are above 500 ppm, whereas these values are in the range of 400 to 500 ppm for bottled water. Again, district 4 had the highest TDS and EC values, which highlights the need to improve the monitoring process.

Conclusions

The quality of tap water meets WHO standards and reflects good treatment processes. However, some parameters, such as the TDS, EC and sulfate levels, are near the upper limits, which indicate a critical situation. In addition, the demand for bottled water is increasing, and its consumption trends upward. Thus, to organize and properly monitor the sector, there is an urgent need to establish a local standard for bottled water. Furthermore, the packing code, material, and label information should include this standard to facilitate future monitoring and market surveying. Finally, radiological tests are highly recommended for future work to investigate the effects of the various tragic wars that occurred in Iraq in the past few years.

Author Contributions

GAA-D designed the research, collected the samples, and performed the analysis. MKY helped with the research design and manuscript preparation and writing.

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