Original Research

Chemical Pollution Risks for Many Drinking Water Sources in Baghdad City, Iraq

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Abstract

To determine contamination levels of pollutants in all of Baghdad's drinking water sources, all samples were taken from different water sources which are used in research areas and examined by AAS, pH, turbidity and TDS meters. The results indicate the mean concentrations of heavy elements (Cd, Co, Pb, and Cr (except for the concentration of chromium in one site)) were within WHO permissible limit> in the samples of drinking water were higher than the international limits. Mean concentrations of other heavy elements (Cu, Fe, and Ni) in water samples were below WHO recommendations permitted limits. The findings of the sample pH values were within the international acceptable limits. Turbidity values for all samples were within the Iraqi and global limits except 4 sites that exceeded acceptable WHO and Iraqi guideline limits. The levels of TDS in all samples were also lower than WHO except the samples in two sites which show levels of TDS higher than the Iraqi and WHO limits. According to the results above, all the drinking water projects in the Tigris River and water wells in Baghdad city must be monitored, Adequate and new drinking water treatment methods shall also be used. The Heavy Pollution Index (HPI) findings indicate that the drinking water sources in the city of Baghdad have been substantially polluted with Cd, Co and Pb.

Keywords: heavy metals, drinking water, Tigris River, Baghdad

Introduction

Following decades of corruption during the wars and trade restrictions of the 1980s and 1990s, and the serious environmental damage caused by the US occupation of Iraq after 2003, Iraq's pollution levels reached a peak. Where the water quality in Iraq's main rivers: Tigris and Euphrates has greatly degraded and is considered the country's life-blood. Tigris water contamination is the worst, and is one of Iraqis' major sources of cancer [1]. High levels of pollution in recent years are due to various factors including directly from wars, factories, and the discharge of water from houses and hospitals directly into the Tigris River which contains many polluted materials (chemicals, pesticides, and agricultural fertilizers). Certain factors that aren't explicitly due to government negligence and the lack

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of a systematic management strategy to tackle these pollution causes. Since 2003, all governments in Iraq have not assumed responsibility for this environmental disaster and did not recognize the issues or even try to find solutions to the rate of massive pollution and raise it [2].

Researches that shed light on the levels of chemical contamination for drinking water sources in Iraq in general and Baghdad, in particular, are few compared to the effect of the serious water pollution that Iraq is suffering at present in addition to the absence of accurate governmental statistics for the levels of water pollution of drinking water sources in actual. Thus, we decided to start an actual study to measure and evaluate concentration for some heavy elements, pH, Turbidity and Total Dissolved Solids (TDS) for several drinking water sources in the city of Baghdad. Drinking water includes various dangerous heavy metals, including lead, cadmium, chromium, copper, cobalt, iron, nickel and others; which are considered to be at high levels that threaten the lives of humans and causing many chronic diseases and cancer [3].

Many recent studies have demonstrated major environmental and public health effects of the heavy elements. The entry of these elements into the human body leads to toxic effects on the human body or organisms [4]. The lead element (Pb) is one of the most dangerous elements that affect the body system and cause serious damage, especially to children. Lead is also a contributing factor for cancer [5]. The accumulation of cadmium element (Cd) within the human body when its concentration exceeds safe critical limits, causes serious health damage and is classified as a group I carcinogen; it is harmful to the kidney, liver, reproductive system and nervous system [6]. The chromium (Cr) element has several oxidants; hexagon chromium (VI) is quite toxic. Risks of this type of the human body include lung cancer, skin rash, gastric disorders and ulcers, breathing disorders, weakness in the efficiency of the immune system and other [7]. Increasing the concentration of the copper (Cu) element in the body leads for poisoning, heart problems, and jaundice and ultimately can lead to death [8]. Although cobalt (Co) is considered a heavy element, its effect as an element is quite different from other heavy elements. Cobalt is a part of vitamin B-12 synthesis and is important for bone and muscle growth, but increasing the concentration of cobalt in the human body leads to atrophy of the heart muscle, and hypothyroidism [9]. Although the iron (Fe) level is not harmful in itself, iron is classified in drinking water as a secondary pollutant. If iron levels are too high, serious health effects will be created with the liver, heart, and pancreas in addition to the risk of diabetes and anemia [10]. As it is known, the nickel element is not deposited in the human body but is excreted through urine, feces, and sweat. However, while accumulating, nickel compounds in the body can lead to many dangerous diseases, such as contact dermatitis, pulmonary fibrosis, renal cardiovascular

disease and lung cancer [10]. For pH, it does not effectively affect human life or the environment, but it is recommended that the pH is less than 10 to reduce corrosion in the water pipes as well as to maintain the taste, smell and appearance of water [12]. Several studies have shown an important relationship between drinking water and cancer concentration rates of TDS, coronary heart disease. Mortality rates from cancer and heart disease increase when the TDS concentrations increase in drinking water [13, 17].

Despite the unprecedented serious environmental pollution in the Baghdad city (the capital of Iraq), there is little attention by the researchers, the government, and international organizations paid to this site due to the lack of funds allocated for research in addition to the ongoing, financial crisis in Iraq, and the absence of law to protect rivers and lakes from dumping hazardous waste into freshwater [18-21].

Baghdad is actually one of Iraq's most populated cities located in the Middle East, having the most polluted population, especially pollution of the Tigris River and other sources of drinking water in Baghdad. This pollution in some places is serious in dozens of times than global standards. If environmental pollution, especially the pollution of the Tigris River will be continuously neglected, this will eventually lead to the spread of to tens of thousands of cases of cancerous diseases and other fatal diseases; the effects of this pollution are now being noticed [22].

This work primarily seeks to quantify and calculate the percentage of cadmium, chromium, copper, cobalt, iron, zinc, and nickel pollution, as well as pH, turbidity, and TDS in Baghdad's major drinking water sources, including the Tigris River, water wells, bottled drinking water, and Tap Water. This study is considered as the first actual attempt to measure various basic drinking sources in Baghdad. The result of the research can be used to reduce pollution, and improve drinking water quality, especially in Baghdad and Iraq in general.

Material and Methods

Geographical Study Sites

The research sites (tap water, water wells, and the Tigris River (Fig. 1)) are situated in separate areas of Al-Rusafa and Al-Karkh (City of Baghdad is split into two parts: provinces Al-Rusafa and Al-Karkh) (Fig. 2), while bottled drinking water (Pearl, Al-saad and Aquafina) were purchased from different shops (used by about 70% of the population) in Baghdad city, and we chose the time to study samples in the rainy season in Iraq (Table 1).

Sample Collection

Water samples were randomly obtained from several locations inside Baghdad (Figs 3 and 4). All

Fig. 1. The map of Iraq shows the Tigris and Euphrates rivers, modified by the authors.

the samples were collected in plastic sealed tubes. The collection process took about 5 months (from November 2018 to March 2019). Drinking water samples collected from the following sites: S1- Al-A'amel Neighborhood (4 samples), S2- Kasraa Wa Ataash Neighborhood (5 samples), S3- Hayfaa Street (4 samples), S4- Al Fadhilia Neighborhood (3 samples), S5- Bab Al-Moatham Neighborhood (5 samples), S6- Al-Sarafiya Bridge, S7- Pearl company (bottled drinking water- 7 samples), S8- Al-saad company (bottled drinking water- 6 samples) and S9- Aquafina company (bottled drinking water- 4 samples).

Instrumentation

All samples were analyzed by Atomic Absorption Spectrometer (AAS, model: novAA 400 - Analytik Jena, 2005, Germany). The drinking water tests were conducted using the Traditional Water and Wastewater Examining Process [23]. All instrumental parameters were established according to the recommendations of the manufacturer and the chemicals used were of analytical grade type [24, 25]. The pH and turbidity for all drinking water samples were examined by pH meter (model: WTW, Germany) and turbidity meter (model: HACH, USA), while the total dissolved solids were examined by a handy TDS meter (Millipore filter device, model: LABSCO, Germany). The drinking water samples were measured in the laboratories of the Iraqi Ministry of Science and Technology.

Fig. 2. Location of Tigris River in Baghdad City (showing how the Tigris River splits Baghdad city into Al-Rusafa and Al-Karkh regions).

Table 1. Geographical Study Sites, Samples Locations and Date of Collection in Baghdad city.

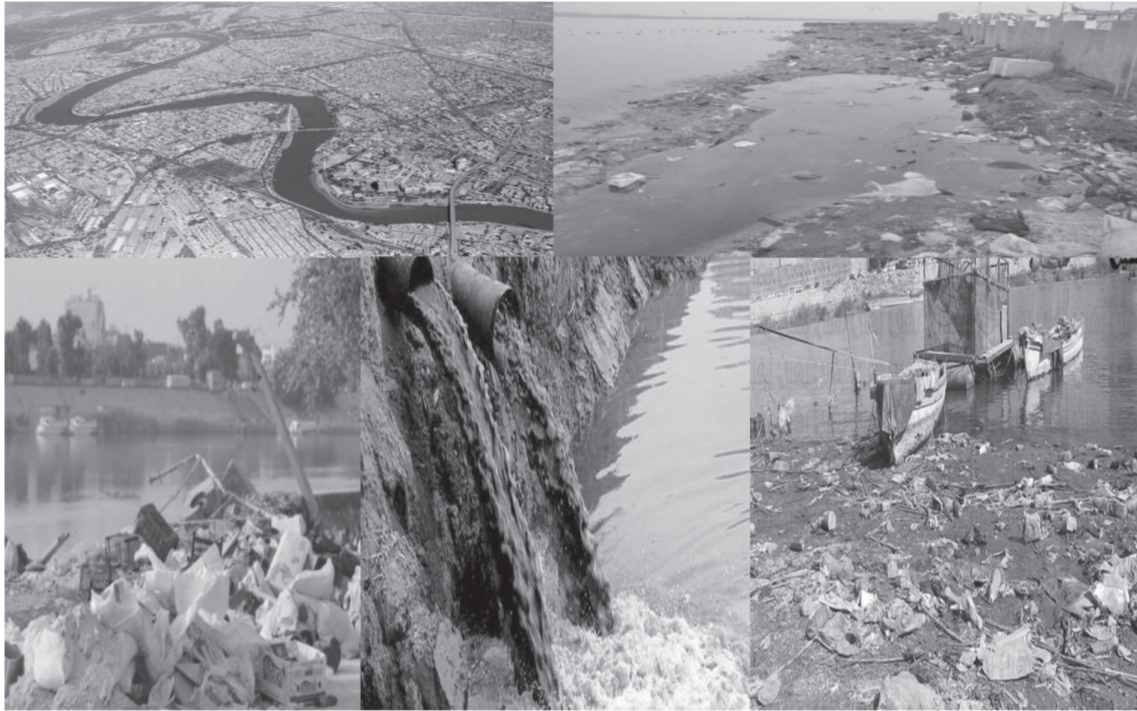| Sample №	Sample Location	Geographical Study Sites	Date of collection
S1	Tap Water	Al-A'amel Neighborhood	12-11-2018
S2	Tap Water	Kasraa Wa Ataash Neighborhood	15-11-2018
S3	Water Well	Hayfaa Street	13-11-2018
S4	Water Well	Al Fadhilia Neighborhood	22-11-2018
S5	Tigris River	Bab Al-Moatham Neighborhood	05-12-2018
S6	Tigris River	Al-Sarafiya bridge	05-12-2018
S7	Bottled Drinking Water	Pearl Company	12-11-2018
S8	Bottled Drinking Water	Al-saad Company	04-03-2019
S9	Bottled Drinking Water	Aquafina Company	04-03-2019

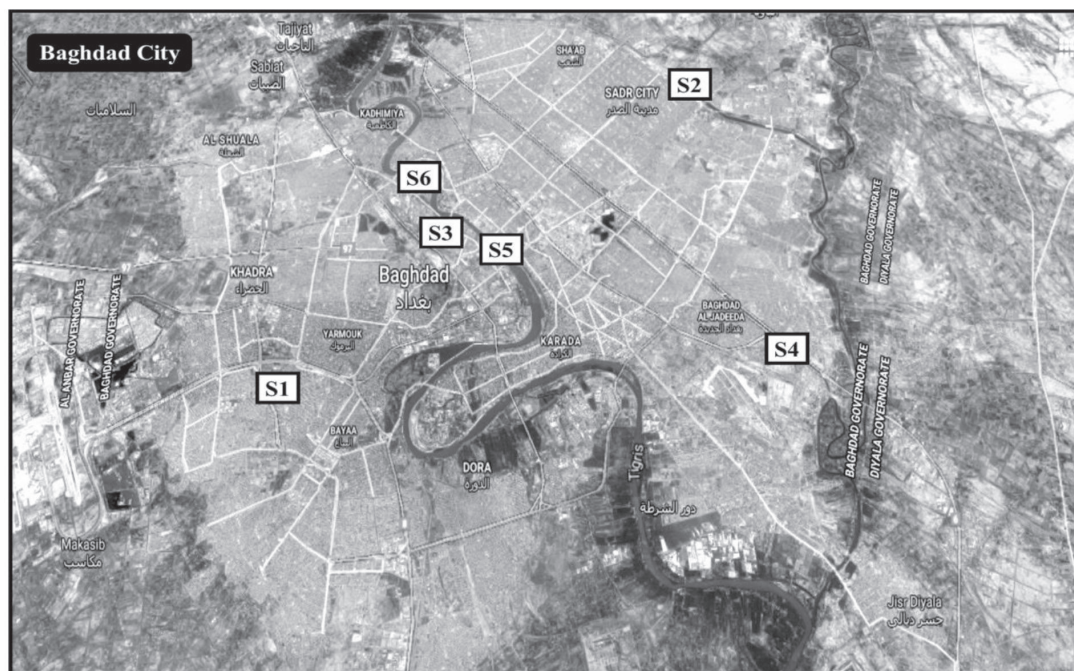Fig. 3. Some pictures of the Tigris River and its pollution (the pictures were taken in 2018 and 2019).

Fig. 4. Various sites for collecting drinking water samples in the Baghdad city.

Heavy Metal Quality Index (HPI)

We used the Heavy Metal Pollution Index (HPI) to assess the consistency of the heavy metals water for drinking water supplies in Baghdad City. HPI is calculated using the equation given below:

$$HPI = \sqrt{[(C_e/S_e)^2_{max} + (C_e/S_e)^2_{min}]/2}$$

...where C_e is each element's recorded concentration, and where S_e is the normal permissible value for the element. HPI is categorized as follows into five groups: <1 (no effect), 1-2 (slightly affected), 2-3 (medium affected), 3-5 (strongly affected) and >5 (extremely affected); [26].

Table 2. Guideline levels for certain drinking water heavy elements (mg/l).

Heavy Element	WHO	Iraqi Standard	European Union	Canada	United States
Cadmium, Cd	0.003	0.003	0.005	0.005	0.005
Chrome, Cr	0.050	0.050	0.050	0.050	0.100
Copper, Cu	2.000	1.000	2.000	1.000	1.300
Cobalt, Co	0.001 - 0.002	-	0.00033	-	-
Iron, Fe	0.300	0.300	0.200	0.300	0.300
Lead, Pb	0.010	0.010	0.010	0.010	0.015
Nickel, Ni	0.070	0.020	0.020	0.010	0.100

Table 3. The standard values for drinking water for different physico-chemical parameters include pH, turbidity and total dissolved solids (TDS).

Physicochemical Parameters	WHO	Iraqi Standard	European Union	Canada	United States
pH	6.5 – 8.5	6.5 – 8.5	6.5 – 9.5	6.5 – 8.5	6.5 – 8.5
TDS (mg/l)	1000	1000	500	500	500
Turbidity (N.T.U)	5	5	4	0.1 – 1.0	0.5-1.0

Results and Discussion

Several global organizations have established appropriate levels of concentrations for heavy metals, such as the World Health Organization (WHO) and others, and other physicochemical parameters as seen in Tables 2 and 3 [27-31].

Results of the examined samples of drinking water are presented in Table 4 and Fig. 5. Fig. 5 show the results for the seven toxic chemicals concentration which are measured in this study: Cadmium, chrome, Copper, Cobalt, Iron, Lead, and Nickel. Physiochemical parameters (pH, TDS, and Turbidity) values for drinking water samples which were selected from many sites in Baghdad City are given in Table 4.

Table 4. Some physicochemical parameter values for drinking water samples, which selected from different locations in Baghdad City.

Sample №	pH	TDS (mg/L)	Turbidity (N.T.U)
S1	7.64	296	2.49
S2	7.84	341	9.44
S3	7.67	2740	2.70
S4	7.32	1720	51.09
S5	7.87	386	62.23
S6	7.91	312	30.23
S7	6.62	5	0.08
S8	7.11	36	1.40
S9	6.80	22	0.15

The high concentrations of cadmium (Cd) in drinking water are quite damaging to the environment, to life and to the human body, which leads to different diseases, especially kidney failure, and various cancers diseases. The mean concentrations of cadmium (Cd) in samples of drinking water (Fig. 6) for various areas of the city of Baghdad is as follows: Site 1- (0.130±0.07), Site 2- (0.170±0.02), Site 3- (0.180±0.09), Site 4- (0.170±0.06), Site 5- (0.180±0.06), Site 6- (0.130±0.03), Site 7- (0.120±0.02), Site 8- (0.170±0.05) and Site 9- (0.011±0.08). According to WHO, Iraqi standards and other standards (Table 2), the maximum allowed cadmium concentration in drinking water must be between 0.003-0.005 mg/L. The results show that cadmium concentrations in measured drinking water samples are quite high and this is why we are concerned about a humanitarian disaster in Baghdad if the water is not treated as soon as possible. The cadmium pollution in Bab Al-Moatham Neighborhood (Tigris River) and Haifa Street (Water Well) is about 60 times more than the international limit, while cadmium concentration in Kasraa Wa Ataash Neighborhood (Tap Water), Al Fadhilia Neighborhood (Water Well) and Al-saad Company (Bottled Drinking Water) is 56 times more than the permitted concentration. In other sites, cadmium concentration is increased 43 times (Al-A'amel Neighborhood (Tap Water) and Al-Sarafiya Bridge (Tigris River), 40 times in Pearl company (Bottled Drinking Water) and 4 times in Aquafina company (Bottled Drinking Water) respectively more than the limits allowed concentrations according to Iraqi and international standards. In Baghdad the highest concentration of Cd pollution is in the Tigris River and water wells. This can be shown as follows:
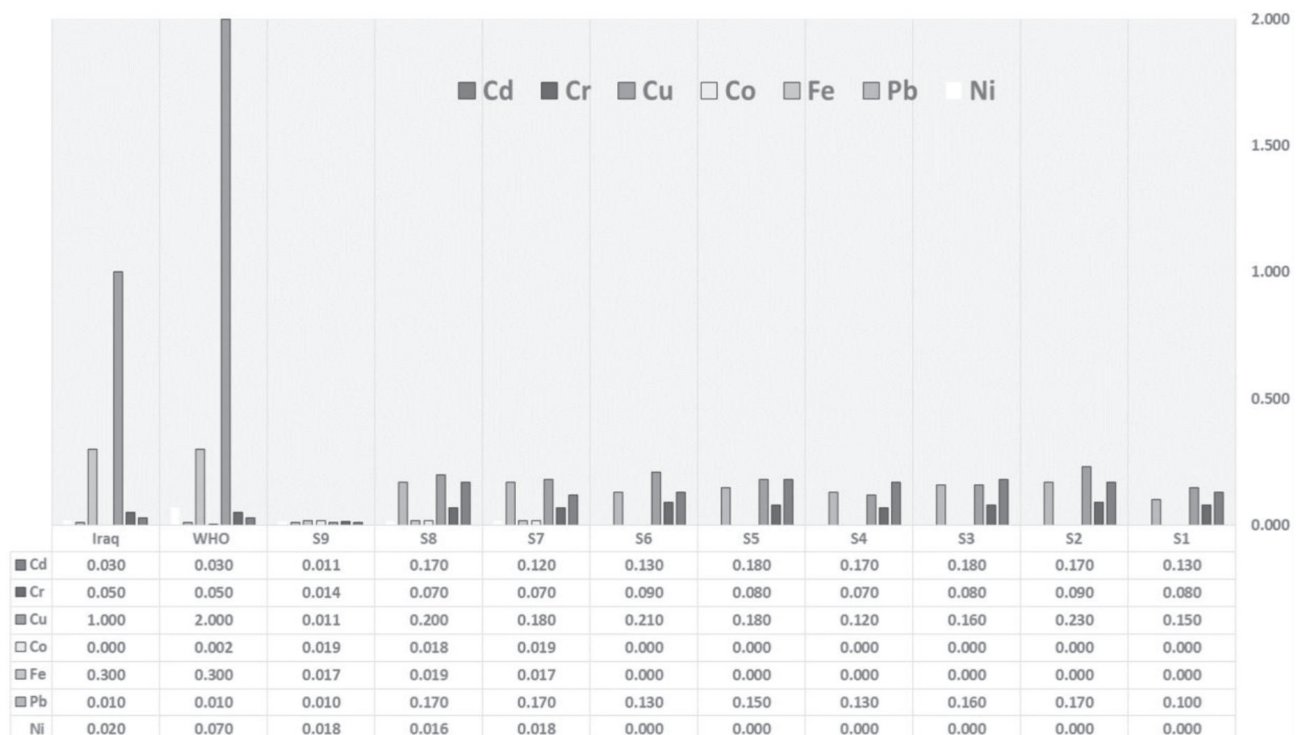
	Iraq	WHO	S9	S8	S7	S6	S5	S4	S3	S2	S1
■ Cd	0.030	0.030	0.011	0.170	0.120	0.130	0.180	0.170	0.180	0.170	0.130
■ Cr	0.050	0.050	0.014	0.070	0.070	0.090	0.080	0.070	0.080	0.090	0.080
■ Cu	1.000	2.000	0.011	0.200	0.180	0.210	0.180	0.120	0.160	0.230	0.150
□ Co	0.000	0.002	0.019	0.018	0.019	0.000	0.000	0.000	0.000	0.000	0.000
▣ Fe	0.300	0.300	0.017	0.019	0.017	0.000	0.000	0.000	0.000	0.000	0.000
▣ Pb	0.010	0.010	0.010	0.170	0.170	0.130	0.150	0.130	0.160	0.170	0.100
Ni	0.020	0.070	0.018	0.016	0.018	0.000	0.000	0.000	0.000	0.000	0.000

Fig. 5. Plot of mean concentration (mg/L) versus heavy elements (Cd, Cr, Cu, Co, Fe, Pb, and Ni) samples selected from different sites in Baghdad City.
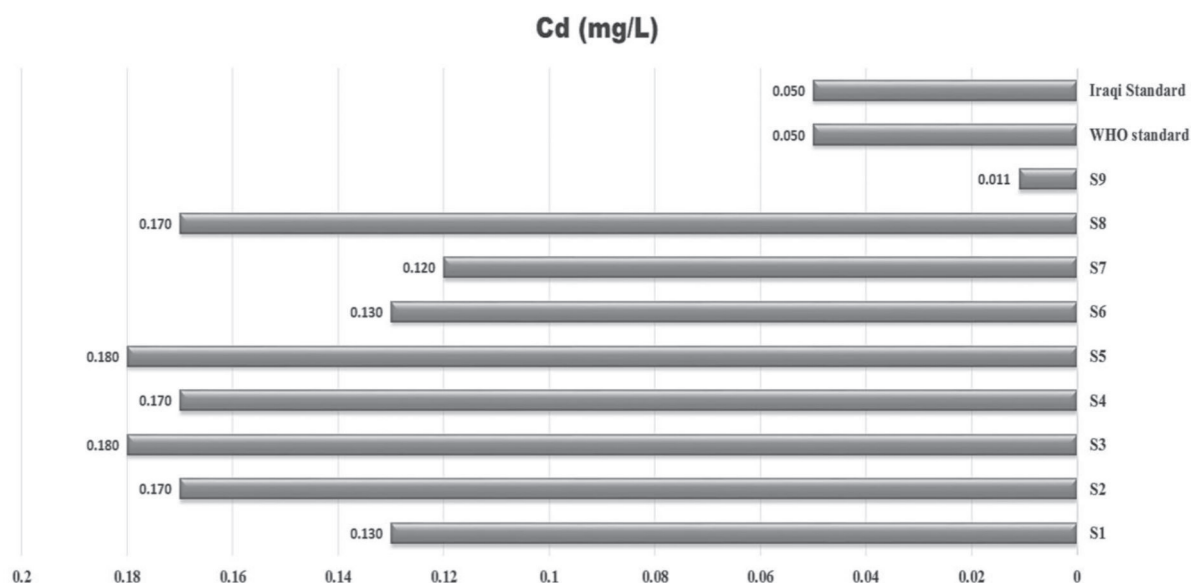

Fig. 6. Concentrations of Cd in different studied sites.

These results can be shown as follows: Tigris River and Water Well>Tap Water and Bottled Drinking Water.

In drinking water samples chromium (Cr) mean concentrations which were taken from Taps Water ranged between 0.080±0.02 mg/L (S1- Al-A'amel Neighborhood) to 0.090±0.04 mg/L (S2- Kasraa Wa Ataash Neighborhood); chromium concentrations in sample collected from Water Wells ranged between 0.080±0.05 mg/L (S3- Hayfaa Street) to 0.070±0.01 mg/L (S4- Al Fadhilia Neighborhood), while they ranges from 0.080±0.07 mg/L (S5- Bab Al-Moatham Neighborhood) to 0.090±0.04 mg/L (S6- Al-Sarafiya Bridge) in the samples taken from the Tigris River. Chromium concentrations measurements in Bottled Drinking Water samples that were purchased from different regions of Baghdad city were 0.070±0.09 mg/L (S7- Aquafina Company), 0.070±0.05 mg/L (S8- Al-saad Company) and

Cr (mg/L)

0.050	Iraqi Standard
0.050	WHO standard
0.014	S9
0.070	S8
0.070	S7
0.090	S6
0.080	S5
0.070	S4
0.080	S3
0.090	S2
0.080	S1

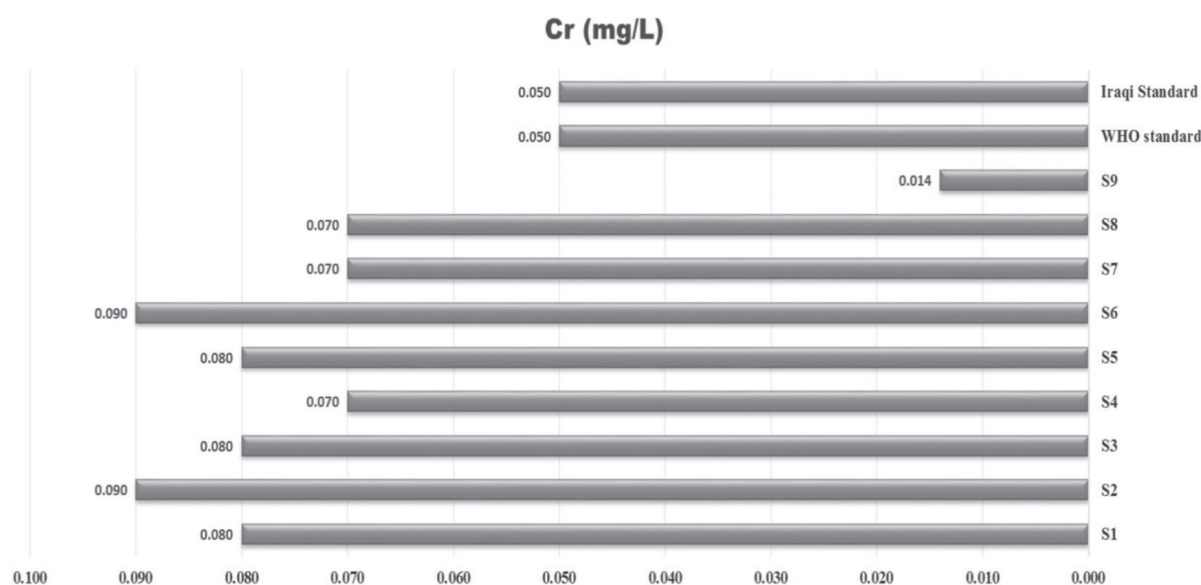0.100 0.090 0.080 0.070 0.060 0.050 0.040 0.030 0.020 0.010 0.000

Fig. 7. Concentrations of Cr in different studied sites.

0.014±0.03 mg/L (S9- Pearl Company). In the sites from S1 to S8, levels of chromium concentrations are between 1.5-2 times higher than global standards (Fig. 7) and can be attributable to many reasons such as remnants of war weapons, soil pollution, and others, whilst the chromium concentrations in bottled drinking water are below reasonable limits (Aquafina company). The Tigris River and Tap water are the highest concentration of drinking water pollution by Cr in Baghdad. This can be described as: Tigris River and Tap Water>Water Well > Bottled Drinking Water.

Copper is present in river water and other drinking water supplies due to industrial waste pollution as well as the spraying of agricultural pesticides. Copper is one of the basic elements of the human body, where the human body fulfills its needs of copper by eating, drinking and breathing. However, high concentrations of copper are harmful to human health. The concentrations of the copper (Cu) in Baghdad city, the scale from 0.011 to 0.230 mg/L in our sample sites (Fig. 8). All drinking water samples show low copper mean concentrations (Site 1- 0.150±0.09 mg/L; Site 2- 0.230±0.02 mg/L; Site 3- 0.160±0.09 mg/L; Site 4- 0.120±0.08 mg/L; Site 5- 0.180±0.05 mg/L; Site 6- 0.210±0.01 mg/L; Site 7- 0.180±0.07 mg/L; Site 8- 0.200±0.03 mg/L; Site 9- 0.011±0.06 mg/L) compared with WHO, Iraqi and other organizations standard (Table 2).

There is an important relationship between cancer diseases, and the high concentrations of cobalt and its compounds in the human body; increasing the concentration of cobalt in drinking water in a particular area leads to an increase in the proportion of people with different cancers diseases [32]. Cobalt (Co) concentrations in bottled drinking water samples clarified that the Pearl Company's mean concentration of cobalt in water samples was 0.019±0.01, while
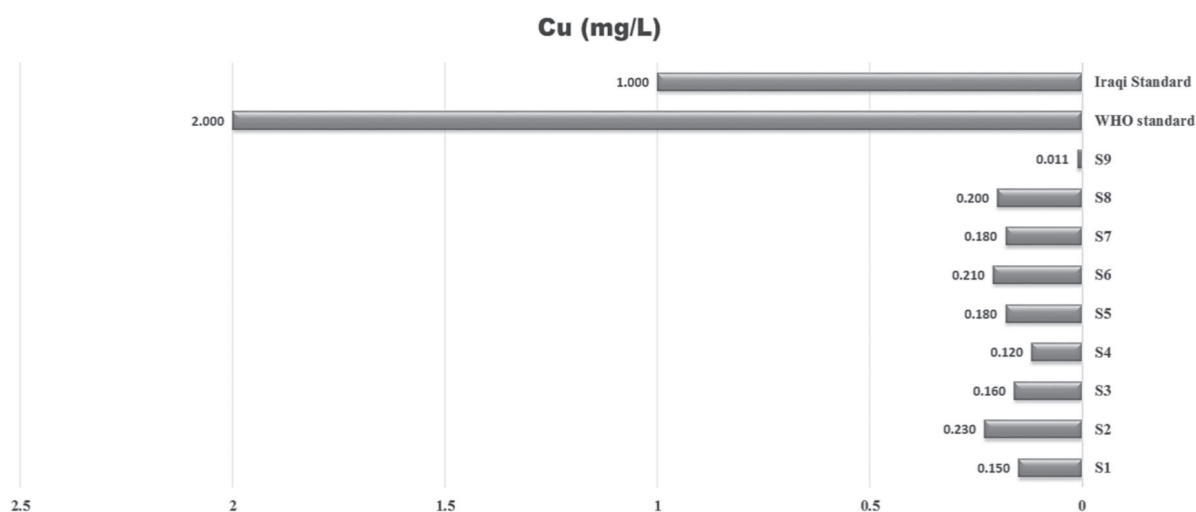
Cu (mg/L)

1.000	Iraqi Standard
2.000	WHO standard
0.011	S9
0.200	S8
0.180	S7
0.210	S6
0.180	S5
0.120	S4
0.160	S3
0.230	S2
0.150	S1

2.5 2 1.5 1 0.5 0

Fig. 8. Concentrations of Cu in different studied sites.

Co (mg/L)

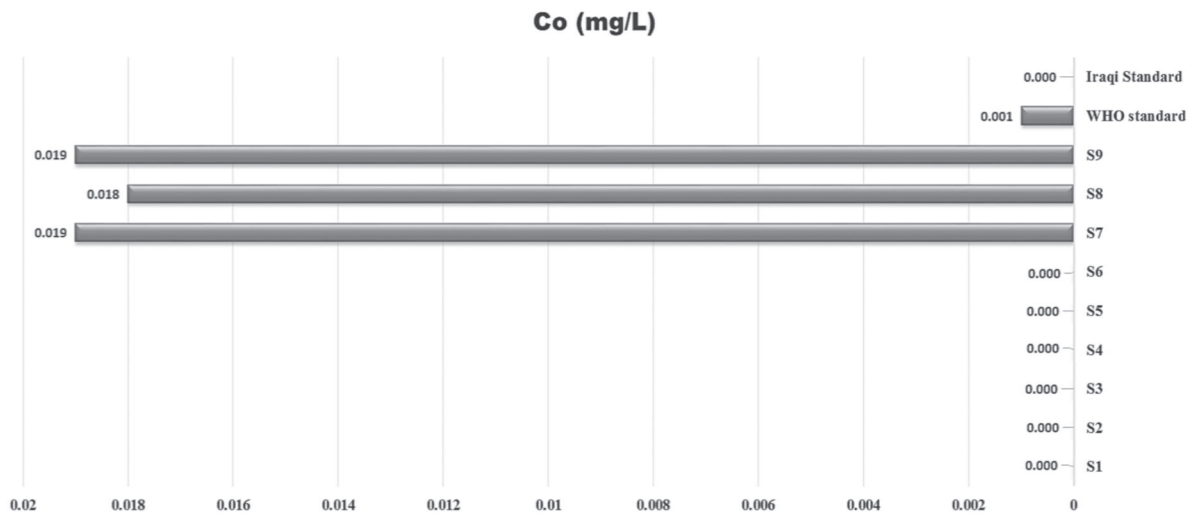

Fig. 9. Concentrations of Co in different studied sites.

the mean cobalt (Co) Concentration in the Al-saad Company water samples were 0.018±0.03 and the mean concentration of cobalt element in Aquafina Company water samples was 0.019±0.03. It can be noticed that cobalt pollution of bottled drinking water samples in two companies (Pearl and Aquafina) is about 19 times higher than WHO standard and in Al-saad Company bottled drinking water samples it increases 18 times compared with the international limit (0.001 mg/L) (Fig. 9).

The results of the mean concentrations of lead (Pb) (Fig. 10) for the drinking water samples in the different studying sites were as follows (mg/L):- First, in Al-Karkh region: Al-A'amel Neighborhood (0.100±0.03), Hayfaa Street (0.160±0.09), Al-Sarafiya Bridge (0.130±0.08). Second, the results in the Al-Rusafa region: Kasraa Wa Ataash Neighborhood (0.170±0.05), Al Fadhilia Neighborhood (0.130±0.03), Bab Al-Moatham Neighborhood (0.150±0.06). Third, the results of Bottled Drinking Water: Pearl Company (0.170±0.02),

Al-saad Company (0.170±0.06), and Aquafina Company (0.020±0.03).

These results confirm there is serious chemical pollution by lead. Additionally to the environmental impact, pollution of drinking water by lead in the major sources of drinking water in the city of Baghdad is a significant hazard to the health of public water consumers. The results revealed that the lead pollution in Al-A'amel Neighborhood (Tap Water) is ten times higher than the permitted international limit, while the pollution in Kasraa Wa Ataash Neighborhood (Tap Water), Pearl and Al-saad Companies (Bottled Drinking Water) increases 17 times. Pollution in the areas of Al-Sarafiya Bridge (Tigris River) and Al Fadhilia Neighborhood (Water Well) increases by 13 times and in Haifa Street (Water Well) increases 16 times, and in Bab Al-Moatham Neighborhood (Tigris River) increases 15 times, although Aquafina Company (Bottled Drinking Water) has concentrations of lead is about two times higher than the Iraqi and international
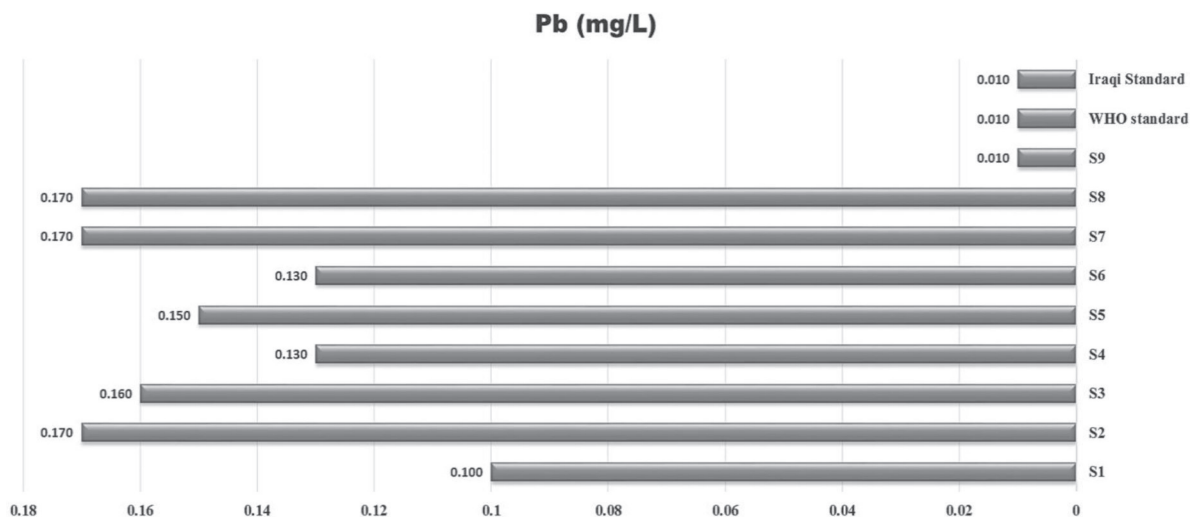
Pb (mg/L)

Fig. 10. Concentrations of Pb in different studied sites.
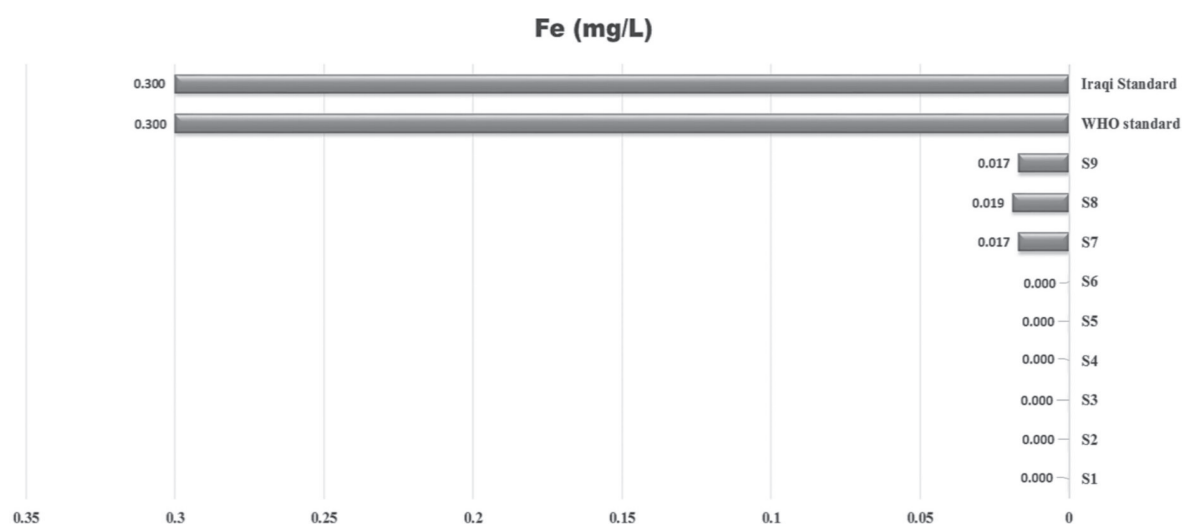
Fe (mg/L)

Fig. 11. Concentrations of Fe in different studied sites.

limits (Table 2). The highest rate of Pb drinking water pollution in Baghdad is the bottled drinking water and Tap water. Such results of the analysis may be defined as: bottled drinking water and tap water>well water> Tigris River.

The concentrations of iron (Fe) and nickel (Ni) in bottled drinking water samples showed a low mean concentration in all analyzed samples. The mean iron concentrations in bottled drinking-water samples are S7- 0.017±0.03 mg/L, S8- 0.019±0.04 mg/L and S9- 0.017±0.01 mg/L mean nickel concentrations in bottled water samples are S7- 0.018±0.06, S8- 0.016±0.09 and S9- 0.018±0.04 (Figs 11 and 12); these data reflect there is no pollution of iron or its compounds in some drinking water sources in Baghdad city, and they are in a good agreement with the concentrations identified by the World Health Organization (WHO), together with some other international standards.

In Table 4, low pH values can be observed in bottled drinking water samples S7 (6.62), S8 (7.11) and S9 (6.80)

with a low concentration of heavy elements in the same samples except for lead and copper. Nevertheless, the highest and lowest pH values calculated in this research were within the approved global and Iraqi drinking water limits ranging from 6.5-8.5.

The highest values of Total Dissolved Solids (TDS) for analyzed drinking water samples found in water wells in Hayfaa Street are (2740 mg/L) and in Al-Fadhilia Neighborhood are (1720 mg/L) while the lowest values found in bottled drinking water samples they are are (5 mg/L; 36 mg/L; 22 mg/L). Besides, TDS values in Al-A'amel Neighborhood are S1- 296 mg/L and in Kasraa Wa Ataash Neighborhood they are 341 mg/L (Tap Water) and the values of TDS have reached 386 mg/L and 312 mg/L in Bab Al-Moatham Neighborhood and Al-Sarafiya Bridge sequentially. Results of TDS analysis showed drinking water samples have high concentration of TDS in water wells in Al-Rusafa (about 2 times higher than the Iraqi and WHO limits) and in Al-Karkh it is about 3 times higher than
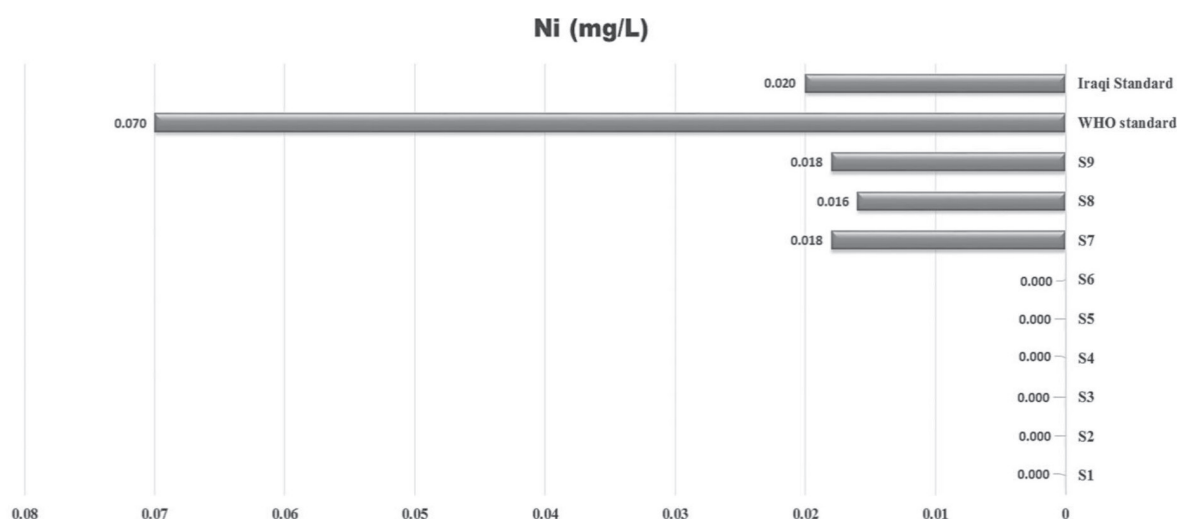
Ni (mg/L)

Fig. 12. Concentrations of Ni in different studied sites.

Table 5. HPI for some heavy elements in water supply samples from selected locations in the City of Baghdad.

Sample №	Cd	Cr	Cu	Co	Fe	Pb	Ni
Site 1 (S1)	42.18	1.58	0.08	-	-	9.85	-
Site 2 (S2)	55.84	1.76	0.11	-	-	16.76	-
Site 3 (S3)	58.52	2.20	0.08	-	-	15.56	-
Site 4 (S4)	55.20	1.39	0.06	-	-	12.85	-
Site 5 (S5)	58.56	1.53	0.22	-	-	14.70	-
Site 6 (S6)	42.08	1.76	0.10	-	-	12.84	-
Site 7 (S7)	39.65	1.33	0.23	9.25	0.05	16.75	0.22
Site 8 (S8)	55.72	1.36	0.12	8.28	0.06	16.76	0.18
Site 9 (S9)	2.69	0.25	0.03	9.24	0.05	1.86	0.22
Mean	45.61	1.64	0.12	8.92	0.05	13.10	0.21

the Iraqi and WHO limits because of the absence of the purification method to reduce total dissolved solids concentration, as well as the deficiency of water pressure in the water pipes leads to a mixture of drinking water with the other surrounding groundwater particularly when there is a leak or cracks in the network pipes. Effects of high TDS concentrations in drinking water can cause stiffness of the joints, hardening of the arteries, causing stone in the kidneys, gallstones and blockages of arteries where liquids flow through our bodies [33, 34]. The other drinking water samples show low TDS concentrations compared with WHO, Iraqi standard and other organizations (Table 3).

In this work, we observed low turbidity values in samples of drinking water of Al-A'amel Neighborhood (2.49 N.T.U); Hayfaa Street had (2.70 N.T.U); Bottled Drinking Water: Pearl Company- had 0.08 N.T.U; Al-saad Company- included 1.40 N.T.U and Aquafina Company- had 0.15 N.T.U. These results are within the Iraqi and global limit (5 N.T.U). The high turbidity values found in the sites: Kasraa Wa Ataash Neighborhood (9.44 N.T.U), Al-Sarafiya bridge (30.23 N.T.U), Al Fadhilia Neighborhood (51.09 N.T.U) and Bab Al-Moatham Neighborhood (62.23 N.T.U). All the high turbidity samples (more than 5 N.T.U) exceeded by 2 times (S2), 6 times (S6), 10 times (S4) and 12 times (S5) respectively, the limits permitted for WHO and Iraqi guidelines. The index of turbidity values shows that the turbidity is less than 1 (5 NTU). Thus, we can classify our drinking water samples as follows: samples S7 and S9 are Goods; samples S1, S3 and S8 are fair and the samples S2, S4, S5, and S6 are Poor water [16]. High turbidity levels in drinking water are undesirable and threatening to health. Turbidity can provide food for many pathogens. Therefore, if the turbidity is not removed, this will lead to water-borne diseases, which cause momentous cases of gastroenteritis. Hence, increasing turbidity levels in drinking water may increase the risks for newborn and elderly populations.

The results of the Heavy Metal Pollution Index (HPI) estimate are illustrated in Table 5. According to HPI, the metals of certain drinking water sources in the city of Baghdad show varying rates of contamination. The findings obtained revealed that showing Cd and Pb seriously affected drinking water, with the exception of sites 9 displaying moderately to slightly affected. Chromium has a slight effect on drinking water while site 9 does not have any effect. The Fe, Ni, and Cu results were no effect. In Baghdad city the mean HPI of heavy metals was contained in drinking water sources as follows: Cd>Pb>Co>Cr>Ni>Cu>Fe.

Conclusions

For this analysis, heavy metal concentrations were calculated by seven chosen elements for seven different sources of drinking water and three various kinds of bottled water. In addition, pH, turbidity, and TDS were measured also in different drinking water sources in Baghdad city. Study time for all samples continued for the period from November 2018 to March 2019. The results show that the main drinking water sources (Tap Water, Water Wells, Tigris River, and Bottled Drinking Water) in Baghdad city which have been examined are almost polluted by heavy elements. The HPI values indicated that Cd, Pb, and Co were seriously affected by drinking water, while HPI ranged from no effect to slightly affect by other elements.

The main factors behind the increase of the pollution in drinking water sources in Baghdad city in particular and Iraq, in general, are automobile exhaust, irresponsible industrial activities, dumping hospital waste in the Tigris River, deficiency of advanced systems to extract heavy and toxic metals and ions from water, as well as the military operations and dangerous security conditions in the Baghdad city and continuous neglect of the government to find solutions for these problems. So, our recommendations to

reduce the pollution levels in Baghdad drinking water sources: manufacturing facilities built along with the Tigris River should be improved to treat polluted water before being put into Tigris River, maintaining the drinking water pipes from the fractures or extending new pipelines, and developing a comprehensive plan to protect drinking water sources and ecological components in Baghdad city, considering it as a part of the national program and problem-solving of the ongoing power outage in Baghdad because of its impact on the stations of filtering and sterilization of drinking water reaching homes.

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Conflict of Interest

The authors declare no conflict of interest.

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