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Geochemical Assessment of The Trace Elements in Selected Bottled Water from Baghdad City-Iraq; Environmental Impact Approach

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Abstract

Twenty seven samples of drinking bottled water are commercially available in Baghdad Capital City –Iraq, were collected from local markets to investigate the levels of 17 trace elements (As, B, Ba, Cd, Cr, Cu, Co, Fe, Hg, Mn, Mo, Ni, Pb, Se, U, V and Zn) for the confidence building of the consumers. Inductively Coupled Plasma-Mass Spectrometry (ICP-MS) technique was used for the analysis of trace elements in the bottled water samples. The estimated trace elements are ranked as B> Fe >Ba> As, Se > Zn> Cr> V> Mo> Cu> Ni> Pb> Hg> Mn> Cd, Co> U. The results of this study were compared for the suitability for human consumption within the acceptable levels of World Health Organization (WHO,2008) and Iraqi Standards (IQS 2009) guidelines for drinking water. The mean concentrations of the trace elements in the tested water samples obtained in this study were fall within the level values in the guidelines/directives of WHO / IQS indicating the potability of the bottled waters and hence, could be consumed without any possible health problems.

Keywords: Geochemical assessment, Bottled water, trace elements, WHO standards, ICP-MS, Water quality

1. Introduction

Waters are widely used in human life and represents essential resource for domestic, industrial and agricultural purposes and its importance to man cannot be overemphasized due to its essentiality in the body metabolism and proper functioning of cells (Ainsworth 2004; Buchholz, 1998; Fewtrell & Bartram 2001; Rouse 2003).

Generally, water pollution is described as the presence of objectionable material in water for enough harmful or to damage the waters quality. Water pollution has many sources and characteristics. Although, human activities have always had impact on coastal areas, most of these impacts have led to environmental pollution, i.e., the introduction of substance by man into the environment, which may put water resources and human health at risk (Fewtrell & Bartram 2001; His et al., 1999; Rouse 2003). Major trace metals associated with water pollution includes; Zn, Cu, Pb, Cd, Hg, Ni and Cr (Fewtrell & Bartram 2001; Higgins, et al., 2003; Rouse 2003; Schmoll & Chorus 2003; Voudouris & Voutsa 2012). The presence of trace elements in aquatic environment is partially due to natural processes such as volcanic activities, erosions and weathering for certain types of rocks and minerals. The most important infection was coming from the industrial processes particularly those concerned with mining and processing of metal ores, the finishing and plating of metals and the manufacturing of metal objects (Fewtrell & Bartram 2001; Hernandez-Hernandez *et al.,* 1990; Voudouris & Voutsa 2012). High trace elements concentrations in food and drinks can invoke serious health hazards in humans life. All of the essential trace elements become toxic when its concentration level become excessive (Higgins, et al., 2003; Saleh et al., 2001; Schmoll & Chorus 2003; Voudouris & Voutsa 2012). Potential sources of trace elements are varied as (I) Natural processes, (II) Agricultural activities, (III) Human settlements, (IV) Industries (including industrial wastewater discharges), and (V) Production and distribution. The concentrations of many trace elements ions in natural water samples are generally determined by µg/L level (Divrikli and Elci 2002; Voudouris & Voutsa 2012).

The present study, aims to investigate the characteristic of important trace elements of twenty seven (27) randomly collected from different bottled water brands sold in Baghdad city and their environmental impact on the human health.

2. Materials and Methods

Twenty seven (27) brands of bottled water were purchased in duplicate polyethylene terephthalate (PET) containers during summer 2013, from randomly selected grocery shops and supermarkets from Baghdad City. The tested container volume varied from 0.5 to 1.0 l. All brands of bottled water were kept in refrigerator at $4^{O}C$ until the time of analysis. To keep the brand names anonymous, bottled water samples were given a numerical code according to manufactured origin and this convention was used throughout the study. Water samples were analyzed for trace elements As, B, Ba, Cd, Cr, Cu, Co, Fe, Hg, Mn, Mo, Ni, Pb, Se, U, V and Zn by Inductively Coupled Plasma - Mass Spectrometry (ICP-MS) technique at the ALS Laboratory in Spain.

3. Results and Discussion

Water is inevitable for life and enters in all details of the human life. It serves as the principal vehicle and mediator of physiological activities. Water is a major source of all the essential minerals that play important role in human nutrition and proper functioning of various body systems (Buchanan *et al.,* 2000; Versari *et al.,* 2002; Voudouris & Voutsa 2012).

All concentration levels of the investigated trace elements in the tested bottled water are present below the allowed levels in the water quality standards of the World Health Organization (WHO,2008), (IQS 2009) and Voudouris & Voutsa (2012) (table 1 ; Figure 1). Trace elements in bottled water brands are ranked as B> Fe >Ba> As,Se > Zn> Cr> V> Mo> Cu> Ni> Pb> Hg> Mn> Cd, Co> U. Details of the determined trace elements are discussed below:

Arsenic (As) compounds are rapidly and extensively absorbed from the gastrointestinal tract. Arsenic has not been demonstrated to be essential in humans. The acute toxicity of arsenic compounds in humans is predominantly a function of their removal rates from the human body (WHO 2008; Voudouris & Voutsa 2012). Arsenic level shows non-poisonous concentrations in the tested bottled water samples, which attains (<10 µg/l) and falls within the allowed limit of the national and international guidelines.

Boron (B) compounds are used in the manufacture of glass, soaps and detergents and as flame retardants. The general population obtains the greatest amount of boron through food intake as it is naturally found in many edible plants. Boron is found naturally in groundwater, but occurrences in surface water is frequently consequence of the discharge of treated sewage effluent, in which it arises from use in some detergents, to the surface waters (Voudouris & Voutsa 2012; WHO,2008)

The mean boron concentration in the tested bottled water is (131.81 µg/l). The sample 6B brand contains (940 µg/l) higher than the level listed in the Iraqi and international guidelines, which is (500 µg/l). While the lowest level value is (10 µg/l) in the tested samples 3S,4S,1D,2D brands.

Barium (Ba) is present as a trace element in both igneous and sedimentary rocks, in which the barium compounds are used in varieties of industrial applications. However, barium in water comes primarily from natural sources. Food is the primary source of intake for the non-occupationally exposed population. There is no evidence that barium is carcinogenic or mutagenic, but the toxicological end-point of greatest concern to humans appears to be its potential to cause hypertension (Voudouris & Voutsa 2012; WHO,2008).

Barium concentration shows very low values with mean of (15.58 µg/l), in which the highest value was in the samples 2D brand (100 µg/l) and the lowest was (0.11 µg/l) in the samples 1B brand.

Cadmium (Cd) metal is used in the steel industry and in plastics. The cadmium compounds are widely used in batteries. Cadmium is released to the environment in wastewater, and diffuse pollution is caused by contamination from fertilizers and local air pollution. Contamination in drinking water may also be caused by impurities in the zinc of galvanized pipes and solders and some metal fittings. Food is the main source of daily exposure to the cadmium, which accumulates primarily in the kidneys and has long biological half-life in humans for 10-35 years (Voudouris & Voutsa 2012; WHO,2008).

Cadmium concentrations show (< 0.1 µg/l) in all water brands samples, below the levels of national and international guidelines.

Chromium (Cr) is widely distributed trace elements in the Earth's crust. In general, food appears to be the major source of intake. In epidemiological studies, an association has been found between exposure to chromium (VI) by the inhalation route and lung cancer (Voudouris & Voutsa 2012; WHO,2008).

All samples of bottled water shows concentration levels less than those in national and international guidelines with mean value of (3.5 µg/l). the sample 1S brand contains higher (Cr) level and reaches (9µg/l), while the lowest value is (1.0 µg/l) in the samples 1B, 2B, 5B,6B10B brands.

Copper (Cu) is essential nutrient and drinking water contaminant. It is commercially important and entrance in various industries, e.g. pipes, valves and fittings and used in alloys as well as coatings. Copper concentration levels show wide variations in the drinking water. Copper concentrations in treated waters are often increases during distribution, especially in the systems of acidic pH media or high carbonate waters with alkaline PH. Food and water are the primary sources of copper exposure in the developed countries (Voudouris & Voutsa 2012; WHO,2008).

The copper concentrations are very low in all tested water samples with mean of (0.62 µg/l). The highest value is (5.4 µg/l) in sample 14B brand and the lowest is (0.3 µg/l) in the others.

Cobalt (Co) is represents important poisonous trace metal in the human uses e.g. waters and foods (WHO 2008). Cobalt shows low concentration levels in all tested samples and is (< 0.1 µg/l).

Iron (Fe) is one of the most abundant trace element in the earth's crust. Iron ions may be present in drinking water as a result of the use of iron coagulants or corrosion of steel and iron cast in pipes during water distribution. Iron is an essential element in human nutrition (Voudouris & Voutsa 2012; WHO,2008).

The higher concentration level of iron shown in the sample no. 2D and is (90 µg/l), while the lowest level shown in many another samples and is (20µg/l).

Table 1: Concentration of trace elements in investigated bottled water brands(µg/l).

Brand Code	As	B	Ba	Cd	Cr	Cu	Co	Fe	Hg	Mn	**Mo**	Ni	Pb	Se	U	V	Zn
1B	< 10	90	0.11	<0.1	1	0.3	<0.1	20	<0.2	0.1	1	0.5	0.2	10	0.01	1	2
2B	< 10	80	6.28	<0.1	1	0.3	<0.1	20	<0.2	0.1	1	0.5	0.2	10	0.05	1	4
3B	< 10	40	8.06	<0.1	2	0.3	<0.1	20	<0.2	0.1	1	0.5	0.2	10	0.04	1	2
4B	< 10	50	23.5	<0.1	4	0.8	<0.1	40	<0.2	0.2	1	0.5	0.2	10	0.15	3	5
5B	< 10	900	0.94	<0.1	1	1.4	<0.1	20	<0.2	0.2	1	0.9	0.2	10	0.01	1	7
6B	< 10	940	0.21	<0.1	1	0.3	<0.1	20	<0.2	0.1	1	0.5	0.2	10	0.01	1	4
7B	< 10	60	21.9	<0.1	4	0.7	<0.1	70	<0.2	0.1	1	0.5	0.2	10	0.16	3	3
8B	< 10	60	11.55	<0.1	2	0.3	<0.1	40	<0.2	0.1	1	0.5	0.2	10	0.06	2	2
9B	< 10	50	10.8	<0.1	2	0.4	<0.1	20	<0.2	0.3	1	0.5	0.2	10	0.07	2	3
10B	< 10	150	1.37	<0.1	1	0.3	<0.1	20	<0.2	0.1	1	0.5	0.2	10	0.03	1	5
11B	< 10	80	8.63	<0.1	2	0.3	<0.1	20	<0.2	1.1	1	0.5	0.2	10	0.08	2	51
12B	< 10	50	17.8	<0.1	4	0.3	<0.1	30	<0.2	0.1	1	0.5	0.2	10	0.12	3	4
13B	< 10	50	7.93	<0.1	2	0.3	<0.1	20	<0.2	0.1	1	0.5	0.2	10	0.06	2	2
14B	< 10	50	17.85	<0.1	4	5.4	<0.1	30	<0.2	0.1	1	0.5	1.3	10	0.12	2	5
1S	< 10	20	13.55	<0.1	9	0.3	<0.1	40	<0.2	0.1	1	0.7	0.2	10	0.12	3	23
2S	< 10	30	6.46	<0.1	3	0.3	<0.1	60	<0.2	0.2	1	0.5	0.2	10	0.12	2	2
3S	< 10	10	13.9	<0.1	6	0.3	<0.1	40	<0.2	0.1	1	0.6	0.2	10	0.15	5	3
4S	< 10	10	13	<0.1	8	0.3	<0.1	20	<0.2	0.2	1	0.5	0.2	10	0.1	4	19
1D	< 10	10	27	<0.1	6	0.3	<0.1	50	<0.2	0.1	1	0.8	0.2	10	0.25	4	2
2D	< 10	10	100	<0.1	8	0.3	<0.1	90	<0.2	0.1	1	1	0.2	10	0.16	7	2
1K	< 10	20	21.5	<0.1	5	0.3	<0.1	70	<0.2	0.1	1	0.6	0.2	10	0.13	3	2
1H	< 10	140	10.45	<0.1	2	0.3	<0.1	50	<0.2	0.1	1	0.5	0.2	10	0.1	1	2
Range																	
Mean	< 10	131.81	15.58	<0.1	3.54	0.62	<0.1	36.81	<0.2	0.17	1	0.57	0.25	10	0.09	2.45	7
IQS, 2009	10	500	700	3	50	100		300	1	100	--	20	10	10	--		3000
WH, 2008	10	500	700	3	50	200		300	6	400	70	70	10	10	15		3000

*B: Baghdad city, S: Sulimania city, D: Duhok city, K: Kirkuk city, H: Hillah,

Mercury (Hg) is used in the electrolytic production of chlorine, electrical appliances, dental amalgams and as a raw material for various mercury compounds. Methylation of inorganic mercury has been shown to occur in fresh water and in seawater. Although almost all mercury in uncontaminated drinking water is thought to be in the form of Hg^{+2} ion. The toxic effect of inorganic mercury compounds are seen mainly in humans, acute oral poisoning results primarily in haemorrhagic gastritis and colitis; the ultimate damage is to the kidney (Voudouris & Voutsa 2012; WHO,2008).

The concentration level of mercury is (< 0.2 µg/l) in all tested water samples, which is below the levels listed in the national and international guidelines.

Manganese (Mn) is one of the most abundant metals in the Earth's crust, usually occurring with iron. It is used principally in the manufacture of iron and steel alloys, as oxidant for cleaning, bleaching and disinfection as potassium permanganate and as an ingredient in various products. Manganese green- sands are used in some locations for potable water treatment. It is an essential element for humans and animals, which is occurred naturally in many food sources. Manganese is naturally occurring as ion in many surface and ground waters sources, particularly in anaerobic or low oxidation conditions, which represents the most important source for drinking water. The greatest exposure to manganese is usually from food. Adverse effects can result from both deficiency and overexposure. Manganese is known to cause neurological effects following inhalation exposure, and particularly in occupational settings (Voudouris & Voutsa 2012; WHO,2008).

Manganese concentration level is very low and ranges from (0.1) to (0.2 µg/l) in all tested water samples with mean value of (0.17 µg/l) .

Molybdenum (Mo) is naturally found in soil and is used in the manufacture of special steels, and in the production of tungsten and pigments. Molybdenum compounds are used as lubricant additives and in agriculture to prevent molybdenum deficiency in crops. It is considered to be an essential element (Voudouris & Voutsa 2012; WHO,2008).

Molybdenum concentration level is very low in all tested water samples and attains (1.0 µg/), which is below the levels of national and international guidelines.

Nickel (Ni) is used mainly in the production of stainless steel and nickel alloys. Food is the dominant source of nickel exposure in the non-smoking, non-occupationally exposed population. Water is generally represents minor contributor to the total daily oral intake. However, where there is intense pollution in areas where nickel is naturally occurs in groundwater is mobilized or where there is use of certain types of kettles of non-resistant material in wells. Moreover, water that is coming into contact with nickel or chromium-plated taps. Nickel contribution from water may be significant in water pollution (Voudouris & Voutsa 2012; WHO,2008).

All of the tested water samples contain nickel concentration level less than Iraqi and international guidelines, in which the mean value is (0.57 µg/l). The highest level value is (1.0 µg/l) and was recorded in the water sample 2D brand and the lowest level is (0.5 µg/l) was recorded in many another water samples.

Lead (Pb) is used principally in the production of lead-acid batteries, solder and alloys. The organolead compounds tetraethyl and tetramethyl lead have also been used extensively as antiknock and lubricating agents in petrol. It is important to refers that the use of lead in these purposes is being phased out in many countries. Owing to the decreasing use of the lead-containing additives in petrol and the lead-containing solder in the food processing industry, concentrations in air and food are declining and intake from drinking-water constitutes a greater proportion of total intake. Lead is rarely present in tap water as a result of dissolution from natural sources. Rather more, it is primarily present from household plumbing systems containing lead in pipes, solder, fittings or the service connections to homes. The amount of lead dissolved from the plumbing system depends on several factors, including pH, temperature, water hardness and standing time of the water, with soft, acidic water being the most plumbo-solvent.

Lead is a general toxicant that accumulates in the skeleton. It is also interferes with calcium metabolism, both directly and by interfering with vitamin (D) metabolism. Lead is toxic for both central and peripheral nervous systems inducing neurological and behavioral effects (Voudouris & Voutsa 2012; WHO,2008).

The mean lead concentration level is (0.25 µg/l) , and all tested samples contain less than standard of the Iraqi and international guidelines. The highest concentration level value is (1.3 µg/l) and appears in the water sample14B, while the lowest concentration level is (0.2 µg/l) in the other tested samples.

Selenium (Se) is present in the Earth's crust, often associated with sulfur-containing minerals. It is an essential trace element, and foodstuffs such as cereals, meat and fish, and are the principal source of selenium in the general population. levels in food is vary greatly according to geographical area of production. Selenium is an essential element for humans health. No clinical or biochemical signs of selenium toxicity were reported in a group of (142) persons with mean daily intake of 0.24 mg (maximum 0.72 mg) from food (Voudouris & Voutsa 2012; WHO,2008).

Selenium level concentrations value is (< 10 µg/l) in all tested water brands, which falls within the allowed levels of guidelines.

Uranium (U) is widespread trace element in nature, occurs in granites, pegmatite and various other mineral deposits. Uranium is used mainly as fuel in nuclear power stations. Uranium is present in the environment as a result of leaching from natural deposits, release in mill tailings, emissions from the nuclear industry, the combustion of coal and other fuels and the use of phosphate fertilizers that contains uranium. Intake of uranium through air is low, and appears that intake through food is between (1) and (4 mg/day). Intake of uranium through drinking-water is normally extremely low. However, in circumstances, the source of uranium pollution in human life is most probably comes from the intake of drinking-water (Voudouris & Voutsa 2012; WHO,2008).

There are insufficient data regarding the carcinogenicity of uranium in human and experimental animals. Little information is on the chronic health effects of exposure to environmental uranium in human life. A number of epidemiological studies of populations exposed to uranium in drinking-water have shown a correlation with alkaline phosphates and b-microglobulin in urine along with modest alterations in proximal tubular function (Voudouris & Voutsa 2012; WHO,2008)..

The mean concentration level of uranium is (0.09 µg/l), which is below the allowed levels listed in the guidelines. The highest concentration value is (0.25 µg/l), which is present in the water sample 1D brand and the lowest one is (0.01 µg/l) in water samples1B, 5B, 6B brands.

Vanadium (V) trace element shows normal concentration levels in the tested samples of bottled water. The mean concentration level is (2.45 µg/l). the highest value is (7 µg/l) in the water sample 2D brand and the lowest value is (1 µg/l) in many other brands.

Zinc (Zn) is an essential trace element found in virtually all food and potable water in the form of salts or organic complexes. The diet is normally principal source of zinc. Although, levels of zinc in surface and ground waters normally do not exceed (0.01) to (0.5 mg/l) respectively. Zinc concentration in tap water can be much higher as a result of dissolution of zinc from pipes (Voudouris & Voutsa 2012; WHO,2008).

All the tested water samples show low zinc concentration level, in which the mean concentration value is (7 µg/l). The highest value is (51 µg/l), which present in the water sample 11B brand and the lowest is (2 µg/l) in many other brands.

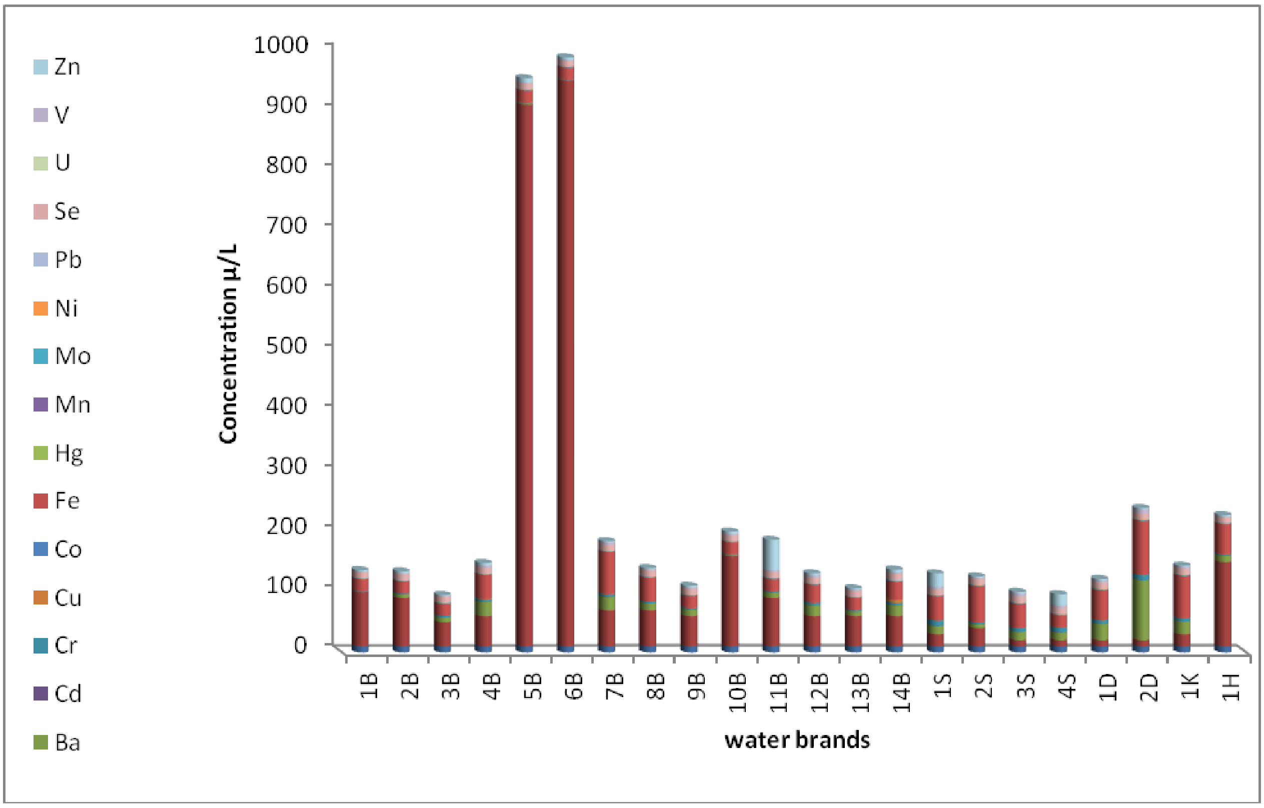

Fig 1: Statistical presentation of the trace elements concentrations obtained from the tested samples of bottled water brands from Baghdad City.

The summary of this study shows that the mean concentration levels of the trace elements in the tested bottled waters show values below the upper limits in the standards of the World Health Organization (WHO,2008) and IQS (2009) water quality standards as well as Voudouris & Voutsa (2012). This agreed with most studies like El-Harouny *et al*., (2008), who found that the mean concentrations of the trace elements (e.g. Pb, Cd, As, Na, Ca, Mg, Zn and Se) in drinking water obtained in Dakhaliya Governorate in Egypt are of acceptable values falls within the range levels of the World Health Organization (WHO,2008) and Voudouris & Voutsa (2012) guidelines. David *et al*., (2013) in Nigeria, found that the concentrations levels of (Mg, Ca, Mn, Fe, and Cd) in the water samples are of low values in comparison with the standard levels of the World Health Organization standard (Voudouris & Voutsa 2012; WHO, 2008).

Moreover, Yabanli (2012) found that the concentration levels of (Al, Cr, Cu, As, Cd, and Pb) in the drinking bottled water sold in Izmir-Turkey, are lying within the concentration levels of WHO and the international standards.

4. Conclusion

The geochemical analysis of the trace elements concentrations in the drinking bottled water brands sold in Baghdad City shows positive results, which are safe for human consumption. In this study, the geochemical investigation of the trace elements show no environmental impacts on the human life in Baghdad City. The measured concentration levels of the trace element constituents in the bottled water brands falls within the standard limits set by WHO (2008), IQS (2009) and Voudouris & Voutsa (2012) in guidelines for drinking water. However, the present trace element concentrations in the tested bottled water samples are variable, which is most probably depends on many factors such as natural environment, source and composition of waters and the types of the treatment/purification techniques applied during the production. Additional changes in the water chemistry may also occur during storage and transportation, especially when bottles are exposed to direct sunlight. However, long term effects if there is not enough check maybe of major concern. Consequently, close monitoring of heavy metals must be carried out.

This study recommends that regular needs for nationwide survey about the quality of waters including tap and river and ground waters as well as geochemical comparative studies. Additionally, the analysis and labeling of another parameters such as microbiological controls of water is needed to protect public health as well.

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