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SCIENTIFIC JOURNAL
OF MEDICAL RESEARCH

Vol. 3, Issue 9, pp 3-9, Winter 2019

ISSN: 2520-5234

ORIGINAL ARTICLE

Investigation of Water Quality from Tap Water and Filter Water in Two Towns in Iraq and the Effect of Some Metals on Human Health

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ARTICLE INFORMATIONS

Article History:
Submitted: 26 July 2018
Revised version received:
24 August 2018
Accepted: 27 August 2018
Published online: 1 March 2019

Key words:
Tap water
Acidity in pH.
Electrical conductivity
Concentration of heavy metals
Water quality
Chemical oxygen demand (COD)
World Health Organisation (WHO)

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ABSTRACT

Objectives: This study includes comparative investigations of water quality from tap water and filter water from two towns in Iraq and the influence of impurities on human health.

Methods: Laboratory analysis of water samples from tap water and filter drinking water from two main towns in Iraq were undertaken and the results compared with a control; a) drinking tap water samples, b) bottle still drinking water from a European country, and with World Health Organisation (WHO) guidelines for water quality assessment. The laboratory study included measuring water quality properties such as; Acidity in pH units, Electrical Conductivity (EC), concentration of heavy metals namely Nickel, Zinc, Strontium, Copper, Sodium and Potassium, and an analysis of the Chemical Oxygen Demand (COD).

Results: The measured properties of the water samples from the filter drinking water are less than the values recommended by WHO quality guidelines for drinking water. Sodium content in tap water samples from Iraqi towns A and B are higher than the sodium contents in the control tap drinking water collected from a European country and significantly higher than the value of 20mg/L recommended by WHO guidelines. Whereas filtered drinking water samples have significantly less levels of sodium and the other measured metal concentrations. The percentage reductions in sodium content between filtered drinking water and tap water were 92.895% in town A and 89.852%.in town B.

Conclusion: The metal contents in the filtered drinking water are significantly less than the concentrations found in both the tap and still bottle drinking water normally consumed in the European country. Sodium chloride contents in the tap water samples from both towns are high which can adversely affect those that consume it.

Citation: Al Asadi S.M.A. "Investigation of Water Quality from Tap Water and Filter Water in Two Towns in Iraq and the Effect of Some Metals on Human Health". Sci. J. Med. Res. 2019, 3 (9): 3-9.

INTRODUCTION

Fresh water from both surface water and wells (groundwater) are fundamental for a sustainable development of any country in terms of environmental, social and economy. Providing a sustainable water supply for any nations and/or countries reveals good return in terms of human and animal health, food supply, industrial productions in addition to a healthy ecosystem and the growth of the services they meets. In a WHO study on meeting the Millennium Development Goals (MDGs), 1.5% of gross domestic product of the countries included in its study was lost due to inadequate supply of water and sanitation[1]. Increased discharges and waste from untreated wastewater, industrial factories and units, animal waste, residential areas, industrial plants, and waste from natural events such as flooding all contribute to the degradation of water quality in surface and groundwater.

Organic pollution to surface water, indicated by the Biochemical Oxygen Demand (BOD) can have severe impacts on food security, inland and offshore fisheries, and livelihoods of poor rural communities[2].

Of all natural disasters, the most socially and economically destructive are water-related disasters. Due to storms, droughts and floods more than 4.2 billion people suffered in 1992, and 1.3 trillion USD is the estimated cost of damage[3].

Community health fitness is highly dependent on, among other factors, both water quality and quantity. High quality water used for drinking, industrial and household uses and/or in irrigations are vital for reducing water quality-related diseases and supporting community economic developments.

Over-dosage of heavy metals in water may cause health illness. For example, sodium chloride may cause adverse effects such as fainting, migraine, stomach infections, muscle contractions in the body, and vomiting and convulsions[4]. Excessive salt intake has serious effects on chronic congestive heart failure as reported by WHO Regional Office for Europe[5], Department of National Health and Welfare Canada[6] and Elton N W et al[7].

In recent years Iraq, and namely from 2012-to-date, filter drinking water is used widely in houses and industry, social events, government and private buildings in both urban and rural areas. Different companies install drinking water systems in the houses and premises, which involves connecting these devices to the tap water supply system, and the tap water passes through a series of filters to supply the occupants with filtered drinking water. In this paper, the author concentrates on the analysis of the tap water, filtered water and control sample of drinking water from a European country, in terms of comparing their properties. Namely, pH, Electrical Conductivity, an analysis of the Chemical Oxygen Demand (COD) to estimate its organic content. Together with determining the concentration of heavy metals namely Nickel (Ni), Zinc (Zn), Strontium (Sr), Copper (Cu), Sodium (Na) and Potassium (K).

This study is conducted with the aim of determining and/or exploring the differences in the said measured quality indicators between the filtered drinking water and that from tap water, and comparing them both with the quality of the tap drinking water and still bottle drinking water from a European country.

MATERIALS AND METHODS

For pH tests, both digital meter and litmus paper (LP) are used to measure the pH of the tested samples. LP under acidic conditions turns red and turns blue when the solution is in basic or alkaline conditions.

The Electrical Conductivity (EC) of water samples were used as indicators for quantity of salts and other solid impurities in the samples tested. The higher the EC in the tested samples the higher the level of impurities. In this study Cobra 3 laboratory equipment was used to measure the values of the EC of the studied samples.

Toxicity Characteristic Leaching Procedure (TCLP) has been adopted to determine the concentrations of Nickel (Ni), Zinc (Zn), Strontium (Sr), Copper (Cu), Sodium (Na) and Potassium (K).

Sample Analysis and Properties Measured

Water was sampled from;

Town A = Tap water and filtered drinking water

Town B = Tap water and filtered drinking water

European country = Tap drinking water and bottled still drinking water .

From each water source, four samples were tested to determine their;

1. Alkalinity and or acidity in pH units.
2. Electrical conductivity in (mS/cm).
3. Chemical oxygen demand, COD, in mg/L to estimate its organic content.
4. Concentration of heavy metal namely; Nickel, Zinc, Strontium, Copper, Sodium and Potassium.

pH of Tested Water Samples: PH test results indicate if the samples tested are neutral (pure water), alkaline or acid. For:

pH < 7 water samples considered acid

pH = 7 water is pure (neutral)

pH > 7 water is considered alkaline

pH values for some liquids are shown in Table 1 below.

In this study both litmus paper and a laboratory digital multi-parameter meter are used to determine the pH of the studied samples.

Table 1: pH results of values for different fluids.

Liquid	pH	Liquid	pH
Pure Water	7.0	Tomato Juice	4.0
Orange/Apple Juice	3.5	Seawater	7.7 - 8.3
Vinegar	2.9	Milk	6.5
Cola	2.5	Coffee	5.0
Lemon Juice	2.4	10M Hydrochloric acid	-1.0

(BBC Bitesize, 2014)[8]

Electrical Conductivity of Water Samples: A laboratory Cobra 3 device shown in Figure 1 was used to measure the Electrical Conductivity of the samples.


Figure 1: Cobra 3 device for measurement of pH and EC.

Chemical Oxygen Demand (COD) of Water Samples: The amount of organic and inorganic components in water can be indicated by measuring the COD of water samples. COD indicates the organic and inorganic components in water as the oxygen equivalent that is liable to be oxidised by chemical oxidant for example by dichromate.

COD test does not identify the water components liable for oxidation nor distinguishes between inorganic and organic materials in the oxidisable impurities. In addition, in the presence of dichromate some types of organic materials do not oxidise, thus COD values do not represent the total organic components in the tested sample. Having said that, COD is still often used by scientists and has been for a long time[9].

In high quality water (unpolluted), COD content is in the range of 20mg/L and in polluted water this value can exceed 200mg/L O_2. For example, in surface water contaminated with waste industrial discharge the COD may range from 100mg/LO_2 to 6000mg/L O_2.

Sealed glass containers were used for storing the samples. Figures 2 and 3 show the lab equipment used.

Figure 1: COD analysis, Digestion phase. LT 200 thermostat reactor.

Concentration of Heavy Metals: The leaching of some pollutants such as heavy metals in water is a significant threat to the health of humans and the environment in general. The presence, for example, of sodium is important to human life and there is no agreement on the minimum daily requirement. The total daily intake of 120 mg to 400 mg will be adequate for meeting the needs of growing infants and young children, and for adults is 500mg[9].

Figure 3: DR2800 Spectrophotometer for measuring COD.

Over-dosage of sodium chloride may cause many heath problems, such as fainting, dizziness, motion sickness, low blood sugar and food poisoning, vomiting and convulsions. Excessive salt intake has serious effects on chronic congestive heart failure as reported by WHO Regional Office for Europe[5], Department of National Health and Welfare Canada[6] and Elton N W *et al*[7]. Also, low concentrations of arsenic, more than 10 µg/L, in drinking water, leads to skin cancer and damage to the central nervous system[10].

The concentration of Nickel (Ni), Zinc (Zn), Strontium (Sr), Potassium (K) and Sodium (Na) in this study are determined using the Toxicity Characteristic Leaching Procedure (TCLP) test. The test is an effective method for determining the potential for organic and inorganic waste to leach hazardous chemical concentrations into the environment. In the lab, the author adapted the procedures detailed in the method recommended by the US Environmental Protection Agency[11].

Figures 4a and 4b show the rotary extractor and atomic adsorption spectrophotometer respectively, the main parts of TCLP testing.

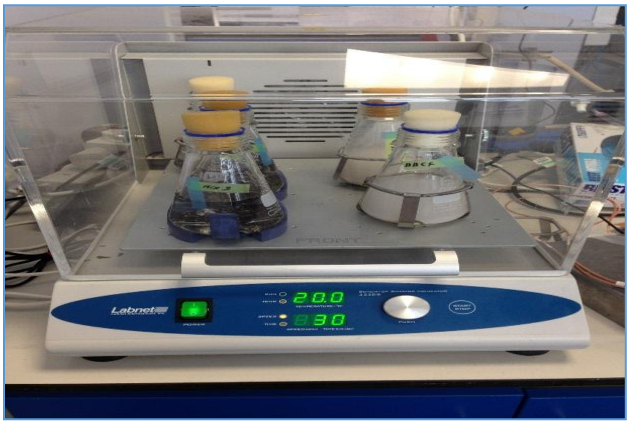

Figure 4a: Rotary extractor

Figure 4b: Atomic adsorption spectrophotometer – sample under test.

RESULTS

Table 2: shoes the pH, EC and COD for the tested samples .

Location	Source of Water	pH	pH bottled still drinking water in a previous study[13]	EC (mS/cm)	COD mg/L
Iraqi Town A	Tap water	7.56	6.79–7.57	0.72	3.26
	Filtered drinking water	7.65	6.79–7.57	0.41	2.94
Iraqi Town B	Tap water	7.33	6.79–7.57	0.81	9.55
	Filtered drinking water	7.94	6.79–7.57	0.34	1.18
European Country	Tap drinking water	7.31	6.79–7.57	0.3	1.08
	Bottled still drinking water	7.32	6.79–7.57	0.3	1.97

The range of the recommended pH, EC and COD are as follows:

- $6 < pH < 8.5$ is the recommended limit for drinking water by World Health Organisation[12].
- For $EC \geq 2.5$mS/cm, river water is considered not drinkable according to European standards[14]
- 10ppm or 10mg/L is the recommended limit for COD in drinking water by World Health Organisation [9,14]

COD of a Local European Country Small River Stream Water Samples: Samples from a local small river (stream surface water) were analysed for the COD to show the reader the high contents of COD in surface river water and the reduction in COD with time since sample taken from the river. The detected range of COD for the samples tested are shown in Table 3 and Figure 5.

Table 3: COD results at 5 minutes intervals

Time interval (minutes)	COD (mg/l)	COD reduction (%) at the time of testing in minutes
0	162.5	0.00
5	101.20	37.85
10	74.80	53.97
15	59.05	63..66
20	50.09	69.18
25	38.68	76.17
30	34.01	79.10

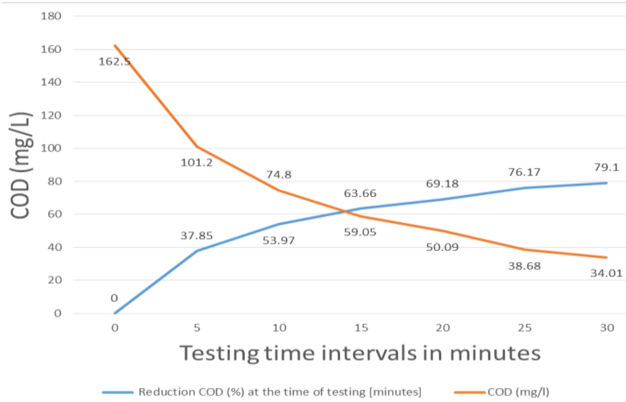

Figure 5: COD (mg/L) and COD reduction % at 5 minutes testing time intervals.

Content of heavy metals: Table 4 shows the contents of some heavy metals in the tested samples.

Table 4: Contents of some heavy metals (mg/L) in the samples of water tested.

Sample Source	Nickel (Ni)	Zinc (Zn)	Strontium (Sr)	Copper (Cu)	Sodium (Na)	Potassium (K)
Tap Water Iraqi Town A	0	0.0262	0.5533	0.60483	85.2364	1.37566
Filtered water Iraqi Town A	0	0.0119	0.305	0.603653	6.055321	0.203768
Tap water Iraqi Town B	0	0.1068	0.5988	0.498715	77.80805	4.214621
Filtered water Iraqi Town B	0	0.0179	0.2727	0.561976	7.895577	0.36981
Tap drinking water EU Country	0	0.0169	0.3373	0.687446	28.29653	2.736683
Bottled still drinking water EU country	0	0.0099	0.2664	0.769821	14.04983	2.092925

Recommended values	
Nickel (Ni)	0.1mg/L to 0.14mg/L[16]
Zinc (Zn)	$\leq$ 0.02mg/L. In tap water can be 1.1mg/L[17,18]
Strontium (Sr)	Average concentration in drinking water in Germany is 0.34 and USA is 1.1mg/L[19]
Copper (Cu)	$\leq$ 0.005 to < 30mg/L[20]
Sodium (Na)	Typically < 20mg/L[21]
Potassium (K)	Average concentration in raw and drinking water (range from < 1 and 8 mg/L[22]

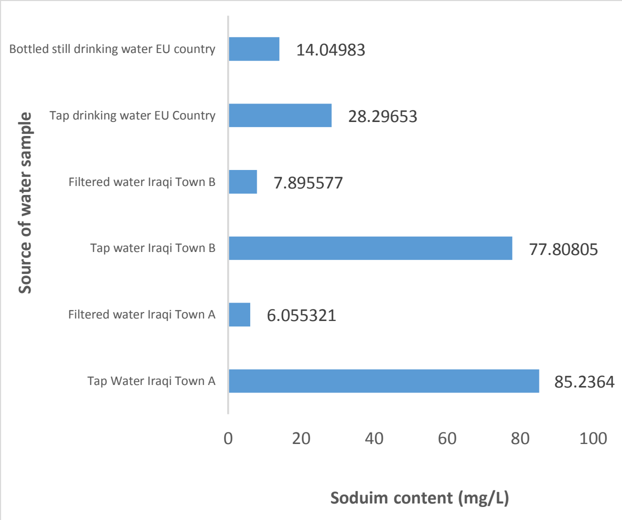

Figure 6: Contents of some heavy metals (mg/L) in the samples of water tested

Discussion

pH, EC and COD of the tested samples: The results shown in Table 2 indicating that the tap drinking water and bottled still drinking water from a European country show the lowest values of pH of 7.31 and 7.32 respectively. pH results for the tap water samples from both Iraqi towns and that of the filtered water range from 7.33-7.94, which is within the range of the pH of safe drinking water according to WHO[12].

Table 2 also shows the Electrical Conductivity of the tested water samples. Naturally, high values of EC reflect a high content of dissolved constituents. The samples are ranked according to their EC values as follows:

- European Country tap and bottled still drinking water samples have the lowest EC at 0.3 mS/cm.
- Filtered drinking water from Iraqi Town B (0.34 mS/cm).
- Filtered drinking water from Iraqi Town A (0.41 mS/cm).

This indicates low content of dissolved constituents in all samples.

The results of Table 2 for COD were:

- Tap water: 1.08 mg/L (EU-Tap drinking water (Control)), 3.26mg/L (Town A), 9.55 mg/L (Town B),
- Filtered drinking water: 1.18 mg/L (Town B), 2.94 mg/L (Town A),
- Bottled still drinking water from the European Country: 1.97mg/L.

10 ppm or its equivalent approximate value of 10mg/L is the acceptable limit for COD in drinking water by World Health Organisation[9,14]. This indicates that all samples tested returned COD results within the recommended limit.

In Table 2, the pH for bottled still drinking water as reported by Aris et al[13] is included for comparison with the pH values of the tested samples.

COD of a Local European Country Small River Stream Water Samples

In Table 3 and Figure 5, the samples of water collected from a river in a European Country shows the COD at 5 minutes intervals. At the time the sample was first collected and tested the detected COD measured 162.5 mg/L.

The detected COD after 30 minutes is 34.01mg/L. The nonlinear trend of the removal of COD can be seen in the figure. The rate of removal of COD is high from 0-5 and 5-10 minutes, and reduced gradually at the time of testing of 10 to 30 minutes. At 30 minutes of testing, 79.1% of the COD in the river water had been removed and only about 34.01 mg/l remained. This value is still high when compared to the median value of Most Common Natural Concentration (MCNC) for major world rivers that are minimally polluted[15].

Content of heavy metals: Table 4 shows the contents of some heavy metals in the tested samples. Interestingly for the Nickel (Ni), Zinc (Zn), Strontium (Sr), Sodium (Na) and Potassium (K), of all the tested samples, the content of these metals:

- are less than the recommended levels as detailed in Table 4.
- in the tap water from both Iraqi Town A and Town B are higher than the content found in the filtered drinking water from the same tap water from which the filtered water originates.
- in the tap drinking water levels are higher than those found in the bottled still drinking water from same European country.

As can be seen in Table 4 and Figure 6, Sodium (Na) content in mg/L for Iraqi Town A and Town B has exceeded the recommended value by 65.236mg/L and 57.808 mg/L respectively. Also, tap drinking water from the European country only exceeded the recommended value by a small margin of 8.296 mg/L. Both filtered drinking water from Iraqi Town A and Town B had sodium contents less than the recommended values and reduced the amount of sodium found in tap water by 92.89% and 89.85% , respectively.

In fact, the filters produced drinking water with sodium content less than the recommended values. More interestingly, the sodium content from the filtered drinking water and from both Iraqi Town A and Town B produced drinking water with less sodium content compared with the control tap drinking water and bottled still drinking water commonly used for human consumption in the European Country (EU).

Sodium is important to human life and there is no agreement on the minimum daily requirement. However, according to National Research Council, Washington DC, recommended the total daily intake of between 120mg and 400mg will be adequate for meeting the needs of growing infants and young children and for adults is 500mg.

Over-dosage of sodium may cause acute ill effects, which may include nausea, muscular twitching and rigidity, vomiting and convulsions. Excessive salt intake has serious effect on chronic congestive heart failure as reported by WHO Regional Office for Europe[5], Department of National Health and Welfare Canada[6] and Elton NW *et al*[7]. In the human body, the main source of sodium are found in foods and drinking water. Table 5 below shows sodium concentration in typical foods[4,5].

Table 5: Sodium concentration in typical foods[4,5].

Food sources	Sodium contents
Cheese and cereals	10-20g/kg
Fresh vegetables and fruits	< 10 to 1000mg/kg
Human milk	180mg/Litre
Cows' milk	770mg/Litre

20mg/L is the typical sodium level in drinking water, which contributes to 8-10% of the human body daily needs[4].

Conclusions

In this study laboratory water quality investigations were carried out on tap water and filtered drinking water from two main towns in Iraq. The laboratory study included measurements of:

- pH and EC to indicate the acidity and the electrical conductivity respectively.
- COD to estimate samples organic content.
- concentrations of heavy metal namely Nickel, Zinc, Strontium, Copper, Sodium and Potassium.

Results were compared with tap water and bottled still drinking water samples from a European Country and with WHO guidelines for water quality assessment. The following conclusions can be reported:

1. When quality of drinking water is not within the limits specified by World Health Organisation (WHO) and/or other credited standards such as European Standards, several diseases can widely spread. This will have an adverse influence on peoples' health, social, economic and wealth-associated matters.
2. Water samples from different sources were tested for pH, EC, COD and concentration of heavy metal elements, namely Nickel, Zinc, Strontium, Copper, Sodium and Potassium, to determine if water quality of each tested sample is in line with WHO recommendations and guidelines for consumption by people.
3. The tap drinking water and bottled still drinking water from the European Country showed the lowest values of pH of 7.31 and 7.32 respectively. pH results for the tap water samples from both Iraqi towns and that of the filtered water range from 7.33-7.94 which is within the range of pH of drinking water recommended by the World Health Organisation.
4. Naturally high values of EC reflect a high content of dissolved constituents. The samples are ranked according to their EC values as follows;
   - European Country tap and bottled still drinking water samples have the lowest EC at 0.3 mS/cm,
   - Filtered drinking water from Iraqi Town B (0.34 mS/cm),
   - Filtered drinking water from Iraqi Town A (0.41 mS/cm).

   For EC ≥ 2.5mS/cm, river water is considered not drinkable according to European standards[12].
5. All tested samples showed results less than the allowable limit of COD in water of 10 mg/L.
6. The contents of Nickel (Ni), Zinc (Zn), Strontium (Sr), Copper (Cu) and Potassium (K), are less than the recommended levels in all the tested samples. However, in the tap water from both Iraqi Town A and Town B these metals are found in higher levels than in the filtered drinking water sources from the same tap water in these towns. In the tap drinking water from a European Country the content of these metals are within the recommended limit. However, the said metal contents are higher than those found in the bottled still drinking water from the same European Country.
7. Sodium (Na) content in mg/L for the tap water and for both Iraqi Town A and Town B exceeded the recommended value [20mg/L] by 65.236mg/L and 57.808 mg/L respectively. Tap drinking water from the European Country only exceeded the recommended value by a small margin of 8.296 mg/L. Filtered drinking water from both Town A and Town B has given sodium measurements significantly less than the recommended values and reduced the amount of sodium in both tap water in Town A and Town B by 92.89% and 89.85% respectively. More interestingly, the sodium content from the filtered drinking water from both Town A and Town B produced drinking water with less sodium content compared with the control tap drinking water and bottled still drinking water commonly used for human consumption in the European Country.
8. Sodium content in water is important for human life. Although, minimum daily requirements for humans is not specified, the total daily intake of 120 mg to 400 mg will be adequate for meeting the needs of growing infants and young children and for adults it is 500mg. Over-dosage of sodium chloride may cause adverse effects such as motion sickness, dizziness, migraine, fainting, low blood sugar, gastroenteritis (stomach infection) or food poisoning, vomiting and convulsions. According to WHO Regional Office for Europe[5], high levels of sodium in drinking water cause ill effects.

In the human body, the main source of sodium is found in foods and drinking water. 20mg/L is the typical sodium level in drinking water, which contributes to 8 – 10 % of the human body needs[4,5].

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