QUALITY ASSESSMENT OF SOME BOTTLED WATER THAT AVAILABLE IN ERBIL CITY, IRAQ BY USING WATER QUALITY INDEX FOR DRINKING PURPOSES

JANAN JABBAR TOMA
Dept. of Environmental Sciences, College of Science, University of Salahaddin, Kurdistan Region-Iraq
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ABSTRACT

Consumers are reacting with water quality problems by buying bottled water which is an expensive solution and only partially resolve the problem. Subsequently, sales of bottled water have increased dramatically in the last ten years; therefore this study was conducted in Erbil city with the major objective of assessing suitability of bottled water quality for drinking purposes through water quality index (WQI) investigation. This was done by subjecting 84 bottled samples collected from different market within 6 months from January to June 2012 to comprehensive physico-chemical analysis using standard methods of analysis. For calculating the WQI, 10 parameters have been considered: Turbidity, Electrical conductivity, Total Dissolved Solids, pH, Alkalinity, Hardness, Calcium, Magnesium, Nitrate and Sulfate. The WQI for these samples ranges from 11.953 to 137.532. Using the water quality index all the bottled samples were classified as excellent to good water they are suitable for drinking purposes except Vauban bottled water which was bad and unsuitable for drinking. A comparison between water quality and the maximum permissible levels depended on the world health organization (WHO) guidelines was reported and discussed. They were varied in composition among the brands and from.

KEYWORDS: Quality, Bottled water, Water Quality Index

INTRODUCTION

Water is the elixir of life (Vidvan Vishvam, 2003) and plays a vital role in the earth's ecosystem. It is one of the most critical, scarce, precious and replenishable natural resource which cannot be created (Prasad, 2008). It is well known that clean water is absolutely essential for healthy living (Mandalam et al., 2009). The importance of water to man cannot be overemphasized due to its essentiality in body metabolism and proper functioning of cells (Buchholz, 1998). Water is also a useful resource for domestic, industrial and agricultural purposes. Though, water is abundant in nature occupying 71% of the earth surface (Gleick, 2006) however, only 1 % is accessible for human consumption (Lefort, 2006). Even the accessible drinking water would require series of treatments before it could be safe or fit for drinking. Bottled water is only reliable healthy drinking water in any parts of the globe. It is widely accepted as potable and thereby free from physical, chemical and microbia contaminants that could initiate adverse health effects in humans when consumed. Bottled waters are becoming increasingly popular worldwide. Italy ranks as the country with the greatest annual production (10 billion L/year) and consumption (151 L/per capita/year) (Versari et al., 2002). Surveys have indicated that consumers are turning to bottled water as a healthy alternative to soft drinks or because they are concerned about the safety or taste of their drinking water (Dorothy and Nicholas, 2005). Bottled water comes from variety of sources, like spring and mineral water drawn from underground; they differ in their composition and mineral content (Warburton and Austin, 2000). Environmental pollution is one of the most horrible crises that we are facing today. Due to the increased urbanization and industrialization. Surface water pollution has become a crucial problem. It is necessary to have a precise and an appropriate information to observe the quality of any water resources and to develope of some useful tools for monitoring the quality of such free resources to retain their excellence quality for various beneficial uses (Alam& Pathick, 2010).

Water quality index is one of the most effective tools to monitor the surface as well as ground water pollution and can be used efficiently in the implementation of water quality upgrading programme. The objective of an index is to turn multifaceted water quality data into simple information that is comprehensible and useable by the public (Alam& Pathick, 2010). Water quality index was first formulated by (Horton, 1965) and later on used by several workers for the quality assessment of different water resources. It is one of the aggregate indices that have been accepted as a rating that reflects the composite influence on the overall quality of numbers of precise water quality characteristics (Tiwari and Mishra, 1985). Water quality index provide information on a rating scale from zero to hundred. Higher value of WQI indicates better quality of water and lower value shows poor water quality. Much of the work has been done on the water quality indices of several rivers and lakes in Iraq and abroad by various workers (Shekha and Al-Abaychi, 2010), (Ali, 2010), (Abdul Hameed et al., 2010a), (Abdul Hameed et al., 2010b) and (Toma, 2012). This study was conducted to assess the quality of bottled water brands in Erbil city by calculating water quality index (WQI) and comparing World Health Organization (WHO) guidelines in order to the safety of bottled water for human consumption.

MATERIALS AND METHODS

The present study was carried out during 6 month period from January to June-2012 on a total of 84 bottled water samples belong to 14 commercial brands produced in Iraq, Turkey, Lebanon and France and were collected in various shops in the Erbil city. The studied area (Erbil city) covers about 70Km^2 between latitude 36º 09¯ to 36º 14¯ N and between longititude 43º 58¯ to 44º 03¯ E, with population of as 885586 inhabitants (as in 2007) (Toma, 2004 and Shekha, 2011).The water type and source of each is represented in table (1). Bottled water samples were collected monthly, preserved, and analyzed physically and chemically variables include (Turbidity, electrical conductivity, total dissolved solids, pH, alkalinity, total hardness, calcium, magnesium, nitrate and sulfate) according to the Standard Methods for the Examination of Water and Wastewater. (A.P.H.A, 1998)

Table (1): The Bottled Water Type and Source of Each Brand

Bottled water brands	Water type	Source of water
Sirwan	Mineral spring water	Sulaimaniah-Iraq
Massafi	Natural mineral water	Erbil -Iraq
Shireen	Natural spring water	Duhok-Iraq
Bakoor	Natural spring water	Erbil -Iraq
Jin	Natural spring water	Duhok-Iraq
Rim	Natural mineral water	Sannine-Lebanon
Vauban	Natural mineral water	France
Lolav	Natural spring water	Istanbul-Turkey
Lava	Natural spring water	Istanbul-Turkey
Tiyan	Natural spring water	Zakho-Iraq
Mira	Natural mineral water	Erbil -Iraq
Grand-Barbier	Natural mineral water	France
Reni	Natural spring water	Erbil -Iraq
Mazi	Natural spring water	*Duhok-Iraq*

Calculation of the WQI

For computing WQI three steps were followed. **In the first step**, each of the 10 parameters has been assigned a weight (wi) according to its relative importance in the overall quality of water for drinking purposes. The maximum weight of 5 has been assigned to the parameter nitrate due to its major importance in water quality assessment. Alkalinity was given the minimum weight 1 as it plays an insignificant role in the water quality assessment. (Srinivasamoorthy et al, 2008). **In the second step**, the relative weight (RW) was computed by the following equation (Horton, 1965):

$$\mathbf{RW = wi \,/\, \sum_{i}^{n} Wi \text{ ----------------} 1}$$

Where, RW is the relative weight, wi is the weight of each parameter and n is the number of parameters. Calculated relative weight (RW) values of each parameter are also given in (Table 2).

In the third step, a quality rating scale (qi) for each parameter except pH was assigned by dividing its concentration in each water sample by its respective standard according to the guidelines recommended by (WHO,2004) and the result multiplied by 100:

Qi = (Ci/Si) × 100 ---------------2

Qi pH= [Ci ×Vi / Si ×Vi] × 100 ---------3

where qi is the quality rating, Ci is the concentration of each chemical parameter in each water sample in mg/L, and Si is the drinking water standard for each chemical parameter in mg/L according to the guidelines of the WHO standard of corresponding parameter, Vi = the ideal value which is considered as 7.0 for pH**.**

Equations 2 and 3 ensures that *Qi* = 0 when a pollutant is totally absent in the water sample and *Qi* = 100 when the value of this parameter is just equal to its permissible value. Thus the higher value of *Qi* is, the more polluted is the water (Mohanty, 2004**).**

For computing the WQI, SI is first determined for each chemical parameter, then it was used for calculation of WQI as follows

SI i = RW ×Qi -------------------4

WQI= Σ SI i------------------------5

In the basis of WQI, water quality can be classified to the following categories: Excellent WQI< 50; Good 50.1-100; Poor 100.1-200; Very poor 200.1-300 and unsuitable>300 (Ramakrishnaiah et al, 2009).

Table 2. WHO standards weight (wi) and calculated relative weight (Wi) for each parameter

Parameters	Unit	Water quality standard	Weight (wi)	Relative Weight (RW)
Turbidity	NTU	5	3	0.103448
pH		6.5-8.5	4	0.137931
EC	µs/cm	1000	3	0.103448
TDS	mg /L	500	3	0.103448
Alkalinity	mgCaCO3/L	200	1	0.03448
T. Hardness	mgCaCO3/L	200	2	0.068965
Calcium	mg /L	100	2	0.068965
Magnesium	mg /L	30	2	0.068965
Nitrate	mg /L	50	5	0.172413
Sulfate	mg /L	250	4	0.137931
			Σwi = 29	ΣRW= 1

RESULTS AND DISCUSSION

Description for all water quality parameters examined (Turbidity, electrical conductivity, total dissolved solids, pH, alkalinity, total hardness, calcium, magnesium, nitrate and sulfate) are shown in (figures 1 to 10**).**

Turbidity is regarded as an important parameter for drinking water. However, the observed values were still within the permissible level recommended by the WHO for drinking water. The results of pH ranged from 6.8 to 7.7, indicating that the bottled water samples are almost neutral to sub-alkaline in nature (Ahipathy & Puttaiah, 2006). pH is an important factor that determines the suitability of water for various purposes (Ahipathy & Puttaiah,2006). The observed values show relative agreement with pH values of surface water which lie within the range of 6.5 to 8.5 (WHO, 2004). Electrical Conductivity (EC) measure salt content which is greatly affects the taste and thus has significant impact on the user acceptance of the water as potable (WHO, 2004). It is an indirect measure of total dissolved salts. High conductivity may arise through natural weathering of certain sedimentary rocks or may have an anthropogenic source, e.g. industrial and sewage effluent (WHO, 2004). The results showed that EC values were within the permissible level recommended by the WHO for drinking water except the value of EC in Vauban bottled water was 1780µs/cm. High TDS could impact taste in drinking water while water of very low TDS may be unacceptable because of flat inspirable taste (Bruvold and Ongerth, 1969). Low alkalinity values were observed in the bottled water samples (< 200 mg CaCO3/L). However, the values still within WHO standard of 200 mg L-1 in drinking water (WHO, 2004). No health implication has been identified with alkalinity.

The results of total hardness through the present study fluctuated from minimum of 40.0mgCaCO3/L recorded in Grand-Barbier water and the maximum of 780mgCaCO3/L recorded in Vauban water, this means the hardness in bottled water varied from soft to very hard water, this may be due to source, geographical and soil properties of the catchments area, various human activities as well as climate condition have been to influence on the hardness value in any water sources (Cole, 1983). The maximum acceptable level of total hardness in bottled and drinking water according to (WHO, 2004) guideline is 500mg$CaCO_3$/L, thus all bottled waters were considered safe for drinking purposes, except Vauban bottled water . Water supplies with hardness greater than 200 mg L-1 are considered poor, but have been tolerated by consumers; those in excess of 500 mg/ L are unacceptable for most domestic purposes (WHO, 1993). Water hardness (very high value) may cause an adverse health effect on humans (WHO, 1993). Studies have shown weak correlations between cardiovascular health and water hardness (Marque et al., 2003).

Calcium and magnesium concentration in bottled water varied from 12.02-296.59mg/L in Grand-Barbier and Vauban and 2.43-38.89mg/L in Grand-Barbier and Massafi respectively. Calcium and magnesium regarded an important major cations in water, and this variation in the concentrations of both cations may be related to water source which in turn related with weathering of rocks and mineral content of each ion such as sedimentary rocks, limestone, dolomite, gypsum, aragonite, mineral of igneous rock, feldspars amphibole and pyroxene and pH value of each source (Hem, 1985). Generally calcium ion level passes the level of magnesium ions in this investigation, this case related to the chemical properties of the soil and geological origin of water source (Hassan, 1998). The concentration of calcium and magnesium ions in all bottled water located within the desirable level of WHO and IBWA(International Bottled Water Association) guideline and considered safe for drinking purposes (WHO, 2004) except in Vauban water where level exceeded of WHO guideline.

Nitrate values were generally low in all the brands of the bottled water and fell within WHO permissible standard of 50 mg/ L in drinking water (WHO, 2004). Short-term exposure to nitrate drinking water above the permissible standard could lead to health problems in infants below six months leading to a disease known as methemoglobinemia or baby-blue syndrome (McCasland et al., 2007). Sulphate values in these analyzed brands of bottled water were also low, and fell below the permissible sulphate limit less than 250 mg/L for drinking water except Vauban water with value reach up to 650mg/L.

Sulphate is one of the least toxic anions in water. However, high sulphate could contribute to undesirable taste in water (NAS, 1977). The physico-chemical parameters analyzed were all located within the WHO standards (WHO, 2004) for bottled samples except Vauban water were above the WHO standards. The lower values of WQI indicate that the water is very clear, free of any impurities. WQI values for individual bottled water samples represented in (Table 3) and (Figure 11) varies from 11.95 to 137.53.

On the basis of the WQI classification, all bottled water samples under study were classified within excellent & good categories hence they are acceptable for human consumption except Vauban water which was classified as poor.

Table 3: Computed water quality index in bottled water samples during the studied period

Bottled water	Water Quality Index	Water Quality status
Sirwan	37.64	Excellent water
Massafi	59.39	Good water
Shireen	36.78	Excellent water
Bakoor	22.83	Excellent water
Jin	52.23	Good water
Rim	50.57	Good water
Vauban	137.53	Poor water
Lolav	26.70	Excellent water
Lava	24.11	Excellent water
Tiyan	31.94	Excellent water
Mira	40.15	Excellent water
Grand-Barbier	11.95	Excellent water
Reni	48.67	Excellent water
Mazi	25.24	Excellent water

CONCLUSION

The WQI for the bottled water samples that available in Erbil city ranges from 11.95 to 137.53. Only Vauban water sample was classified within the poor category, while the rest samples were classified either as excellent or good. Therefore, the bottled water quality needs further investigations and continuous monitoring. Thus, enables to conduct water quality management as the water quality indices are among the most effective ways to communicate the information on water quality trends to the general public or to the policy makers.

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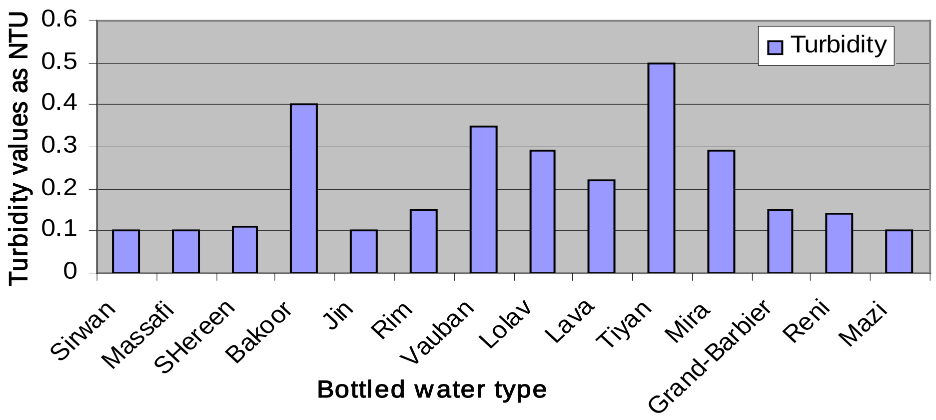
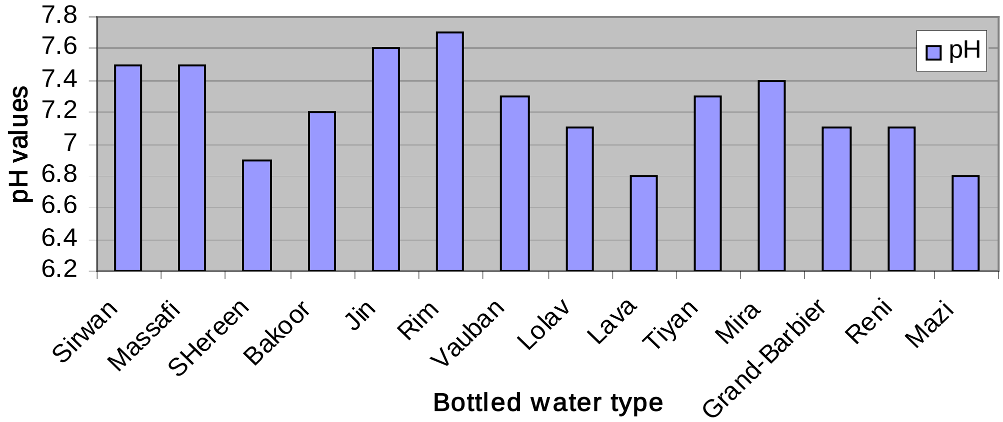
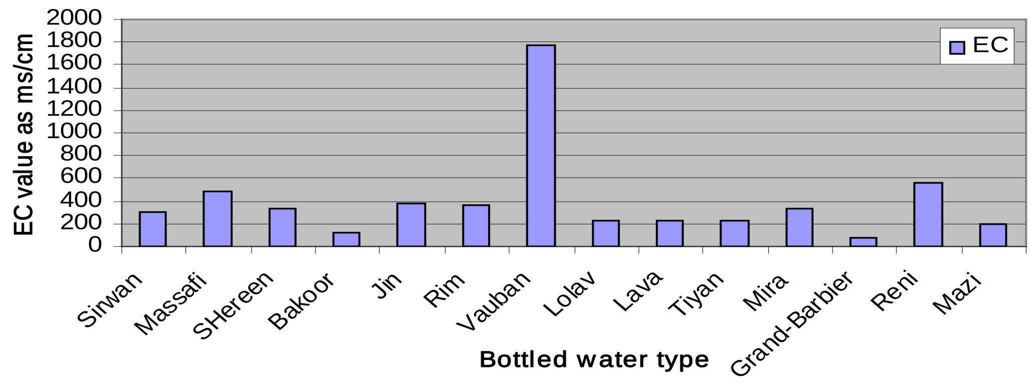


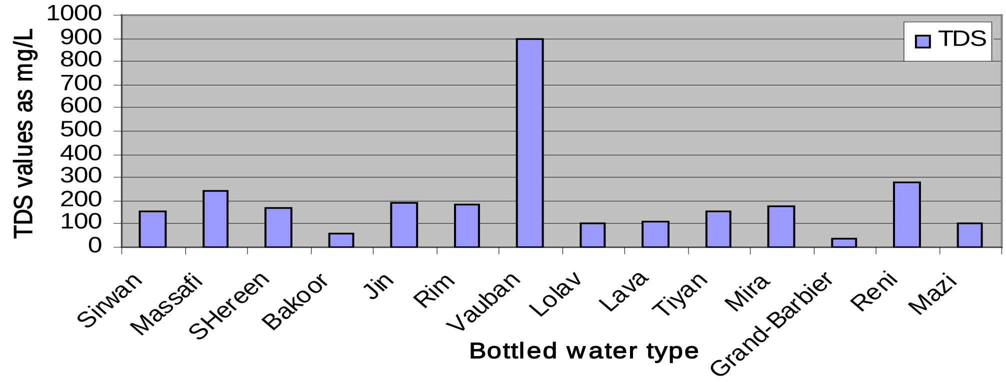
Figure(1):-Turbidity values in bottled water under study



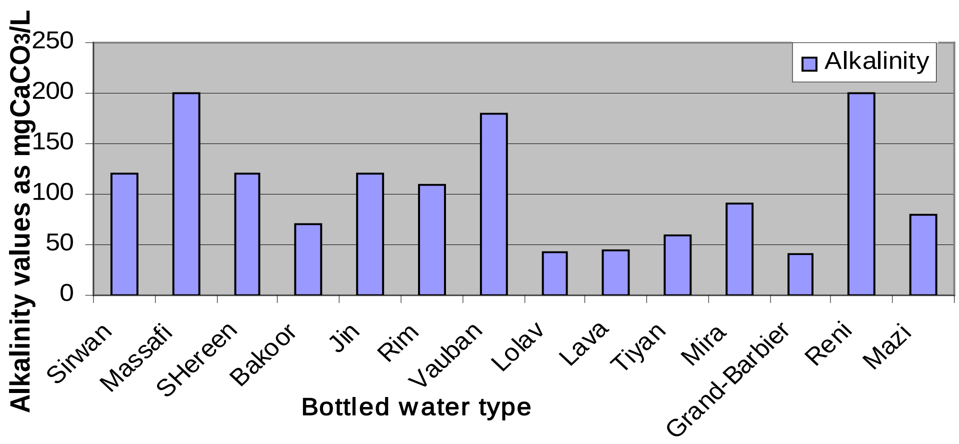
Figure(2):-pH values in bottled water during under study



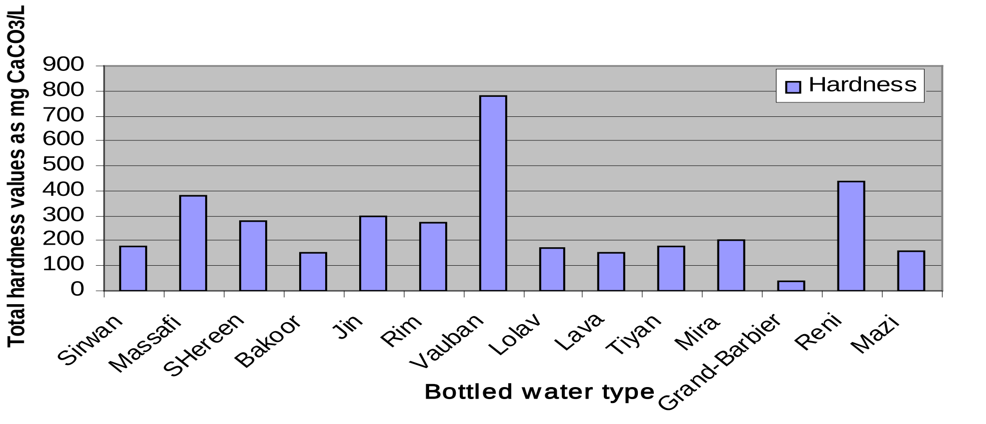
Figure(3):-Electrical conductivity values in bottled water under study



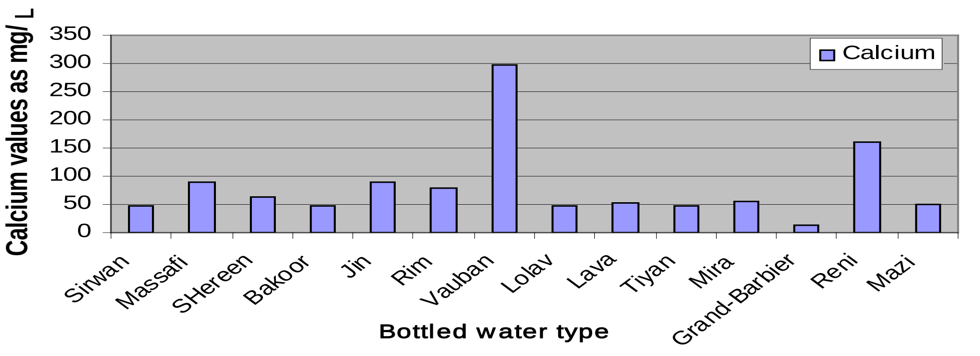
Figure(4):-Total dissolved solids values in bottled water under study



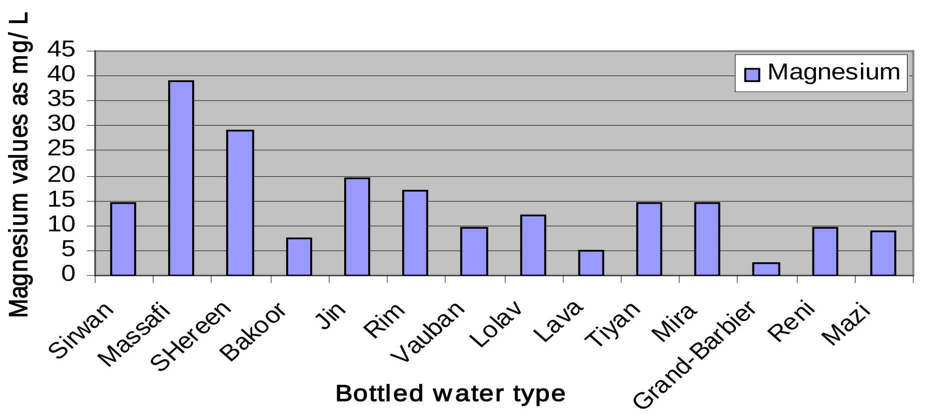
Figure(5):-Alkalinty values in bottled water under study



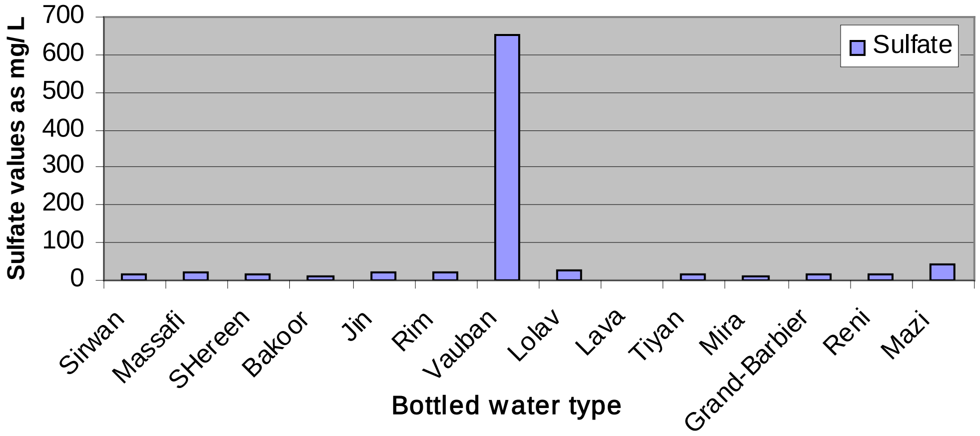
Figure(6):-Total hardness values in bottled water under study



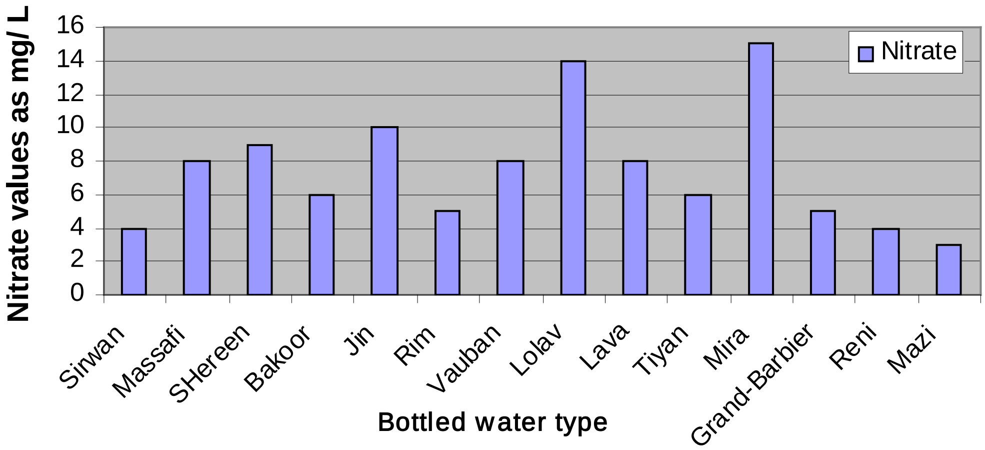
Figure(7):-Calcium values in bottled water under study



Figure(8):-Magnesium values in bottled water under study



Figure(9):-Sulfate values in bottled water under study



Figure(10):-Nitrate values in bottled under study water

هەڵسەنگاندني جۆري هەندێ ئاو قوتوكراوي بەردەست لە شاري هەولێر–عيراق بە بەكارهێناني بەڵكەي جۆري ئاوي بو مەبەستي خواردنەوە

پوخته

بەكارهێنەران كارلێك دەكەن لەگەل كێشەكان جۆري ئاو لە رێگەي كريني ئاوە قوتوكراوەكان كە گران بەهايە و چارەسەرو كاتيە. وەلەم سالآنەي دوايدا زيادبونێكي بە رچاو هەبوو لە كريني ئاوي قوتوكراو. لەبەرئەوە ئەم لێكولينەوە ئەنجامدا لەشاري هەولێر بەمەبەستي هەڵسەنگاندن ئاستي گونجاوي ئاوەكان لەروي جۆرايەتيەوەي وشياوي بۆ خواردنەوە بە دياركردني بەڵگەي جۆري ئاوي لە رێگەي شيكردنەوەي فيزياوي وكيمياوي چواردە (14) جۆري ئاوي قوتوكراو زۆر بەكار هاتووە لەشارەكە بۆ ماوەي شەش مانگ واتە كانووني دووەم تاكو حوزيران 2012 وشيكردنەوەكان بريتي بوو لە (لێڵي . خستي ئايوني هايدروجيني، توانايي گەياندني كارەبا و دنكۆڵە تواوەكاني، تفتي، سازكاري، كالسيوم، مغنسيوم، سلفات و نيترات.

ئەنجامەكان بەدەرياخست كە بەلگەي جۆري ئاوەكان كەوتوبوە نيوان 11,95– 137,53 وهەروەها ئاو قوتوكراوەكان هەمووي گونجاوبوون بۆ خواردنەوە واتەي ناياب وباش بوون تەنها ئاوي (ڤوبان) نەبێت كە نەگونجاو بوو بۆ خواردنەوە بە گۆيرەي بەڵگەي جۆري ئاوي. بەراوركردني پێكهاتەي ئاوەكاني لەگەڵ ئاستي سەروي پيسبوون كە رێكخراوي تەندروستي جيهان چەسپاندويەتي وتاتۆي كراوە .

تقيم نوعية بعض المياه الشرب المبأة المتوفرة في مدينة اربيل–العراق باستخدام دليل جودة مياه الشرب وذلك لغرض الشرب

الملخص

يتفاعل المستهلكون مع مشاكل نوعية المياه عن طريق شراء مياه الشرب المعبأة في قناني التي هي مكلفة وهي احدى الحلول التي تعالج المشكلة جزئيا. زادت مبيعات مياه الشرب المعبأة بشكل كبير في السنوات العشر الاخيرة ، لذلك تم اجراء هذه الدراسة في مدينة اربيل بهدف تقيم مدى ملائمة نوعية هذه المياه لغرض الشرب بواسطة دليل جودة مياه الشرب. وقد تم ذلك عن طريق اخضاع العينات التي تم جمعها والتي هي 84 نوع من مياه الشرب المعبأة في غضون ستة اشهر وذلك من كانون الثاني الى حزيران– 2012 الى التحاليل الفيزياوية والكيمياوية باستخدام الطرق القياسية لحساب جودة مياه الشرب وقد شملت هذه العوامل (العكورة،قيمة الاس الهيدروجيني،قابليلة التوصيل الكهربائي، المواد الكلية الذائبة، القاعدية، العسرة، الكالسيوم، المغنسيوم، الكبريتات والنترات. دليل جودة المياه لهذه المياه المعبأة تتراوح بين 11,95 الى 137,53 . كل المياه المبأة عدت صالحة للشرب وذات نوعية ممتازة وجيدة ماعدا مياه (فوبان) التي عدت سيئة وغير ملائمة لاغراض الشرب.جرى مقارنة محتوى المياه مع مستويات التلوث القصوى التي وضعتها منظمة الصحة العالمية تم تمت مناقشتها .