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Research Article

Application of Water Quality Index for Assessment Water Quality in Some Bottled Water Erbil City, Kurdistan Region, Iraq

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Abstract: Water quality index was applied to assessment water quality of six different types of bottled water that's available in Erbil city (Life, Shireen, Kani, Al-Hayat, Rawan, and Masafi) for drinking purposes, depending on the physicochemical parameters of water (Turbidity, EC, TDS, pH, Alkalinity, Hardness, Ca^{+2}, Mg^{+2}, and No_3^{-2}). The water quality index showed that the Life, Rawan, and Masafi are excellent; also Shireen, Kani, and Al-Hayat are good for drinking purposes depending on the World Health Organization (WHO) standards. The results indicate the bottled water quality generally changed from years 2009 to 2012, some of the bottles have changed to the better and improved their quality, and another's changed to the worse side and declined their quality. WQI is also suggested as a very helpful tool that enables the public and decision makers to evaluate water quality of different bottled waters.

Keywords: Water, Quality, Index, Bottled, Water, Erbil.

1. Introduction

Water is the single most abundant substance in the human body, making up to 60% of an adult's weight and up to 80% of an infant's weight (Abd El-Salam *et al*., 2008). Bottled water is the fastest growing drink choice over the world, Some people drink bottled water as an alternative to other beverages; others drink it because they prefer its taste or think it is safer than their tap water (Oyelude and Ahenkorah, 2012). Bottled water as only reliable healthy drinking water in many parts of the globe cannot be overemphasized having undergone a series of treatments. It is widely accepted as potable and thereby free from physical, chemical and microbiological contaminants that could initiate adverse health effects in humans when consumed (Taiwo *et al*., 2010). Bottled water is not regulated by the Environmental Protection Agency (EPA) which is responsible for regulating public tap water supplies but by the Food and Drug Administration (FDA) because it is considered a food product not drinking water. Despite the FDA attempts to follow the EPA's tap water standards, it is not required to do so, thus allowing a greater range of bacterial contaminants to be present in bottled water. For example, bottled water is required to be tested less frequently for bacteria and chemical contaminants (Fulazzaky *et al*., 2000). Water Quality Index (WQI) is a very useful and efficient method for assessing the suitability of water quality; it is also a very useful an arithmetical tool used to transform large quantities of water quality data into a single cumulatively derived number and for communicating the information on overall quality of water, to the concerned citizens and policymakers. It, thus, becomes an important parameter for the assessment and management of water quality (both surface and groundwater). WQI reflects the composite influence of different water quality parameters and is calculated from the point of view of the suitability of (both surface and groundwater) for human consumption (Akoteyon *et al*., 2011). The purpose of the study is evaluating the quality of water of some bottled water that presents in Hawler city, Kurdistan of Iraq for drinking purposes by using quality index.

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2. Description Area

The study was carried out in Erbil city. The studied area (Erbil city) covers about 70 Km^2 between latitude 36º 09¯ to 36º 14¯ N and between longitude 43º 58¯ to 44º 03¯ E (Toma *et al*., 2013) . The six different bottled waters were collected in the various shops in Erbil city, with the four replications in (November 2012). The present study was used six types of common bottled water that come to the Erbil city and consume by peoples in the wide range. These bottled waters have different sources (Erbil, Duhok, and Turkey). The water type and source of each are represented in Table (1).

Table 1. Type and source of bottled water.

Bottle water brands	Water type	Source of water
Life	Natural spring water	Duhok-Iraq
Kani	Natural spring water	Erbil-Iraq
Al-Hayat	Natural spring water	Adana-Turkey
Rawan	Purified drinking water	Erbil-Iraq
Masafi	Natural mineral water	Erbil-Iraq
Shireen	Natural spring water	Duhok-Iraq

3. Materials and Methods

Historical water quality data related to bottled water were collected in the years 2009 by Toma, 2009. Also, six different bottled water (Life, Kani, Al-Hayat, Rawan, Shireen and Masafi) were collected from different markets in Erbil city with four replications during November and December 2012. Analysis was carried out for the 9 physicochemical parameters including Turbidity, EC, TDS, pH, Alkalinity, Hardness, Ca^{+2}, Mg^{+2}, and No_3^{-2}. Sampling analyzed following methods outlined in the Standard Method for Examination of Water and Wastewater (APHA, 1989). WQI was calculated for assessing the suitability of water for biotic communities and also drinking purposes (Ramakrishnaiah, 2009) (Table 2 & 3).

Table 2. Water quality classification based on WQI value.

Water Quality Index Level	Water Quality Status
<50	Excellent
50-100	Good
100-200	Poor
200-300	Very poor
>300	Unsuitable

3.1 Calculation of Water Quality Index

The calculation of WQI was made using weighed Arithmetic method in following steps. Let there be water quality parameters and quality rating (qi) corresponding to nth term parameter is a number reflecting the relative value of this parameter in the polluted water with respect to its standard permissible limit value, qi values are given by the relationship (Yisa and Jimoh, 2010).

$$qn = 100 (Vn – Vi) / (Vs – Vi)$$

Where, Vs = standard value;
Vi = ideal value,
In most cases Vi = 0 except in certain parameters like pH, dissolved oxygen etc., the calculation of quality rating for pH and DO (Vi was not zero).

$$q\ pH = 100 (V\ pH – 7.0) / (8.5-7.0) \text{ and;}$$
$$q\ DO = 100 (V\ DO – 14.6) / (5.0-14.6)$$

Table 3. Drinking water standard and unit weight of the water quality parameters.

Parameters	Unit	Water Quality Standards	Unit Weights (Wi)
Turbidity	NTU	5	0.2
EC	µs/cm	1000	0.001
TDS	mg/L	500	0.002
pH		6.5-8.5	0.133
Alkalinity	$mgCaCO_3/L$	200	0.005
Total Hardness	$mgCaCO_3/L$	200	0.005
Calcium	mg/L	100	0.01
Magnesium	mg/L	30	0.033
NO_3	mg/L	50	0.02

3.2 Calculation of Unit Weight

The unit weight (Wi) to various water quality parameters is inversely proportional to the recommended standards for the corresponding parameters.

$$Wi = 1/ Si$$

Where, Wi = unit weight for the nth parameter;
Si = standards permissible value of nth parameter.
The unit weight (Wi) values in the present study are taken.

3.3 Calculation of WQI

$$WQI = \Sigma\ qi\ Wi / \Sigma\ Wi$$

4. Result and Discussion

The result obtained from analysis of water samples in six bottled waters are shown in table 9, 10, 11, 12, 13 and 14. Drinking water quality is deteriorating continually due to biological contamination from human waste, chemical pollutants from industries and agricultural inputs (Chauhan and Singh, 2009). During the physicochemical parameters, turbidity is a measure of cloudiness in water (Shivasharanappa *et al*., 2011). The turbidity level was differing from one bottle to another, but generally, they were close to the acceptable level for drinking purposes in bottled water or fewer. However, the observed values in this study were still within the permissible level recommended by the WHO for drinking water (WHO, 2004). The electrical conductivity of the bottled water sample showed with short variation, which ranges from (21- 430.5ms/cm) and all samples are with the WHO and IBWA limit for

drinking water. Conductivity is the important water quality measurement because it gives a good idea of the amount of dissolved material in the water. The difference in value of EC of bottled water samples may be due to the composition of water of the different source area, diversity of soil composition and different mineral rock. The increase in conductivity of water accompanied by increasing the total dissolved solids, this means that there close relationship between EC and TDS (WHO, 2004). The importance of Electrical Conductivity (EC) is due to its measure of cations, which greatly affects the taste and thus has significant impact on the user acceptance of the water as potable (WHO, 2004). Hydrogen ion concentration plays an important role in the biological processes of almost all aquatic organisms (Welch, 1952). pH valued showed a remarkable difference between pH measured and the reported on the labels, the pH value in this survey within the drinking water guideline according to WHO is specified as 6.5-8.5 (WHO, 2004). The observed values of alkalinity were within the permissible level recommended by the WHO for drinking water (WHO, 2004), was ranged from 40-142mg $CaCO_3$/L. Total Hardness (TH) is also an important parameter of water quality whether to be used for domestic, industrial or agricultural purposes (Hameed, 2010). The results obtained from water surveys conducted in this investigation showed that TH values were often lower than the minimal permissible level recommended by the WHO for drinking water (WHO, 2004). Calcium and magnesium concentration in bottled water varied from 12.825-28.86-mg/L in Hayat and Masafi and 2.431-21.879mg/L in Rawan and Shireen 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 to 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 the WHO permissible standard of 50mg/ L in drinking water (WHO, 2004). In this study, the computed WQI value ranges from 13.92 to 62.74 and therefore, can be categorized into six bottled water types from excellent water to the well water. As a result of this study, we got that it's very easy and essential to use WQI for detecting the quality of bottled water to drinking purpose, and makes the peoples understand from the result of some researches more easily than by indicating the parameters. WQI we can determine that if the quality of water declined or increased its value during a period of time. Water quality index (WQI) is the most effective way to communicate water quality. Water quality index (WQI) = 0 means the complete absence of pollutants (Malviya, 2011; Parmar & Parmar, 2010). The computed overall WQI was ranged from 29.71 in Rawan bottled water to 54.75 in Al-Hayat bottled water during 2009 and therefore can be categorized into "excellent water" to "good water", and during this study were sampled collected in November 2012 with four replications, computed water quality index values ranged from 13.92 in Life bottled water to 62.74 in Al-Hayat bottled water 2009 and therefore can be categorized into "excellent water" to "good water".

Table 4. Variation of physicochemical parameters in Life bottled water in November & December 2012.

Parameters	R1	R2	R3	R4
Turbidity	0.34	0.28	0.22	0.1
EC	173	172	173	174
TDS	110.72	110.08	110.72	111.36
pH	7.5	6.9	6.9	7.1
Alkalinity	60	50	60	60
Total Hardness	140	94	104	88
Calcium	18.436	24.048	16.032	14.428
Magnesium	16.044	14.654	15.558	12.641
NO_3	8	3	12	3.5

R= Replication

Table 5. Variation of physicochemical parameters for Kani bottled water in November & December 2012.

Parameters	R1	R2	R3	R4
Turbidity	1.22	0.7	0.71	0.29
EC	276	293	293	277
TDS	176.64	187.52	187.52	177.28
pH	7.7	7.6	7.6	7.6
Alkalinity	140	120	90	140
Total Hardness	140	130	76	128
Calcium	25.651	25.651	24.849	25.651
Magnesium	18.475	16.044	3.403	15.558
NO_3	15	4.5	3	3.5

R= Replication

Table 6. Variation of physicochemical parameters for Shireen bottled water in November & December 2012.

Parameters	R1	R2	R3	R4
Turbidity	0.01	0.11	0.12	0.05
EC	216	211	209	210
TDS	138.24	135.04	133.76	134.4
pH	7.1	7.1	7.2	7.3
Alkalinity	90	90	100	110
Total Hardness	140	100	110	108
Calcium	20.04	17.635	23.246	16.833
Magnesium	21.879	13.613	12.641	16.044
NO_3	3	2.05	2.3	12

R= Replication

Table 7. Variation of physicochemical parameters in Rawan bottled water in November & December 2012.

Parameters	R1	R2	R3	R4
Turbidity	0.16	0.4	0.01	0.13
EC	128	133	129	133
TDS	81.92	85.12	82.56	85.12
pH	7.5	7.5	7.4	7.6
Alkalinity	40	60	60	58
Total Hardness	108	70	90	82
Calcium	16.833	24.048	24.849	17.635
Magnesium	16.044	2.431	74.927	8.751
NO_3	2.3	2	7	7.5

R= Replication

Table 8. Variation of physicochemical parameters in Al-Hayat bottled water in November & December 2012.

Parameters	R1	R2	R3	R4
Turbidity	0.57	0.65	0.59	0.23
EC	158	157	156	158
TDS	101.12	100.48	99.84	101.12
pH	7.8	7.8	7.9	7.9
Alkalinity	100	80	80	60
Total Hardness	70	100	106	120
Calcium	12.825	18.436	17.635	16.032
Magnesium	9.237	13.127	15.072	19.448
NO_3	4	3.6	2.2	1.8

R= Replication

Table 9. Variation of physicochemical parameters for Masafi bottled water in November & December 2012.

Parameters	R1	R2	R3	R4
Turbidity	0.29	0.4	0.27	0.2
EC	329	329	333	323
TDS	210.56	210.56	213.12	206.72
pH	7.4	7.4	7.4	7.4
Alkalinity	140	142	140	120
Total Hardness	122	122	124	136
Calcium	27.25	28.86	28.05	28.05
Magnesium	13.127	12.155	12.474	16.044
NO_3	8.2	8	2.5	2.4

R= Replication

Table 10. Calculation of water quality index for Life bottled water.

Parameters	Observed Value	Standard Value	Unit Weight (Wi)	quality rating scale (qi)	Water Quality Index (WQI)
Turbidity	0.235	5	0.2	4.7	0.94
EC	173	1000	0.001	17.3	0.017
TDS	110.72	500	0.002	22.144	0.044
pH	7.1	6.5-8.5	0.133	20	2.66
Alkalinity	57.5	200	0.005	28.75	0.143
Total Hardness	106.5	200	0.005	53.25	0.266
Calcium	18.236	100	0.01	18.236	0.182
Magnesium	14.724	30	0.033	49.08	1.196
NO_3	6.625	50	0.02	13.25	0.265
			Σ wi= 0.409		**Σ qi wi = 5.696**

Overall WQI = Σ qi wi /Σ wi = 13.92

Table 11. Calculation of water quality index for Kani bottle water.

Parameters	Observed Value	Standard Value	Unit Weight (Wi)	quality rating scale (qi)	Water Quality Index (WQI)
Turbidity	0.73	5	0.2	14.6	2.92
EC	284.75	1000	0.001	28.475	0
TDS	182.24	500	0.002	36.448	0.072
pH	7.6	6.5-8.5	0.133	120	15.96
Alkalinity	122.5	200	0.005	61.25	0.306
Total Hardness	118.5	200	0.005	59.25	0.296
Calcium	25.45	100	0.01	25.45	0.254
Magnesium	13.369	30	0.033	44.563	1.47
NO_3	6.5	50	0.02	13	0.26
			Σ wi= 0.409		**Σ qi wi= 21.566**

Overall WQI = Σ qi wi /Σ wi = 52.72

Table 12. Calculation of water quality index for Al-Hayat bottled water.

Parameters	Observed Value	Standard Value	Unit Weight (Wi)	quality rating scale (qi)	Water Quality Index (WQI)
Turbidity	0.51	5	0.2	10.2	2.04
EC	157.25	1000	0.001	15.725	0.015
TDS	100.64	500	0.002	20.128	0.04
pH	7.8	6.5-8.5	0.133	160	21.28
Alkalinity	80	200	0.005	40	0.2
Total Hardness	99	200	0.005	49.5	0.247
Calcium	16.232	100	0.01	16.232	0.162
Magnesium	14.221	30	0.033	47.403	1.564
NO_3	2.9	50	0.02	5.8	0.116
			Σ wi= 0.409		**Σ qi wi=25.664**

Overall WQI = Σ qi wi /Σ wi =62.74

Table 13. Calculation of water quality index for Shireen bottle water.

Parameters	Observed Value	Standard Value	Unit Weight (Wi)	quality rating scale (qi)	Water Quality Index (WQI)
Turbidity	0.072	5	0.2	1.44	0.288
EC	211.5	1000	0.001	21.15	0.021
TDS	135.36	500	0.002	27.072	0.054
pH	7.1	6.5-8.5	0.133	20	2.66
Alkalinity	97.5	200	0.005	48.75	0.243
Total Hardness	114.5	200	0.005	57.25	0.286
Calcium	19.438	100	0.01	19.438	0.194
Magnesium	16.044	30	0.033	53.48	1.764
NO_3	4.837	50	0.02	9.674	0.193
			Σ wi= 0.409		**Σ qi wi= 5.703**

Overall WQI = Σ qi wi /Σ wi =13.94

Table 14. Calculation of water quality index for Rawan bottle water.

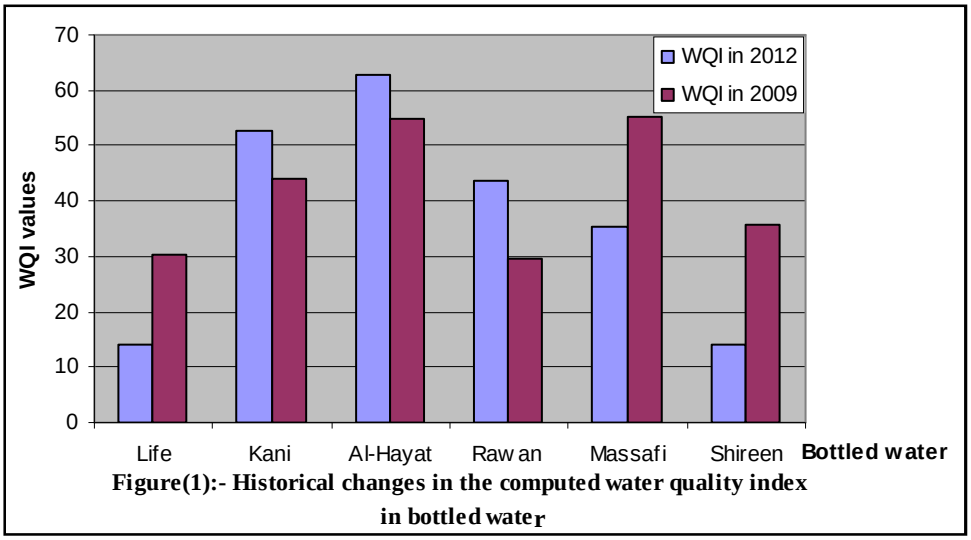
Parameters	Observed Value	Standard Value	Unit Weight (Wi)	quality rating scale (qi)	Water Quality Index (WQI)
Turbidity	0.175	5	0.2	3.5	0.7
EC	130.75	1000	0.001	13.075	0.013
TDS	83.68	500	0.002	16.736	0.334
pH	7.5	6.5-8.5	0.133	100	13.3
Alkalinity	54.5	200	0.005	27.25	0.136
Total Hardness	87.5	200	0.005	43.75	0.218
Calcium	20.841	100	0.01	20.841	0.208
Magnesium	25.538	30	0.033	85.126	2.809
NO_3	4.7	50	0.02	4.9	0.098
			Σ wi= 0.409		**Σ qi wi= 17.816**

Overall WQI = Σ qi wi /Σ wi =43.55

Table 15. Calculation of water quality index for Masafi bottle water.

Parameters	Observed Value	Standard Value	Unit Weight (Wi)	quality rating scale (qi)	Water Quality Index (WQI)
Turbidity	0.29	5	0.2	5.8	1.16
EC	328.5	1000	0.001	32.85	0.032
TDS	210.24	500	0.002	42.048	0.084
pH	7.4	6.5-8.5	0.133	80	10.64
Alkalinity	135.5	200	0.005	67.75	0.338
Total Hardness	125	200	0.005	63	0.315
Calcium	28.05	100	0.01	28.05	0.28
Magnesium	13.45	30	0.033	44.833	1.479
NO_3	5.275	50	0.02	10.55	0.211
			Σ wi= 0.409		**Σ qi wi= 14.539**

Overall WQI = Σ qi wi /Σ wi =35.54



Figure(1):- Historical changes in the computed water quality index in bottled water

4. Conclusion

There are some limitations of WQI. For instance, WQI may not carry enough information about the real quality situation of the water. Also, many uses of water quality data cannot be met with an index. But there are more advantages of WQI than disadvantages. An index is a useful tool for "communicating water quality information to the public and to legislative decision makers;" it is not "a complex predictive model for technical and scientific application (P). On the bases of our results, we can conclude the following: By using WQI we have gotten, the quality of some drinking water that belong to six types of bottled water. We found if they are suitable for drinking purpose or not.

During this study bottled water quality classified to:

Life = Excellent water
Shreen = Good water
Hayat =Good water
Rawan= Excellent water
Masafi =Excellent water
Kani =Good water

The concentration levels of various physiochemical parameters in the studied bottled water types did not exceed the international guidelines for drinking water. By making the comparison between our research and another one, that researcher has done in 2009 for same bottled waters, we found that these waters depend on the WQI standards, they remain in the same situation of water quality, but in spite of that there were some changes by degree. Some of them declined their quality, and some another's increased their quality level.

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