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Efficiency of water treatment in some bottled water companies in Erbil city, Kurdistan region of Iraq

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Abstract: Many humans around the world, including Iraqians, have turned to bottled water as their most important source of drinking water. The aim of this study is to determine the efficiency of treatment plant in some local bottled water company in Erbil, Iraq for human consumption. A total of 5 bottled water brands (Bakoor, Massafi, Mira, Rawan and Safeen) consisting of 'natural mineral (NM)' 'natural spring (NP)' and 'purified spring (PS)' types were collected in two sites one before treatment plant (raw water) and second site after treatment plant (production). This was done by subjecting 30 bottled samples each sample was collected on three replication during February to April 2015, and analyzed for Major cations concentration (calcium, magnesium, sodium and potassium), anions concentration (sulfate and nitrate) and turbidity, hydrogen ion concentration (pH), electrical conductivity (EC) and total dissolved solids (TDS), alkalinity and total hardness by using standard methods. Results showed the efficiency treatment plant in Bakoor is 33.77% it means is more efficiency than others factory while in Mira is 12.41%, is less efficiency than other bottled water under this survey. Lower values for major cations and anions in the bottled water samples recorded in after treatment plant than raw water, likely an indication that these were removed by water treatment. Generally, the overall quality of the supplied bottled water was in accordance to standards and guidelines set by WHO and safe for consumption.

Keywords: Efficiency, Bottled water, Cations, Anions, Companies

I. Introduction

Water consumed by human comes in different forms and from the various sources, bottled water was once from that forms [1]. Bottled water can be defined as natural mineral water – that is, “water that originates from an underground layer, comes from one or more natural or artificial springs and has particularly hygienic characteristics and perhaps properties which are beneficial to health” [2]. For the past three decades, bottled water consumption has been increasing steadily [3]. In the year 2006 alone, 115 billion liters of bottled water was sold globally and by 2011, the market is forecasted to have a volume of 174 billion liters, which is an increase of 51 % from 2006 [4]. In order to protect health, people turn to consume bottled water and spend a lot of money to buy bottled drinking with assumption that the bottled water is clean and safe than boiled water [5]. In Iraq The manufacturing bottled water becomes very popular especially after the last war in 2003, in which the number of factories represents 54.5% of the overall food and beverage factories that are officially approved by the General Directorate for Industrial Development in addition to the imported types [6]. Change the quality of the product itself due to changes in the quality of the source water used in processing plants, such as water, groundwater and variance of the season for another season and type of containers used for the storage of the product and the quality of the treatment [7], these data led to ask among people about the benefit of using local bottled water which types most heather compared to other bottled water that product locally used of drinking water supplied by the municipality. For that, This study was conducted to calculate the efficiency of treatment plant for each company of bottled water under this survey through the study cations and anions concentration and other physical and chemical factors to assessment which company is more efficiency to removal nutrient and become more healthy to humans and compare them with the specifications With the specification of the Iraqi water to indicate the most suitable for consumers

II. Materials and methods

Five various brands of local bottled drinking water company in Erbil city (Bakoor, Massafi, Mira, Rawan and Safeen). This has been determined by collecting bottled water samples from two sites of treatment stages in company until production (raw water, and production) through three months. This was done by subjecting 30 bottled samples each sample was collected on three replication during February and April 2015. Erbil province is the capital of Iraqi Kurdistan with about two million populations and situated in the northeast of Iraq. Its boundaries extended from longitude 43° 15' E to 45° 14' E and from latitude 35° 27' N to 37° 24' N. [8]. The

climate most closely to Irano–Turanian type .The annual rain fall may exceed 1000 mm. The average rain fall in Erbil city is 440 mm. Erbil city is currently served by two types of water resources[9]. Each brand name & Origin are given in (table1). The concentrations of all cations and anions (Calcium, magnesium, sodium, potassium, sulfate and nitrate), turbidity, pH,electrical conductivity, total dissolved solids, alkalinity and total hardness were analyzed following standard analytical methods for the examination of water and wastewater. [10].

Table (1): Classification of bottled water samples

Brand Names	Type	Place Of production
Bakoor	Natural spring water	Erbil -Iraq
Massafi	Natural mineral water	Erbil -Iraq
Mira	Natural mineral water	Erbil -Iraq
Rawan	Purified drinking water	Erbil -Iraq
Safeen	Natural spring water	Erbil -Iraq

A. Calculation of the WQI

For the calculation of WQI 12 parameters such as: calcium , magnesium , sodium ,, potassium , sulphate , nitrate , turbidity, pH, electrical conductivity, total dissolved solids ,alkalinity and total hardness have been used. To compute WQI four steps are followed. In the first step, each of the 12 parameters has been assigned a weight (wi) according to its relative importance in the overall quality of water for drinking purposes (Table 2). The maximum weight of 5 has been assigned to parameter like nitrate due to their major importance in water quality assessment[11] . Alkalinity, sodium and potassium is given the minimum weight of 1 as it plays an insignificant role in the water quality assessment.

Other parameters were assigned a weight between 1 and 5 depending on their importance in the overall quality of water for drinking purposes. In the second step, the relative weight (Wi) is computed using a weighted arithmetic index method given below[12 &13] in the following steps:

$$RW = \frac{\sum_{i=1}^n w_i}{\sum w_i} \quad 1$$

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 [14] and the result multiplied by 100:

$$Q_i = (C_i/S_i) \times 100 \quad 2$$

$$Q_i \text{ pH} = [C_i - V_i / S_i - V_i] \times 100 \quad 3$$

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[15] .

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

$$SI_i = RW \times Q_i \quad 4$$

SIi is the sub index of ith parameter and Qi is the rating based on concentration of ith parameter.

The overall water quality index (WQI) was calculated by adding together each sub index values of each groundwater samples as follows:

$$WQI = \sum SI_i \quad 5$$

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 [16].

B.Efficiency (E%)

Efficiency (E%) of the Water Treatment Plants situated at Bottled water companies was calculated by determining the WQI of the raw water and treated water supplied by using the formula given below:

$$E\% = \frac{WQI \text{ of raw water} - WQI \text{ of treated water}}{WQI \text{ of raw water}}$$

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

Parameters	Unit	WHO standard	Weight (wi)	Relative Weight (RW)
Calcium	mg /L	100	2	0.064516129
Magnesium	mg /L	30	2	0.064516129
Sodium	mg/L	200	1	0.032258065
Potassium	mg/L	10	1	0.032258065
Sulfate	mg /L	250	4	0.129032258
Nitrate	mg /L	50	5	0.161290323
Turbidity	NTU	5	3	0.096774194
pH		7.5	4	0.129032258
EC	µs/cm	1000	3	0.096774194
TDS	mg /L	500	3	0.096774194
Alkalinity	mgCaCO ₃ /L	200	1	0.032258065
T. Hardness	mgCaCO ₃ /L	200	2	0.064516129
			Σwi =31	ΣRW=1

III. Results and discussions

The concentrations of major cations, anions, turbidity, electrical conductivity and others variables in bottled water samples are shown in Tables(3 to 7).

The chemical composition of natural water depends on many factors which includes chemistry of atmospheric precipitation, mineralogy of the rocks encountered along the flow path, residence time of the surface or groundwater, topography and climate [17].

Concentration of major cations ranges for in bottled water were (in mg/l): 23–93 for calcium;7–39 for magnesium; 6.6–11.0 for sodium and 2.4–6.9 for potassium. This is due to two factors which are the source of water and the type of treatment undergone. The mineral rocks have contributed ion into the water causing the NM water to have high minerals[17] . However, water treatments will directly or indirectly cause the removal of the cations such as calcium, magnesium, potassium and sodium to a certain degree. The values for calcium, magnesium, potassium and sodium of raw water are consistently higher than other bottled water samples, which are relatively low in production [18]. All the studied water brands have major anions levels falling within the WHO standard for drinking purposes[14 & 18] . Sulphate level varied between (6.2 – 14.0)mg/L .

Sulfate concentrations in all of the analyzed samples were within the ranges of the WHO and IBWA drinking water standards. The sources of sulfates in the soil resulting from the oxidation Sulfide, which is derived from natural rocks As well as organic materials break sulphate is reduced Sulfates by anaerobic bacteria, as well as from sources Other sulfate natural groundwater[19] .

Nitrate concentration levels ranged from 5.2 to 10.8 mg/L in bottled water. The guidelines standards values for nitrate in drinking water were respected in all of the tested brands within the recommended value of 50 mg/L[14 & 18] .

Turbidity Values after treatment in different bottled water company within the limits(IBWA : 0.0 - >0.5) , it may be happen due to the water sources & treatment the exact water samples.

The result of these physical properties for all samples fall within the permissible limits, values shown relatively low for EC. & T.D.S., the treatment processing steps which are used by all brand factories lead to reduce the values of T.D.S.which it is a strong function of the values for EC.[20] .

T. hardness & alkalinity values also appeared within the range permitted by the[14 & 18] (WHO,2006 and IBWA,2000),Is a numeric expression for the water content of minerals, particularly calcium and magnesium ions and other alkali metals and is directly related to the type of source water and the climate surrounding [20] &[21] . Water quality index (WQI) = 0 means complete absence of pollutants. When 0< 100, indicates the water is under consideration and fit for human use and WQI > 100 reflects its unsuitability for human use [22].Computed WQI values are usually classified into five categories: excellent, good, poor, very poor and unfit water for drinking purposes[16] . Calculation of WQI for bottled water befor and after treatment sample represented in (Table 8), varies from 54.90to 69.14in raw water in Rawan and Safeen bottled water and41.19 to 58.80 after treatment(production) in Bakoar and Mira respectively. It is obvious from this classification that on the basis of the WQI, bottled water samples from the study area is of acceptable quality for human consumption, similar conclusion observed by [23]. It is inferred from the results that overall quality of water is good at the sampling site befor treatment and good to excellent after treatment(production). In this research paper the application of WQI approach to bottled water quality in Erbil city had the purpose of providing a simple, valid method for expressing the results of several parameters in order to assess the groundwater quality. The high value of WQI at

these stations has been found to be mainly from the higher values of calcium, magnesium, sodium, potassium, sulfate, nitrate, total dissolved solids, hardness and alkalinity in the bottled. Assembling different parameters into one single number leads an easy interpretation of index, thus providing an important tool for management purposes[24].

The efficiency of water treatment plant in five bottled water companies varied from 12.41% and 33.77% in Mira and Bakoor company respectively. This variation of the efficiency of treatment plant of these companies may be due to the treatment units Mira company is inefficient and more turbid when it compare with Bakoor factory. Because the treatment plant Mira company may be is an old, and probably needs repairing and reconstruction. Although Turbidity has no health effect but it can interfere with disinfection and provide a medium for microbial growth it may indicate the presence of microbes[25].

Table 3: Major cations concentration, anions concentration and others properties of Bakoor Bottled water

Sites	Site(1) Raw water				Site(2) Production			
Parameters	R1	R2	R3	Mean	R1	R2	R3	Mean
Calcium	70	68	60	66	30	28	29	29
Magnesium	30	30	34	31	7.0	7.0	7.0	7.0
Sodium	10	11	9	10	9.4	9.3	8.9	9.2
Potassium	3.5	3.7	3.6	3.6	3.0	2.6	2.4	2.8
Sulfate	12.5	13	12	12.5	11.6	11.1	11.2	11.3
Nitrate	7.8	8.4	7.0	7.6	5.2	5.2	5.2	5.2
Turbidity	0.10	0.04	0.04	0.060	0.00	0.00	0.00	0.00
pH	8.05	8.1	8.0	8.05	7.96	7.91	7.92	7.93
EC	363	360	358	361	204	203	208	205
TDS	181	187	187	185	126	132	126	128
Alkalinity	232	226	232	230	111	100	104	105
Hardness	279	276	270	275	140	131	134	135

R: Replication

Table 4: Major cations concentration, anions concentration and others properties of Massafi Bottled water

Sites	Site(1) Raw water				Site(2) Production			
Parameters	R1	R2	R3	Mean	R1	R2	R3	Mean
Calcium	89	93	88	90	44	49	45	46
Magnesium	22	26	21	23	12	10	11	11
Sodium	8.1	8.4	7.9	8.2	7.4	7.1	7.1	7.2
Potassium	4.2	4.7	4.6	4.5	4.0	4.0	4.0	4.0
Sulfate	11	11	14	12	11.8	11.5	11.5	11.6
Nitrate	8.0	8.3	8.0	8.1	8.0	8.0	8.0	8.0
Turbidity	0.05	0.06	0.05	0.055	0.00	0.00	0.00	0.00
pH	7.86	7.84	7.94	7.88	7.96	7.94	7.86	7.92
EC	356	352	354	354	143	142	138	141
TDS	234	226	224	228	86	90	85	87
Alkalinity	211	212	209	211	76	78	77	77
Hardness	230	237	232	233	120	131	124	125

R=Replication

Table 5: Major cations concentration, anions concentration and others properties of Mira Bottled water

Sites	Site(1) Raw water				Site(2) Production			
Parameters	R1	R2	R3	Mean	R1	R2	R3	Mean
Calcium	50	53	49	51	32	28	27	29
Magnesium	26	22	21	23	22	18	17	19
Sodium	9.2	9.4	9.3	9.3	8.1	8.1	8.1	8.1
Potassium	6.4	6.9	6.5	6.6	5.1	5.6	5.2	5.3
Sulfate	7.6	8.0	7.5	7.7	6.2	6.2	6.2	6.2
Nitrate	10.3	10.8	10.4	10.5	9.3	9.0	8.9	9.1
Turbidity	0.04	0.05	0.04	0.045	0.00	0.00	0.00	0.00
pH	8.15	8.20	8.15	8.15	8.00	8.10	8.05	8.05
EC	458	450	448	452	393	380	382	385
TDS	294	287	289	290	251	244	246	247
Alkalinity	353	352	348	351	320	322	321	321
Hardness	245	236	234	230	216	216	216	216

R=Replication

Table 6: Major cations concentration, anions concentration and others properties of Rawan Bottled water

Sites	Site(1) Raw water				Site(2) Production			
Parameters	R1	R2	R3	Mean	R1	R2	R3	Mean
Calcium	38	37	33	36	26	23	23	24
Magnesium	20	23	20	21	14	14	14	14
Sodium	7.3	7.8	7.4	7.5	6.6	6.6	6.6	6.6
Potassium	3.6	3.5	3.1	3.4	3.0	2.8	3.2	3.0
Sulfate	9.3	9.8	9.4	9.5	8.1	7.8	8.1	8.0
Nitrate	7.1	7.3	7.2	7.2	6.7	6.5	6.3	6.5
Turbidity	1.0	0.80	0.9	0.9	0.00	0.00	0.00	0.00
pH	8.15	8.10	8.11	8.12	7.92	7.96	7.94	7.94
EC	247	239	240	242	196	192	191	193
TDS	158	153	154	155	127	122	123	124
Alkalinity	192	188	187	189	161	156	157	158
Hardness	156	155	154	155	120	122	121	121

R=Replication

Table 7: Major cations concentration, anions concentration and others properties of Safeen bottled waters

Sites	Site(1) Raw water				Site(2) Production			
Parameters	R1	R2	R3	Mean	R1	R2	R3	Mean
Calcium	46	50	45	47	30	35	31	32
Magnesium	35	39	34	36	15	14	16	15
Sodium	10.5	11.5	11.0	11.0	9.1	9.6	9.2	9.3
Potassium	6.2	5.8	6.0	6.2	5.1	5.2	5.0	5.1
Sulfate	12.2	12.8	12.5	12.5	11.0	10.8	10.9	10.9
Nitrate	9.8	9.4	9.3	9.5	7.1	7.1	7.4	7.2
Turbidity	0.80	0.80	0.80	0.80	0.00	0.00	0.00	0.00
pH	8.12	8.17	8.13	8.14	7.09	8.00	8.10	8.00
EC	345	355	350	350	241	250	244	245
TDS	222	227	223	224	157	159	155	157
Alkalinity	391	400	394	395	276	278	277	277
Hardness	235	225	230	230	168	173	169	170

R=Replication

Table 8: Water Quality Index and Efficiency for Bottled water and treatment during this survey

Sites	Site(1) Raw water Water Quality index	Site(2) Production Water Quality index	Efficiency of Treatment plants
Bakoor	62.21	41.19	33.77%
Massafi	57.14	41.98	26.52%
Mira	67.13	58.80	12.41%
Rawan	54.90	43.12	21.46%
Safeen	69.14	51.13	26.06%

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