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Bottled Water Quality in KSA

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Abstract: Bottled water has grown to become such a large industry in the Kingdom of Saudi Arabia, KSA for a number of socio-economic and cultural issues. Some of those reasons attribute it to its advantages over ordinary tap water served by the municipality, huge advertisements praising bottled water's qualities, relative convenience by an individual, communal prestige and taboos for bottled water appealing to many people as being far more convenient than tap water. This is besides bottled water safety and purity. As such, bottled water is available virtually everywhere in supermarkets, sales points, service stations, cafeterias and restaurants, vending machines, etc. There are many different kinds of bottled waters, and each one has specific requirements regarding its source, composition, treatment and quality. This research project reviewed the quality of bottled water furnishing a baseline survey for its production and management in the Eastern Region of KSA; stressing upon characteristics and extent of bottled water used for drinking purposes and comparing its quality with acceptable standards and guidelines. Samples were drawn from different factories, localities and sales points for laboratory investigations for physical, chemical and bacteriological quality over a period of around 6 months during a final year research project task. Carried out research showed that most bottled waters from KSA factories are safe and proved to be of high quality and relatively free of contaminants. Nonetheless, the quality of some brands was spotty, however, and such products may pose a health risk, primarily for people with weakened immune systems. When comparing results of environmental laboratory for various water quality parameters with drinking water standards set by various regulatory bodies, levels of different physical parameters such as pH, total dissolved solids (TDS), calcium, magnesium, sodium, potassium, NO3, chlorine, and SO4 have been registered disparity for some bottled water.

I. INTRODUCTION

The bottled water could contain chemicals pollutants or bacteria or natural toxic substances. This occurrence may affect the public health and human life especially if these contaminants are present in excess of allowable standards concentrations. Generally, bottled water should not contain any substances that affect color, odor and taste. Bottle outside shape and surface ought to be acceptable and entirely free from loose soil, dirt, mud, dust, hair and any other visible and noticeable undesired material.

Bottled water has become very popular for quenching thirst and as a dietary supplement especially for mineral constituents. Growth in total bottled water volume sales showed an increasing trend in KSA especially in the Eastern region. Bottled water consumption is deemed necessary by consumers and thought of healthier and more pleasant than tap water. Many intervening factors contributed towards alleviating growth in sales and trades. Among influential parameters are population growth, city sprawl, levitating incomes, bottled water innovative dispatches of brands and marketing promotional movements and notions. The popularity of bottled water increased in the last years as a result of factors such as availability, uncertainty of quality, safety of tap water, and fashion for a healthy lifestyle, marketing strategies and increasing consumer awareness of the benefits of regularly drinking water. The rising popularity and acceptance of bottled waters dictates addressing quality aspects, degree of potential contaminants, marketing progress and management relationships.

Bottled waters may be subjected to direct and/or indirect contamination at source, preparation, marketing, distribution, transportation, storage and environment, and water. The water quality for human use was a difficult challenge. Bottled

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water can be defined into three categories as per contamination that may affect their quality: external contamination at the bottling plant, contaminants migrating from the packaging material and compounds present in the source (e.g. aquifer) (Diduch et al, 2011 and Ghrefat, 2013).

Contaminating constituents and physiochemical parameters that are to be considered within Saudi and Gulf specifications may include: total and dissolved solids, aluminum, antimony, ammonia, arsenic, barium, beryllium, boron, cadmium, chloride, chromium, copper, cyanide, fluoride, iron, lead, manganese, mercury, nickel, nitrate (NO_3), nitrite (NO_2), selenium, silver, sodium, sulfur, tin, uranium, gaseous substances such as hydrogen sulfide, pH. The importance of drinking both potable and palatable water is vital and of paramount importance to maintain a healthy living and sustainable environs (Al-Zahrani, et al).

Some bottled water in Saudi market is said to contain high amounts of sulfates (SO_4) which if increased will be harmful to the human body. Some of others may contain dangerous substances such as radioactive uranium, which if present in the water for a long period is a major cause of cancer and various diseases (Altofil, 2008).

Importance of this research study may be summarized as follows (Al-Zahrani, et al, 2014):

- Establishing a baseline survey for bottled water production and management in the Eastern Region of KSA.
- Gathering data relating to bottled water source, quality issues, production, manufacture, use, virtual market and water footprints in KSA.
- Exploring consumer ideas, concepts and suggestions about bottled water.
- Comparing Saudi bottled water product to worldwide standards.

Research main and specific objectives and expected outcomes may be briefed as follows:

- To evaluate quality of bottled water and compare laboratory results for local varieties and imported items with local and international standards for bottled drinking water.
- To compare laboratory findings with labeled content of water as mentioned on packaging and manufacturer labels and evaluate difference in water quality between refills for each category.
- To recognize companies committed to Saudi's bottled water standards and assess possible risks from consumption of drinking water from unreliable sources.
- To survey variety of different bottled water containers (plastic, glass, clear, colored etc.)
- To formulate baseline data information on bottled water in Eastern region in KSA exploring production, warehousing, distribution, final trade outlet location, consumer products.
- To assess user understanding and ideas regarding improvement in bottled water production, storage, use and management.

Research hypothesis assumes that consumers who are dissatisfied with the taste, odor, and/or appearance of tap water are more likely to purchase bottled water. Likewise, it is expected that bottled water purchases do not solely reflect risk prevention behavior.

II. LITERATURE REVIEW

Bottled water is a primary source for drinking water in the Kingdom of Saudi Arabia, KSA. It's also marketed as an ideal for other uses such as nursery drinking water or infant formula preparation (Aleissa et al, 2011). Bottled water has different forms that can be package such as glass or plastic. It comes from multiple sources such as springs, desalination plants and groundwater wells. Currently, the bottled water factories in KSA reached over seventy, compared to six factories, thirty three years ago. Only in Al-Riyadh City there are fourteen factories (See table 1). These factories produce annually 5 billion liters of bottled water, Local annual bottled water consumption is around 2.5 billion liters which causes a surplus in production and a consequent drop in price (Al-Hias, 2005).

Table (1) Approved local water bottling companies[7].

Water	Product Name	Bottled or Bulk
Springs Water Factory	Springs, Nestle	Bulk
Aqua Cool Saudi Arabia Co. Ltd	Aqua Cool	Bulk
Sawaco Water Desalination	Sawaco	Bulk
Rivers Water Factory Co.	Rivers	Bulk

[7] Other bottled waters from other factories and sources were reported to have too much Bromide which could cause cancer.

Qassim Health Water Factory	Qassim	Bottled
Delta Marketing Co. Ltd.	Al-Ain, Delta, AFS	Bottled
Makkah Water Company (SAFA)	SAFA	Bottled
Al Manhal Water Factory Co Ltd	Manhal, Nestle	Bottled
Health Water Bottling Co. Ltd.	Nova	Bottled
Al-Hada Factory Jeddah	Al-Hada	Bottled
National Plant for Health Water	Hana	Bottled
Al-Jouf Mineral Water Company	Al-Jouf	Bottled
AlOyoun Water Bottled Water Plant	Al-Oyoun	Bottled

In the USA most of the bottled water comes from groundwater sources making the quality of the water different from day to day and usually it contains less pollutants than surface water. However it still contains naturally high amounts of some pollutants like arsenic and nitrates or it may be affecting other activities like industrial wastes, underground gas and chemical tanks (Free drinking water, 2013). In KSA the primary source of freshwater is from desalination units (See figures 1). KSA ranks top of countries that produce freshwater from sea. In 2002 KSA produced 797 million cubic meter of freshwater, that covers 70% of the country's needs of drinking water (Albassam, 2013). In 2011 the desalination plants covered half of drinking water needs. While 40% comes from groundwater the remaining 10% comes from surface water. This situation continued for nine years whereby the freshwater comes from desalination has decreased by about 20%. Nevertheless, it is still the primary source of drinking water in the kingdom. Desalination in KSA supplied water from 27 desalination operating plants located in 17 locations producing a total of 3.3 million cubic meters per day (1.2 billion cubic meters per year). 21 plants are situated along the red sea while the other 6 plants are located on the eastern coast (Wikipedia, 2013).

Fig. (1) Desalination plants in KSA. (Google maps 2013)

Some people drink bottled water as an alternative to other beverages (Prithviraj, 2009). Others drink it because they prefer its taste or think it is safer than tap water. As tap water taste and quality may vary from place to place, bottled water's taste and quality also vary and even within brands. This basically depends on quality of the source water, including its natural mineral content (EPA, 2013).

National regulations relating to the requirements for water intended for human use may be divided into three categories, chemical, microbiological, and organoleptic. This is based on international rules and guideline values set by the World Health Organization. A study in Riyadh municipality tested quality of bottled water in nine domestic and three imported bottled water brands. The results showed that the quality satisfied requirements and directives of international standards. For different regulatory agencies the level of physical and chemical parameters such as: Ca, Mg, Na, K, NO_3, Cl, SO_4 , pH and total dissolved solids, TDS, for all the brands met international standards set by these regulatory agencies (Diduch et al, 2013 and Alfadul et al, 2011)

Organic contaminant presence in water is becoming a common problem. The main reason is the impact of human activities in the natural environment. Other factors are treatment processes and conditions of transport. Compounds of organic contaminates were detected in samples of bottled water which caused problems. This is due to reasons that include: interactions between constituents present in the samples, low levels of target analyses in samples and the complex composition of samples. (Diduch et al, 2013)

Water to be used for drinking purposes is of significance enacted by human need. The water must be free from chemicals and microorganisms, with suitable supply to meet demand, and should impose no risk to public health. This water should be palatable, free of turbidity, color, smell and with acceptable taste. Attention must be seriously paid when analyzing the water. Consequently, there are several difficulties facing this, including lack of cooperation with water companies specialists, reluctance in providing required information for analysis such water source and method of water treatment (Robles, et al, 1999). When sampling for analysis it is vital to note cleanliness of the laboratory, presence of even small amounts of dirt, oil or rust or other foreign material that could lead to wrong conclusions. This is true in particular on measurements of iron or manganese. In such cases, even fractions of one part per million may be of great importance. Lack of interest in sampling may lead to faulty results with respect to content of iron in the water. Samples taken from a rusty pipe may add to the amount of iron making iron measurements in the sample meaningless (Evans et al, 2003).

III. MATERIALS AND METHODS FOR CASE STUDY

Methodology, actions plan (project phases and tasks, methods used, experiments, models, statistical models, design criteria etc…), literature review from reputable localities constituted a pillar for the work undertaken. The research work aims at classifying sources and characterizing properties of bottled water manufacturing and processes. This calls for data collection through a survey of selected firms, establishments and factories. Data collection was done through predesigned and set interviews and questionnaires for a reasonable sample.

Study area

The Kingdom of Saudi Arabia (KSA) is situated in southwest Asia between latitudes 16 –32° North and longitudes 35 – 65° east. The total area of the kingdom is about 2.25 million km^2 which represents about 80 % of the area of the Arabian Peninsula (Al-Omran et al, 2013). Table (2) gives general demographical information and data.

Table (2) General demographical information and data.

Item	Data
KSA population (July 2008)	28,161,417 including 18% or 5,576,076 non naturals rapidly increasing.
Current population growth rate	about 1.945%
Age structure forms	0-14 years: 38.1% 15-64 yrs: 59.5% 65 & above: 2.4%. median age
Total	21.5 years male – 22.9 years female – 19.7 years
Birth Rate	28.83 births/1000 people
Fertility Rate	3.89 children / woman
Ethnic group	Arabs : 90% Afro Asians : 10%
Literacy rate	78.8% (can read / write)
City / Oasis density	1000 people / sq km
Westerners	100,000

Saudi Arabia is the second largest market for bottled water production and consumption among the Gulf Cooperation Council (GCC), and reaches 65 % in beverage consumption. Total beverage utilized in GCC in 2007 reached 15.5 billion litres. Beverage type gives a volume in million Litres of Packed Water: 5321, Hot Tea: 3207, Carbonated soft drinks: 2506, Liquid milk: 1865, Juice Products: 1367, Hot Coffee: 1183, Laban: 538 and all other beverages: 620 (Saudi Arabia GCC, 2013). The Beverage Marketing Corporation, BMC, classified KSA among the top 20 bottled water consuming countries for the years from 1997 to 2010 as per-capita consumption reported in litre per person per year (See figure 2 and table 3).

Fig. (2) Bottled water factories in KSA. (Google maps 2014)

Table (3) Per-Capita Bottled Water Consumption by Top Countries, 1999–2010 (Litters per person per year)

Countries	1999	2000	2001	2002	2003	2004	2005 (BMC)	2007 (BMC)	2009 (Canadean)	2010 (BMC)
Mexico	117	124	130	143	157	169	179	205		243
Italy	155	160	164	167	179	184	191	202	189	187
United Arab Emirates	110	114	119	133	145	164	181	260		153
Belgium-Luxembourg	122	118	118	124	133	148	160	150	120	148
Germany	101	102	103	105	121	125	128	126	165	134
France	118	126	131	141	148	142	139	136	112	132
Spain	102	105	109	112	127	137	146	120	124	124
Lebanon	68	77	85	94	96	102	107	111		121
Thailand	67	70	73	76	77	77	77	89		114
Hungary	30	39	46	51	62	66	70	108	109	111
Switzerland	90	90	90	92	96	100	104	107		108
United States	64	67	74	82	85	91	99	111		107
Slovenia	48	56	64	71	78	80	81	95	56	107
Croatia	42	47	52	56	62	69	78	92		101
Cyprus	67	72	76	81	86	92	98	91		98
Qatar							81			95
Saudi Arabia	76	80	85	90	88	88	93	91		95
China/ Hong Kong							69			95
Czech Republic	62	68	74	80	84	87	90	93	77	92
Austria	75	75	78	79	86	82	81	95	95	91
Israel	23	29	38	47	56	61		88		
Portugal	70	72	73	76	78	80	83	85		

Source: http://efbw.eu/bwf.php?classement=07 (European Federation of Bottled Waters) and the Beverage Marketing Corporation.

Table (4) offers a general overview for bottled water factories in KSA and their locations and water sources.

Table (4) Bottled water factories location and water source

#	Name	Location	Water source
1	Safa	Makkah	Underground water & desalinated water
2	Hada	Makkah	Underground water & desalinated water
3	Nova	Al-Riyadh	Underground water & desalinated water
4	Alqassim	**Al-Badaya**	Underground water & desalinated water
5	Manhal	Al-Riyadh	Underground water & desalinated water
6	Najran	Najran	Underground water
7	Pure Aqua	Dammam	Underground water & desalinated water
8	Alyanabea	Dammam	Underground water & desalinated water

Recently the Saudi Arabian food-processing sector and local companies have experienced rapid growth. The government supports the food and drink industry by providing attractive financing and subsidies on selected equipment, and through the imposition of high tariffs on imports that compete with locally-produced equivalents. Important sub-segments in Saudi Arabia's water industry have developed to meeting the majority of domestic demand (Saudi Arabia GCC, 2013).

The selected study area is Dammam Khobar district in the Eastern region. Data collection is from factories, water sources, treatment methods, storage and distribution, management. Site inventory evaluation began on October, 2013 to gather background data that would reveal the status of the bottled water industry in the Khobar-Dammam areas in terms of:

- Determining number of bottled water factories and companies owned, end run by governmental, private sector and non-governmental organizations, NGOs and CBOs,

- Identifying existing types of technologies or systems used in water production, manufacture, sales, distribution and quality governance.
- Evaluating the status of each company or factory, level of water treatment unit, design capacity, year of construction, and selected location.
- Interviews conducted with researchers, relevant NGOs, water treatment facilities designers, municipalities and governing councils and institutions.

This research project is a trial to collect data and information for the selected and chosen area through developing appropriate research questionnaires. For appropriate data collection and information gathering two questionnaires were designed. One questionnaire is aimed to address aesthetics in relying on bottled water for drinking purposes. This questionnaire explores personal preferences for the product in terms of aesthetical and environmental perspectives. In order to make a preliminary study to assess the main issues related to the situation of bottled water industry in KSA Khobar Dammam areas, a questionnaire has been set. The idea is to gather specific data about each existing bottled water company or factory in the project area. The questionnaire would assist in collecting relative information towards monitoring of bottled water quality in the study area. One questionnaire is set for relevant factory personnel and mangers and the other addresses the general public, stakeholders and beneficiaries. The questionnaire is divided into three sections. The first one consists of a number of questions of multiple choices while the remainder requires a short answer. These questions are designed to gather the basic information about the bottled water source, treatment, packaging, quality and unit operation issues. In addition, it introduces technical history for each unit. There are a number of tables that address issues related to main operational and technical problems for each process. Other questions identify the most critical process parameters that may affect efficiency of bottled water manufacture and distribution. Bottled water questionnaires included basic data of units, information about treatment processes, control and monitoring systems. It is needed to provide basic information about existing bottled water units in the Eastern Region in KSA, in terms of assessing and monitoring plants' process performance. This is in an effort to check performance and attempt appropriate remedial solutions if need be, and to be able to add a technical enhancement for processes if possible. The other questionnaire is addressed to the general public needs, their knowledge about bottled water and their tolerance to altering to municipality tap water in the future. This questionnaire included personal information and introduction to bottled water health and safety measures (Guernsey Water, 2013; University of Barcelona, 2013 and USGS, 2013).

The questionnaire has been done to a number of random persons. Most of these people were from age 21 to age 40. Number of respondents to distributed questionnaires reached 78%. 54% of them consider themselves as a water drinker while the others are not. Most of tested personnel drink bottled water and 50% of them purchase their bottled water daily while 20% of them purchase bottled water twice a week and the rest of them once a week. The reason why they're drinking bottled water, most of them chose because it's clean and safe, most of them do not drink from tap water. Most bottled water companies that have been chosen were Hada, Safa and Nestle and Nova, pure aqua and other companies. Selection of factories was based on comments and observations from many people regarding: preference, availability, attractiveness, cost and continuity of supply.

The selected water samples were sent to the Environmental Analysis laboratory to measure the concentration of certain parameters that included: pH, TDS, Ca, Mg, Na, K, Fe, HCO_3, SO_4, NO_3, Cl, F and BrO_3.

The devices that have been used are the inductively coupled plasma optical emission spectroscopy (ICP-OES) and Shimadzu High Performance Liquid Chromatography (SHPLC) (EAG, 2014).

Figure (3) is a photo of the equipment used at the Environmental Analysis laboratory at the Environmental Engineering Department of the College of Engineering of University of Dammam.

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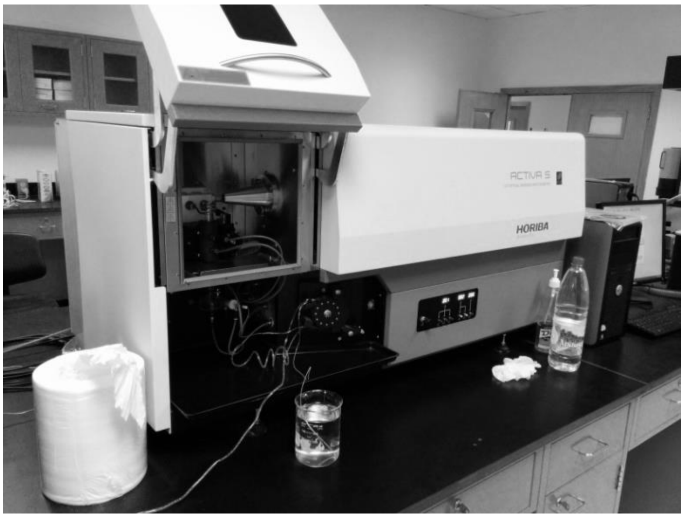

Fig. (3) Inductively coupled plasma optical emission spectroscopy (ICP-OES).

The following steps denote the standard operation procedure followed while conducting experiments with ICP-OES equipment:

1. Fill-up the Chiller system (cooler) with Deionized water to the maximum line.
2. Turn on the fume hood.
3. Turn on the Aragon gas tank valve. Make sure the pressure cylinder read at 2000 PSI and the ICP pressure valve read at 90 PSI.
4. Turn on the computer, Click on the Icon ICP 5.4 ACTIVA and select "Start Version 4" and Click on Start on the top left, to start ICP. Place the Nebulizer tube into a beaker filled with Deionized water.
5. Click on Method Selection, type a title on the **INPUT METHOD NAME, SELECT TYPE OF THE SOURCE (ICP) ,** then click next.
6. If you making a new calibration, select **FROM THE BASE OF ELEMENTS** and select **DEFULT CONCENTRATION UINT** (AS EXAMPLE mg/l) AND Click next.
7. Select the elements by clicking on their symbols: Na, Cd, Pb…. And click next.
8. Type the concentration range of, low and high value. It can be done by highlight all elements, and press F 11 and click on next.
9. Select the wavelength of the elements you trying to analyze. This can be done by referring to the wavelength line that saved on the desk top and click on next, then click on finish.
10. Go to the main screen, click on **task and sequences, new**, and click on **peaks search, then profile**. Then click on Run. Use the highest standards to search for peaks.
11. For calibration, Click on Task and Sequence, Calibration, enter all calibration values. Then click on Analysis.
12. For analyzing samples, Click on Task and Sequences, click on analysis, Type samples ID, and click on run.

NOTE 1: Aragon GAS (Purity 99.999 %) is required for the operation of ICP-OES
NOTE 2: Prepare you Calibration Standards "You don't have to make standards each time you running the ICP". If pervious standards still exist, it could be used for several months.

The second device that's been used is the Shimadzu Ion Chromatography (IC). The Ion chromatographs are able to measure concentrations of major anions, such as fluoride, chloride, nitrate, nitrite, and sulfate, as well as major cations such as lithium, sodium, ammonium, potassium, calcium, and magnesium in the parts-per-billion (ppb) range and Parts-per-million (ppm). Concentrations of organic acids can also be measured through ion chromatography **(**Monica, 2014). Figure (4) is a photograph of the Shimadzu High Performance Liquid Chromatography equipment used at the Environmental Analysis laboratory.

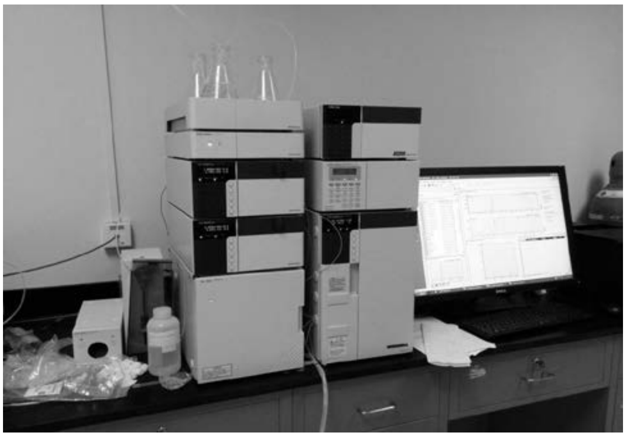

Fig. (4) Shimadzu Ion Chromatography.

Standard operation procedure for the Shimadzu High Performance Liquid Chromatography (SHPLC) equipment stresses on sample preparation (Anion is pump A and Cation for pump B) in accord with the following steps:

1. Prepare your standards
2. Check your mobile phase solutions (for an Ion you need to have 12mM NaHCO3+0.6 mM Na_2CO_3 which is 0.636 g of $NaHCO_3$+1.008g of Na2CO_3 in 500 ml and dilute with 1-20 of DIW).
3. CBM.20 connect the software with the detectors
4. CDD is Conductivity detector. Get Peaks
5. CTO-20hcsp: is Filter (suppressor system)
6. Very important: for cation remove the two cartridges and replace them with the two stopper.

Turn on the machine, each button.

A. Place injector and mobile phase tubes into right spot.
B. Click on shimadzu LC solution
C. Click on instrument 1 to connect to the software
D. Load the method and press download

Calibration and injecting samples:

1. for calibration: Patch processing, wizard, make sure You select standards only, select levels and # of standards0.1,2,3, and click on start patch.
2. For running sample, patch processing, wizard, select unknown sample, and click start patch with filling out all the information required to finalize the wizard.
   NOTE: you can enter your info manually without going out through the wizard
   If an error happened it might be of selecting the method, so please make sure you select sample rack L.

IV. RESULTS AND DISCUSSIONS

There are about 70 factories of bottled water in KSA. Each of these brands has physo-chemical properties labeled on side of bottle that may address the following parameters: pH, TDS, Ca, Mg, Na, K, Fe, HCO_3, SO_4, NO_3, Cl, F and BrO_3. Table (5) shows given concentrations of these elements as reported by the factories themselves.

Experiments were conducted on around 25 samples for each of the selected brands. Comparison was done for factory labels, experimental results with values that have been set by Saudi Arabian Standards Organization (SASO, 2009) and other international standards. Table (5) shows the major ions concentration and physical properties of bottled waters for brand names that included: Hayat, Tania, Farah, Al-Loulouah, Hana, Aquafina, Fayha, Safa, Mozn, Pure Life, Zulal, Al-Qassim, Dala, Arwa, Yanabea Alwadi, Faifa Mountain, Dome, Al Manhal, Hada, Nova, Shallal Water, Safia, Rafan, Al Ain, Haley, Aloyoun, Maeen, Mawared, Hilwa, Honey, Tamani Health Water, Nabah Alhada, ABC, Cloud Water, Hania, Al-Rai, Springs, Yanabi Hail, Juda, Najran, Sahtain, Oam, Sahatak, Naga Alshallal, Al Ryan, Shamous water, Al Salama, Sahat Malan, Donia, Alwadi, Al Ghadeer, Al Jazeera and AlShifa as reported by the factories.

Table (5) Major ions concentration and physical properties of bottled waters in Saudi Arabia

Brand code	Brand name	Capacity			mg/L (ppm)										
		(Liter)	pH	TDS	Ca	Mg	Na	K	Fe	HCO_3	SO_4	NO_3	Cl	F	BrO_3
1	Hayat	0.33	7.2	125	10.0	3.0	20.0	1.30	0.01	37.0	18.0	6.00	25.0	0.85	-
2	Tania	19	7.2	120	14.4	3.0	12.2	1.50	0.00	24.0	28.0	2.00	17.5	0.90	-
3	Farah	19	7.2	116	25.0	11.0	25.0	1.00	0.01	25.0	22.0	7.00	25.0	1.00	-
4	Al-Loulouah	19	7.1	125	10.0	2.4	18.0	1.40	-	30.0	11.8	3.10	25.0	1.00	-
5	Hana	0.60	7.2	127	8.0	3.0	18.0	2.00	-	28.0	36.0	25.00	32.0	0.85	-
6	Aquafina	0.60	7.0	110	<5	13.0	16.0	1.00	0.01	1.3	51.0	<0.10	27.5	1.00	-
7	Fayha	0.60	7.0	110	15.0	4.0	13.0	0.90	0.02	12.0	50.0	4.00	14.0	0.90	-
8	Safa	0.60	7.0-7.6	100-155	19.0	3.0	19.0	1.80	0.00	39.0	27.0	2.80	33.0	1.00	<0.01
9	Mozn	0.30	7.0-7.6	160 - 175	17.0	7.0	20.0	2.50	0.00	80.0	12.0	2.00	27.0	1.00	-
10	Pure Life	0.60	7.1	235	36.0	4.7	18.0	0.20	0.02	42.0	22.0	0.50	68.0	0.00	<0.01
11	Zulal	0.33	7.2	133	21.0	4.5	20.0	1.20	0.01	37.5	32.0	7.10	20.0	0.80	-
12	Al-Qassim	0.60	7.1	125	8.4	1.0	22.4	0.50	-	7.0	21.0	2.00	32.0	0.95	-
13	Dala	0.60	7.0-7.6	120-140	9.5	3.5	19.0	1.70	0.00	24.0	22.0	1.20	26.0	1.00	-
14	Arwa	0.50	6.7	120	0.3	22.0	1.4	0.40	<0.10	6.2	88.0	<0.10	<1	<1	-
15	Yanabea Alwadi	2	7.0-7.6	120-140	9.5	3.5	19.0	1.70	0.00	24.0	22.0	1.20	26.0	1.00	-
16	Faifa Mountain	0.60	7.0-7.8	100-150	18.0	6.0	22.0	2.00	-	70.0	15.0	5.00	25.0	1.00	-
17	Dome	19	7.2	110	14.0	4.0	13.0	1.20	0.00	28.0	29.0	11.00	15.0	0.91	-
18	Al Manhal	19	7.0	110	16.5	2.4	12.0	0.10	<0.02	30.0	13.0	<0.05	34.0	0.90	<0.01
19	Hada	0.33	7.2	109	13.0	4.0	20.0	0.80	0.00	30.0	20.0	5.00	30.0	0.80	-
20	Nova	0.33	7.0	120	10.0	4.5	16.8	1.10	-	20.0	35.0	3.10	17.0	0.80	-
21	1	0.33	7.2	127	8.0	3.0	18.0	2.00	-	28.0	36.0	2.50	32.0	0.85	-
22	Shallal Water	15	7.0	110	16.7	2.0	13.3	0.20	0.01	22.7	22.0	0.00	26.0	0.95	-
23	Safia	19	7.5	111	16.7	2.0	13.3	0.00	<0.01	22.7	4.0	6.00	34.6	0.80	-
24	Rafan	15	7.2	120	15.0	5.0	12.0	0.20	0.01	26.0	30.0	2.00	18.0	0.90	-
25	Al Ain	19	7.3	115	14.0	25.0	19.0	0.80	0.01	42.0	15.0	6.50	21.5	0.80	-
26	Haley	0.33	7.3	110	8.8	2.4	21.0	1.50	0.01	30.0	23.0	1.40	24.0	0.90	-
27	Aloyoun	0.60	7.0	110	15.0	5.0	19.0	0.20	0.02	50.0	50.0	0.10	15.0	0.80	-
28	Maeen	0.60	7.2	135	25.0	15.0	18.5	1.30	0.01	37.0	30.0	3.50	20.0	0.90	-
29	Mawared	0.33	7.2	120	14.4	3.0	12.3	1.50	0.00	24.0	28.0	2.00	17.5	0.90	<0.01
30	Hilwa	0.60	7.4	210	28.5	11.9	23.7	13.40	0.00	120.0	47.4	0.00	32.0	0.80	-
31	Honey	0.50	7.3	110	8.8	2.4	21.0	1.50	0.01	30.0	23.0	1.40	24.0	0.90	-
32	Tamani Health Water	0.33	7.2	123	21.2	4.5	20.0	1.20	0.01	37.5	32.0	7.10	20.0	0.80	-
33	Nabah	19	7.2	110	5.0	192	14.5	0.80	0.02	50.0	17.0	7.00	15.0	0.80	-

	Alhada														
34	ABC	0.33	7.2	105	15	10	<10	<0.10	-	26.0	0.0	<0.10	<56	-	
35	Cloud Water	0.25	7.7	120	8	2.91	23.2	1.60	0.01	23.0	21.0	2.00	22.0	0.80	-
36	Hania	5	7.3	105	14	2.0	14	0.25	0.01	34.0	8.0	3.00	24.0	1.10	-
37	Al-Rai	19	7.2	110	14.5	5.0	19.2	0.84	0.00	50.0	17.0	7.00	15.0	0.80	-
38	Springs	19	7.0	110	15.0	3.0	17	0.70	0.03	40.0	12.0	1.00	30.0	0.85	<0.01
39	Yanabi Hail	15	7.3	120	12.0	2.7	21	1.90	0.01	28.8	18.0	5.50	16.0	0.90	-
40	Juda	0.33	7.2	105	15.0	10.0	<10	<0.10	-	26.0	0.0	<0.10	<56	-	
41	Najran	0.60	7.4	120	19.0	3.5	18	1.50	-	33.5	27.0	3.20	13.5	0.80	-
42	Sahtain	0.65	7.0	110	6.0	1.0	20	1	0	13.0	15.0	12.00	30.0	0.75	-
43	Oam	5	7.0	120-150	14.4	3.4	18.5	1.20	0.01	38.0	37.0	1.90	12.8	0.83	-
44	Sahatak	0.25	7.4	120	40.0	12.0	20	2	0.10	55.0	20.0	4.00	20.0	0.85	-
45	Naga Alshallal	2	7.3	125	14.0	2.5	19	0.80	0.01	42.0	15.0	6.50	21.5	0.80	-
46	Al Ryan	15	7.2	110	15.0	5.0	12	0.20	0.02	50.0	50.0	0.10	15.0	0.70	-
47	Shamous water	16	7.2	120	14.4	3.0	12.3	1.50	0	24.0	28.0	2.00	17.5	0.90	-
48	Al Salama	19	7.2	110	20.0	0.01	19	3.50	0.01	35.0	25.0	7.10	28.0	0.70	-
49	Sahat Malan	0.33	6.8-7.4	105-120	8-12	1.4-3.1	25-35	0.80-1.20	-	15-30	20-36	3-4.5	25-45	0.80-1.20	-
50	Donia	20	7.2	100-120	6.7	1.6	19.5	0.20	-	7.3	273	22.00	20.8	0.60	-
51	Alwadi	0.65	7.5	116	2.4	0.5	24.6	0.80	0.02	40.0	12.0	5.00	30.0	0.75	-
52	Al Ghadeer	50	7.1	110	18.0	3.0	14	0.20 0.02	20.0	14.0	0.05	35.0	0.90	<0.01	52
53	Al Jazeera	0.33	73	100	11	4	20	1.600	17	2	1	45	0.80	<0.02	53
54	AlShifa	1.50	7.0	110	2	0.9	35	2 -	30	6	3.55	30	0.95	<0.01	54

Parameter	Water brands	SASO (2009)	1BWA (2004)	FDA (2002)	WHO (2008)

Table (6) shows quality of tested bottled drinking water in KSA factories tested in the environmental engineering laboratory of UoD as compared to local and international standards.

Table (6) quality of tested bottled drinking water in KSA as compared to the local and international standards

SASO: Saudi Arabian Standards Organization; IBWA: International Bottled Water Association; FDA: Food and Drug Administration; WHO: World Health Organization

Parameter	Water brands	SASO (2009)	1BWA (2004)	FDA (2002)	WHO (2008)
pH	7-8	6.30-8.30	6.50-8.50		6.5-8.5
TDS (mg/L)	100-235	100-500	500	500	1000
Ca mg/L)	030-40	200	-	-	100
Mg (mg/L)	0.01-25	150	-	-	50
Na (mg/L)	1.40-35	100	-	-	200
K Olga)	0-13A0	-	-	-	12
HCO3 mg/L)	130-120	-	-	-	125-350
Sat (mg/L)	0-88	150	250	250	250
NO3 (mg/I1)	0-25	50	44	44	50
Cl (mg/L)	<1-68	150	250	250	250
TH (mg/L)	15-110	200	-	-	500
F (mg/L)	0-120	02-150	020-130	0.80-140	13
BrO3 (mg/L)	<0.01- <0.02	0.01	0.01	0.01	-
Fe (mg/L)	0-0.03	30	30	0.30	3

Brand code	Water type	Total hardness	Water hardness type
1	Na-Ca-HCO3-C1	37	Soft
2	Ca-Na-SO4-HCO3	40	Soft
3	Ca-Na-HCO3-C1	45	Soft
4	Na-Ca-HCO3-C1	-	-
5	Na-Ca-SO4-C1	-	-
6	-	53	Moderately hard
7	Ca-Na-SO4	55	Moderately hard
8	Ca-Na-HCO3-C1-SO4	60	Moderately hard
9	Na-Ca-HCO3-C1	-	-
10	Ca-Na-C1-HCO3	110	Hard
11	Ca-Na-HCO3-SO4	80	Moderately hard
12	Na-Ca-C1-Sa4	-	-
13	Na-Ca-C1-HCO3-SO4	36	Soft
14	-	-	-
15	Na-Ca-C1-HCO3-SO4	36	Soft
16	Na-Ca-HCO3	-	-
17	Ca-Na-SO4-HCO3	52	Moderately hard
18	-	52	Moderately hard
19	Na-Ca-C1-HCO3	-	-
20	Na-Ca-SO4-HCO3	4354	Soft
21	Na-Ca-SO4-C1-HCO3	-	-
22	Ca-Na-C1-HCO3-SO4	49	Soft
23	Ca-Na-C1-HCO3	49	Soft
24	Ca-Na-SO4-HCO3	50	Moderately hard

25	Mg-Na-HCO3-C1	-	-
26	Na-Ca-HCO3-C1-SO4	32	Soft
27	Na-Ca-SO4-HCO3	50	Moderately hard
28	Ca-Na-Mg-HCO3-SO4	40	Soft
29	Ca-Na-SO4-HCO3	40	Soft
30	Ca-Na-HCO3	-	-
31	Na-Ca-HC S -C1-S0	32	Soft
32	Ca-Na-HCO3-SO4	80	Moderately hard
33	Mg-Na-HCO3	50	Moderately hard
34	-	-	-
35	Na-HCO3-C1-SO4	40	Soft
36	Na-Ca-HCO3-C1	-	-
37	Na-Ca-HCO3	50	Moderately hard
38	Ca-Na-HCO3	45	Soft
39	Ca-HCO3-504	-	-
40	Na-Ca-HCO3-C1	-	-
41	Na-Ca-HCO3	58	Moderately hard
42	Ca-Na-HCO3-504	18	Soft
43	Na-C1	50	Moderately hard
44	Na-Ca-HCO3-504	65	Moderately hard
45	Ca-Na-HCO3	-	-
46	Na-Ca-HCO3-C1	50	Moderately hard
47	Ca-Na-HCO3-504	40	Soft
48	Na-Ca-HCO3-C1	-	-
49	Ca-Na-SO4-HCO3	25-40	Soft
50	Ca-Na-HCO3-C1-504	22.5	Soft
51	-	-	-
52	Na-504-NO3-C1	57	Moderately hard
53	Na-HCO3-C1	15	Soft
54	Ca-Na-C1-HCO3	-	-

Table (7) offers a classification of bottled drinking water brands based on total hardness values.

The range of labelled measures of bottled water by concerned factories is meeting the local and international standards. Nonetheless, this finding deserves further checking and confirmation. As such, tests were conducted for bottled water at the laboratory of the Environmental Engineering Department. Random samples were taken for different brands to measure the elements and determine whether they match with the value labelled for each brand given by factory label. Table 8 shows the concentration of 23 brands of bottled water factories in KSA chosen randomly. Tests measured the concentration of ferric/ iron (Fe), calcium (Ca), magnesium (Mg), chloride (Cl^-), sulfate (SO_4^{-2}) and nitrate (NO_3^-) in ppm by two devices. The first one is inductively coupled plasma optical emission spectroscopy which measures (Fe, Mg and Ca). The second device is the Shimadzu Ion Chromatography which measures (Cl^-, SO_4^{-2} and NO_3^-).

The first device (ICP-OES is used to measures trace metals such as, Fe, Mg, Ca, Na and K, but due to availability of standards, it is only used to measure the first three elements. Multi-Standards are prepared with variety of concentrations of -, 15 ppm, 25 ppm and 50 ppm with a result of linear calibration. The 23 samples were analyzed based on the linear calibration.

The second device Shimadzu Ion Chromatography (IC) is used to measure anions such as (Cl^-, SO_4^{-2} and NO_3^-). The Four different standard levels were prepared by dividing the molar mass of NaCL (58.5 g/mol) by the molar mass of Cl

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35.5 to give up a mass of 1.65 g of Cl^-. The second standard is prepared by dividing the molar mass of $NaNO_3$ (84 g/mol) by the molar mass of NO_3 which is 62 g/mol to go give up mass of 1.37 g. The last standard is prepared by dividing the molar mass of Na_2So_4 (142 g/mol) - by the molar mass of SO_4 (96 g/mol) to give up a mass of 1.48 g. The mass were dissolved in one liter of deionized water to make 1000 ppm solution, and then diluted to (15 ppm, 25 ppm, 50 ppm and 100 ppm. These two devices measured the results shown in table (8) for 23 brands of bottled water factories with an accurate calibration method been used.

Table (8) Measured major ions concentration in the laboratory of bottled waters in Saudi Arabia

Brand number	Brand name	Concentration in mg\l (ppm)					
		Fe	Mg	Ca	Cl^-	So_4^{-2}	No_3^-
1	Tamimi Market	0	0	2.84	24.088	15.520	2.708
2	Berain	0	1.99	41.51	75.710	14.888	1.535
3	Almanhal	0	.31	17.50	28.032	8.064	0
4	Aqua prime	0	0	2.18	40.469	9.213	1.214
5	Nova	0	1.69	11.20	17.301	28.263	3.758
6	Fayha	0	1.82	8.38	16.021	52.089	2.954
7	Taiba	0	0	0	54.585	1.747	42.772
8	Afnan	0	.50	7.34	38.897	21.456	17.121
9	Aljazeerah	0	0	0	44.649	0	0.864
10	Abar	0	2.90	13.12	15.797	34.762	3.121
11	Panda	0	0	2.98	25.973	17.477	3.790
12	Alwadi	0	0	0	31.412	1.136	27.566
13	Mozn	0	1.61	8.05	19.655	5.061	4.202
14	Pure aqua	0	0	13.92	36.025	0.628	0
15	Arwa	0	23.08	0	0	0	0
16	Nestle	0	3.27	44.37	74.354	17.631	0
17	Moya	0	0	7.79	20.961	5.838	1.110
18	Honey	0	2.20	11.38	16.406	30.670	2.998
19	Aqua gulf	0	0	0	13.648	1.214	0.642
20	Alshifa	0	0	2.49	36.151	14.173	3.163
21	Alqassim	0	0	14.10	36.478	24.785	16.747
22	Hana	0	.50	5.41	34.560	25.621	4.038
23	Makkah	0	0	16.66	28.152	5.429	0

Table (9) shows the result from Environmental laboratory with the actual result that's showing in the side of the bottled water to compare them and to get the percent of mismatch.

Table (9) Measured and actual concentration with percent of mismatch.

Brand number	Brand name	mg/L (ppm) (actual concentration)					
		Fe	Mg	Ca	Cl^-	SO_4^{-2}	NO_3^-
1	Hana	-	3	8	32	36	25
2	Fayha	0.02	4	15	14	50	4
3	Mozn	0	7	17	27	12	2
4	Nestele	0.02	4.7	36	68	22	0.5
5	Al-Qassim	-	1	8.4	32	21	2
6	Arwa	<0.10	22	0.3	<1	88	<0.10
7	Al Manhal	<0.02	2.4	16.5	34	13	<0.05
8	Nova	-	4.5	10	17	35	3.1
9	Honey	0.01	2.4	8.8	24	23	1.4
10	Alwadi	0.02	0.5	2.4	30	12	5
11	Al	17	4	11	0.8	1	45

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	Jazeera						
12	AlShifa	30	0.9	2	0.95	3.55	30
mg/l (ppm) measurements in lab concentration							
1	Hana	0	0.5	5.41	35	26	4
2	Fayha	0	2	8	16	52	3
3	Mozn	0	2	8	20	5	4
4	Nestele	0	3	44	74	18	0
5	Al-Qassim	0	0	14.1	36	25	17
6	Arwa	0	23	0	0	0	0
7	Al Manhal	0	0.3	17	28	8	0
8	Nova	0	2	11	17	283	4
9	Honey	0	2.2	12	16	31	3
10	Alwadi	0	0	0	31	1	28
11	Al Jazeera	0	0	0	45	0	1
12	AlShifa	0	0	3	36	14	3
Percent of mismatch (%)							
1	Hana	-	83	32	8	29	84
2	Fayha	-	55	44	14	42	26
3	Mozn	-	77	53	27	58	110
4	Nestele	-	30	23	9	20	100
5	Al-Qassim	-	100	68	14	18	737.35
6	Arwa	-	5	100	-	-	-
7	Al Manhal	-	87	6	18	38	-
8	Nova	-	62	12	2	19	21
9	Honey	-	8	29	32	33	-
10	Alwadi	-	100	100	5	91	-
11	Al Jazeera	-	100	100	-	-	98
12	AlShifa		100	25	-	-	89

Some of the brands conform to set standards while others do not. There are different reasons that can be attributed to both factories and laboratory tests as justified by calculated experimental percent of error. Factories don't apply what they produced to the market. The concentration in some brands higher than the ones that have been measured in the laboratory. This could be due to several factors such as transportation of product itself since water industry relies on various types of transporters to deliver their raw materials and product from plants to sales domains. During this period, the bottled water would be exposed to different temperatures that reach 52 degree Celsius, especially in the Gulf region. Some samples have earlier production date which affects quality of course. Others were left under the sun too long. There are several factors that influence quality of samples chosen from the market and not directly from factory. Laboratory results differed from labeled values for a range of products. Nonetheless, results neither across local nor international standards of bottled water quality. Yet this difference in results calls into questioning the credibility of the company to the costumers and public. Overall results are within the range of the international standards.

V. CONCLUSION AND RECOMMENDATIONS FOR FURTHER STUDY

The following conclusions emerged from this research work:

- Most bottled waters from KSA factories appear to be safe as per conducted tests at the laboratory. The majority proved to be of high quality and relatively free of contaminants.
- The quality of some brands was spotty, however, and such products may pose a health risk, primarily for people with weakened immune systems (such as the frail elderly, some infants, transplant and cancer patients, etc.) for chemical contaminants at levels above strict state health limits. If consumed over a long period of time, some of these contaminants could cause cancer or other health problems.
- The results of the analysis of the environmental laboratory of bottled water in Saudi Arabia for the various parameters of water quality were compared with drinking water standards set by the various regulatory bodies. Levels of different physical parameters such as pH, total dissolved solids (TDS), calcium, magnesium, sodium, potassium, NO_3, chlorine, and SO_4 have been registered disparity for some bottled water.
- Choice of the factories is based on familiarity and reliability among the society, which was gained during many years of operation. This research clarified the importance of water components and water quality indices that are measurable rather than the history and reputation of companies.
- It is important to keep bottled water away from sources of heat and out of bright light.
- It is recommended to wash bottle under a running facet before drinking. This is important to wash out any surface contamination that may have resulted during handling since it left the factory.

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