Sudan University of Science and Technology

Faculty of Agricultural Studies

Department of Food Science and Technology

Comparison study of some bottled water with their label content according to WHO and SSMO standards

دراسة مقارنة لبعض ماركات المياه المعبأة بمجتويات الديباجة وفقا لمعايير منظمة الصحة العالمية وهيئة المواصفات والمقاييس السودانية

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بِسۡمِ ٱللَّهِ ٱلرَّحۡمَٰنِ ٱلرَّحِيمِ

قال تعالى:

{ أَوَلَمْ يَرَ الَّذِينَ كَفَرُوا أَنَّ السَّمَاوَاتِ وَالْأَرْضَ كَانَتَا رَتْقًا فَفَتَقْنَاهُمَا ۖ وَجَعَلْنَا مِنَ الْمَاءِ كُلَّ شَيْءٍ حَيٍّ ۖ أَفَلَا يُؤْمِنُونَ }

سورة الأنبياء الآية (30)

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Abstract

Three different brands of locally produces bottled drinking water, collected from different retail shops in Khartoum, were analyzed for different chemical parameters to verify the accuracy of their label contents and to ascertain their compatibility with recommended levels by WHO and SSMO. It was found that all under investigation brands chemical composition didn't match with their label values. Nitrate and chloride were found to be much lower than the recommended levels. pH, nitrite and sodium were found to be in the recommended range, while TDS level was found to be higher than the recommended level. For all brands Fluoride levels was fount be lower than the recommended levels. A closer look at the chemical properties of the water has led to the conclusion that though bottled water is regarded as safe and healthy, they should be consumed with care especially if bottled water is the sole source of water used for drinking purposes.

الملخص

تم تحليل ثلاث ماركات مختلفة من مياه الشرب المعبأة المنتجة محليا ، والتي تم جمعها من محلات البيع بالتجزئة المختلفة في الخرطوم، تم تحليلها كيميائيا للتحقق من دقة محتوياتها والتأكد من توافقها مع الديباجة الخاصة بها و المستويات الموصى بها من قبل منظمة الصحة العالمية و هيئة المواصفات والمقاييس السودانية . وقد تبين أن جميع العينات لم تطابق محتوياتها من العناصر الكيميائة المختلفة القيم المذكوري في الديباحة الخاصة بكل منتج. وقد وجد أن NO^{-3} و Cl أقل بكثير من المستويات الموصى بها. وقد وجد أن pH و NO^{-2} و Na في النطاق الموصى به في حين وجد أن مستوى TDS أعلى من المستوى الموصى به. محتوي حميع العينات من الـ F كان أقل من المستويات الموصى بها. ولذلك على الرغم من أن المياه المعبأة تعتبر آمنة و صحية، إلا أنه لا يمكن اعتمادها كمصدر وحيد لمياه الشرب.

CHAPTER ONE

1 INTRODUCTION

Water is indispensable and irreplaceable for life, but water contamination with disease- causing organisms can be just as deadly as to water at all **(Sharp 1984).**

The universal solvent as they call it.is absolutely, essential for all forms of life not only for human life but also for animals and vegetation. Indeed it is a part of life itself, since the protoplasm of most living cells contains about 80 percent water, and only substantial reduction in this amount occurs during the metabolism and growth of living cells. the lack of satisfactory drinking water is a major problem for a significant proportion of the global population, resulting in the spread of water borne diseases are major contributors to morbidity and which mortality in developing countries, resulting in up to 6 million deaths per year **(Thielman and Geurrant 1996).**

In Khartoum state drinking and general purpose water is supplied by surface water, and wells of ground water In many regions depend upon the ground water do not subjected to any type of treatment even chlorination.

Considerable proportion of people in Khartoum Sate consumes bottled drinking water (mineral water), recent years, consumption of bottled drinking water rate increased. This associated with spread of factories that producing bottled drinking water and soft drinks. With this increase in numbers of manufactures and diversity in facilities, equipment and effectiveness of their quality control it was important to check the accuracy and reliability of their label contents. Therefore, the objective of the present investigation was carried out in attempt to study the Accuracy of bottled drinking water label content in Khartoum state at different locations during a period between June-2017 to septemper-2017 with sub objective of comparing the results with the WHO standards for bottled drinking water.

Objectives

To compare and verify the label content of some bottled water of different water plants in Sudan with World Health Organization (WHO) and Sudanese Standard and Metrology Organization (SSMO) standards for bottled drinking water.

CHAPTER TWO

2 LITERATURE REVIEW

2.1 Importance of water

Water is the most abundant natural resource. it is responsible for sustaining life of our planet it plays central role in the economic and social activities of man .

It is very essential for development of irrigated agriculture industry and hydroelectric power it is not only essential for human life, but also for animal and plant lives as well.

All the reaction that happen into the body cells of man, animal and plant cannot go on without water those living cells contain about 80% of water.

Water is the most abundant compound in the body , it is necessary for the digestion and transport of food to the tissues , for the elimination of body wastes for the circulation of body fluids like blood and lymph ,for a lubricant in the joins and internal organs and for the regulation of body temperature Water is part of the blood system holding dissolved minerals like calcium and magnesium in solution making them available to body tissue where they are required for proper health **(FDW,2008).**

2.2 Physical characteristics of water

2.2.1 Colour

The colour of drinking water is usually due to the presence of coloured organic matter associated with human, fraction of soil. Colour is strongly influenced by the presence of iron and other metal either as natural impurities or as corrosion products. It may also result from the water source with industrial effluents and maybe the first indication of hazardous situation. Colour bellow

15TCU (true colour units) is usually acceptable to consumers, but acceptability may vary according to local circumstances **(WHO, 2011)**.

2.2.2 Taste and Odour

Taste and odour originate from natural and biological sources (e.g. aquatic microorganisms) or processing from contamination by chemicals or by product of water treatment (e.g. chlorination). Taste and odour in drinking water may be indicative of some forms of pollution or of malfunction during water treatment. The taste and odour should not be offensive to the consumer (**WHO, 2011).**

2.2.3 Turbidity

Turbidity in drinking water is caused by the presence of in organic particular matter in some ground waters; high level of turbidity can protect microorganisms from the effect of disinfection and can stimulate bacterial growth. The appearance of water with a turbidity less than 5NTU (Nephleometric turbidity unit) is usually acceptable to consumers **(WHO, 2011).**

Higher turbidity levels are often associated with high levels of disease-causing microorganisms such as viruses, parasites and some bacteria **(EPA,2001)**

2.2.4 Electrical Conductivity

Conductivity or specific conductance is measure of the ability of water to conduct an electric current. It is sensitive to variation in dissolved solids, mostly mineral salts **(Hussein, 2002).**

Table 1 Physical standards of drinking water of Sudanese Standard and Metrology Organization SSMO (2002) and WHO (2011).

Parameters	SSMO(2002)	WHO(2011)
Colour	15 TCU	15 TCU
Taste and odour	Acceptable	3 t.o.n
Turbidity	5 NTU	4 NTU
Electrical conductivity	1600 micromohs/cm	1600 micromohs/cm

2.3 Chemical Characteristics

2.3.1 pH

pH number is an expression of the concentration of H+ ion in the solution. pH less than 6.5 or greater than 9.2 would markedly impair the portability of the water **(WHO Guidelines 2006)**. pH lower than 4 will produce sour taste and higher value above 8.5 bitter taste. pH below 6.5 starts corrosion in pipes, thereby releasing toxic metals such as Zn, Pb, Ct, Cu etc. **(Chemical analysis of drinking water 2003).**

2.3.2 Total Dissolved Solids (TDS)

TDS comprise inorganic salts (principally calcium, magnesium, potassium, sodium, bicarbonates, chlorides, and sulfates) and small amounts of organic matter that are dissolved in water. Health effects associated with the ingestion of TDS in drinking water are not available, and no health-based guideline value is proposed. However, a guideline value of 1,000 mg/l was established, based on taste considerations. Water with extremely low concentrations of TDS may also be unacceptable because of its flat, insipid taste **(WHO 2011).**

2.3.3 Calcium and Magnesium

The WHO limits hardness for drinking water between 100 – 500 mg/l. Hardness of water which is due to the presence of calcium and magnesium salts in water, does contribute towards total calcium and magnesium human dietary needs, which has a beneficial effect on bone structure **(Chiarenzelli and Pominville 2008).** Studies on water hardness and cardiovascular disease mortality have suggested a lower incidence of heart disease in communities drinking hard water. Extremely hard water (hardness4500 mg/l) is also unfit for consumption because the constituent minerals such as calcium can deposit inside the body if present in high amounts leading to kidney or gall bladder stones **(Garzon & Eisenberg 1998).** Consumption of very soft water (less than 50 mg/l) lacking in essential minerals like calcium, magnesium and other trace minerals is also harmful for the body because water low in mineral content would rob off the body's minerals **(Consumer Research 1991).** People drinking such treated water excrete huge amounts of calcium, magnesium and other trace minerals in urine (Consumer Research 1991). The more the mineral loss, the greater the risk for osteoporosis, osteoarthritis, hypothyroidism, coronary artery disease, high blood pressure and a long list of degenerative diseases generally associated with premature aging. Also, cooking food in soft water pulls the minerals out of them and lowers their natural value.

2.3.4 Sodium and Potassium

Sodium and potassium both are very important for human body and regulate the water balance and the acid base balance in the blood and tissue **(Beers & Berkow 1997).**

The major intracellular cation is potassium, with an average concentration of 140m Eq/l. The extracellular potassium concentration, though very important and tightly regulated, is much lower, at 3.5 – 5m Eq/l. The major extra-cellular cation is sodium; with an average concentration of 140m Eq/l. Intracellular concentration sodium concentration is much lower at about 12m Eq/l. These differences are maintained by the Na+, K+ -ATPase ion pump located in the cell membranes of virtually all the cells (McCarron no date). Sodium and potassium both are essential nutrients and The Food and Nutrition Board of the National Research Council of America recommends that sodium intake be limited to no more than 2400mg per day **(Beers & Berkow 1997).** The Committee on Dietary Allowances recommends 1875 – 5625 mg per day of potassium in order to maintain adequate and safe levels of potassium balance **(McCarron).** Sodium in drinking water is not a health concern for most people because in healthy people, excess sodium is eliminated through the kidneys and the correct balance of sodium and water is maintained. But for people with heart disease, hypertension, kidney disease and circulatory illness or on a sodium-controlled diet, it may be an issue of health concern because of their inability to maintain the required body balance of sodium **(Beers & Berkow 1997).** The WHO and United States Environmental Protection Agency (USEPA) have restricted people with hypertension or those on sodium-restricted diet to drink water with sodium content not more than 20 mg/l. Those on moderately restricted diet should not drink water containing more than 270mg/l of sodium **(Canadian Water Quality Guidelines 1987).**

There is no fixed health guidelines for the amount of potassium present in water that would be considered safe by the WHO. Drinking water is not the major dietary source of potassium, and the concentration in water seldom reaches 10 mg/l **(McCarron**). However United States Environmental Protection Agency (USEPA) has set a maximum level of 100 mg/l. In people on low potassium diets, strokes, high blood pressure, and diabetes occur more frequently than in those who consume sufficient or high potassium diets. Low potassium may impair glucose metabolism and lead to elevated blood sugar. Research has found that a high sodium diet with low potassium intake influences vascular volume and tends to elevate the blood pressure **(McCarron).**

2.3.5 Fluoride (F)

WHO recommends that the appropriate level of F in the drinking water should range from 0.6–0.8 ppm for annual average of maximum daily temperature of 26.3–32.6◦C to 0.9–1.7 ppm for temperature of 10–12◦C **(WHO Guidelines 2006).** However, the recommended level for tropical countries like Sudan, where the maximum temperature goes above 45◦C during summer season, should be in the range of0.6–0.7 ppm **(Akpata et al. 1997; Galgan and Vermillion 1957).** Presence of large amount of F is associated with dental and skeletal fluorosis (>1.5 ppm) and inadequate amounts with the dental caries (<0.6 ppm). Furthermore, the concentration of F between 0.9–1.2 ppm may give mild dental fluorosis **(WHO Guidelines 2006).**

Table 2 Chemical standards of drinking water of Sudanese Standard and Metrology Organization SSMO (2002) and WHO (2011).

Parameters	SSMO(2002)	WHO(2011)
Ph	6.5-8.5	6.5-8.5
Total dissolved solids	100mg/L	100mg/L
Antimony	0.004mg/L	0.005 mg/L
Arsenic	0.007 mg/L	0.01 mg/L
Barium	0.2 mg/L	0.7 mg/L
Boron	0.5 mg/L	2.4 mg/L
Cadmium	0.003 mg/L	0.003 mg/L
Chromium	0.04 mg/L	0.05 mg/L
Copper	1.50 mg/L	2.0 mg/L
Cyanide	0.05 mg/L	0.05 mg/L
Fluoride	1.50 mg/L	1.5 mg/L
Lead	0.007 mg/L	0.01 mg/L
Manganese	0.50 mg/L	0.04 mg/L
Mercury(total)	0.0007 mg/L	0.0006 mg/L
Molybdenum	0.05 mg/L	0.07 mg/L
Nickel	0.014 mg/L	0.07 mg/L
Nitrate NO^{-3}	45-50 mg/L	50 mg/L
Nitrite NO^{-2}	2.0-10.0 mg/L	3 mg/L
Selenium	0.07 mg/L	0.04 mg/L
Aluminum	0.2 mg/L	0.1-0.2 mg/L
Ammonia	1.5 mg/L	1.5 mg/L
Chloride	250 mg/L	250 mg/L
Residual chloride	0.2 mg/L	0.2 mg/L
Hydrogen sulfide	0.05 mg/L	0.05-0.1 mg/L
Iron	0.30 mg/L	0.30 mg/L
Sodium	20 mg/L	50 mg/L
Zinc	3.0 mg/L	3.5 mg/L
Total alkalinity	100-500 mg/L	500 mg/L

2.4 Water Quality Concept

Water quality is defined in followings:

- Water that is free from pathogens.Fairly clear.
- Free of any constituents that change colour, taste and odour.
- Free of any chemical substances or radioactive ones that harm human, plant or animals.

The nature of water environment needs to be defined in relation to the use for which the water is required drinking water therefore concerns both quantity and quality of the water required to meet the needs of man in efficient and economical matter **(Ciacio and Cardenas, 1973).**

2.4.1 Drinking Water

Safe drinking water is to be clear, colourless, for agreeable taste. It contains only small amount of minerals and a maximum of 0.15 gm/liter lime salts. It should be free of ammonium nitrate, organic pollutants, and toxic substances such as lead salts and arsenic, as well as poisonous gases. It is totally free of parasites, ova and larva, as well as disease-causing germs. It may contain not more than 10 to 100 nonpathogenic germs per one cubic centimeter. Polluted water is that contain inorganic chemical, organic matter resulting from degeneration process, or disease-causing germs or parasites, polluted water is often turbid, with particularly unpleasant odour and taste. However it may remain colourless while containing large number of pathogenic germs, these require special methods of detection. **(WWD, 2001).**

2.5 Bottled water

2.5.1 about bottled waters

"Bottled Water" means water that is intended for human consumption and that is sealed in bottles or other containers with no added ingredients except that it may optionally contain safe and suitable antimicrobial agents**. (IBWA, 2012)** When sold in groceries or supermarkets, bottled waters all look like the same. However, there are important differences: all bottles don't contain the same product. There is very little in common between natural mineral water and purified water, as the chemical compositions or the treatments these waters can undergo respond to very different criteria that can change from one country to another. In some cases bottled water is merely bottled tap water.

2.5.2 Major types of bottled water

Three major types of bottled water can be identified: natural mineral water, spring water and purified water.

2.5.2.1 Natural mineral water

Natural mineral water corresponds, in the European Union, to an extremely specific product that must meet certain criteria. It is "microbiologically wholesome water, originating in an underground water table or deposit and emerging from a spring tapped at one or more natural or bore exits"1. Natural mineral water, whether still or aerated, is very different from other types of bottled water, because of:

- Its nature, characterized by a constant level of minerals and trace elements. Natural mineral water is particularly wholesome and can have health-benefiting effects.
- Its original state, preserved intact because of the underground origin of the water, which has been protected from all risks of pollution.

Natural mineral water has to be recognized as such by a responsible authority in EU member states 2, assessing their characteristics from geological, hydrological, Physical, chemical and microbiological points of view. If necessary, pharmacological, physiological and clinical tests can be conducted. Natural mineral waters are not sterile water and can contain natural microflora. It is a raw product that cannot be treated, i.e. disinfected, nor have any exogenous element such as additives or flavours put into it3. However, some exceptions are admitted, as long as they do not alter the composition of the water, in particular:

- The separation of unstable elements, such as iron and sulphur compounds.
- The separation of undesirable constituents, such as manganese or arsenic.
- The total or partial elimination of free carbon dioxide by exclusively physical methods.

In United States, the definition for natural mineral bottled water is far less restrictive. According to the International Bottled Water Association **(IBWA),** this sort of water should not contain less than 250 parts per million (ppm) total dissolved solids. The water should come from a source tapped at one or more bore-holes or springs, originating from a geographically and physically protected underground water source. Mineral water is distinguished from other types of bottled water by its constant level and relative proportions of mineral and trace elements at the point of emergence from the source, taking into account the fluctuations of natural flows. No minerals can be added to this product. **(IBWA).**

2.5.2.2 Spring water

Spring water is underground water, protected against pollution hazards, microbiologically safe, suitable for human consumption without any additional treatment, except those authorized such as aeration (Ferrier, 2011). In Europe, spring water is different from natural mineral water as it must stick to the same standards applicable to drinking water. It doesn't need to have a constant mineral composition. The consumption of this type of water is increasing, as it is generally cheaper than natural mineral water. In United Sates, the IBWA understands spring water as "water derived from an underground formation from which water flows naturally to the surface of the earth". Spring water must be collected only at the spring or through a bore hole tapping the underground formation finding the spring. Spring water collected with the use of an external force must be from the same underground stratum as the spring and must have all the physical properties, before treatment, and be of the same composition and quality as the water that flows naturally to the surface of the earth **(IBWA, 2012).**

2.5.2.3 Purified water or drinking water

Purified water or drinking water is water taken from rivers, lakes or underground springs that has undergone some form of treatment. It can be produced by "distillation, deionization, reverse osmosis or other suitable processes" **(IBWA, 2012).** It can be chemically treated in order to have some components disappear. Waters with different components can be mixed. Considering the way it is produced, there is little difference between purified water and municipal tap water, except in the distribution method and retail price. Some companies also market enriched water, i.e. purified water that was added some minerals: this is the case; Purified water is actually a manufactured product.

2.5.3 Additional types of bottled water

The International Bottled Water Association considers four additional categories of bottled waters (**IBWA, 2012).**

2.5.3.1 Artesian water / artesian well water is bottled water from a well that taps a confined aquifer (a water-bearing underground layer of rock or sand) in which the water level stands at some height above the top of the aquifer.

2.5.3.2 Drinking water is water that is sold for human consumption in sanitary containers and contains no added sweeteners or chemical additives (other than flavours, extracts or essences). It must be calorie-free and sugar-free. Flavours, extracts or essences may be added to drinking water comprising less than one-percent-by-weight of the final product or the product will be considered a soft drink. Drinking water may be sodium-free or contain very low amounts of sodium.

2.5.3.3 Sparkling water is water that after treatment and possible replacement with carbon dioxide contains the same amount of carbon dioxide that it had at emergence from the source.

2.5.3.4 Well water is bottled water from a hole bored, drilled or otherwise constructed in the ground which taps the water of an aquifer. If these waters contain the minimum required mineral content according to US standards, they can be called "mineral waters". So many different categories of bottled water, changing from one country to another, are not easy for consumers to differentiate. In addition, bottled water brands do not ease the identification of the product, often showing misleading images on their bottles' labels, such as lakes and mountains when the water actually comes from municipal networks **(IBWA, 2012)**.

2.5.4 Multiple packaging

Packaging used for water can have very different shapes and colours and are made of different materials. For a long time, bottled water was only available in glass, a very good but heavy material. At the end of the 1960s, bottlers started to use packaging made of PVC (vinyl polychlorure). In the 1980s, a new kind of plastic started being used: PET (polyethylene terephtalate). PET is progressively replacing PVC because of its numerous advantages.

2.5.5 The bottled water industry

Bottled water is the fastest-growing beverage category in the world: it “has expanded from a tap water substitute into the beverage arena**” (Lenzner, 1997).** The bottled water industry is extremely prosperous, involving companies with different histories and approaches to water. Which are the major companies and brands in this sector? What are main trends of the bottled water market?

2.5.6 Bottled Water Companies

Bottled water is a booming and very competitive market involving numerous companies: in 1992 in the United States, there were 700 brands of bottled water produced by 430 bottling facilities **(Olson, 1999).** Although bottled water is a world market, with companies present world-wide, 75% of it is still controlled by local actors. Three major types of bottled water companies compete on this market:

2.5.6.1 Private Companies

Companies that were created to run and market one specific brand of bottled water, for instance Perrier or Evian. Some of them are century-old and family-owned, but most of them have grouped or are now under control of major multinational food companies,

2.5.6.2 Sodas or soft drinks companies

Sodas or soft drinks companies now turn to the very profitable bottled water market. Coca-Cola and PepsiCo, for example, take advantage of their large world-wide network of bottlers which provides them with immediate access to the markets. To purified and aerated water used to make sodas is added a concentrated solution of minerals and sold as purified, enriched water, on the same principle as Coca-Cola and Pepsi. Like for colas, benefits for the company come from the sale of mineral concentrates to local bottlers.

2.5.6.3 Companies providing tap water

Companies providing tap water, with extensive know-how in water purification and pipe distribution now turn to a more lucrative way of distributing water. They now develop water services, such as home and office deliveries of water carboys.

Table 3 Chemical composition of locally produced bottled drinking water as shown in their labels

Parameters	Brand A	Brand B	Brand C
pH	7.5	7-8	8.00 mg/L
TDS	100 mg/L	130-180 mg/L	140 mg/L
Sulphate	3 mg/L	5-25 mg/L	13.00 mg/L
Chloride	4.8 mg/L	20-35 mg/L	15.00 mg/L
Fluoride	0.1 mg/L	0.03-0.1 mg/L	0.36 mg/L
Nitrite	<0.02 mg/L	0.0-0.02 mg/L	0.00 mg/L
Nitrate	<0.3 mg/L	0-2 mg/L	
Magnesium	5.5 mg/L	5-12 mg/L	7.70 mg/L
Calcium	6.3 mg/L	20-35 mg/L	35.27 mg/L
Sodium	20 mg/L	15-25 mg/L	12.80 mg/L

CHAPTER THREE

3 Materials and Methods

3.1 Collection of samples

Three brands of commercially available bottled water consisting of natural mineral and packaged drinking types were purchased randomly from three different supermarket stores in Khartoum state, Sudan between July and August 2017. To keep the brand names anonymous, the samples were given code names and this convention is used throughout the study. All brands were sold in 500, 600 and 300ml plastic bottles and are sealed with plastic screw caps. The water bottles obtained were from the same production year. As most consumers purchase bottled water from supermarket shelves these sources were preferred for analysis. The size of the bottle, production date, and the concentration of pH, TDS, Na, K, Ca, Mg, SO4, CL, NO^{-2}, NO^{-3} and F values were noted from the labels of the bottles. The samples were analyzed for pH, TDS, Na, K, Ca, Mg, SO4, CL, NO^{-2}, NO^{-3} and F concentrations in the laboratory of Sudan University of Science and Technology. The data were entered in to the computer and analyzed using Minitab 18 ANOVA test was employed to compare the values of label, laboratory and WHO standards. And the results were displayed as groups using the Tukey Method and 95% Confidence. One-sample Kolmogorov–Smirnov test was performed to verify the normal distribution condition of the observations.

3.2 Analytic procedure

3.2.1 pH

Direct reading by using pH - meter.

3.2.2 Total Dissolved Solids (TDS)

Direct reading by using conductivity-TDs - meter. Results were reported in mg/L TDs according to Alpha (1980).

3.2.3 Sodium and Potassium

Flame photometer was used to determine the sodium and potassium concentration in water according to APHA (1980).

3.2.4 Calcium

Calcium in water is general, determined using EDTA titrimetric method. The general principal is that solution to water containing calcium and magnesium ions, it reads the calcium before the magnesium. Calcium can be determined in the presence of magnesium by EDTA titration; the indicator used in one that react with calcium only. Indicator solution gives a colour change when all of the calcium has been complexed EDTA at pH of 12-13.

Procedure

1. A colour comparison blank was prepared by placing 50 ml of distilled water in a white porcelain dish. 2. Then 50 ml of the target were placed in a white porcelain dish as well.

3. Two ml of NaOH solution were added to both the sample and the comparison blank and were stirred; the pH was adjusted to 12-13.

4- Two drops of Murexide indicator solution was added to the blank and stirred, then one to two drops of EDTA titrant from the burette were added each time while stirring till the colour turned from red to an orchard purple.

5- The burette reading was recorded.

6- The blank was kept to be used as colour reference comparison.

7- The sample was titrated as described for the blank in step 4.

8. The burette was read and the volume of EDTA titrant used by subtracting the burette reading from reading of step 5.

Calcium concentration was calculated as follow:

$$Ca = A \times C \; 400.8 / \text{ml, sample}$$

Where

A= Volume of EDTA titrant used for titration of sample (ml).

C= ml of standard calcium solution/ml of EDTA.

The results were recorded as Ca (mg/L),

3.2.5 Magnesium

Magnesium was determined by subtracting the calcium hardness from total hardness. The remained amount contributed to magnesium **(*Greenberg et al.1998*)**

3.2.6 Sulphate

Sulphate was determined using powder pillow method is which is used to determine the sulphate concentration in water by direct reading using spectrophotometer DR2000 HACH. Programme procedure adjusted to the wave length 450nm is used for analysis.

Results were reported in mg/l sulphate according to **APHA (1995)**

3.2.7 Chloride

Chloride was determined in a neutral or slightly alkaline solution by titration with standard silver nitrate solution using potassium chromate as an indicator. Silver chloride was quantitatively precipitated before red silver chromate was formed the method used was that described by ***Greenberg et al. (1998*****).**

Procedure

1- Sample of 100 ml was measured into porcelain dish and pH was adjusted to about 8.

2- One milliliter of potassium chromate indicator solution was added and stirred.

3- The sample was titrated with silver nitrate solution with constant stirring until slight reddish coloration persisted.

4- Steps 1 to 3 were repeated on 100 ml distilled water blank to allow for the presence of chloride in any of reagents and for the solubility of silver chromate.

Calculation

Chloride (ml/L) as CI= (V1_V2) x1000/ volume of sample.

Where

V1=volume of silver nitrate required by the sample (ml).

V2 =Volume of silver nitrate required by the blank (ml).

3.2.8 Nitrate and Nitrite

The method used to determine the Nitrate and Nitrite concentration in water was by direct reading using Spectrophotometer DR2000-HACH Programme procedure adjusted to the wave length 500 nm for nitrate and 507nm for nitrite were used for analysis. Results were reported in mg/L, nitrate, and nitrite according to **APHA (1995).**

3.2.9 Fluoride

The method used to determine the fluoride concentration in water was by direct reading using S DR2000 HACH programme procedure adjusted to the wave length 580 were used for analysis. Results were reported in mg/L, fluoride according to **APHA (1995).**

CHAPTER FOUR

4 Results and discussion

4.1 Results and discussion

Through the tests were made on chemical composition of some brands of Sudanese bottled drinking water the results were shown on table (4) and compared with Sudanese Standards and Metrology Organization and WHO standards for bottled drinking water quality in table (5) also the results was compared with the brands label content.

pH

There was significant difference ($P \leq 0.05$). In pH value between the brands in table (4) and the results was in the range of their label content (7.5, 7-8 and 8 respectively) and SSMO (2002) and WHO (2011) standards in table (5).

TDS

The TDS for the brands was found to be significantly different ($P \leq 0.05$) as shown in table (4) and contain a higher value than their label contents (100, 130-180 and 140 respectively) and SSMO (2002) and WHO (2011) as shown in table (5).

Sodium

The sodium content of the brands was significantly different ($P \leq 0.05$) as shown in table (4), also none of the brands matched their label value which was (20, 15-25, and 12.80 respectively), brand B has the closest to SSMO as in table (4) and its label content.

Calcium and magnesium

There results of calcium and magnesium content of the brands was not significantly different ($P \leq 0.05$) shown on table (4), but on the other hand none of the brands matched its label content which was as following (6.3, 20-35 and 35.27 respectively) for calcium and (5.5, 5-12, 7.70 respectively) for magnesium. SSMO standard for these two elements was not available while WHO standard was much lower than the obtained result and the label values for the three brands.

Sulphate

The sulphate results had shown no significant difference ($P \leq 0.05$). None of the brands matched its label value which was (3, 5-25 and 13 respectively), No standard was available for this compound.

Chloride

The chloride results of the under investigation brands shown no significant difference ($P \leq 0.05$) as shown in table (4). Also the results was much lower than their label values (4.8, 20-35 and 15 respectively), brand A has the least difference between label value and laboratory finding. The SSMO and WHO standard for chloride was much higher than obtained results and the label value see table (5).

Nitrite

The nitrite results of the brands was significantly different ($P \leq 0.05$), also it was higher than their label values which was (<0.02, 0.0-0.02 and 0.00 respectively).but all the results was in the acceptable level for both SSMO and WHO.

Nitrate

There is no significant difference ($P \leq 0.05$) between the nitrate results of the brands as in table (4). But the results didn't match the label values of the brands which was (<0.3, 0-2 and there was no label value for brand C). Also the results were lower than SSMO and WHO standard see table (5).

Fluoride

The results of the fluoride shown no significant difference ($P \leq 0.05$) shown on table (4), also it nearly matched the label values of the brands (0.1, 0.03-0.1 and 0.36 respectively). The results were below the recommended level for both SSMO and WHO as in table (6).

Table 4 Chemical composition of locally produced bottled drinking water

Parameters	Brand A	Brand B	Brand C
	[n = 3 ± SD]		
pH	7.60±0.00[a]	7.60±0.00[a]	7.50±0.00[b]
TDS	184.33±0.58[a]	121.33±1.15[b]	227.33±0.58[c]
Sodium	48.30±2.30[a]	27.60±2.30[b]	58.27±3.51[c]
Calcium	4.00±0.00[a]	4.00±0.00[a]	4.00±0.00[a]
Magnesium	4.05±1.40[a]	4.05±1.40[a]	7.29±2.43[a]
Sulphate	25. 60±15.43[a]	33. 60±24.00[a]	30.40±15.43[a]
Chloride	3.54±0.00[a]	3.54±0.00[a]	3.54±0.00[a]
Nitrite	0.27±0.14[a]	0.036±0.03[b]	0.017±0.01[b]
Nitrate	6.257±0.7[a]	4.73±0.751[a]	5.47±0.37[a]
Fluoride	0.143±0.08[a]	0.120±0. 05[a]	0.33±0.04[a]

SD ≡ Standard Deviation.

n ≡ Number of independent determinations.

Mean ± S.D value(s) bearing different superscript letter(s) within rows are significantly different (P≤0.05).

Table 5 the comparison of chemical parameters of the selected brands of bottled water with SSMO (2002) and WHO (2011) guidelines for drinking water quality (mg/l)

Parameters	Brand A	Brand B	Brand C	SSMO 2002	WHO 2011
pH	7.60	7.60	7.50	6.5-8.5	6.5-8.5
TDS	184.33	121.33	227.33	100	100
Sodium	48.30	27.60	58.27	20	50
Calcium	4.00	4.00	4.00	NA	0.2
Magnesium	4.05	4.05	7.29	NA	0.2
Sulphate	25. 60	33. 60	30.40	NA	NA
Chloride	3.54	3.54	3.54	250	250
Nitrite	0.27	0.036	0.017	2.0-10.0	3
Nitrate	6.257	4.73	5.47	45-50	50
Fluoride	0.143	0.120	0.33	0.6-1.50	0.6-1.5

NA≡ Not Available

Mg/L≡ Milligram per Litter

SSMO≡ Sudanese Standards and Metrology Organization

WHO ≡ World Health Organization

CHAPTER FIVE

5 Conclusions and Recommendation

5.1 Conclusions

- Findings like pH, nitrite and sodium were found to be in the recommended range by the WHO and SSMO, therefore, should have no obvious health implications.
- TDS level was found to be higher than recommended level by WHO and SSMO.
- Nitrate and chloride were found to be much lower than the recommended levels by WHO and SSMO.
- Most of the findings were lower or higher than their label values.
- All the brands had fluoride levels below 0.5 mg/l. Thus, those people, especially children, consuming only bottled water for drinking purposes are advised to supplement their fluoride intake, maybe by the use of fluoridated toothpastes.

5.2 Recommendation

The present study recommended the following:

- The competent authorities shall increase the supervision of the factories.
- The bottled drinking water factors must review their label values and make sure to not misguide the consumers.
- Consumers shouldn’t relay on bottled water as only source for drinking water.
- Further studies should be done on the bottled drinking water including microbial examinations to increase the awareness and safety of the consumers.

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