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Assessment of Chemical Quality of Major Brands of Bottled Water Marketed in Gondar Town, Ethiopia

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ABSTRACT

The chemical quality of six commercially available bottled water samples were analyzed and compared with WHO and EC guidelines. Chemical quality of some anionic and cationic balance were analyzed by standard 8000 photometer transmittance and flame emission spectrophotometer methods. Sodium and aluminum were found entirely absent in all analyzed bottled water samples. Fluoride content of analyzed water is less than minimum permissible value recommended by WHO guideline. Magnesium and calcium content range from 0.32 ppm to 6.5 ppm and 3 ppm to 28.2 ppm respectively. Recorded results showed that great variation exists in the chemical content of all the six commercially available bottled water.

Keywords: Bottled water, Chemical quality, Anions, Cations, Spectrophotometer.

INTRODUCTION

The saying "water is life" is found in many cultures around the world. It underscores the fact that clean water is an absolute prerequisite for health (Zeyede K et al,1998).

Water is not absolutely pure in nature contain impurities which vary from dissolved gases, chemicals to suspended water and pathogenic microorganisms. Almost every known element existing normally in the environment can become poisonous when introduced in to the human system in larger than normal quantities. One major way of introducing these elements in to the environment and later in to the human system is through the discharge of industrial effluents in to water sources such as river, ground water, spring water etc (Ethiopian Federal Democratic Republics water resources policy, 1997).

Bottled water is the fastest growing drink choice of the world. Sales and consumption of bottled water have skyrocketed in recent years. However, bottled water is not necessarily safer than tap water, and over the year, concerns have been raised about the quality of bottled water marketed worldwide. A number of chemical contaminants have been identified in drinking water viz., aluminum, arsenic, fluoride, lead, nitrate, pesticides, cadmium, mercury and sulphate, either organic or inorganic origin. Naturally occurring contaminants are generally the result of leaching from geologic formations and are found primary in ground water. Concentrations of these contaminants range from less than nanograms per litre (ng/L) to milligrams per litre (mg/L). The treatment process can be a significant source of chemical contaminants (Calderone RL, 2000).

Many toxic minerals are contained in water supplies, usually at high levels. Treatment and potabilisation plants work very well reducing these minerals to safe levels. Minerals can enter surface or ground water through natural sources, industrial sewage, and leakage from urban or agricultural areas, water pipes walls or even from domestic sources, these include aluminium, sulphates, nitrites and nitrates (Greenwood NNE,2002) (USEPA &CDC,1999).

WHO (World Health Organization) publishes guidelines for drinking-water quality which many countries use as the basis to establish their own national standards. The guidelines represent a scientific assessment of the risks to health from biological and chemical constituents of drinking water and of the

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effectiveness of associated control measures. As the WHO guidelines for drinking-water quality are meant to be the scientific point of departure for standards developments, including bottled water, actual standards will sometimes vary from the guidelines (WHO, 1993).

Bottled water is regulated through a comprehensive regulatory system at the federal and state level. Over the past several years, the US food and drug administration (FDA) adopted several new bottled water quality standards, as well as issued guidance and regulations to address increased security threats. The drinking water research foundation (DWRF) is an independant not-for-profit organization that was founded in 1984 to sponsor peer-reviewed scientific research that addresses the production of safe and affordable drinking water, including bottled water (Mwashote BM, 2003). In the above context the present study was aimed at the analysis of bottled water for major cations (calcium, magnesium,aluminum,potassium and sodium)and anions (sulphate, fluoride, chloride and nitrate); to compare the levels of cations and anions in bottled water consumed with that of other countries and to compare the levels of cations and anions of bottled waters consumed in Gondar town with WHO, EC and USEPA guideline for drinking water.

MATERIAL AND METHODS

Study was conducted in Gondar a historical city which served as a capital city of Ethiopia during the regime of emperor Fasil. A sets of three bottles each (volume 1-1.5 liter) from six major brands of commercially available bottled water was purchased randomly from grocery shops and supermarkets in Gondar town for assessment of their chemical quality in May 2015. All the samples were contained in their original sealed containers and kept at room temperature until the water was analyzed for the ions of interest. The product name, the size of the bottle, production date and the concentration of calcium, sodium, potassium, magnesium, chloride, fluoride, nitrate, aluminum, and sulphate values were noted from the labels of the bottles.

Reagents: The following analytical reagents were used during the experiment. For calcium-calcicol tablet; for chloride-acidifying CD & chloricol tab; fluoride- floride No 1&2 tab; magnesium-magnicol tab; nitrate-nitricol no 1&2 tab; sulphate-sulphate turb tab; aluminum no 1&2 tab. For each analysis single tablet or reagent was used.

Analytical methods

The photometer was calibrated with 10ml of distilled water before analysis of the samples. The samples were analyzed for all the ions listed (table 2) in the bottle in Gondar town water treatment and quality control laboratory and North Gondar zone soil and water research center using photometer 8000/ transmittance-display photometer and flame emission spectrophotometer. For the analysis of bottled mineral water samples that, two analytical method were selected based on the accessibility and availability of reagents and instruments. i.e photometer 8000 and flame emission photometer. For the analysis of major cation's (calcium, magnesium) and common anions (sulphate, fluoride, chloride, aluminum, nitrate) photometer 8000 was used, potassium and sodium were analyzed by flame atomic photometer based on the standard procedures set by WHO and USEPA. The data reported is the mean value of three samples. The chemical quality of the bottled water brands was evaluated and compared with the World Health Organization (WHO) and the European Union (EU) guidelines for drinking water.

Table.1 Brand information about the commercially available brands of bottled water studied

Brand code #	Bottled capacity (liter)
1	1
2	1.5
3	1.2
4	1
5	1.5
6	1

Table.2 World Health Organization (WHO), European Union (EU) in drinking water standards

Parameters	EU (MAC)	WHO (MPL)
Fluoride	-	1.5 ppm
Sulphates	250 ppm	250 ppm
Chlorides		250 ppm
Nitrate	-	50 ppm
Calcium	100 ppm	-
Magnesium	50 ppm	-
Sodium	150 ppm	200 ppm
Potassium	12 ppm	-
Aluminum	-	0.2 mg/L

European Union (EU2002) directives for drinking water and World Health Organization (WHO) guidelines for drinking water (WHO 1993).

RESULTS AND DISCUSSION

Table.3 Level of some anions (chloride, nitrate, sulphate, fluoride) in the brands of bottled water studied

Brand #	Chloride (ppm)	Nitrate (ppm)	Sulphate (ppm)	Fluoride (ppm)
1	0.93	0.251	ND	0.113
2	6.07	0.389	4.02	0.153
3	6.3	0.33	1.6	0.11
4	0.72	ND	0.06	0.03
5	0.4	ND	0.57	0.1
6	2.93	ND	ND	0.09

Table.4 Levels of calcium, magnesium, sodium, potassium, aluminum in the brands of bottled water studied

# Brand	Calcium (ppm)	Potassium (ppm)	Sodium (ppm)	Magnesium (ppm)	Aluminum (ppm)
1	22.0	ND	ND	6.5	ND
2	28.3	4.1	ND	3.5	ND
3	16.8	ND	ND	5.0	ND
4	5.7	ND	ND	0.39	ND
5	3.0	ND	ND	0.32	ND
6	10.7	1.2	ND	0.81	ND

ND – not detectable

Table.5 Comparison of the result obtained by current study with results from other countries

Country	Analytes					
	F^-	Cl^-	Na^+	Mg^{2+}	K^+	Ca^{2+}
Present study (Ethiopia)	0.03-0.15	0.4-6.3	ND	0.32-6.5	1.2-4.1	3-28.3
Egypt	0.12-0.48	11.1-221.1	4.94-169	1.54-23.3	0.11-18.5	1.39-44.8
Australia	0.10-0.22	5.9-47.4	2.4-34.5	5.7-38.6	0.7-20.0	0.5-4.6
Portugal	0.0-0.05	8.6-15.8	7.6-11.8	1.5-13.6	1.5-13.6	0.0-22.1
Canada	0.2-0.36	0.0	0.0-1.5	0.2-6.0	0.2-6.0	3.0-7.9
China	0.07-0.79	0.0-67.0	8.1-31.4	0.4-24.1	0.4-24.1	0.7-1.4

Table.6. Comparison of current results with some national & international guidelines

Guidelines	ppm								
	Cl^-	F^-	No_3^-	So_4^{2-}	Na^+	K^+	Mg^{2+}	Ca^{2+}	Al^-
WHO	250	1.5	50	250	200	-	-	-	0.2
EC	250	1.5	50	250	200	-	-	-	-
USEPA (1993)	250	2	44	250	-	-	-	-	-
Ethiopian limit	533	3	50	450	350	-	-	-	-
Brand 1	0.93	0.113	0.251	ND	ND	ND	6.5	22	ND
Brand 2	6.07	0.153	0.389	4.02	ND	4.1	3.5	28.3	ND
Brand 3	6.3	0.11	0.33	1.6	ND	ND	5	16.8	ND
Brand 4	0.72	0.03	ND	0.06	ND	ND	0.39	5.7	ND
Brand 5	0.4	0.1	ND	0.57	ND	ND	0.32	3	ND
Brand 6	2.93	0.09	ND	ND	ND	1.2	0.81	10.7	ND

Note :- the ‘’—‘’ indicates the limits are not given.

Determination of common anions

Determination of common anions was carried out by using photometer 8000. Common anions fluoride, chloride, sulphate, nitrate were determined.All the brands of bottled water analyzed for anions nitrate, sulphate, chloride, fluoride showed levels below the WHO/EC maximum acceptable limits for these anions (table 3).

Chloride:- Chloride content of the six brands range from 0.4ppm in brand 5 to 6.3ppm in brand 3 bottled waters, where as the WHO prescribed limit was 250 in drinking water. Thus all the bottled water samples were safe for drinking from the chloride point of view. If we compare the chloride concentration level in bottled water relatively brand 3 and 2 have high chloride content to that of other brands respectively.

Nitrate: The values of nitrate found in brands 1, 2, 3 are well below the WHO recommended limit of 50 and hence does not pose much health concern. The nitrates were not detected in brands 4, 5 and 6.

Sulphate: Sulphate is not detected in brand 1 and 6. The concentration of sulphate was detected in other brand varied from 0.06 ppm in brand 4 to 4.02 ppm in brand 2. Sulphates are labelled on brand 4 as 0.12 and brand 5 as 1.2 but it was detected in all bottled water samples. The amount detected in brand 3 was 1.6 and in brand 2 were 4.02. This shows non-uniformity in the labelling of the composition of chemical quality of bottled waters which again leads to lack of transparency to the consumers. Sulphate is one of the least toxic anions. The lethal dose for human as potassium sulphate or zinc sulphate is 45g. The major physiological effects resulting from ingesting large quantities of sulphate are catharsis, dehydration and gastrointestinal irritation. No health-based guideline value for sulphate in drinking water is proposed by WHO (Mahamud AS et al 2001).

Fluoride: WHO recommends that the appropriate level of fluoride in the drinking water should ranged from 0.6 – 0.8 ppm for annual average of maximum daily temperature of 26.3 – 32.6 ^{0} C to 0.9 – 1.5 ppm for temperature of 10 – 12 ^{0} C. However, the recommended level for tropical countries like Ethiopia, where the maximum temperature goes above 32.6 degree centigrade during summer season, should be in the range of 0.6 – 0.7 ppm. The presence of fluoride is associated with dental and skeletal fluorosis (>1.5 ppm) and inadequate amounts lead to dental carries (<0.6 ppm) (Nazeer BK, 2007). In the present study all analyzed bottled water showed fluoride levels less than 0.6 which may cause dental carries. Furthermore, the concentration of fluoride between 0.9 -1.2 ppm may cause mild dental fluorosis (WHO, 2006).

Determination of common cations

The chemical analysis of common cations did not show much variation between analyzed and actual values on the bottles as detailed in table 4.

Calcium: The calcium content of the six brands of bottled water was below the maximum prescribed value of WHO standards. The calcium content varied from 3 ppm -28.3 ppm. Excess amount of calcium can alter water taste and cause scaling problem in pipes and household appliance.

Magnesium: The magnesium content of the analyzed bottled water is between 0.32 ppm and 6.5 ppm. The recommended value of magnesium in drinking water by EC is 50 ppm. So far magnesium is responsible for several biologic processes that influence membrane and mitochondrial integrity, such as the proper functioning of adenosine tri phosphatise (sodium-potassium ATPase) and also essential for synthesis and stability of nuclear DNA and for the mineralization of bone.

Sodium: The sodium ions were not detected in all the analyzed bottled water. It is the most abundant extracellular cation, which maintains the osmolarity of extracellular fluid and the main determinant of extracellular fluid volume. Acid-base balance and the transmission of nerve impulses are other important functions performed by sodium (Tolonen M, 1990).

Potassium: -The common cation found in the earth and in the body is potassium. The amount of potassium in the analyzed bottled water was below WHO recommended value but as compare to each other brand 6 and 2 has better potassium. Potassium is important for our body in the optimal range but if there is deficiency of potassium an individual will encounter fatigue, drowsiness, dizziness, confusion, electro cardio graphic changes, muscle weakness and muscle pain (Kinney JM, 1988).

Aluminum: All brand bottled waters analyzed did not contain aluminum. Among the six brands of bottled water brand 2 and 6 are labeled aluminum as zero.Minimum permissible limit of aluminum is 0.2mg/L. All analyzed bottled water was safe for drinking as regarding to aluminum.

Comparison of current study with results from other countries

There are some reports from countries like Egypt, Australia, Portugal, Canada, and China on the analysis of bottled water for their content of some inorganic ions. The number of brands reported was as follows, Egypt 5 brand (E_1,E_2,E_3,$E_4$and E_5); Australia 6 brand (A_1, A_2, A_3, A_4, A_5, and A_6); Canada 2 brands (Ca_1 and Ca_2); china 8 brand (C_1, C_2, C_3, C_4, C_5, C_6, C_7 and C_8) and Portugal 2 brands (P_1 and P_2). The report show that, all mineral water sample where analyzed for common ions (F^-, Cl^-, Na^+, K^+, Mg^{2+}, Ca^{2+}). The results of the present study were compared with these results (table 5). For common anions and cations except some outlined results the composition of the bottled mineral and other water samples from different countries was more or less similar.

Comparison of current results with some national and international guide lines:

The WHO published guidelines for drinking water quality which many countries use as the basis to establish their own national standards. WHO recommends that social, economic and environmental factors be taken in to account through a risk-benefit approach when adapting the guideline value to national standards. As the WHO guidelines for drinking-water quality are meant to be the scientific point of departure for standards development, including bottled water; actual standards will sometimes vary from the guidelines (Oi-Wah L, 2002).

In the present study about four national and international guidelines developed depending up on the guidance of WHO guideline were considered for comparision of the results in the present study (table 6). These standard guidelines are EC, WHO, USEPA and Ethiopian limit. The Ethiopian standard was developed on March 2002 for drinking water depending on the WHO guidance and considering the geographical, economical and cultural values of the country (Ethiopian guidelines, 2002). According to these standard guidelines, no results are above the given standards. Therefore all the water samples are safe for drinking.

CONCLUSION AND RECOMMENDATION

The present study revealed that there is a large variation in the composition of bottled water in different brands compared. The consumer can choose the bottled water according to its preference. Most of the samples investigated for their chemical quality had values within the acceptable limits of WHO, EC, USEPA. The detection of sodium and aluminum in the six analyzed brands may be rated as a negative attribute. Fluoride content of all brand bottled water was below the minimum permissible value recommended by WHO which may cause dental carries in children. The low values of essential chemicals (minerals) and micronutrients is a gray area, which merits critical review by chemists, nutritionists and epidemiologists.

The study covers a limited number of branded bottled water, it is recommend that all marketed bottled waters be monitored for quality, identity and be licensed by concerned authorities to safe guard consumers' health. Further studies should focus on the possibility to verify the origin, physical microbiological and authenticity of Ethiopian bottled waters taking into account of increased number of samples and additional heavy metals like Fe, Cr, Cd, Zn, etc.

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