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Assessment of quality of packaged water marketed in Ibb city, Yemen for drinking purpose

[1]Wadie Ahmed Al-Shargabi, [2]Raya Qaid Alansi, [3]Ravikumar, R and[4]Janardhana, M.R.

[1]*Department of Medical Laboratories, Faculty of Medical and Health Sciences, Turba Branch, Taiz University, Taiz, Yemen*
[2]*Yemen Standardization and Metrology Organization, Yemen.*
[3]*Department of Geology, Sahyadri Science Collage, Kuvempu University, Shivamogga, Karnataka, India.*
[4]*Department of Geology, Yuvaraja's collage, University of Mysore, Mysore, Karnataka, India.*

Abstract: *The current study involves the analysis and evaluation of the 38 bottled water samples being sold in 0.75, 1.5 and 5 liters capacity containers across Ibb city, Yemen. Water samples were evaluated for physico-chemical and biological characteristics to assess the suitability for drinking purpose. The evaluated physical parameters consist of net weight of the samples, seal of the bottle caps, taste and odor. The collected samples were analyzed for pH, TDS and TH as well as the determination of the concentration of Mg, Cu, Zn, Fe, Cd, Mn, Ni and Cr elements and SO_4. The microbial analysis was also conducted in terms of most probable number (MPN) of total coliforms in water samples. The results showed that most of the water samples are slightly alkaline in nature. The packaged water is characterized by the palatable taste, odorless, concentration of chemical elements ranging from below the detection limit to within the permissible limits of Yemen Standard and Measure Organization (YSMO). The microbial analysis reveals the absence of most probable number (MPN) of total coliforms and Escherichia coli (E. coli) in water samples. Correlation analysis among most of the chemical parameters indicates positive correlation of TDS, Mg and SO_4 with TH while pH is negatively correlated with TH and others are not significant. All parameters evaluated are well within the permissible limits of YSMO standard and suitable for drinking purpose.*

Key words: Packaged water. Physico-chemical parameters. E-coli. Correlation matrix. Ibb city. Yemen.

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I. Introduction

The quality of drinking water is closely associated with human health, and supply of potable drinking water by any governments, is one of the important public health priorities (Sarker et al., 2016). The non-availability of good quality drinking water has resulted into a number of health challenges as water is known to be a primary causative agent of many contagious diseases. In developing countries of the world, 80 % of all diseases and over 30 % of deaths are related to drinking water (Sarker et al. 2016; Onweluzo and Akuagbazie, 2010). Access to safe drinking water is key to sustainable development, food production, poverty reduction and quality health (Adekunle et al., 2004). Unfortunately, such water sources are scarce and even when they are available; they are seldom safe for consumption. Approximately three out of five persons in developing countries do not have access to safe drinking water (Mengesha and Baye2004). Under such circumstances, it is generally considered that treated packaged water is safe for usage by people.

Ibb city (Fig. 1) located between Sana'a, the capital of Yemen, and Taiz governorates, bounded by latitude 13°58'48'' and longitude 44°10'48'', lacks any surface fresh water resources. Ibb is situated at an elevation of about 2000 m above sea level. The population of the governorate of Ibb is about 1.5 million, and according to the Yemeni National Information Center (YNIC), its population constitutes 10.8% of the total population of the Republic, and is the third largest governorate of the Republic in terms of population. Population density is 1932 persons/Km^2. In the absence of any surface fresh water resources, the population of Ibb city relies entirely on groundwater for their demands. At the present time, more than twenty wells are in operation, ten of which feed directly into the pipe network and ten feed the high level reservoir. The depth of the wells ranges from 135 up to 333m (Dar Al Handasah, 2006) below ground level.

Provision of safe drinking water is one of the most essential amenities to be made available for citizens in the modern world (Joseph et al., 2018). Local authorities of Ibb city, supply water to its citizens through pipe network however it cannot be consumed directly due to its aesthetic value. A significant number of people consume packaged water which is partially treated using filters for purification and ozone for sterilization.But, there is still a debate on the efficiency of filtration system to comply with the regulations as water that

physically looks colorless, odorless and even tasteless is not sufficient to determine that the water is safe for consumption, So, the drinking water should be examined on microbiological and physicochemical quality (Chan and Norrakiah, 2007). At the same time, the insufficiency of water supply has given rise to the involvement of private individuals in the production of packaged drinking water (pure water) (Dada, 2009). The present study deals with the examination of the quality of the packaged water being sold in Ibb city, Yemen for the presence of any undesirable substances including toxic metals and its suitability for drinking purpose.

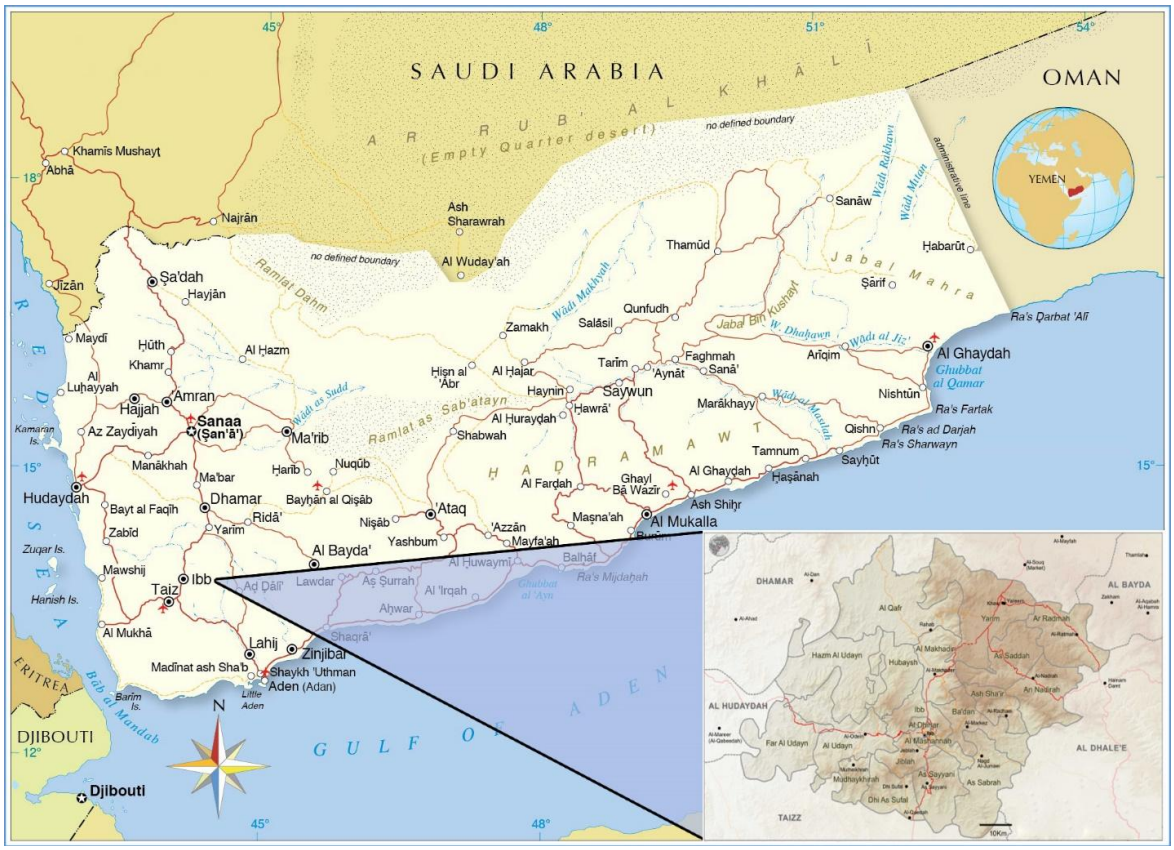

Figure1. Location map of the study area

II. Materials And Methods

During October 2019, 38 samples of 0.75, 1.5 and 5 litre packaged drinking water of assorted brands from Ibb city were collected in duplicate for the evaluation of the quality of water. All the analyses of the water samples were carried out at the laboratories of General Authority for Standardization and Metrology in Yemen following the standard analytical procedures prescribed by APHA 1998. All the key physico-chemical and biological including sensory parameters were measured to evaluate the acceptability and quality of the packaged water being sold in the open market in Ibb city. The physical including sensory parameters evaluated are net weight, taste and odor. In addition, each bottle was checked whether they are sealed properly or not. The chemical parameters, that were measured, are pH, TDS, TH, SO_4, Mg, Cu, Zn, Fe, Cd, Mn, Ni and Cr. MPN and E. coli are the two biological parameters that were measured.

III. Results

Physical, sensory and biological parameters evaluated indicate that there is no variation in the results obtained for 38 samples of packaged drinking water samples of Ibb city and they are well within the permissible limits of Yemeni Standardization and Metrology Organization (YSMO). All the bottles were found to be properly sealed and bottled capacity were 0.75, 1.5 and 5 liters as per the recommendation of the YSMO. Collected bottled water samples were found to be free from any visible impurities; taste was palatable and odorless thus conforming to YSMO standards. Escherichia coli (E. coli) which is principally associated with fecal contamination (Edberg et al., 2000, Tharannum et al., 2009and Bej et al., 1990) and Most Probable Number (MPN) were not recorded in any of the samples thus discarding the fecal contamination of the bottled water. The obtained results of the chemical analysis of the samples are presented in Table 1.

pH

pH values of the water samples rangefrom 6.95to 7.99 (Table 1).Most of the bottled water samples of Ibb area have pHvalues above 7indicating that they are slightlyalkaline in nature. The maximum pH value (7.99) was recorded in sampleS13 and the minimum (6.9) in S32 sample (Table 2). The mean value was 7.50 with SD of 0.331.Statistically, there were significant differences ($p<0.05$) of pH among all samples, but the all values were within the permissible limit prescribed by YSMO (table 2).

Total Dissolved Solids (TDS)

The Total Dissolved Solids (TDS) content of the water which indicates the degree of mineralization of water (Ahmad2014), varies from about 16 ppm to 337 ppm(Table 1). Themaximum value (337.00 ppm) was recorded from S27 while the minimumvalue of about 16 ppm was found in S4 sample (Table 2). The mean value of the concentration of TDS was 126.92 withSD 59.093. Statistically, there are significant differences ($p<0.05$) of TDS among all samples. The permissible limit prescribed by YSMO is 600 ppm(Table 1) thus, all the samples based on TDS,are found to be suitable for drinking purpose.

Total Hardness (TH)

Total Hardness is caused by calcium and magnesium and is usually indicated by precipitation of soap scum and the need for excess use of soap to achieve cleaning. Usually the hardness is not harmful to health but it has been suspected to play some role in heart diseases (Ahmad 2014). The value of TH fluctuates from 11.60 ppm to 200.00 ppm(Table 1). The maximum value (200.00 ppm) was recorded from S27 sample and the minimum value (11.60 ppm) was recorded from S25 sample. The mean value of the concentration of TH was 56.59 with

Table 1: Physico-chemical characteristics of the packaged water samples

Sample No.	pH	TDS	T H	SO_4	Mg	Cu	Zn	Fe	Cd	Mn	Ni	Cr
S1	7.07	93.70	64	18.72	5.35	0	0.04	0	0	0	0	0
S2	7.22	114	72	14.9	10.70	0	0	0	0	0	0	0
S3	7.43	48	16	23.24	2.9	0	0	0	0	0	0	0
S4	7.84	16.20	16	11.06	1.94	0	0	0	0	0	0	0
S5	7.73	155.50	52	36.22	5.35	0	0	0	0	0	0	0
S6	7.86	169	52	33.33	2.92	0.026	0	0	0	0	0	0
S7	7.87	159.30	116	19.56	6.81	19.56	0	0	0	0	0	0
S8	7.33	76.70	70	29.42	13.13	0.001	0	0	0	0	0	0
S9	7.88	63.50	20	7.20	1.95	0.001	0	0	0	0	0	0
S10	7.22	114	72	14.9	10.70	0	0	0	0	0	0	0
S11	7.85	105	40	41.15	3.40	0	0	0	0	0	0	0
S12	7.85	165	22	121.80	1.94	0.013	0	0	0	0	0	0
S13	7.99	113	36	16.46	3.40	0	0	0	0	0	0	0
S14	7.33	132	114	39.09	9.72	0	0	0	0	0	0	0
S15	7.84	111	26	32.09	1.45	0.007	0	0	0	0	0	0
S16	7.72	73.50	29	65.42	0	0	0	0	0	0	0	0
S17	7.45	158	12	6.38	1.55	0.01	0	0	0	0	0	0
S18	7.33	132	114	39.09	9.72	0	0	0	0	0	0	0
S19	7.99	113	36	16.46	3.40	0	0	0	0	0	0	0
S20	7.1	122	100	20.57	8.75	0	0	0	0	0	0	0
S21	7.42	206.70	24	36.62	3.40	0	0	0	0	0	0	0
S22	7.07	93.70	64	18.72	1.93	0.01	0	0	0	0	0	0
S23	7.88	63.50	20	7.20	5.35	0	0.04	0	0	0	0	0
S24	7.14	82.60	60	37.65	10.20	0.002	0	0	0	0	0.02	0
S25	7.87	159.3	11.6	30.30	5.81	0	0	0	0	0	0	0
S26	7.45	158	12	6.38	0	0	0	0	0	0	0	0
S27	7.12	337	200	144	4.37	0	0.03	0	0	0	0	0
S28	7.14	32.60	60	37.15	10.20	0.002	0	0	0	0	0.001	0
S29	7.16	33	65	23	0.001	0	0	0	0	0	0	0
S30	7.62	122.20	30	22.22	2.91	0	0	0	0	0	0	0
S31	7.07	172.80	74	57.2	5.84	0	0.02	0	0	0.02	0	0
S32	6.95	169.65	28	28.59	0.79	0	0	0	0	0	0	0
S33	7.7	146	76	36	3.57	0	0.09	0	0	0	0	0
S34	7	194.40	132	119	13.60	0	0.04	0	0	0	0	0
S35	7.6	193.05	70	42.59	0	0	0	0	0	0	0	0
S36	7.58	151.08	15.1	32.51	0	0	0	0	0	0	0	0
S37	7.41	111	94	69.33	8.75	0	0	0	0	0	0	0
S38	7.94	162	36	11.06	25.30	6.9	0	0	0	0	0	0
Units	-----	Ppm	ppm	Ppm	ppm	ppm	ppm	ppm	ppm	ppm	Ppm	ppm
Standard	6.5-8	100-600	< 250	< 250	< 150	< 1.0	< 0.1	< 0.3	<	<	< 0.2	< 0.05

									0.003	0.1		

SD 40.981 (Table 2). Statistically, there are significant differences ($p<0.05$) of TH among all the samples. However, TH values of all the samples are within the permissible limit prescribed by YSMO (Table 1).

Table 2: Descriptive Statistics of chemical parameters of the studied samples

S. No	Parameters	Minimum	Maximum	Mean ± SD	P value
1	pH	6.95	7.99	7.50± 0.331	0.000
2	TDS	16.20	337.00	126.92±59.093	0.000
3	TH	11.60	200.00	56.59±40.981	0.000
4	SO_4	6.38	144.00	35.96±31.424	0.000
5	Mg	0.00	25.30	5.45±5.124	0.000
6	Cu	0.00	19.56	0.69±3.335	0.580
7	Zn	0.00	0.09	0.006±0.018	0.000
8	Fe	0.00	0.00	0.00±0.000	-----
9	Cd	0.00	0.00	0.00±0.000	-----
10	Mn	0.00	0.02	0.0005±0.003	0.000
11	Ni	0.00	0.02	0.0006±0.003	0.000
12	Cr	0.00	0.00	0.0000±0.000	------

SD= Standard Deviation

Sulphate (SO_4)

Groundwater usually contains insignificant concentrations of sulphates (SO_4), unlessthe water has been contaminated (Alan et al. 2000). The value of sulphatesin the bottled water samples of the study area ranges from 6.38 ppm to 144.00 ppm (Table 1). The maximum value (144.00 ppm) was measured from S27 sample while the minimum (6.38 ppm) was measured from S17 sample (Table 2). The mean value of the concentration of SO_4 was 35.96with SD 31.424. Statistically, there were significant differences ($p<0.05$) of SO_4 among all samples, but the all values were within the permissible limit prescribed by YSMO (Table 2).

Magnesium (Mg)

Magnesium is a beneficial metal but toxic at high concentrations and cause hardness as well as exerts a cathartic and diuretic action (APHA 1998). Mg was not detected in four samples viz., S16, S26, S35 and S36 and the maximum value of 25.30 ppm was found in S38 sample(Table 2). The mean value of the concentration of Mg was 5.45with SD 5.124. Statistically, there were significant differences ($p<0.05$) of Mg among all samples, but the all the values were within the permissible limit prescribed by YSMO (table 2).

Copper (Cu)

Copper is a metal that is naturally present in the environment, but the levels of contamination can be increased around agricultural land (manure spreading), near smelting facilities, and phosphate fertilizer plants. The most common health effects of the excessive consumption of copper bearing water would be; nausea, vomiting, diarrhea, upset stomach, and dizziness. There are also significant amounts of copper released from wastewater treatment plants, which could lead to problems downstream for a community that uses this water as their source of drinking water (Gurmessa2015). Cu concentration was below the detection limit in the following samples: S1, S2, S3, S4, S5, S10, S16, S18, S19, S20, S21, S23, S25, S26, S7, S29, S30, S31, S32, S33and S34. However, a maximum concentration of 19.56 ppm was recorded in the sample S7 (Table 1). The mean value of the concentration of Cu was 0.69with SD 3.335. Statistically, there were no significant differences ($p > 0.05$) of Cu among all samples, but the all the values were within the permissible limit as per the standard prescribed by YSMO (Table 1).

Zinc (Zn)

The recommended Daily Dietary Allowance of Zn is 15 mg for adults and 20 to 25 mg for pregnant and lactating women. Acute Zn toxicity in human causes vomiting, dehydration, drowsiness, lethargy, electrolytic imbalance, abdominal pain, nausea, lack of muscular coordination, and renal failure. Chronic dose of Zn increases the risk of developing anemia, damage to the pancreas, lowers down HDL cholesterol levels and raises LDL cholesterol levels and possibly enhances the symptoms of the Alzheimer's disease. Workers exposed to Zn fumes from smelting or welding have suffered from a short-term illness called mental

fume fever.(Prasad And Oberleas, 1976, NRC-NAS, 1980). The value of Zn in the packaged water of the study area fluctuates from 0 to 0.09 ppm (Table 1). The maximum value (0.09 ppm) was measured from S33 sample while Zn was not detected in most of the samples except S1, S23, S27, S31, S33 and S34 samples (Table 1). The mean value of the concentration of Zn was 0.006with SD 0.018. Statistically, there were no significant differences ($p > 0.05$) of Zn among all samples, but the all values were within the permissible limit prescribed by YSMO (Table 1).

Iron (Fe)

Iron (Fe) is an essential element for human health that performs various function in our body; the most well-known of them is production of protein hemoglobin, which carry oxygen from our lungs to transfer it throughout the body. Insufficient or excess levels of iron can have negative effect on body functions (Anonymous, 2008). Groundwater usually contains more of these two minerals than surface water. Iron and manganese are irritants that should be avoided if in excess of 0.3 mg/l and 0.1 mg/l correspondingly. They stain clothing and plumbing fixtures, and the growth of iron bacteria causes strainers, screens to clog, and metallic conduits to rust. The appearance of a reddish brown or black precipitate in a water sample after shaking indicates, respectively, the presence of iron or manganese (Alan et al. 2000).In all the samples, iron was found to be below the detection limit (Table 1).

Manganese (Mn)

At levels exceeding 0.1 mg/l, manganese in water supplies causes an undesirable taste in beverages and stains sanitary ware and laundry. The presence of manganese in drinking water, like that of iron, may lead to the accumulation of deposits in the distribution system. Concentrations below 0.1 mg/l are usually acceptable to consumers (WHO 2017). In the packaged water samples of the study area, Mn values range from 0 5to 0.02 mg/l (Table 1).

Cadmium (Cd)

In human body, Cd accumulates within the kidney and liver over long time. Long-term low-level exposure leads to cardiovascular disease and cancer. It is known to primarily affect renal tubular function of reabsorbing protein, sugar and amino acids. Cadmium exposure in conjunction with Ca, Fe, Zn, protein, fat and vitamin D deficiencies, led to ostomalacia and bone fractures in postmenopausal women in polluted Jintsu valley, Japan commonly referred to as Itai-Itai disease. Cadmium even in very low concentrations (≥0.003 mg/l) can affect calcium, phosphorus and bone metabolisms in both industrial workers and people exposed to Cd in general Environment(McLaughlin et al. 1999, Noda and Kitagawa 1990). However, in the present study area, none of the samples recorded Cd owing to the below detection limit (Table 2).

Nickel (Ni)

Nickel induces embryo toxic and population from exposure to coins, jewelry, watchcases, clothing and fasteners. It causes conjunctivitis, eosinophilic oesophagitis, asthma and local or system reaction to Ni containing prostheses such as joint replacements, pins, cardiac valve replacements, cardiac pacemaker wires and dental inlays (Athar and Vohora, 1995). Nickel is a potential carcinogen for lung and may cause skin allergies, lung fibrosis and cancer of respiratory tract in occupationally exposed populations (EPA 2003). Nickel was detected only two samples viz., S24 and S28 and the maximum Ni value recorded is 0.02 ppm(Table 1). The mean value was 0.0006with SD of ±0.003. Statistically, there were significant differences ($p < 0.05$), but all the values are within the permissible limit prescribed by YSMO (Table 2).

Chromium (Cr)

The harmful effects of Cr to human are mostly associated with its hexavalent form. Chromiumtoxicity includes liver necrosis, membrane ulcers and cause dermatitis by skin contact. Differentiation between the biological effects caused by Cr^{+6} and Cr^{+3} is difficult because after penetration through membrane the Cr^{+6} gets reduced into Cr^{+3} form (O'Brien et al. 2003). In none of the packaged water samples of Ibb cite, Cr was not detected (Table 1).

CORRELATION STUDIES

From the Pearson correlation matrix (Table 3), it is clear that the majority of the parameters show Non-Significant (NS) values. Magnesium (Mg) shows positive correlation with TH indicating that the Mg contributed for the TH of the packaged water. Sulphate (SO_4) shows moderate positive correlation with TH and TDS. TH shows moderate negative correlation with pH and moderate positive correlation with TDS.

Table 3: Correlation coefficient matrix of the physico-chemical variables of the water samples

S. No	Parameters	pH	TDS	TH	SO_4	Mg	Cu	Zn	Fe	Cd	Mn	Ni	Cr
1	Cr	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	1
2	Ni	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	1	
3	Mn	NS	NS	NS	NS	NS	NS	NS	NS	NS	1		
4	Cd	NS	NS	NS	NS	NS	NS	NS	NS	1			
5	Fe	NS	NS	NS	NS	NS	NS	NS	1				
6	Zn	NS	NS	NS	NS	NS	NS	1					
7	Cu	NS	NS	NS	NS	NS	1						
8	Mg	NS	NS	.361*	NS	1							
9	SO_4	NS	.555**	.543**	1								
10	TH	-.479**	.447**	1									
11	TDS	NS	1										
12	pH	1											

NS – Not significant

IV. Summary And Conclusions

Research have shown that when clean water and needed hygiene condition are provided, the chances of occurrence of diarrhea, sleeping sickness and guinea worm infestation can be eliminated or prevented by 50, 80 and 100% respectively (Alhassan and Ujoh, 2012). In the absence of fresh water sources, filtered water is the main source of safe and reliable drinking water (Chan and Norrakiah 2007) because of its pleasant taste, the absence of odor and the belief that it is mostly free of germs (Güler and Alpaslan 2009). The present study carried out in Ibb city of Yemen, involved the collection of 38 partially treated packaged water samples of 0.75, 1.5 and 5 liter capacity and physico-chemical as well biological analyses of the water samples to assess the suitability for drinking water needs. The evaluated parameters are: colour, taste, odor and net weight. All the bottles were found to be properly sealed. Examined water samples were characterized by colorless, odorless and proper net weight as indicated on the external surface of the bottle. Chemically, the samples of packaged water were found to have pH varying from neutral to slightly alkaline on pH scale whereas TDS, TH, SO_4 and Mg content were found to be well below the permissible limits prescribed by YSMO. The concentration levels of Cu, Zn, Fe, Cd, Mn, Ni and Cr were found to be very low and in most of the samples, they were not detected. The present study demonstrates that the quality of packaged water being sold in Ibb city of Yemen is found suitable and the partial water treatment being given is satisfactory.

References

[1]. Adekunle, L., et al., An assessment of the health and social economic implications of satchet water in Ibadan, Nigeria: A public health challenge. African Journal of Biomedical Research, 2004. 7(1).

[2]. Ahmad Ashfaq and Faizan Ahmad.2014. Assessment of Drinking Water Quality: A Case Study. International journal of current microbiology and applied science. ISSN: 2319-7706Volume 3Number 9 pp. 608-611. http://www.ijcmas.com.

[3]. Alan C., T., Don D., R., & Malcolm J., B. 2000. Water Supply. (5. edition, Ed.) TOKYO: Published.

[4]. Alhassan, M.M. and UjohF. 2012. Assessment of the chemical quality of potable water sources in Abuja, Nigeria. British Journal of Applied Science & Technology,2(2): p. 146.

[5]. Anonymous.2008. Assessment of surface water for drinking quality. Directorate of Land Reclamation Punjab, Irrigation and Power Department, Canal Bank, Mughalpura, Lahore, Pakistan.

[6]. APHA., 1998. Standard methods for the examination of water and wastewater. 20th Ed. American Public Health Association. USA.

[7]. Athar, M and VohoraS.B. 1995. Heavy metals and environment. In: Man and environment series (Ed: P.K Ray). Wiley Eastem Ltd. New Delthi, 1-195.

[8]. Bej, A. K., Steffan, R. J., DiCesare, J., Haff, L., & Atlas, R. M. (1990). Detection of coliform bacteria in water by polymerase chain reaction and gene probes. Appl. Environ.

[9]. Chan, C.L., Zalifah, M. and NorrakiahA. 2007. Microbiological and physicochemical quality of drinking water. Malaysian Journal of Analytical Sciences,. 11(2): p. 414-420.

[10]. Dada, A. 2009. Sachet water phenomenon in Nigeria: Assessment of the potential health impacts. African Journal of Microbiology Research, 3(1): p. 15-21.

[11]. Dar Al Handasah, 2006. Water Supply and Sanitation for Ibb city. Ministry of Water and Environment. Yemen. Sana'a.

[12]. Edberg, S. C. L., Rice, E. W., Karlin, R. J., & Allen, M. J. (2000). Escherichia coli: the best biological drinking water indicator for public health protection. Journal of applied microbiology, 88(S1), 106S-116S.

[13]. EPA. 2003. Nickel and Nickel Compound. Pollution Prevention Fact Sheet, 96, 1-2 (2002), K. Prazak, K.S., F. W. (Jr.) Sunderman and S. Salnikow: Nickel carcinogenesis. Mutat Res., 533: 2-26.

[14]. Güler, C. and AlpaslanM. 2009. Mineral content of 70 bottled water brands sold on the Turkish market: assessment of their compliance with current regulations. Journal of Food composition and Analysis, 22(7-8): p. 728-737.

[15]. Gurmessa Oljira Erena, 2015. Investigation of drinking water quality from the source to point of distribution (The case of Gimbi town in Oromia regional state of Ethiopia). A Thesis Submitted to the School of Graduate Studies of Addis Ababa University in

Partial Fulfillment of the Degree of Master of Science in Civil& Environmental Engineering. Addis Ababa university, Addis Ababa. Ethiopia, June.
[16]. Joseph, N., et al. 2018. Bacteriological assessment of Bottled Drinking Water Available at Major Transit Places in Mangalore City of South India. Journal of environmental and public health.
[17]. McLaughlin, M.JParker., D.R. and ClarkeJ.M.199. Metals and micronutrients- Food safety issues. Field Crop Res. 60, 143-163.
[18]. Mengesha, A., W. Mamo, and BayeG., A survey of bacteriological quality of drinking water in North Gondar. Ethiop J Health Dev, 2004. 18(2): p. 112-5.
[19]. Noda, M. and KitagawaM. 1990. A quantitative study of iliac bone histopathology on 62 cases with itai-itai disease. Calcif Tissue Int. 47, 66-74.
[20]. NRC-NAS. 1980. Recommended Dietary Allowances" 9thed, Food and Nutrition Board, National Research council, National Academy of Sciences, Washington D.C.
[21]. Onweluzo, J. and AkuagbazieC.2010. Assessment of the quality of bottled and sachet water sold in Nsukka town. Agro-Science,9(2).
[22]. O'Brien, T.J., Cerjak S. and PatiernoS.R. 2003. Complexities of chromiumcarcinogenesis: Role of cellular response, repair and recovery mechanisms. Mutat Res. 533, 2-26.
[23]. Sarker, A., et al., Assessment of microbial quality of water in popular restaurants in Sylhet city of Bangladesh. Bangladesh Journal of Agricultural Research, 2016. 41(1): p. 115-125.
[24]. Prasad, AS. And D. Oberleas. 1967. Trace elements in human health and disease, Vol. 1: Zinc and copper, Academic Press, New York.
[25]. Tharannum, S., Sunitha, S., Nithya, J., Chandini, M., Vanitha, J., Manjula, T. S., & Shyam Sundar, C. (2009). Molecular confirmation of the presence of coliforms in drinking water using polymerase chain reaction. Kathmandu university journal of science, engineering and technology, 5(2), 130-6.
[26]. WHO. 2017. Guidelines for Drinking-water Quality. FIRST ADDENDUM TO THIRD EDITION. Volume 1, Recommendations.

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