Assessment of Drinking Water Quality Status of Butana Mining Sites, Eastern Sudan via Determination of Physicochemical Parameters and Heavy Metal Concentration Levels (I)

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Abstract:
This investigation, the first of its kind in Sudan, is aimed at the assessment of the safety and quality status of the drinking water during the Dry and Wet Seasons in Butana mining area, Eastern Sudan. Random sampling was conducted in 6 sampling sites covering an area of about 16897.1 Km^2. The assessment was carried out in terms of the determination of 6 physicochemical parameters during the Dry (Wet) seasons: pH 7.43 (8.03), water hardness 133.66 (211.7) mg/L (combination of calcium and magnesium ions). The conductivity measurement 1280 (2078) µS/cm, while the total dissolved solids 841.66 (1050) mg/l and the Cl^-, SO^{4-} and NO^{3-} 44.00(65.12), 240.30 (257.90), 44.66 (45.84). All values obtained for the Dry Season are in accord with those of International Specifications of Drinking Water, with the exception of the extremely high total dissolved solids. Values for the (Wet) Season are either extremely higher, moderately higher or, rarely, approximately equal to those of the Dry season and also higher than those values of some International Specifications of Drinking Water The assessment also includes the quantification of the minerals concentration levels in the Dry and (Wet) Seasons, adopting Atomic Absorption Spectrometer Savant AA 5th generation AAS from GBC to quantify: nickel 0.004-0.018 (0.009-0.035) ppm, chromium 0.016-0.052 (0.003-0.167) ppm, cobalt 0.056-0.075 (0.078-1.03) ppm, zinc 0.0005-0.001(0.0012-0.090) ppm, copper 0.009 (0.001-0.012) ppm), lead 0.242-0.294 (0.287-0.450) ppm, cadmium 0.008-0.023 (0.027-0.720) ppm, manganese

0.178-1.019 (0.0250-1.962) ppm, iron 0.011-1.792 (0.3700-2.92) ppm and mercury 0.0002-0.004 (0.00037-0.095) ppm. It could, confidently, be concluded that some parameters such as pH, water hardness and heavy metals levels such as nickel, chromium, cobalt, zinc and copper were within the permissible levels of the international specifications (WHO, SSMO, US-EPA) for values obtained in the Dry Season. On the other hand, values for physicochemical parameters and heavy metals concentration levels obtained for the Wet Season are, comparatively, higher than those obtained for the Dry Season and also higher than the international specifications levels (WHO, SSMO, US-EPA). The concentration levels of lead, cadmium and manganese (in all localities), mercury (in Wad Bushara and Shawor localies), iron (in all localities except Khiari and Subagh localities) are exceptionally greater than the permissible international specifications levels of heavy metals for both seasons. It is recommended that, for both seasons, continuous and routine monitoring tests must be performed by the Water Authorities in that State, and a risk-base assessment approach be implemented.

Keywords: Butana Mining Area, Drinking Water, Physicochemical Parameters, International Specifi cations, Heavy Metals Levels, Permissible Values, Atomic Absorption Spectrometery.

Introduction

Access to a safe and reliable supply of drinking water is essential for the wellbeing of all human beings. However, the availability of fresh water is getting scarce let alone its quality, which becomes a major issue in world. Tough water is important to life; it is one of the most poorly managed resources in the world (Fakayode, 2005). Besides the shortage, the pollution of water by different agents is also a threat to human health and economic growth. These critical drinking water problems are more pronounced in the underdeveloped and some developing countries. Polluted water sources may become the source of undesirable substances, which are dangerous for human health causing's various cancers, cardiovascular or neurological diseases (Galušková *et al*., 2010).

Water intended for human consumption must conform to standard magnitude of physicochemical parameters such as pH, hardness, conductivity and turbidity. It must also abide to certain permissible levels of heavy metals (Hanaa *et al*., 2000; Maigari *et al*., 2014, Younis and Zerabruk 2016). Actually specific drinking water standards are not given or not mentioned for all the four parameters by WHO. On the other hand, USEPA has quoted the pH acceptable value, which is normally, considered as a ((Secondary Maximum Contaminant Level)) Where the regulations are based on aesthetic considerations. The EU regulations document also has given standards for conductivity only (WHO, 2011; USEPA, 2012; EU, 1998). Moreover, drinking water must be free from disease producing microorganisms (Lamikaran, 1999; Shittu *et al*., Zerabruk *Younis*, 2015).

A heavy metal is any metallic element that has a relatively high density and is toxic or poisonous even at low concentrations (Lenntech, R. 2004). Heavy metals exist as natural constituents of the earth crust and are persistent environmental contaminants, because they cannot be degraded or destroyed (Lenntech, R. 2004; United Nations. 2004).Whilst these elements occur naturally they are often bound up in inert compounds. However, their concentrations have increased several folds as a result of anthropogenic activities (Mason, *et al.,* 2012). Human exposure to harmful heavy metals can occur in many ways, ranging from the consumption of contaminated food, exposure to air-borne particles, and contact or consumption of contaminated water and accumulate over a period of time (Lenntech, R. 2004; United Nations. 2004).. Water related diseases can often be attributed to exposure to elevated heavy metal concentrations of both organic and inorganic contaminants. The development in the world in various fields such as industry, agriculture and other technology led to contamination the surrounding environment. The most important of these contaminants are heavy metals contamination such as lead Pb, arsenic As, cadmium Cd, and mercury Hg which is used in extraction of gold in the most mining areas worldwide.

Mining has been identified as one of the human activities which can have a negative impact on the quality of the environment (Donkor *et al*., 2005). The major environmental impact associated with mining is the persistent release of harmful and toxic substances such as Hg, Pb, Cd, and As, among others (Aryee *et al*., 2003; Paruchuri *et al*., 2010).

Groundwater contamination by heavy metals is also often associated with mining activities and the subsequent processing of ores. Heavy metals enter the surface water in dissolved form and in association with substances washed off the ground, whereby they can migrate over long distances (Frankowski *et al*., 2009).

Unorganized public gold mining activities with no scientific basis and safety precautions have been practiced and prevailing all over the Sudan, particularly the Butana region. No governmental or regional official public heath safety rules have been executed or interferences been enforced. Such a situation requires a proper assessment of heavy metals in the water to ensure the availability of harmless drinking water and safe environmental sustainability. The present study is a continuation of our research attempts in environmental issues related to public health (amin & Younis 2009, Mohamed & Youns 2015, Zerabruk & Younis 2016, Younis & Zerabruk 2017). The primary objective of the current research envestigation is to assess the safety and quality of the drinking water in Butana area that conform to International specifications [Table 1]. The present research investigation is also continuation of our previous research attempts in establishing a validated laboratory criterion that could be adopted to assess the safety and quality of drinking water in Sudan and neighboring countries (Zerabruk and Younis, 2015, 2016, Younis and Zerabruk 2017).

Table1: Heavy Metals Levels International Specification in Drinking Water

Standard Name	**Heavy Metals (µg/L)**									
	Hg	**Cd**	**Co**	**Cr**	**Cu**	**Fe**	**Mn**	**Ni**	**Pb**	**Zn**
USEPA, 2008	NC	5	100	100	1300	300	50	100	15	5000
EU, 1998	NC	5	NC	50	2000	200	50	20	10	NC
WHO, 2008	0.006	3	NC	50	2000	NGL***	400	70	10	NGL**
SSMO	0.006	10	NC	50	1000	1000	500	NC	50	NC

NC = No Record; ** NGL= No Guideline; *** No Guideline, because it is not of health concern at concentrations normally observed in drinking water, but may affect the acceptability of water at concentration above 300 µg/L; NGL[a] No Guideline but desirable less than 5 NTU; [b] based on quality (Aesthetic) not safety (Health risk); [c] Chromium as Cr^{+6} not total Cr.

Materials and Methods:

Site Description and water Sampling:

The study area is located in central Butana area [Fig 1] within the administrative boundaries of rural Subagh locality of Gedarif State, Eastern Sudan, It comprises vast clay plains extending from the Gedarif area in the south up to latitude -15^{o}N and from the banks of the Blue Nile River in the west up to banks of the Atbara River in the east. Climatically, the area is set within semi arid to Savannah region (Van der Kevie, W.; 1973) with high temperature in summer is around 40-45^{0}C (March - October) and cold winter 18-25 ^{0}C in winter (December-February). The vegetation is spares, confined to the valleys and is made up of acacia type (Acacia Sayal and Acacia mallifera). The rainy season in the Central Butana is between 150 to 400 mm during the months of July and September, raining although intermittent increases from north to south. There are two main facilities for surface water storage in the study area. The Hafirs are very common water reservoirs throughout the Sudan. They are water harvest catch-up of rain water in the form of small dams. They are the only sources of water supply for human and animal consumption. The other source of water supply is ground water, in which wells are scattered through far distances.

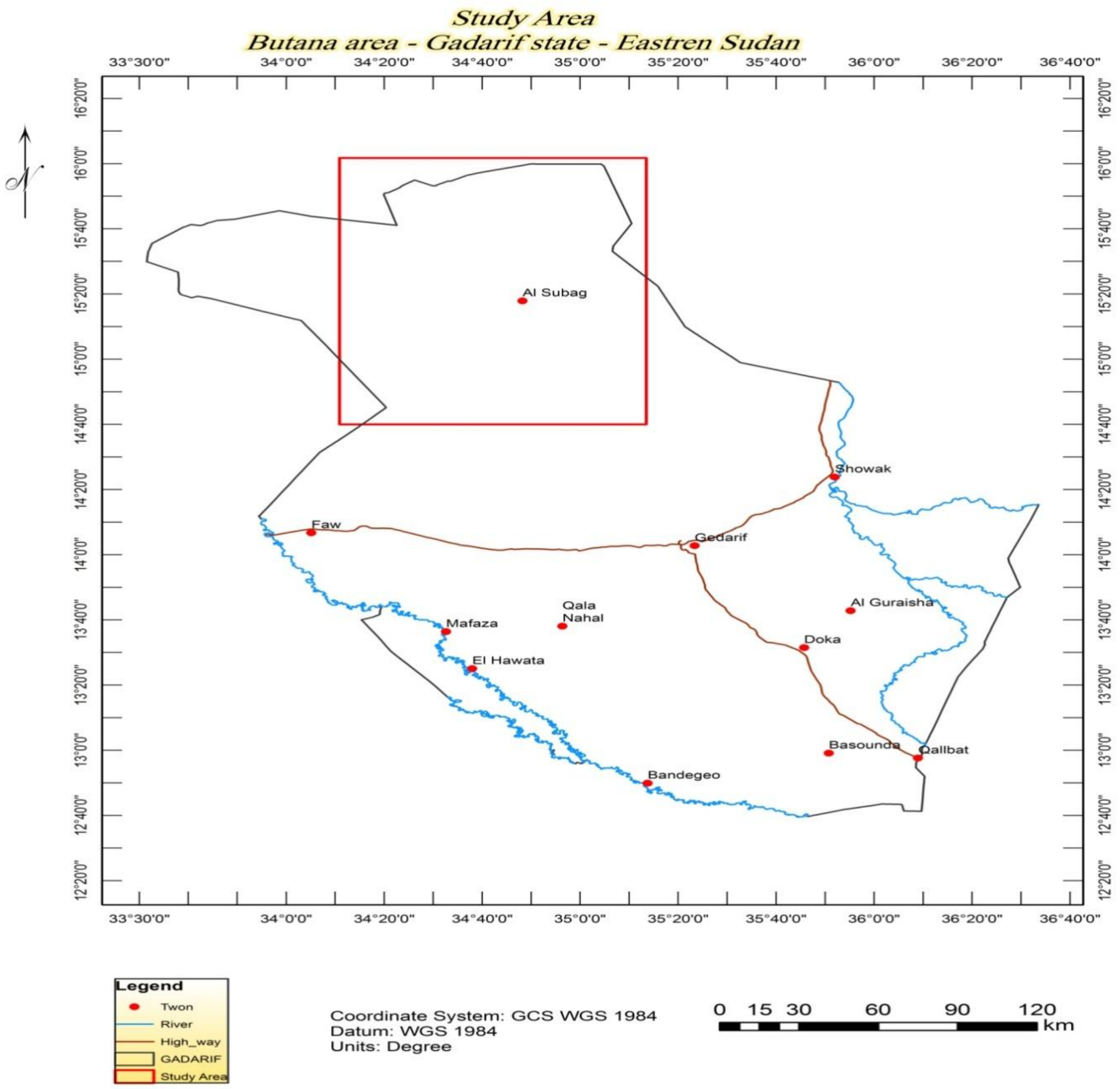

Fig 1: Map of Study Area

Sampling Procedure:

A total of 64 water samples were collected from 6 sites in Butana mining area. Random sampling was adopted. Sampling has been done for the month of May (summer) 2015 and October (rainy) 2015 to authenticate the seasonal variations. The water samples used for the determination physicochemical parameters were collected in pre-sterilized screw capped Borosilicate glass bottles of 250 ml capacity, according to APHA and WHO guidelines (APHA, 1998; WHO, 2006). Samples of drinking water for the analyses of metals and hardness were collected in prewashed polyethylene bottles of 0.5 liter capacity. For preservation, the samples were acidified *in sit* to pH < 2 with concentrated Nitric acid (HNO_3) in the proportion of 1.5 ml of concentrated HNO3 per 1 liter of sample water (APHA, 1998). These water samples were then carefully packed and transported to Khartoum and analyses were performed upon arrival.

Preparation of water samples and standards:

The water samples were filtered with 0.45 µm pore-size filter papers into a 50 mL volumetric flask and then introduced directly in the instruments (pH meter, Conductivity meter, Turbidity meter, Atomic Absorption Spectroscopy (AAS)), and without any prior treatment (Bader and Zimmermann, 2012).

Determination of Physicochemical Parameters

Measurement of pH and Conductivity

The pH and conductivity parameters were determined by electrochemical methods; with the adoption of the WTW-pH/Cond 340i instrument, following the instructions recorded in the Instruction Manual (WTW, 2007; Radiometer Analytical SAS, 2004) provided by the manufacturer. Measurements in triplicate runs for both parameters were taken at 20°C.

Determination of Turbidity

Turbidity was determined by adoption of Palintest Photometer 7500 instrument. The measurement runs were performed according to the instructions described in the Instruction Booklet of the manufacturer (Palintest Instruments, 2009). Values were in Formazin Turbidity Units (FTU) based on the fact that FTU is equivalent to Nephlometric Turbidity Units (*NTU*) as recommended by the manufacturer.

Determination of Hardness

Determination of hardness was performed by the method described in (Vogel, 1989). The titration involved water sample against EDTA (Ethylene Di amine Tetra Acetate) using Eriochrome black T as indicator. An average value for triplicate determinations was recorded.

Determination of the concentration levels of heavy metals

The analytical instrument used for the determination of heavy metals in the water samples were performed using Savant AA 5^{th} generation AAS from GBC. The air-acetylene flame was adjusted according to the manufacturer's recommendation. For each of the heavy metals, the standard solutions were prepared by serial dilution from known standard stock solutions of 1000 mg/L. A calibration curve was prepared and then the analysis of the samples for the heavy metals was performed. All measurements were made in triplicate.

Statistical Analysis

The SPSS statistics 24 was used for data analysis has been adopted.

Results and Discussion:

Indisputably, surface water, running or reserved, in areas near, within or around industrial sites and mining activities is prone to be polluted with several kinds of chemical pollutants and hence be unsafe for drinking. The objective of present study is to assess the safety and quality status of Butana area, which is recently undergoing a boom of public mining activities. It is noteworthy to mention that the primary general aim of the current investigation is to adopt a simple, easy to implement and reliable research protocol to examine and investigate the safety and quality of drinking water, irrespective of its source and its kind. This research idea is original and the laboratory attempts and results outcomes would be subjected to validation and verifications. The idea is based on, simply, the selection of suitable conventional physicochemical parameters determinations and also determinations involving concentration levels of heavy metals for both the Dry and Wet Seasons Table 2 and Table 3. Accordingly, the present study involved the measurements and determinations of pH, hardness, turbidity, conductivity and total dissolved salts (Table 2), in addition to the concentration levels of 10 heavy metals of different kinds and ranges of health risk effects, namely: Cd, Co, Cr, Cu, Fe, Mn, Ni, Pb, Hg and Zn**,** given in Table 3:

Table 2: Values of Physicochemical parameters Determinations (Dry and Wet) Seasons in the drinking of rural Subagh locality of Butana Region.

Parameter	**Standard Name**			**Sample mean value in Dry Season**	**Sample mean value in Wet Season**
	WHO	**SSMO**	**US-EPA**	**This Study**	**This Study**
pH	6.5 – 10.0	6.5 - 8.5	6.5-8.5	7.43	8.03
Conductivity µs/c	250	NM	NM	1280	2078
Turbidity FTU	NG	NM	0.5-1	7.09	16.87
Total Dissolved solids mg/L	NGL**	80- 500	500	841.66	1050
Total Hardness mg/L	200	200	NM	133.66	211.7
Chloride mg/L	250	250	NM	44.00	65.12
Sulphate mg/L	250	250	NM	240.3	257.9
Nitrate mg/L	50	20	NM	44.66	45.84

NM=Not Mentioned; NG=Not Given

It could be noticed in Table 2 that the mean values obtained for the pH parameter in dry season 7.43 and wet season 8.03 are, generally, within the acceptable range of the permissible levels of WHO, USEPA and SSMO standards (Table2). Although the water in the Wet season has adheres to the alkaline property more than in the dry season, yet and the difference in pH between two seasons is slight.

The Electrical conductivity (EC), which is a measure of water's ability to conduct an electric current is also related to the amount of dissolved minerals and their salts in water TDS. Moreover, higher value of EC is a good indicator of the presence of contaminants such as sodium Na^+, potassium K^+, chloride Cl^- or sulphate SO^{4-} (Orebiyi *et al.*, 2010). Analysis has revealed that EC value (2078 µs/c) for the Wet season is twice as high as that of the Dry season (1280 µs/c) but extremely above the WHO permissible value (250 µs/c). Furthermore, the conductivity value in the Wet season is higher than conductivity in Dry season by 798 µs/c.

According to WHO (2008), there is no health based limit for TDS in drinking water, as TDS occurs in drinking water at concentrations well below toxic effects, but the palatability of water with TDS level of less than 500 mg/L is generally considered to be acceptable and sometimes considered to be graded as good. Drinking water becomes significantly and increasingly unpalatable at TDS Levels greater than about 1000 mg/L. TDS greater than 1200 mg/L may be objectionable to consumers and could have impacts for those need to limit their daily salt intake e.g. Severely hypertensive, diabetic, and renal dialysis patients (London *et al.*, 2005). The samples analyzed were found contain TDS value of greater than 500 mg/L in both seasons, the TDS value in wet season 1050 mg/L is moderately higher than TDS in dry season is 841.66 mg/L (Table 2).

Total hardness is defined as the sum of the calcium and magnesium concentration, both expressed as CaCO3, in mg/L. the total hardness were found in samples analyzed in wet season (211.7 mg/L) (Table 2) is greater than the WHO (2008) (Table 1) maximum admissible limit(200 mg/L).Whilst the hardness levels in dry season is less than limit.

The total hardness in wet season is moderately higher than hardness in dry season by 78.04 mg/L.

The mean annual value of turbidity of the in wet season16.87FTU is more than two folds higher than that of turbidity in dry season7.09 FTU . The difference could, obviously, be attributed to differences in seasons (rainy season).

The sulphate level in wet season (257.9) mg/L (Table 2) is above WHO (2008) maximum admissible limit(250 mg/L).The chloride and nitrate levels in drinking water in study area from both dry and wet season are below the maximum admissible limit (250 mg/L)and (50 mg/L) respectively.

Concentration Levels of Heavy Metals:

Guidelines for the presence of heavy metals in drinking water have been set by different international organizations like US EPA, WHO, European Union commission (Momodu and Anyakora, 2010) and many national organizations like Bureau of Indian Standards (BIS) Sudan have also set their own drinking water standards (Table 1). As specified by these organizations there are maximum admissible limits for heavy metals in drinking water.

The concentrations of heavy metals: Hg, Cd, Co, Cr, Cu, Fe, Mn, Ni, Pb, and Zn in the drinking water samples analyzed are presented in Tables 3.

Table 3: Concentration Levels of Heavy Metals in Dry and Wet Seasons in Micro sites of the Butana Region

Metal	Statistic value	Season	Sample location Label					
			Fuwail	Khiari	Wad Bushara	Shawor	Subagh	Ead Wahash
Ni	Mean	Dry	0.004	0.008	0.013	0.005	0.008	0.018
		Wet	0.020	0.110	0.350	0.014	0.009	0.142
Cr	Mean	Dry	0.029	0.018	0.024	0.016	0.041	0.052
		Wet	0.082	0.064	0.154	0.003	0.053	0.167
Co	Mean	Dry	0.056	0.073	0.075	0.063	0.065	0.063
		Wet	0.097	0.323	1.03	0.080	0.078	0.129
Zn	Mean	Dry	0.003	0.003	ND	0.001	ND	0.0005
		Wet	0.022	0.090	0.0385	0.0012	ND	0.0045
Cu	Mean	Dry	0.009	ND	ND	ND	ND	ND
		Wet	0.010	0.002	0.012	0.001	ND	0.005
Pb	Mean	Dry	0.256	0.288	0.242	0.278	0.294	0.261
		Wet	0.300	0.305	0.287	0.290	0.450	0.419
Cd	Mean	Dry	0.018	0.014	0.008	0.020	0.023	0.014
		Wet	0.065	0.025	0.031	0.080	0.072	0.061
Mn	Mean	Dry	0.208	0.178	1.019	0.997	ND	ND
		Wet	0.710	0.256	1.962	1.150	0.025	0.046
Fe	Mean	Dry	0.826	0.011	0.463	1.792	0.244	0.467
		Wet	1.591	0.402	1.032	2.921	0.370	1.073
Hg	Mean	Dry	ND	0.0002	0.004	0.001	ND	ND
		Wet	0.0045	0.070	0.095	0.015	ND	0.0037

ND=Not Detected

The highest heavy metal concentration was found for iron (2.921 mg/L) in water sample from Shawor micro site. On the other hand, the level of lead and cadmium were above the stipulated limit of the WHO and USEPA in all the samples. Cobalt, which is not mentioned in the WHO and SSMO specifications is the only heavy metal that was below the permissible limit of USEPA in any of the samples.

The concentration level of nickel in the Dry Season ranged from 0.004 to 0.018 mg/L, and it is in the range of 0.009 to 0.035 mg/L in the Wet Season which is twice higher than that recorded for the Dry

Season. It is important to notice that the Nickel levels in drinking water in Wet Season in Khiari, Wad Bushara, Shawor, Ed AL Wahash sites were below WHO permissible limit of 0.07 mg/L for drinking water.

Chromium is an essential micronutrient for animals and plants, and is considered as a biological and pollution significant element. Generally the natural content of chromium in drinking water is very low ranging from 0.01 to 0.05 mg/L except for the regions with substantial chromium deposits (Jayana *et al*., 2009). Chromium in excess amounts can be toxic especially in the hexavalent form. Sub chronic and chronic exposure to chromic acid can cause dermatitis and ulceration of the skin. Long-term exposure can cause kidney, liver, circulatory and nerve tissue damages. Chromium often accumulates in aquatic life, adding to the danger of fish that may have been exposed to high level of chromium (Hanaa *et al*., 2000; Pandey *et al*., 2010).

In this study, the chromium concentrations of samples collected in dry season ranged from 0.016 to 0.052 mg/L and from 0.003 to 0.167 in Wet season. The chromium levels was detected in only one sampling area in dry season and in 5 of the sampling areas in wet season which are above the WHO (2008) maximum admissible limit of Cr in drinking water (0.05 mg/L). The highest level of chromium recorded for samples from Ed Al Wahash site. (mean concentration, 0.167 mg/L).

The cobalt concentration ranges from 0.056 to 0.075 mg/L in dry season and from 0.078 to 1.03 mg/L in wet season with the maximum (1.03 mg/L) in drinking water sampled from Wad Bushara mining area and minimum (0.075 mg/L) from Al subagh site. Though the maximum admissible limit of cobalt is not mentioned by WHO (2008), all the samples analyzed in dry season and some in wet season comply with the New Zealand (1 mg/L) and US EPA (0.1 mg/L) maximum admissible limits of cobalt in drinking water except the samples of Wad Bushara, Khiari and Ed Al Wahash sites.

The zinc concentrations recorded in samples collected in dry season ranged from (0.0005 to 0.001) mg/L and from (0.0012 to 0.090) mg/L in Wet season. The zinc concentrations recorded from all mining sites in different season were within the WHO permissible limit of 3.0 mg/L for drinking water. However, zinc concentrations were higher in samples collected in Wet season as compared with samples in dry season. Zinc is an important trace element that plays a vital role in the physiological and metabolic process of many organisms including humans. Nevertheless, higher concentrations of zinc can be toxic to organisms (Ferner, D.J. 2001).

Contamination of drinking water with high level of copper may lead to chronic anemia (Acharya *et al*., 2008). In this study, Copper concentration was found to be below the detection limit in 5 of the sampling areas in dry season. In the other season, copper concentration ranges from 0.001 to 0.012mg/L with the maximum (0.012 mg/L) in drinking water sampled from Bushara site and minimum (0.001 mg/L) from Shawor site, the copper levels in all samples in both season were below the WHO (2008) maximum admissible limit of Cu in drinking water (2.00 mg/L); there was no health related risk due to the presence of copper in drinking water of the study areas.

Lead is the most significant of all the heavy metals because its high toxicity, very common (Gregoriaadou *et al*., 2001) and harmful even in small amounts and the inorganic forms are absorbed through ingestion by food and water, and inhalation (Rajkovic, *et al.*, 2008). High concentration of lead in the body can cause death or permanent damage to the central nervous system, the brain, and kidneys (Hanaa *et al*., 2000). In this The lead concentrations in samples ranged from 0.242 to 0.294 mg/L in dry season, samples in Wet season recorded lead concentrations ranging from 0.287 to 0.450 mg/L. Samples in dry season recorded the lowest lead concentration. Almost all samples from Butana sites in Wet and Dry Season exceeded the WHO stipulated limit of 0.010 mg/L for drinking water.

The maximum concentration of Pb in dry and wet season was recorded in the Al Subagh Sites and the minimum was recorded in Wad Bushara site. The high content of Pb in these sites could be due to weathering and leaching of lead from waste rocks dumps.

Cadmium concentrations obtained from samples in dry season ranged from 0.008 to 0.023 mg/L and in wet season ranged from 0.025 to 0.72 mg/L. The mean Cd concentrations of all sampling sites from both season exceeded the WHO permissible limit of 0.003 mg/L for drinking water. The lowest concentration was recorded in wet season from Khiari sampling site whilst the highest concentration was recorded from Al Subagh site. Cadmium causes adverse health effects such as kidney damage, bronchitis, and osteomalacia (soft bones) at very low exposure levels (Young, R.A.2005); Cadmium affects the nervous system, causes damage to DNA and the immune system, and enhances the development of cancer. It can also cause other non-cancerous diseases that include loss of sense of smell and taste, fibrosis, upper respiratory diseases, shortness of breath, skeletal effects, lumbago, hypertension, tubular proteinuria, and cardiovascular diseases (APHA, 2001).

Manganese level varies from (0.178- 1.019) mg/L in dry season to (0.025- 1.962) in wet season. WHOs' (2008) for manganese is 0.4 mg/L and in two sampling area in dry season and 3

Sampling areas in wet season of the drinking water samples analyzed show above the limit.

Iron is the fourth most abundant element by mass in the earth's crust. In water, it occurs mainly in ferrous or ferric state (Ghulman *et al., 2008*). Iron in surface water generally present is ferric state. It is an essential and non-conservative trace element found in significant concentration in drinking water because of its abundance in the earth's crust. Usually, iron occurring in ground water is in the form of ferric hydroxide, in concentration less than 0.5mg/L (Oyeku and Eludoyin, 2010). The shortage of iron causes disease called "anemia'' and prolonged consumption of drinking water with high concentration of iron may lead to liver disease called as haermosiderosis (Rajappa *et al.*, 2010; Bhaskar *et al*., 2010). In the areas studied, iron content varies from 0.011 to 1.792 mg/L in dry season and from 0.370 to 2.921 mg/L in sample taken in wet season. All samples taken in Wet season not comply with the desirable concentration of iron in drinking water (0.3 mg/L) set by WHO (2008),No guideline is set by WHO (2008) for iron content in drinking water because it is not of health concern at concentrations normally observed in drinking water

Mercury concentrations in water samples in dry season ranged from 0.0002 to 0.004 mg/L, whilst levels recorded in wet season ranged from 0.00037 to 0.095 mg/L. Mean Hg levels in drinking water in Wet Season in Khiari, Bushara, Shawor sites were above World Health Organization WHO permissible limit of 0.010 mg/L for drinking water. Drinking water sources in wet season recorded higher concentrations of Hg compared to the dry season. This could be due to the washing of gold-bearing ores close to the water bodies. In Bushara and Khiari ores are transported from mining sites, crushed, washed, and the gold extracted with Hg very close to available water bodies. The water bodies were polluted perhaps due to the direct washing of gold bearing ores in the area and the percolation of Hg-ladened waste water released from the washing bay. Generally, mercury concentrations were high in water bodies that were close to the mining activities in each community.

Conclusions:

It could be concluded that the drinking water consumed by humans and animals in the Butana study area is the one that is reserved in Haffeirs, which are actually catch-ups reservoirs that harvest rain water that run and passing through the gold mining areas and other wash-up that transport salts and heavy metals associated with the gold ore, to end in these reservoirs in addition to other activities such as mineral exploitation, crude gold ore transportation, smelting, refining and the unorganized disposal of tailings (waste materials). During these processes heavy metals, particularly Hg, Cd, As and others are expected to be carried over to be the main persistent environmental hazardous pollutants of the harvested water in Haffeirs. Such toxic pollutants are expected to be detected in the water bed itself or may be precipitated on the bottom of Haffeirs as sediment. The chemical components of the sediment may ooze through the soil and hence pollute the ground water as well. It could also be concluded that: the 6 physicochemical parameters of (pH, EC, TDS, turbidity, water-hardness, and some acidic radicals) are not adhering to, or extremely higher than the stipulated WHO (WHO, 2008) standards. It could also be concluded that results have shown that the concentration levels of heavy metals in Wet Season is remarkably, higher than the Dry Season. Presumably, due to the washings processes existing in the tailings and mining wastes. The Cr, Cd, Hg and Pb, which were above or equal to the permissible maximum concentration levels of USEPA and/or EU, but higher that the WHO permissible values. The guideline levels for Fe and Zn are not given by WHO as they are not considered health hazards. However, there is a need for improvement in the water treatment processes, especially in the Wad Bushara and Shawor mining areas where measures should be implemented to remove or reduce the levels of Cr, Pb and Hg to the acceptable levels. It was also being observed that there is no water treatment practices of any kind in these areas add to health implications due to water quality in that territory. It is important to mention here that, during the sampling periods, severe drinking water shortages and weak drinking water storage practices have also been observed. It is recommended that an investigation should be carried out on Haffeirs sediment to uncover its chemical constitution compatible to previous endeavor (Zerabruk and Younis 2016). Moreover, a risk-based assessment should be performed relative to our previous reported studies (Zerabruk and Younis 2017). It is noteworthy to mention that this paper is reporting the initial phase of a five-year scheduled plan to test the drinking water quality, safety and accessibility parallel to the intensification of mining year after year.

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