Small Scale Gold Mining And Heavy Metal Pollution: Assessment of Drinking Water Sources In Datuku In The Talensi-Nabdam District.

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Abstract:- Most people in rural areas in sub-Saharan Africa are poverty stricken. They support their livelihoods by the exploitation of natural resources in their vicinity which often result in environmental degradation. This study was carried out in Datuku in the Talensi-Nabdam District in the Upper East region of Ghana to assess the effect of small scale gold mining on the quality of drinking water in the community. Water quality was based on physico-chemical analysis of samples collected from water source in the community. A total of seventy-two water samples were collected from surface and ground water sources in the study area for a period of six months and analysed. Generally many of the parameters analysed were well within the World Health Organisation's (WHO) recommended limits for drinking water quality. pH ranged from 6.72 to 7.95 (7.3), conductivity ranged from 204 to 1565 µs/cm (666.5 µs/cm), chloride ranged from 8 to 113 mg/l (44.13 mg/l), sulfate ranged from 4.7 to 428 mg/l (39.81 mg/l) and 0.018 to 19.41 mg/l (2.23 mg/l) for total iron. A few of the parameters were however, above WHO's limits. Turbidity, nitrate, cadmium, total iron, manganese and arsenic levels were higher than WHO's recommended limits for drinking water quality. Turbidity ranged from 1 to 447 NTU (55 NTU), nitrate ranged from 0.15 to 595 (47.1), cadmium ranged from 0.005 to 0.029 mg/l (0.014 mg/l), manganese ranged from 0.036 to 2.24 mg/l (0.66 mg/l) and 0.001 to 0.009 mg/l (0.003 mg/l) for arsenic.

Key words:- Datuku, small scale gold mining, Water quality, heavy metal pollution.

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1 INTRODUCTION

In most African countries, even in relatively advanced countries, safe drinking water is not easily available. In 2002, it was reported that out of the 6 billion people on earth, more than one billion lack accesses to safe drinking water and, about 2.5 billion do not have access to adequate sanitation services [1]. Ghana is one of the lucky countries in the world that is endowed with rich natural resources including gold. The wealth and strength of large ancient Ghanaian empires and cultures was due to the gold deposits which resulted in Ghana being named the 'Gold Coast' during the colonial exploration [2]. Gold exploitation in Ghana is in two types. That is large scale mining and small scale mining. Whereas the large scale mining involve the use of scientific methods and sophisticated machines in mining, the small scale mining makes use of simple tools in the recovery of gold from the land. Although gold mining has played a significant role in the socioeconomic life of Ghana for the past hundred years [3], gold mining in recent times has become unpopular as it is regarded as a significant source of heavy metal contamination of the environment owing to activities such as mineral exploitation, ore transportation, smelting and refining, disposal of the tailings and waste waters around mines [4], [5], [6], and [7].

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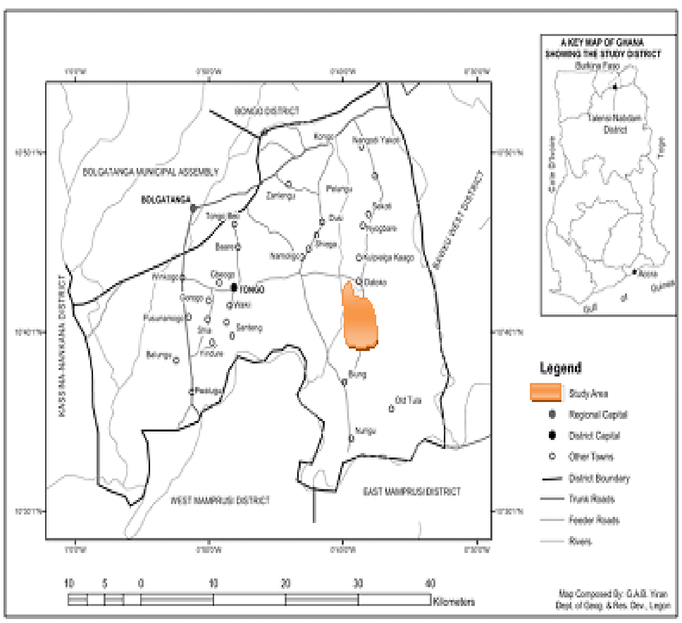
Both anthropogenic pressures and natural processes account for degradation in surface water and ground water quality [8]. In Ghana, contaminations of surface and ground water bodies have particularly been experienced in gold mining communities [9], [10], [11], and [6]. Some of the impacts associated with gold mining include land degradation, destruction of vegetation and pollution of aquatic environments. With regards to gold mining in Datuku in the Upper East region of Ghana, gold bearing ore is ground thoroughly and mixed with mercury to form an amalgam. The gold amalgam is roasted to release mercury and to concentrate the gold. Excess mercury in the mine tailings is discarded onto the environment which ends up in water bodies through run off. Methylmercury in water and mercury oxides in air that result from gold amalgam finds itself in humans through inhalation or ingestion of water or mercury-contaminated fish or food [12]. Weathering of rocks and heaped waste materials in mining sites also result in the release of toxic chemicals into the environment especially, into aquatic bodies [3]. The discovery of gold in the Talensi traditional area in the early 1990s has affected gender and other social relations in many communities including Datuku in the Talensi-Nabdam District [13] though, small scale gold-mining provide thousands of indigenous peoples with employment and making important contributions to foreign exchange earnings. Other ills observed in the community since the inception of small scale mining activities are rapid lost of farm lands, water In the study area, mining results in heaping of rocks and mine waste around trees. Silting of rivers and streams is also evident. Contaminations of surface and ground water bodies have particularly been experienced in gold mining communities in Ghana [6]. Heavy metals that can be leached from waste rocks into water bodies include arsenic (As), cadmium (Cd), chromium (Cr), mercury (Hg), lead (Pb) and zinc (Zn) [14]. Literature sources point to the fact that most cognitive impairments especially in children is due to the presence of elevated levels of trace metals such as mercury (Hg), lead (Pb), zinc (Zn), arsenic (As) and cadmium (Cd) in the environment. Afrikids-Ghana (NGO) reported that poor academic performance of pupils in some communities in the Talensi-Nabdam District is due to the fact that pupils lavish their time and attention on mining to get quick money to the neglect of their books. However development of low intelligent quotient and other health risks could also be linked to exposure to trace metals such as Hg and As [12]. Since the inception of small scale gold mining in Datuku in early 1990s, no work has been done on water quality. The main goal of this paper is to determine the levels/concentration of some of the physicochemical parameters and trace metals (Hg, As, Cd, Mn, Fe and Zn) in drinking water in Datuku and, to compare the values with international organization such as the World Health Organisation's (WHO's) recommended drinking water standards. This will help to determine the state of the quality of drinking water in the community and suggest measures to reduce or prevent water pollution in the area.

2 MATERIALS AND METHODS

2.1 Study area

The study was conducted in Datuku in the Talensi traditional area of the Talensi-Nabdam District of Upper East Region. The community is located in the south- eastern belt of Tongo, the District capital (Fig 1) which lies 5 miles south from the Upper East regional capital Bolgatanga. The district lies between latitudes $10^{0}15´$ and $10^{0}60´$ north of the equator and longitudes $0^{0}31´$ and 105´ west of the Greenwich meridian. The community has a dry savannah climate and vegetation, poor soils, and irregular rainfall patterns leading to poor crop yields and inadequate levels of food production.



(Awumbila and Tsikata, 2005).

Figure 1: Map of Talensi-Nabdam District showing Datuku community.

2.2 Water sampling and analyses

Random sampling techniques were employed in the selection of sampling sites in the study area. Sampling was done between October 2011 and March 2012. A total of seventy-two water samples were collected from six drinking water sources for a period of six months from the study area. Sample bottles were rinsed with deionised water twice before samples were collected. Collected samples were preserved in ice chest with ice at temperature of $4^{o}c$. Samples were taken in separate containers for physicochemical and trace metal analysis respectively. Samples for trace metal analysis were each preserved with 0.5 ml of concentrated nitric acid before transporting to the laboratory at Water Research Institute, Tamale for analysis. The samples were analysed for various parameters including electrical conductivity, pH, total dissolved solids, total suspended solids, turbidity and trace metals such as mercury (Hg), arsenic (As), cadmium (Cd), manganese (Mn), total iron (Fe) and zinc (Zn). Physical parameters like conductivity and total dissolved solids of the samples were measured using conductivity meter. pH and turbidity were recorded using pH meter and turbidimeter respectively. Trace metals (Zn, As, Cd, Fe, Mn and Hg) analysis was done using the Shimadzu model AA 6300 in accordance with APHA standard methods [15].

3. RESULTS AND DISCUSSIONS

The range, mean and standard deviation of six physicochemical parameters (electrical conductivity, pH, total dissolved solids, Sulfate (SO_4), turbidity and Nitrate) as well as WHO's maximum admissible limit for each of the parameters are presented on Table 1. Total dissolved solids (TDS) in water samples from Datuku ranged from 121 mg/l in AB to 936 mg/l in AAP (Table 1). The values for TDS in all the water sampling locations were within WHO, 2008 guidelines for drinking water quality. According to WHO (2008), there is no health based limit for TDS in drinking water, as TDS in drinking water at concentrations well below toxic effects may occur. However the palatability of water with TDS level of less than 500 mg/L is generally considered to be 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 the consumer.

Table 1: Level of some physicochemical parameters for drinking water samples from Datuku

Sampling Location		TDS	EC (µS/cm)	pH (pH unit)	SO_4	NO_3-N	Turbidity (NTU)
	MIN	371	621	7.2	11.6	2.6	3
AAP	MAX	936	1565	7.97	17.9	595	57
	MEAN	586	979.5	7.538	14.84	231.1	20.8
	SD	207.3	346.4	0.268	2.424	230.9	20.97
	MIN	121	204	6.9	4.7	0.16	1
AB	MAX	679	1126	7.73	44.2	58.8	22
	MEAN	460.8	767.8	7.43	25.72	20.79	6.8
	SD	205.3	339.6	0.295	17.42	24.82	8.207
	MIN	323	532	7.14	11.3	0.15	4
OAP	MAX	600	1004	7.56	25.7	6.01	30
	MEAN	406.8	679.2	7.388	17.92	2.93	20.2
	SD	98.53	165.3	0.145	5.30	2.36	8.68
	MIN	261	434	6.84	11	7.52	2
US	MAX	673	1124	7.44	58.3	18.5	201
	MEAN	350.6	582.8	7.258	32.72	10.57	68
	SD	161.4	270.9	0.22	17.93	4.09	76.928
	MIN	195.9	329	6.72	12.6	1.36	3
MS	MAX	770	1285	7.4	119	8.9	447
	MEAN	355.4	593.2	7.196	44	5.33	131.6
	SD	209.4	349.2	0.244	40.1	2.68	160.49
	MIN	170.5	285	6.93	11.8	7.38	2
DS	MAX	277	463	7.42	428	23.4	380
	MEAN	238.7	397	7.168	103.6	11.82	119.4
	SD	42.1	69.53	0.173	162.7	5.93	141.92
	WHO Guideline	**1000**	**NG**	**6.5-8.5**	**400**	**10**	**5**

All units are in mg/l unless otherwise stated
NG- No guideline stated by WHO, 2008.
AAP - "Accra" Abandoned Pit.
AB - "Accra" Borehole.
OAP- Obuasi" Abandoned Pit
US- Upstream.
MS- Midstream.
DS- Down stream

Electrical conductivity of the samples was in the range of 204 to 1565 µS/cm with the minimum value (204) from AB and the maximum value (1565) from AAP. Electrical conductivity (EC) is a measure of water's ability to conduct an electric current. This is due to the presence of some dissolved minerals in the water. Electrical conductivity therefore indicates presence of minerals but it does not give an indication of which element is present but higher value of EC is a good indicator of the presence of contaminants such as sodium, potassium, chloride or sulfate [16]. Although the WHO, 2008 guidelines for drinking water quality does not give maximum admissible limit for EC in drinking water quality, maximum values of greater than 1000 µS/cm were recorded in water samples from all sampling locations except DS. pH of the samples was between 6.72 (MS) and 7.97 (AAP). The samples analyzed were within WHO, 2008 admissible limit (6.5-8.5) for drinking water quality. The concentration of sulfate (SO_4) ranged from 4.7 mg/l (AB) to 428 mg/l (DS). Analysis of the results shows that all the sampling points have mean sulfate value less than the WHO (2008) (Table 1) maximum admissible limit. According to WHO (2008), no health-based guideline is proposed for sulfate. However, because of the gastrointestinal effects resulting from ingestion of drinking water containing high sulfate levels, it is recommended that health authorities be notified of sources of drinking water that contain sulfate concentrations in excess of 500 mg/l. Nitrate concentration varied from 0.15 mg/l (OAP) to 595 mg/l (AAP). Of the samples analyzed, samples from AAP, AB, US and DS were found to contain nitrate value of greater than 10 mg/L. High level of nitrate in drinking water causes methaemoglobinaemia in infants [17]. Turbidity is a measure of cloudiness of water. It has no health effects. However, turbidity can interfere with disinfection and provide a medium for microbial growth. The level of turbidity in water samples from drinking water source in Datuku ranged from 1 NTU in AB to 447 NTU in MS. Mean level of turbidity in all sampling points exceeded the maximum admissible limit for drinking water quality set by WHO, 2008. The high turbidity in surface water was due to run offs and waste water from the extraction of gold. Turbidity in ground water could be caused by inorganic particulate matter from the weathering of rocks. The concentrations of trace metals (total iron, cadmium, manganese, arsenic, mercury and Zinc) in the drinking water samples analysed are presented in table 2. Mercury and zinc were the only trace metals that were below maximum admissible limit for drinking water quality. Cadmium in AAP, OAP and US were below detection limit (Table 2).

Table 2: Level of some trace metals parameters for drinking water samples from Datuku

Sampling Location		T. Iron	Cd	Mn	As	Hg	Zn
	MIN	0.116	<0.005	0.218	0.002	4.00E-04	0.13
AAP	MAX	1.463	<0.005	2.188	0.005	0.005	0.13
	MEAN	0.67	<0.005	0.854	0.003	0.002	0.13
	SD	0.54	<0.005	0.762	0.001	0.002	0
	MIN	0.179	0.008	0.036	0.001	2.00E-04	0.004
AB	MAX	3.346	0.008	0.303	0.007	0.004	0.004
	MEAN	1.762	0.008	0.113	0.004	0.002	0.004
	SD	1.583	0	0.098	0.002	0.002	0
	MIN	0.018	<0.005	0.098	0.002	5.00E-04	<0.005
OAP	MAX	1.937	<0.005	2.037	0.005	0.008	<0.005
	MEAN	0.933	<0.005	0.792	0.003	0.004	<0.005
	SD	0.738	<0.005	0.668	0.001	0.003	0
	MIN	0.078	<0.005	0.075	0.001	4.00E-04	<0.005
US	MAX	3.244	<0.005	1.944	0.009	0.002	<0.005
	MEAN	1.198	<0.005	0.723	0.003	0.002	<0.005
	SD	1.204	<0.005	0.762	0.003	6.00E-04	0
	MIN	0.036	17	0.065	0.001	0.003	0.029
MS	MAX	4.642	17	1.548	0.005	0.02	0.029
	MEAN	1.422	17	0.577	0.002	0.009	0.029
	SD	1.877	0	0.605	0.002	0.008	0
	MIN	0.125	0.005	0.073	0.001	0.002	0.154
DS	MAX	19.41	0.005	2.241	0.003	0.009	0.154
	MEAN	6.657	0.005	0.872	0.002	0.004	0.154
	SD	7.841	0	0.851	0.001	0.003	0
	WHO Guideline	**0.3**	**0.003**	**0.5 (p)**	**0.001**	**0.01**	**5**

All units are in mg/l unless otherwise stated, where < = below detection limits
NG- No guideline stated by WHO, 2008, AAP - "Accra" Abandoned Pit
AB - "Accra" Borehole, OAP- Obuasi" Abandoned Pit
US- Upstream, MS- Midstream, DS- Down stream

The content of total iron recorded in water samples throughout the study period ranged from 0.018 mg/l in OAP to 19.41 mg/l

in DS. The results indicated that all drinking water source in Datuku from which water samples were taken contain level of total iron that exceed maximum admissible limit for drinking water quality set by WHO. Iron is ubiquitous in the earth's crust and an essential element in human nutrition. No health-based guideline value is proposed for iron [17]. However, at levels above 0.3 mg/litre, iron stains laundry and plumbing fixtures. The main sources of cadmium are industrial activities. However, the presence of Cadmium in some of the water sources in the study area could be caused by seepage from the parent rock. The use of cadmium containing products such as batteries, plastics and mining tools are also sources of cadmium in water bodies. Cadmium causes adverse health effects such as kidney damage, bronchitis, osteomalacia (soft bones) at very low exposure levels [18] (Young, 2005). Cadmium was detected in three sampling locations (AB, MS and DS) and ranged from below detection in samples from AAP, OAP and US to 17 mg/l in MS. Cadmium in samples from AB, MS and DS was above WHO's limit. In the study, manganese content varied from 0.036 mg/l in samples taken from AB to 2.24 mg/l in samples taken from DS. Manganese in all sampling points except AB showed mean concentration above WHO recommended limit for drinking water quality. At levels exceeding 0.1 mg/l, manganese in water supplies causes an undesirable taste in beverages and stains sanitary ware and laundry. Concentrations below 0.1 mg/l are usually acceptable to consumers. Manganese is an essential element for humans and other animals. However there have been epidemiological studies that report adverse neurological effects following extended exposure to very high levels in drinking water [17]. Arsenic concentration was found to be higher than WHO limit in all the sampling locations in Datuku with highest mean value (0.004 mg/l) recorded in (AB) and 0.002 mg/l in DS and MS as the least mean value (Table 2). Arsenic in mined rocks and ore stock piles heaped close to surface water bodies could be washed through runoffs into surface water bodies such as the stream [19]. Arsenic is carcinogenic in compounds of all its oxidation states and high level exposure can cause death [20]. Mercury is toxic and has no known function in human biochemistry and physiology. Poisoning by its organic forms includes neurological disorders, total damage to the brain and CNS and is also associated with congenital malformation [21]. In this study, mercury concentration varied from 0.0002 mg/l in AB to 0.02 mg/l in MS. Mean concentration of mercury in all sampling locations were below WHO admissible limit for drinking water quality.
Zinc is one of the important trace elements that play a vital role in the physiological and metabolic process of many organisms. Nevertheless, higher concentrations of zinc can be toxic to the organism [22]. In this study a minimum of <0.005 mg/l and a maximum of 0.13 mg/l zinc concentration were recorded in water samples from Datuku.

4 CONCLUSION

The main goal of this study was to assess the effect of mining on the quality of drinking water in Datuku in the Talensi-Nabdam District with special emphasis on trace metals. A total of seventy-two water samples were collected from six drinking water sources for a period of six months from the study area. All the samples were analyzed for physicochemical parameters and six trace metals (As, Cd, Hg, Mn, Fe and Zn). The results show that values of most of the physicochemical parameters were within the standards set by WHO. However concentrations of nitrate, turbidity and four trace metals (As, Cd, Fe and Mn) in some of the samples were above WHO's recommended limits for drinking water quality. This is an indication of pollution hazards and poses a threat to human health. Water samples from AAP, AB, US and DS were found to contain nitrate values above WHO recommended limit. Turbidity values were higher than recommended limit in all sampling locations. The study revealed that concentration of arsenic and total iron in all sampling points was above WHO limits for water quality. Cadmium was high in AB, MS and DS while concentration of manganese was high in all sampling locations except AB. This study, therefore, recommends that activities of miners should be monitored to ensure that gold extraction and other mining activities do not occur close to drinking water sources. Also miners and the entire community should be educated on the health risk associated with human exposure to trace metals to prevent them from polluting water bodies.

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