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Assessing the potential health impact of selected heavy metals that pollute lake amponsah in Bibiani, Western North region, Ghana

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ABSTRACT

Gold mining contributes significantly to social, economic, and infrastructural development in Ghana. Apart from these benefits, mining activities have negative impacts on the environment as well as the health of fringe communities who depend on the environmental resources for survival. However, despite the increase in small scale mining in the Bibiani Anhwiaso Bekwai Municipal, the extent to which these activities have impacted on the quality of the Amponsah lake is largely unknown. This study, therefore, assessed whether or not the activities of small- scale miners have impacted the quality of the Amponsah lake as well as the health of the people living in the fringe communities who depend on it for survival. The study used qualitative and quantitative data obtained from the laboratory analysis of water samples as well as the thoughts and opinions of occupants of the fringe communities to achieve the objectives of the study. Findings showed that aside total suspended solids, all the physical parameters assessed were below the Ghana Environmental Protection Agency standards. The mean recorded values for pH, temperature, dissolved oxygen, conductivity, total dissolved solids, and total suspended solids were 7.20, 29 °C, 4.80 mg/cm, 383.00 µS/cm, 185 ml/l and 132.40 mg/l respectively. Also, mean concentrations of 0.0053 mg/l, 0.3110 mg/l, 0.0372, and 0.0440 mg/l were recorded for Hg, As, Cd, and Zn respectively with the concentration of zinc only falling below the Ghana Environmental Protection Agency standards. Further, human activities such as small-scale mining, discharge of waste from nearby communities as well as leachate from a dumping site, are the major contributing factors causing pollution in the lake. Mercury source in Lake Amponsah could be through activities of small- scale miners operating around the lake over the years. The unusually high concentration of As could be likely due to the geology of Bibiani. In conclusion, the physicochemical characteristics of the Lake Amponsah have been compromised pointing to a polluted status except for Zn and total suspended solids.

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Introduction

Ghana formerly called Gold Coast is known for its richness in natural resources such as gold. It is the largest gold producing country in Africa, producing 4.8 million ounces of gold [5].

Gold mining in Ghana is referred to as one of the central occupations [13]. A reviewed report by the Ministry of Lands and Natural Resources, states that mining has contributed a lot to the socioeconomic development of Ghana in terms of social development and infrastructure. The activities of artisanal and small-scale mining in Ghana are very intense especially along the tributaries of Tano, Pra, Offin, and the Ankobra Rivers. Gold mining communities in Ghana mostly depends on groundwater (wells and boreholes) as their basic water resource, but access to potable water is very significant to human health and developmental issues in a country as it is a basic human right and a component of an effective policy for the protection of health [17]. Fundamentally, water has been used for domestic and industrial purposes as well as a support to the aquatic ecosystem.

Aside from all the benefits of water, environmental challenges such as water pollution have been one of the general problems Ghana has been facing as a result of mining [8]. Human activities such as excessive abstraction, changing the land cover, using the resource as convenient sinks for the indiscriminate disposal of domestic, industrial, and agricultural waste which causes the liberation of pollutants, have been continuously polluting water bodies [12]. Small scale mining, is one of the activities that is carried out by some of the citizens in Ghana to sustain their livelihood. However, the activities of small-scale miners within some parts of the country have brought major developmental challenges. These developmental challenges have resulted in the increased pollution load, health and transportation problems, water quality, and reduced ecosystem to most of the endangered species, posing a lot of threats to sustainable development. As a result, there has been a lot of public concern about the condition of freshwaters in Ghana due to the rapidly growing nature of the small-scale mining industry [4].

The working definition for small-scale mining in this research or study refers to any mining method that does not involve the use of high capital expenditure or heavy machinery by a group of persons, with the sole aim of panning for gold [18]. During the extraction process, nitric acid (HNO_3) and mercury are used. The miners do not have any mechanism put in place for recovery and management, hence dispose of these chemicals into the environment.

Arsenic (As), Cadmium (Cd), Mercury (Hg), and Lead (Zn) are the four heavy metals which are of utmost concern to human [4]. Their toxicity causes a lot of damaging effects even at very low concentrations. The Agency for Toxic Substances and Disease Registry (ATSDR) in Atlanta, Georgia, a part of the U.S. Department of Health and Human Services compiled a priority list called the "Top 20 Hazardous Substances." The heavy metals arsenic (1), lead (2), mercury (3), and cadmium (7) appeared on this list. Heavy metals are produced from a variety of natural and human activities such as small-scale mining activities. When it comes to implementing strong environmental and safety regulations as well as adopting voluntary codes of practice and standards, these small-scale operators are ignorant of it [16]. The objective of this study seeks to assess the level of Mercury (Hg), Arsenic (As), Zinc (Zn), and Cadmium (Cd) of the Amponsah Lake to ascertain the level of pollution by the activities of small-scale mining operators and other activities at the banks. Specifically, the study focuses on (1) determining the degree of pollution of heavy metals such as Mercury (Hg), Arsenic (As), Zinc (Zn), and Cadmium (Cd) of the Amponsah Lake, and (2) to determine the effects of heavy metal pollution of the Amponsah Lake on human.

Materials and methods

Description of study area

Bibiani is located in the Bibiani Anhwiaso Bekwai Municipal Assembly (BABMA), a mining township in the Western-North Region of Ghana. The town is situated approximately between latitude 6.47° North and longitude 2.33° West and an elevation of 260 m above sea level as shown in Fig. 1. The total population of the district according to the 2010 population and housing census is 123,272 with 18, 517 people dwelling in and around the lake [6].

The district is bordered to the West by the Sefwi Wiawso District in the Western- North Region, East by the Upper Denkyira West and Amansie Central in the Central Region and Ashanti Region respectively, North by the Atwima Mponua District in the Ashanti Region, and to the South by the Wassa Amanfi in the Western Region [6].

The district has an annual rainfall average between 1200 mm and 1500 mm with a bimodal rainfall pattern. The bimodal climate is characterized by March-August and September-October. The district has an average relative humidity of 75% in the afternoon and 95% in the nights and early mornings. The main water bodies found in the area include Tano, Ankobra, Kyirayaa, and Pamuru, and are mostly used by the nearby communities for drinking and domestic activities [6,7]. Pipe-borne outside dwelling, and pipe-borne inside dwelling, as well as public tap/standpipe, are the main sources of drinking water for the communities in and around the lake [6]. It has natural vegetation and located within the equatorial rain forest zone in the Western-North Region. It has a moist-deciduous forest having odum, mahogany, and sapale as the main tree species of the area [6]. The physiographic characteristics of the area of study are underlain by Precambrian metamorphic rocks of the birimian system. These rock formations (birimian) are known to be gold-bearing rocks. The geological information is encroached by rocks of the eburnean plutonic suite namely micaceous granite, pegmatites, dolerite dykes gabbros, hornblende rich granites, granodiorite, and monzonites [14].

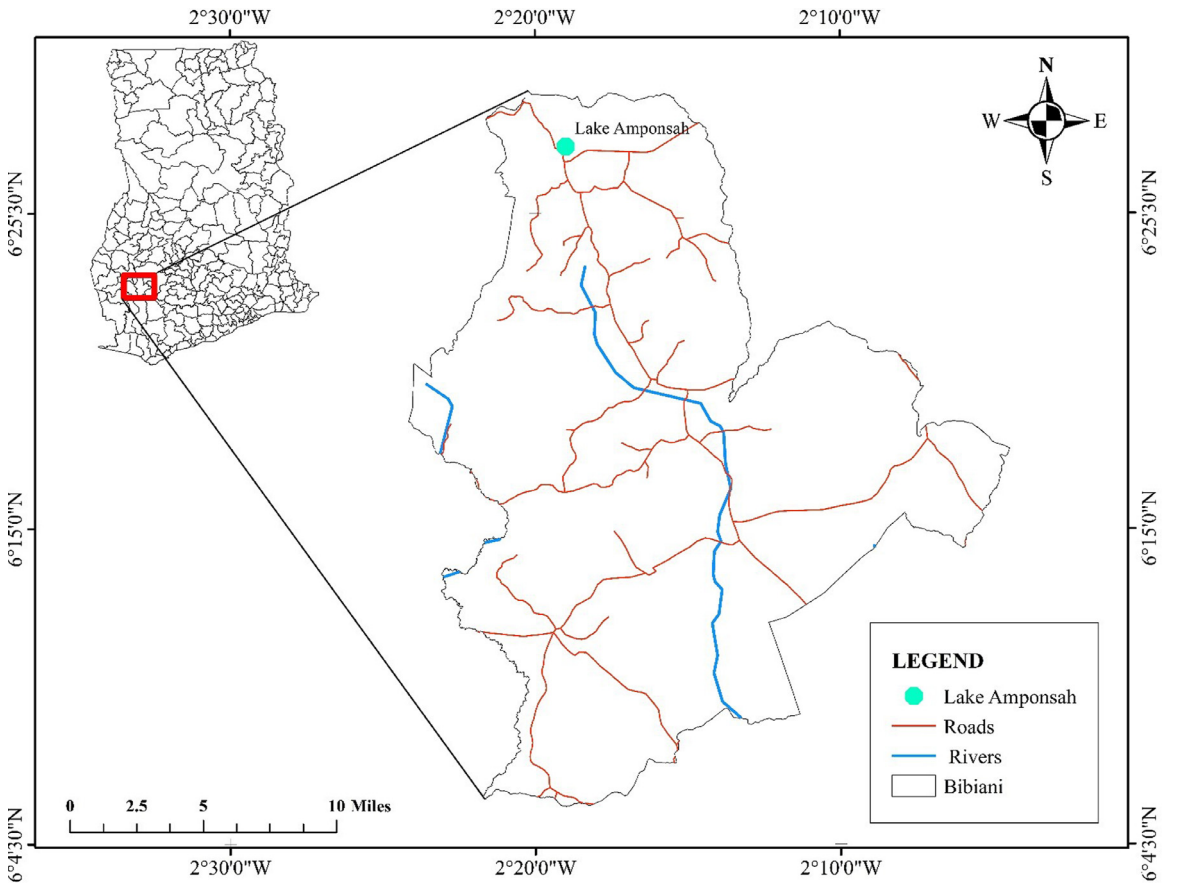

Fig. 1. A Map of Bibiani showing the location of the Amponsah Lake.

Amponsah Lake was constructed by the State Gold Mining Company in the Bibiani Zongo community for domestic water use [12]. The lake has about 168,204.40 m^3 of water (37 million gallons of water) storage capacity covering an area of 0.051 square kilometers. Its greatest depth is about 19 ft (5.79 m) [12]. The major activities in and around the lake include; fishing, bathing, small scale gold extraction activities, and palm kernel extraction activities.

Data collection and preparation

To establish a reliable result, two broad areas were considered as a primary and secondary source of data collection:

a The primary source of data collection included the administration of questionnaires to some workers (small-scale miners) and individuals within the study area as well as hospital officials (doctors working within the study area), interview with some proponents within the nearby communities, and field observation. This was to establish whether or not the lake is indeed posing any health risks to the people who use it.
b A sampling of water for laboratory analysis- laboratory analysis of chemical parameters e.g. trace metals (mercury, arsenic, cadmium, and zinc), DO, as well as a physical parameter of the lake, were analyzed to determine the water quality status of the lake. Parameters such as temperature, total suspended solids (TSS), conductivity, pH, TDS, and dissolved oxygen (DO) were determined onsite with the aid of a portable meter.

This was to determine whether or not the activities of the small-scale miners and others around the lake posed any adverse health impacts to the lake as well as the flora and fauna in and around the community.

Water sampling

Materials used for sample collection included a 250 ml bottled container, 500 ml plastic container, hand gloves, ice chest, ice cubes, concentrated nitric acid for acidification of samples. Sixteen-composite samples were taken starting from February to April.

Procedure for water sampling and analysis

Samples were collected in a bi-weekly interval which started from 4th February 2019 and ended 1st April 2019. They were collected with the aid of a canoe. Samples were carefully collected at designated sampling points. All sampling containers (250 ml bottle) were washed with tap water and detergent, and further flushed thoroughly with distilled water. The bottles were further flushed with concentrated HNO_3 acid, to reduce or eliminate potential contaminants to obtain reliable results.

Specifically, a total of sixteen composite samples were taken from four sampling locations or points, namely; SP-QR_1, SP-QR_2, SP-QR_3, and SP-QR_4. The samples were taken bi-weekly in two months (February to April). Composite samples were chosen due to the following reasons;

I Due to the different activities at the various points of the lake.
II To reduce cost during sample analysis.

Parameters such as temperature, pH, total dissolved solids (TDS), and conductivity were measured on-site using a portable pH meter. After sampling, all samples were acidified with concentrated nitric acid, sealed, labeled (showing sample type, location, site name, and date), and stored over ice in a thermo-insulated container to maintain the samples at a temperature below 4 °C before transportation to the laboratory.

The analysis of the water quality parameters at the laboratory was done following the protocols outlined in the APHA, Standard Methods for the Examination of Water and Wastewater [3].

Questionnaire administration

Administration of the questionnaire was in two forms, namely:

v *Primary form*; this was administered to those who use the lake for most of their daily activities such as small-scale miners as well as people who use the lake daily for fishing, washing, bathing, construction, and extraction processes.

A total of forty-seven (47) questionnaires were administered to respondents to seek their views on the health-related impacts of the activities of the small-scale miners to the flora and fauna of the lake. Forty of the questionnaires were issued to the people of Zongo and Old- Town Community as well as some small-scale mining operators, but thirty of these were retrieved giving a response rate of about 64%. d. This sample size was selected because there were difficulties in engaging with the small-scale mining operators.

v *Secondary form*; engagement with health officials in the health sector within the Bibiani township. This was to determine whether individuals have been reporting cases related to pollution of heavy metals (mercury, arsenic, cadmium, and zinc).

Seven (7) questionnaires were administered to health officials in three different health sectors, which included; the Bibiani Government Hospital, Divine Love Hospital, and the DAKS Medical Health centre.

Results and discussion

Physicochemical parameters of the amponsah lake

Table 1 presents the results of the physicochemical parameters of the water samples from the Amponsah lake. The measured values for the physicochemical parameters assessed were all within the acceptable limits of the Ghana EPA except TSS which exceeded due to the runoff, domestic wastewater, and spent water from mining activities discharged into the lake.

Metal analysis

Table 2 shows the results of the level of heavy metals of the water samples of the Amponsah lake. Dissolved mercury ranges from 0.002 mg/l to 0.008 mg/l, with a mean concentration of 0.0053 mg/l. The value recorded exceeds the concentration limit of the GEPA guideline of 0.001 mg/l. This result was similar to those reported by Owusu-Boateng & Kumi-Aboagye,

Table 1
Physicochemical parameters of water samples of the Amponsah Lake.

Parameters	Mean	Standard Deviation	GEPA Standard
pH.	7.20	0.201	6- 9
Temperature (°C)	29.0	0.702	22- 29
DO (mg/l)	4.80	0.476	5.000
Conductivity (µS/cm)	383.0	7.832	1500.000
TDS (ml/l)	185.0	16.26	1000.000
TSS (mg/l)	123.0	14.89	50.000

Metal Analysis.

Table 2
Levels of heavy metals in water samples from lake Amponsah.

Parameters	Mean	Standard Deviation	GEPA Limit /mg/l
Mercury (mg/l)	0.0053	0.00249	0.0010
Arsenic (mg/l)	0.3110	0.23605	0.0100
Cadmium (mg/l)	0.0372	0.00893	0.0050
Zinc (mg/l)	0.0440	0.04015	10.0000

[15], in which the recorded mean value of mercury was 0.007 mg/l, and thus indicated that the mercury pollution could be the direct discharge of mercury compound into the lake by small-scale miners. Similarly, Hogarh et al., [9], also reported that illicit and continuous application of mercury could cause serious environmental concern. For example, the bioaccumulation of methyl-mercury in varieties of aquatic life (for instance fish) resulted in the Minamata disease. In a similar study Ansong et al., [2] divulge that there was a relatively high concentration of mercury (about 0.00309 mg/l) in river water around the mining areas of Dunkwa-On-Offin, Ghana which was above WHO/ GEPA guideline. Inorganic mercury could result in kidney infections and other neurologic effects. These reports stated and the responses from the respondents from the community, in which about eighty-six percent (86%) of them reported that they are experiencing health-related cases related to mercury pollution. This assertion was confirmed by health officials that patients in and around the community have been reporting cases about mercury pollution. Therefore, it can be concluded that the Lake Amponsah of Bibiani, Ghana is compromised.

Dissolved arsenic in the lake varied from 0.066 mg/l and 0.628 mg/l, with a mean concentration of 0.311 mg/l. The concentration of dissolved arsenic generally exceeds the GEPA guideline limit of 0.01 mg/l. The unusually high concentration of As could be likely due to the geology of Bibiani. In general, it is known to be made up of arsenopyrite, which contains arsenic, and the activities of small- scale mining operators around the lake exposed the rocks bearing it. According to Ismail et al., [10] arsenic, unlike other heavy metals, has a potential threat to the aquatic environment which could result in serious health issues. Also, a report by Ansong et al., [2] showed that the level of arsenic in some rivers around the Obuasi, Ghana mining vicinity has concentrations above the WHO/GEPA guideline, recording 2.25 mg/l and 1.4 mg/l in dam and drinking water respectively. After absorption of arsenic, it binds to hemoglobin, and therefore deposit in the lungs, skin, liver, and kidney. This can result in severe health problem such as stomach ache, nausea, vomiting, diarrhea and fatigue who depend on this water source and measures need to be put in place. There was a direct correlation between the results obtained (Table 2) and the health complains stated by the respondents from the community from the questionnaires issued on arsenic pollution.

Concentration levels of cadmium varied from 0.0290 mg/l to 0.0470 mg/l, whiles the mean value of dissolved cadmium was 0.0372 mg/l. This shows that the level of cadmium in the lake exceeds the limit recommended by GEPA. Geochemical implications of cadmium to human health as a result of industrial activity (small- scale mining) resulting in water pollution lead to lung and renal dysfunction as reported by Dadzie, [4]. Also, exposure to cadmium may result in reproductive and developmental effects. The oxidation state of both cadmium and zinc is the same, therefore it can replace zinc which is essential to the human body, hence preventing zinc from acting as free radical scavenger within the body cells. The International Agency for Research on Cancer (IARC), classified cadmium, and its compounds as a Group 1 carcinogen for humans [11]. A similar study by Ismail et al., [10] revealed that the source of cadmium pollution could be attributed to effluents from fertilizer production industries as well as electronic products such as batteries. Relatively, investigations show that Amposah Lake is known to receive runoffs from the immediate communities [9] as well as waste dumping sites located within the catchment area. About 86% of the respondents within the catchment area disclosed that they have been experiencing health-related issues symptomatic to cadmium contamination from the lake use.

Zinc concentrations ranged from 0.0030 mg/l to 0.0930 mg/l. Whiles the mean value was 0.0405 mg/l, which falls within the recommended guideline of GEPA (10.000 mg/l). Notwithstanding, zinc is an essential trace element for the human immune system. Lack of it in the human system may lead to a variety of health risks. It is responsible for healthy growth in children and helps in regulating and controlling immune responses. Nevertheless, excessive intake of zinc may lead to several body disorders, such as vomiting, diarrhea, nausea, headache, etc. A high level of zinc may also lead to the pancreas and other kidney infections. It can also result in respiratory malfunctions [1]. Although, all respondents from the questionnaire issued stated that they have been experiencing kidney infections and headache symptomatic to zinc pollution, however, the results (Table 2) show that zinc is within the GEPA recommended guideline. There is a likelihood that the stated health implications arise from the other heavy metal pollution (mercury, arsenic, or cadmium) but not zinc.

Questionnaire

For accuracy and reliability, it was relevant to the survey to get the opinion of the people living in the community. The main purpose of this was to know whether or not the activities of the small-scale miners around the lake are a threat to the health of flora and fauna. The questionnaire administered was in three sections, the demographic section, impacts caused by the presence of heavy metals in the lake, and the response(s) from health officials.

Aspects considered in the questionnaire included residential, gender, age, usage, years of usage, purpose(s), observed physicochemical properties and impacts of arsenic (As), mercury (Hg), cadmium (Cd), and zinc (Zn) to users as well as

health records from health officials. A comparative qualitative method was used to bring out trends in thought and opinions from the people and dived into the problem. Most of the respondents confirmed that the physicochemical parameters were compromised. Whereas almost all the respondents strongly agreed that they had observed some changes in the physicochemical properties of the lake that concerned the activities going on and around the lake, they added that solid wastes and wastewaters were also washed into the lake directly or indirectly from the community and also during rainfall. Many of the respondents who had been using the lake reported observing some health problems during the time of use. Also, a respondent from the health sector (Doctors) within the Bibiani municipality indicated that most of the individuals living in the communities around the lake have been reporting health disorders such as kidney infections, carcinogenic disorders, increases in blood pressure or heart rate, skin rashes, diarrhea, eye irritation, fatigue, etc., but have no clue as to where those diseases were contracted from. Whereas 90 percent of the respondents complained about diseases related to both mercury and arsenic. This is because mercury is the chemical used in the extraction process and the geology of the land having a high concentration of arsenopyrite. They have no clue (i.e. mercury) about its impact on both the environment and humans. They do not put on any PPE during the gold recovery process.

Interview with the study community

Interview

Small scale mining is an important activity that cannot be overlooked and has the prospective benefit of contributing to the development of areas where natural resources can be found. A respondent during the interview stated that *small scale mining operations can be made acceptable if the right initiatives are put in place by the government and the small-scale miners*. Also, stakeholders and authorities of the environment should ensure that small-scale miners adapt to a livable mining operation. The study indicates that women's involvement in these activities was relatively minimal. The small-scale mining activities had a larger number of people in which men constitute about 97% and of whom we had the opportunity to interview some, while the kernel extraction industry had a few people who are involved in the extraction of whom we had a privilege to interview some females. Women know of water resource and water quality development and protection. The women around Lake Amponsah could generate a piece of vital information that would help to sustain water conservation.

The dominant occupations within the community are farming, followed by small-scale mining activities. However, during the dry season when agricultural activities are low, other farmers take on small-scale mining activity which increases the number of miners as compared to that of the raining season. This promotes the occurrence of illegal mining. The small-scale miners are both natives and more are foreigners. The government ban on small-scale mining activities across the nation has led to the reduction of foreigners around the area and also the small-scale activities in the area.

Conclusion

The physicochemical characteristics of Lake Amponsah assessed were above expectations when viewed against available guideline values mainly those prescribed by the GEPA for both domestic purposes and aquatic life. Anthropogenic activities particularly discharge of effluents from small- scale mining activities in the vicinity of the Lake together with the indiscriminate discharge of domestic waste and effluents into the Lake are the potential causes. The causes and effects of factors that lead to water quality decline and the general degradation of the environment have not been well appreciated by the community. This was demonstrated in the extent to which the Lake water has been negatively impacted. From the study, it was found that the concentration of Hg, Cd, Zn, and As in Lake Amponsah were all above the GEPA threshold except Zn.

Investigations revealed that disorders disclosed by health sector officials (resident medical doctors and nurses) could be from heavy metal pollution status of the lake. The investigation further disclosed that the source of mercury in Lake Amponsah could be direct Hg input through activities of small-scale miners operating around the lake over the years. The exceptionally high concentration of As could be inferable from the geology of Bibiani in general which is known to be made up of arsenopyrite, which contains arsenic and small- scale mining activities around the lake exposed the rocks bearing it. From the results, it is concluded that the physicochemical characteristics of the Lake have been compromised pointing to a polluted status except in Zn and TSS.

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Declaration of Competing Interest

There is no conflict of interest to report.

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Supplementary materials

Supplementary material associated with this article can be found, in the online version, at doi:10.1016/j.sciaf.2020.e00531.

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