Galena Mining And Water Quality Of Amata, Southeastern Nigeria

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ABSTRACT

The study investigated galena mining and water quality of Amata community in Ishiagu clan of Ivo Local Government Area, Ebonyi State southeastern Nigeria. The study adopted the completely randomized block design (CRBD) due to the similarity of the experimental points (i.e. sampling frames) where the water samples (i.e. surface and groundwater) are taken. Instruments like: multiparameter water quality meter, water analyzer, Atomic Absorption Spectrometer (AAS), one liter plastic containers and GPS were used to collect, determine and analyze chemically if galena mining in any way impacts on the water quality in Amata community. The results revealed relatively low concentrations of temperature, alkalinity, TDS, EC, Ca, Mg^3, SO_4, and Cl far below the WHO and NAFDAC tolerance limits for declaring water suitable for consumption. However, the pH ranging from 4.52–6.59, salinity of above 0.1% permissible limit, turbidity above 5.00mg/l, including DO and K^+ of above 5.00 mg/l, and $PO4^3$ levels ranging from 13.79-41.23 far above the 10.00 mg/l WHO and NAFDAC tolerance limit, makes the waters in Amata community moderately acidic, salty, muddy, unclean, contaminated and unfit for human consumption, certain plant growth, and sustaining some aquatic organisms. The study suggested the treatment of effluents prior to their discharge land and water bodies in order to forestall the contamination of the water quality of Amata.

Keywords: Galena, mining, water quality, Amata, southeastern, Nigeria

Introduction

The alteration, interference or demystification of natural or nature resources and systems especially through irrational, senseless or unsustainable extraction of solid minerals deposited in space, could trigger issues like degradation of the environment (i.e. stratosphere, land and aquatic) quality. In specific locations across the community (like Amata), district (like Ishiagu), province (like Ivo), state (like Ebonyi), region (like southeast), country (like Nigeria), and globe certain economically important mineral like galena deposits that is available underneath and unearthed or mined using diverse techniques, processes, technology, strategies, and materials comes with its attendant cost, effluents or wastes, influences, and impacts (social, health, pollution, etc.). These impacts could accentuate hazards, diseases and infections as enunciated by Chellan and Sadler

(2015); Hajeb, Sloth, Shakibazadeh, Mahyudin and Afsah-Hejri (2014) to potentially cause harm to humans, animals, and plants in that environment.

Galena is a lead sulfide mineral with a chemical composition of PbS (i.e. an equal number of lead and sulfide ions). Galena is a jealous and easily identified mineral that comes with its own water, any stain changes its distinct silver colour. It is also a bright metallic luster mineral found in igneous and metamorphic rocks in medium- to low-temperature hydrothermal veins, while in sedimentary rocks it occurs as veins, breccia cements, and isolated grains (Lead Fact Sheet, 2016). Similarly, if rocks containing galena are exposed to heat, then lead is recovered from under the ashes when the fire goes out. Galena is one mineral that can easily melt or smelt under low-temperature, leading to the liberation of byproducts like lead ore, zinc ore, and silver ore (Young, Taylor & Anderson, 2008). Specifically, galena is regularly mined for its 1–2% silver content, which is a byproduct with revenue that far outweighs that derived from lead and zinc ore (Obarezi & Nwosu, 2013). Hence, some mines could generate more income from the silver content of their galena more than that from the lead and zinc content.

Olubambi, Ndlovu, Potgieter and Borode (2008) states that galena is a major mineral of the zinc-lead mines (i.e. mining sites) in Ishiagu, Ivo province (i.e. local government area). This makes the mineral to have a high specific gravity (7.4 to 7.6) that is instantly noticed when picking up even small pieces. Furthermore, the silver ore within the galena cause disruptions like: changing the crystal structure to have curved appearance, staining the silver colour to dull gray, and also its content of minor quantities of antimony, arsenic, bismuth, cadmium, copper, and zinc, which sometimes determines the variability of the prospecting, mining or extraction of this mineral (Obarezi & Nwosu, 2013). Also, the few percent silver contained in the galena is 364 times more valuable than an equal weight of lead. This accounts for the reason underlying mining companies (like Palladium Mining Limited), and artisanal miners (like artisans, children, youth, adults, etc.) interest and excitement in methodologically or operationally moving to an area or locality (like Amata community) with deposits of the argentiferous galena (i.e. galena with silver content).

Succinctly, the galena mine establishment in Amata is about 45m or 130ft deep gotten from a vein (i.e. an igneous outcrop). In addition, the mining of galena at Amata was hitherto perceived to provide inhabitants with income outweighing that from farming, this explains the proliferation of organized and artisan mining sites considered as a lucrative venture around this vicinity. Deductively, specific stages, activities, method (like open pit, opencast, underground, etc.), and exploration technique (like drilling rig) adopted or utilized during the extraction of the galena results in the production of majorly lead (Pb), moderately zinc (Zn), and minor silver (Ag). These products as heavy metals contains toxins, contaminants or impurities that endangers the water quality (surface and underground) thereby, making it unsafe for drinking and industrial usage including upsetting the area's hydrology (Ishaya, Mamman & Abubakar, 2018).

The stages (i.e. life cycle and closure) in galena mining can affect the quality of water resources (both surface and groundwater). Regrettably, the rising business and artisanal miners in Africa has resulted in insightful and irreversible cycle of environmental destruction that continues to worsen the issue of water quality pollution (Oelofse & Turton, 2008). These hazardous issues must be addressed within the context of the instituted environmental regulations operational within the jurisdiction of the area (Oden, 2012). In view of this, Nuwer (2015) stated that attempts at limiting the devastation to the aquatic environment would help to sustain the existence and productivity of the inherent biodiversity and ecosystem. Hence, value for water quality underlies properly assessing and curbing the associated hazards encountered in the process of mining galena.

Odika, Anike, Onwuemesi, Odika and Ejeckam (2020) assert that embarking on rigorous scrutiny of the stages, activities, methods, processes and techniques adopted in galena mining is extremely important. Otherwise, the ensuing jettisoning of proper environmental regulations and enforcement for the conduct of mining activities intensifies unethical practices, alongside chemical contamination of water and soil systems leading to disease prevalence, loss of lives and property from this profitable venture in mining sites (e. active, abandoned and concluded). Notwithstanding, the extent of regulations instituted during interactions (like mining activities) on the surface or physical environment, it inevitably produces effluents that would pollute underground systems and vice versa. In view of this, Dami, Ayuba and Amukali (2013) stated that engaging in standardized treatment prior to the discharge of effluents from mining sites even into water bodies is a proficient risk assessment that could forestall the far-reaching effects of toxic chemicals derivable ground water pollution due to mining activities. This is the crux of the matter articulated in this study.

Statement of the Problem

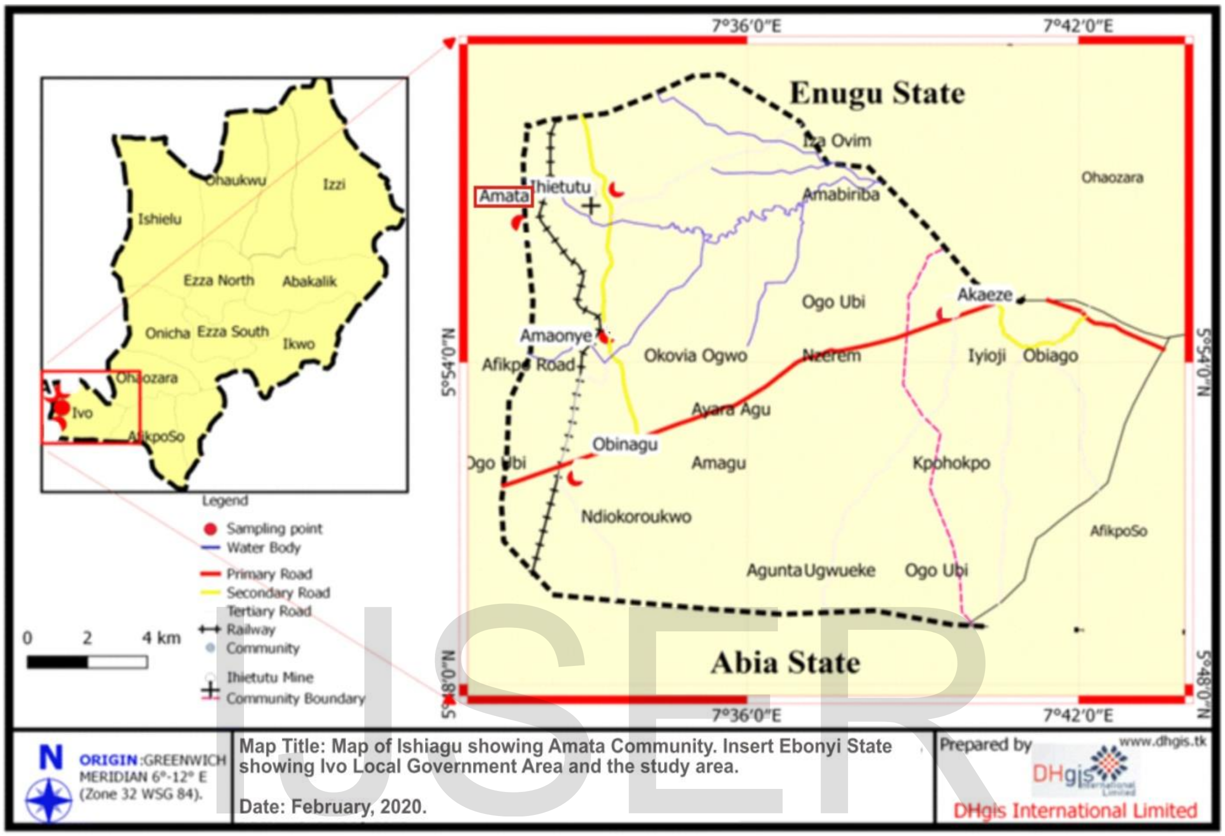
The mining of solid minerals (like galena) which date back to the1960s (NGSA, 2010), gives rise to chemicals like lead, zinc, and silver with effluents or discharges likely to affect environmental resources especially underground and river water which represent the main source of domestic, commercial, and industrial water for both rural and urban population. Thus, certain anthropogenic activities (like mining of lead, etc.) engaged in order to stimulate the economy, provide employment, and industrialized the society generates residues, effluents (like wastewater), and other byproducts with elements that increases the level of pollution, hazards or impurities. For instance, Ishaya *et al*. (2018) stated that certain harmful impurities are released into the environment whilst processing a metal like lead into finished products such as lead-acid batteries used as standby power supplies for computer networks, communication facilities, and other critical systems used in energy storage systems associated with power generation and hybrid vehicles.

Furthermore, inappropriate planning and disregard for regulations erupts substantial level of environmental degradation especially on the water quality around galena mining sites (like Amata community). Equally, the ensuing devastating impacts of heavy metals on humans and the water quality has overtime triggered anxieties on the health and safety of humans who supposedly have benefited socially, economically, and developmentally from the extraction of a solid mineral like galena. This, raises fears on the adequacy of the existing surface and groundwater supplies to remain suitable for human use and biodiversity sustenance in this area, thereby culminating to the contemplation of measures to tackle the imminent infection or poison from drinking such water.

However, the inability to adopt modern, viable and functional mining regulations has led to the rise of professional mining firms, and artisans or unprofessional miners (like children, youth, women or unaccredited persons/group) mining and discharging their effluents indiscriminately without prior standard treatment processes. This has increased the pollution of the water and other environmental resources prompting the consideration of a crude and impracticable approach like the cessation of mining. Previous studies focused largely on the trace metal status of streams receiving acid mine drainage (Aroh, Ubong, Eze & Abam, 2006), characterization of toxicity distribution of selected heavy metals in stream sediments (Ameh, Idakwo, Ameh & Lekdukum, 2017), and effects of barite mining on water quality (Ishaya *et al*., 2018). This prompted an investigation on galena mining and water quality of Amata, southeastern Nigeria.

The Study Area

The study was conducted in Amata community in Ishiagu district in Ivo Local Government Area (LGA) of Ebonyi State (i.e. southeast geopolitical zone), Nigeria. Amata lies between latitudes 5.56–6.12ºN and longitudes 7.33–7.37ºE. According to Odika *et al*. (2020), normal temperature in this area ranges from 20^o to 38^oC, and from 16^o to 28^oC during the dry and rainy seasons respectively. The relief shows visible presence of undulating hills and hillocks rising up to 93m above sea level where significant deposits of solid minerals like galena lies. Equally, substantial part of the Amata galena mining field is operated by Palladium Mining Limited, the site is four (4) cadastral unit (i.e. 1 km sq.) in a border town between Abia and Enugu States (see Fig. 1).



Map Title: Map of Ishiagu showing Amata Community. Insert Ebonyi State showing Ivo Local Government Area and the study area.

Date: February, 2020.

Figure1: Ishiagu showing Amata Community. Inset Ebonyi State with a red shading showing the Ivo Local Government Area and the study area.

Source: *DHgis International Limited*, February, 2020

Furthermore, Amata community is located in the Ishiagu district of Ivo LGA Ebonyi State southeastern Nigeria, which belongs to the unique Lower Benue Trough with both savannah vegetation with tall grasses and small trees, and rainforest vegetation zone that makes the community to traditionally engage in flourishing occupation of farming in annual crops like rice, cassava, yams and vegetables like pumpkin and spinach (Edeani, 2015), and perennial crops (like orange, African pea, mango, cashew, etc.). But, mining has now emerged as modern occupation due to the perceived slightly additional revenue. Also, in terms of climatic condition, there are two major seasons; the wet season (from March/April to October) and the dry season (from November to February/March). Odika *et al*. (2020) states that these seasons arise from the two prevailing winds at different periods of the year; the dry harmattan wind from the Sahara desert and the marine wind from the Atlantic Ocean. Similarly, the Amata mining site operated by Palladium Nigeria Limited uses the open pit (i.e. pit-lake) method of about 45m or 130ft deep, which are abandoned at the close or expiration of galena mining.

MATERIAL AND METHODS

The researcher embarked on a reconnaissance survey to the Amata mining sites prior to the commencement of the actual study for the collection of water samples. In specificity, twelve (12) water samples (i.e. sampling points/frames) were purposively taken as thus: three (via upstream, midstream, and downstream) from Ivo river (i.e. stream sediment sample), three pit lakes drains, five well water, and one wetland around the study area or vicinity. Thereafter, the physio-chemical parameters of the 12 water samples via: temperature (T), pH, electrical conductivity (EC), salinity, total dissolved solid (TDS), dissolved oxygen (DO), nitrate (NO_3), sulphate (SO_4), chloride (Cl), phosphate ($PO4^3$), total alkalinity, turbidity, calcium (Ca), magnesium (Mg^3), and Potassium (K^+) were considered, explored or analyzed. Thus, the physicochemical quality of the water samples were determined using the National Agency for Food Drugs Administration and Control (NAFDAC, 2001), and World Health Organization standardize guidelines for drinking-water quality (WHO, 2011).

Table 1: Points of water samples collection

S/N	Location	Time	Easting	Northing
1	Well Water	4:13pm	9.625103	8.564083
2	Well Water	3:39pm	9.625717	8.569170
3	Well Water	4:11pm	9.627362	8.585765
4	Well Water	5:02pm	9.628538	8.625927
5	Well Water	3:57pm	9.626016	8.654082
6	Wetland Water	4:01pm	9.624473	8.576053
7	Pit-lake Water	3:35pm	9.635782	8.625378
8	Pit-lake Water	3:39pm	9.620394	8.630167
9	Pit-lake Water	3:45pm	9.630936	8.582735
10	Upstream Water	5:39pm	9.634635	8.519363
11	Midstream water	6:10pm	9.631962	8.624962
12	Downstream water	6:16pm	9.635081	8.635054

***Source:** Researcher Fieldwork, 2019*

Instrumentation, Method of Water Sample Collection and Analysis

The instruments used for the study include: multiparameter water quality meter (Hanna 93103), water analyzer, Atomic Absorption Spectrometer (AAS) (OMA 300 process analyzer), one liter of plastic containers, masking tape, marker, writing pad, and Automated Global Positioning System

(GPS for taking the coordinates of sampled points). The nitric acid washed-plastic plastic bottles were flushed with the water prior to collection of the twelve water samples in November, 2019, in order to reduce contamination. The phases of measurement were: firstly, parameters like EC, TDS, salinity, pH and temperature (taken at 10am in the morning) were determined and recorded in the field (i.e. in-situ) using the multiparameter water quality meter (Hanna 93103). Next, nitric acid (0.2%) was added as a preservative for the collected water samples which were marked and labeled with the masking tape for the water source, sampling location and date of collection before being transported to the laboratory for analysis of the other parameters within four (4) days.

Thirdly, dissolved oxygen, salinity and turbidity were determined by water analyzer with the help of indicator Systronic-371, alkalinity was measured with the water analyzer using Phenolphthalein indicator. Fourth and finally, nitrate, phosphate, and calcium were measured by the Atomic Absorption Spectrometer (AAS). Also, the complete randomized block design (CRBD) was adopted due to the likeness of the experimental points where the surface and groundwater samples were taken. Similarly, the quality assurance and control of data were performed according to the specified method (Ishaya *et. al.*, 2013).

RESULTS

Table 2: Physicochemical parameters of surface water

S/N	**Parameters (units in mg/l)**	**Location of Surface Water**				**Tolerance Limits (WHO, 2011; NAFDAC, 2001**	
		IPSW ^{up}	**IPSW $_{mid}$**	**IPSW $_{down}$**	**IPWW**	**WHO**	**NAFDAC**
1	**Temp. (^{0}C)**	27.0	27.0	27.4	26.9	-	40.00
2	**pH**	6.59	6.24	5.67	6.18	7.00-9.00	6.50-8.50
3	**Salinity (%)**	1.28	1.34	0.37	1.24	0.1	0.1
4	**TDS**	18.6	19.5	12.6	17.3	1000	1000
5	**Dissolve Oxygen (DO)**	5.69	5.93	5.87	5.51	13-14	13-14
6	**EC (µS/cm)**	25.0	26.3	76.9	52.8	1000	1000
7	**Calcium (Ca)**	17.06	5.14	22.93	11.38	75	75
8	**Magnesium (Mg^3)**	4.01	1.68	10.35	5.72	50	-
9	**Potassium (K$^+$)**	3.74	8.61	6.42	4.13	2.00-3.00	2.00-3.00
10	**Turbidity**	4.15	4.37	6.06	5.24	5.00	5.00
11	**Total Alkalinity**	25.30	24.00	36.70	98.20	100.00	100.00
12	**Sulphate** (SO4^2)	7.65	13.57	21.64	17.26	250.00	100.00
13	**Nitrate (NO$_3$)**	2.38	0.59	2.83	2.61	10.00	0.002
14	**Chloride (Cl)**	18.39	18.31	20.25	19.73	200.00	75.00
15	**Phosphate (PO4^3)**	13.79	26.48	32.73	20.51	10.00	10.00

Location: IPSW ^{up} = Upstream water, IPSW ^{mid} = midstream, IPSW ^{down} = downstream, IPWW = wetland water

Source: *In-situ and laboratory analysis*

The result of the surface water samples in Table 2 shows that temperature falls within the NAFDAC permissible limit of 40^0C. The pH levels (except for IPSW ^{up}) which fell below both the WHO and NAFDAC tolerable limit indicates an acidic water quality. The salinity is greater than the WHO and NAFDAC permissible limits of 0.1mg/l. Similarly, the total dissolved solid in the IPSW ^{up}, IPSW ^{mid}, IPSW ^{down}, and IPWW were 18.6mg/l, 19.5mg/l, 12.6mg/l, and 17.3mg/l which are far below the permissible limits of 1000mg/l. The values for dissolve oxygen which range between 5.51-5.93 did not exceed the tolerance limit of 13-14 mg/l. The conductivity level of the samples had 25.0 µS/cm for upstream, 26.3 µS/cm for midstream, 76.9 µS/cm for downstream, and 52.8 µS/cm for wetland. These values are far below the WHO and NAFDAC permissible limit of 1000. Also, the levels of phosphate in Table 2 which exceeds the tolerable limit of 10 mg/l could result in the wild growth of algal and aquatic plants that will then choke up the water way. The level of turbidity in the water samples (except for the IPSW ^{up} and IPSW ^{mid}) were above the WHO and NAFDAC tolerance limit, this can make disinfection ineffective and dangerous for microorganisms. The levels of nitrate and potassium in the water samples exceeds the WHO and NAFDAC tolerance limits for surface water. Lastly, the level of sulphate, calcium, total alkalinity, magnesium, and chloride also fell within the WHO and NAFDAC permissible or tolerable limits.

Table 3: Mean values the physicochemical parameters of surface water in comparison with WHO and NAFDAC tolerance limits

S/N	Parameters	Unit	Mean Values for Surface Water	Tolerance Limits (WHO, 2011; NAFDAC, 2001	
				WHO	NAFDAC
1	**Temperature (Temp.)**	**^{0}C**	27.1	-	40.00
2	**pH**	Ug/m^3	6.17	7.00-9.00	6.50-8.50
3	**Salinity (%)**	Ug/m^3	1.06	0.1	0.1
4	**Total Dissolve Solids (TDS)**	Ug/m^3	17	1000	1000
5	**Dissolve Oxygen (DO)**	Ug/m^3	5.75	13-14	13-14
6	**Electrical Conductivity (EC)**	**µS/cm**	45.25	1000	1000
7	**Calcium (Ca)**	Ug/m^3	14.13	75	75
8	**Magnesium (Mg^3)**	Ug/m^3	5.44	50	-
9	**Potassium (K^+)**	Ug/m^3	5.73	2.00-3.00	2.00-3.00
10	**Turbidity**	Ug/m^3	5.00	5.00	5.00
11	**Total Alkalinity**	Ug/m^3	46.05	100.00	100.00
12	**Sulphate** ($SO4^2$)	Ug/m^3	15.03	250.00	100.00

13	**Nitrate (NO_3)**	Ug/m^3	2.10	10.00	0.002
14	**Chloride (Cl)**	Ug/m^3	19.17	200.00	75.00
15	**Phosphate (PO4^3)**	Ug/m^3	23.38	10.00	10.00

Source: *Researcher's computation, 2019*

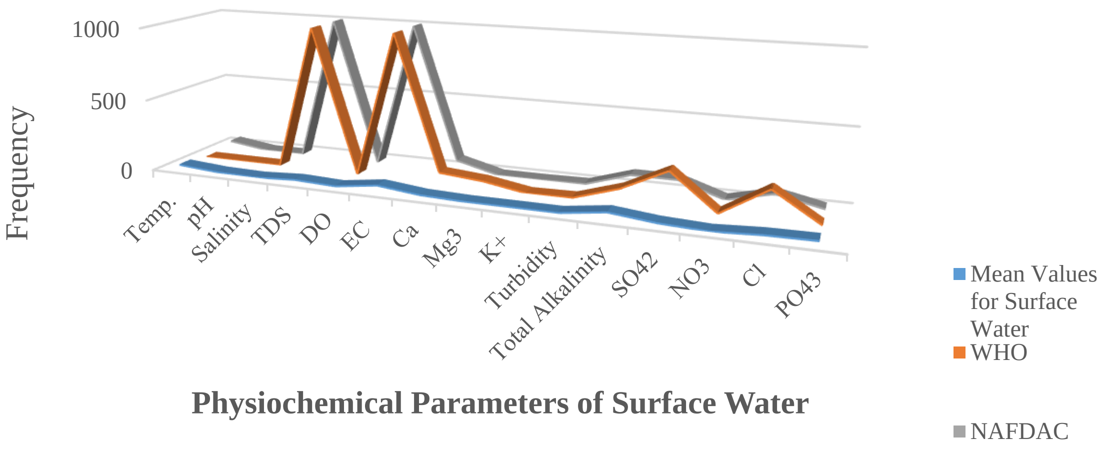


Figure 2: Comparison of mean values of of physiochemical parameters of surface water vs. WHO and NAFDAC tolerance limit

Table 4: Physicochemical parameters of groundwater

S/N	Parameters (units in mg/l)	Location of Groundwater								Tolerance Limits (WHO, 2011; NAFDAC, 2001	
		WW1	**WW 2**	**WW 3**	**WW4**	**WW5**	**PW1**	**PW2**	**PW3**	**WHO**	**NAFDAC**
1	**Temp. (^{0}C)**	26.3	31.6	28.2	28.7	32.4	24.9	30.1	27.6	-	40.00
2	**pH**	7.37	5.13	6.26	7.15	5.94	4.52	5.36	6.04	7.00-9.00	6.50-8.50
3	**Salinity (%)**	0.66	1.35	0.73	0.61	1.25	1.07	1.83	2.08	0.1	0.1
4	**TDS**	36.51	121.4	96.2	104.9	251.7	272.6	158.1	69.5	1000	1000
5	**Dissolve Oxygen (DO)**	6.13	4.54	5.38	4.69	7.16	5.73	6.28	6.01	13-14	13-14
6	**EC (µS/cm)**	64.1	58.8	43.5	21.3	17.8	34.9	66.1	87.6	1000	1000
7	**Calcium (Ca)**	25.31	20.72	23.82	19.38	16.13	27.04	28.46	32.59	75	75
8	**Magnesium (Mg^3)**	16.82	10.61	9.05	12.36	8.73	15.36	17.46	11.38	50	-
9	**Potassium (K^+)**	3.03	4.95	3.53	5.38	6.20	12.52	9.39	8.43	5.00	5.00
10	**Turbidity**	6.04	5.93	5.66	4.62	7.28	8.63	8.49	7.31	5.00	5.00
11	**Total Alkalinity**	13.64	17.82	19.56	21.80	22.74	55.26	92.68	86.15	100.00	100.00
12	**Sulphate (SO4^2)**	5.28	5.74	16.05	8.93	7.44	9.25	14.31	10.84	250.00	100.00
13	**Nitrate (NO_3)**	4.17	3.38	1.05	0.52	5.37	10.49	11.02	10.18	10.00	0.002
14	**Chloride (Cl)**	15.63	14.62	20.74	16.03	12.28	21.17	18.92	9.41	200.00	75.00

15	**Phosphate (PO4^3)**	16.52	22.82	15.90	18.26	15.31	27.61	39.04	41.23	10.00	10.00

Location: WW1 = well water sample 1, WW2 = well water sample 2, WW3 = well water sample 3, WW4 = well water sample 4, WW5 = well water sample 5, PW1 = pit lake water site 1, PW2 = pit lake water site 2, PW3 = pit lake water site 2.

Source: *In-situ and laboratory analysis*

The result of the groundwater samples comprising well water (i.e. WW1-WW5) and pit-lake water (i.e. PW1-PW3) in Table 4 indicate that temperature fell within the NAFDAC permissible limit of 40^0C. The pH levels (except for WW1 and WW4) which falls below both the WHO and NAFDAC tolerable limit. The salinity levels is greater than the WHO and NAFDAC tolerance limits of 0.1mg/l. Similarly, the total dissolved solid in all the groundwater samples were far below the permissible or tolerance limits of 1000mg/l. The values for dissolve oxygen (except for WW2 and WW4) falls within the range of 5.38-7.16 which is still below the tolerance limit of 13-14 mg/l. The conductivity level of the samples ranged between 17.8-87.6 µS/cm that is below the WHO and NAFDAC permissible limit of 1000.

Also Table 4 shows that the potassium levels in the well water samples (except for WW1, WW2, and WW3) and all the pit-lake water (i.e. PW1-PW3) were above the WHO and NAFDAC tolerance limits of 5.00 for groundwater. Also, the turbidity level in the groundwater samples (except for WW4) were above the WHO and NAFDAC tolerance limit. The levels of phosphate in all the groundwater samples exceeds the WHO and NAFDAC tolerable limit of 10 mg/l. The nitrate levels of especially the pit-lake water exceeds the WHO tolerance limit of 10 mg/l. Lastly, the level of sulphate, total alkalinity, calcium, magnesium, and chloride also fell within the WHO and NAFDAC permissible limits for declaring the water suitable for consumption.

Table 5: Mean values the physicochemical parameters of groundwater in comparison with WHO and NAFDAC tolerance limits

S/N	**Parameters**	**Unit**	**Mean values for well water**	**Mean values for pit-lake water**	**Tolerance Limits (WHO, 2011; NAFDAC, 2001**	
					WHO	**NAFDAC**
1	Temp.	**^{0}C**	29.4	27.5	-	40.00
2	pH	Ug/m^3	6.37	5.31	7.00-9.00	6.50-8.50
3	Salinity	Ug/m^3	0.92	1.66	0.1	0.1
4	TDS	Ug/m^3	122.1	166.7	1000	1000
5	DO	Ug/m^3	5.58	6.01	13-14	13-14
6	EC	**µS/cm**	41.1	62.9	1000	1000
7	Ca	Ug/m^3	21.07	29.36	75	75
8	Mg^3	Ug/m^3	11.52	14.73	50	-
9	K$^+$	Ug/m^3	4.62	10.11	5.00	5.00

10	Turbidity	Ug/m^3	5.91	8.14	5.00	5.00
11	Total Alkalinity	Ug/m^3	19.11	78.03	100.00	100.00
12	SO4^2	Ug/m^3	8.69	11.47	250.00	100.00
13	NO_3	Ug/m^3	2.90	10.56	10.00	0.002
14	Cl	Ug/m^3	15.86	16.50	200.00	75.00
15	PO4^3	Ug/m^3	17.76	35.96	10.00	10.00

Source: *Researcher's computation, 2019*

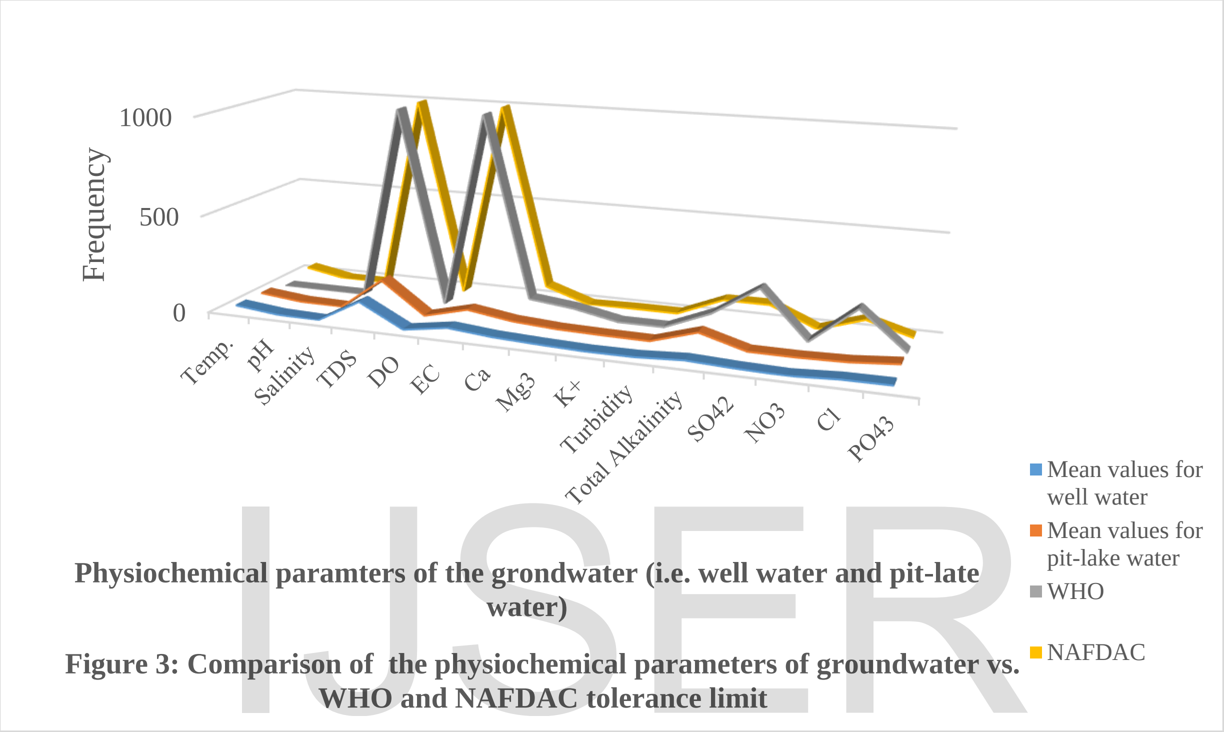


Figure 3: Comparison of the physiochemical parameters of groundwater vs. WHO and NAFDAC tolerance limit

Discussion of Findings

The result in Tables 2 and 3 revealed that the surface water samples contains levels and mean values respectively, of parameters like: pH, salinity, phosphate, turbidity, potassium, and nitrate above the WHO and NAFDAC tolerance limit for surface water. Although, the values for dissolve oxygen fell below the WHO and NAFDAC tolerance limit of 13-14 mg/l for surface water, however, DO exceeding 5.0 mg/l is not good for agricultural purposes which is the major occupation of the people in Amata community. This finding is in agreement with earlier findings by Envuladu, Chihgle, Banwat, Lar, Yusuf, Audu, Dakhin and Zeakah (2016) that the high phosphate level in stream and wetland waters could result in the wild growth of algal and aquatic plants that will then choke up the water way, affect plant growth (via high potassium level), thereby leading to inadequate filtration and ineffective disinfection that is dangerous to microorganisms (due high turbidity level), whilst the high nitrate level poses great threat to both pregnant women and infants under six months.

The result of the groundwater samples in Tables 4 and 5 indicate that the levels and mean values respectively, of parameters like temperature, conductivity, sulphate, calcium, magnesium, alkalinity and chloride fell within the WHO and NAFDAC tolerance or permissible limits for groundwater suitable for consumption. However, the levels and mean values of pH, salinity, phosphate, turbidity, potassium, and nitrate levels above the WHO and NAFDAC tolerance limit for groundwater. Alongside, the level for dissolve oxygen surpassing 5.00 mg/l (but still within the WHO and NAFDAC tolerance limit of 13-14 mg/l) makes the groundwater samples in Amata community moderately acidic, salty, muddy, very toxic, and unsuitable for agriculture, drinking, and other uses. This finding is consistent with Envuladu *et al*. (2016) who stated that the pH value lower than 7.0 to 9.0 including DO and turbidity level higher than 5.00 mg/L makes groundwater which supplies water to streams and wetlands acidic, unfit for agricultural purposes, irrigation, manufacturing and other uses, thereby, adversely affecting the life of fresh water fish and bottom dwelling invertebrates. Also, Kumar and Puri (2012) reiterate high level of phosphate and potassium in groundwater above 10 mg/l and 5.00 mg/L respectively can lead to the wild growth of algal and aquatic plants which block or obstruct the water way and then affect plant growth. Whilst Amoo and Akinbode (2007) stated that nitrate level beyond 10 mg/l makes such groundwater dangerous for pregnant women whose infants are susceptible to blue baby syndrome (i.e. blood losing its ability to carry sufficient oxygen).

Conclusion

The study concludes that both the organization and artisanal mining of galena in Amata community, southeastern, Nigeria led to the discharge, seepage, and absorption of chemicals and noxious waste into the surface water, groundwater, and pit-lake drains around the vicinity. This made the water quality to be very acidic, salty, muddy, toxic, unclean, and improper or unsafe for agriculture, certain plant growth, sustenance of specific aquatic organisms, drinking, and other uses including dangerous to human (especially infants) health and life in such a rural and agrarian environment. This aligns with Mejia (2015) report that the unregulated, unprofessional, and artisanal gold mining in Zamfara State in northern Nigeria resulted in high lead concentration of

1270mg/l in the local river leading to the poisoning and death of more than 300 persons (mainly artisans comprising children, youth and women) in 2010.

Hence, it was thus suggested: the adoption of sensible and sustainable environmental regulations like prior treatment of effluents before their actual discharge into land and water bodies. The design and execution of regulatory frameworks to accommodate both commercial and artisanal miners. Steadily building miners capacity towards jettisoning the crude, inefficient, and unethical act of curbing or stoppage of mining; for properly regulated and professional mining practices that could reduce the hitherto pollution of the water quality/systems and promote the development of Amata.

Acknowledgement

The effort of Philip Emmanuel in digitizing the map is greatly acknowledged. Also, appreciation goes to Dr. Clinton Ezekwe for promoting the conduct of this research. Whilst, Uyi Hanson of the Institute of Pollution Studies (IPS) Rivers State University (RSU) Port Harcourt which provided the AAS used for the chemical analysis is highly appreciated.

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