© 2016 IJSRSET | Volume 2 | Issue 4 | Print ISSN: 2395-1990 | Online ISSN : 2394-4099
Themed Section: Engineering and Technology

Effects of Illegal Mining Activities on Water Resources for Irrigation Purposes, Amansie West District, Ghana

Gabriel Quansah*[1], Adams Sadick[1], Joseph Fenning[2], Kwabena Nketia[3], Eric Asamoah[3]
*[1]Soil Chemistry and Mineralogy, Soil Research Institute, Kumasi, Ghana
[2]Soil Microbiology, Soil Research Institute, Kumasi, Ghana
[3]Soil Genesis, Survey and Evaluation, Soil Research Institute, Kumasi, Ghana

ABSTRACT

This paper assessed the suitability of water in the Amansie West District in the Ashanti Region of Ghana for irrigation purposes and future planning of clean water resources. Twenty one (21) locations were selected on the major rivers and their tributaries in the district for sampling and the water samples taken at the depth of 15cm from the rivers. The samples were analyzed at Soil Research Institute's Laboratory for irrigation water quality parameters and compared with international water quality standard set for irrigation. All the irrigation water quality parameters, pH, temperature, ECw, TDS, Ca, Mg, Na, K and SAR were within the permissible limit and suitable for irrigation. Heavy metals (Fe, Pb and Cd) levels were all within allowable limits except Mn and Zn. However, further study to examine anions such as bicarbonate and carbonate for irrigation suitability is recommended.

Keywords: Water Quality, Irrigation, Rivers, Cations, Anions

I. INTRODUCTION

The mining industry is the backbone of many economies in the developing world. Its recovery in Ghana since 1989 was driven by the global paradigm which emphasizes private sector-led development as the engine of economic growth in developing countries. The historical importance of mining in the economic development of Ghana is evident in the country's colonial name, Gold Coast (Akabzaa T. and Darimani A., 2001).

The mining industry of Ghana accounts for 5% of the country's GDP and minerals make up 37% of total exports, of which gold contributes over 90% of the total mineral exports. Export earnings from minerals averaged 35%, and the sector is one of the largest contributors to Government revenues through the payment of mineral royalties, employee income taxes, and corporate taxes and employment generation. The mining industry therefore remains critical to Ghana's socio-economic growth and development (Ghana Chamber of Mines, 2008).

Small and large-scale mining operations are inherently affecting the environment, producing enormous quantities of waste that can have negative impacts for decades (UNEP, 1997). Mining activities that affect water quality include the disposal of waste rock, tailings deposition, and effluent discharges from different stages of mineral processing (Dock, 2005). According to Ripley (1996) effluent released from gold mines is made up of heavy metals mainly from pyrite (FeS2) and chalcopyrite (CuFeS2). Koryak (1997) argues that the effluent produced from waste rock dumps has a potential of causing acid mine drainage (AMD) in stream and river waters.

Research on brook trout by Mc. Kim and Benoit (1971) revealed that water polluted by gold mining activities due to AMD had concentrated heavy metals such as Fe, Mn, Zn, Cu, Pb and Cd. Iron concentration of 0.3 mg/l could affect fish population, while zinc concentration of 0.18 mg/l significantly reduced egg production of the fathead minnow (Mc. Kim and Benoit, 1971). Low pH values of less than 5 could also affect behaviours and reproduction of aquatic organisms in West Virginia streams (Mount, 1973). Philips et al. (2001) and BOT (2002) have documented the advantages of mining, which include; creation of employment; contribution to Government revenue; foreign currency earnings and increase of Gross Domestic Product (GDP).

The purpose of the study was to assess and analyse the levels of some selected heavy metal pollutants and irrigation water quality parameters in the major rivers and their tributaries in the study area as a result of mining activities and compare the levels to international standard and guideline respectively.

II. METHODS AND MATERIAL

A. Description of the study area

Amansie West District is located in the Ashanti Region of Ghana, and it is an area where Galamsey activities (illegal mining) are very rampant (Figure 1). Rivers served as a source of drinking water for the local people living in the area and currently serves as irrigation water for the farmers in the area especially during dry season and erratic weather condition.

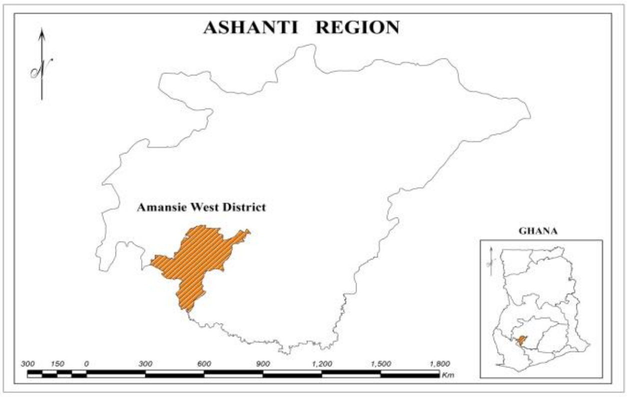

Figure 1: Map of Ashanti Region showing the location of River Nwiene

B. Water sampling and analysis

Twenty one (21) locations were selected on major rivers and their tributaries (Offin, Oda, Subin, Nwiene, Aponapon etc.) for sampling. This was done during the month of January, 2015. Water samples were taken at a depth of 15cm from the river, their temperature, pH, EC and TDS were recorded using a portable pH/EC/TDS/Temp, field Instrument.

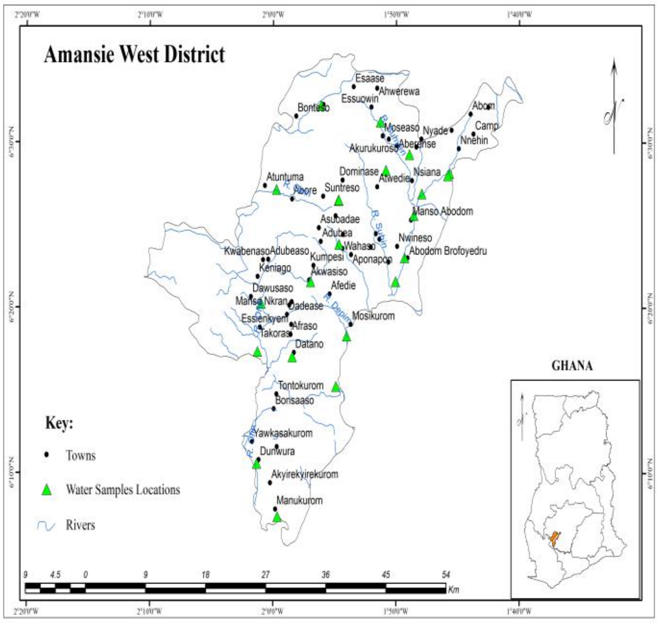

Figure 2 : Water Sampling Locations at Amansie West District

Water samples were then stored at a temperature of 4º C and taken to the laboratory for further analysis. Sampling points were Geo-referenced. The bottles used for sampling were cleaned with dilute hydrochloric acid (HCl) and rinsed repeatedly with deionized water as suggested by De (1989). The bottles were kept air tight and labeled for identification.

Sodium (Na) and Potassium (K) were determined using flame photometer, Calcium(Ca), Magnesium (Mg), Iron (Fe), Cadmium (Cd), Lead (Pb), Manganese (Mn), Copper (Cu) and Zinc (Zn) were determined using Atomic Absorption Spectrophotometer (AAS) respectively Ibitoye (2006). Sodium Adsorption Ratio (SAR), which was the determinant for the suitability of water for irrigation was estimated according Richards, 1954.

III. RESULTS AND DISCUSSION

A. Irrigation Water Quality Parameters

The basic criteria for evaluating pollution levels and other water uses are the estimation of heavy metals (mg/l) and irrigation water quality parameters.

Table 1 shows the results of the analysis of irrigation water quality parameters and table 2 represents the results of pollutants (heavy metals) as a results of mining activities in river bodies. The estimation of electro-neutrality was less than 10% indicating that the chemical analysis was assumed to be good (Hounslow, 1995). The results from table 1 indicate that pH, temperature and ECw varied from the highest of 6.92, 24.30ºC and 184.70μscm^{-1} to the lowest of 5.89, 23.90ºC and 72.60μscm^{-1}. pH, temperature and EC_w are within the accepted limit (UCCC, 1974). In terms of degree of restriction on use of EC_w, the rivers are suitable for irrigation as they fall under category 'None'. TDS is very important in assessing irrigation water quality because many of the toxic solid materials may be found in the irrigation water, which may cause harm to the plants (Matthess, 1982, Asamoah et al., 2015). Also in the absence of non-ionic dissolved constituents, TDS and EC are indicative of saline water (Michael, 1992). The average value of TDS from table is 62.34 mg/l and falls under category 'None'.

Although plant growth is primarily affected by the salinity level of the irrigation water, the application of water with sodium imbalance can further reduce yield under certain soil texture condition (Matthess, 1982). Irrigation water with high sodium (Na^+) can bring about a displacement of exchangeable cations Ca^{2+} and mg^{2+} from the clay minerals of the soil, followed by the replacement of the sodium cation, a situation leading to destruction of soil structure thereby increasing runoffs (Matthess, 1982). Higher sodium content in irrigation water causes an increase in soil solution osmotic pressure. Since plant roots extract water through osmosis, the water uptake of plants decreases (Asamoah et al., 2015). This situation is known as Sodium Adsorption Ratio (SAR). The average value of SAR in the study area was 0.003. According to Richards (1954), for salinity classification (Figure 3), all the irrigation water samples fell under low sodium hazard (S1) and low salinity hazard (C1). Salinity classification was estimated using the diagram in figure 3. This was designed by US salinity laboratory (Richards, 1954). The diagram classifies 16 classes with reference to SAR as an index of sodium hazard and EC as an index of salinity hazard.

At the same level of salinity and SAR, adsorption of Na^+ by soils and clay mineral is greater when Mg:Ca ratio is high. This is because the bonding energy of Mg^{2+} is less than that of Ca^{2+}, allowing more Na^+ adsorption and it happens when the ratio exceeds 4.0 (Michael, 1992). Ayers and Westcot (1985) also reported that soil containing high level of exchangeable Mg^{2+} causes an infiltration problem. The results show that the ratios of Mg^{2+} and Ca^{2+} were less than 1.0 (Table 2). It therefore indicates that there is healthy proportion between Ca^{2+} and Mg^{2+}. The presence of high Na^+ in irrigation water promotes soil dispersion and structure breakdown when Na^+ to Ca^{2+} ratio exceeds 3.1 (Michael, 1992). This also results in severe water infiltration problems, mainly due to insufficient Ca^{2+} to suppress the dispersing effect of Na^+ (Ayers and Westcot, 1985). Excessive Na^+ also creates problems in crop water uptake, poor seedling germination, lack of aeration, plant and root disease (Ayers and Westcot, 1985). Toxicity of the water was determined from the Cu, Mn and Pb, Fe, Zn and Cd levels; these are high except Mn and Zn (Figure 4), and can have effect on the quality of irrigation water and the productivity of the crop cultivated according to Chiroma et al., 2014. Crops require these metals in smaller quantities as nutrients, at high levels they become toxic to crops and affect productivity (Chiroma et al., 2014).

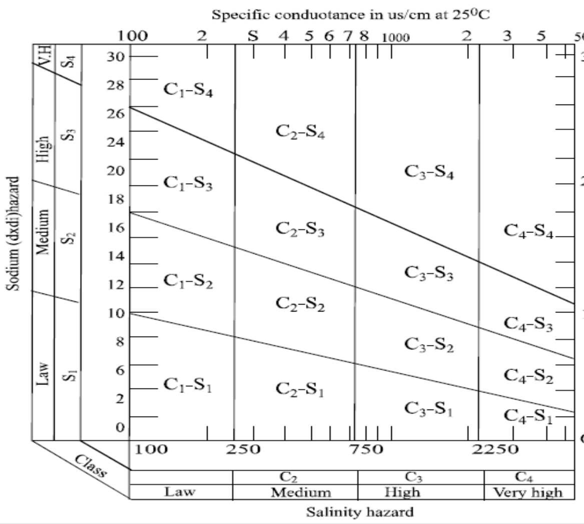

Figure 3. Salinity classification of Irrigation water samples (Richards, 1954)

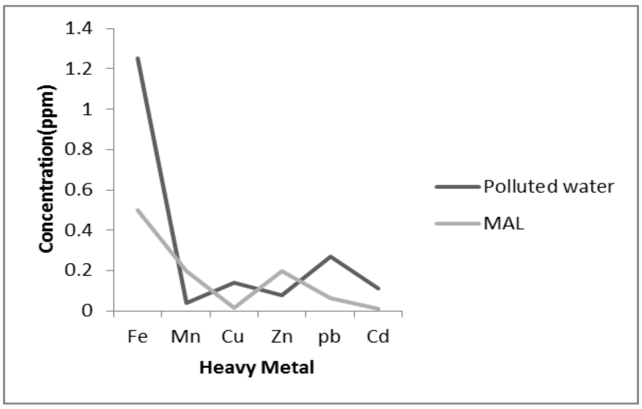

Figure 4: Mean concentration of heavy metals and maximum allowable dose

TABLE I
GUIDELINE FOR INTERPRETATION OF WATER QUALITY FOR IRRIGATION (UCCC, 1974)

Potential Irrigation Problem	Units	Degree of Restriction on Use None	Slight to moderate	Severe
Salinity (affect crop water availability				
EC_w	ds/m	<0.7	0.7-3.0	> 3.0
Or				
TDS	mg/l	<450	450-2000	> 2000
Infiltration (affect infiltration of water into the soil. Evaluate using EC_w and SAR together)				
SAR = 0-3	And EC_w =	0.7	0.7-0.2	<0.2
= 3-6	=	>1.2	1.2-0.3	<0.3
= 6-12	=	>1.9	1.9-0.5	<0.5
= 12-20	=	>2.9	2.9-1.3	<1.3
= 20-40	=	>5.0	5.0-2.9	<1.9
Specific Ion Toxicity				
Sodium	meq/l	<3.0	3.0-9.0	>9.0
Chloride	meq/l	<4.0	4.0-10.0	>10.0
Boron	meq/l	<0.7	0.7-3.0	>3.0
Miscellaneous effect				
Nitrogen(NO_3-N)	meq/l	<5	5-30	>30

TABLE II
IRRIGATION WATER QUALITY PARAMETERS

Label	pH	Temp	EC_w	TDS
		ºC	μscm^{-1}	mg/l
001	6.55	24.30	134.70	67.50
002	6.61	24.30	154.40	77.30
003	6.65	24.20	184.70	92.40
004	6.71	24.20	184.70	92.50
005	6.92	24.10	77.10	38.60
006	6.74	24.10	90.70	45.50
007	6.58	24.10	111.30	55.80
008	6.60	24.10	140.00	70.10
009	6.54	24.10	116.20	58.20
010	6.49	24.10	100.90	50.50
011	6.45	24.10	139.20	69.70
012	6.62	24.10	76.60	38.50
013	6.53	24.00	107.90	54.20
014	5.89	24.00	123.10	61.50
015	6.14	24.00	72.60	36.30
016	5.95	24.00	79.80	40.10
017	6.03	23.90	136.30	68.10
018	6.12	23.90	150.50	75.20
019	6.26	23.90	108.50	54.30
020	6.24	23.90	170.10	85.00
021	6.29	23.90	155.50	77.80
Mean	6.42	24.06	124.51	62.34

TABLE III
IRRIGATION WATER QUALITY PARAMETERS (CONTINUATION)

Label	Ca	Mg	Na	K	Ca:Mg	SAR
	mg/l					
001	6.41	6.80	0.04	0.06	1.06	0.002
002	6.41	6.80	0.07	0.12	1.06	0.003
003	11.22	7.78	0.04	0.08	0.69	0.002
004	9.62	7.78	0.06	0.07	0.81	0.002
005	3.20	2.92	0.03	0.04	0.91	0.002
006	4.81	5.35	0.03	0.04	1.11	0.002
007	4.01	5.35	0.01	0.02	1.33	0.001
008	4.81	4.37	0.03	0.04	0.91	0.002
009	4.81	5.35	0.01	0.02	1.11	0.001
010	6.41	4.37	0.03	0.05	0.68	0.002
011	8.02	6.80	0.07	0.13	0.85	0.003
012	6.41	2.43	0.01	0.01	0.38	0.001
013	4.81	1.46	0.01	0.01	0.30	0.001
014	8.02	2.92	0.01	0.01	0.36	0.001
015	4.01	2.43	0.06	0.07	0.61	0.004
016	4.81	1.94	0.04	0.05	0.40	0.003
017	11.22	5.83	0.04	0.07	0.52	0.002
018	12.82	4.86	0.06	0.11	0.38	0.003
019	7.21	5.35	0.01	0.01	0.74	0.001
020	12.82	7.78	0.01	0.01	0.61	0.001
021	14.43	6.80	0.08	0.06	0.47	0.004
Mean	7.44	5.02	0.05	0.03	0.73	0.003

TABLE IV
VALUES OF SELECTED HEAVY METALS OF WATER SAMPLES

Label	Fe	Mn	Cu	Zn	pb	Cd
	mg/l					
001	2.482	0.044	0.137	0.089	0.049	0.080
002	3.055	0.044	0.149	0.066	0.023	0.085
003	1.163	0.053	0.164	0.090	0.062	0.096
004	1.553	0.045	0.143	0.057	0.112	0.094
005	0.195	0.046	0.133	0.060	0.125	0.088
006	0.219	0.038	0.382	0.071	0.075	0.100
007	0.310	0.042	0.557	0.101	0.098	0.100
008	0.280	0.034	0.270	0.075	0.225	0.106
009	0.840	0.027	0.074	0.069	0.250	0.107
010	1.133	0.039	0.223	0.073	0.310	0.117
011	0.308	0.033	0.039	0.073	0.279	0.113
012	0.276	0.042	0.040	0.105	0.387	0.114
013	0.885	0.041	0.043	0.098	0.224	0.119
014	2.890	0.034	0.049	0.120	0.301	0.119
015	3.100	0.026	0.031	0.101	0.297	0.113
016	2.425	0.041	0.043	0.100	0.410	0.122
017	1.582	0.037	0.048	0.120	0.307	0.115
018	1.295	0.026	0.053	0.109	0.343	0.118
019	0.609	0.054	0.099	0.018	0.540	0.138
020	0.254	0.060	0.115	0.031	0.561	0.134
021	1.315	0.061	0.119	0.028	0.584	0.140
Mean	1.246	0.041	0.139	0.079	0.265	0.110
MAL	0.500	0.200	0.017	0.200	0.065	0.010

MAL = Maximum Allowable Limit; Source: Chiroma et al. 2014

IV. CONCLUSION

Irrigation water quality parameters and heavy metals from major rivers and their tributaries (Offin, Oda, Subin, Nwiene, Aponapon etc.), in the Amansie West District in the Ashanti Region of Ghana were analyzed and compared with the international water quality standard set for irrigation. The parameters analyzed were pH, temperature, EC_w, TDS, Ca, Mg, Na, K and SAR, and Fe, Mn, Cu, Zn, Pb and Cd. On the basis of the irrigation water quality parameters it can be concluded that the water is suitable for irrigation. However, with the except of Mn and Zn, the levels of heavy metals were above the maximum permissible limit and may have adverse effect on the crops.

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