International Journal of Development and Sustainability
Online ISSN: 2186-8662 – www.isdsnet.com/ijds
Volume 1 Number 2 (2012): Pages 212-224
ISDS Article ID: IJDS12101001

Some physiochemical and heavy metal concentration in surface water stream of Tutuka in the Kenyasi mining catchment area

B.M. Tiimub [1*], A. Bia [1], R.T Awuah [2]

[1] *University of Education, Winneba, College of Agriculture, Faculty of Science and Environment, Department of Environmental Health and Sanitation, P. O. Box 40 Asante, Ghana*

[2] *Department of Theoretical and Applied Biology, Kwame Nkrumah University of Science and Technology, Kumasi, Ghana*

Abstract

The research was conducted in the Akantansu stream of Tutuka in Kenyasi in the Brong Ahafo Region of Ghana from October 2010 to January 2011. The objectives of the study were to find out the contamination levels of pH, BOD_5, Lead, Chromium, and Arsenic in the Akantansu stream of Tutuka to promote public health safety of people patronizing the stream for bathing and cooking. Determination of pH was achieved using Etech instrument (PC 300 series where as BOD_5 level was assessed by means of empirical standard laboratory test which determined the relative oxygen requirements of waste water, effluents and polluted water using the standard procedure as per America Public Health Association (2006). An AAS 220 atomic absorption spectrometer was used for the analyses of heavy metals (lead, chromium and arsenic). The Research revealed that, the geometric mean levels of (0.01- 0.02, 0.03 – 0.26, 0 - 0.01, 3.99 – 7.06) mg/L and 5.64 – 6.40 for Arsenic, Lead, Chromium, BOD_5 and pH compared to the EPA Maximum Permissible Limits of (0.5, 0.1, 0.1, 50) mg/L and 6-9 were respectively within the acceptable standards. However, due to slightly higher concentration of chromium (0.26 mg/L) up the stream, the people of Tutuka may develop health effects such as nausea, vomiting, diarrhea, hallucinations, headaches, depression, sleeping disorders, skin cancers, tumours in lungs, bladder, kidney and liver if they continue to use water from the stream for bathing and cooking.

Keywords: Arsenic, Lead, Chromium, pH, Concentration, Upstream, Mid-stream, Downstream

Cite this paper as: Tiimub, B.M., Bia, A. and Awuah R.T. (2012), "Some physiochemical and heavy metal concentration in surface water stream of Tutuka in the Kenyasi mining catchment area", *International Journal of Development and Sustainability,* Vol. 1 No. 2, 212–224.

* Corresponding author. *E-mail address:* benmakimit@yahoo.com

1. Introduction

Modern mining is an industry that involves the exploration for and removal of minerals from the earth economically and with minimum damage to the environment. Mining is important because minerals are the major sources of energy. Mining is necessary for all nations to have adequate and dependable supplies of minerals and materials to meet their economic and defense needs at acceptable environmental, energy and economic costs (Armah et al., 2010).

For many, mining is one of the lucrative jobs in Ghana. Often, citizens think of what they will get in a short while and tend to forget about the future. Citizens do not know that, the nature of mining process creates a potential negative impact on the environment both during the mining operations and for years after the mine is closed. The rate at which mining operations are polluting water bodies in Ghana is a source of serious concern and worry. This impact has led to most of the world's nations adopting regulations to moderate the negative effects of mining operations (Bunce, 1994).

James describes water as "mining's most common casualty". The chronicle issue of July 25, 2003 gave a vivid picture of Ghana's water crisis when it reports a statement attributed to Ashanti Regional Programmes Officer of Environmental Protection Agency (EPA) that, Ghana is listed among countries in Africa that would experience water stress of 1,700 cubic meters or less per person annually by 2025. This is due to the pollution of water bodies (Armah et al., 2010). The theme for the celebration of this year's world water day "clean water for a healthy world" aptly reflects the relationship between clean water and the health status of many people who rely on natural water resources to meet their biological, cultural, recreational and household needs.

The year 2010's theme for the celebration of the world's water day was to afford the opportunity for citizens of every country to discuss the relationship between water availability and water quality so as to meet the Millennium Development Goals (MDGs) as noted by Mr. Kofi Annan, the former UN secretary general that "providing access to clean drinking water is also fundamental for achieving the other millennium development goals such as poverty, hunger and malnutrition, increasing gender equality, providing more opportunities for education and ensuring environmental sustainability" by 2015 (UNICEF, 2010).

Water Aid in 2010 believes that access to safe water, improved hygiene and sanitation is a basic human right issue. These essential services underpin human development and transform lives, enabling people to overcome poverty. In its erstwhile journal on equity and inclusion, a rights-based approach in January, 2010, Water Aid unveils it is fundamentally believed that poverty, marginalization and social exclusion are inextricably linked. In order to realize our vision as a world where everyone has access to safe water and sanitation, Water Aid, Friend of the Earth and its sister Non Governmental Organizations are working hard to implement pollution control mechanisms at point and non point sources of water resources and to address other equity issues, particularly those which are likely to be disadvantaged including women, children, people with disabilities, older people, people living with chronic illnesses including HIV/ AIDS, people belonging to specific castes, religions, ethnic groups, etc.

The Ghana Living Standard Statistical Survey (GLSS, 2008) states that more than 40% of Ghanaians in rural, urban and peri urban centers especially children die each year from diseases associated with unsafe water, inadequate sanitation and poor hygiene. According to GLSS (2008) report on the average, women and children walk a distance of 6km each day carrying 20 litres of water. Mining affects water availability to people through the use of large volumes of fresh water for processing as well as water pollution caused by discharge of mine effluent and seepage from tailing dams and waste rock impoundments. Increasingly, human activities such as mining threaten the water sources on which human beings depend with consequential attendant pollution with oils, suspended solids, heavy metals etc (Lester, 1997).

Among all the lucrative jobs in Ghana, mining has been noted by experts as a serious contributor to water pollution (EPA, 1996) and the WHO in 1993 further spelt out that water quality deterioration has the potential for trans-boundary health defects on human populations once water is noted to be a global resource. As such, the quality of water must be assured whether for drinking, household chores, recreation, farming or industrial purposes. There is therefore the need for research to complement studies on water quality assurance and pollution control from surface water streams (WHO, 1993, Web & Walling, 1992).

2. Justification

Chemical substances from mining companies which find its ways through diverse ways into the Tutuka stream in small quantities can cause harm to aquatic habitats and also inhabitants. Inhabitants of these areas may use the water for irrigation, washing foodstuffs, and other domestic activities (Agyemang, 1998).

The research is deemed fit in the study area because, the children bath in the stream; people of Tutuka and the surrounding area use the water for washing and sometimes drink it when the only borehole in for the community is spoilt and they have no other option for potable water. Sometimes people who use this water get strange skin rashes and sickness.

The research therefore sought to investigate the concentrations of chemicals in surface water streams, with the hope to identify some management practices that could be recommended to eliminate or minimize or control the water pollution incidents and its associated public health hazards.

2.1. General objective

The general objective was to understand the level of contamination of surface water stream with attendant traced metals and physicochemical indicator pollutants from the Tutuka stream within the catchment area of Newmont Ghana Gold Limited located at Ahafo Kenyasi in the Brong Ahafo Region of Ghana.

The specific objectives were to:

- Determine the contamination levels of pH, BOD, lead, chromium and arsenic in the water,
- Find the measures adopted by the community for the prevention of the stream from pollution.

2.2. Profile of the study area

Tutuka is one of the Villages in Brong Ahafo region and the Republic of Ghana with a population of about 600 people. It is located in Asutifi district. One can easily locate it between Kenyasi and Ntotroso. Some nearby villages are Kramokrom, Yawsukrom, Mampong, Tawiahkrom and Asempanaeye. The residents of Tutuka consist of people from different regions such as Western, Volta, Eastern and Brong Ahafo but those from Northern region dominate the settlement. Settlement in the area is nucleated with detached buildings. Tutuka is a food producing area with the main source of employment being farming.

There is a small market centre which is patronized on Tuesdays. There is one primary and one Junior High School but no Senior High School or tertiary. The only sources of light in the village at night are torch light, lantern and solar lighting systems. Unfortunately they have no rural bank nor hospital and neither a clinic so they depend on traditional herbal medical care.

The entire Tutuka community is surrounded by a large, dark, misty creepy heavily dense green forest, even though; sunlight can be seen filtering through the trees. Some of the trees are intertwined and winding. The forest vegetation is characterized by thick denser growth of epiphytes and creeping lianers on the trees which form pyramid and cone shaped canopies.

Plate 1. Vegetation around the Tutuka stream

The leaves in the forest have different textures, some of which are glittering and shiny, quilted and pleated, hairy and bristly, weaved twisted and curled. Leaves also vary in colour, some of which are rich and dark green, light and soft green, yellow to gold, and reds and purples. There are different plants in Tutuka forest. The plants seem to very close so they form shapes as canopies, pyramid and cone.

3. Materials and methods

3.1. BOD_5

The biochemical oxygen demand (BOD_5) determination is an empirical test which determines the relative oxygen requirements of waste water, effluents and polluted water. Microorganisms utilize dissolved oxygen in water to oxides polluting organic substance. By way of measuring the initial concentration of oxygen sample and that after five days of incubation 20 ^{0}C, the BOD_5 can be determined.

Using a wide tip volumetric pipette, a desired volume of sample was added to two bottles (300ml)**.** For each sample dilution, two BOD bottles were prepared**.** The bottles were filled with enough dilution water so that insertion of the stopper displaced all the air leaving no air bubbles. Two more BOD bottles were filled with dilution water to serve as blank. Bubbles in the bottles were avoided and the dissolved oxygen concentration for one blank was determined.

This determination was performed within 15minutes of the sample or blank preparation. The second bottle was tightly stoppered, water sealed and incubated for five days at 20 ^{0}C. The dissolved oxygen determination on the incubated samples was carried out at the end of the 5th day.

Calculation: BOD_5, mg/L = $\frac{D_1 - D_2}{P}$; where D_1 = DO of diluted sample immediately after preparation, mg/L, D_2 = DO of diluted sample after 5 days incubation at 20°C, mg/L, and P = decimal volumetric fraction of the sample used.

3.2. pH

Determination of pH was achieved using Etech instrument (PC 300 series). The cap was removed and the ON/OFF button was pressed to switch on the meter. The electrode was rinsed with distilled water and then dipped into about 2 to 3cm into the test sample, stirred once and the reading allowed to stabilize.

3.3. Analysis of Metals

An AAS 220 atomic absorption spectrometer was used for the analyses of heavy metals concentration from the surface water from upstream, mid-stream and downstream of the Tutuka River.

Fundamentally, quantitative analysis by atomic absorption spectroscopy is a matter of converting samples and standards into solution whilst comparing the instrumental responses of standards and samples and using these comparative responses to establish accurate concentration values for the elements of interest. This method was used to determine Lead, Chromium and Arsenic concentrations in surface water from the Tutuka Stream.

Plate 2. Amma Biaa Marfo, taking water sample from the Tutuka River

Plate 3. Amma acidifying water with nitric acid for laboratory analysis

The raw water which served as solution was measured, containing the analytic element (the analytical blank). Series of calibration solutions were made up containing known amounts of analytic elements (the standards). A calibration group was plotted showing the response obtained for each solution. The sample solution was atomized and the response was measure. The trace element concentration in mg/L of the sample was then determined from the calibration.

3.4. Statistical Analysis

Statistical analysis was performed on the data collected. Monthly variation of each parameter was analyzed using the Statistical Package for Social Scientists (SPSS Version 17) at P>0.05 level of significance and compared with EPA Standards and WHO Guideline values shown on Table 1.

Table 1. EPA Ghana 1996 Standards and WHO 2006 Guideline values for trace metals, pH and BOD of surface water

Parameter	**EPA Ghana tandard**	**WHO Guideline Value**
Chromium	0.1mg/L	0.1mg/L
Arsenic	0.5mg/L	0.5mg/L
Lead	0.1mg/L	0.1mg/L
pH	6-9	6-9
BOD_5	50mg/L	50mg/L

3.5. Limitations of the research

Distance from the site to the laboratory was very long. Reaching the laboratory at the appropriate time was a major challenge due to the struggle involved in patronizing commercial vehicles from Tutuka. It was also difficult to cover a lot of parameters due to the high cost of analysis involved.

4. Results

Figure 1 below shows the mean concentrations of trace metals with pH in raw water samples from the Tutuka stream in October, 2010.

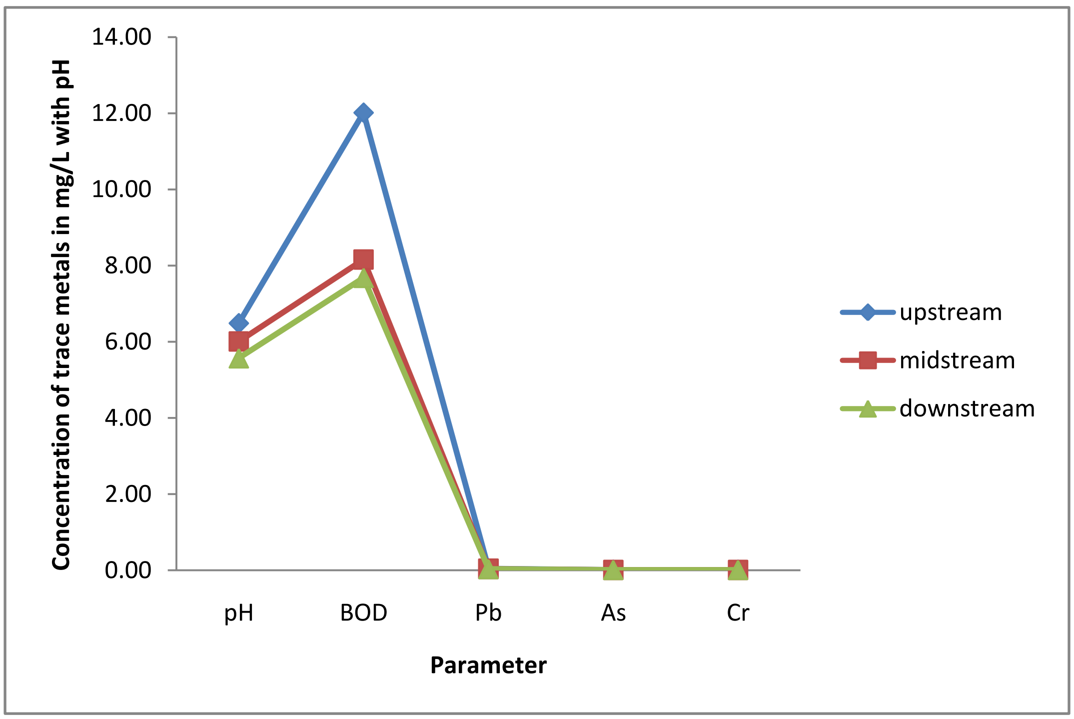

Figure 1. Trace metal concentrations with pH in raw water from Tutuka stream for October, 2010

From Figure 1 above, the mean trace metal and pH concentrations in the raw water samples depicted a varying trend from the different points of sampling. The pH values ranged from 5.57mg/L – 6.48mg/L. The lowest value was recorded downstream whilst the highest value was recorded upstream. The midrange value (6.01mg/L) was however recorded at the stream. The BOD values ranged from 7.68mg/L – 12.01mg/L. The lowest value was recorded downstream whilst the highest value was recorded upstream. The midrange value (8.16mg/L) was however recorded at the mid-stream.

The lead values ranged from 0.03mg/L – 0.04mg/L. The lowest value was recorded downstream whilst the highest value was recorded upstream. The midrange value (0.04mg/L) was however recorded at the stream. The overall mean chromium levels and Arsenic levels detected in all samples over the three month sampling period were 0.01mg/L. The same amount was also detected between upstream, midstream and downstream.

Figure 2 shows the mean concentrations of trace metals with pH in raw water samples from the Tutuka stream in November, 2010.

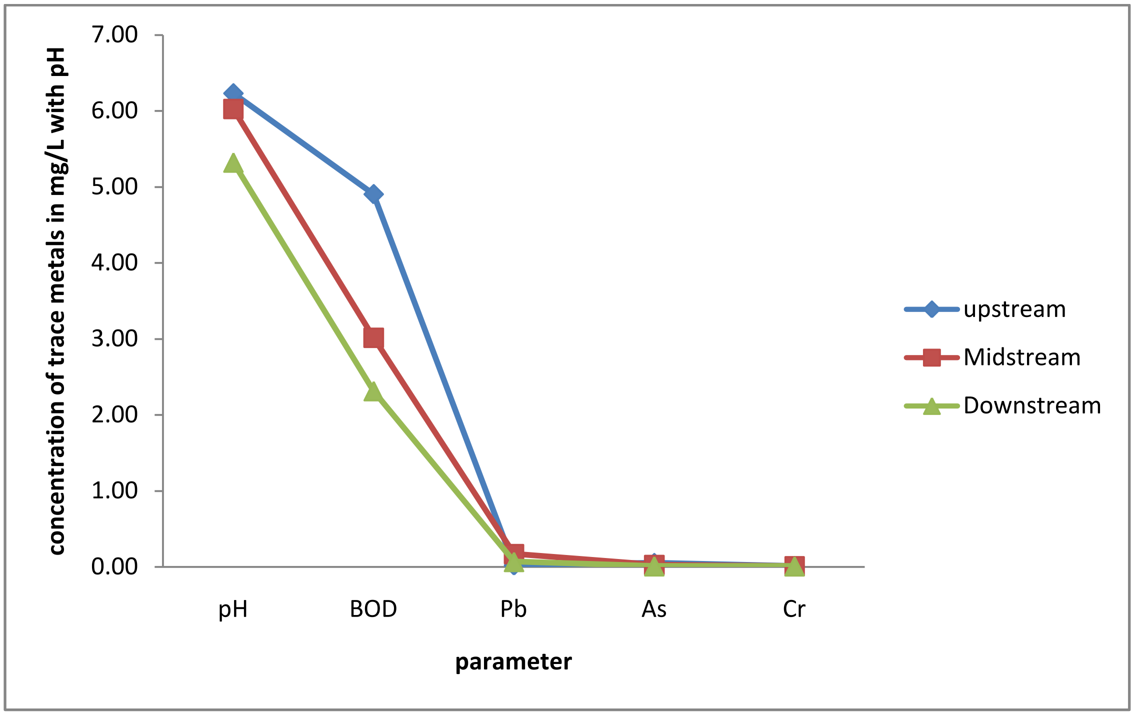

Figure 2. Trace metal concentrations with pH in raw water from Tutuka stream in November, 2010.

From Figure 2 above, the mean trace metal and pH concentrations in the raw water samples depicted a varying trend from the different points of sampling. The pH values ranged from 5.32mg/L – 6.24mg/L. The lowest value was recorded downstream whilst the highest value was recorded upstream. The midrange value (6.02mg/L) was however recorded at the mid-stream. The BOD values ranged from 2.32mg/L – 4.90mg/L. The lowest value was recorded downstream whilst the highest value was recorded upstream. The midrange value (3.01mg/L) was however recorded at the mid-stream. The lead values ranged from 0.02mg/L – 0.17mg/L. The lowest value was recorded upstream whilst the highest value was recorded midstream. The midrange value (0.07mg/L) was however recorded at the mid-stream. The Arsenic values ranged from 0.01mg/L – 0.05mg/L. The lowest value was recorded downstream whilst the highest value was recorded upstream. The midrange value (0.03mg/L) was however recorded at the mid-stream. The overall mean chromium levels detected in all raw water samples over the three months sampling period were 0.01mg/L. The same amount was also detected at the upstream, midstream and downstream.

Figure 3 shows the mean concentrations of trace metals with pH in raw water samples from the Tutuka stream in January, 2011.

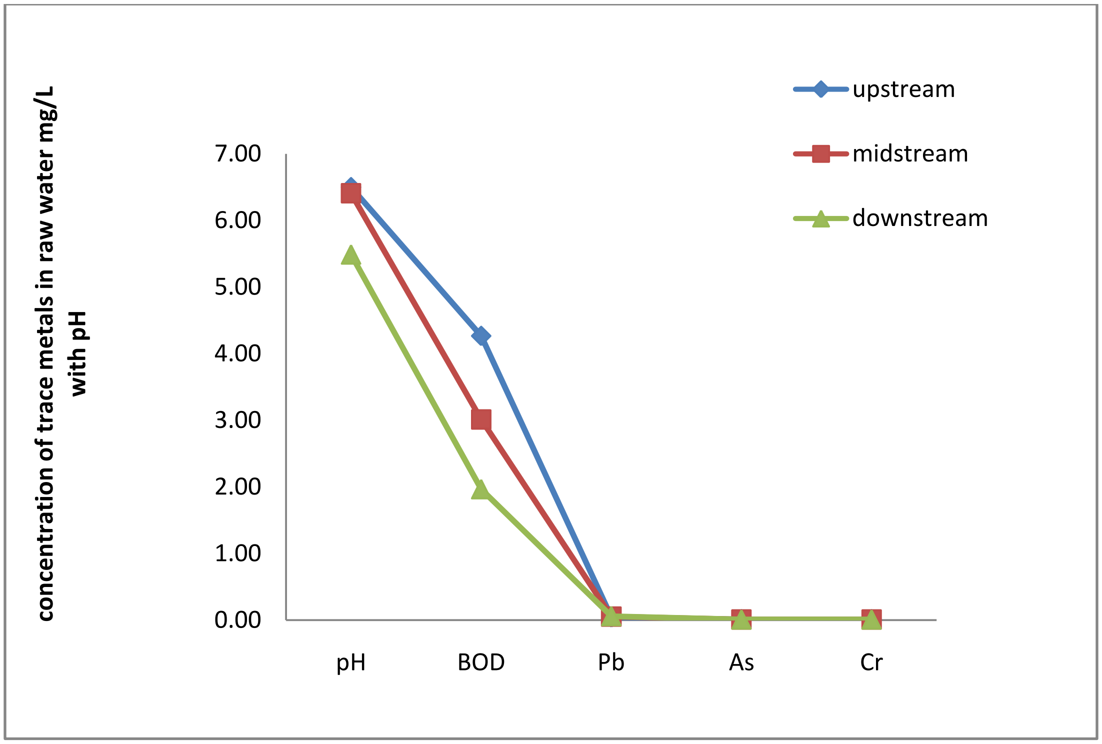

Figure 3. Trace metal concentrations with pH in raw water from Tutuka stream in January, 2011

From Figure 3 above, the mean trace metal and pH concentrations in the raw water samples depicted a varying trend from the different points of sampling. The pH values ranged from 5.49mg/L – 6.50mg/L. The lowest value was recorded downstream whilst the highest value was recorded upstream. The midrange value (6.41mg/L) was however recorded at the stream. The BOD values ranged from 1.97mg/L – 4.27mg/L. The lowest value was recorded downstream whilst the highest value was recorded upstream. The midrange value (3.01mg/L) was however recorded at the mid-stream.

The lead values ranged from o.o4mg/L – 0.06mg/L. The lowest value was recorded upstream whilst the highest value was recorded downstream. The midrange value (0.05mg/L) was however recorded at the mid-stream. The overall mean chromium levels and Arsenic levels detected in all samples over the three month sampling period were 0.01mg/L. The same amount was also detected upstream, midstream and downstream.

Figure 4 shows the geometric mean concentrations of trace metals with pH in raw water samples from the Tutuka stream over the three months periods.

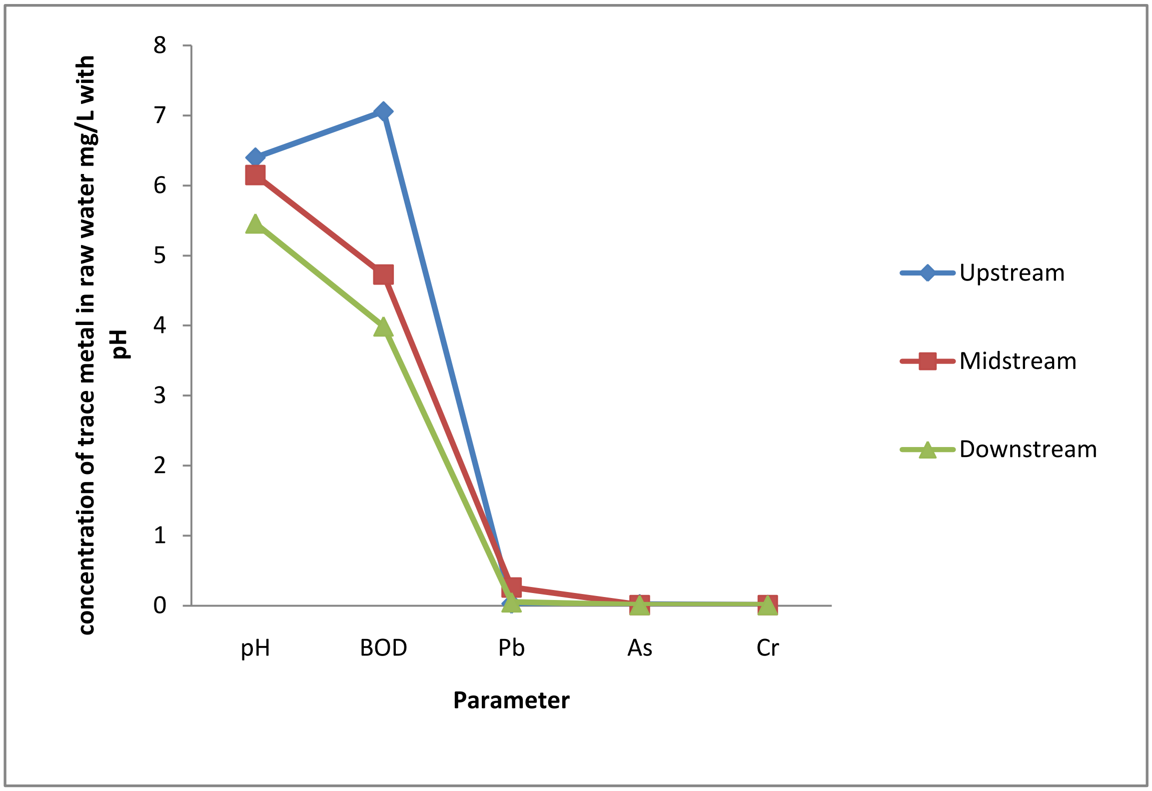

Figure 4. Geometric mean concentration of trace metal with pH in raw water from Tutuka stream from October, 2010 – January, 2011

From Figure 4 above, the mean trace metal and pH concentrations in the raw water samples depicted a varying trend from the different points of sampling. The geometric mean pH values ranged from 5.46mg/L – 6.40mg/L. The lowest value was recorded downstream whilst the highest value was recorded upstream. The midrange value (6.15mg/L) was however recorded at the stream. There was however significant differences between them ($p>0.001$).

The geometric mean BOD level ranged from 3.99mg/L - 7.06mg/L. The lowest value was recorded downstream whilst the highest value was recorded upstream. The midrange value (4.73mg/L) was however recorded at the mid-stream. However, between the three points of sampling, there was no significant difference between them ($p>0.880$).

The geometric mean lead values ranged from 0.03mg/L – 0.26mg/L. The lowest value was recorded upstream whilst the highest value was recorded midstream. The midrange value (0.05mg/L) was however recorded downstream. There was a statistically significance between the three points sampling values ($p>0.003$) in terms of lead concentration recorded over the three months period.

The Arsenic values ranged from 0.01mg/L – 0.02mg/L. The lowest value was recorded downstream whilst the highest value was recorded upstream. The midrange value (0.01mg/L) was however recorded at the mid-stream. The geo mean values recorded upstream, mid-stream and downstream did not show statistically significant difference between them ($p>0.545$). The geometric mean chromium levels detected in all the raw water samples over the three months period were 0.01mg/L. The same amount was further detected upstream, midstream and downstream generally observed over the three months sampling period.

5. Discussion

There was a general definite pattern of behaviour of pollutants as it was observed from the three sampling points within the three months study period. It was observed that in most cases, the pollutant concentration reduced in a stretch of water flow down the stream. This confirms the idea that pollutants particularly, heavy metals in water turn to decrease along the distance of travel for a moving surface water body when exposed to bleaching and oxygenation. This may be attributed to the fact that larger organisms such as rooted plants and rocky sediments may induce a trapping effect which renders for the gradual removal of pollutants (trace metals) from the water (USGS, 1999).

The results of the physiochemical parameters from the stream were compared with the prescribed water quality standard given by WHO 2006 and EPA 1996. The geometric mean levels of (0.01- 0.02, 0.03 – 0.26, 0 - 0.01, 3.99 – 7.06) mg/L and 5.64 – 6.40 for Arsenic, Lead, Chromium, BOD_5 and pH compared to the EPA Maximum Permissible Limits of (0.5, 0.1, 0.1, 50) mg/L and 6-9 were respectively within the acceptable standards. There was a slight increase in the levels of metals in the water as compared with the EPA standard and WHO Guidelines.

For instance, as chromium level in water increased to 0.26 mg/L up the stream, the people of Tutuka may develop several health effects such as nausea, vomiting, diarrhea, hallucinations, headaches, depression, cardiac arrhythmia, confusion, sleeping disorders, skin cancers, and tumours in lungs, bladder, kidney and liver if they continue to use water from the stream for bathing and cooking. When there is high level of metals in the stream they could further develop paralysis, stomach upsets and ulcers, respiratory problems, weakened immune systems, kidney and liver damage, alteration of genetic material, lung cancer and death (GSWQ: SDW 2008).

Heavy metals, present in various forms of domestic waste and the metals from the detergents in laundry waste waters discharged and drained into the rivers could scale up the level of surface water pollution (APHA, 1998). Besides, farming with agrochemicals could be an additional factor to stream pollution (USEPA 1990) since people living at Tutuka till closer to the stream. The use of herbicides, pesticides and artificial fertilizers could further increase the crude content of chromium, lead and arsenic in the soil while erosion would take off the top soil leading to mineral dissolution into water bodies (Bradley & Kutz, 2006).

It has been observed that traces of chemicals in surface waters may be as a result of prolific use of various pesticides, organochlorine and organophosphate fertilizers to boost crop yields (Bunce, 1994). Therefore, traced metals found in the Tutuka stream could be the result of extensive cultivation of cocoa and other food crops at the alluvial banks of the stream thereby leading to the contamination of the stream. Similar trends of surface water pollution have been observed in developing countries where fertilizer usage is on the ascendancy. (Bradley & Kutz, 2006). Mining activities can also be a factor. The waste rock left at the mining places oxidizes to release free metals to the environment which causes heavy metal poisoning resulting from disposal of waste chemicals into the environment which mistakenly get into the stream (Gilvear & Bradley, 2000).

6. Recommendations

Boreholes should be constructed and malfunctioning ones repaired for the people of Tutuka by Newmont Ghana Gold Limited, so that they do not rely solely on the river for household water demands. Wells should be constructed for farmers around their farms so that it could be used for irrigation purposes.

Waste chemicals from the mining company should be treated to remove toxin substrates and concentrates from the raw water before it is released into the environment. EPA Ghana should conduct routine water quality monitoring surveys to determine the concentration of traced metals released into environment by the Newmont Mining Company. Anyone who flouts the law should be punished or fined and the money be used to cater for those who are affected or pay for the huge cost of environmental amelioration.

Mines should not be sited closer to towns and villages. The villages inside the mining concession should therefore be relocated to new places which are far from the mines and consequently the mining companies should take up some responsibilities to provide some social amenities such as hospitals, schools, toilets, post offices and good drinking water to raise the living standards of citizens. Newmont should give the people of Tutuka some motivation in terms of food or money to help them survive or replace all their lost lands.

7. Conclusion

The study revealed a pattern of gradual decrease in concentration of pollutants (trace metals) along the surface water resources from upstream to downstream and it appears that the pollution could be directly related to the kinds of economic activities particularly, mining which is vigorously done by Newmont Ghana Gold Limited. Hence, monitoring of the water quality should be done on frequent basis by the EPA and there should be an effective collaboration between resource developers and the communities who greatly rely on the Tutuka stream for drinking, farming and other household chores to control pollution of the stream. At best, an integration of appropriate water resources management policies should be promoted in order that the residents who ought to directly enforce initiatives towards the catchment area's protection could be held responsible.

Acknowledgement

The Authors are grateful to the Authorities of Newmont Ghana Gold Limited at Ahafo Kenyase for assisting with laboratory facility to analyze the data**.** We are further grateful to Professor, Richard Tuyee Awuah for mentoring and encouraging us to write.

References

Agyemang, P. (1998), *Mining and threats of the environment,* Chicago Press, USD, pp. 16-23.

American Public Health Association (1998), Standard *Methods for the examination of water and waste water*, 20thEds APHA, Washington.

Armah, F.A., Obiri, S., Yawson, D.O., Pappoe A.N.M. and Bismark, A. (2010), "Abstract Mining and Heavy Metal Pollution: Assessment ofAquatic Environments in Tarkwa (Ghana) using Multivariate Statistical Analysis", *Journal of Environmental Statistics,* Vol. 1 No. 4, pp. 1-13.

Bradley, P. and Kutz, F.W. (eds) (2006), *Proceedings of the Workshop on Stormwater Management and Mosquito Control*, U.S Environmental Protection Agency, Office of Research and Development, EPA /903/R-06/004.

Bunce, N.J. (1994), *Environmental chemistry,* 2nd edition. Wuerz, Winnipeg, pp. 131-158.

Environmental Protection Agency (1996), *Environmental Assessment in Ghana. A Guide,* Accra, Ghana, p. 89.

GLSS - Ghana Living Standards Survey (2008), Report of the fifth round (GLSS 5), Ghana Statistical Service, September 2008.

GSWQ - Ghana Standard Water Quality: Specifications for Drinking Water (2008), GS 175- 1.

Gilvear, D.J. and Bradley, C. (2000), "Hydrological monitoring and surveillance for wetland conservation and management; a UK perspective", *Phy Chem. Earth Pt B,* Vol. 25, pp. 571-588.

Lester, W.F. (1997), "Polluted River, River Trent, England", in: B.A. Whition (ed), *River ecology,* Blackens Scientific Publication, London, pp. 489-513.

UNICEF (2010), "Millenium Development Goals", available online at: http/www.marthamine.co.nz/env-com.

USEPA (1990), *Pesticides in drinking well waters,* US Environmental Protection Agency, Office of Groundwater Protection, Washington, DC. Rep 20T-1004.

USGS (1999), *The quality of our nation's waters: nutrients and pesticides,* US Geol Surv Cir 1225.

Water Aid (2010), *Equity and inclusion: A rights based approach, January,* 2010, pp. 4-5.

Web B.W. and Walling D.E. (1992), "Water Quality. II. Chemical Characteristics", in Calow, P. and Petts G.E. (Ed.) *The Rivers Handbook, Volume 1*, Black well Scientific Publication Oxford, UK, pp. 73-100.

WHO - World Health Organization (1993), *Guidelines for drinking water quality,* Geneva, Switzerland.

WHO - World Health Organization (2006), *Guidelines for Drinking water Quality*, Third edition, WHO Press, Geneva, Switzerland, p. 398.