THE IMPACT OF MINING ON THE RIVERINE ECOSYSTEM OF GHANA-AN SEA PERSPECTIVE

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Abstract

A Strategic Environmental Assessment (SEA) of the mining sector is underway in Ghana. One component of the SEA is the study of the cumulative impact of mining on the riverine ecosystem of Ghana. Twenty-two sampling stations have been established within three river basins, which host the heavily mined districts of the country. A further two stations were selected from a 'mine-free' basin to serve as control. Physico-chemical characteristics including trace metal pollutants like mercury, arsenic as well as cyanide in different environmental compartments of the river systems are being analysed using ICP-MS. In addition to water and sediment sampling, seventeen of the sites are being used to assess aquatic biota, especially the fish and macroinvertebrates employing such methods as Catch Per Unit Effort (CPUE), coefficient of Condition (K) and Gonadosomatic Index (GSI). Fish are an important source of protein in the diet of the rural population of Ghana. These assessments will form the basis for the formulation of policies and actions to assist in conserving the biological diversity of the rivers and streams of Ghana.

Key Words : SEA, Biophysical monitoring, Mining Sector, Ghana

Introduction

The mining sector in Ghana has experienced a boom since 1999 when a new mining law came into force. However, a section of the Ghanaian population has regarded at this upsurge in the activities of the extractive industry critically, due to the negative impacts that mining operations have wrought on the environment. The impacts are especially pronounced in surface mining operations where losses of forest cover, other indigenous fauna, as well as flora have been most severe (Coakley 1998; Sweeting and Clark 2000).

A recent review of the environment of the mining sector in Ghana noted several adverse impacts, especially of surface mining, on the environment (Lundberg and Larmie 2001). The review showed that the decision by government to liberalise the mining sector was not accompanied by a comprehensive study of the impacts of this policy on the environment, nor on the socio-economic conditions associated with communities in which mining companies operated (Lunderg and Larmie 2001; Akabzaa and Darimani 2001).

The Strategic Environmental Assessment (SEA) is a component of the National Environmental Impact Assessment and Strategic Environmental Assessment Project, which in turn is a major part of the Mining Sector Support Programme (MSSP), funded by the European Union (EU) and carried out under supervision of the Minerals Commission. One part of this study is an assessment of the impact of mining on the aquatic ecosystem of rivers draining the mining areas in Ghana. The study is intended to assist in formulating policies that would promote more environmentally friendly and sustainable operations by the mining companies. Secondly, the study can provide a method for assessment of the impact of the operations of the mining companies on the physico-chemical quality and biota of the streams and rivers draining the mining areas, to help safeguard the biodiversity of the freshwater bodies in mining areas in Ghana.

Approach to Study

Selection of monitoring sites

A reconnaissance survey was undertaken in December, 2005 to choose 24 monitoring stations on the Bia (2), Tano (5), Ankobra (5), and Pra (12) rivers. There is no current mining activity in the Bia basin. The stations on the Bia, therefore, serve as reference (control stations) for impact assessment. The stations were:

a. Bia Basin	Kasapin or Biaso Dadieso
b. Tano Basin	Techiman, Hwidiem, Sefwi Wiawso (Dwinase), Jomuro and Nsuano (Elubo)
c. Ankobra Basin	Ankwaso, Bepo Prestea (Himang), Dominase and Bonsaso.
d. Pra Basin	Dadieso (Near Nkawkaw), Dunkwa on Offin, Bekwai, Assin Praso, Offinso, Adiembra, Twifo-Praso, Daboase, Mmuronuem, Ampunyase, Akim Oda and Osino.

Materials and Methods

Physico-Chemical Monitoring

Samples were collected every two months from January to December 2006, hence six sampling expeditions have been carried out. This adequately takes care of seasonal changes in water quality which is influenced immensely by rainfall. There are two rainy seasons within the project basins occurring from April to July and from September to October.

Temperature (°C), pH, Conductivity (µS/cm), and Turbidity (NTU) were measured directly in the field. Water samples were acidified with concentrated nitric acid to obtain a pH of about 2 units and shipped immediately to Sweden for metals analysis using ICP methods. Wet river sediments were similarly sent for processing and metal analysis.

Biological Monitoring

Seventeen of the stations listed above also served as biological monitoring sites.

Fish Samples

Eight gill nets with mesh sizes of 12.50, 15.0, 17.50, 20.0, 22.50, 25.0, 30.0 and 40.0 mm were used to sample the fish populations within the reaches of the rivers. Each net measured 25m x 2m (50.0 m^2). Nets were set parallel to the banks of the river at dusk (17:00h) and retrieved the following morning (06:00h – 07:00h). Fish caught by each gill net were identified to the species level by using appropriate keys such as Dankwa *et al*. (1999) and Lévêque *et al.*, (1992).

Estimation of Fish Bio-Indices

The standard length (SL), total length (TL), body depth (B dpt.) and weight of each fish was measured. In addition, the state of the gonad of each fish was assessed by opening the fish and examining the gonad visually. The stage of maturity of the gonad was scored on a scale of 1 – 4 following standard procedure (Lavaetsu, 1965). The number of fish caught , the species caught by each mesh size , SL, TL B. dpt. and weight of each fish were then used to estimate the following indices:

a. Catch Per Unit Effort (CPUE in Number) = $\frac{Nx100}{lxdxnx2}$ (Lévêque *et al*., 1990); where N = Total number of fish caught by gill net l = Length of gill net; d = Depth of immersed portion of gill net n = Number of nights fishing undertaken.

or b. Catch Per Unit Effort (CPUE by Weight) = $\frac{Wx100}{lxdxnx2}$ (Lévêque *et al.* 1990); where W = Total weight of fish caught.;

c. Coefficient of Condition K = $\frac{10^5 xW}{L^3}$ (Williams, 2000);where W = Weight of fish, L = Standard length of fish

Macroinvertebrate Sampling

Macroinvertebrates were collected from 50 to 100m stretches along the river at each site. Macroinvertebrate samples were collected from the rivers at the peak of the dry season i.e. between March and June when the rivers were at their lowest discharges.

A combination of sampling methods was used in collecting benthic macroinvertebrates from rivers. The specific methods, however, depended on the hydrological conditions prevailing at the site at the time samples were collected. An Ekman grab was recommended for sampling from bottoms that are deeper than 0.50m. In shallower waters, on the other hand, a modified Surber sampler measuring 15 x 15 cm was used for collection of benthic macroinvertebrates (Yaméogo *et al*. 1993; Resh *et al.* 2004).

Samples were supplemented by an extensive sampling of the reach (50 – 100m length) of the river by using a D-frame hand net with mesh size of 250 µm. The net was held with the mouth facing upstream. Stones, cobbles and snags just in front of the mouth of the net were lifted and washed in the stream water so that any clinging macroinvertebrates were swept into the net. The process was repeated along the banks. Five Ekman grab or modified Surber samples were collected from each site and supplemented by three three-minute sweep net samples as described above. All samples were kept separately and preserved in a suitable preservative such as 4% formalin, Kahle's fluid or 70% ethanol. Macroinvertebrate samples were examined under a dissecting microscope, all individuals sorted out of the samples and identified to the family level with the help of available keys (Dejoux *et al*. 1982).

The data obtained were used to estimate:

a. $$H' = -\sum_{i=1}^{\alpha}(ni/n)\log(ni/n).$$

b. Density = Number of individuals /m^2 of bottom sampled.

The various macroinvertebrates collected from each river were assigned to their appropriate 'Functional Feeding Group' by following the scheme developed by Merritt and Cummins (1996) or information provided by Dejoux *et al* . (1982).

Preliminary Findings

Physico-Chemical Water Quality

The results presented here are only preliminary and a more rigorous assessment is underway. In the interim, this paper attempts to describe the following conditions of Arsenic in the water bodies:

- Arsenic (As) levels in sediments for the different river systems; and
- Spatial distribution of Arsenic in water in each river system, and particularly in comparison with the control basin, Bia

There was no extreme occurrence of pH during the study period and monitoring results ranged from 6.5 to 7.5 units. Any possible linkages between As in the water and sediment environmental components at specific monitoring sites or for the entire basins are yet to be explored.

Arsenic (As) in river sediments

The results from a sampling exercise carried out in August, 2006 are summarised in the table below:

Table 1: Summary of sediment As concentration (mg/kg TS) in the respective river basins

Statistic	Ankobra	Tano	Pra*	Bia**
Median	124.0	14.8	25.3	3.1
Upper Quartile	179.0	24.8	34.8	3.3
Lower Quartile	9.8	3.3	10.0	3.0
No of samples	5	5	11	2

*1750mg/kg As was measured at Ampunyase (Pra basin) and may be considered an outlier in statistical analysis. This value was therefore not used for the calculation of the statistical parameters shown above. ** Control basin

The non- parametric statistical approach is employed which is insensitive to outliers and also suitable for situations where the data points are few. The results are presented in Figure 1. The figure suggests that the Ankobra river has the highest concentration of As in its sediment and the Bia which is the control basin has as expected, the least. The US EPA standard for arsenic in sediments is 70mg/kg As. Some of the monitoring sites had As levels in excess of this concentration. The respective percentages of samples in excess of this standard are provided in Table 2. This further confirms the vulnerability of the Ankobra River to As pollution. The table also indicates that the median As concentration for Ankobra, Tano and Pra basins are about 40 times, 5 times, and 8 times respectively, higher than the control value measured in the Bia basin.

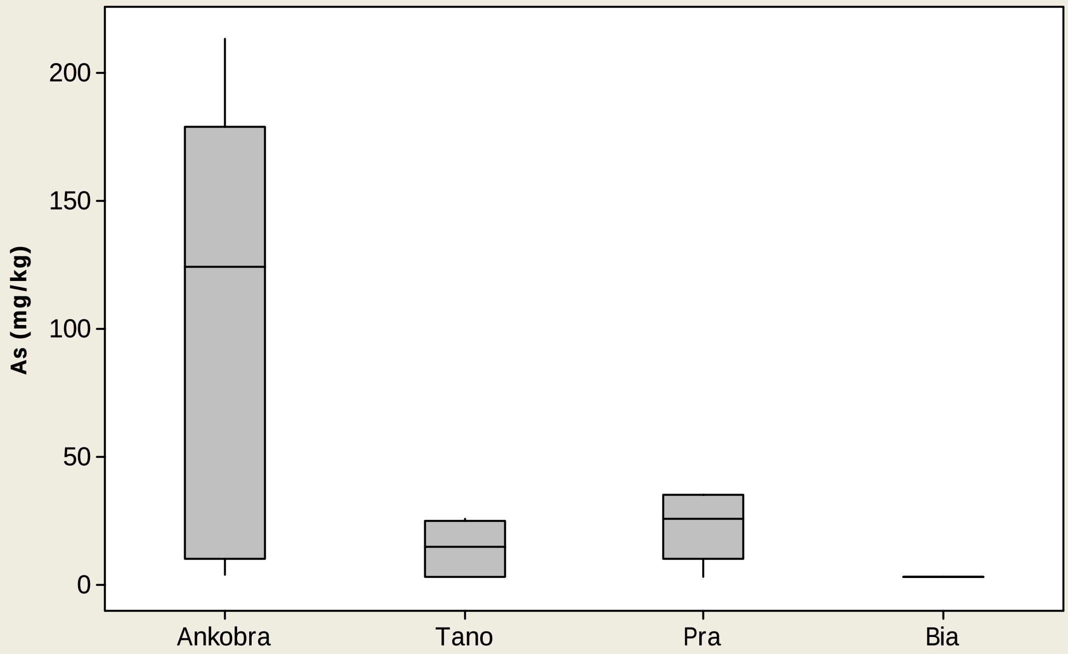

Fig. 1: Box Plot of Arsenic Concentrations in Sediments in the Study area

Table 2: Comparison of As in sediments in project basins with Standard and Control Basin

River Basin	% of samples in excess of US EPA 70mg/kg standard	No of times median As conc. is in excess of Control (Bia Basin)
Ankobra	60	40
Tano	0	5
Pra	18	8
Bia	0	-

Spatial distribution of As in the river systems

The distribution of As in water along the respective river reaches is presented in Figure 2. The Bia monitoring stations namely Kasapin and Dadieso, which provide control data have been included for comparison. From these graphs, it appears that the level of As in the background (upstream) sampling sites of the Ankobra, Tano and Pra rivers correspond closely to the levels found in the control (Bia) basin. With the exception of the Ankobra, the highest As levels occur in the mid reaches which suggests proximity to the Arsenic generating sources. There is dilution downstream to reduce As concentration towards the mouth of the respective rivers.

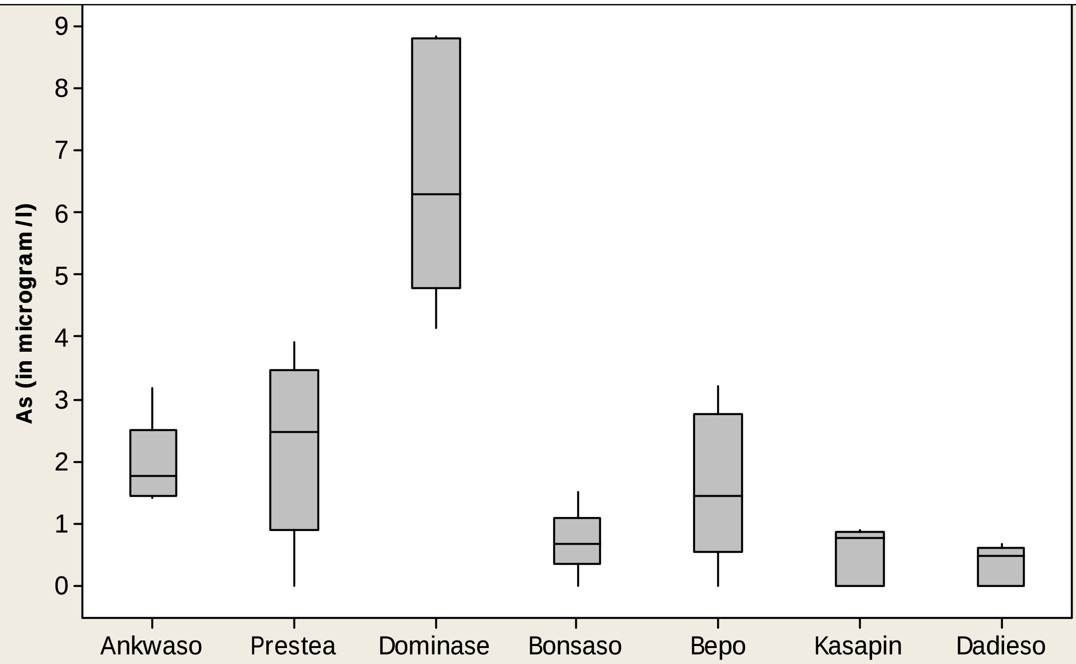

Fig. 2: Boxplot of Arsenic in Ankobra Basin

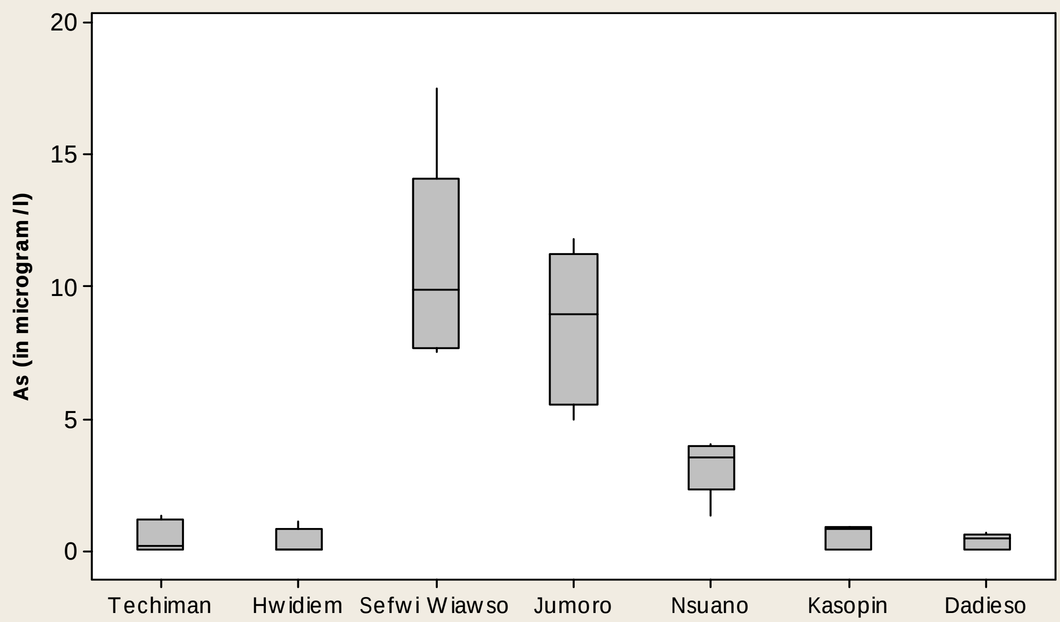

Fig. 3: Boxplot of Arsenic in Tano Basin

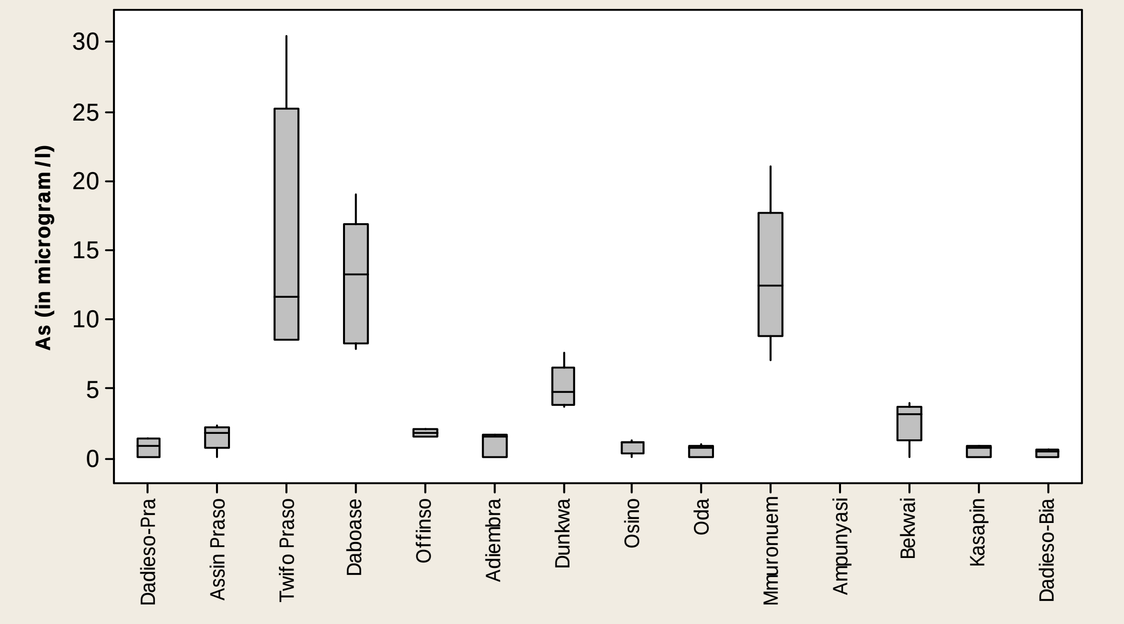

Fig. 4: Boxplot of Arsenic in Pra Basin..

Fauna

The results presented here are based on data obtained from fish collected during the low water period within the basins (March to June). Fifty-five species of fish representing 24% of the total freshwater fish species in Ghana were caught from all study basins.

Catch Per Unit Effort (CPUE)

The mean CPUE of fish at Kasapin and Bia-Dadieso (Control Stations for the study) was 24.21 and 36.56 individuals/100m^2/night respectively (Fig 5). Although mean CPUE at Ankwaso (a background station on the Ankobra was 33.21 individuals (about the same order of magnitude as Bia-Dadieso all other CPUE values were lower than those for the control basin.

Coefficient of Condition (K)

Frequency distribution of coefficients of condition of *Brycinus longipinnis* (Planktivorous) *Petrocephalus bovei* (Benthic insectivorous/macroinvertebrate eating) and *Schilbe mystus* (Pelagic Piscivorous/insectivorous) are presented in Fig. 6, Fig. 7 and Fig. 8 respectively. The median K for *Brycinus longipinnis* ranged from 2.51 at Prestea to 3.13 at Jomuro. The range for *Petrocephalus bovei* was from 1.85 at Nsuano to 2.35 at Bepo whereas for *Schilbe mystus,* the range of median K was 1.14 at Nsuano to 1.55 at Akim Oda.

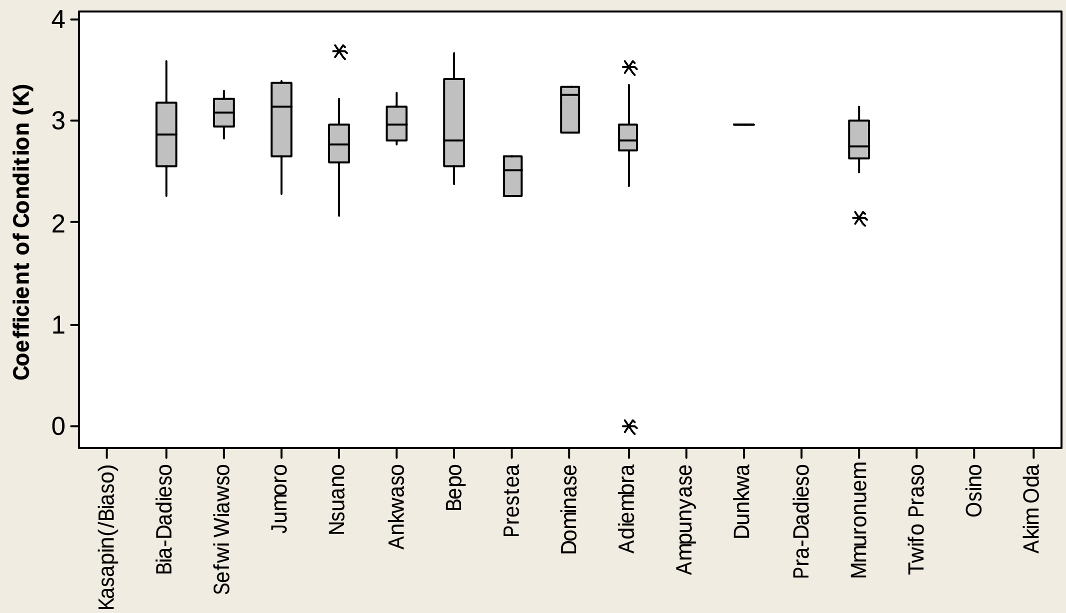

Fig.6:Boxplot of Coefficient of Condition of Brycinus longipinnis from River Basins

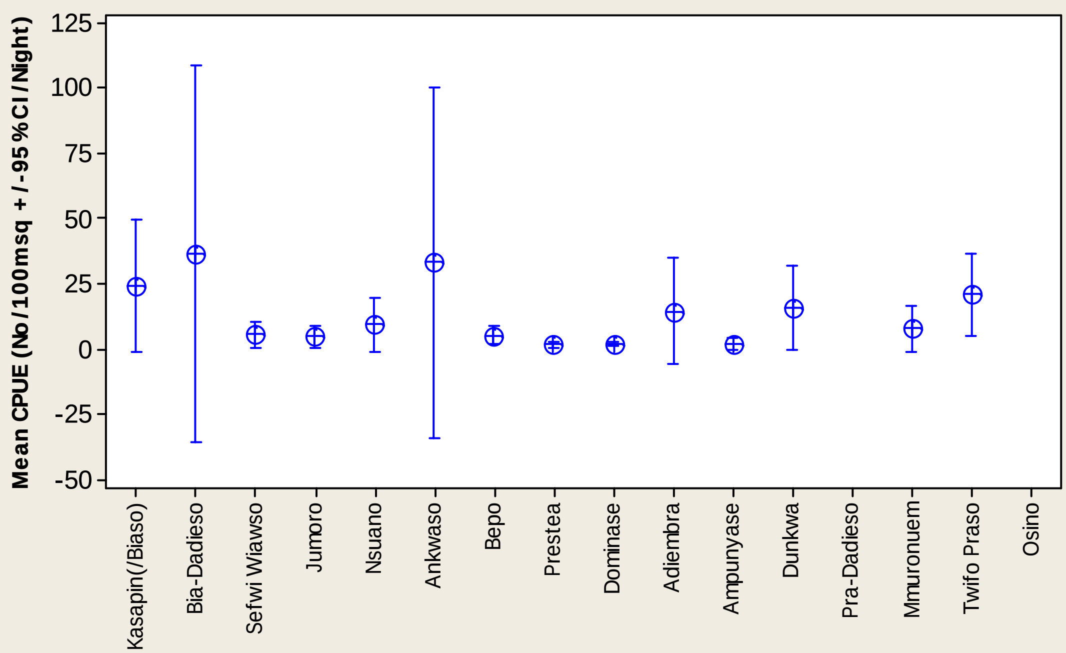

Fig. 5: Productivity of Fish in Various River Basins

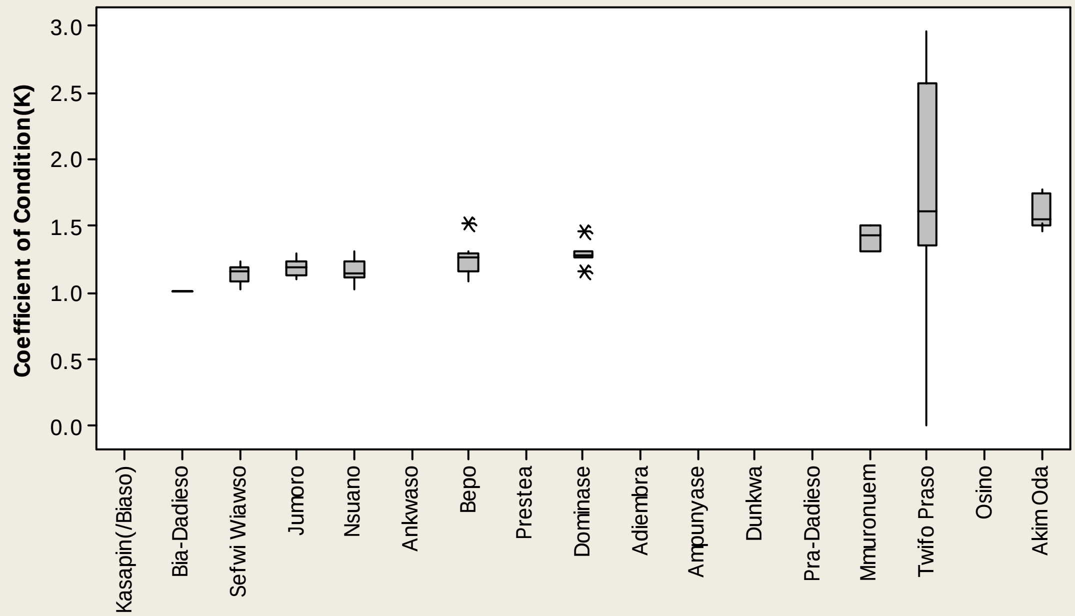

Fig. 8: Boxplot of K of Schilbe mystus fron River Basins

Conclusions

Physico-Chemical Environment

Some inconsistency is detected in As prevalence in the water and sediment environmental compartments within the project basins. The Ankobra River has high Arsenic in its sediments but not in river water. On the other hand, the Pra River has relatively high Arsenic in its water but not in sediments. There was no Arsenic in excess of the World Health Organisation (WHO) water quality guideline value of 10 µg/l in any of the 25 water samples collected from the Ankobra whereas about 24% of the samples from the Pra were above the 10µg/l limit. We believe that As continues to leach out of sediments into the water environment. Further work is required to fully understand the underlying physico-chemical processes for the adoption of appropriate remedial and management measures.

Fish Fauna.

Catch per Unit Effort (CPUE) and K estimates across the basins varied. The variance in the CPUE at some of the control and background stations was high; and the frequency distribution of K was skewed in many cases. This may be due to inadequate sample size. There is need, therefore, to undertake further field work to establish the minimum number of individuals that may be required for the routine usage of the two indices in routine monitoring work.

Effluent discharges from mining companies eventually enter rivers and streams traversing the communities in which the mines operate. There is an urgent need therefore, for a policy framework that would incorporate bio–physical monitoring of the rivers in Environmental Management Plans (EMP) of all mining companies in Ghana. These assessments will form the basis for the formulation of policies and actions to assist in conserving the biological diversity of the rivers and streams of Ghana.

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