Current Journal of Applied Science and Technology

22(1): 1-7, 2017; Article no.CJAST.34436
Previously known as British Journal of Applied Science & Technology
ISSN: 2231-0843, NLM ID: 101664541

Investigation of Aba River Contamination Using *Eichhornia crassipes* as Bio-indicator

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Authors' contributions

This work was carried out in collaboration between all authors. Author CIA designed the study, wrote the protocol and managed the literature searches. Authors VIEA and PACO supervised the field work and laboratory analysis. Authors AUN and COA designed the statistical approach. Authors CIA, COA and AUN interpreted the results and produced the final draft. All authors read and approved the final manuscript.

Article Information

DOI: 10.9734/CJAST/2017/34436
Editor(s):
(1) Camille Eichelberger Granada, Programa de Pos-Graduaçao e Biotecnologia (PPGBiotec), Centro Universitario Univates, Lajeado, RS, Brazil.
Reviewers:
(1) C. R. Ramakrishnaiah, Visvesvaraya Technological University, India.
(2) Obiekea Kenneth Nnamdi, Ahmadu Bello University, Nigeria.
Complete Peer review History: http://www.sciencedomain.org/review-history/19879

Original Research Article

Received 27th May 2017
Accepted 26th June 2017
Published 5th July 2017

ABSTRACT

The seasonal variation of heavy metal contamination levels in Aba River of Abia State in Nigeria was investigated using *Eichhornia crassipies*. Routine sampling was performed on bi-monthly bases to cover the Nigerian Rainy season and Harmattan season. Iron (Fe) showed more abundance with maximum concentration (69.5 mg/kg) mainly in Dec/Jan at UST, PZA, ABT and DST sampling points. The lowest concentration of iron was obtained in Apr/May for UST and DST and in Oct/Nov for PZA and ABT. Manganese showed maximum concentration (7 mg/kg) in the dry season at PZA and NBL during Oct/Nov months. The lowest concentration was in Dec/Jan at UST, PZA and ABT which were Harmattan seasons. The varied concentrations of zinc (Zn) demonstrated no pattern or trend except at Oct/Nov of ABT at value of 9.7 mg/kg, while lead (Pb) metal was significantly identified during the months of Feb/March (end of Harmattan) and April/May (beginning of Rains) during the seasonal study. Chromium metal (Cr) was uniformly distributed but significant at NBL

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during months of Jun/Jul. Nickel (Ni) metal was detected mainly at UST, PZA and NBL at trace levels. Copper was mainly detected during rainy seasons of Apr/May and Jun/July but remained at low concentrations when compared to other metals. Hence, UST and PZA sampling points contained the most active level of heavy metals, while Harmattan season showed the highest phyto-chemical activity of the heavy metals. Therefore *Eichhornia crassipes* showed metal removal in the following order Fe > Mn> Cr > Ni > Pb > Zn > Cd.

Keywords: Contamination; river; bio-indicator; Eichhornia crassipes; pollution index.

1. INTRODUCTION

The routine assessment of contamination in rivers has remained an integral part of quality assurance practices in Nigeria. This often provides information on water quality and consumption safety. In a recent research in Bayelsa, Nigeria, it was reported that both cultivable and uncultivable bacterial species were present in a local river utilized daily by the public [1]. The presence of Macrophytes in Rivers is often a significant indication on the accumulation of heavy metals content in water bodies [2]. Thus, aquatic plants are potentials for contamination indicators in rivers and application in waste water treatment. [3]. A study conducted in Iran demonstrated that aquatic and semi-aquatic plants are major bio-accumulators of heavy metals in aquatic ecosystems [4]. More so, certain species like *Pistia stratiotes, Eicchornia spp., Lemna spp. and Salvinia spp* have been found as effective phyto-remediating species for heavy metals [5] for e.g. rhizomes Glyceria maxima, Phragmites australis, Typha latifolia, and Phalaris arundinacea, were used in Slupia River as an indicator of environmental pollution [6]. Hence, heavy metals have been identified to be mainly deposited in river sediments and taken up by theses plants [7]. On the other hand, study has also shown the ability of aquatic plants like *Salvinia natans* to phytoextract organic pollutants like pesticides and PAH alongside inorganic pollutants from sediments [8].

Accordingly, the increasing uptake of heavy metals among the nutrients of these plants is often accompanied by a decrease in plant biomasses [9]. These changes may be accompanied by reduced cell size of the parenchyma tissue, epidermis and reduction in vascular bundles. [10]. Thus these aquatic plants have enlarged capacity to either bio-accumulate or bio-indicate the levels of heavy metal concentrations for sediments and polluted water bodies [11,12] and act as efficient accumulator of other nutrients. In order words the nutritional composition of these plants, may provide dietary information and properties of the aquatic plants [13,14]. Among the macrophytes, stands out the water hyacinth (*Eichhornia crassipes*). This aquatic plant is advantageous in possessing competitive sorption advantage through chelating and coordination with heavy metals. Its nutritional value is a good source of leaf protein concentrate and non toxic in nature [15,16]. Hence, *Eichhornia crassipes* has even been tagged hyper accumulators for heavy metals [17] and therefore utilized in this work. The objective of this research work therefore is investigate an annual level of contamination by heavy metals in Aba River in Abia State of Nigeria [18,19] using *Eichhornia crassipes* on a bi-monthly assessment of heavy metal content and their pollution index within the selected period of one year.

2. MATERIALS AND METHODS

2.1 Site Location

Aba River is a major river in Abia State of Nigeria. It is a tributary of Imo River and the major river that passes through Aba Town and flows through Azumiri River that empties in the Atlantic Ocean. It is Located on longitude 7° 19 E to 23' E and latitude 5° 10' N in Aba, Abia State, Nigeria and boldly described in our previous publication [20]. Five areas were selected along the course of the river channel indicating points of possible industrial discharges. The latitude and longitude of the sampling points are as follows: The Upstream (UST) 05° 076' 93" N, 007^{O} 22' 668" E. The Petterson Zechonics area (PZA) 05° 16' 472" N, 007° 22' 749" N, The Nigerian Brewery area (NBA) 05° 16' 551" N, 007° 22' 430" E, The Abattoir (ABT) 05° 72' 62" N, 007° 22' 434" E., and The downstream area (DST) 05° 72' 75"N, 007° 22' 448" E. The Upstream (UST) was chosen as the reference point been the outermost flow point. A stretch of about 100 meters of the river channel was examined for this study from the discharge points with a distance of about 20 meters from each station.

2.2 Sample Collection

The plant samples (*Eichhornia Crassipes*) were harvested as whole plant including the (leaf, stem and root) samples from the five selected sites (UST, PZA, NBA, ABT, DST) along the course of the Aba River. The plant samples were washed to remove sand, debris and some organic matters that are on the plant body. The plant tissues were sorted into plant parts (leaf, stem and root) and packaged in black polythene bags for analyses. The plant samples were then taken to the Crop Science Laboratory of the Federal University of Technology Owerri, Nigeria for preservation and analysis. The samples were collected bimonthly as follows: June/July, August/September, October/ November, December/January, February/March and April May for the period of 2014/2015. This was done to take account of any seasonal variation of analytes in the water hyacinth [20].

2.3 Sample Collection

Procedures for analysis of heavy metals in water hyacinth were followed and modified as discussed below. The plant parts were air dried for seven days and dried further in the oven (moisture extractor) at 105℃. Samples were cut into small sizes and ground to near powder using pestle and mortar. Powdery samples were sieved to using 2 mm sieve (mesh) size, to remove coarse particles. 5 g of sample was weighed out for analysis into a dry crucible and placed in a muffle furnace. The furnace temperature was gradually increased to 500℃ for two hours. Samples were removed and cooled to room temperature in a desiccators and been stored at 4 to 5℃. 1 g of the ash samples was taken and placed in acid washed glass beakers and digested by the addition of 10 ml of 0.25 M HNO_3 heated to near dryness, followed by the addition of a second 10 ml of 0.25 M HNO3 and 3 ml of Concentrated $HClO_3$ which was added to obtain a slurry. Sample solutions were obtained by leaching the residues with 4.0 ml of 2 M HCl, diluted to 100 ml with distilled de-ionized water, labeled and dated. The metal concentrations were now determined using AAS. The blank samples were prepared. The stock and standard solutions were prepared for the following possible contaminants of interest Pb, Zn, Fe, Cr, Ni, Cd, Cu, Mn. [3,9,11,14].

2.4 Sediment Analyses

The sediments were taken on based on the experimental design. The sample collection was done on bi-monthly bases for an eight month period using Ekman grab. The collected sample was placed inside a polythene bag and covered before taken to the lab for analysis. A 10 g finest weight was dried at 105℃ and digested using HNO_3 and H_2O_2. All concentrations were in mg/Kg [20].

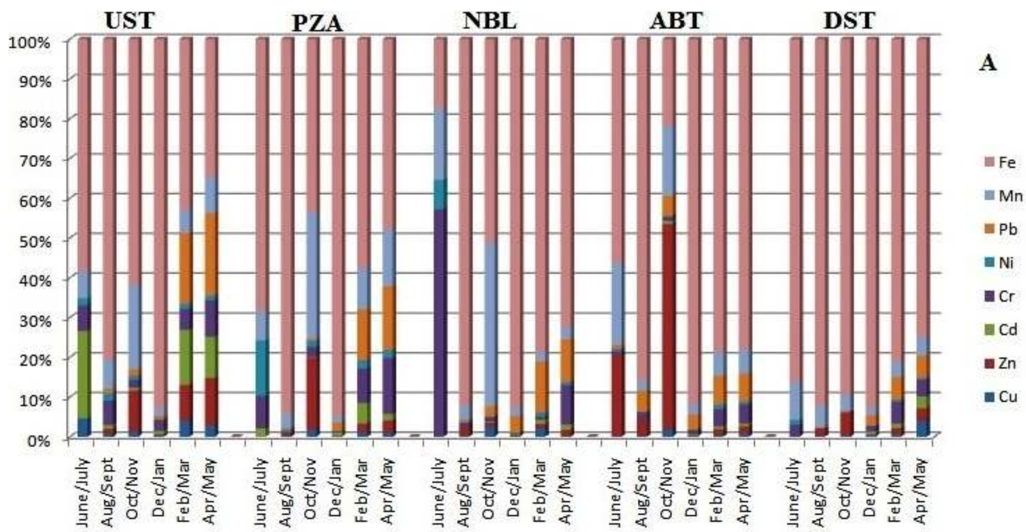
3. RESULTS AND DISCUSSION

The percentage plots of the metal concentrations in Aba River are is shown in Fig. 1A. The bi-monthly periods of sampling covering the two seasons (Rainy and Harmattan season) in Nigeria would also be seen on the horizontal axis. The five sampling points were also indicated respectively at the top of the plot. From Fig. 1A, the results obtained imply that iron (Fe) was the most abundant, metal present in Aba River and was substantially dictated. The maximum iron concentration was obtained in Dec/Jan at UST, Dec/Jan at PZA, Aug/Sept at NBL, Dec/Jan at ABT and Dec/Jan at DST all in Harmattan season. Remarkably, the lowest was in Apr/May for UST, Oct/Nov at PZA, June/July at NBL, Oct/Nov at ABT and April/May at DST. This re-occurring consistency may be as a result of self purification of the river which may be intensified during April/May peak of Rainy season and Oct/Nov Start of Harmattan season.

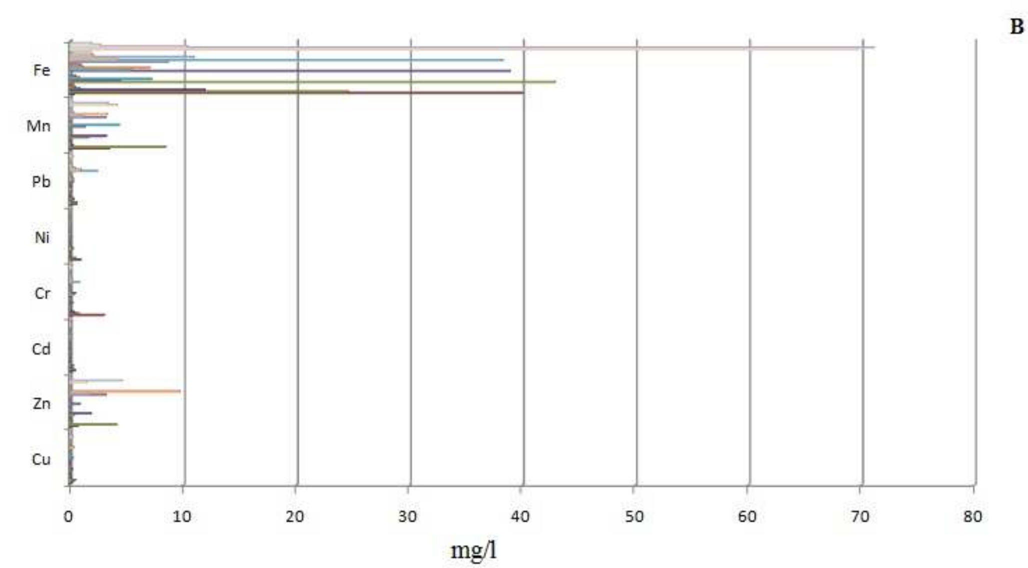
The overall analysis showed that the concentration of iron (Fe) was about 70% more than the other elements analyzed from the river sample. However, the high iron concentrations may suggest a form of absorption mechanism that favors iron mineral absorption over the other metals. This occur because water hyacinth provides amine and oxygen containing groups as binding sites and iron has high affinity for oxygen [15]. Next to iron was Manganese (Mn), which was at highest point in Oct/Nov at PZA and NBL respectively. The smallest concentration was determined in Dec/Jan at UST, PZA, and ABT respectively. The presence of Zinc (Zn) was only significant in OCT/NOV at PZA, June/July and OCT/NOV of ABT sampling point. Lead (Pb) metal demonstrated uniform distribution but had more during Feb/March, Apr/May in all the sampling point at both seasons. Cadmium (Cd) was majorly detected at UST during June/July, Feb/Mar, Apr/May sampling period. The other detected point was at PZA during Feb/Mar. The other points were very low and thereafter remained insignificant. The chromium (Cr) was very significant in Jun/July at NBL. The other traces of chromium were uniformly distributed.

Nickel (Ni) could be seen as the tiny bluish strip immediately above the purple stripes. It was at trace level concentrations in DST and ABT. The availability was seen and detected at UST, PZA and NBL but at low concentrations. Copper could be seen as the first bluish strip at the bottom of each composite plot. The availability of copper was pronounced at Jun/July, Feb/Mar, and Apr/May in UST. The other sampling points (bi-monthly) analysis showed that copper was sparingly detected throughout the other sites. This result further confirms the adaptation of *Eichhornia crassipes* to different aquatic physicochemical conditions with respect to the metals studied [5].

The Fig. 1B expresses the exact concentration of the metals at their respective sampling points. It would be observed that Fe (Iron) had as much as 69.5 mg/kg concentrations at the downstream (DST) while the concentration of iron at the other four sites were averaged at around 40 mg/Kg.



Percentage plot of all the heavy metals showing their proportions at the five sampling point respectively



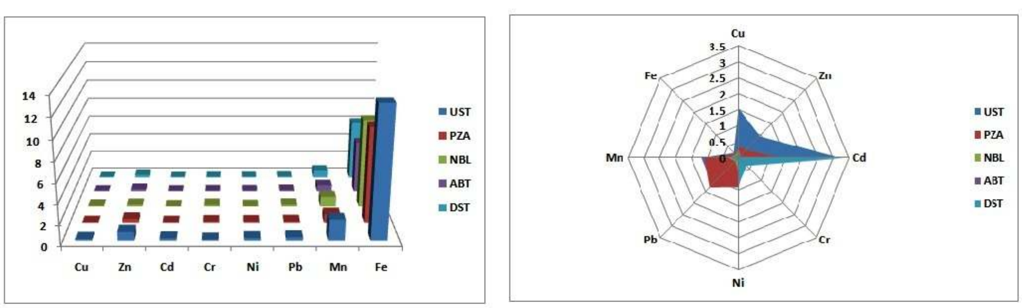
Plot of concentrations of the metals at their respective sampling points

Fig. 1. (A) Percentage composition plot of heavy metals; (B) Actual concentrations determined at the sampling sites

On the other hand, manganese was more abundant than the other six metals (average around 2 mg/Kg to 7 mg/Kg) and followed closely by Zn which had a maximum concentration at 9.7 mg/Kg dictated at the abattoir sampling site (ABT) and lowest at NBL sampling site. furthermore, Nickel (Ni), Copper (Cu) and Cadmium (Cd), were all at trace levels concentrations at all sampling sites while lead (Pb) and Chromium (Cr) showed up at very negligible concentrations in the sites. This demonstrated water hyacinth as a good indicator of levels of Cu and Pb in water bodies. Hence, can be utilized as a potential application in Rivers contaminated with household and industrial wastewaters with pesticides and organic compounds [8].

The mean values were calculated and plotted against their respective sampling sites. The graph actually showed that copper (Cu) and Chromium (Cr) had no significant difference at their varied sampling points. Zinc (Zn) was observed to be slightly higher at DST, while Nickel (Ni) and Lead (Pb) were similarly observed to be higher at DST. Manganese (Mn) metal (Mn) concentration varied greatly across the five sampling sites throughout the season. The highest concentration was also at DST. Notably, iron (Fe) was the most abundant element and had the highest concentration at DST irrespective of the season. DST demonstrated to be point of heavy metal accumulation. The seasonal variations were prominently observed with iron (Fe) concentrations. The lowest concentration of iron (Fe) was observed at the abattoir. Hence, these shows that Aba River could be classified as hard water. The source could be either through surface runoff from iron roof of neighboring or consist of bed stones rich in iron mineral or may be from tributaries. Such water body would be slight to moderately acidic. This high concentration of iron correlated with previous studies that suggested high levels of pollution in the downstream [18,19]

The average mean plot was plotted in Fig. 2A while the bio-concentration factor was calculated and plotted in radar plot in Fig. 2B. Although the iron concentration was high as indicated by the average mean value plot in Fig. 2A, however, there was a synergism that its accumulation ration was relatively positive; the more it accumulates in the plant body, the more it distributes. The Manganese (Mn) showed that there was accumulation at UST and PZA while distribution occurred at the other sampling points. Lead metal (Pb) accumulated only at PZA sampling point. Nickel and Chromium metals phyto-accumulated at DST, while Zinc (Zn) metal accumulated at UST and PZA respectively. Cadmium was the only metal that experienced the least phyto-accumulation in *Eichhornia crassipies*. The occurrence of phyto-accumulation in Cadmium was seen at UST, PZA and DST respectively. Hence, this analysis confirmed that water hyacinth is good bio-accumulators of heavy metals in the following order: Fe > Mn> Cr > Ni > Pb > Zn > Cd. This order was similarly observed in *Wallago attu* (lanchi) from Indus River [21]. On the other hand, the bio-concentration factors of Cu and Zn in the upstream (UST) were significantly higher than those in the downstream (DST). While the bio-concentration factor of Ni and Cr in the downstream were higher than those of upstream. Whereas, Cd metal bio-concentration was the same in both upstream and downstream. Mn, Pb and Ni bio-concentration were prevalent in PZA. Hence, may indicate the focal points and nature of bio-remediation needed at all sampling points by concerned environmental agencies [22].



A B

Fig. 2. (A) The average mean values of all sampling points. (B) The bio-concentration factor shown in radar plot

4. CONCLUSION

Iron (Fe) was the most abundant, metal present in Aba River and was substantially dictated. The maximum iron concentration was obtained in Dec/Jan in UST, Dec/Jan in PZA, Aug/Sept in NBL, Dec/Jan in ABT and Dec/Jan in DST all in Harmattan season. Manganese (Mn), which was at highest point in Oct/Nov at PZA and NBL respectively. The smallest concentration was determined in Dec/Jan at UST, PZA, and ABT respectively. The zinc metal varied greatly, along the course of the river while lead (Pb) was significant only in Feb/Mar and Apr/May in all sampling points. The Chromium metal was mostly in trace levels. Nickel metal was at very low concentrations compared to other metals. The bio-concentration factor showed that iron was accumulating and being dispersed at same time while the other metals showed strong accumulation during certain sampling points. Hence, UST and PZA sampling points contained the most active level of heavy metals while Harmattan season showed the highest phyto-chemical activity of the heavy metals. Thus the result was in agreement with other reported studies in Aba River [18,19] and that water hyacinth is a good indicator and remover of heavy metals in water bodies [2,16].

COMPETING INTERESTS

Authors have declared that no competing interests exist.

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DOI: 10.1016/j.scitotenv.2007.11.032

Peer-review history:
The peer review history for this paper can be accessed here:
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