EVALUATION OF HEAVY METALS IN SEDIMENT OF SOME SELECTED DAMS FROM KATSINA STATE NIGERIA

*[1]Yaradua AI, [2]Alhassan AJ, [1]Nasir A, [1]Matazu KI, [1]Muhammad I, [2]Idi A, [2]Muhammad IU and [1]Aliyu SM.

1Department of Biochemistry, Faculty of Natural and Applied Sciences, Umaru Musa Yar'adua University, P.M.B. 2218, Katsina, Nigeria

2Department of Biochemistry, Faculty of Basic Medical Sciences, Bayero University Kano, P.M.B. 3011, Kano, Nigeria

ABSTRACT: *This work contributes to the monitoring of water pollution of some selected Dams in Katsina State, North western Nigeria by assessing the degree of heavy metal pollution in the Dams sediment samples. The study was conducted in the year 2017 within some selected Dams in the State (Ajiwa, Zobe, Sabke/Dannakola) that are beehives of fishing and Agricultural activities in Katsina State. Analysis for the concentration of these heavy metals; Cr, Cd, Fe, Ni, Mn, Pb and Zn was conducted by the use of AAS (by Atomic Absorption Spectrophotometry) method. Several indices were used to assess the metal contamination levels in the sediment samples, namely; Geo-accumulation Index (Igeo), Enrichment Factor (EF), Contamination Factor (CF), Degree of Contamination (Cd), Pollution Load Index (PLI) and Potential Ecological Risk Index (PERI). The result of this study has shown that generally among the heavy metals evaluated, the highest concentration was observed for Fe (range: 2.6718-4.2830 ppm), followed by Zn (range: 0.4265-0.7376 ppm), Cr (range: 0.1106-0.1836 ppm), Cd (range: 0.1333-0.1273 ppm) and Mn (range: 0.1136-0.1271 ppm). While Pb has the lowest concentration (range: 0.0472-0.0598 ppm). For all the site sampled the heavy metal Ni was below detection level (BDL). From the results of heavy metals I-geo values, according to Muller's classification, all the sediment samples from the selected dams were unpolluted (class 0). The result for the enrichment factor has shown that for all the selected dam sediment samples the heavy metals show deficiency to minimal enrichment. Also based on the contamination factors for all sediment samples the heavy metal Cd has a CF values range of 0.5430-0.6665 (~1), indicating that the sediment samples are moderately contaminated with Cd. In contrast, the rest of the heavy metals exhibit low contamination in general. The value of PLI ranges from 0.2408 to 0.4935, indicating unpolluted to moderate pollution. The Eri values for all samples are all < 40, presenting low ecological risk. The results suggest that the sediment samples from the selected dams in Katsina state has low contamination by the heavy metals evaluated.*

KEYWORDS - *Contamination factor, Heavy metals, Katsina state, Pollution load index, Sediment*

I. INTRODUCTION

Heavy metals contamination in aquatic environment is of critical concern, due to toxicity of metals and accumulation in aquatic habitats. Trace metals in contrast to most pollutants, are not biodegradable, and they undergo a global ecological cycle in which natural water are the main pathways. Of the chemical pollutants, heavy metal being non-biodegradable, they can concentrated along the food chain, producing their toxic effect at points often far removed from the source of pollution (1).The heavy metal contamination of aquatic system has attracted the attention of researchers all over the world and has increased in the last decades due to extensive use of them in agricultural, chemical, and industrial processes that are becoming a threat to living organisms (2). Sediments are essential and integral parts of water regime. They can provide the substrate for organisms and through interaction with the overlying waters play an important responsibility in the aquatic ecosystem (3). In the aquatic ecosystem sediments have been commonly used as environmental indicators due to high physical-chemical stability and their chemical analysis can provide considerable information on the assessment of anthropogenic activities (4), but nothing of such has been monitored on the heavy metal levels emanating from water sediments in Katsina state Northwestern Nigeria and their possible effects on the quality of aquatic life, water and human health. Therefore, it is important to investigate the level of heavy metals in water sediments to ascertain pollution levels.

The aim of this study is to assess the water quality of selected dams in Katsina state north western Nigeria in terms of heavy metals by determining their concentrations from sediment samples taken from the selected dams. The relative enrichment factors and the potential ecological risk index were used to study the pollution status of heavy metals in sediments and assess their potential ecological risk. The results provide a comprehensive sediment contamination status of heavy metals, giving insight into decision making for water source security.

II. Materials and Methods

2.1 Study Area

Katsina State, Nigeria located between latitude 11˚ to 13˚25'N and longitude 6˚45' to 9˚E is a state of North West Zone of Nigeria, with an area of 24,192km2 (9,341 sq meters) of which 67% (about 1.6 million hectares) is devoted to cultivation (5)) Katsina State is divided into 36 Local Government Areas (LGAs) with a total population of about 6 million people (6). The state is an agrarian state and Agriculture in the form of crop and livestock production, is the main employer of labour. There are several dams used as irrigation sites distributed all over the state. For sampling, a comprehensive list of all the major irrigation sites in Katsina state with characteristic 100 and above hectares size of area of cultivation were obtained from the State Ministry of Agriculture and natural resources. With the use of table of random numbers three sites were selected

(a) Zobe Dam located in Dutsin Ma local government area of the state with a water reservoir capacity of 177.0ccu and 5000 hectares size of area of cultivation

(b) Sabke/Dannakola Dam located in Daura local government area of the state with a water reservoir capacity of 62.0ccu and 1000 hectares size of area of cultivation

(c) Ajiwa Dam located in Batagarawa local government area of the state with a reservoir capacity of 50.0ccu and 300 hectares size of area under cultivation and also provides portable drinking water to 3 local government areas namely Katsina, Batagarawa and Rimi.

2.2 Sample Collection, Preparation and Analysis

Sediment samples were taken from the selected dams in August 2017. These samples were air dried, homogenized and sieved through a 2-mm polyethylene sieve to remove large debris, stones and pebbles, after which they were disaggregated with a porcelain pestle and mortar. Then sediment samples were stored in clean self-sealing plastic bags for further analysis. To estimate the total heavy metal content, sediment samples were digested by mixed acid (HCl-HNO3). The digested samples were cooled and filtered through whatman No.42 filter paper and then the volumes were made up to 100 ml using volumetric flasks (7). The concentrations of the heavy metals (Mn, Zn, Pb, Cd, Ni, Fe and Cr) were measured by an atomic absorption spectrometer (AA210RAP BUCK Atomic Absorption Spectrometer flame emission spectrometer filter GLA-4B Graphite furnace, East Norwalk USA) according to standard methods (8) and the results were given in part per million (ppm).

III. Results and Discussion

A total of 3 sediment samples from 3 selected dams in Katsina State were analyzed in this study. As shown in Table 1, among the heavy metals evaluated, the highest concentration was observed for Fe (range: 2.6718-4.283 ppm), followed by Zn (range: 0.4265-0.7376 ppm), Cr (range: 0.1106-0.1836 ppm), Mn (range: 0.1159-0.1336 ppm) and Cd (range: 01086-0.1333 ppm). While Pb has the lowest concentration (range: 0.0472-0.0598 ppm) and the concentration range for the heavy metal Ni was BDL in all the sediment samples.

The Pb concentration range for the sediment samples in this study is lower than those reported for the Pb concentration in sediment from Tigris river in Bagdad (9), and also in Pb levels in sediments reported in studies conducted on heavy metals in sediments of Balok river Malaysia, lake Dunghu China, Abi lake north west China and river Turaq Bangladesh (10, 11, 12, 13).

The Cd concentration range for the sediment samples in this study is similar to that reported by Banu et al., (13) for Cd values for sediment samples from river Turaq, Bangladesh and that reported for sediment of Balok River Pahang Malaysia (10). But the values are lower than that reported in studies for the Cadmium concentration in Tigris river sediment and water sediment of lake Dunghu China (9, 11). Even though it is an essential heavy metal, Fe has the tendency to become toxic to living organisms, even when exposure is low. In the present study, the mean Fe concentration in both the sediment samples was lower than that reported for sediment samples from Lake Aheme southern Benin West Africa and lake Bini Cameroon (15, 14). In the present study, the mean Mn concentration in both the sediment samples were lower than that reported for sediment samples from Balok river Malaysia (10) and that of a study conducted by Saikia et al., (16) on heavy metals in sediment from Brahmaputra river.

Zinc plays a vital role in the physiological and metabolic process of many organisms. Zinc acts as catalyst in over 200 enzymes, thereby, influencing immune system, has an anti-diarrhoea activity and regulates fertility (17) it is also, required for the growth and repair of body tissues, as well as an important element of ligaments and tendons (18). The concentration values for the heavy metal Zn in the sediment samples in the present study is lower than the Zn concentration values for sediment samples from lake Dunghu China, Balok river Malaysia, Tigris river and river Turaq (11, 10, 9, 13), the values are still lower than those reported in studies conducted in Cameroon and Benin West Africa (14). The heavy metal Cr concentration range in this study is lower than Cr values reported in other studies (10, 11, 12, 13, 14, 16).

TABLE 1: Heavy Metals Concentration in Sediment Samples from Some Selected Dams in Katsina State (ppm)

Location			Heavy Metal				
	Mn	Zn	Pb	Cd	Ni	Fe	Cr
Ajiwa	0.1271 ± 0.0005	0.7376 ± 0.0004	0.0598 ± 0.0002	0.1273 ± 0.0003	ND	4.2830 ± 0.0009	0.1836 ± 0.0003
Zobe	0.1336 ± 0.0015	0.5178 ± 0.0002	0.0521 ± 0.0003	0.1086 ± 0.0001	ND	2.6718 ± 0.0012	0.1048 ± 0.0002
Dannakola	0.1159 ± 0.0006	0.4265 ± 0.0003	0.0472 ± 0.0008	0.1333 ± 0.0003	ND	3.1133 ± 0.0002	0.1106 ± 0.006

Values are expressed as Mean ± Standard deviation

3.2. Indices

Several indices were used to assess the metal contamination levels in the sediment samples, namely; Geo-accumulation Index (Igeo), Enrichment Factor (EF), Contamination Factor (CF), Degree of Contamination (Cd), Pollution Load Index (PLI) and Potential Ecological Risk Index (PERI). World surface rock average data of heavy metals which was used as background values were taken from Martin and Meybeck (19).

3.2.1 Geo-accumulation index

Geo-accumulation index (I-geo) was employed to evaluate the heavy metals pollution in the sediment samples. This method has been used by Müller since the late 1960s (20). I-geo was calculated using the following equation:

$$\text{I-geo} = \log_2 / (C_n / 1.5B_n)$$

Where C_n is the measured content of the examined metal in the sediment samples and B_n is the geochemical background content of the same metal. The constant 1.5 is introduced to minimize the effect of possible variations in the background values, which may be recognized to anthropogenic influences. The index of geo-accumulation (Igeo) is characterized according to the Muller seven grades or classes profile of the geo-accumulation index i.e. the value of sediment quality is considered as unpolluted (Igeo is ≤0, class 0); from unpolluted to moderately polluted (Igeo is 0 - 1, class 1); moderately polluted (Igeo is 1 - 2, class 2); from moderately to strongly polluted (Igeo is 2 - 3, class 3); Strongly polluted (Igeo is 3 - 4, class 4); from strongly to extremely polluted (Igeo is 4 - 5, class 5) and Extremely polluted (Igeo is >6, class 6) (20).) Therefore, from the results of heavy metals I-geo values on table 2, according to Muller's classification, all the sediment samples were unpolluted (class 0). The Igeo values in this study are similar to the Igeo values for heavy metals in water sediment conducted by Saikia et al., (16) in Brahmaputra river and different to that of a study conducted on heavy metal pollution in sediment of Aibi lake, Xinjiang north west China that reported moderate pollution (12).

TABLE 2: Heavy Metals Geo-accumulation Values for Sediment Samples from Some Selected Dams in Katsina State

		I-geo				
Site	Mn	Zn	Pb	Cd	Fe	Cr
Ajiwa	-3.5229	-2.4089	-2.6021	-0.3723	-0.7617	-2.7696
Zobe	-3.5229	-2.5686	-2.6576	-0.4413	-0.9666	-3.0000
Dannakola	-3.5229	-2.2924	-2.6989	-0.3526	-0.9003	-3.0000

3.2.2 Enrichment Factor (EF)

Enrichment Factors (EF) were considered to estimate the abundance of metals in the sediment samples. EF was calculated by a comparison of each tested metal concentration with that of a reference metal (21). The normally used reference metals are Mn, Al and Fe (22). In this study Fe was used as a conservative tracer to differentiate natural from anthropogenic components, following the hypothesis that its content in the earth crust has not been troubled by anthropogenic activity and it has been chosen as the element of normalization because natural sources (98%) greatly dominate its contribution (23). According to Rubio et al. (24), the EF is defined as follows:

$$EF= \frac{\left(\frac{M}{Fe}\right)sample}{\left(\frac{M}{Fe}\right)Background}$$

Where EF is the enrichment factor, (M/Fe)sample is the ratio of metal and Fe concentration of the sample and (M/Fe)background is the ratio of metals and Fe concentration of a background. Five contamination categories are reported on the basis of the enrichment factor (25). EF <2 deficiency to minimal enrichment, EF = 2-5 moderate enrichment, EF = 5-20 significant enrichment, EF = 20-40 very high enrichment, EF>40 extremely high enrichment. As shown in Table 3, for all the sites sampled all the heavy metals show deficiency to minimal enrichment, a result that differs from that reported for lake Aheme Benin republic with a higher heavy metal enrichment factor (15).

TABLE 3: Enrichment Factor values for Sediment samples from Some Selected Dams in Katsina state

			Enrichment	Factor (EF)		
site	Mn	Zn	Pb	Cd	Fe	Cr
Ajiwa	0.0004	0.0058	0.0037	0.6376	0.2595	0.0026
Zobe	0.0004	0.0041	0.0033	0.5439	0.1619	0.0015
Dannakola	0.0004	0.0034	0.0030	0.6676	0.1887	0.0016

3.2.3 Contamination factor

Contamination Factor (CF) was used to determine the contamination status of the sediments in the current study. CF was calculated according to the equation described below (26):

$$C= \frac{Mc}{Bc}$$

Where Mc is the Measured concentration of the metal and Bc is the background concentration of the same metal. Four contamination categories are documented on the basis of the contamination factor (27). CF<1 low contamination; 1≤CF≥3 moderate contamination; 3≤CF<6 considerable contamination; CF>6 very high contamination, while the degree of contamination (Cd) was defined as the sum of all contamination factors. The following terms is adopted to illustrate the degree of contamination: Cd<6: low degree of contamination; 6≤Cd<12: moderate degree of contamination; 12≤Cd<24: considerable degree of contamination; Cd>24: very high degree of contamination indicating serious anthropogenic pollution. The result of the contamination factors for the evaluated heavy metals is shown on table 3. From the table, the relative distributions of the contamination factor among the samples are: Cd > Fe > Pb > Cr > Pb > Mn. Sediments have been used as environmental indicators, and this ability to identify heavy metal contamination sources and monitor contaminants is also well documented. Thus, the accumulation of metals in the sediment is strongly controlled by the nature of the substrate as well as the physicochemical conditions controlling dissolution and precipitation (28). For all sediment samples the heavy metal Cd has a CF values range of 0.5430-0.6665 (~1), indicating that the sediment soil samples are moderately contaminated with Cd. In contrast, the rest of the heavy metals exhibit low contamination in general.

TABLE 4: Contamination Factor for Sediment Samples from Some Selected Dams in Katsina State

		Contamination	Factor	(CF)		
Site	Mn	Zn	Pb	Cd	Fe	Cr
Birchi	0.0004	0.0058	0.0037	0.6376	0.2595	0.0026
Dabai	0.0004	0.0041	0.0033	0.5430	0.1619	0.0015
Daura	0.0004	0.0034	0.0030	0.6676	0.1887	0.0016

3.2.4 Degree of Contamination and Pollution Load Index

The degree of contamination (Cd) was defined as the sum of all contamination factors. The following terms is adopted to illustrate the degree of contamination: Cd<6: low degree of contamination; 6≤Cd<12: moderate degree of contamination; 12≤Cd<24: considerable degree of contamination; Cd>24: very high degree of contamination indicating serious anthropogenic pollution. Pollution Load Index (PLI) was used to evaluate the extent of pollution by heavy metals in the environment. The range and class are same as Igeo. PLI for each sampling site has been calculated following the method developed by Tomlinson et al. (1) as follows:

$$\text{PLI} = (CFI + CF2 + CF3 \ldots \ldots \ldots CFn)^{\frac{1}{n}}$$

Where n is the number of metals and CF is the contamination factor.

The value of PLI ranges from 0.1190 to 0.1516 (Table 5), indicating unpolluted to moderate pollution. However, the sediment sample for Ajiwa dam displayed the highest PLI value while the sediment sample from Zobe dam has the lowest PLI.

TABLE 5: Degree of Contamination and Pollution Load Index of Sediment Samples from Some Selected Dams in Katsina State

Site	Degree of Contamination	Pollution Load Index
Ajiwa	0.9096	0.1516
Zobe	0.7142	0.1190
Dannakola	0.8647	0.1441

PLI value > 1 is polluted while PLI value < 1 indicates no pollution (Chakravarty and Patgiri, 2009)

3.2.5. Potential Ecological Risk Index

This research employed the Potential Ecological Risk Index (PERI) proposed by Hakanson (27) to evaluate the potential ecological risk of heavy metals in the sediment of water bodies. This method comprehensively considers the synergy, toxic level, concentration of the heavy metals and ecological sensitivity of heavy metals (29, 30, 31). PERI is formed by three basic modules: degree of contamination (CD), toxic-response factor (TR) and potential ecological risk factor (ER).The ecological risk index (Eri) evaluates the toxicity of trace elements in sediments and has been extensively applied to soils (32). To calculate the Eri for individual metals, the following Equation was used;

$$RI = \sum_{I}^{M} E_r^i = \sum_{I}^{M} T_r^i \times C_r^i = \sum_{I}^{M} T_r^i \times \frac{c^i}{c_n^i}$$

Where RI is the potential ecological risk index of heavy metals in sediment, Eri is the potential ecological risk coefficient of a particular heavy metal, Cir is the pollution factor, Ci is the amount of heavy metal, cir is the reference value of heavy metal i. Tri is the toxicity coefficient of each metal whose standard values are Cd = 30, Ni = 5, Pb = 5, Cr = 2, and Zn = 1, Mn = 1 (27, 33), and can reflect the toxicity, pollution levels and the sensitivity of the environment to heavy metals. The relation between evaluation indices and the pollution degree and potential ecological risk are shown in Table 6.

TABLE 6 Corresponding Relationships between Evaluation Indices Pollution Degree and Potential Ecological Risks

C_f^i	Monomial contamination factor	E_r^i	Monomial potential ecological risk factor		Sum of all risk factors
< 1	Low	<40	Low	<150	Low
1-3	Moderate	40-80	Moderate	150-300	Moderate
3-6	High	80-160	High	300-600	High
≥ 6	Very High	≥320	Very High	≥600	Very High

The risk factor was used as a diagnostic tool for water pollution control, but it was also successfully used for assessing the contamination of soils in the environment by heavy metals (34). The eri values for all samples are all < 40 (Table 7), presenting low ecological risk.

TABLE 7 Evaluations Results of Bio-available Heavy Metal, Ecological Risk Index

Site	E_r^iMn	E_r^iZn	E_r^iPb	E_r^iCd	E_r^iCr	PERI
Ajiwa	0.1271	0.7376	0.2990	3.8190	0.3673	5.3500
Zobe	0.1336	0.5178	0.2605	3.2580	0,2096	1.5948
Dannakola	0.1159	0.4265	0.2360	3.9990	0.2212	4.9986

IV. CONCLUSION

The main goal of this research is to assess the levels of some heavy metals in Sediments of some selected dams of Katsina state, north western Nigeria, in order to determine the impact of anthropogenic heavy metal pollution arising from Agricultural activities and other factors that may like contribute to pollution. Several indices were used to assess the metal contamination levels in the sediment samples, namely Geo-accumulation index (I-geo), Pollution Load Index (PLI), Enrichment Factors (EF), Contamination Factor (CF) and Degree of Contamination (Cd). The result of this study has shown that generally among the heavy metals evaluated, the highest concentration was observed for Fe (range: 2.6718-4.2830 ppm), followed by Zn (range: 0.4265-0.7376 ppm), Cr (range: 0.1106-0.1836 ppm), Cd (range: 0.1333-0.1273 ppm) and Mn (range: 0.1136-0.1271 ppm). While Pb has the lowest concentration (range: 0.0472-0.0598 ppm). For all the site sampled the heavy metal Ni was below detection level (BDL). From the results of heavy metals I-geo values, according to Muller's classification, all the sediment samples from the selected dams were unpolluted (class 0). The result for the enrichment factor has shown that for all the selected dams sediment samples the heavy metals show deficiency to minimal enrichment, also based on the contamination factors for all sediment samples the heavy metal Cd has a CF values range of 0.5430-0.6665 (~1), indicating that the sediment soil samples are moderately contaminated with Cd. In contrast, the rest of the heavy metals exhibit low contamination in general. The value of PLI ranges from 0.2408 to 0.4935, indicating unpolluted to moderate pollution. The Eri values for all samples are all < 40, presenting low ecological risk. The results suggest that the sediment samples from the selected dams in Katsina state has low contamination by the heavy metals evaluated.

REFERENCES

[1.] Tomlinson, DL., Wilson, JG., Harris, CR. and Jeffney, DW. Problems in the Assessment of Heavy-Metal Levels in Estuaries and the Formation of a Pollution Index. Helgoland Marine Research 1980; 33(1-4), 566-72.

[2.] Dutta, HM. and Dalal R. The effect of endosulfan on the ovary of blue gill sun fish: a hispathological study (Leponis macrochirussp). Int. J. Environ. Res 2008; 2: 215-224.

[3.] Burden, FK, McKelvie, I., Forstner U., and Guenther A. Environmental Monitoring Handbook, eBook 2002, McGraw-Hill Company

[4.] Malhotra, P., Chopra, G. and Bhatnagar, A. Studies on Sediment Chemistry of River Yamuna with Special Reference to Industrial Effluents in Yamunanagar, India, Current World Environment 2014; 9(1), 210-215.

[5.] Katsina State Government. Katsina State investor's handbook, Yaliam Press Ltd 2016: 12-15

[6.] WWW.Population.gov.ng/indexphp/Katsina State (accessed on 25 November, 2017)

[7.] Page, AL., Miller, RH. and Keeney, DR. Methods of Soil Analysis, Part 2, 2nd Edition, 1982 Agron. Monogr, ASA and SSSA, Madison.

[8.] A.O.A.C Official Methods of Analysis 18th Edition, Association of Official Analytical Chemists, 1995 U.S.A.

[9.] Abdul Hameed, MJ., Obaidy, A., Adel H., Shahad, T. and Zaki, R. Environmental Assessment of Heavy Metal Distribution in Sediments of Tigris River within Baghdad City. International Journal of Advanced Research (2014), Volume 2, Issue 8, 947-952.

[10.] Abdullah, MZ., Louis, VC. and Abas MT. Metal Pollution and Ecological Risk Assessment of Balok River Sediment, Pahang Malaysia. American Journal of Environmental Engineering 2015, 5(3A): 1-7 DOI: 10.5923/c.ajee.201501.01

[11.] Ntakirutimana, T., Du, G., Guo, J., Gao, X. and Huang, L. Pollution and Potential Ecological Risk Assessment of Heavy Metals in a Lake. Pol. J. Environ. Stud. 2013; Vol. 22, No. 4, 1129-1134..

[12.] Abuduwaili J, Zhang ZY, Jiang FQ. Assessment of the Distribution, Sources and Potential Ecological Risk of Heavy Metals in the Dry Surface Sediment of Aibi Lake in Northwest China. PLoS ONE 2015; 10(3): e0120001. https://doi.org/10.1371/journal.pone.0120001

[13.] Banu, Z., Chowdhury, S., Hossain, D. and Nakagami, K. Contamination and Ecological Risk Assessment of Heavy Metal in the Sediment of Turag River, Bangladesh: An Index Analysis Approach. Journal of Water Resource and Protection, 2013, 5, 239-248.

[13.] 14. Oumar, B., Ekengele, NL., Balla A. O. D., Afr.Sci. 10 (2014) 184 –198

[14.] 15. Hounkpè, JB., Kélomè, NC, Adèchina, R. and Lawani RN. Assessment of heavy metals contamination in sediments at the lake of Ahémé in southern of Benin (West Africa). JMES, 2017; 8 (12), pp. 4369-4377

[15.] 16. Saikia, B., Parthasarathy, G., Borah, R. and Borthakur, R. Raman and FTIR Spectroscopic Evaluation of Clay Minerals and Estimation of Metal Contaminations in Natural Deposition of Surface Sediments from Brahmaputra River. International Journal of Geosciences, 2016; 7, 873-883. doi: 10.4236/ijg.2016.77064.

[16.] 17. Ikeda, M., Zhang, ZW., Moon, CS., Shimbo, S., Watanabe, NH. and Matsuda, NI. Possible effects of environmetal cadmium exposure on cadmium function in the japonese general population. Int. Arch. Occup. Environ. Health, 2000; 73: 15-25.

[17.] 18. Annalakshmi, R., Uma, R., Subashchandran, G., Sahayam, CS., and Charles, A. Evaluation of elemental content of leaves of Madhuca longifolia by X-ray fluorescence spectroscopy (XRF). J. Nat. Prod. Plant Resour., 2012, 2 (4):490-493

[18.] 19. Martin, J. and Meybeck, M. Elemental Mass-Balance of Material Carried by Major World Rivers. Marine Chemistry 1979; 7(3), 173-206.

[19.] 20. Müller, G. Index of Geoaccumulation in Sediments of the Rhine River, Geojournal 1969; 2(3), 108-118.

[20.] 21. Muller, G. The Heavy Metal Pollution of the Sediments of Neckars and Its Tributary, A Stocktaking Chemische Zeit 1981; 150, 157-164.

[21.] 22. Liu, WH., Zhao, JZ., Ouyang, ZY., Söderlund, L. and Liu, GH. Impacts of Sewage Irrigation on Heavy Metal Distribution and Contamination in Beijing, China, Environmental International 2005; 31(6), 805-812.

[22.] 23 Tippie, VK. An Environmental Characterization of Chesapeake Bay and a Frame Work for Action, In: V. Kennedy, Ed., The Estuary as a Filter, Academic Press, New York, 1984.

[23.] 24. Rubio, R. and Vilas, F. Geochemistry of Major and Trace Elements in Sediments of the Ria de Vigo (NW Spain) an Assessment of Metal Pollution, Marine Pollution Bulletin, 2000; 40(11), 968-980.

[24.] 25. Sutherland, RA. Bed Sediment Associated Trace Metals in an Urban Stream, Oahu, Hawaii, Environmental Geology, 2000; 39(6), 611-627.

[25.] 26. Pekey, H., Karakas, D., Ayberk, S., Tolun, L. and Bakoglu, M. Ecological Risk Assessment using Trace Elements from Surface Sediments of Izmit Bay (Northeastern Marmara Sea) Turkey, Marine Pollution Bulletin, 2004; 48(9-10), 946-953.

[26.] 27. Hakanson, L. An ecological risk index for aquatic pollution control a sedimentological approaches, Water Research 1980; 14(8), 975-1001.

[27.] 28. Venkatramanan, S., Ramkumar, T., Anithamary, I. and Vasudevan, S. Heavy Metal Distribution in Surface Sediments of the Tirumalairajan River Estuary and the Surrounding Coastal Area, East Coast of India, Arabian Journal of Geosciences, 2012; 7(1), 123-130.

[28.] 29. Nabholz, JV. Environmental hazard and risk assessment under the United States Toxic Substances Control Act, Sci. Total Environ. 1991; 109, 649–665, doi:10.1016/0048-9697(91)90218-4.

[29.] 30. Singh, A., Sharma, RK., Agrawal, M. and Marshall, FM. Health risk assessment of heavy metals via dietary intake of foodstuffs from the wastewater irrigated site of a dry tropical area of India, Food Chem. Toxicol., 48, 611–619, doi:10.1016/j.fct.2009.11.041, 2010.

[30.] 31. Douay, F., Pelfrêne, A., Planque, J., Fourrier, H., Richard, A., Roussel, H. and Girondelot, B. Assessment of potential health risk for inhabitants living near a former lead smelter, Part 1: metal concentrations in soils, agricultural crops, and homegrown vegetables, Environ. Monit. Assess., 2013; 185, 3665–3680.

[31.] 32. Liang, J., Liu, JY., Yuan, XZ., Zeng, GM., Lai, X., Li, XD., Wu, HP., Yuan, YJ and Li, F. Spatial and temporal variation of heavy metal risk and source in sediments of Dongting Lake wetland, mid-south China. J. Environ. Sci. Health 2015, 50, 100–108.

[32.] 33. Xu, Z., Ni, S., Tuo, X., and Zhang, C. Calculation of Heavy Metals Toxicity Coefficient in the Evaluation of Potential Ecological Risk Index. Environ. Sci. Technol. 2008, 31, 112–115.

[33.] 34. Mugoša, B., Đurović, D., Nedović-Vuković, M., Barjaktarović-Labović, S., and Vrvi, M. Assessment of Ecological Risk of Heavy Metal Contamination in Coastal Municipalities of Montenegro. International Journal of Environmental Research and Public Health 2016; 13 (4): 393.