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Anthropogenic Impact of Five Heavy Metals on Benya Lagoon Water-Ghana

M. K. Vowotor[1], S. S. Sackey[2], E. K. Amewode[3], C. Dumenya[4]
[1,2,3]Department of Physics, University of Cape Coast, Cape Coast, Ghana
[4]School of Allied Sciences, Ghana Atomic Energy Commission, Accra
([1]mvowotor@ucc.edu.gh, [2]ssackey@ucc.edu.gh, [3]emmanuel.amewode@ucc.edu.gh, [4]castroldumenya@yahoo.com)

Abstract-Heavy metals' concentrations in water samples collected from the the Benya Lagoon located in the Komenda Edina Eguafo Abrem Municipality (KEEA) of Ghana were determined using atomic absorption spectrophotometry (AAS). The range of the studied heavy metals concentration in the water samples are as follows: (As: 0.004 – 0.080 mg/l), (Cd: 0.208 – 0.520 mg/l), (Cr: 0.004 – 0.160 mg/l), (Cu: 0.012 – 0.060 mg/l) and (Pb: 0.024 – 0.456 mg/l). Contamination Factor (CF) results revealed that the Benya Lagoon is mainly polluted with Cd due to its high contamination factor. The degree of contamination of the metals were in the order Cd > Pb > (As = Cr = Cu). According to its Pollution Load Index (PLI), the Benya Lagoon is heavily affected by anthropogenic sources with the potential ecological risk index (RI) values at each sampling station very high (RI $\geq$ 440). These findings can be attributed to some negative practices carried out by natives within the district. Educating the natives about the impact of such practices can result in an improvement in the pollution parameters and a reduction in the concentration of the heavy metals in the lagoon.

Keywords- *Benya Lagoon, Water Quality, Anthropogenic Sources, Heavy Metal Pollution, Potential Ecological Risk Index, Enrichment Factor*

I. Introduction

Water is very important for life. It is needed for many things like quenching our thirst, cooking, agriculture, industry, washing our hands, self and clothing. Water is the main constituent of our streams, lakes, lagoons, oceans, and the fluids of most living organisms therefore it is needed by all life forms to be safe, but over one billion people worldwide still lack access to safe water due to unhealthy sanitation practices which directly affect gross domestic product per capita [1].

Heavy metals have high densities and are toxic, exposure to which have been linked to negative effects on our intelligence and behaviour and diseases such as development retardation or malformation, kidney damage, cancer, abortion/miscarriage, and even death in cases of extreme exposure [2, 3]. Heavy metals could get into water bodies through the inappropriate disposal of domestic waste, agricultural runoff and the direct channelling of industrial and mining wastes into drainage systems that lead to such water bodies.

The aim of this study is to find out whether the human influence around the Benya Lagoon, Ghana has affected the quality of its water. The levels of concentration of five selected heavy metals (Arsenic As, Cadmium Cd, Chromium Cr, Copper Cu and Lead Pb) would be looked at.

II. Materials and Methods

A. Study Area

Figure 1 is a map showing the Benya lagoon and the 12 sampling stations where the study was conducted. Elmina, is a town located within the Komenda Edina Eguafo Abrem (KEEA) municipality, south-facing bay on the Atlantic Ocean coast of Ghana, about 12 km west of Cape Coast. The Benya Lagoon is located within the KEEA, (05°05′N, 01°21′W). The Benya Lagoon maintains contact with the Gulf of Guinea throughout the year [4].

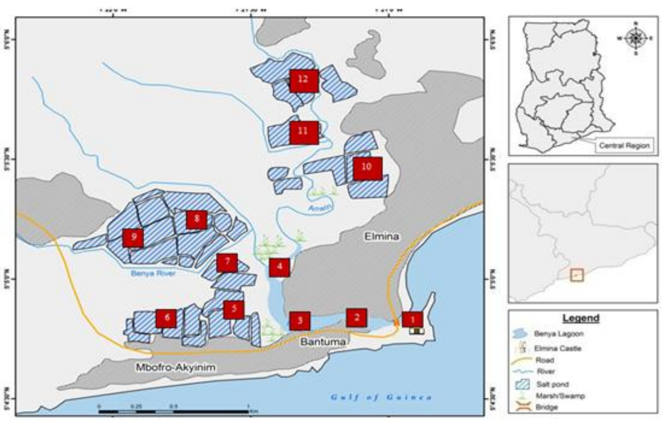

Figure 1. A map of Benya lagoon showing the 12 sampling stations [5]

This lagoon is of utmost importance to the natives because aside serving as their only source of water for domestic chores, they carry out fishing activities in the lagoon, mining of salt through damming of certain portions and uses the water to irrigate their farms. All products from the lagoon (foodstuffs from farms irrigated using the water, fishes, salt and other edible organisms) are transported and sold within the environs and beyond the KEEA District. The lagoon is also considered to be "the mother and final destination" of all the drainage systems within the district to the extent that all wastes are emptied directly into it. In the KEEA District some practices adopted by fishermen contribute to the contamination of the lagoon. Typically in this district, fishermen keep their treated wood meant for boat construction in the open at proximal distance to the lagoon, and therefore after rains, the chemicals used to treat the wood wash directly into the lagoon. Fishermen also attach lead-ingots to their fishing nets to help sink their nets to the bottom of the lagoon. Despite such practices, the lagoon still serves as the principal source of water and its products a source of livelihood to the inhabitants of the KEEA District.

B. Water Sample Collection

Fishermen were used throughout the sampling period as they aided us with their boats and skills in reaching some of the not-easily-accessible stations investigated. Twelve fixed sampling stations were selected and marked along the Benya Lagoon as shown in Figure 1. All sampling equipment and containers used were pre-cleaned with heavy-metal grade acetone before and after use. Heavy-metal grade HCl was also used to rinse the containers before placing the samples in them. Some pre-cleaned blanks were tested for background contamination and values obtained subtracted from the main values for compensation. The water samples were collected by submerging the water sampler beneath the lagoon surface. Each water sample was sieved with an inline filter unit, measured into a pre-cleaned 1.5 litre bottle and coded with an indelible pen after which 5% suprapur HCl was added for preservation. Each water sample was placed in a labelled Ziploc plastic bag to avoid cross contamination. The water samples were then stored in the dark at room temperature before the laboratory analysis. Samples were transported to the Ghana Atomic Energy Commission (GAEC) Preparation Laboratory for digestion and analyses.

C. Heavy Metal Composition

Calibration and concentration measurement of elements in the samples were carried out using a PC–based Varian AA240 fast sequential hydride generation atomic absorption spectrophotometer (AAS). AAS was the preferred choice due to its simplicity in sample preparation and handling, high sensitivity, detection limit, degree of accuracy and reproducibility and its general advantage over flame photometry and colorimetry methods [6]. Each prepared solution was taken to the AAS instrument for readings with standards from Fluka Analytical (Sigma –Aldrich Chemie GmbH, Switzerland) to serve as internal positive controls.

Working standard solutions of As, Cd, Cr, Cu and Pb were prepared from stock standard solutions. 5.0 mL of each water sample was filtered through a 2 µm membrane filter and pipetted into a 10.0 mL pyrex volumetric flask. It was then wet-ashed with 3 mL aqua regia and placed on a hot plate (95 ^{o}C) to heat for an hour. The solution was cooled, filtered and topped to the 10.0 mL mark with deionised water after which it was sent for hydride generation AAS analyses. Calibration curves were prepared for each element individually in each sample by applying a linear correlation least square method. A blank reading was taken and the necessary correction made during the determination of the concentration of the various elements present in each sample.

Determination of As concentration using cold-vapor AAS [7] was done using Varian AA 240 fast sequential hydride generation AAS. The instrument was set up according to the manufacturer's specifications and was equipped with argon to drive the hydride system. HCl (6 M) and NaBH4 (0.6%) generated the hydride.

The quantitative analysis involved the calculation of the final concentrations from the identified elements' initial concentrations and converting them into the final concentrations using Equation 1.

$$\text{Final concentration} = \frac{\text{Initial Concentration} \times \text{Normal Volume}}{\text{Sample Weight in Grams}} \qquad (1)$$

Nominal volume was given as 20 ml and the sample weight for soil was 1.5 grams. The data was statistically analysed using the software Microsoft Excel 2010.

III. RESULTS AND DISCUSSIONS

A. Assessment According to Heavy Metal Concentrations

The elemental distribution at the twelve stations is illustrated in Figure 2, whiles Table 1 summaries the concentration of the heavy metals from all sampling stations.

The mean concentrations are such that Cd > Pb > Cr > (As = Cu). The high standard deviation between these concentrations indicates a non-uniform distribution of the metals across the lagoon, indicating the non-consistent manner in which the lagoon is polluted by these metals. Such unbalanced variations could be attributed to the diverse activities being carried out at each of these stations, now and from time in memorial [8].

The Drinking Water Directive has its range of limits aimed at the protection of public health and therefore metal concentrations are quoted in much lower quantities compared to any other regulation such as that of surface water. Comparing these recommended Directives to the measured concentrations, it can be deduced that the Benya Lagoon is highly polluted with the metals investigated. It is therefore unhealthy to use it directly for activities like cooking or drinking or indeed engage in any activity (like bathing) which will create a means for the water to be ingested directly into the body. In a decreasing order of their mean concentrations, the heavy metals investigated can be arranged as follows: Cd > Pb > Cr > (As = Cu).

According to the Surface Water Regulations for Irrigation [9], all the stations recorded Cd concentrations above the recommended surface water values for irrigation of 0.010 mg/l. Also Cr concentrations at Stations 6, 8, 9 and 10 exceeded it by 0.048 mg/l, 0.060 mg/l, 0.032 mg/l and 0.004 mg/l respectively.

Although many studies have found that these heavy metals occur naturally in water, soil, and biota, and are important and necessary micronutrients for living organisms, but toxic at certain concentrations. Their concentrations depend on local geology as well as anthropogenic activities.

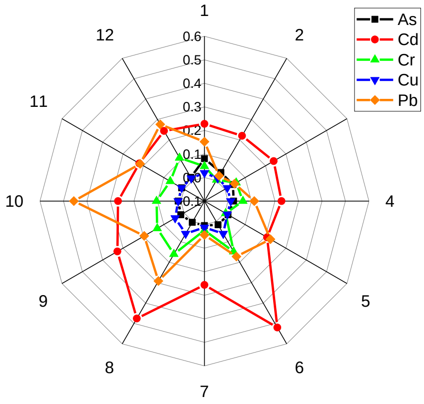

Figure 2. Radar Plot of the elemental distribution at the twelve stations

TABLE I. SUMMARY OF CONCENTRATION OF HEAVY METALS FROM ALL SAMPLING STATIONS AND ACCEPTED LEVELS OF TRACE ELEMENTS (MG/L)

	As	Cd	Cr	Cu	Pb
Stations Min	0.004	0.208	0.004	0.012	0.024
Stations Max	0.080	0.520	0.160	0.060	0.456
Stations Mean	0.023	0.286	0.077	0.023	0.184
Stations SD	0.021	0.104	0.054	0.019	0.123
Drinking Water Directive [10]	0.010	0.003	0.050	2.000	0.010
Drinking Water Directive, [11]	0.010	0.005	0.100	1.300	0.000
Drinking Water Directive [98/83/EC] I/PV value [10]	0.010	0.005	0.050	0.002	0.010
Surface Water Regulations [1989] I/PV value [10]	0.050	0.005	0.050	0.050	0.050
Surface Water Regulations for Irrigation [9],	0.100	0.010	0.100	0.200	5.000

Elevated levels of these heavy metals in the environment may arise from natural or anthropogenic routes including consumption of food from contaminated environments [12]. The human body is designed to detoxify naturally, and will do so quite efficiently as long as your entire detoxification system is working properly. Your glutathione system is an important part of your detox system, and foods high in glutathione precursors, such as whey protein, and sulfur-rich foods like garlic, are important for maintaining optimal functioning of your glutathione system [13]. Table 2 gives a summary of the five trace elements and how they function and affect the human body.

Some specific practices and activities being carried out within the KEEA community can explain this observed trend. Cd registered the highest concentration amongst the metals studied. For its source, cadmium can be found in Ni-Cd batteries, enamel and industrial coatings, cigarettes, plastics and glasses. The people in the community unfortunately dispose-off their household wastes, which include lots of these items, directly into the lagoon. The construction of new boats, which involves painting and also takes place at the edge of the lagoon, is a means through which Cd can find its way into the lagoon. Most of the fishermen happen to smoke heavily and this contributes to the Cd concentration as the butts get dumped into the lagoon.

Arsenic is an element used for the preservation and treatment of wood, production of insecticides, making of agricultural products, in microelectronics and in the manufacture of semiconductors [14, 15]. Due to the carpenters working on boats by the lagoon, lots of treated wood is stored along the banks of the lagoon and with boat construction works taking place there as well. Wood filings and saw dust derived from planning of such woods (preserved with chemicals containing arsenic) end up in the lagoon. During our data collection, we noticed the presence of many electrical shops that engaged in the sale of microelectronic products and semiconductor electrical components located around the lagoon. Settings as these could be a source of As pollution in the lagoon. Runoffs from farms that have used pesticides are also sources of As pollution as most of such chemicals contain As.

Cr is used in stainless steel due to its hardness, shiny nature and its high resistance to corrosion. It is therefore utilized in the fabrication of domestic items like spoons, knives, sinks and sauce pans and for the electroplating of car parts and bicycles rims which results in a smooth and silvery finish [16, 17]. There are car and bicycle washing bays along the banks of the lagoon and the waste water ends up draining into it. The wear and tear due to washing of domestic chromium wares flow through the drainage systems of most homes and ultimately end up in the lagoon.

Cu is a metal with a wide range of uses. It is used in making door knobs, sinks, coins and jewellery [18 – 20]. The linkage of household drainage systems directly into the lagoon using copper pipes as conduit could possibly be a means of copper contamination in the lagoon. The disposal of wastes, perhaps containing coins and jewellery, could also taint the lagoon. Metal-work and carpentry shops dotted around the lagoon are also likely to be major contributors to the copper concentration in the Benya lagoon.

Pb registered the second highest concentration and there may be a good explanation why. Lead ingots are normally attached to fishing nets to serve as sinks for the net and this may be one major way for lead to end up in the lagoon.

In addition to that, historically until the late 1980's fuel in Ghana had been laced with Pb. Considering the fact that outboard motors used on the lagoon are propelled by such fuels, one will expect the fuel leakage to boost Pb concentration [8].

The KEEA District, which happens to be a very old district, used to be the hub for the Portuguese and the Dutch in the 15th and 17th century and therefore boasts of some really old castles and buildings.

TABLE II. THE FIVE ELEMENT AND HOW THEY FUNCTION AND AFFECT THE HUMAN BODY

Element	Function	Adverse Effect of Deficiency	Adverse Effect of Excessive Consumption
As	As may be found in the human body to control gene expression, support reproductive health and treat digestive problems	Abnormal growth, problems with heart and bones.	Anaemia, risk of cancer in the liver, bladder, kidneys, prostate, and lungs, inflammation of the skin. Causes depression, gastrointestinal problems and even death
	[21, 22]		
Cd	Cd has no known beneficial function in the human body. Cd is a cumulative toxin. Greatest contributors to Cd exposure are industrial fumes and cigarette smoking.	The greatest Cd concentrations are found in the kidneys and the liver. Due to slow excretion, Cd accumulates in the body over a lifetime and its biologic half-life may be up to 38 years.	Diarrhoea, Nausea, Excessive salivation, Abdominal pain, Increased bone fractures, Low back pain, Chest pain, anaemia, hypertension, and hepatitis
	[23, 24]		
Cr	Chromium is an essential mineral that plays a role in how insulin helps the body regulate blood sugar levels. Insulin is a hormone your body uses to change sugar, starches, and other food into the energy you need for daily activities.	Increase blood sugar, triglycerides (a type of fat in the blood), cholesterol levels, and increase the risk for a number of conditions, such as diabetes and heart disease.	Reduce how effective insulin is at controlling blood sugar and cause stomach irritation, itching, and flushing, fast and irregular heart rhythms, liver problems, and kidney damage.
	[25]		
Cu	Cu is required to fix calcium in the bones and to build and repair all connective tissue. This includes the tendons, ligaments, skin, hair, nails, arteries, veins and a few other tissues.	Low libido in women and men is also linked to copper imbalance. Deficiency of Cu increases the lipid peroxidation in the heart in 2-folds.	Vomiting, nausea, abdominal pain, menstrual cramps weakness, and metallic taste in the mouth. It can cause damage to the liver and kidney. Dr. Paul Eck found that elevated tissue Cu is associated with homosexual desire.
	[26]		
Pb	Pb is one of the commonest elements in the environment. Low levels in adults are not harmful. However, low levels in children are a cause for concern. Pb is not known to help in any body function. Pb poisoning usually occurs over a period of months or years	Pb is a highly toxic metal and a very strong poison found in lead-based paints, including paint on the walls of old houses and toys. It is also found in: art supplies, contaminated dust and gasoline products	Abdominal pain and cramps, fatigue, aggressive behaviour, constipation, loss of appetite, sleep problems, headaches, irritability, high blood pressure, anaemia, numbness or tingling in the extremities, memory loss, kidney dysfunction loss of developmental skills in children.
	[27]		

The periodic renovation of such buildings which includes painting also causes the lead-pollution of the lagoon as most of the paints are lead-tainted and therefore get washed-up into the lagoon as runoffs after rains and this is facilitated by the topology of the community. All these activities mentioned can be controlled so as to curb the ascendency of the concentration levels of the five metals worked-on in the Benya Lagoon.

B. Assessment According to Contamination Factor (CF) and Degree of Contamination (CD)

The CF is the ratio obtained by dividing the concentration of each metal in the water sample by the baseline or background value (Bn). CF which reflects the extent of environmental contamination [28] was used to evaluate the possible anthropogenic input of metals to the salt. This factor is mathematically expressed in equation 2

as:

$$C_F = \frac{\text{Measured Concentration}}{\text{Background Concentration}} \tag{2}$$

Under the European Union, the Republic of Ireland Environmental Protection Agency, Parameters of Water Quality [10] had set the Background Concentration value of the metals in surface water, and was used as Bn for this work.

The degree of contamination (CD) was used to determine the contamination status and assesses the excessive values of monitored elements in the Salt [28]. Mathematically it is expressed in equation 3 as:

$$CD = \Sigma\, C_F^i, \tag{3}$$

where, C is the contamination factor for the i-th element.

The five standard CF ranges, pollution grades and intensities are given in Table 3. The CF values of the metals studied from all the five sampling stations are also shown on Table 4. Classification of the Stations studied, based on the extent of pollution, is presented in Table 5.

TABLE III. CF RANGES AND THEIR DESIGNATED POLLUTION GRADE AND INTENSITY [28]

CF	Grade	Intensity
CF < 1	I	Low contamination factor
1 ≤ CF < 3	II	Moderate contamination factor
3 ≤ CF < 6	III	Considerable contamination factor
CF ≥ 6	IV	Very high contamination factor

TABLE IV. C_F AND C_D FOR THE WATER SAMPLES FROM THE BENYA LAGOON

Stations	C_F, Contamination factor					C_D, Degree of Contamination
	As	Cd	Cr	Cu	Pb	
1	1.60	45.60	0.96	0.40	3.04	51.60
2	0.80	44.00	0.08	0.24	0.48	45.60
3	0.80	48.00	1.12	0.24	0.96	51.12
4	0.48	45.60	1.28	0.24	2.24	49.84
5	0.32	41.60	0.08	0.24	4.48	46.72
6	0.32	104.00	2.96	1.20	3.44	111.92
7	0.08	51.20	0.48	0.24	0.88	52.88
8	0.08	95.20	3.20	1.20	5.84	105.52
9	0.32	65.60	2.64	0.88	3.92	73.36
10	0.24	53.60	2.08	0.24	9.12	65.28
11	0.24	44.00	1.36	0.24	4.32	50.16
12	0.32	48.80	2.24	0.24	5.52	57.12
Mean	0.47	57.27	1.54	0.47	3.69	

TABLE V. POLLUTION GRADE AND INTENSITY FOR THE WATER SAMPLES FROM THE TWELVE STATIONS

Stations	C_F, Contamination factor					C_D, Degree of Contamination
	As	Cd	Cr	Cu	Pb	
1	II	IV	I	I	III	7th
2	I	IV	I	I	I	12th
3	I	IV	II	I	I	8th
4	I	IV	II	I	II	10th
5	I	IV	I	I	III	11th
6	I	IV	II	II	III	1st
7	I	IV	I	I	I	6th
8	I	IV	III	II	III	2nd
9	I	IV	II	I	III	3rd
10	I	IV	II	I	IV	4th
11	I	IV	II	I	III	9th
12	I	IV	II	I	III	5th
Mean	I	IV	I	I	III	

The highest contamination factor was obtained for Cd, followed by Pb, whose contamination factor was 'considerable' on the average. As, Cr and Cu showed 'low' contamination on the average. Cd contamination factor was observed to be 'very high' for all twelve Stations. The Degree of Contamination, CD, was in the order: Station 6 > Station 8 > Station 9 > Station 10 > Station 12 > Station 7 > Station 1 > Station 3 > Station 11 > Station 4 > Station 5 > Station 2. This order is not consistent with our observation with respect to the frequency of human activities along the banks of the lagoon as between Station 1 to Station 5 experienced the most of the human activities while Station 12 experienced the least. This shows that as the high tides from the Atlantic Ocean enter the Lagoon it sweeps all the contaminants up stream away from the human activities.

C. Assessment According to Pollution Load Index (PLI)

Another parameter use to evaluate metal pollution in marine environment is the Pollution load index (PLI). Although the value of CF can be used to identify the contamination of an individual metal in a station or basin, an estimation of PLI can be used to identify whether a site is collectively polluted or non-polluted by metals [29]. It can be calculated from the following equation given by [30].

$$PLI = \sqrt[n]{\left(C_F1 \times C_F2 \times C_F3 \times .... \times C_Fn\right)} \quad (4)$$

where CF is contamination factor and n is the number of metals investigated.

A PLI value greater than one (>1) indicates that an area is polluted, whereas values less than one (<1) indicates no pollution or only background levels of pollutants are present [29]. The PLI value for these five metals at the twelve Stations was greater than two. Therefore the PLI > 1, indicating that the water in the Lagoon and its' environs is polluted.

D. Assessment According to Potential Ecological Risk (PER)

Potential ecological risk (PER) is a Hakanson index diagnostic tool for water or sediment purposely used to assess pollution control, i. e. to sort out which lakes or basins and substances should be given a special attention [31]. The methodology is based on the assumption that the sensitivity of the aquatic system depends on its productivity. The PER assessment system is based on the element abundance and several preconditions:

(1) Concentration – the RI will increase with the aggravated metal pollution degree in sediments;

(2) Species number – the metals in sediment express the additive effect, namely a PER is larger with multiple metals. The metals As, Cr, Cd, Cu and Pb are prior considered objects;

(3) Toxic-response – heavy biological-toxicity metals have larger evidence for RI and magnitude for abundance correction;

(4) Sensitivity – based on the biological production index (BPI), namely sensitivity was different in varying water quality systems [32, 33]. Mathematically the PER is:

$$E_r^i = T_r^i \times C_F^i \quad (5)$$

where the metal toxic response factor for a given substance [34]. The values for each element are in the order Cr = 2 < Cu = Pb = 5 < As = 10 < Cd = 30. C_F^i : the contamination factor (a ratio between reference records, and measured concentration values in sediments, B_n^i);

The potential ecological risk (PER) of a given contaminant is defined on Table 7. The sum of the individual potential risks (RI) is the potential risk for the water body (Table 8) [32].

Mathematically:

$$RI = \Sigma E_r^i \quad (6)$$

TABLE VI. INDICES AND GRADES OF POTENTIAL ECOLOGICAL RISK FACTOR

Critical Range for *i* th Heavy Metal	Grade for Ecological Risk Factor
$E_r^i < 40$	Low
$40 \le E_r^i < 80$	Moderate
$80 \le E_r^i < 160$	Considerable
$160 \le E_r^i < 320$	High
$E_r^i \ge 320$	Very high

TABLE VII. INDICES AND GRADES OF POTENTIAL ECOLOGICAL RISK INDEX

RI Class	Critical Range for Heavy Metal	Grade for Ecological Risk Index
A	RI < 110	Low
B	110 ≤ RI < 220	Moderate
C	220 ≤ RI < 440	High
D	RI ≥ 440	Very high

TABLE VIII. POTENTIAL ECOLOGICAL RISK ASSESSMENT FOR WATER OF THE BENYA LAGOON

Stations	Potential Ecological Risk Assessment					RI
	As	Cd	Cr	Cu	Pb	
1	16	1368	1.92	2.0	15.2	1403.12
2	8.0	1320	0.16	1.2	2.4	1331.76
3	8.0	1440	2.24	1.2	4.8	1456.24
4	4.8	1368	2.56	1.2	11.2	1387.76
5	3.2	1248	0.16	1.2	22.4	1274.96
6	3.2	3120	5.92	6.0	17.2	3152.32
7	0.8	1536	0.96	1.2	4.4	1543.36
8	0.8	2856	6.40	6.0	29.2	2898.4
9	3.2	1968	5.28	4.4	19.6	2000.48
10	2.4	1608	4.16	1.2	45.6	1661.36
11	2.4	1320	2.72	1.2	21.6	1347.92
12	3.2	1464	4.48	1.2	27.6	1500.48
Mean	4.7	1718	3.08	2.33	18.4	1746.513
ER Grade	Low	Very high	Low	Low	Low	All Σ RI = Very high

According to the cumulating coefficients calculated shown on Table 8, Cadmium was the main heavy metal polluting the Lagoon and its mean value was 1718. The calculated PER value for As, Cr, Cu and Pb suggests that these metals present a low potential ecological risk. On the basis of the mean values of PER, the values for metals are in the following order: Cd > Pb > As > Cr > Cu. The PER values is not strongly reinforced by RI values at each sampling station which are all very high (RI ≥ 440).

In a nutshell, the heavy metals under investigation in water reflected a low ecological risk factor to the water body with the exception of cadmium which posed a very high ecological risk to the whole lagoon. But the very high ecological risk factor suggests that the Benya Lagoon needs dredging.

E. Assessment According to Correlation Matrix and Sources of Elements

Pearson's correlation coefficient was used to draw parallels between any two of the micronutrients. The matrix between the elements, shown in Table 9, gives information about their possible sources [7, 35]. The correlation coefficient which is significant at 95% confidence level, and could indicate the same or similar source input is highlighted in red and discussed. Though 95% confidence level was used to ascertain the strength of their relationship, there are other strongly correlated elements with high coefficients of determination, hence cannot be ruled out and are also highlighted in blue, green and black. Focus would be on the strength of relationship and while reporting statistical significance [36]. The interpretation of the strength of the correlation coefficients usually depends on the researcher, however there are suggested guidelines. Such as: Exactly ±1.0: A perfect downhill/uphill (negative/positive) linear relationship; ± 0.7: A strong downhill/uphill (negative/positive) linear relationship; ± 0.5: A moderate downhill/uphill (negative/positive) relationship; ± 0.3: A weak downhill/uphill (negative/positive) linear relationship; 0 : No linear relationship [37].

TABLE IX. CORRELATION MATRIX BETWEEN THE FIVE HEAVY METALS

	As	Cd	Cr	Cu	Pb
As	1				
Cd	– 0.348	1			
Cr	– 0.368	0.792	1		
Cu	– 0.233	0.952	0.775	1	
Pb	– 0.367	0.222	0.547	0.178	1

The three most significant correlations on Table 9 can be drawn between Cd and Cr (r = 0.792), Cd and Cu (r = 0.952) and Cr and Cu (r = 0.775). These pairs could each indicate the same or similar source inputs. Elmina is a town where most activities are carried out along the banks of the Benya lagoon. There are lots of shops that deal and work with metal scraps.

The presence of Cu and Cd in the lagoon may be attributed to spillages from products such as Cd batteries, detergents, paints, inks used for printing, boating activities, domestic garbage dumps and sewage treatment plants, urban wastewater runoffs and industrial effluents, phosphate fertilizers in agricultural runoff, mining activities, impurities from electroplating steel, and the remixing of petroleum products. Cr is used in the manufacture of cements, pigments for paints, paper, rubber and metal alloys. Some activities around the lagoon make use of cement, paints and paper products, which eventually end up being washed into the lagoon [6, 8].

IV. CONCLUSION

The results of water samples taken from twelve locations showed that the Lagoon has been contaminated by heavy metals and its pollution can be attributed to human activities near its bed. The calculated potential ecological risk indices showed that the Lagoon was polluted by heavily by Cd. Cd had very high potential ecological risk to the ecological environment and was the main contributor to potential toxicity response indices for various heavy metals in the Benya Lagoon. Though the levels of copper and arsenic detected in the water from the lagoon fell below the [10] and [11] limits, the high concentrations of cadmium, lead, and chromium render the lagoon unsafe to be used directly as it may be hazardous to users. There is the hope that people would be more careful as there are more write-ups and education about heavy metals contribution of the possible source of health hazards in humans.

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