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Assessment of Chemical and Nutrient Characteristics of Selected Wetland Waters and Sediments in Bo-Moyamba Districts, Southern Sierra Leone

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ABSTRACT

The impact of anthropogenic activities on chemical and nutrient characteristics of selected wetlands in Moyamba and Bo districts was investigated. Water and sediments samples for nutrient and trace metal analysis were collected for two seasons (wet and dry) at eight sampling sites. Anthropogenic activities such as industrial effluent, domestic and agricultural waste disposal constitute major sources of wetland pollution in the selected districts. Samples of water and soil were analyzed for metals (Cr, Co, Cd, Ni, Pb, Mg, Mn, Fe, Cu and Zn) and nutrients (Ca, K, P and Na) levels were determined and their seasonal variations were compared at ($p>0.05$) significant levels. Physico-chemical parameters such as temperature, dissolved oxygen, ammonia, nitrate, nitrite, pH, general hardness and total alkalinity were also measured. Fe was the most concentrated metal in water (mean range 15.93±1.51 to 33.65±7.79 mg L^{-1}) and in sediment (15748±3526 to 107702±84038 mg L^{-1}), while Cr and Mg were the least concentrated (0.34±0.14 to 0.53±0.09 mg L^{-1}) and (0.07±0.01 to 0.22±0.08 mg L^{-1}), respectively. Generally, trace metal levels in sediment of the study area were relatively higher than the concentration in water. Na was the most concentrated nutrient in both water and sediment while calcium was the least. Calcium plays an important role in blood clotting, muscular contractions and in some enzymatic processes and as such its level in the studied wetlands must be augmented. Accumulations of metals in the environmental matrices are ecologically undesirable as they pose threats to man who is the end user of the values of wetland ecosystems and consequently the need for policy intervention in the effective management of both domestic and industrial wastes.

Key words: Trace metals, nutrients, physico-chemical, wetlands, anthropogenic, policy intervention

INTRODUCTION

Wetland contributes in diverse ways to the livelihoods of millions of people in Africa and Asia and is of huge economic importance (Kiepe, 2006). More than three billion people, around half the world's population, obtain their basic water needs from inland freshwater wetlands. Wetland habitats contain a multitude of ecological niches and support a wide variety of flora and fauna with different ecological functions (EPA., 2004). As human populations and consumption have increased, anthropogenic influences on wetlands have also increased (Verhoeven *et al.*, 2006). Nutrient enrichment, one component of this human influence, has been a major cause of reduced biodiversity and changes in community structure and composition of wetlands worldwide (Keddy, 2000). The aquatic environment according to Mohamed (2009) is subjected to different types of pollutants which enter water bodies. The transformation, composition and distribution characteristics of nutrients in natural wetlands are significantly affected by human activities, such as large-scale water conservancy projects and agricultural activities. As nutrient loads to a wetland increase, biogeochemical processes are especially altered and, consequently, levels of chemicals change in the water as well as in the soil which is critical for much of the vegetation found in wetlands. While phosphorus and nitrogen are required by wetland organisms, exposure to abnormally high amounts (i.e., nutrient enrichment) represents a critical change in the overall environment. Nutrient enrichment has been shown to influence all trophic levels within a wetland ecosystem and effects include changes in species abundance, displacement of species, reduced species diversity and shifts in community structure and composition (Piceno and Lovell, 2000; Murkin *et al.*, 1991; Boeye *et al.*, 1997; Hann and Goldsborough, 1997; Guntenspergen *et al.*, 2002). Heavy metals have a potential to contaminate soil and water which can be dispersed and accumulated in plants and animals and taken in by humans through consumption (Wcislo *et al.*, 2002). Heavy metal contamination of sediments can critically degrade aquatic systems (Charkhabi *et al.*, 2005). In the aquatic environment, sediments have a high storage capacity for contaminants. In the hydrological cycle, less than 0.1% of the metals are actually dissolved in the water and more than 99.9% are stored in sediments and soils (Karbassi *et al.*, 2007; Pradit *et al.*, 2010). Bo and Moyamba districts are located in the southern province of Sierra Leone where most of the people are agrarian and rice farming is a dominant agricultural activity. Farmers grow rice throughout the year in boli lands (wetlands). Heavy mining of rutile, bauxite, gold and diamond takes place in the catchment of the districts and sources of waters that enter the wetlands are from the catchment of these mining places. Obviously, the chemical nature of waters and sediments in these areas would have their influence on aquatic species. This present study investigates anthropogenic influences on physical, chemical and nutrient characteristics of selected wetlands in Bo and Moyamba districts, southern Sierra Leone.

MATERIALS AND METHODS

Study area: Sierra Leone lies between latitude 7-10°N and between longitude 10-14°W and has a total land area of 72,325 km^2, with a coastal zone extending to a distance of about 560 km (MFMR., 2008). The climates of Moyamba-Bo districts are mainly tropical and have distinct dry and wet seasons. The wet seasons last from April to October, while the dry seasons extend from November to March. The mean temperature ranges from 21-33°C for the greater part of the dry season. The vegetation consists of farm bush, grass land and inland valley swamps (Gwynne-Jones *et al.*, 1978).

Sampling procedure: The sampling locations stratified into eight sites was sampled in both wet and dry seasons for a period of one year (Fig. 1, 2). Water quality parameters (pH, alkalinity, nitrite-nitrogen, nitrate-nitrogen, general hardness, ammonia, dissolved oxygen and temperature) were determined with water analytical kits (PONDLAB 2000), oxygen probes and thermometer. Soil sample analysis for metals and nutrients was carried out according to Udo and Ogunwale (1986).

Statistical analysis: Spatial and temporal flow in water quality parameters was determined using mean and standard deviation. One-way analysis of variance tests was used to find level of

Fig. 1: Map of sampling location (Njala University Campus is pinpoited in red) www.maps.google.com

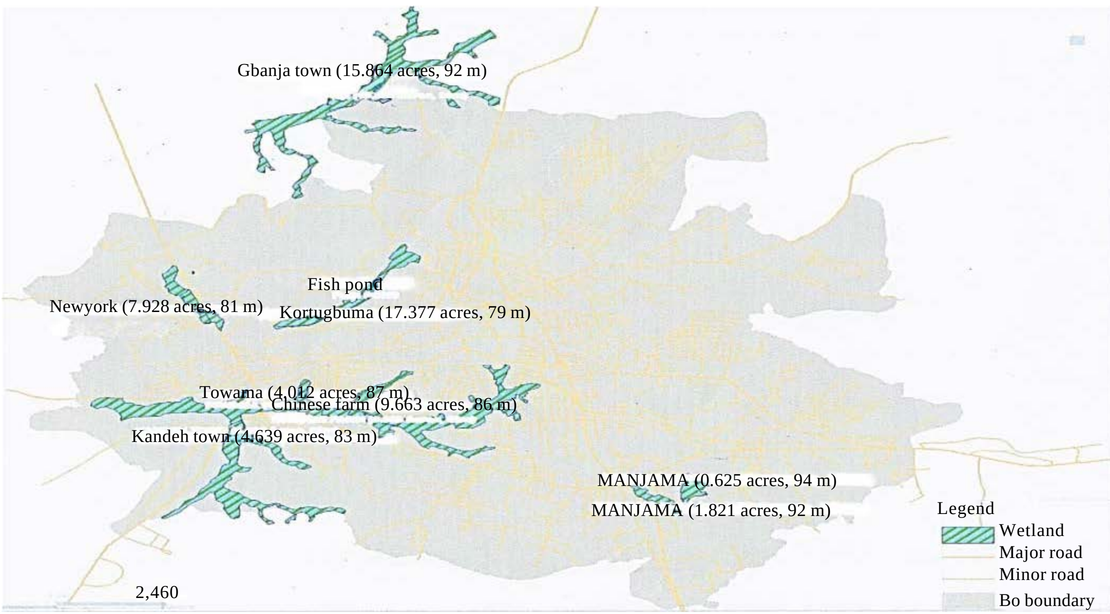

Fig. 2: Map of sampling locations (Bo locations)

significance in seasonal variation of water quality parameters (SAS., 1998). The data on physico-chemical parameters and water quality assessment were in tables while significant variables were subjected to Least Significant Difference tests (LSD).

RESULTS AND DISCUSSION

Table 1 shows the physical parameters of water in the selected wetlands in Bo and Moyamba districts.

Temperature: Temperature values recorded for all the locations which are not above the recommended values for fish farming and rice cultivation ranged between 26.91±0.77 and 29.77±0.47°C.

Dissolved oxygen: Dissolved oxygen concentration in all the locations was not significantly different. DO values recorded ranged between 4.34±0.26 and 5.92±0.47 were above the critical level of 3-4 mg L^{-1} recommended for the culture of the African cat fish (Omitoyin, 2007). Seasonal fluctuation in dissolved oxygen content are controlled by factors such as organic waste load, flow velocity, temperature, turbidity, photosynthetic activity and respiratory activity of aquatic organisms (Schmidt-Nielson, 1990 as cited by Oduwole (1997).

The pH of a water body is important in the chemical speciation, bioavailability and toxicity of trace metals. Mean pH values of 6.70±0.21-8.17±0.17 obtained in this study was within the range associated with most natural waters (Chapman, 1992) and are within the "no effect" range of 6.0-9.0 for drinking water use (WRC., 2003).

Total alkalinity: The Total alkalinity of the sampling locations ranged from 28.6±3.98 to 123.8±11 mg L^{-1}. According to Baird (2000) in the absence of sufficient carbonic acid, the bicarbonate ion in the water dissociates to form additional carbon dioxide and algae are known to readily exploit this carbon dioxide for their photosynthetic needs, at the cost of allowing a build-up of hydroxide ions to such an extent that the water becomes quite alkaline. Kandeh town wetland recorded the highest alkalinity value of 123.8±11.6 while the least alkalinity value of 28.6±2.97 was obtained at Njala University Campus. The low alkalinity value obtained at Njala Campus could probably be due to the reaction of the excess hydroxide ions with other reactive species in the stream channel course.

Table 1: Mean values of physico-chemical parameters in selected wetland waters (±SD)

				NO_2	NO	NH_4	O_2	
Variables	KH	GH	pH	--------(mg L^{-1})--------				Temperature (°C)
B	44.5±3.98	19.7±3.57	6.70±0.21	0.83±0.00	7.99±3.82	0.67±0.11	5.92±0.47	29.77±0.47
CF	80.1±3.98	51.4±8.20	7.00±0.00	1.65±0.37	45.22±15.77	0.65±0.17	5.91±0.33	28.65±0.48
GT	47.5±7.50	65.3±3.75	7.30±0.21	2.35±0.46	45.83±14.03	1.17±0.28	5.21±0.31	26.91±0.77
MI	62.3±7.60	68.2±12.51	7.00±0.00	1.24±0.18	11.55±4.67	0.40±0.06	5.92±0.16	27.53±0.55
KT	123.8±11.6	142.4±7.96	8.47±0.17	0.96±0.14	16.50±5.50	2.21±0.25	4.74±0.32	28.73±0.73
NC	28.6±2.97	50.4±5.47	7.17±0.17	1.24±0.18	15.30±2.200	1.02±0.21	5.86±0.25	28.95±0.52
NY	47.5±5.93	71.2±7.96	7.50±0.22	0.96±0.14	0.30±0.01	0.86±0.24	4.34±0.26	28.93±0.35
T	80.1±3.98	169.7±8.50	7.00±0.45	1.93±0.28	30.56±11.62	0.72±0.10	4.53±0.15	28.03±0.20

B: Baima, CF: China farm, GT: Gbanja town, MI: Manjama institute, KT: Kandeh town, NC: Njala campus, NY: New York, T: Towama

Table 2: Mean values of nutrients in selected wetland waters (mg L^{-1}±SD)

	Nutrients			
Variables	Ca	K	P	Na
B	9.05±3.31[a]	10.98±2.50[a]	0.01±0.002[a]	13.17±1.36[a]
CF	4.98±1.36[a]	6.16±0.84[bc]	0.01±0.001[a]	12.90±1.80[a]
GT	1.77±0.60[a]	5.35±0.36[bc]	0.04±0.009[ac]	8.80±0.92[ab]
MI	11.12±3.87[ab]	6.11±0.54[bc]	0.03±0.009[ac]	16.56±1.93[ac]
KT	13.22±4.01[ab]	10.61±2.47[a]	0.04±0.015[ac]	12.24±1.00[a]
NC	5.54±3.03[a]	5.65±0.90[bc]	0.05±0.011[bc]	10.35±3.64[ab]
NY	9.31±4.42[a]	4.47±0.51[bc]	0.04±0.008[ac]	8.78±0.59[ab]
T	29.83±17.48[b]	0.09±0.029[b]	8.07±1.260[ac]	16.73±2.39[ac]

B: Biama, CF: China farm, GT: Gbanja town, MI: Manjama institute, KT: Kandeh town, NC: Njala campus, NY: New York, T: Towama, Values in the same column and with the same superscript are not significantly different ($p>0.05$)

Table 3: Mean values of nutrient in selected wetland sediment (mg kg^{-1}±SD)

	Nutrients			
Variables	Ca	K	P	Na
B	0.002±0.001[a]	0.12±0.05[a]	0.11±0.04[a]	151.00±27.19[a]
CF	0.0001±0.0002[a]	0.04±0.02[a]	0.10±0.03[a]	170.25±43.41[a]
GT	0.0009±0.0001[a]	0.09±0.04[a]	0.11±0.04[a]	167.25±47.67[a]
MI	0.001±0.0001[a]	0.08±0.03[a]	0.12±0.05[a]	164.91±30.29[a]
KT	0.002±0.001[a]	0.07±0.03[a]	0.13±0.06[a]	173.88±38.36[a]
NC	0.001±0.0001[a]	0.18±0.04[a]	0.10±0.03[a]	210.75±47.63[a]
NY	0.001±0.0001[a]	0.19±0.10[a]	0.10±0.03[a]	133.42±35.59[a]
T	0.001±0.0002[a]	0.16±0.07[a]	0.12±0.05[a]	177.17±43.96[a]

B: Biama, CF: China farm, GT: Gbanja town, MI: Manjama institute, KT: Kandeh town, NC: Njala campus, NY: New York, T: Towama, Values in the same column and with the same superscript are not significantly different ($p>0.05$)

General hardness: Hardness of the study areas ranged from 19.7±3.57 to 169.7±8.50 mg L^{-1} $CaCO_3$. The variation in hardness recorded at the eight locations could be due to salt solubility and anthropogenic activities such as farming. The water of the studied locations can be described as being soft to moderately soft since some of the values recorded fell within the soft to moderately soft range of 0-100 mg L^{-1} (WRC., 2003).

NH_4-N, NO_3-N and NO_2-N are considered to be non-cumulative toxins (Dallas and Day, 1993). High concentrations of NO_3-N and NO_2-N may give rise to potential health risks particularly in pregnant women and bottle-fed infants (Kempster *et al.*, 1997; Kelter *et al.*, 1997). NO_3-N at elevated concentrations is known to result in cyanosis in infants. Ammonia is naturally present in surface water and groundwater and can be produced by the deamination of organic nitrogen containing compounds and by the hydrolysis of urea. The problem of taste and odour may, however, arise when the NH_4-N level is greater than 2 mg L^{-1} and above 10 mg L^{-1}, appreciable amounts of NO_3-N may be produced from NH_4-N under suitable anaerobic conditions (WHO., 1993; Kempster *et al.*, 1997). The minimum and maximum mean values of NO_2, NO_3 and NH_4 are (0.83±0.00 and 2.35±0.46), (0.30±0.01 and 54.83±14.03) and (0.40±0.06 and 2.21±0.28), respectively. The values obtained for some of the locations were above the "no effect" range for drinking water (WRC., 2003) and this could be attributed to surface run-off from farms and slurry from houses and animal pens into the wetlands.

Nutrients investigated in the selected wetlands are calcium (Ca), potassium (K), phosphate (PO_4-P) and Sodium (Na). Their concentrations are presented in Table 2 and 3.

Table 4: Mean values of trace metal concentrations in selected wetland waters (mg L^{-1}±SD)

	Metal concentration									
Variables	Cr	CO	Cd	Ni	Pb	Mg	Mn	Fe	Cu	Zn
B	0.53 ± 0.09^{a}	0.43 ± 0.09^{a}	0.16 ± 0.04^{a}	0.77 ± 0.08^{a}	1.12 ± 0.16^{a}	11.86 ± 4.62^{a}	0.85 ± 0.49^{a}	27.91 ± 14.33^{a}	2.84 ± 1.27^{a}	0.33 ± 0.11^{a}
CF	0.43 ± 0.14^{a}	0.45 ± 0.07^{a}	0.14 ± 0.05^{a}	0.69 ± 0.10^{a}	0.78 ± 0.17^{ab}	11.58 ± 4.54^{a}	3.48 ± 2.67^{a}	19.80 ± 5.98^{a}	3.88 ± 1.74^{a}	0.71 ± 0.32^{a}
GT	0.39 ± 0.12^{a}	0.45 ± 0.10^{a}	0.13 ± 0.05^{a}	0.66 ± 0.09^{a}	0.82 ± 0.16^{ab}	10.25 ± 3.80^{a}	3.23 ± 2.88^{a}	16.74 ± 1.64^{a}	4.94 ± 2.22^{a}	0.70 ± 0.15^{a}
MI	0.34 ± 0.14^{a}	0.30 ± 0.11^{a}	0.13 ± 0.38^{a}	0.65 ± 0.11^{a}	0.98 ± 0.10^{ab}	10.98 ± 3.97^{a}	0.56 ± 0.12^{a}	16.45 ± 1.24^{a}	8.00 ± 3.59^{ab}	0.59 ± 0.24^{a}
KT	0.39 ± 0.15^{a}	0.44 ± 0.15^{a}	0.16 ± 0.05^{a}	0.67 ± 0.15^{a}	0.54 ± 0.17^{b}	12.42 ± 4.73^{a}	0.76 ± 0.14^{a}	33.65 ± 7.79^{a}	8.88 ± 3.69^{ab}	0.42 ± 0.13^{a}
NC	0.48 ± 0.10^{a}	0.32 ± 0.12^{a}	0.12 ± 0.05^{a}	0.68 ± 0.19^{a}	0.74 ± 0.23^{ab}	11.93 ± 4.10^{a}	0.64 ± 0.25^{a}	17.21 ± 3.14^{a}	14.93 ± 6.31^{b}	0.85 ± 0.38^{a}
NY	0.44 ± 0.12^{a}	0.34 ± 0.10^{a}	0.12 ± 0.05^{a}	0.83 ± 0.13^{a}	0.72 ± 0.16^{ab}	10.98 ± 3.56^{a}	0.29 ± 0.10^{a}	15.93 ± 1.51^{a}	9.21 ± 6.31^{ab}	0.29 ± 0.09^{a}
T	0.47 ± 0.07^{a}	0.28 ± 0.08^{a}	0.70 ± 0.16^{a}	0.82 ± 0.12^{a}	0.84 ± 0.09^{ab}	12.18 ± 4.13^{a}	0.19 ± 0.06^{a}	22.88 ± 3.79^{a}	8.02 ± 6.35^{ab}	0.67 ± 0.11^{a}

B: Biama, CF: China farm, GT: Gbanja town, MI: Manjama institute, KT: Kandeh town, NC: Njala campus, NY: New York, T: Towama, Values in the same column and with the same superscript are not significantly different ($p>0.05$)

Calcium: Calcium plays an important role in blood clotting, in muscular contractions and in some enzymes which assist in metabolic processes. Ca tends to be a coordinator among inorganic elements, such that when K, Mg and Na are present in quantities beyond a particular limit in the body, Ca assumes a corrective role (Fleck, 1976). The mean Ca values recorded ranged between 1.77±0.60 to 9.31±0.4.42 mg L^{-1} in water and 0.0001±0.0002 to 0.002±0.001 mg L^{-1} in sediment. Calcium contents of sediments are known to be highly dependent on the density of macro benthos community. Low calcium concentrations recorded could be due to low biological productivity in the area of study.

Sodium: Sodium is of great importance as an essential nutrient in wetland ecosystems. Concentration in the study locations had appreciably low sodium levels which fell within WHO maximum acceptable limits for drinking water. The mean sodium values recorded ranged from 8.78±0.59 to 16.73±2.39 mg L^{-1} in water and 151.00±27.19 to 210.75±47.63 in sediment.

Phosphate: The mean phosphate values recorded in water ranged from 0.01±0.001 to 8.07±1.26 mg L^{-1} and 0.10±0.03 to 0.12±0.05 mg L^{-1} in sediment. The levels in water were significant ($p<0.005$) but were not statistically different. These values which are indicative of less enrichment are below the EPA maximum guideline values of 2.0 mg L^{-1} for total phosphorus with the exception of Towama where a value of 8.07±1.26 mg L^{-1} was recorded. The high phosphate value recorded at Towama could be attributed to the excessive application of phosphate containing inorganic fertilizer to rice paddy. Phosphorus is also of great importance as an essential nutrient in wetland ecosystems. Phosphorus is an essential nutrient and can exist in water in both dissolved and particulate forms. It is vital to the production of living organisms in the aquatic environment (Baird, 2000). Chapman (1992) noted that phosphorus in most natural surface waters range is from 0.005 to 0.020 mg L^{-1} as PO_4-P.

Potassium: Mean values of potassium recorded ranged from 4.47±0.51 to 10.98±2 .50 in water and 0.04±0.02 to 0.19±0.10 in sediments. K is primarily an intracellular cation found mostly bound to protein in the body along with sodium where they influence osmotic pressure and contribute to normal pH equilibrium (Fleck, 1976).

Trace metal concentrations at the eight sampling locations for water and sediment is presented in Table 4 and 5. Selenium and arsenic were not detected in the ambient water and sediments. Heavy metal contents of the sampling locations were generally high. Cr, Co, Mg and Ni are all toxic metals though not significant from the point of working environments and do not cause aquatic

Table 5: Mean values of trace metals concentration in selected wetland sediment (mg kg^{-1}±SD)

	Metal concentration									
Variables	Cr	CO	Cd	Ni	Pb	Mg	Mn	Fe	Cu	Zn
B	40.81±2.48[a]	112.22±1.22[a]	3.09±0.38[a]	24.36±3.24[a]	18.25±4.10[ae]	0.08±0.01[a]	63.00±14.13[a]	26933±7682[a]	13.04±2.53[a]	97.01±39.20[a]
CF	43.35±5.69[ab]	10.82±1.05[a]	2.70±0.35[ab]	24.05±2.26[a]	23.77±6.64[ade]	0.07±0.01[a]	130.17±45.70[b]	107702±84038[ab]	19.10±4.80[a]	170.01±66.00[a]
G	31.68±4.01[a]	11.95±1.56[a]	3.27±0.56[a]	24.68±3.50[a]	14.53±3.39[a]	0.07±0.01[a]	44.42±12.78[a]	15854±4384[ac]	13.63±2.32[a]	32.16±12.75[a]
MI	40.54±4.69[a]	20.28±4.55[b]	3.50±0.43[a]	26.85±3.51[a]	30.62±3.85[ef]	0.08±0.01[a]	47.50±9.34[a]	15748±3526[ac]	12.83±2.06[a]	85.26±22.10[a]
KT	33.92±8.20[a]	9.71±2.67[a]	2.92±0.47[ab]	21.98±4.04[ab]	14.22±4.49[a]	0.09±0.03[a]	43.38±10.53[ac]	30031±10568[a]	13.66±1.35[a]	63.14±18.58[a]
NC	43.47±3.66[ab]	12.85±1.18[a]	3.39±0.35[a]	24.55±2.96[a]	36.52±5.47[bdf]	0.22±0.08[b]	58.21±11.75[a]	22910±6600[a]	18.93±3.70[a]	84.08±35.47[a]
NY	28.52±2.53[a]	11.28±1.05[a]	3.22±0.25[a]	21.27±2.46[ab]	27.49±3.14[af]	0.14±0.05[ab]	52.42±13.26[a]	15475±4129[ac]	12.46±0.59[a]	27.53±5.55[a]
T	57.31±9.32[b]	13.29±2.63[a]	4.20±0.25[ac]	31.87±2.38[ac]	46.84±6.93[cg]	0.14±0.04[ab]	102.75±21.94[ab]	58719±13888[a]	32.15±4.70[b]	368.88±143.3[b]

B: Biama, CF: China farm, GT: Gbanja town, MI: Manjama institute, KT: Kandeh town, NC: Njala campus, NY: New York, T: Towama; Values in the same column and with the same superscript are not significantly different (p>0.05)

pollution problems in general (Varshney, 1983). The mean Cr, Co, Mg and Ni concentrations in water and sediments of the sampling locations ranged from (0.34±0.14 to 0.53±0.09, 0.28±0.08 to 0.45±0.07, 10.25±3.80 to 12.42±4.73 and 0.65±0.11 to 0.83±0.13) and (28.52±2.53 to 57.31±9.32, 9.71±2.67 to 13.29±2.26, 0.07±0.01 to 0.22±0.08 and 21.27±2.46 to 31.29±2.38), respectively. Iron was the most concentrated metal in wetland waters and sediments but cobalt was the least metal in water while magnesium was the least concentrated in sediments of the studied locations.

Cadmium (Cd): It is one of the most toxic elements with widespread carcinogenic effects in humans (Goering *et al.*, 1994) and is widely distributed in the aquatic environment. The mean Cd concentrations in water and sediments of the sampling locations varied from 0.12±0.05 to 0.70±0.016 and 2.70±0.050.35 to 4.20±0.25, respectively. Possible Cd effects in human include accumulation mainly in the kidney and liver. High concentrations have been found to lead to chronic kidney dysfunction, inducing cell injury and death by interfering with calcium (Ca) regulation in biological systems, toxicity to fish and other aquatic organisms (Woodworth and Pascoe, 1982) and its involvement in endocrine disrupting activities which could pose serious health problems. However, concentrations of cadmium in water are only likely to be of health concern in environments where pH is less than 4.5 (WHO., 2004).

Lead (Pb): It has been found to be responsible for quite a number of ailments in humans, such as chronic neurological disorders especially in foetus and children. Results from the study showed that the waters of the study area may be detrimental to foetuses and children with possible development of neurological problems since Pb levels in these waters were >0.1 mg L^{-1}. Mean values of Pb in water and soil ranged from 0.72±0.16 to 1.12±0.16 mg L^{-1} and 14.22±4.49 to 46.84±6.93 mg L^{-1}, respectively.

Manganese (Mn): It is an element of low toxicity having considerable biological significance and one of the more bio-geochemically active transition metals in aquatic environment (Evans *et al.*, 1977). Mn occurs in surface waters that are low in oxygen and often does so with Fe and are also known to dissolve from sediments under anaerobic conditions and precipitates under aerobic conditions (WRC., 2003). The mean concentration of Manganese in both water and sediments of the eight locations were above the WHO (1984) maximum permissible limits of 0.05 mg L^{-1} and are above the "no effect" range of 0-0.05 mg L^{-1} for drinking water (WRC., 2003).

Zinc: Zn is one of the earliest known trace metal and a common environmental pollutant which is widely distributed in the aquatic environment. It has been found to have low toxicity effect in man. However, prolonged consumption of large doses can result in some health complications such as fatigue, dizziness and neutropenia (Hess and Schmidt, 2002). Studies have also shown that Zn could be toxic to some aquatic organisms such as fish (Alabaster and Lloyd, 1980). In the waters of the study area, the mean Zn concentrations varied from 0.29±0.09 to 0.85±0.38 mg L^{-1}, while in soil it is 27.53±5.55 to 368.88±143.3 mg L^{-1}. This could be attributed to natural sources resulting from the weathering of minerals and soils (Merian and Clarkson, 1991).

Copper (Cu): Copper is intimately related to the aerobic degradation of organic matter (Das and Notling, 1993) and has been shown to cause acute gastro intestinal discomfort and nausea at concentrations above 3 mg L^{-1} (WHO., 2004). The mean Cu concentrations varied from 2.84±1.27 to 9.21±6.31 mg L^{-1} in water and 12.46±0.59 to 32.15±4.70 mg L^{-1} in sediments. The high Cu levels could be attributed to the level of organic load which enhances the process of aerobic degradation of organic matter which invariably, is intimately related to the deposition of Cu (Das and Notling, 1993). The United States Environmental Protection Agency has classified lead (Pb) as being potentially hazardous and toxic to most forms of life (USEPA., 1986). Iron (Fe) has frequently been used as an indication of natural changes in the trace metal carrying capacity of sediments (Rule, 1986) and its concentration has been related to the abundance of metal reactive compounds supposedly not significantly affected by man's action (Luoma, 1990).

Iron (Fe): Iron is found in natural fresh and groundwater but have no health-based guideline value, although high concentrations give rise to consumer complaints due to its ability to discolour aerobic waters at concentrations above 0.3 mg L^{-1} (WHO., 2004). The mean Fe concentration for water and soil varied from 15.93±1.51 to 33.65±7.79 mg L^{-1} and 15748±3526 to 107702±84038 mg L^{-1}, respectively. The concentration of dissolved iron in water is dependent on the pH, redox potential, turbidity, suspended matter, the concentration of aluminum and the occurrence of several heavy metals notably manganese (WRC., 2003).

REFERENCES

Alabaster, J.S. and R. Lloyd, 1980. Water Quality Criteria for Fish. 2nd Edn. butterworths, London.

Baird, C., 2000. Environmental Chemistry. 2nd Edn., W.H. Freeman and Co., New York, Pages: 557.

Boeye, D., B. Verhagen, V. van Haesebroeck and R.F. Verheyen, 1997. Nutrient limitation in species-rich lowland fens. J. Vegetation Sci., 8: 415-424.

Chapman, D., 1992. Water Quality Assessment-A Guide to the Use of Biota, Sediments and Water in Environmental Monitoring. 1st Edn., Cambridge University Press, Cambridge, Pages: 585.

Charkhabi, A.H., M. Sakizadeh and G. Rafiee, 2005. Seasonal fluctuation in heavy metal pollution in Iran's Siahroud River. A preliminary study. Environ. Sci. Pollut. Res. Int., 12: 264-270.

Dallas, H.F. and J.A. Day, 1993. The effect of water quality variables on riverine ecosystems: A review. WRC Report No. TT 61/93, Water Research Commission, Pretoria.

Das, J.D. and R.F. Nolting, 1993. Distribution of trace metals from soils and sewage sludge's Abay refluxing with aqua regia. Analyst, 108: 277-285.

EPA., 2004. Environmental protection of wetlands. Position Statement No. 4, Environmental Protection Authority (EPA), Government of Western Autralia, November 2004. http://www.epa.wa.gov.au/EPADocLib/1034_PS4.pdf.

Evans, D.W., N.H. Cutshall, F.A. Cross and D.A. Wolfe, 1977. Manganese cycling in the Newport estuary, North Carolina. Estuar. Coastal Mar. Sci., 5: 71-80.

Fleck, H., 1976. Introduction to Nutrition. 3rd Edn., Macmillian Publishing Co. Inc., New York, ISBN: 9780023384301, Pages: 552.

Goering, P.L., M.P. Waalkes and C.D. Klaassen, 1994. Toxicology of Cadmium. In: Handbook of Experimental Pharmacology: Toxicology of Metals, Biochemical Effects, Goyer, R.A.C. and M.G. Herian (Eds.). Vol. 115, Springer Verlag, New York, pp: 189-213.

Guntenspergen, G.R., S.A. Peterson, S.G. Leibowitz and L.M. Cowardin, 2002. Indicators of wetland condition for the Prairie Pothole Region of the United States. Environ. Monitor. Assess., 78: 229-252.

Gwynne-Jones, D.R.G., P.K. Mitchell, M.E. Harvey and K. Swindell, 1978. A New Geography of Sierra Leone. Longman Group Ltd., London, pp: 45.

Hann, B.J. and L.G. Goldsborough, 1997. Responses of a prairie wetland to press and pulse additions of inorganic nitrogen and phosphorus: Invertebrate community structure and interactions. Arch. Hydrobiol., 140: 169-194.

Hess, R. and B. Schmidt, 2002. Zinc supplement overdose can have toxic effects. J. Peadiat. Hematol./ Oncol., 24: 582-584.

Karbassi, A.R., J. Nouri and G.O. Ayaz, 2007. Flocculation of Cu, Zn, Pb, Ni and Mn during mixing of Talar river water with Caspian seawater. Int. J. Environ. Res., 1: 66-73.

Keddy, P.A., 2000. Wetland Ecology: Principles and Conservation. Cambridge University Press, Cambridge, UK.

Kelter, P.B., J. Grundman, D.S. Hage, J.D. Carr and C.M. Castro-Acuna, 1997. A discussion of water pollution in the United States and Mexico: With high school laboratory activities for the analysis of lead, atrazine and nitrate. J. Chem. Educ., 74: 1413-1413.

Kempster, P.L., H.R. van Vliet and A. Kuhn, 1997. The need for guidelines to bridge the gap between ideal drinking-water quality and that quality which is practically achievable and acceptable. Water SA., 23: 163-167.

Kiepe, P., 2006. Characterization of Three Key Environments for Integrated Irrigation-Aquaculture and their Local Names. In: Integrated Irrigation and Aquaculture in West Africa: Concepts, Practices and Potential, Halwart, M. and A.A. van Dam (Eds.). FAO, Rome, ISBN: 9789251054918, pp: 1-6.

Luoma, S.N., 1990. Rocesses Affecting Metal Concentrations in Estuarine and Coastal Marine Sediments. In: Heavy metal in the Marine Environment, Furness, R.W. and P.S. Rainbow (Eds.). CRC Press, Boca Raton, FL., pp: 51-66.

MFMR., 2008. Fisheries of Sierra Leone. 3rd Edn., Ministry of Fisheries and Marine Resources (MFMR), Freetown, Sierra Leone.

Merian, E. and T.W. Clarkson, 1991. Metals and their Compounds in the Environment: Occurrence, Analysis and Biological Relevance. 2nd Edn., Wiley-VCH, New York, ISBN-13: 9780895735621, Pages: 1438.

Mohamed, F.A.S., 2009. Histopathological studies on *Tilapia zillii* and *Solea vulgaris* from Lake Qarun, Egypt. World J. Fish Mar. Sci., 1: 29-39.

Murkin, H.R., M.P. Stainton, J.A. Boughen, J.B. Pollard and R.D. Titman, 1991. Nutrient status of wetlands in the Interlake region of Manitoba, Canada. Wetlands, 11: 105-122.

Oduwole, A.G., 1997. Indices of pollution in Ogunpa and Ona Rivers Ibadan: Physico-chemical, trace metals and Plankton studies. Ph.D. Thesis, University of Ibadan, Nigeria.

Omitoyin, O.B., 2007. Introduction to Fish Farming in Nigeria. Ibadan University Press, Nigeria, ISBN-13: 9789781214271, Pages: 90.

Piceno, Y.M. and C.R. Lovell, 2000. Stability in natural bacterial communities: I. Nutrient addition effects on rhizosphere diazotroph assemblage composition. Microb. Ecol., 39: 32-40.

Pradit, S., G. Wattayakorn, S. Angsupanich, W. Baeyens and M. Leermakers, 2010. Distribution of trace elements in sediments and biota of Songkhla Lake, Southern Thailand. Water Air Soil Pollut., 206: 155-174.

Rule, J.H., 1986. Assessment of trace element geochemistry of Hampton Roads Harbor and lower Chesapeake Bay area sediments. Environ. Geol. Water Sci., 8: 209-219.

Schmidt-Nielsen, K., 1990. Animal Physiology: Adaptation and Environment. 4th Edn., Cambridge University Press, Cambridge.

SAS., 1998. SAS Users Guide Statistics. 7th Edn., SAS Inst. Inc., Cary, NC., USA.

USEPA., 1986. Quality Criteria for Water 1986. 1st Edn., United Environmental Protection Agency Office of Water Regulation and Standards. Washington, DC.

Udo, E.J. and A.J. Ogunwale, 1986. Laboratory Manual from the Analyses of Soil, Plant and Water Samples. 2nd Edn., University of Ibadan, Nigeria, pp: 70-76.

Varshney, C.K., 1983. Water Pollution and Management. New Age Intl. (Pvt.) Ltd., New Dehli, India, Pages: 237.

Verhoeven, J.T., B. Arheimer, C. Yin and M.M. Hefting, 2006. Regional and global concerns over wetlands and water quality. Trends Ecol. Evol., 21: 96-103.

WHO., 1984. Guidelines for Drinking-Water Quality, Volume 1: Recommendations. 2nd Edn., World Health Organization, Geneva, Switzerland, ISBN-13: 9789241541688, Pages: 130.

WHO., 1993. Guidelines for Drinking-Water Quality. Vol. 1, World Health Organization, Geneva.

WHO., 2004. Guidelines for Drinking-Water Quality: Volume 1: Recommendations. 3rd Edn., World Health Organization, Geneva, USA., ISBN-13: 978-9241546386, Pages: 366.

WRC., 2003. Ghana Raw Water Criteria and Guidelines, Vol. 1. Domestic Water. CSIR-Water Research Institute, Accra, Ghana.

Wcislo, E., D. Ioven, R. Kucharski and J. Szdzuj, 2002. Human health risk assessment case study: An abandoned metal smelter site in Poland. Chemosphere, 47: 507-515.

Woodworth, J.C. and V. Pascoe, 1982. Cadmium toxicity to rainbow trout salmon gairdneri Richardson a study of eggs and alevins. J. Fish. Biol., 21: 47-57.