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Distribution of Cr, Pb, Cd, Zn, Fe and Mn in Lake Victoria Sediments, East Africa

John Mmari Onyari* and Shem O. Wandiga

Department of Chemistry, College of Biological and Physical Sciences, University of Nairobi, P.O. Box 30197, Nairobi, Kenya

The presence of many metals at trace or ultra-trace levels in the human environment has received increased global attention (WHO 1977; Hutton 1982; IRPTC 1984). Surveillance of concentrations of heavy metals in the environment is of global interest since elements like cadmium, lead and mercury are listed as environmentally dangerous chemical substances. Sediments as a sink for pollutants are widely recognized pollution sources and diagenesis and biochemical transformations within the sediment may mobilize pollutants posing a threat to a wider biological community. The natural (background) concentrations of heavy metals in lake sediments can be estimated either by analysis of surface sediments in non-polluted regions or by analysis of core samples antedating modern pollution. The degree of contamination of selected rivers and lake sediments by lead, zinc and cadmium has been reviewed by Warren (1981). The distribution pattern of heavy metals in tropical freshwater systems has been little studied. Kilham (1972) studied the biogeochemistry of African lakes and rivers. Onyari (1985) found increased concentrations of lead and other trace metals in Lake Victoria. Thus this study was initiated in order to further investigate the distribution patterns of lead and other metals in Lake Victoria.

MATERIALS AND METHODS

Lake Victoria with a surface area of 68,000 km sq. is the second largest lake in the world. Sixty sediment samples were collected from the Winam Gulf of Lake Victoria (Fig. 1) using an Ekman grab during the period 3/18/87 to 7/2/87. The sediments were oven dried at 105° C for 24 hours. Final preparations of the samples included grinding and homogenization. For analysis, 2.0 g of the sediment samples were weighed into digestion tubes. The method of analysis is a modifi-

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Send reprints requests to John Mmari Onyari

Current Address: *Traditional Medicines and Drugs Research Centre, Kenya Medical Research Institute, P.O. Box 54840, Nairobi, Kenya

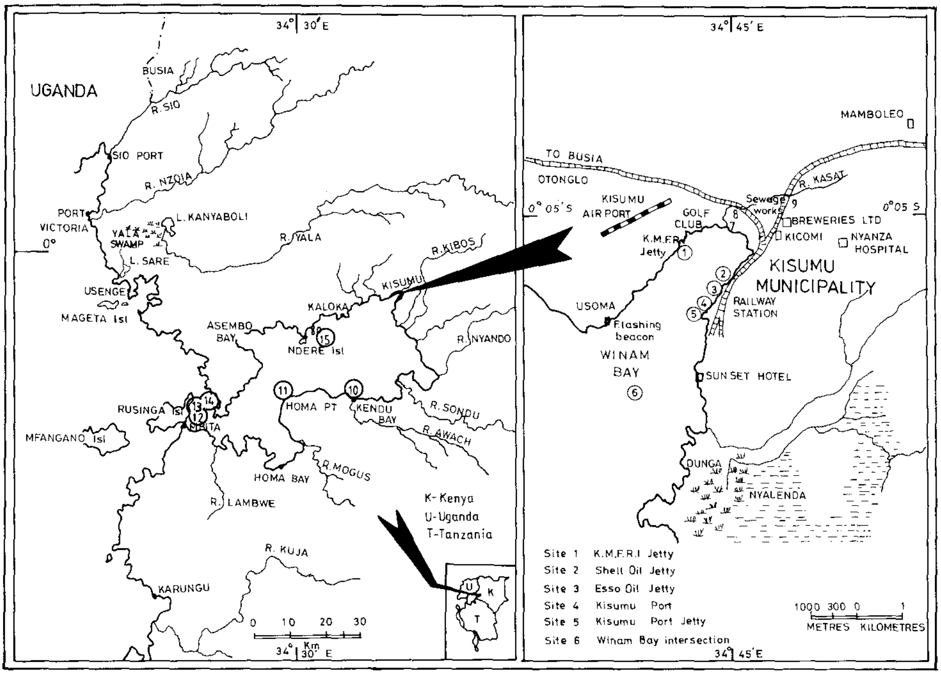

Figure 1. Sampling localities in the Winam Gulf of Lake Victoria

-cation of that reported by Agemian et al (1980). A second digestion method involved 25 cm^3 of hydrochloric acid. The tubes were heated at 100° C in an aluminium heating block with programmed heating speed. After 3 hours, the digests were allowed to cool and quantitatively transferred into 50 cm^3 volumetric flasks. A Perkin Elmer Atomic Absorbtion spectrophotometer model 2380 was used for analysis of the samples after preparation of appropriate standards. To check the accuracy and precision of the method, a lake sediment (SL-1/1979) certified reference material obtained from the International Atomic Energy Agency was analysed. The results reported by Onyari (1985) indicate good agreement between experimental and certified values. The analysis of variance was used to infer the differences among the mean metal contents of each type of sample. The Duncan new multiple range test (Duncan, 1955) was performed to compare among means at the nine different sites in the Winam Gulf of lake Victoria.

RESULTS AND DISCUSSION

The regional distribution of seven trace metals is presented in tables 1 and 2. There were statistically significant differences among the mean contents from different locations. The Duncan new multiple range test was used to compare among means at different sites. The data in Table 2 illustrate elevated concentration of some trace elements at some localities which indicates a localized pollution problem. Of the metals studied, the cadmium content was the lowest, but significant variations (at P = 0.05) were observed between the different sites. Clark (1986) reported that sewage sludge contains up to 30 mg/kg cadmium. Globally, phosphate rocks may contain 100 mg/kg cadmium and phosphate fertilizers are a potential source of cadmium in the environment.

Usually, the deeper regions (e.g. Ndere Islands and Mbita) of the Winam Gulf were characterized by low metal content, while some shallow regions (Kisumu Port, Shell and Esso Oil jetties) contained elevated levels of lead, cadmium, zinc and copper (Table 2). Maximum values of lead (228 mg/kg), copper (62.8 mg/kg) and zinc (370 mg/kg) have been obtained at the shell oil jetty at Kisumu port (Urasa and Onyari, 1986). All five stations (1-5) located inside the port region contained elevated levels of heavy metals and the Duncan new multiple range test indicated statistically significant differences compared to other localities.
Industrial and municipal wastes discharged from the wastewater treatment works through Kasat River are partly responsible. However, upon comparing the heavy metal content of Pb, Cu, Zn and Cd in Kasat River

Table 1. Comparisons between the average values of some heavy metals in sediments of the Winam Gulf of Lake Victoria (values in mg/kg dry weight)

Location	Mn wt %	Fe wt %	Cu	Zn	Cd	Pb
Golf Club Beach	0.01±0.00	0.22±0.10	0.97±0.01	3.4±0.9	≤0.01±0.00	5.1±0.0
Kasat River Club	0.62±0.00	5.3 ±0.0	9.4 ±0.6	73.8±7.3	0.73±0.01	24.4±0.4
Kasat River,Busia Road	0.51±0.02	3.8 ±0.0	8.1 ±0.4	66.6±2.3	0.71±0.01	22.2±2.0
Kisumu Town Zone	0.06±0.00	1.8 ±0.0	24.8 ±0.0	144 ±0	0.61±0.00	25.5±0.0
K.M.F.R.I. Jetty	0.15±0.01	2.8 ±0.0	74.9 ±3.7	256 ±8	0.99±0.03	62.2±7.3
Kendu Bay	0.12±0.00	1.9 ±0.3	38.4 ±0.5	98.7±1.4	0.50±0.07	17.7±0.2
Homa Point	0.11±0.03	1.7 ±0.0	46.6 ±0.6	157 ±30	0.57±0.16	17.7±0.5
Rusinga Island	0.05±0.01	3.3 ±0.4	52.5 ±0.3	147 ±1	0.72±0.01	23.9±0.2
Mbita	0.07±0.00	2.8 ±0.5	56.0 ±0.5	122 ±1	0.83±0.15	20.7±3.8
Luanda Naya	0.07±0.00	1.8 ±0.4	66.4 ±0.8	101 ±1	0.59±0.14	15.3±2.9
Ndere Islands	0.05±0.00	2.0 ±0.1	40.3 ±0.1	142 ±2	0.57±0.14	22.3±1.5

Reference a (Onyari, 1985)

sediments and other localities in the lake (Table 1) it is clear that port activities are of even greater significance, especially discharge of ship bilge waters and oil spillages during routine operations. These occur while loading petroleum products transhipped to Uganda and Tanzania. In addition, alkyl lead is used as a fuel additive. This is reflected by the high lead levels (Table 2) at the Shell and Esso oil jetties compared

Table 2. Comparison of mean content of heavy metals in sediments of Winam Gulf of Lake Victoria (values in mg/kg, dry weight).

Location	Cu	Zn	Cd	Pb	Cr
1 K.M.F.R.I. Jetty	48.1 b	242 b	1.11 c	92.8 c	37.8 de
2 Shell Oil Jetty	44.8 bc	268 a	1.36 b	138 a	39.0 de
3 Esso Oil Jetty	42.0 c	236 b	1.51 a	112 b	41.6 de
4 Kisumu Port	64.1 a	226 b	1.23 c	110 b	37.1 e
5 Kisumu Port Jetty	36.1 d	190 c	1.09 c	77.2 d	43.8 d
6 Mid Bay	25.1 e	133 d	0.82 d	35.5 e	43.5 de
Ndere Islands	26.8 e	127 e	0.61 e	25.8 e	70.8 c
Mbita (West)	7.6 g	17.8 f	0.34 f	2.5 f	82.9 b
Mbita (East)	15.0 f	38.4 f	0.53 e	5.0 f	131 a
SE (Standard Error)	±1.1	±6.3	±0.05	±4.8	±1.9
CV % (Coefficient of Variation)	6.4	7.7	9.4	14.4	6.5

Note: Means followed by similar letter are not significantly different at P = 0.05 (Duncan new multiple range test)

to stations 6 (mid bay) and 15 (Ndere Islands) situated approximately 2 km and 30 km respectively from the port region.

In global terms, the lead, copper and zinc levels obtained in the Winam Gulf are not exceptional. Brugman (1981) reviewed the heavy metals levels in the Baltic Sea sediments and the highest concentrations reported e.g. Pb, 2-400 mg/kg, Cu, 1-283 mg/kg and Zn, 12-2090 mg/kg were in the near shore sediments. Hamilton-Taylor (1979) obtained lead and zinc levels of 500 mg/kg and 1000 mg/kg, respectively, in sediments of Windermere Lake, England. To illustrate the lead pollution problem in the Winam Gulf, 90% of the samples examined in 1984 contained low lead levels <25 mg/kg. However, 63% of the samples covered in our 1987 survey are of high lead content (>60 mg/kg), according to the metal classification reported by Donazzolo et al. (1984). The highest mean lead content of 138 mg/kg obtained at the Shell oil jetty gives an enrichment factor of 55 times compared to the uncontaminated sediments of Mbita east. The increase in lead levels in the Kisumu Port region

(Stations 1-5) is largely due to increased shipping traffic and associated operations.

The results in Table 3 demonstrate good comparison in copper, chromium and zinc content in N.E. Kenya and N.W. Uganda regions of Lake Victoria. However, higher iron concentrations have been reported in N.W. lake Victoria (Mothersill 1976). This difference in metal content reflects the difference in geological rock structure.

Table 3. Comparison between the metal content of some trace metals in sediments obtained from Kenyan and Ugandan regions of Lake Victoria (mg/kg, dry weight).

Element,	N.E. Lake Victoria (Winam Gulf)			N.W. Lake Victoria (Uganda)[c]	
	1984 Survey[a]	1985/85 Survey[b]	1987 Survey	Range	Mean
Mn	53.1- 6160	800- 5050	-		
Fe	1180 -52800	39300-65000	-	33,000-157,000	64,000
Cu	0.96-78.6	5.6- 62.8	7.6 - 66.9	11- 96	41
Zn	2.5 -265	51.0-370	17.8 - 286	49-115	86
Cd	0.00- 1.0	1.3- 3.8	0.34- 1.8	-	-
Pb	6.0 -69.4	21.4-228	2.5 - 152	-	-
Cr			33 - 131	40-103	67

a. Onyari, 1985
b. Urasa and Onyari, 1986
c. Mothersill, 1976

Table 4. Regression lines for various combinations of elements in sediments of Winam Gulf of Lake Victoria.

Elements (X,Y)	Year	Mean concentration mg kg^{-1} $\bar{X} \pm$ SD	$\bar{Y} \pm$ SD	a	b	r
Cu - Zn	1984	34.3 ± 23.7	120 ± 67	41.7	2.3	0.81
	1987	39.0 ± 14.6	191 ± 68	44.2	3.7	0.80
Mn^x - Fe^x	1984	0.17 ± 0.21	2.4 ± 1.4	1.5	5.6	0.86
	1987	-	-	-	-	-
Cd - Pb	1984	0.61± 0.26	24.0 ± 14.4	-0.73	40.9	0.74
	1987	1.1 ± 0.3	79.0 ± 43.8	-43.6	116	0.90
Zn - Cd	1984	120 ± 67	0.61± 0.26	0.29	0.00	0.66
	1987	191 ± 68	1.1 ± 0.3	0.23	0.00	0.87
Zn - Pb	1984	120 ± 67	24.0 ± 14.4	2.9	0.18	0.82
	1987	191 ± 68	75.0 ± 43.8	-34.9	0.60	0.93
Cu - Cd	1984	34.3 ± 23.7	0.61± 0.26	0.40	0.01	0.54
	1987	39.0 ± 14.6	1.1 ± 0.3	0.41	0.02	0.71
Cu - Pb	1984	34.3 ± 23.7	24.0 ± 14.1	11.8	0.36	0.59
	1987	39.0 ± 14.6	79.0 ± 43.8	-13.2	2.4	0.79
Fe - Cd	1984	2.4 ± 1.4	0.61± 0.26	0.30	0.13	0.65
	1987	-	-	-	-	-

Note 1 a=y intercept, b=slope, r=correlation coefficient, SD = Standard Deviation

Note 2 Mn^x and Fe^x concentration values in Wt %

Note 3 r values for Cu-Fe, Cu-Mn, Zn-Mn, Zn-Fe, Mn-Cd, Pb-Mn and Pb-Fe not significant

Table 4 lists the correlation coefficients between metals in Lake Victoria sediments. Copper gave a positive correlation with zinc (r = 0.81) suggesting incorporation of similar proportions of the metals. The results also suggest that zinc was initially formed or precipitated in the sediments' interstitial matrix prior to copper. Saad et al (1981) observed a similar relationship for Mediterranean Sea sediments. Table 4 also gives the relationships obtained between manganese and iron; copper and cadmium; and copper and lead. Closer examination of the relationship obtained in 1987 between copper and lead reveals a steeper slope (b = 2.363, r = 0.786) compared to 1984 data (b = 0.346, r = 0.585). This implies that within Kisumu port region lead is increasing at a faster rate compared to copper, indicative of a lead point source. A similar relationship was obtained between cadmium and lead (b = 116, r = 0.900) and also zinc and lead (b = 0.595, r = 0.926). Our survey has revealed that although lead is a natural constituent of the environment, its distribution in Lake Victoria has been overshadowed by the man-made dissemination of the metal. Lead taken into the human body enters the blood from where it is redistributed to soft tissues and the skeleton. Excessive lead exposure causes a variety of biological effects, of which the disturbance of the haem synthesis is best characterized. With the rapid industrialization taking place in many developing nations, pollution problems need to be anticipated. The cumulative effects of industrialization, population growth, agricultural runoff, storm waters, traffic increase and other pollution generating activities must become a matter of public and government concern. In view of the foregoing account, the importance of sustainable development cannot be overemphasized and governmental environmental policies need to reconcile economic development and environmental protection.

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