

Impact of Farming Practices on Water Quality in the Chemelil Sugar Belt

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There has been great emphasis on cleaner environment in the recent past and studies involving pollutants such as heavy metals in water and sediments have been used as a bio-indicator of their accumulation in the aquatic system. A study of the levels of heavy metals; lead, cadmium, chromium, copper, zinc and manganese in water and sediments from Chemelil sugar belt (CSB), a catchment of Lake Victoria, practicing commercial sugar cane farming as a predominant activity has been undertaken. Water and sediments were collected from different sampling points in the CBS and the sediments were dried, crushed, sieved, weighed and digested. The prepared samples were subjected to heavy metals analysis using atomic absorption spectrophotometer (AAS). The detected levels of Pb and Cd in water samples were higher than the WHO/FAO limits of 0.01 ppm and 0.003 ppm, respectively. Lead in water was sixty times higher than WHO/FAO maximum limits of 0.01 ppm and six times higher than the KEBS maximum limits of 0.1 ppm. Cadmium in water was over 10 times higher than the WHO /FAO limits of 0.003 ppm. However, the levels of Cu, Zn, Mn, Cr and Co in water samples were within permissible levels. The levels of Co, Cr and Mn in sediments were higher than the WHO/FAO maximum limits of 0.1 ppm, 0.05 ppm and 0.1 ppm, respectively. Manganese values were the highest and much exceeded the FAO/WHO maximum limits of 0.1 ppm. Chromium values were also above the FAO/WHO maximum limits of 0.05 ppm, while cobalt levels were around five times higher than the FAO/WHO maximum limits of 0.1 ppm. Copper, cadmium and zinc in sediments were, however, below the maximum permissible limits, while, the levels of lead at several sampling points were above the FAO/WHO recommended values. Generally, levels of heavy metals in sediments were higher than in water samples. For instance, the levels of manganese in sediments were particularly more than two hundred times higher than those in water. If this trend continues unchecked then the water quality in the CBS will increasingly become life threatening with a consequential ensuing of un-sustainability of the eco-system.

Key words: Heavy metals, sediments, water quality, sustainability and urbanization.

Introduction

Chemelil sugar belt is a catchment of Lake Victoria, agricultural activities in the region include; large scale sugarcane, tea, coffee, maize, and tobacco and rice cultivation. Other farming activities include; horticulture, food crop farming and livestock rearing.

There is increasing awareness of the potential hazards that exist due to contamination of fresh water impoundments by toxic metals, phosphates and nitrates associated with agricultural activities, urbanization and the mining industry (Dupreez *et al.*, 2003). The most commonly used pesticides include; insecticides, herbicides, fungicides, rodenticides, acaricides and auxins.

The use of artificial fertilizers and pesticides has contributed greatly to the increase in food production worldwide and this has improved human and animal health. However, side effects such as toxicities to non target species have been observed, for instance copper used as a fungicide caused inactivity and mortality in larval clams (La-breche *et al.*, 2002). This toxicity can extend to human beings since some of the pesticides persist in soils and sediments for long (Anonymous, 1993). To avoid this problem organic farming is practiced in some countries where crops are grown using environmentally friendly techniques, no synthetic chemicals are used instead natural compost such as dung ash, natural phosphate etc are used (Moellhausen, 2006).

The major consequences of environmental contamination by heavy metals, nitrates and phosphates are their toxicity to humans after entering the food chain (Odero *et al.*, 2000). Toxicity of these metals has been investigated and it has been reported that; Zn, Cu, Cr, and Mn have chronic poisoning effect on animals if acceptable daily intake levels are exceeded. Lead can impair intellectual capacity at levels of 50 µg/dl of blood (Alloway, 1995).

In Kenya heavy dependency on these chemicals for food production has led to death of fish in Lake Victoria, this in turn has led to the ban of exportation of fish to the European Union (Ntiba *et al.*, 2001). The total loss of income due to this ban was estimated to be more than US\$300 million (Kengara, 2003).

Methods and Materials

Sampling

The area was divided into 3 zones with respect to sediments samples and 2 zones with respect to water samples. Sediment samples were collected from 14 points by a core sampler. All the samples were transported in cool boxes with freezer packs and stored at between -5°C to -10°C in the laboratory awaiting analysis.

Water samples were collected from 13 rivers by grab samples, in the morning, midday and late afternoon. The water was mixed in 1 litre plastic bottles which had been previously washed detergent, tap water, 10 % nitric acid and the thoroughly rinsed with double distilled water.

Zone one (S) had the rivers; Kedowa (9), Masaita (18)s, Murgut (19), Nyando at Muhoroni- Kericho road (15) and Nyando at IGD 7 (6).

Zone two (S) had the rivers, Ainaprigetuny (7), Great Oroba at Miwani -Chemelil bridge (23), Nyando at Ogilo (3), Ahero irrigation channel (20) and Nyando at Ahero (25).

Zone three (S) had the sampling sites; Parget (12), Ainabngtetuny (4), Mbogo (13) and Ainamutua at Kibigori (1)

Zone one (W) had the sampling sites; R. Masaita (4), R. Kedowa (9), R. Kimison at Kipkelion (10), R.Kipchorian at Kipkelion (7), R. Namting near Fort-Tenan (14), R. Murgut at Fort-Tenan (2), R. Nyando at Muhoroni-Kericho road (6), R. Nyando at IGD7 (15), R.Nyando at Ogilo (8) and R. Nyando at Ahero bridge (11)

Zone two (W) had the sampling sites; R. Parget (12), R. Mbogo (5), R. Ainamutua (13), R. Nyando at Ogilo (8) and R. Nyando at Ahero bridge (11).

Reagents

All reagents were of analytical grade quality and these were; hydrogen peroxide (30 %) lithium sulphate, selenium powder and sulphuric acid.

Sample Digestion

Sediments samples were air-dried, crushed and sieved through a 0.2 mm sieve as directed by Okalebo and others (1998). Accurately weighed 0.3 g of ground sediments was transferred to a digestion tube.

About 4.4 mL digestion mixture, which had been prepared by taking 0.42 g selenium powder and 14 g of lithium sulphate that had previously been added to 350 mL of 30% hydrogen peroxide, mixed well and 420 mL of concentrated sulphuric acid added slowly with care while cooling in an ice bath. Digestion was done at 360 °C for two hours in a block digester. The solution was allowed to cool and 50 mL of de-ionised water added and the mixture well mixed to dissolve sediments. Water samples were also digested using the same procedure. The solution was made up to 100 mL with thorough mixing and allowed to settle for AAS analysis using the CTA 2000 and AA-680 equipment.

Results and Discussion

The results were summarized in tables and figures presented below:

Table 1: concentration of heavy metals (Pb, Cd, Cu, Cr, Co, Mn, Zn) in sediments-zone 1

| Site | Cu | Mn | Zn | Cd | Cr | Co | Pb |
|------|-------------|--------------|-------------|---------|-------------|-------------|-------------|
| 9 | 0.650±0.014 | 4.700±0.5 | 1.987±0.012 | 0±0 | 1.291±0.015 | 0.655±0.031 | 0.405±0.110 |
| 18 | 0.104±0.010 | 14.400±0.432 | 1.016±0.002 | 0±0 | 0±0 | 0.359±0.050 | 0±0 |
| 19 | 0.273±0.005 | 10.440±0.055 | 0.955±0.002 | 0±0 | 0.284±0.011 | 0.416±0.031 | 0.045±0.019 |
| 15 | 0.488±0.008 | 11.100±0.366 | 1.046±0.002 | 0.002±0 | 0.993±0.013 | 0.671±0.019 | 0.165±0.019 |
| 6 | 0.423±0.012 | 11.430±0.20 | 0.985±0.003 | 0±0 | 0.954±0.010 | 0.423±0.05 | 0.07±0.032 |

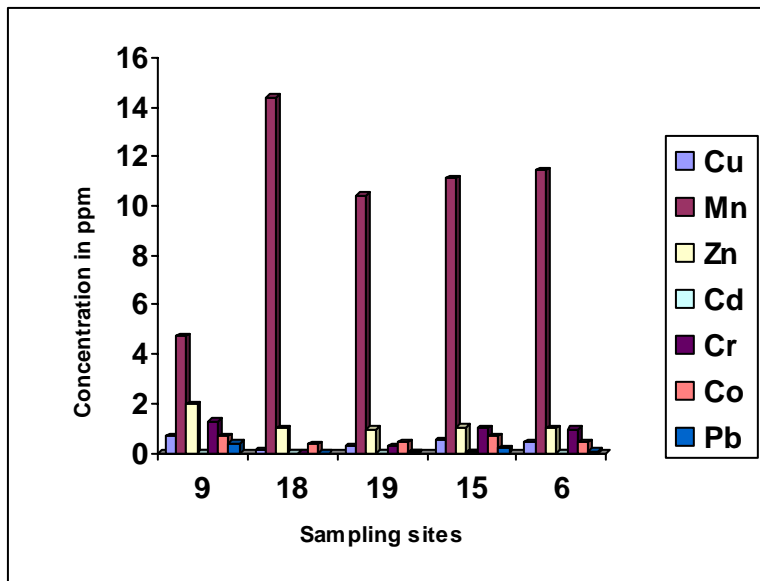


Figure 1: Concentration of heavy metals (Pb, Cd, Cu, Zn, Cr, Co, Mn) in sediments-zone 1

From table 1 and Figure 1 it can be shown that, there was a general increase in the concentrations of copper downstream. This could be due to the use of copper as a component of most pesticides upstream and then it is transported by water bodies downstream and accumulates towards the lake. The lowest mean concentration of copper in this zone was 0.104 ppm at R. Masaita while the highest was 0.65 ppm at R. Kedowa.

Mean concentration of lead and zinc in sediments decreased downstream. The highest value of lead was at R. Kedowa (0.405 ppm). The value was 40 times higher than FAO/WHO maximum limits of 0.01 ppm. The high levels of lead could be attributed to its natural availability in soils as a result of weathering of rock fragments on which soil develops (Omoga and Kagwanja, 1999). The levels of zinc in zone 1 were all lower than the KEBS and FAO/WHO maximum limits. Cadmium was not detected in all the sediment samples except the one from R. Nyando at Muhoroni (0.002 ppm).

Mean concentration of manganese increased downstream, the lowest value recorded was 4.70 ppm at R. Kedowa while the highest value was at R. Masaita (14.40 ppm). These values were mostly a hundred times higher than those prescribed by both WHO/FAO and KEBS as maximum acceptable limits of 0.1 ppm. Surprisingly, the mean concentrations of manganese were highest recorded in the analysis. This could be because of the parent material, i.e., concentration found in mineral salts that could reflect the composition of parent material. It was earlier reported also that manganese commonly occurs as mineral oxides birnessite and vernadite (Gilkes and McKenzie, 1988). Apart from the natural mineralogical sources the only other significant source of manganese in the soils is the results of application of the elements to deficient soils. Application to soil is normally in the form of $MnSO_4$, MnO or as an addition to macronutrient fertilizers. High level of manganese in the soil poses a risk because it can be released into the water system resulting in its bioavailability.

Increase in chromium could be an indicator that chromium used in farms was washed downstream towards the lake, which could eventually lead to over-enrichment, hence, rendering the water unfit for consumption. Lowest levels of chromium in this zone

appeared at R. Masaita (0.0 ppm), while the highest was at R. Kedowa (1.291 ppm). Highest concentration was, however, over ten times higher than the FAO/WHO maximum limits. It can be concluded that these high levels of chromium could be due to availability of metal and /or its related compounds in the environment. The high levels could also be due to use of chromium related products such as seed protectants and wood preservatives. These levels of chromium should be checked as it is readily mobilized into solution.

Lowest level of cobalt in zone 1 was 0.359 ppm at R. Masaita, while the highest level was at R. Nyando (Muhoroni-Kericho road) the concentration was at 0.671 ppm. These values were generally five times higher than the FAO/WHO maximum limits of 0.1 ppm. Decrease in cobalt levels downstream could be due to dilution by the rivers flowing in from up-stream. It could also be due to the fact that cobalt products are not commonly used in the area hence, cobalt detected could be from the parent rock.

Table 2: Conc. of heavy metals (Pb, Cd, Cu, Zn, Mn, Cr, Co) in sediments-zone 2

| Site | Cu | Mn | Zn | Cd | Co | Pb | Cr |
|------|-------------|--------------|-------------|---------|-------------|-------------|-------------|
| 7 | 0.203±0.009 | 11.500±0.471 | 1.239±0.007 | 0±0 | 0.489±0.054 | 0±0 | 0.214±0.021 |
| 23 | 0.145±0.017 | 11.430±0.114 | 0.976±0.003 | 0±0 | 0.381±0.047 | 0±0 | 0±0 |
| 3 | 0.359±0.008 | 8.520±0.383 | 0.906±0.004 | 0±0 | 0.415±0.055 | 0.040±0.004 | 0.857±0.022 |
| 20 | 0.215±0.013 | 20.440±0.224 | 1.241±0.007 | 0±0 | 0.416±0.043 | 0.260±0.046 | 0.088±0.008 |
| 25 | 0.625±0.009 | 12.760±0.396 | 0.803±0.004 | 0.002±0 | .566±0.053 | 0.510±0.047 | 0±0 |

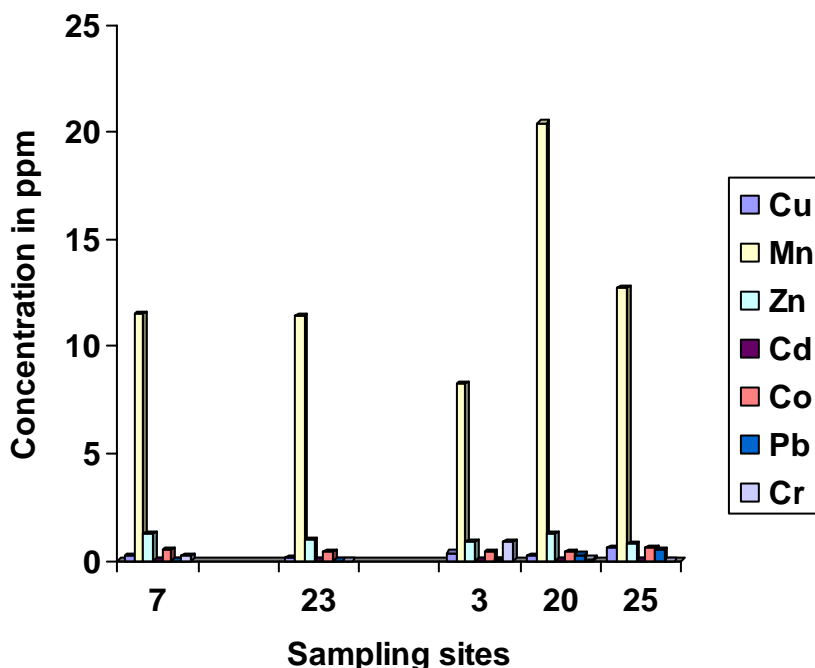


Figure 2: concentration of heavy metals (Pb, Cd, Cu, Cr, Mn, Co, Zn) in sediments-zone 2

From table 2 and figure 2 it can be shown that there was a general increase in mean concentrations of copper and lead downstream, however, copper levels were still lower than the FAO/WHO maximum limits of 1.00 ppm In zone 2, lead was not detected at R.

Ainaprigetuny and the Great Oroba. However, the remaining areas had levels ranging from 0.04 ppm (R. Nyando at Ogilo) to 0.51 ppm (R.Nyando at Ahero), which were very much higher than the FAO/WHO maximum limits of 0.01 ppm. There was a general decrease in the levels of zinc in zone 2; the values were also lower than both the FAO/WHO and KEBS maximum limits.). Cobalt level were lowest at the Great Oroba-code 23 (0.381 ppm) and highest at R. Nyando-Ahero-code 25 (0.566 ppm). These values were about five times higher than the FAO/WHO maximum limits of 1.0 ppm.

Manganese levels, however, decreased and later on increased. The highest level of manganese in this zone was 20.44 ppm at Ahero Irrigation Channel. Surprisingly, this value was higher than all the values in zone 1 (table 4 and figure 6). The lowest value, (8.52 ppm) was again higher than the lowest value in zone 1(4.70 ppm). Comparing the two zones, it can be observed that concentrations of manganese increase downwards. This increase could be due to manganese compounds usually are washed from farms in the upper region. Fluctuation in concentration could be due to dilution by rivers flowing in from upper regions. Chromium levels increased and then decreased this could be due to bioremediation by plants that grow in the rivers/banks. There was no chromium detected at Great Oroba and R .Nyando (Ahero), which are coded as 23 and 25, respectively. The lowest concentration of chromium was at Ahero irrigation channel (0.088 ppm), while the highest was at R. Nyando- Ogilo (0.857 ppm). These levels were more than ten times higher than the FAO/WHO maximum limits of 0.05 ppm. Fluctuation in levels could be due to the dilution effect of some rivers by in-coming rivers and bioremediation by plants that grow in the rivers.

Table 3: Concentration of heavy metals (Pb, Cd, Cu, Zn, Mn, Cr, Co) in sediments-zone 3

| Site | Cu | Mn | Zn | Cd | Co | Cr |
|------|--------------|--------------|-------------|---------|-------------|-------------|
| 12 | 0.478±0.0013 | 11.570±0.381 | 0.975±0.002 | 0.004±0 | 0.560±0.030 | 0.484±0.017 |
| 4 | 0.441±0.010 | 11.420±0.75 | 0.992±0.004 | 0±0 | 0.647±0.068 | 2.473±0.032 |
| 13 | 0.09±0.009 | 30.060±0 | 1.372±0.005 | 0±0 | 0.371±0.025 | 0±0 |
| 1 | 0.595±0.031 | 9.990±0.330 | 1.097±0.004 | 0±0 | 0.503±0.086 | 0.909±0.010 |

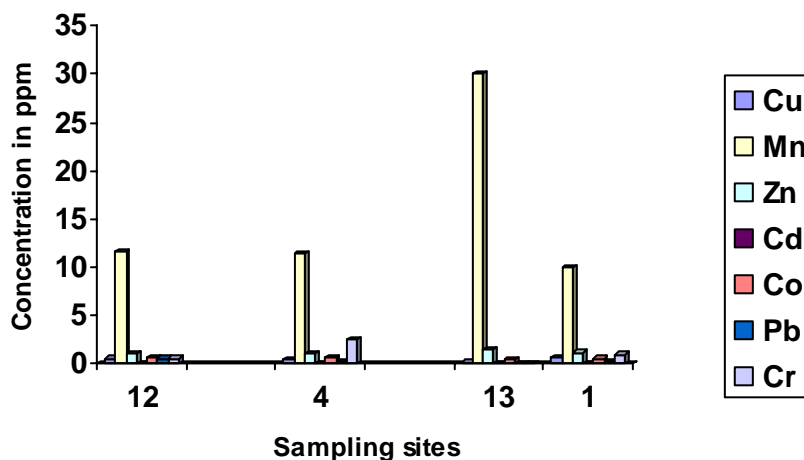


Figure 3: Concentration of heavy metals (Pb, Cd, Cu, Zn, Co, Cr, Mn) in sediments-zone 3

Table 3 and Figure 3 show a general increase in the levels of heavy metals downstream. It can be seen that zone 3 had generally the highest mean concentrations of most of the elements analyzed, i.e., it had the highest levels of Pb (0.202 ppm), Mn (15.76 ppm), Co (0.520 ppm), Cu (0.401 ppm) and Cr (0.967 ppm). However, the zone had the second highest levels of zinc (1.109 ppm). Of particular interest, was manganese, which had a value of 10.416 ppm, 12.93 ppm and 15.76 ppm in zones one, two and three, respectively. Manganese was also the metal with the highest concentrations in sediments in all the samples analysed. The order of the heavy metal distribution per zone was;

Zone 1: Mn>Zn>Cr>Co>Cu>Pb>Cd

Zone 2: Mn>Zn>Co>Cu>Cr>Pb>Cd

Zone 3: Mn>Zn>Cr>Co>Cu>Pb>Cd

Since zone 3 is the one closest to the lake, it implies that the above pollutants are being washed from the farms towards the lake. Over a long period of time the elements are likely to accumulate and cause havoc in the lake ecosystem. The high levels could also mean other activities other than farming are being carried out in zone 3. The activities could include; industries, mining, waste water and sewage disposal.

However, the copper and zinc values in the zone were lower all lower than the FAO/WHO maximum limits. Lead values were between 0 ppm (R. Mbogo) and 0.45 ppm (R. Parget), Cd was not detected in most sites. Zone three had the highest average concentration of most of the elements i.e. copper, zinc acid lead. The mean levels of cd were 0 ppm.

Table 4: concentration of heavy metals (Pb, Cd, Cu, Co, Mn, Cr, Zn) in water -zone 1

| Site | Cu | Cd | Co | Pb | Cr | Mn | Zn |
|------|-------------|-------------|-------------|------------|-------------|-------------|-------------|
| 4 | 0.018±0.009 | 0.034±0.004 | 0.233±0.015 | 0.55±0.004 | 0.123±0.018 | 0.063±0.028 | 0.115±0.004 |
| 9 | 0.027±0.004 | 0.036±0.005 | 0.230±0.017 | 0.55±0.006 | 0±0 | 0.068±0.015 | 0.124±0.002 |
| 10 | 0.031±0.001 | 0.025±0.004 | 0.204±0.013 | 0.53±0.002 | 0±0 | 0.066±0.013 | 0.103±0.002 |
| 7 | 0.030±0.008 | 0.027±0.005 | 0.213±0.012 | 0.50±0.009 | 0.071±0.029 | 0.360±0.027 | 0.102±0.003 |
| 14 | 0.033±0.003 | 0.009±0.002 | 0.131±0.014 | 0.52±0.009 | 0±0 | 0.007±0 | 0±0 |
| 2 | 0.023±0.008 | 0.043±0.003 | 0.256±0.024 | 0.52±0.007 | 0.146±0.005 | 0.107±0.033 | 0.152±0.002 |
| 6 | 0.029±0.000 | 0.028±0.002 | 0.217±0.027 | 0.48±0.011 | 0.051±0.018 | 0.099±0.040 | 0.114±0.003 |
| 15 | 0.023±0.005 | 0.018±0.003 | 0.109±0.011 | 0.47±0.004 | 0±0 | 0.007±0 | 0.113±0.002 |
| 8 | 0.035±0.007 | 0.028±0.003 | 0.213±.021 | 0.52±.012 | 0.002±0 | 0.135±0.018 | 0.123±0.003 |
| 11 | 0.037±0.01 | 0.023±0.012 | 0.188±.022 | 0.54±0.009 | 0.013±.001 | 0.063±0.021 | 0.119±0.003 |

From table 4 and figure 4 it can be shown that cadmium values were between 0.009 ppm at R. Kedowa and 0.043 ppm at R. Margut. These values were all higher than the values in sediment samples. The Pb values were also higher than the values in sediment samples. This would be due to solubility of Pb and Cd compounds formed hence remain in solution and are detected in water. The high Cd levels could be due to use of phosphotic fertilizers in the surrounding farms. There was no noticeable trend in the mean concentrations of zinc, chromium and manganese because the levels either decreased or increased towards the lake. Zinc and copper values in water samples of zone 1 were very low i.e. even lower than the levels in sediments. This could be due to insolubility of their compounds and therefore precipitation and incorporation in sediments.

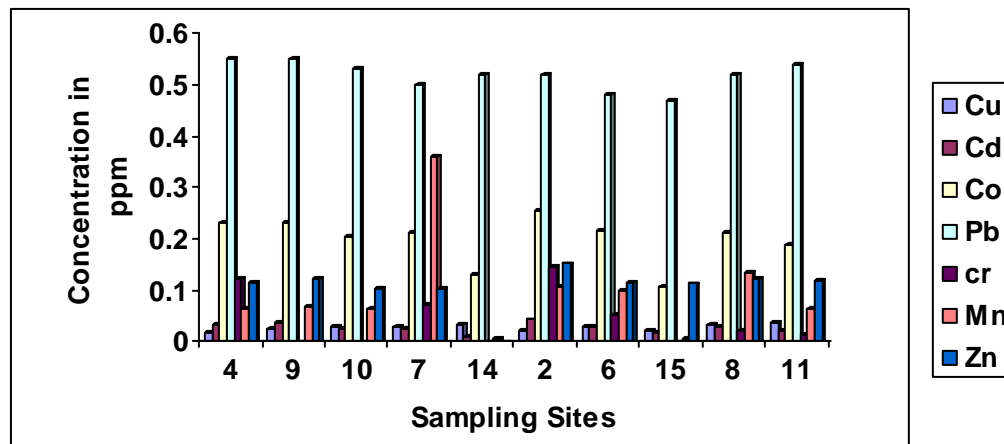


Figure 4: concentration of heavy metals (Pb, Cd, Cu Zn, C0, Mn, Cr) in water zone 1

However, the mean concentrations of cobalt decreased downstream. It was interesting to note that some samples had manganese levels higher than KEBS maximum limits of 0.1 ppm. These included samples collected from R.Kipchorian coded 7 (0.360 ppm), R. Murgut coded 2 (0.135 ppm) and R. Nyando-Ogilo coded 8 (0.107 ppm). Cobalt values were 1-3 times higher than FAO/WHO maximum limits of 0.1 ppm. These values were on average lower than the values obtained for sediment samples. Chromium was detected in some sites. However, in few areas where chromium was detected, mean concentrations were 1-3 times higher than FAO/WHO maximum limits of 0.05 ppm. The low level of chromium in water samples could mean that chromium related compounds are not used much in surrounding areas.

Table 5: Concentration of heavy metals (Pb, Cd, Cu, Zn, Mn, Co, Cr) in water -zone 2

| Site | Cd | Cu | Co | Pb | Cr | Mn | Zn |
|------|-------------|-------------|-------------|-------------|-------------|-------------|-------------|
| 12 | 0.004±0.003 | 0.031±0.003 | 0.156±0.014 | 0.600±0.005 | 0.012±0.001 | 0.044±0.004 | 0.130±0.003 |
| 5 | 0.040±0.007 | 0.026±0.007 | 0.246±0.009 | 0.560±0.007 | 0.111±0.031 | 0.040±0.004 | 0.114±0.006 |
| 13 | 0.011±0.007 | 0.025±0.004 | 0.141±0.013 | 0.560±0.007 | 0±0 | 0.035±0.016 | 0.114±0.006 |
| 8 | 0.028±0.003 | 0.035±0.007 | 0.213±0.021 | 0.520±0.012 | 0.002±0 | 0.135±0.018 | 0.123±0.003 |
| 11 | 0.023±0.012 | 0.037±0.01 | 0.188±0.022 | 0.540±0.009 | 0.013±0.001 | 0.063±0.021 | 0.119±0.003 |

Table 5 and figure 5 show a general decrease in the levels of cadmium and lead. The lead values were between 0.600 ppm at P. Parget and 0.52 ppm at R. Nyando (Ogilo). These values of lead were on average higher than those in zone 1 (Water). This means that there is accumulation towards the lake which is a bad indicator (Parget). The Cd values were between 0.004 ppm (R. Parget) and 0.040 ppm (Mbogo). These values were also higher than the levels in zone 1 (Water) and all the sediment samples.

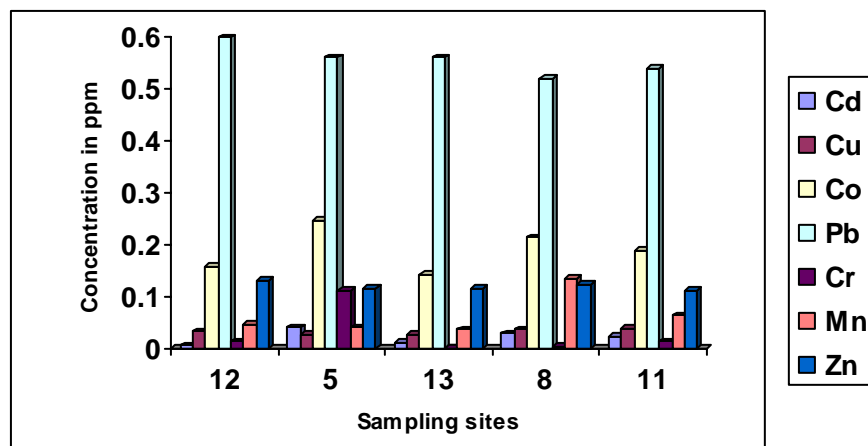


Figure 5: Concentration of heavy metals (Pb, Cd, Cu, Zn, Mn, Cr, Co) in water -zone 2

Chromium was not detected at R. Ainamutua coded as 13. However, other sites recorded concentrations between 0.002 ppm and 0.111 ppm. The highest value in the zone was twice the FAO/WHO maximum limits of 0.05 ppm. These values were, however; lower than the levels in the sediments sampled. This could be due to the fact that most chromium compounds are insoluble and therefore incorporated into sediments.

Cobalt had values between 0.141 ppm (R. Ainamutua) and 0.246 ppm (R. Mbogo), which were about twice the FAO/WHO maximum limits of 0.1 ppm. These values were, however, lower than those in sediments because of precipitation of cobalt compounds. The rest of the elements were very low in concentration. Thus, manganese, zinc, total nitrogen and total phosphorus were below the critical values defined as risk levels. The low levels of zinc in water in this zone could mean that the area is not exposed much to zinc compounds like municipal sewage and waste water pollutants, which are major sources of zinc in the environment. However, copper and zinc remained in very low amounts and their influence could be quite minimal.

Table 6: Comparison of levels pf heavy metals in water and sediments (zone 1)

| Site | Cu | Cd | Co | Pb | Mn | Zn | Cr |
|--------------------------|-------------|-------------|-------------|-------------|--------------|-------------|-------------|
| R.Masaita S (18) W (4) | 0.104±0.010 | 0±0 | 0.359±0.050 | 0±0 | 14.410±0.432 | 1.016±0.002 | 0±0 |
| | 0.018±0.009 | 0.038±.009 | 0.233±0.015 | 0.55±0.004 | 0.063±0.028 | 0.115±0.004 | 0.123±0.018 |
| Kedowa S9 W 9 | 0.650±0.014 | 0±0 | 0.655±0.031 | 0.405±0.110 | 4.700±0.50 | 1.987±0.012 | 1.291±0.015 |
| | 0.027±0.004 | 0.036±.005 | 0.230±0.017 | 0.55±0.006 | 0.068±0.015 | 0.124±0.002 | 0±0 |
| Murgut S19 (F.Tenan) W 2 | 0.273±0.005 | 0±0 | 0.416±0.031 | 0.045±0.019 | 10.44±0.055 | 0.955±0.002 | 0.284±0.011 |
| | 0.023±0.008 | 0.043±0.003 | 0.256±0.024 | 0.52±0.007 | 0.107±0.033 | 0.152±0.002 | 0.146±0.005 |
| R. Nyando S 15 (M-K) W6 | 0.488±0.088 | 0.002±0 | 0.671±0.062 | 0.165±0.019 | 11.1±0.366 | 1.046±0.002 | 0.993±0.013 |
| | 0.029±0.0 | 0.028±0.002 | 0.217±0.027 | 0.48±0.011 | 0.099±0.040 | 0.114±0.003 | 0.051±0.018 |
| R. Nyando S 6 IGD7W15 | 0.423±0.012 | 0±0 | 0.423±0.05 | 0.07±0.032 | 11.430±0.20 | 0.985±0.003 | 0.953±0.010 |
| | 0.023±0.005 | 0.018±0.003 | 0.109±0.011 | 0.47±0.004 | 0.007±0 | 0.113±0.002 | 0±0 |

There was a general decrease in the level of cobalt downstream in both zones 1 and 2. However, the levels of cobalt in sediments were still higher than in water. The high levels in sediments can be attributed to formation of cobalt compounds, which are insoluble, hence, precipitation takes place and the particles eventually get incorporated into sediments. The concentration of manganese fluctuated downstream, i.e., there was an increase followed by a decrease in both zones in water and sediments (tables 6 and 7). Surprisingly, the mean levels of manganese in sediments were very high as compared to all the other heavy metals analyzed. The lowest mean value was at R. Kedowa, which had a value of 4.7 ppm, while the highest value was at R. Mbogo with a mean concentration of 30.06 ppm. These values were much higher than the FAO/WHO maximum limits of 0.1 ppm.

Table 7: Comparison of levels of heavy metals (ppm) in water and sediments (zone 2)

| Site | Cu | Cd | Co | Pb | Mn | Zn | Cr |
|--------------|-------------|-------------|-------------|-------------|--------------|--------------|-------------|
| Parget S 4 | 0.441±0.010 | 0.004±0 | 0.647±0.068 | 0.210±0.092 | 11.420±0.75 | 0.992±0.004 | 2.473±0.032 |
| W 12 | 0.031±0.004 | 0.034±0.007 | 0.156±0.014 | 0.600±0.005 | 0.044±0.004 | 0.130±0.003 | 0.012±0.001 |
| Mbogo S13 | 0.090±0.009 | 0±0 | 0.371±0.025 | 0±0 | 30.06±0 | 1.372±0.0005 | 0±0 |
| Chemelil W 5 | 0.026±0.007 | 0.040±0.006 | 0.246±0.009 | 0.560±0.007 | 0.040±0.004 | 0.114±0.006 | 0.111±0.031 |
| AinamutuaS1 | 0.595±0.031 | 0±0 | 0.503±0.086 | 0.143±0.030 | 9.990±0.330 | 1.097±0.004 | 0.909±0.011 |
| W 13 | 0.025±0.007 | 0.011±0.007 | 0.141±0.013 | 0.560±0.007 | 0.035±0.016 | 0.114±0.006 | 0±0 |
| Nyando S 3 | 0.359±0.008 | 0±0 | 0.415±0.055 | 0.040±0.004 | 8.520±0.383 | 0.906±0.004 | 0.857±0.022 |
| (Ogilo) W 8 | 0.035±0.007 | 0.025±0.003 | 0.213±0.021 | 0.520±0.012 | 0.520±0.018 | 0.123±0.003 | 0.002±0 |
| Ahero S 20 | 0.215±0.013 | 0±0 | 0.416±0.043 | 0.260±0.046 | 20.440±0.224 | 1.241±0.007 | 0.088±0.008 |
| Channel W3 | 0.020±0.002 | 0.040±0.007 | 0.243±0.024 | 0.520±0.011 | 0.059±0.023 | 0.103±0.003 | 0.103±0.020 |
| Nyando S 5 | 0.354±0.006 | 0±0 | 0.457±0.070 | 0.01±0.0005 | 8.53±0.358 | 0.914±0.008 | 0.935±0.010 |
| A-K W 11 | 0.037±0.01 | 0.023±0.012 | 0.188±0.022 | 0.54±0.009 | 0.063±0.021 | 0.0119±0.003 | 0.013±0.001 |
| Tinderet S17 | 0.073±0.011 | 0±0 | 0.319±0.065 | 0±0 | 19.870.377 | 1.073±0.004 | 0.062±0.018 |
| Catch. W1 | 0.042±0.019 | 0.05±0.007 | 0.280±0.012 | 0.54±0.032 | 0.104±0.046 | 0.123±0.009 | 0.208±0.078 |

There was no clear trend in the mean concentration of zinc in both zones, because the values fluctuated by increasing and later on decreasing downstream. The levels were still higher in sediments than in water. The fluctuation of the levels can be attributed to dilution, while the high levels in sediments can be due to precipitation of zinc compounds, hence, incorporated into the sediments. Low values in water may also be as a result of few soluble zinc compounds. The concentrations in sediments were between 1.987 ppm at R. Kedowa and 0.906 ppm at R. Nyando- Ogilo. The values were below both the FAO/WHO and KEBS maximum limits of 5.0 ppm. Moderate levels for zinc can be attributed to its natural abundance in the environment, as it ranks fourth in abundance only surpassed by iron, aluminum and copper. Municipal sewage and waste water are other known sources of zinc. Water samples from Ahero irrigation channel reported a value of 0.103 ppm, while that from R. Murgut had the highest value of 0.152 ppm. The zinc levels were, therefore, low and do not pose any danger since it is required by mammals and the body contains twenty different zinc metal enzymes.

Chromium levels were higher in sediments than in water in most of the sampling sites in zones 1 and 2. However, few sites like R. Mbogo and R. Masaita did not record any detectable values, while Ahero irrigation channel reported a value of 0.088 ppm in water, contrary to the observations. R. Parget had the highest level of chromium, i.e., 2.473 ppm in sediments while R. Masaita and R. Mbogo, had no detectable chromium. The highest concentration of chromium in sediments was fifty times higher than the FAO/WHO

maximum limits of 0.05 ppm. Perhaps, the high level of chromium could be due to increased use of its related products such as fungicides, seed protectants and food preservatives in the surrounding areas.

Cadmium and lead were higher in water than in sediments in both zones (tables 11 and 12). The concentration of cadmium in water was lowest at R. Ainamutua, which had a mean value of 0.011 ppm and highest at R. Murgut, with a mean value of 0.043 ppm (tables 11 and 12). These values were mostly ten times higher than FAO/WHO maximum limits of 0.003 ppm. High levels of cadmium in water can be due to high levels of cadmium in the surrounding soils, since cadmium is a component of phosphate fertilizers and the phosphatic rock (WHO, 1998). In addition, high levels of cadmium in water can be attributed to the possible availability of cadmium related residues, and volcanic activities associated with landforms in the Rift Valley region (where most of the rivers have their sources). Other sources can be due to forest fires, which may lead to the release of cadmium related oxides in the environment. Metal particles enrichment from terrestrial vegetation, is a known source of cadmium (ILZS Group, 1983).

In general, water samples had higher cadmium levels than sediments. This is probably due to pH, temperature and the hardness of water in the area, which are not favorable for precipitation of cadmium. The mean values of lead decreased downstream and there was more lead in water than in sediments. This can also be due to pH and temperature variations of the rivers flowing in this area. It can also be because lead compounds formed are soluble and are, therefore, not precipitated and incorporated in sediments.

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