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Assessment of Heavy Metals in Rooftop dust around Lake Nakuru Basin, Kenya

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Abstract

Samples of sedimented dust on roofs from 34 locations within the Lake Nakuru Basin (LNB), Kenya were analyzed for their heavy metals content. The samples were analyzed for Pb, Ni, Zn, Fe and Cr. Statistical analyses were done using SPSS version 11.5 and Microsoft EXCEL spreadsheets. The result of the analysis showed that Iron (Fe) has the highest concentration level followed by Zn, Cr, and Pb with mean values of 0.2 ppm, 5.1 ppm, 16.1 ppm and 0.3 ppm respectively while the concentration of Ni was below the detection limit. The results of the analysis were used to determine spatial dispersal and scale of heavy metals pollution with respect to direction. The results of this study reveal that heavy metals distribution is not significantly different in the various directions of the LNB.

Keywords: Heavy metal; Sedimented dust; AAS; Lake Nakuru Basin; Pollution.

Introduction

The distribution of heavy metals in the soils is probably controlled by both geogenic and anthropogenic factors[1,2]. Human activities have drastically altered the biogeochemical cycles and balance of heavy metals in the environment. Where natural sources are dominated by parent rocks and metallic minerals, the principal man-made sources of heavy metals are agricultural activities, as fertilizers, animal manures, and pesticides containing heavy metals are widely used, industrial point sources (e.g., mines, foundries and smelters), diffuse sources such as combustion by-product[3], vehicle emissions[4], microelectronic products, and solid waste disposal[5]. Public electricity and heating plus residential sectors have also been found as major contributors towards the emission of heavy metals[6].

These anthropogenic activities have introduced contaminants in top soil from atmospheric deposition by sedimentation, impaction and interception. Soil particles are subsequently entrained into the atmosphere as dust[7]. Numerous studies of heavy metal contamination, of street dust have been carried out in developed countries[7-9], but only limited information is available on heavy metals in the street dust of developing countries, including Kenya.

Lead and a variety of other metals from automobile exhaust have been found to contaminate roadway and parking site dust sampled in Palermo, Italy[10] and Kayseri, Turkey[11]. Key heavy metals are thereby Pd from leaded gasoline (although this is reducing due to use of unleaded gasoline but accumulation from previous years is still evident), Cu, Zn and Cd from car components, tyre abrasion, lubricants and industrial and incinerator emissions[12,13]. Contamination of roadway topsoil material from which dust maybe generated by vehicular and wind action is particularly prevalent in developing countries, where most roads are un-surfaced and in some cases leaded gasoline has been in use[14].

Some heavy metals such as copper (Cu), zinc (Zn), iron (Fe), chromium (Cr), manganese (Mn) and nickel (Ni) though essential to human body, are toxic at elevated levels, whereas cadmium (Cd) and lead (Pb) are non-essential metals and are toxic even in trace amounts. Toxicity is highly aggravated by their non-degradability and tendency to bio-accumulate to toxic levels[15]. Heavy metal toxicity can result in lower energy levels and damage blood composition, lungs, liver, kidneys and other vital organs, damage or reduce mental and central nervous function or even cause cancer[16, 15, 17]. Heavy metal poisoning is more likely to result from inhalation, ingestion, skin contact with the metals or compounds from dust, fumes or materials from workplace, or in residential settings, especially homes with lead paints or old plumbing[18].

Material and Methods

The study area: The Lake Nakuru Basin (LNB) covers an area of 1,800 km². At the sump of this catchment basin is the insulated LNNP and Nakuru Town. The soil in the catchment area is of volcanic origin and therefore its high porosity, permeability and loose structure lead to erosion, land subsidence and fractures during or after heavy rain[19].

Depending on altitude and topography, the Lake Nakuru basin suffers considerable variations in climate. The mean maximum and minimum temperature varies between 10°C – 29°C. The

climate ranges from cold and humid to arid and semi-arid. Mean annual rainfall is approximately 1000 mm with peaks in the months of November to December and April to May[20].

There are various pollution sources in the Lake Nakuru catchment such as organic pollution from domestic, livestock, industry and agricultural areas; heavy metal and other chemical pollution from industries and dumping sites; and agricultural chemical and pesticide pollution from agricultural areas.

The ever-increasing human population, poor enforcement of environmental regulations and unsustainable exploitation of natural resources has gradually caused conflict between humans and natural resources. Denaturation and degradation of forestlands, clearing of riverbanks, poor land use planning and urban development and the prevalence of poverty around the Lake Nakuru National Park has given rise to the conflict between the catchment's natural resources and the human population[19].

Sampling and analytical procedures: Atmospherically deposited dust samples were collected from differing environments during the dry season when there was no precipitation. Systematic random sampling was carried out and samples for each location was obtained from the rooftops on an area of $1m^2$ using polyethylene brush and a tray and kept in a clean self-sealing plastic bag. A total 34 samples were collected in triplicate in all directions from the lake where we have buildings. The sampling locations within the LNB are indicated in figure-1. The locations were numbered randomly and with the aid of GPRS coordinate using Google maps and Scribble maps.

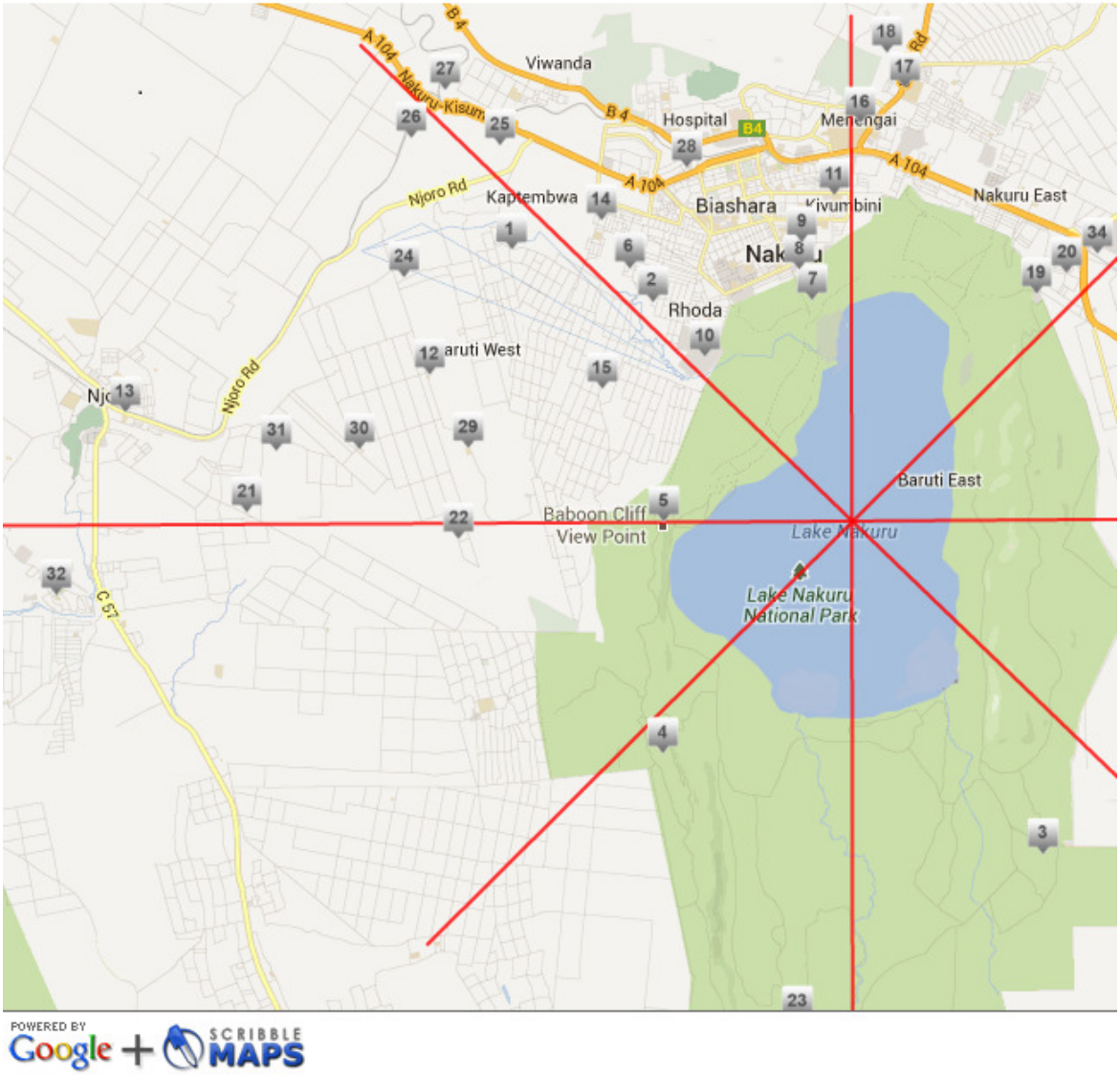

Figure-1
The sampling locations within the LNB

Into 350 mL of 30% H_2O_2, 0.42g of selenium powder and 14g of lithium sulphate were added and the contents mixed well. With care, 420mL of concentrated H_2SO_4 were added while cooling the mixture in cold water. The mixture was stored in the fridge which made it stable for up to four weeks[21].

For each sample, 0.30 ± 0.01g was weighed into a labeled digestion tube and 5 mL of the digestion mixture was added. This was digested at about 360 °C for 2 hrs in a kjeldahl flask. The solutions were expected to be colorless and any remaining sand to be white. For those that was still colored, further heating for one hour was done. The contents were allowed to cool after which 25 mL of distilled water was added and mixed well until no more sediments could dissolve. These were again allowed to cool and made-up to 100 mL with distilled water. Using Whatmann No.4 filter papers, filtering was done into well labeled containers and the samples were now ready to be run in Atomic Absorption Spectrophotometer. A reagent blank was prepared in a 100 mL volumetric flask by using all the other reagents except the samples by following the same procedure[22].

The instrument parameters were set as per the manufacturer's operation manual recommendations for each metal. However the burner height and fuel (acetylene for all the other metals but nitrous oxide for Cr) flow rate were optimized to obtain a maximum absorbance reading with the middle standard for each of the metals. Calibration standards of appropriate concentrations for each metal were prepared by serial dilutions from 1000 ppm stock solutions. The following standards were used to get a calibration curves for Pb, Ni, Zn, Fe and Cr, Zn – 2, 4, 6, 8 and 10mg/L, Fe – 1, 2, 3, 4 and 5 mg/L, Cr – 1, 2, 3, 4, 5, 6, 7, 8, 9 and 10mg/L, Pb – 0.5, 1, 2, 3 and 4 mg/L, Ni – 3, 4, 5, 7.5 and 10 mg/L

A reagent blank was used to zero the instrument reading for the respective samples. Absorbance readings were taken at 213.9 nm for Zn, 248.3 nm for Fe, 357.9 nm for Cr, 283.3 nm for Pb and 232 nm for Ni. Calibration curves were obtained and used to determine the sample concentrations of the heavy metals in the sample extracts.

The equations of the calibration curves of the metals are indicated in Table 1. All the curves gave regressions more than 0.9, an indication of the reliability of the curves.

Results and Discussion

The descriptive statistic results of heavy metal concentrations investigated in the studied samples are shown in table-2.

Table-1
Calibration curves for metals

Metal	Equation	R^2
Lead	y = 0.0076x	0.9837
Nickel	y = 0.0011x	0.9928
Zinc	y = 0.0147x	0.9589
Iron	y = 0.0014x	0.9632
Chromium	y = 0.0013x	0.9884

The maximum recorded levels were 0.6, 20.2, 23.3, and 0.7 mg/L for Pb, Zn, Fe and Cr respectively while the concentration of nickel in all the samples was below the detection limit. The high concentrations of Zn and Fe suggests that metal roofs either galvanized iron or anodized aluminum act as a more potential source of these in the deposited dust. This observation agrees with the reports of Gadd and Kennedy who suggested that galvanized metal roofs contribute more zinc and iron in roof run-off[23]. The concentration of Pb and Cr was attributed to the pollution originated from traffic and anthropogenic sources[24, 25]. This may originate from traffic sources, such as wear, tear of vulcanized vehicle, tires, the corrosion of metallic parts in scrap yards, lubricants and exhaust emissions from both gasoline and diesel fuelled road vehicles[26-29].

The concentrations of the heavy metals according to directions are shown in figure-2.

Concentration of heavy metals with direction: In all samples, the abundances of Fe (12.3-21.7 ppm), Zn (1.3-20.2 ppm), Pb (0.1-0.6 ppm) and Cr (0.0-1.3 ppm). These results do not show significant differences between samples in the four directions except for Zn whose concentration to the north and western direction is higher than in the other sampled directions. The variation in concentration may be mainly due to compositional differences of rooftops and environmental condition[30].The wind direction during the sampling period obtained from the Kenya Meteorological Department was towards the north and northwest of the basin and the high concentrations of Zn in these directions could be indicative that wind could be carrying and dispersing the heavy metals.

Table-2
Heavy metal concentrations

Metal	Lead	Nickel	Zinc	Iron	Chromium
Average±SD	0.2±0.1	BDL	5.5±5.7	16.1±2.5	0.3±0.4

*SD = Standard deviation *Belowdetectable limit

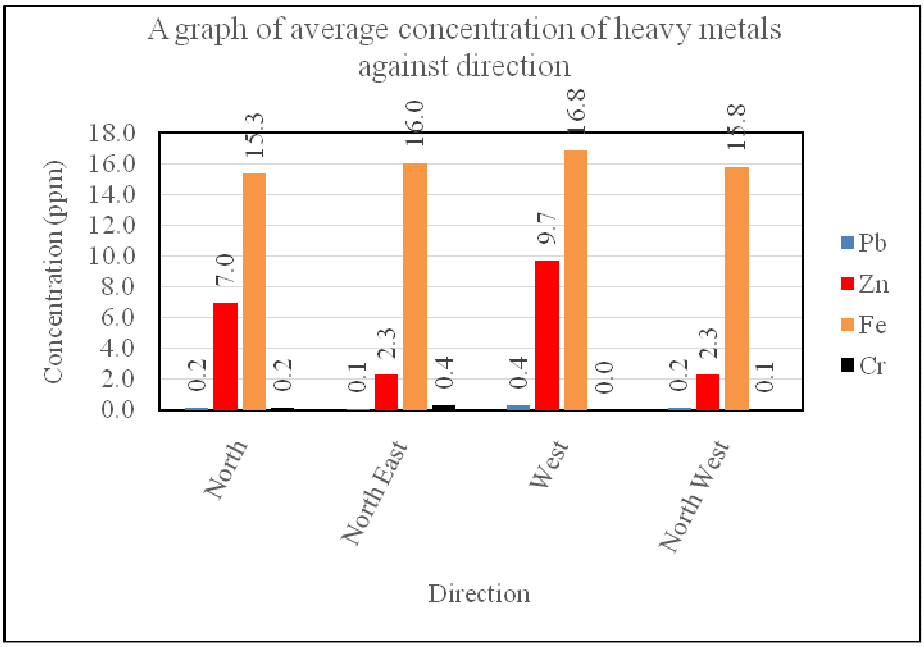

Figure-2
Concentration of heavy metals with direction

Conclusion

This is the first pollution study of rooftop dust in LNB and in the whole adjacent region. The present results suggest that the concentration of, Fe, Zn, Pb, Cr, and Ni in rooftop dusts in LNB are not at an alarming levels. However this may change with the rapid development, increase in vehicle emissions and the lack of sophisticated management of wastes and effluents from industries and other activities. Therefore, management programs such as planned reduction of Pb and other metal contents from fuel, improved treatment techniques for the wastes and effluents of different activities should be implemented by government to minimize the environment pollution in LNB. Such action would also improve air quality in the city.

Little attention has been paid to other trace elements, such as Cd, therefore, its ecological and health implications need further detailed investigations.

The rain water collected for use by the people within the LNB need to be assessed so as to ascertain whether the heavy metals found in the suspended particles do end up in the rain water at levels above the recommended limits.

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