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Evaluation of Elemental Pollution in Roadside Dust Northeast of Nairobi Major Highway and at Thika Town, Kenya

E. G. Maina[1*], A. N. Gachanja[1] and M. J. Gatari[2]

[1]Department of Chemistry, Jomo Kenyatta University of Agriculture and Technology, P.O.Box 62000 – 00200, Nairobi, Kenya.
[2]Institute of Nuclear Science and Technology, College of Architecture and Engineering, University of Nairobi, P.O.Box 30197, G.P.O., Nairobi, Kenya.

Authors' contributions

This work was carried out in collaboration between all authors. Author EGM designed the study, performed the statistical analysis, wrote the protocol and wrote the first draft of the manuscript. Authors ANG and MJG managed the analyses of the study. Author EGM managed the literature searches. All authors read and approved the final manuscript.

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ABSTRACT

Aims: To evaluate the level of elemental pollution in roadside dust.
Study Design: Dust samples were collected along Thika highway at Roysambu and at Thika town.
Place and Duration of Study: Department of chemistry, government of Kenya laboratories, from July to December 2016.
Methodology: Dust samples were collected at Roysambu bus terminal along Thika highway and at Kwame Nkruma road in Thika town. The samples were prepared for analysis according to USEPA method 3050B and analysis of Al, B, Na, Mn, Cr, Cu, Pb, Co, Mg, Fe, Ni, Ca and Zn in the samples was carried out using an inductively coupled plasma optical emission spectrophotometer. The results obtained showed that there was moderate pollution by Pb and Mn, while the samples were

**Corresponding author: E-mail: gachuie2@gmail.com;*

extremely polluted by B as computed using the index of geoaccumulation. Metals Cr, Mn, Pd and Zn were in levels similar to those reported around the world.
Conclusion: These results showed that roadsides along the highway are more polluted than those inside the town, which is probably due to the high vehicular number. In addition, heavy metals may pose a health hazard to people exposed to roadside dust, which is not in line with the sustainable development goals (SDGs) 3 and 11.

Keywords: Metals; pollution; roadside; inductively coupled plasma optical emission spectrophotometer; health; geoaccumulation.

1. INTRODUCTION

Air pollution remains a major challenge in Africa where about 600,000 deaths every year are attributed to air pollution. WHO estimates that air pollution is responsible for 7 million deaths every year with about 23 percent of global deaths are linked to environmental factors [1].

According to the World Health Organization, air pollution levels in global urban areas have increased between 2008 and 2013. This is expected to rise given the increasing level of migration of people to urban areas, which may likely lead to more human activities and pollution. More than 80 percent of people living in urban areas are exposed to air quality levels that exceed WHO limits which is a danger to health and life.

The unprecedented growth in vehicular number because of increasing population in growing cities has contributed to the growing problems of air quality throughout Africa and developing countries [2,3].

Due to the high population density and intensive anthropogenic activities in urban areas, there may be a great number of heavy metals sources in cities, posing a risk to human health [4]. Heavy metals may originate from domestic waste, chemical industry and transportation. These metals may remain in urban soils for many years even after the pollution sources have been removed. Therefore, it is irrefutable that heavy metal concentrations in roadside dust and soils are important environmental issue [5,6,7]. Urban traffic is one of the major sources for urban dust and soil pollution. Roadside dust and soils tend to be reservoir for pollutants from vehicle emissions, which could affect pedestrians and people residing within the vicinity of the roads either by suspended dust or by direct contact [8].

According to Yu et al. [9], stainless steel and alloy steel contain Fe, Cr, Co, Al and Cu, in addition, exhaust emission from petrol and diesel powered vehicles contain variable quantities of these elements.

Zn, Pb, Cr and Ni tend to originate from vehicular activities like tyre wear, wear of brake linings. In addition, studded tyres may be the sources of Ni, Mo, Co, Cd, Ti and Cu. These metals may also be put into the environment by corrosion of bushings, brake wires and radiators.

Iron fillings from metal works, exhaust emissions from vehicles, oil spillage of petrol and diesel, wastes from car batteries, engine oil and lubricating oils, coupled with rusting of non-coated metals have all been reported to contribute Fe, Zn, Pb, Cu, Cr, As, Cd and Ni [10].

In this study, the research area is located on one of the busiest highways in Kenya. In addition, residential houses are located close to the highway as well as shopping 'kiosks'. Since there is no data available on roadside dust pollution by heavy metals in Kenya, this study was developed as a pilot study preceding the major research.

2. MATERIALS AND METHODS

2.1 Study Area

Roysambu is a populated constituency located in northeast of Nairobi at latitude 1° 12' 00" S, longitude 36° 53' 00" E (Fig. 1). It covers five county assembly wards (Githurai, Kahawa west, Zimmerman, Roysambu and Kahawa). The area is 48.80 Km^2, and has a population of 202,284 people [11].

The sampling site which is located along Thika highway offers an excellent area for the study of elemental pollution in roadway dust due to its high vehicular traffic and presence of high commercial activity just besides the road. The second site is Thika town which is one of the busiest towns in Kenya. It is connected to Nairobi by Thika highway (the busiest highway in Kenya).

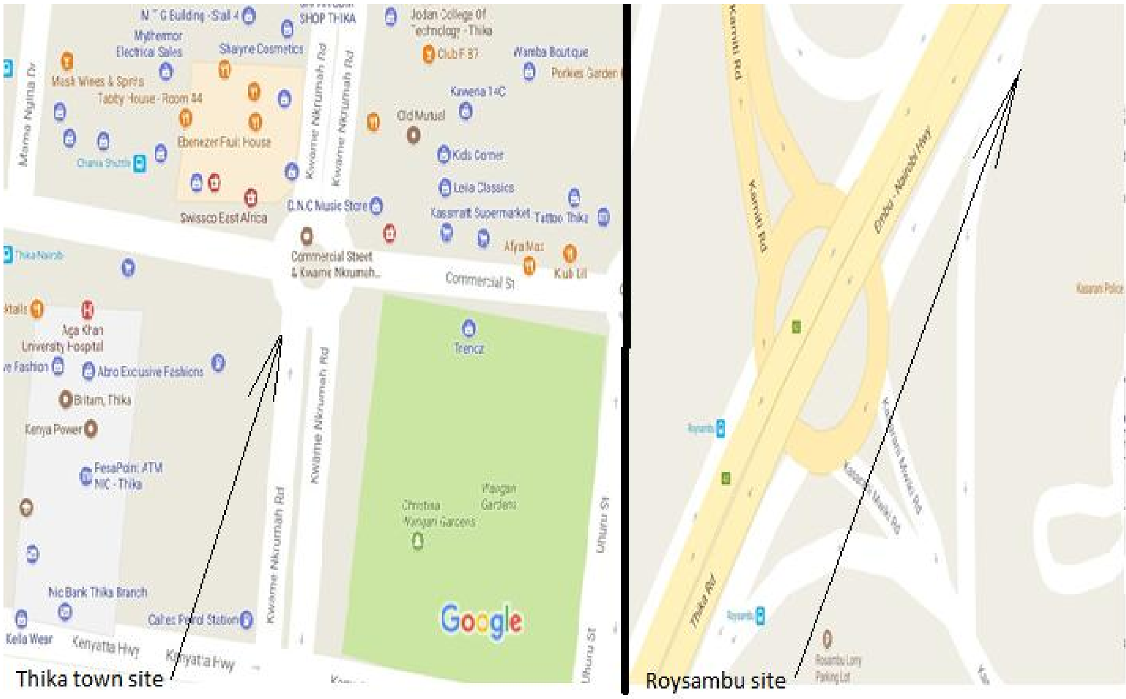

Fig. 1. Map showing Roysambu sampling site and Kwame Nkrumah road sampling site in Thika town

(Source: Google maps)

2.2 Dust Sampling and Preparation

Sampling was done at two sites; one at the bus terminals along Thika road i.e Roysambu at Kasarani coordinates 36°53'33.73"E and 1°13'5.33"S and at Kwame Nkrumah road in Thika town at coordinates 37° 4'27.86"E and 1° 2'12.78"S (Fig. 1). On each sampling site, about 300 g dust composite sample composed of 3 sub-dust samples was collected on the pavement by sweeping using a clean plastic brush and dustpan [12], during July of 2016. The dust samples were air-dried in open air in the laboratory at room temperature and sieved through 125 µm stainless steel mesh wire [13]. 1 g of the sample was weighed to the nearest 0.001 g and transferred to a round bottomed flask and digested according to SW 846 Method 3050B [14].

2.3 Analytical Procedures

An Agilent 720 ICP-OES was employed for the analysis of trace and other elements. To determine the concentration of the samples, a windows 7 compatible software provided by Agilent was also used to process the spectral data and compare the light intensities measured at various wavelengths for standard solutions with intensities from the sample solutions. Instrumental parameters used in the analysis are depicted in Table 1.

2.4 Contamination Assessment by Index of Geoaccumulation

The index of geoaccumulation index (I_{geo}) was selected for this study. It was originally used with bottom sediment by Muller in 1969 [15]. The following equation is used for its computation;

$$I_{geo} = \log_2 \left(\frac{Cn}{1.5\ Bn}\right)$$

Where, C_n is the measured concentration of the element in the road dust and B_n is the geochemical background value of the element in continental crusted average or average shale metal [16,17]. The constant 1.5 is introduced to minimize the effect of probable variations in the background values which may be due to lithologic variations in the sediments [12].

Table 1. ICP-OES instrument operating parameters

Condition	Setting
Power (Kw)	1.20
Plasma gas flow (L/min)	18.0
Auxiliary gas flow (L/min)	1.5
Spray chamber type	Glass single-pass cyclone
Torch	Standard one-piece quartz axial
Nebulizer type	Sea spray
Nebulizer flow (L/min)	2.7
Pump speed (rpm)	0 – 50
Total sample usage (ml)	1
Replicate read time (s)	5
Number of replicates	3
Sample uptake delay time (s)	75
Stabilization time (s)	60
Rinse time (s)	20
Fast pump	Off
Back ground correction	Fitted

3. RESULTS AND DISCUSSION

3.1 Metals in Road Side Dust

Table 2 summarizes the average metal concentrations (Al, Na, B, Mg, Mn, Fe, Co, Cu, Ni, Zn, Ca, S, Cr and Pb) on the selected sampling sites. All the metals of interest were found in the collected sample. The metals concentration ranged from 11.52 µg/g to 35948.94 µg/g. The increasing metals concentration is Co < Ni < Cr < Cu < Pb < Zn < S < B < Mg < Al < Na < Mn < Ca < Fe. It is evident that heavy metals are the least in concentration while the essential elements (metals) are the most.

It has been reported by [18] and [12] that sources of toxic (heavy) metals in road side dust and soil may originate from industrial activities and automotive emissions. A close look at the results in Table 2 reveals that Roysambu site is more polluted by most elements than Thika town. This could be attributed to a high vehicle volume at Roysambu (19771 vehicles) than at Thika town sampling site (2449 vehicles) which was recorded during the sampling day.

3.2 Index of Geoaccumulation

The interpretation for the geoaccumulation index is: $I_{geo} < 0$ means practically unpolluted; $0 < I_{geo} < 1$ menas unpolluted to moderated polluted; $1 < I_{geo} < 2$ means moderately polluted, $2 < I_{geo} < 3$ means moderately to strongly polluted;$3 < I_{geo} < 4$ means strongly polluted;$4 < I_{geo} < 5$ means strongly to extremely polluted; and $I_{geo} > 5$ means extremely polluted.

Table 2 shows that Cu, Al, Na, Mg, Fe, Co, Ca, Ni, Cr and Zn are below 1, and thus the roadside dust was practically unpolluted. On the other hand, Pb and Mn had Igeo value of 1.83 and 1.82 respectively indicating moderate pollution. In addition, boron had Igeo value of 5.24 an indication of extreme pollution of roadside dust. Inhalation of boron may result to infertility in men. In high levels, it may affect the central nervous system, kidneys and liver and in extreme cases may result in death [19].

Table 3 compares the concentration of the most prominent metals as reported around the world to road side dust in this study. As evident in the Table 3, there is little data available Cr and Mn in roadside dust. Cr concentration in the current study was similar to Luanda, while Mn was 10 times higher (5026.72 µg/g) compared to the other cities. Copper concentration in the current study was found to be 33.23 µg/g and 28.15 µg/g which were lower than all the other cities in the Table 3, but was slightly closer to Luanda which had concentration of 42 µg/g.

On the other hand, Nickel was found to be 12.30 µg/g and 15.00 µg/g for Roysambu and Thika respectively in the present study. This was above Luanda (10 µg/g) but below Amman which had 88 µg/g. The lead concentration was slightly high at 66.46 µg/g and 49.79 µg/g which were higher than for Ketu-south (22.89 µg/g), while Shanghai had the highest lead concentration at 294.9 µg/g. The zinc concentration in the present study was found to be 187.20 µg/g and 169.54 µg/g which were higher than Islamabad, Dhaka and Ketu-south, but below Hong Kong at 3840 µg/g.

Table 2. Average metal concentrations and Igeo

Metals	Roysambu			Thika		
	Concentration	Standard deviation	Igeo	Concentration	Standard deviation	Igeo
Al	26675.04	1099	-2.21	23859.34	988	-2.37
Na	2904.82	710	-3.61	2809.42	649	-3.66
B	568.95	57	5.25	1401.31	65	6.55
Mg	1462.92	143	-4.58	1442.44	96	-4.60
Mn	5026.72	745	1.82	3357.73	364	1.24
Fe	35948.94	9285	-1.23	35682.03	9115	-1.24
Co	11.52	1	-1.70	11.42	1	-1.72
Cu	33.23	2	-1.31	28.15	2	-1.55
Ni	12.3	2	-3.19	15.00	1	-2.91
Zn	187.2	0	0.83	169.54	0.4	0.69
Ca	9174.99	917	-2.76	13705.20	997	-2.18
S	219.87	29	-0.83	410.17	43	0.07
Cr	27.37	1	-2.45	46.03	2	-1.70
Pb	66.46	4	1.83	49.79	2	1.41

Table 3. Metal concentrations compared to other places in the world

City	Cr	Cu	Mn	Ni	Pb	Zn	Reference
Hong Kong	-	110	594	28.6	120	3840	[20]
Shanghai	159.3	196.8	-	83.9	294.9	733.8	[21]
Ketu-south District	744.02	60.53	564.42	73.45	22.89	133.52	[18]
Luanda	26	42	-	10	315	317	[22]
Amman	-	177	-	88	236	358	[23]
Dhaka	-	304	-	54	205	169	[24]
Islamabad	-	52	-	23	104	116	[25]
Roysambu, Thika highway	27.37	33.23	5026.72	12.30	66.46	187.20	The current study
Thika town	46.03	28.15	3357.73	15.00	49.79	169.54	

4. CONCLUSION

This study shows that there is pollution by boron, manganese, zinc and lead, as demonstrated by the index of geoaccumulation. A closer look at the comparative metal concentration to the cities around the world, it is evident that there is pollution by Cr, Mn, Pd, Zn and non-metals sulphur and boron. Contamination of roadside dust by these metals results to consequent contamination of foodstuffs which are sold at roadside ‘kiosks’ [10]. In addition, there is possible direct inhalation of this contaminated dust by vendors and persons who spend about 12 hours at the roadside. People residing in buildings close to highways (24 hours exposure) are in danger of health problems since re-suspended contaminated roadside dust can travel up to about 50 meters from the source [26]. These people both children and adults are at high risk of experiencing respiratory health problems and brain damage for children [27].

In conclusion, the results obtained from this study show the need for further studies of heavy metal pollution on major roads in this area and other similar ones as well as the possible health implications heavy metals cause to the people who spend most of their time highways.

COMPETING INTERESTS

Authors have declared that no competing interests exist.

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