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Toxic Heavy Metals in Ambient Air of Kinshasa, Democratic Republic Congo

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Abstract

The particularly high rate of urbanization in Kinshasa is associated with environmental degradation, such as air pollution. However, little documented information exists on the nature and extent of this pollution. In the present study, Atmospheric samples of ambient air were collected in Kinshasa for 4 months (July to October, 2009) and analyzed for As, Cd, Pb and Ni using ICP - MS. The ranges of heavy metal concentrations for the 24-h ambient air samples in roadside sites (residential sites) were 0.9-6.0 ng/m^3 (0.4-2.8 ng/m^3), 2.5-5.9 ng/m^3 (1.2-3.5 ng/m^3), 166.2-1422.5 ng/m^3 (72.0-1685.0 ng/m^3), 48.7-482.0 ng/m^3 (42.0-117.6 ng/m^3) for As, Cd, Pb and Ni, respectively. Current 24-h average levels of all of them show higher levels than those measured in Europe. Toxicologically relevant elements reach levels of public health concern. The Efforts should be made to reduce the levels of metal contamination.

Keywords: Ambient air; Heavy metals; Air pollution; Public health; Kinshasa

Introduction

Heavy metals are ubiquitous in the environment. Their presence occurs in both natural and anthropogenic forms. While usually natural forms are present at relative low concentrations, in recent years a number of anthropogenic sources such as dumping of waste, smelter stacks, waste incineration, vehicle exhausts, fertilizers, agricultural waste, and sewage sludges have implied notable contributions to the increase of environmental metal concentrations [1-4].

With the development of mining, smelting and other industrial activities, heavy metals are increasingly being found in the environment which can pose severe threats to human and environmental health. Pollution by heavy metals such as arsenic (As), cadmium (Cd), lead (Pb) affects the quality of the atmosphere and the soil as well as water bodies and threatens the health and life of animals and human beings by way of the food chain [5-9].

Developing countries are confronted with the great challenge of controlling the atmospheric pollution, especially in the rapidly growing megacities. Concern about air pollution in urban regions is receiving increasingly importance worldwide, especially pollution by trace metals.

The Democratic Republic of Congo (DRC) is particularly rich in natural resources and eastern provinces (Katanga and Kivu) have been the center of extensive mining exploitation. Bas-Congo, close to Kinshasa, also contains a wide variety of mineral species. But, Kinshasa is not considered to be a mining zone. The demography in Kinshasa, the largest city in DRC, has exploded in the recent years [10]. The congested traffic with the widespread use of motorbikes as well as old automobiles coupled with poor maintenance, inadequate infrastructure, and low fuel quality is an important source of outdoor pollution. Wood, charcoal, crop, residual oil, and waste residues combustion for heating and cooking in open fires or poorly functioning stoves are the main source of indoor air pollution [11,12].

Through a study carried out to assess the exposure to trace elements in urine of the Kinshasa population, [13] showed elevated levels of Al, As, Cd, Pb and Hg as compared to other databases. But little documented information exists concerning different sources of trace element exposures in Kinshasa. The present study originated from that observation and its main objective was to investigate background levels of As, Cd, Pb and Ni in ambient air samples from Kinshasa.

Materials and Methods

Description of locations and sample collection in Kinshasa

Kinshasa, the capital city of DRC, is located in the west of the country with an area of 9,965 km². The city is split into 4 districts with more than ten million of residents. Kinshasa has a tropical climate with two seasons: rainy and dry. The dry season extends from 15 May to 15 August. The rainy season can be taken the remaining period.

An air sample is taken over a 24-hour period, every six days from each of three following sites: roadside sites, residential sites and sub-rural sites. Sample sites are given in Figure 1.

Sample collection was done using a high volume sampler on quartz fibre filter according to Australian Standard AS 3580.9.6-1990 Method [14]. All samples were transported in a box to be analyzed at the Louvain Centre for Toxicology and Applied Pharmacology (LTAP, Brussels, Belgium). The samples were mineralized in a microwave preparation system (A Paar Multiwave V3.20.5): each filter was digested with 5 ml of nitric acid (65% Suprapur, E. Merck, Darmstadt, Germany) in Teflon vessel for 0.3 min (A paar Multiwave V 3.20.5). After digestion, solutions were filtered and made up to 25 ml with nanopur water. Laboratory blanks were prepared by using nitrocellulose filters and treating it in the same way as the samples.

Element analysis

Four elements (As, Cd, Pb and Ni) were quantified by inductively coupled argon plasma mass spectrometry (ICP-MS Agilent 7500 CE). Briefly, 0.50 mL sample was diluted with 4.50 mL of diluent (1% v/v HNO_3, 0.5% v/v HCl and 50 ppb Sc, Ge, Rh, and Ir as internal standards (IS)). Matrix-matched calibrators were prepared by adding 0.05 mL of a calibration standard into 0.45 mL of acid (1% v/v HNO_3 and 0.5% v/v HCl) and 4.5 mL of diluent. Both acids, HCl and HNO_3, were of

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suprapur quality and were purchased from Merck (ref 1.00318.1000 and 1.00441.1000). Among the four elements measured by ICP-MS, Cd (m/z 111) and Pb (m/z 208),) were analyzed using the standard mode without using the collision cell. The remaining elements, Ni (m/z 60) and As (m/z 75) were analyzed using helium as collision gas. The limits of detection (LOD) were 0.6 ng/m^3, 0.1 ng/m^3, 0.3 ng/m^3 and 2.3 ng/m^3 for As, Cd, Pb and Ni respectively. The method used for the determination of 4 heavy metals in the present study is ISO15189 certified.

Statistical analysis

The SAS software package, version 9.2 (SAS Institute Inc., Cary, NC) was used for database management and statistical analysis. Median values, minimum and maximum were calculated as well as 25th and 75th quartiles. Values below the LOD were assigned a value at half the LOD. WILCOXON Test was used for comparing different groups. Significant differences were considered at an alpha of 0.05.

Results and Discussion

Assessment of the concentrations of ambient air heavy metals was determined at five locations in Kinshasa, DRC from July to October, 2009. The eight sampling location were selected to reflect the influences from urban, sub-rural, residential, heavy traffic sources in the highly populated greater Kinshasa area. The description of the sampling sites is shown in Figure 1. The concentrations of measured elements are given in Tables 1-3 and varied between urban, sub-rural, roadside and residential sites.

Arsenic

As is released into the atmosphere from both natural and anthropogenic sources. Most man-made emissions are released from metal smelters and the combustion of fuels. Pesticides may be an important source of As. Tobacco smoke may contain As, thereby being a source of exposure in ambient air [15,16]. In the present study, 24-h level of As ranged from 0.90 to 6.0 ng/m^3 in roadside sites and 0.4 to 2.8 ng/m^3 in residential sites. The 24-h median average observed in roadside sites was higher than that found in residential sites (4.0 ng/m^3 vs. 0.9 ng/m^3; $p<0.01$) (Table 4).

No significant difference was found between urban and sub-rural areas (0 for sub-rural area, Median level: 1.5 ng/m^3 vs. 1 for urban area, Median level: 4.0 ng/m^3; $p=0.77$) (Table 5).

Living in Kinshasa is associated with elevated levels of As in ambient air as compared to databases from literature: In Europe, measured 24-h average As concentrations in air of different regions ranged from 0.09 to 2.5 ng/m^3 with 0.6 ng/m^3 as an average [17].

Cadmium

Cd is released into the atmosphere from natural and anthropogenic sources. Volcanoes, windborne particles and biogenic emissions are considered the main natural sources of Cd in the atmosphere. The anthropogenic sources of Cd include non-ferrous metal production, stationary fossil fuel combustion, waste incineration, iron and steel production and cement production [15].

In the present study, 24-h level of Cd ranged from 2.5 to 5.9 ng/m^3 in roadside sites and 1.2 to 3.5 ng/m^3 in residential sites. The 24-h median average observed in roadside sites was higher than that found in residential sites (3.7 ng/m^3 vs. 2.6 ng/m^3; $p=0.02$) (Table 4).

No significant difference was found between urban and sub-rural areas (0 for sub-rural area, Median level: 2.0 ng/m^3 vs. 1 for urban area, Median level: 3.7 ng/m^3; $p=0.25$) (Table 5).

Living in Kinshasa is associated with elevated levels of Cd in ambient air as compared to databases from literature: In Europe, measured 24-h average Cd concentrations in air of different regions ranged from 0.03 to 1.0 ng/m^3 with 0.17 ng/m^3 as an average [17].

The background concentrations of cadmium in air measured in Europe in 1990 ranged between 0.2 and 1 ng/m^3. In 2003, the typical ranges for concentration in air were 0.05–0.2 ng/m^3 in Northern Europe, 0.2–0.5 ng/m^3 in central Europe and 0.06–0.12 ng/m^3 in southern Europe [18].

Lead

Pb is released into the atmosphere from natural and anthropogenic sources. Natural emissions typically include soil dust and sea spray containing Pb, as well as particles found in ashes from volcanoes and forest fires. These emissions are not entirely natural but contain some

Element	Min	Q1	Med	Q3	Max
As	0.9	2.1	4.0	5.0	6.0
Cd	2.5	2.9	3.7	4.9	5.9
Ni	48.7	59.4	73.6	186.5	482.0
Pb	166.2	234.4	358.3	893.7	1422.5

Min: minimum, Q1: 25th quartile, Med: median, Q3: 75th quartile and max: maximum

Table 1: Concentrations of heavy metals (µg/m^3) in urban ambient air of Kinshasa (Roadside sites).

Elements	Min	Q1	Med	Q3	Max
As	0.4	0.5	0.9	1.9	2.8
Cd	1.2	1.4	2.6	3.0	3.5
Ni	42.8	71.5	76.2	79.9	117.6
Pb	72.0	448.5	798.5	1367.5	1685.0

Min: minimum, Q1: 25th quartile, Med: median, Q3: 75th quartile and max: maximum

Table 2: Concentrations of heavy metals (µg/m^3) in urban ambient air of Kinshasa (Residential sites).

Elements	Min	Q1	Med	Q3	Max
As	1.0	1.0	1.5	2.0	2.0
Cd	0.2	0.2	2.0	8.0	8.0
Ni	57.0	57.0	61.0	62.0	62.0
Pb	40.0	40.0	62.0	76.0	76.0

Min: minimum, Q1: 25th quartile, Med: median, Q3: 75th quartile and max: maximum

Table 3: Concentrations of heavy metals (µg/m^3) in sub-rural ambient air of Kinshasa.

Elements	Roadside sites (Median levels, ng/m^3)	Residential sites (Median levels, ng/m^3)	p^a
As	4.0	0.9	<0.01
Cd	3.7	2.6	0.02
Ni	73.6	76.2	0.44
Pb	358.3	798.5	0.40

^{a}p-value (WILCOXON Test)

Table 4: Comparison of heavy metal levels between Roadside and Residential sites.

Elements	Urban area (Median levels, ng/m^3)	Sub-rural area (Median levels, ng/m^3)	p^a
As	4.0	1.5	0.77
Cd	3.7	2.0	0.25
Ni	73.6	46.0	0.09
Pb	358.3	62.0	< 0.01

^{a}p-value (WILCOXON Test)

Table 5: Comparison of heavy metal levels between sub-rural and urban areas.

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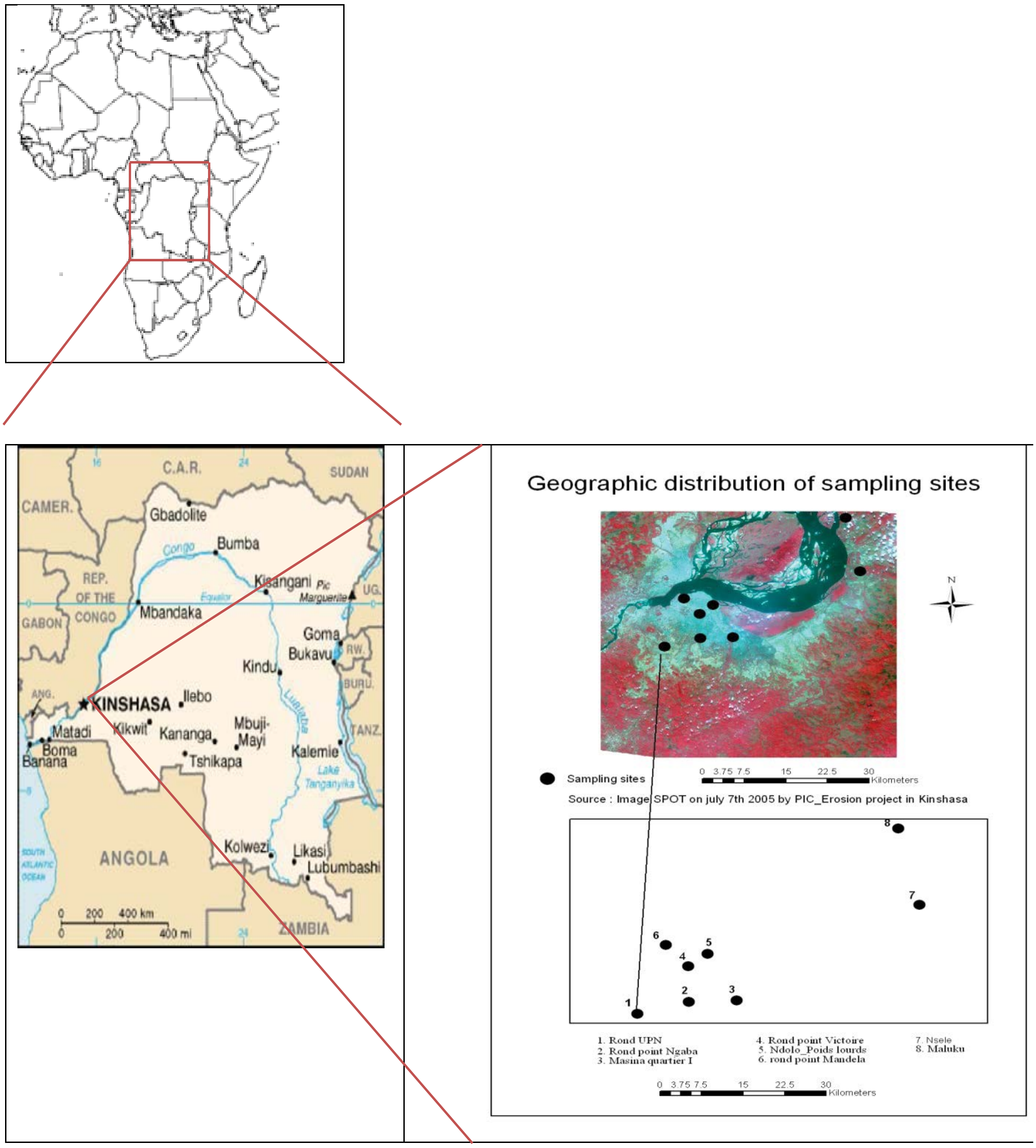

Figure 1: Maps of Africa (left above), the Democratic Republic of Congo (left under) and the Kinshasa City (right). The study took place in urban and sub=rural areas. Source: Adapted from Kinshasa. Wikipédia, l'encyclopédie libre. http://fr.wikipedia.org/w/index.php?title=Kinshasa&oldid=54218607.

deposits of anthropogenic Pb. Major anthropogenic emission sources of Pb on a global scale include the combustion of fossil fuels from, for example, traffic, waste disposal and production of non-ferrous metals, iron, steel and cement. The contribution to emissions from Pb in gasoline has been no longer eliminated in Kinshasa. This followed a complete phase-out through legislation and complete take-up of unleaded gasoline [15].

In the present study, 24-h level of Pb ranged from 166.2 to 1,422.5 ng/m^3 in roadside sites and 72.0 to 1,685.0 ng/m^3 in residential sites. The 24-h median average observed in roadside sites was lesser than that found in residential sites (358.3 ng/m^3 vs. 798.5 ng/m^3; p=0.40) (Table 4).

Significant difference was found between urban and sub-rural areas (0 for sub-rural area, Median level: 62.0 ng/m^3 vs. 1 for urban area, Median level: 358.3 ng/m^3; p<0.01) (Table 5), indicating that Kinshasa is a city where leaded petrol is no longer used [19].

Living in Kinshasa is associated with elevated levels of Pb in ambient air as compared to databases from literature: In Europe, measured 24-h average lead concentrations in air of different regions ranged from 2.4 to 199.0 ng/m^3 with 30.0 ng/m^3 as an average [20-22]. The background concentrations of lead in air were mainly within the 10–30 ng/m^3 range in 1990. In 2003, the concentrations mainly ranged between 5 and 15 ng/m^3 [18].

Nickel

Nickel is a trace metal which occurs in soil, water, air and in the biosphere. Nickel emissions to the atmosphere may occur from natural sources such as wind-blown dust, volcanoes and vegetation. The main anthropogenic sources of Ni emissions into the air are combustion of oil for heat, shipping or power generation, Ni mining and primary production, incineration of waste and sewage sludge, steel manufacture, electroplating and coal combustion [15].

In the present study, 24-h level of Ni ranged from 48.7 to 482.0 ng/m^3 in roadside sites and 42.8 to 117.6 ng/m^3 in residential sites. The 24-h median average observed in roadside sites was not different to that found in residential sites (73.6 ng/m^3 vs. 76.2 ng/m^3; p=0.44) (Table 4).

No significant difference was found between urban and sub-rural areas (0 for sub-rural area, Median level: 46.0 ng/m^3 vs. 1 for urban area, Median level: 73.6 ng/m^3; p=0.09) (Table 5).

Living in Kinshasa is associated with elevated levels of Ni in ambient air as compared to databases from literature: In Europe, measured 24-h average Ni concentrations in air of different regions ranged from 0.8 to 20.0 ng/m^3 with 3.5 ng/m^3 as an average [17].

In conclusion, this study reveals that ambient air of Kinshasa is contaminated with toxic heavy metals which may pose threat to human health and the environment. The Efforts should be made to reduce the levels of metal contamination, especially in roadside and residential sites.

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