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Blood lead levels in the Kinshasa population: a pilot study

by

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Abstract

Objective

Leaded gasoline and lead paints are still in use in the Democratic Republic of Congo but data on blood lead levels in the general population are not available. We evaluated the Pb impregnation in children and adults (0 - 70 years old) in Kinshasa.

Methods

Blood lead was measured by atomic absorption in a sample of 485 healthy people (268 men and 217 women) living in Kinshasa between May 2003 and June 2004.

Results

Geometric mean blood lead was 120 µg/L (95% CI: 115 -125), with a higher concentration in men than in women (127 vs 114 µg/L, p=0.01). Sixty-three percent of children aged less than 6 years old presented blood lead levels above the 100 µg threshold. In the adult population, occupations with a potential risk of exposure to gasoline (car mechanics or garage owners, taxi drivers, conveyors and gas pump attendants) were associated with an extra blood lead of about 65µg/L.

Conclusion

This study indicates a relatively important Pb impregnation of the Kinshasa population. It demonstrates the existence of a major public health issue requiring corrective actions and the implementation of an appropriate regulation.

Keywords

Leaded gasoline, Kinshasa, human exposure, saturnism, blood lead

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Introduction

Lead, which has been used by man for thousands of years because of its many useful physicochemical properties (easy extraction, malleability, ductility, low fusion point, resistance to corrosion, low electrical conductivity, X-Ray absorption,…) was largely dispersed into the environment where it has been accumulating over centuries.

Among populations likely to be particularly exposed, workers, employed to extract or use Pb in their professional activity, paid a heavy price because of the significant toxicity of Pb. Important progress in technology and industrial hygiene allowed the situation to evolve. In the general environment, exposures are usually at lower levels but last over time. Moreover, the general population comprises people less or not informed of the risks, carrying risk factors related to age, pregnancy, pathological medical history or even genetic predispositions, without having the protection means from which workers usually benefit. Lead represents a proven danger for health. It affects many systems and organs, mainly the central and peripheral nervous system, the hematopoietic system, the kidney and the male reproductive organs (1-3). Lead and its inorganic compounds are considered as probable carcinogens for men (Group 2A in IARC classification) (4). Lead accumulates in bone tissue and its elimination from the organism is extremely slow.

Children constitute a group particularly at risk and lead is considered as the main toxic chemical agent for children (5). Indeed, not only are they more exposed to lead than adults (they put their fingers in their mouths, have a tendency to eat non-edible food and ingest paint flakes) but they also absorb it more (absorption rate estimated at about 40% in children against 10% in adults) and, finally, they are more sensitive to the neurotoxic action of lead because they are in a critical period of development of their central nervous system. Relatively low exposure levels may lead to neurological development disorders, mental handicaps, bad motor coordination, visuospatial dysfunctions and language acquisition disorders, deficiency of cognitive functions, IQ deficit, behavioural and mood disorders, attention deficiency, school performances decline and violent behaviours. It was estimated that 15 to 18 million children living in developing countries suffer from permanent cerebral lesions due to lead intoxication. In the European Region, the estimated morbidity load resulting from lead intoxications in children aged less than 5 years amounts to approximately 470,000 DALY[1], which corresponds to 4.4% of all DALY in children of that age (5).

There are many potential sources of exposure to lead and they vary according to the local context: leaded gasoline and lead paints, lead drinking water pipes or solder joints containing lead used for water supply, enameled ceramics, emissions from foundries, recycling industry

[1] The DALY (Disability Adjusted Life Years) constitute a global measure of sanitary effects. For a given cause, the DALY comprises both life years with a disability and lost life years (due to premature death).

for storage batteries, leisure activities, contaminated soils, or even some cosmetics or traditional remedies.

Most nations and international institutions (UNEP, WHO, UNICEF, EU) recognised environmental exposure to lead as being a major risk for health and particularly for children's health. They progressively issued various guidelines or recommendations aimed at limiting or forbidding the use of lead in paints, gasoline or even electrical and electronic equipments. Limitation then suppression of addition of lead tetra(m)ethyl in gasoline in many countries resulted in significant decreases of blood lead levels. In Europe, lead in gasoline was completely suppressed on January the 1st, 2000.

In developing countries, the problem of industrial pollution is often not as serious as in countries from the northern hemisphere but it reaches worrying proportions in some cities (high population density, closeness of industrial parks and car traffic). In Kinshasa, data on blood lead levels are not available. This is worrying because one can observe a rapid and uncontrolled expansion of old second hand vehicles that can constitute a major source of contamination of ambient air (lead but also unburned hydrocarbons, CO, NO_X, CO_2, particles, etc) and can have harmful effects on the population's health. Although leaded gasoline is currently less used or forbidden in the majority of industrialised countries and in some developing countries (Declaration of Dakar in June 2001 and of Johannesburg in 2002), in the Democratic Republic of Congo (DRC), it remains in common use. Through a study carried out to determine heavy metals in food consumed in Kinshasa, Mbuyi et al. showed that vegetables cultivated along the side of the main roads of the city contained high lead levels (7). The use of lead paint is also still widespread in the DRC. The present study originated from that observation and its main objective was to evaluate the Pb impregnation in children and the adult population (0-70 years old).

Methods

Study area

Kinshasa city is a metropolitan area in the south-west of RDC, near Bas-Congo and Bandundu. The city is divided into four districts. There is no industry in the study place susceptible of releasing important amounts of lead in the atmosphere (National Statistics Bureau, 2008)(8).

Population

A preliminary study was carried out in 2003 on a sample of 100 people exposed to road traffic because of their activities alongside the main roads of the city. The results of this study stimulated us to extend the sample to a larger and more diversified group.

A cross-sectional survey was conducted in a large sample of the population living in Kinshasa. The survey was carried out by the laboratory of environmental chemistry at the University of Kinshasa from May the 4th, 2003 to June the 15th, 2004. Inclusion criteria were:

being between 0 and 70 years old, being mentally and physically healthy and living in the city of Kinshasa for at least 6 months. Volunteers were recruited through a mobilisation campaign in the four districts. Because of their importance and location in the city, five health centres (General Hospital of Kinshasa, University Hospital/Clinic of Kinshasa, Paediatrics of Kalembelembe, King Baudouin Hospital and Bondeko Clinic) participated in the sampling. Six hundred persons were invited to go to the proximity health centres (mean of 150 persons per district). After they were informed, gave their consent and filled in the form collecting information on age, sex and socio-occupational category, the 485 persons who were present during the blood sampling period were included in the study (268 men and 217 women divided in 5 age and 4 socio-occupational categories).

Determination of blood lead

Venous blood samples were taken from May the 15th until June the 15th, 2004 on metal-free EDTA tubes that were preserved at 4°C in a refrigerator and transported by plane to the laboratory of the Scientific Institute of Public Health in Brussels to be analysed, with the support of the provincial Institute of Hygiene and Bacteriology of Hainaut. Lead was measured by atomic absorption (Perkin-Elmer AAnalyst 600 with graphite furnace) 10 days after sampling (9). Determinations were calibrated with lead solutions prepared from calibrated lead nitrate solutions (99.99% $Pb(NO_3)_2$, Aldrich, Milwaukee, WI). Blood lead values were means of six analyses, repeated for each sample with a coefficient of variation less than 10%, and the detection limit was 10 µg/L. The laboratory is accredited by the Standards Council of Canada in accordance with the ISO Standards 17025 and successfully participates in several programmes accredited for their quality control (Quality Control Belgium-QCB at the national level, Community Reference Office (Bureau Communautaire de Référence-BCR) at the European level and in the United States (CDC)).

Data analysis

A logarithmic transformation was performed on blood lead concentration and geometric means used for comparisons. Analysis of Variance (ANOVA) and multiple-comparison test (Dunnett's test) were applied to evaluate blood lead differences according to occupation, sex and age of persons participating in the study. A multiple linear regression was also performed to assess the correlation between the studied variables: age, sex and occupation with exposure to gasoline being the independent variables, and blood lead being the dependant variable. All these analyses were performed with the SPSS software v 14.0.

Results

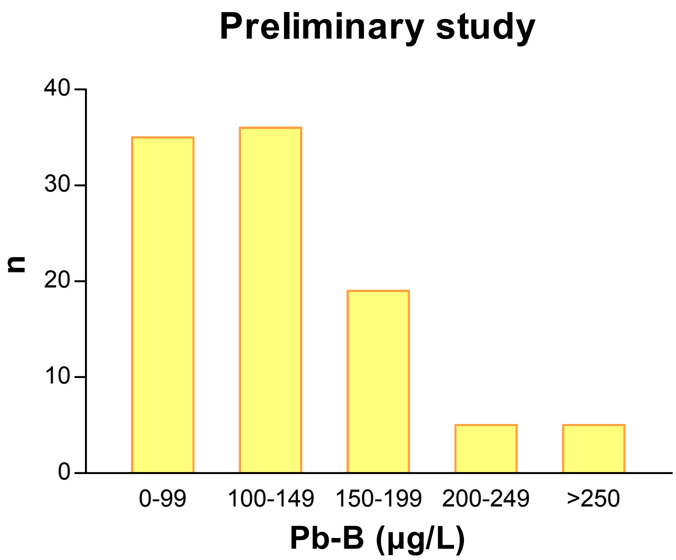
Preliminary study

A first study carried out on a group of 100 people (63 men and 37 women) aged between 18 and 60 years (mean: 32 years old), exposed to road traffic and thus possibly to leaded gasoline, showed that 65% of the sample presented a blood lead level of over 100 µg/L (Figure

1), the mean blood lead level being 126 µg/L with extreme values ranging from 36 to 283 µg/L.

Figure 1: Lead concentration in blood of 100 individuals exposed to road traffic.

Kinshasa Lead Study, pretest, 2003



Extended study

In total, blood lead was determined in 485 volunteers living in Kinshasa, of whom 21% were aged less than 6 years (45% girls and 55% boys). The demographic characteristics of the population are summarised in Table 1.

Mean blood lead for the whole group was 120 µg/L (95% CI: 115-125) with a range of 34 to 366 µg/L (Table 2). A significantly higher mean value was found in men compared with women ($p=0.01$, Table 2). However, when considering the studied age categories separately, no significant difference was observed between sexes even though a tendency can be seen from age 30 years onwards (Figure 2).

Table 1: Characteristics of the study participants. Kinshasa Lead Study, DR Congo, 2003-2004

	N	Age (years)		
		mean	min	max
Men	268 (55%)	23	0	65
Women	217 (45%)	23	0	65
Total	485	23	0	65

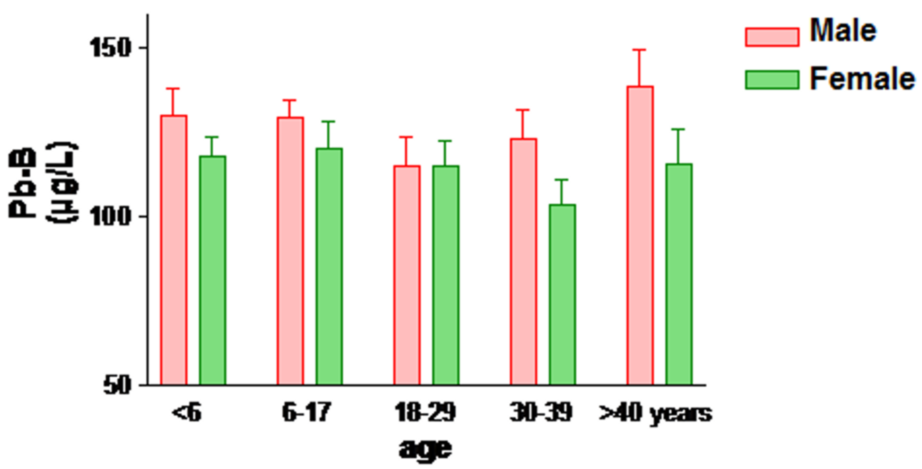
Table 2: Blood lead (µg/L) in a sample of the Kinshasa population. Kinshasa Lead Study, DR Congo, 2003-2004

	N	Blood lead (95% CI)*	p **
Total	485	120 (115 -125)	
Men	268	127 (119 -134)	0.01
Women	217	114 (107 -121)	
Age (years)			
0 – 5	100	124 (114 - 133)	0.26
6 – 17	98	125 (116 -133)	
18 – 29	114	115 (103 - 126)	
30 – 39	86	113 (101 -125)	
40 and more	87	127 (112 - 142)	
Occupational groups			
1: teachers, librarians…	38	85 (67 - 104)	<0.001
2: doctors, (male) nurses…	52	98 (85 - 111)	
3: shopkeepers/storekeepers/retailers/traders…	97	97 (85 - 109)	
4: car mechanics/garage owners, car drivers, gas pump attendants, conveyors.	100	159 (139-179)ᶲ	

* Geometric mean, CI: Confidence Interval
** T-test or ANOVA
ᶲ Significant difference from controls (Dunnett's test)

Similar mean blood leads were recorded in children less than 6 years (124 µg/L), in young people aged 6 to 17 years going to school (125 µg/L), and in adults aged 40 years or more (127 µg/L). A trend towards a slightly lower blood lead was, however, reported in adults aged 18 to 29 years and 30 to 39 years (Table 2).

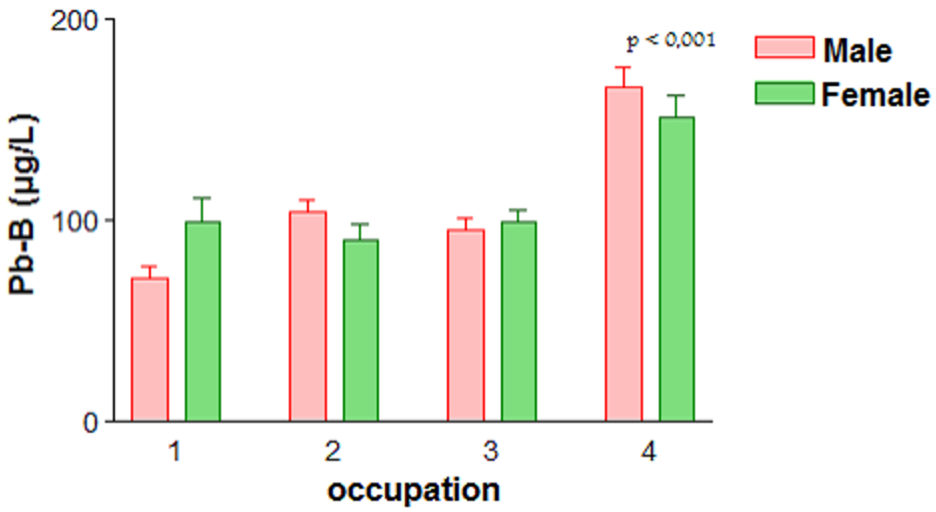
Figure 2: Blood lead variation with age and sex. Kinshasa Lead Study, DR Congo, 2003-2004



The proportion of children less than 6 years old with a blood lead level over 100 µg/L was 63% in boys (n=35) and 64% in girls (n=29).

Mean values less than 100 µg/L were measured in teachers, librarians (occupational group 1), doctors, nurses… (occupational group 2) and traders… (occupational group 3). On the other hand, a mean blood lead level over 150 µg/L was found in car mechanics/garage owners, car drivers, gas pump attendants and conveyors (occupational group 4). A highly significant difference was observed between the occupational groups (ANOVA test, p-value < 0.001) (Table 2 and Figure 3). A Dunnett's test showed that the blood lead level in the occupational group 4 was significantly higher than each of the other groups.

Figure 3: Blood lead by occupation and sex. Kinshasa Lead Study, DR Congo, 2003-2004



1 Teachers, librarians,…
2 Doctors, nurses,…
3 Traders,…
4 Car mechanics/garage owners, car drivers, gas pump attendants, conveyors

The multiple linear regression analysis (Table 3) shows a statistically significant correlation for the whole sample between blood lead, and age and practice of an occupation with a

Table 3: Multiple linear regression: The Association between characteristics of the participants and blood lead levels. Kinshasa Lead Study, DR Congo, 2003-2004

For the whole sample (n=485)		
Variable	B	p-value
(Intercept)	117.987	<0.001
Age	-0.579	<0.001
Sex (0 = Female, 1 = Male)	7.708	0.109
Occupation related to gasoline*	58.821	< 0.001
R^2 = 0.160		

For adults ≥ 18 years old (n = 287)		
Variable	B	p-value
(Intercept)	86.774	<0.001
Age	2.226	0.435
Sex (0 = Female, 1 = Male)	2.255	0.734
Occupation related to gasoline*	64.815	<0.001
R^2 = 0.246		

* 1 when occupational exposure to gasoline (group 4) is present, 0 otherwise

potential risk of exposure to gasoline (p-value < 0.001). Sixteen percent of the variation in blood lead is explained by age and occupational exposure. Among adults aged over 18 (n=287) and having a socio-occupational activity, almost 25% of the variation in blood lead is explained by their occupation with a potential exposure risk to gasoline (p-value < 0.001).

Discussion

The objective of the present study was to evaluate the level of Pb impregnation in children and adults in Kinshasa.

The analysis reveals a mean blood lead level of 120 µg/L for the whole tested population, with concentrations ranging from 34 to 366 µg/L. The results did not show any significant difference among the examined age categories, but a significantly higher mean blood lead in men than in women (127 *vs* 114, p=0.01). This difference is consistent with the data from the literature (1-3, 10-14) and was attributed to a generally lower haematocrit in women, a different behaviour and different lead absorption kinetics.

A close relationship between the use of leaded gasoline and the lead concentration in the air and in the blood of the population exposed to car traffic was regularly demonstrated. Many studies show that the progressive decrease in the use of leaded gasoline correlated with a decrease in mean blood lead levels (15-26). In the United States for example, according to the National Health And Nutrition Examination Survey (NHANES) carried out by the Centers for Disease Control and Prevention (CDC) in 2002, the mean blood lead in the population was 15.6 µg/L, whereas it amounted to about 150 µg/L between 1976 and 1980 (14). In Belgium, where mean blood lead in the population in 1978 was 176 µg/L in Brussels and 182 µg/L in Charleroi, it went down to respectively 31 and 33 µg/L in 2005 (23-25). Values measured in Kinshasa correspond to those observed in industrialised countries before measures were taken to limit lead in gasoline.

A significant difference in the mean blood lead level (159 µg/L vs 93 µg/L, p <0.001) was observed between occupations with a risk of exposure to gasoline and the other occupations. According to the regression equation, these professional activities generate a rise in blood lead of a magnitude of about 65 µg/L. Aware of the negative impact of lead in gasoline on the environment and on human health, the countries of Sub-Saharan Africa, which were among the rare countries still using leaded gasoline, met in Dakar in 2001 during a regional conference. At the end of this conference, 48 African countries undertook action to eliminate lead in gasoline by December the 31st, 2005, through a declaration called the 'Declaration of Dakar'. In 2002, Sudan was the only one of the 48 Sub-Saharan countries to entirely use unleaded gasoline. In May 2004, more than half of the gasoline sold in Sub-Saharan Africa was unleaded. On December the 27th, 2005, the United Nations Environment Program (UNEP) declared that the promise made to free Sub-Saharan Africa from leaded gasoline had just been fulfilled, and that the campaign in favour of suppression of lead in fuel was on the way to become a real success story in the developing world (27). However, in the DRC, leaded gasoline seems to remain in use and thus still constitutes a potential occupational and environmental exposure source to lead in the urban population. One should note that our investigation was carried out in 2004, and that it would thus be interesting to relaunch a measurement campaign. A short visit in December 2008 to the various gas stations of Kinshasa city indicated that the proportion of gas pumps without lead could be estimated at 5%, especially in the city centre.

Children constitute a group which is particularly at risk; they ingest more lead due to their hand-mouth activity, their digestive absorption rate is higher than in adults and their developing nervous system is more sensitive. The blood lead threshold justifying medical care of children was regularly lowered since the 1950s. In 1991, the American CDC (28) set to 100 µg/L the intervention threshold for the establishment of collective corrective actions, and to 200 µg/L the threshold from which a medical evaluation as well as an environmental investigation are required. For the National Institute for Health and Medical Research in France (Institut National de la Santé et de la Recherche Médicale, INSERM), prevention and medical follow-up should already be considered when blood lead levels attain 100 µg/L (2).

Some more recent data, however, allow to believe that even a blood lead level under 100 µg/L could have damaging effects on the child's learning and behaviour (29-34). According to the WHO, in countries where unleaded gasoline is not produced or imported, the proportion of children having a lead level in blood above 100 µg/L often exceeds 10% and sometimes markedly 50% (5). According to current CDC criteria, 63.5% of Kinshasan children aged less than 6 years exceed the tolerance threshold of 100 µg/L. The prevalence of values > 100 µg/L is relatively low compared with the one found in some cities of the developing countries: 70 % in Nigeria (35), 78% in Johannesburg (36) and 80% in Pakistan (37). However, mean values observed in these different studies remain in general similar. These values are, however, very high compared to those reported these last years in industrialised countries: 17 µg/L in the USA (14), 26 µg/L in Helsinki (38) and 37 µg/L in France (2). A prevalence survey carried out in 1995 by the INSERM concluded that 2% of the population of French children (85,000) aged between 1 and 6 years had a blood lead over 100 µg/L and a new survey started in 2008 (39). A survey carried out in Brussels in 1995-1999 among children reported a mean blood lead of 36 µg/L, less than 5% of children living in Brussels presenting a blood lead > 100 µg/L (40). The assessment of the Pb impregnation in children aged 0-5 years in the Province of Hainaut (2000-2006) revealed a mean blood lead less than 16 µg/L, 0.5% of the children presenting a blood lead above100 µg/L (41).

The other risk factors of exposure to lead could not be investigated in the framework of this study. There could still be lead water adduction pipes in Kinshasa. However, according to preliminary analyses performed on drinking water samples taken at different places of the city, lead stands at concentrations of 4 µg/L, which is less than the 10 µg/L threshold set by the WHO since 1994. The European Guideline 98/83/CE on the quality of water for human consumption imposed a progressive reduction of the maximal lead level from 50 µg/L to 25 µg/L at the end of 2003 and to 10 µg/L at the end of 2013. This exposure source seems unlikely in Kinshasa. There are no industries in our study place susceptible of releasing important amounts of lead in the atmosphere. On the other hand, besides leaded gasoline, lead paints are a well-known source of exposure to lead and could very well constitute a source of contamination. Many investigations revealed the role of lead paints in childhood saturnism. So for example, surveillance surveys carried out in Brussels in 1991 and 1995-1999 by the Scientific Institute of Public Health in ancient neighbourhoods and outdated housings showed that more than 50% of the children exceeded the 100 µg/L threshold (<5 % in controls), the major identified cause being lead paints (40).

Conclusion

This study revealed a relatively important Pb impregnation of the Kinshasa population. Leaded gasoline and the presence of lead paints in the different buildings probably constitute sources of exposure in the city of Kinshasa. This demonstrates the existence of a major public health issue, certainly to be controlled by the implementation of regulations aimed at decreasing the lead levels in gasoline and at reducing the impact of lead paints as is the case in some other developing countries and in most industrialised countries. A subsequent study will allow to investigate to what extent the suppression of lead in gasoline is effective and to clarify the contribution of the different sources of exposure.

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