Effect of Environmental Exposure on the Lead Levels in Human Blood in Kenya

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Abstract

Lead is one of the heavy metals associated with a number of health problems such as abdominal pains, constipation and loss of appetite, nausea, vomiting, insomnia, headache, irritability, dizziness and lead encephalopathy. The major source of lead into the environment is through emission from auto exhaust in countries still using leaded fuel, with other contributors being cigarette smoke, burning of lead battery castings, weathering, ceramic industries and paints. Therefore there is need for continued monitoring of the levels of lead in the environment and in people to determine the level of exposure. The aim of the study was to determine the effect of environmental exposure on the levels of lead in human blood in Nairobi City and Nyamira District, Kenya. The subjects who had lived in the study areas continuously for five years were randomly selected and recruited for the study. The study used a questionnaire to assess lead exposure factors of the recruits, while atomic absorption spectroscopy and differential pulse anodic stripping voltammetry were used for determining the lead levels. The subjects in Nairobi City Centre had the highest mean blood lead (BPb) level of 29.9 $\pm$ 16.91 µg/l, while Nyamira Rural subjects had the lowest mean of 24.20 $\pm$ 7.07 µg/l. The mean lead level of the subjects was statistically significant between Nairobi City Centre and Nyamira Rural ($P < 0.01$, df = 99). The smokers, those who travelled frequently, the users of glazed ceramics, those who worked in industries and those who lived near busy roads had higher levels of blood lead. The study provides an additional data pointing to elevated blood lead levels in environmentally exposed individuals.

Keywords: Lead, environmental exposure, human blood, AAS, DPASV.

1. Introduction

Rapid economic development and industrialization has been accompanied by an increase in chemical discharge into the environment, leading to environmental pollution (Lee, 1997). Among the chemical substances which are responsible for environmental pollution are the heavy metals such as lead (Pb) which has raised concern because of its unique sources as a result of its widespread use and high quantities in the environment, relatively high toxicity, and has no known biological function in living organisms (CDC, 2005). Lead originates from many different sources and is present in ambient air , drinking water and many manufactured products such as paints (Kim *et al*., 2006).

The main sources of lead to human beings include gasoline emission, industrial process such as lead smelting and coal combustion, lead-based paint, lead containing pipes or lead based soldier in the water supply systems and use of glazed ceramics (Mbaria, 2007). Lead gets into the human body by either inhalation from emissions of the polluted atmosphere or ingestion through water of food. In major cities inhalation is the most important source of lead intake due to high densities of vehicles using leaded gasoline especially along heavy vehicular highway, even though the use of leaded gasoline is banned in many countries (Ankrah *et al*., 1996). The use of leaded fuel in Kenyan was banned in 2007, though its implementation is a challenge due to lack of funds and poor monitoring services (Mbaria, 2007). Some of the lead particles entering the soil and ground water are taken up by plants and enters the food chain resulting in ingestion (Onyari *et a.l*, 1991). Ingestion mainly comes from food contamination at the source or during preparation, storage and serving in lead glazed earthen ware (Wright *et al*., 2005). However , implementation of policies prohibiting the addition of lead to many consumer products has resulted in rapid decline of human exposure as demonstrable by reductions in human blood lead levels (Hernandez-Avila *et al*., 1996; Lagerkvist *et al*., 1996; Smargiassi *et al*., 2002; levesquet *et al*., 2003; Yaw *et al*., 2004; Sanna *et al*., 2006).

Biological monitoring by determining the lead levels in blood is used to estimate the current exposure, absorption, distribution and elimination of lead (*Kim et al*., 2006). Low lead levels are now reported to affect adult and children health at a much lower concentration, at 10-2 0µg/dl lead level than it has been believed before (Lanphear *et al*., 2000). A study in Nigeria revealed that occupational exposure to lead significantly increased blood lead, with a mean value of 59.6 ± 15.9 µg/ dl in exposed subjects compared with 35 ± 7 µg/dl ($P< 0.01$) in non-exposed subjects (Dioka *et al*.,2004). Another study by Ademuyiwa *et al* (2002) revealed that the male and female University students had a mean blood lead level of 16.27± 2.65 µg/dl and 15.19 ± 2.36 µg/ l respectively while the male and female petrol attendants had a mean blood lead level of 42.40± 2.41 µg/l and 34.95± 4.25 µg/dl respectively; indicating effect of occupational exposure. A report by Mutuku (2003) on the lead levels in Nairobi, Kenya indicates that levels of lead in soil and food stuffs were above the WHO standard. The lead levels in soil were 265,918 µg/Kg in Nairobi Central Business District and 133,790 µg/Kg in Thika Highway, as compared to 110 µg/Kg WHO standard, while kales in the Nairobi Central Business District had lead level of 5,053.6 µg/Kg as compared to WHO standard of 300 µg/Kg. The report shows that the amount of lead in the environment is high in Nairobi, especially among the socially and economically deprived people. Economically deprived people are more likely to be exposed to lead pollution since live in substandard and overcrowded houses and live/ work near in industries and along heavy traffic highways. Exposure to lead is recognized as a major risk factor for several diseases (Oladele & Smith, 2007). There has been limited information on the levels of lead in human blood in Kenya. In this study the environmental factors that have been shown to elevate the human blood lead levels were investigated.

2. Materials and Methods

2.1 Sampling and Sampling Procedures

Four hundred subjects both male and female aged between 18 and 70 years were randomly recruited from four study sites in Nairobi City and Nyamira District. In Nairobi City the Central Business Center assumed to be highly polluted from high vehicular densities, close proximity to industries and other activities and a suburban region with medium level of pollution. In Nyamira District participants from the Nyamira Town as an upcoming town and therefore expected to have medium levels of pollution similar to Nairobi suburban, and a rural region with very few vehicles and no industries nearby were sampled. The subjects filled a questionnaire and provided blood samples. A questionnaire was used to collect information on known risk factors for increased lead exposure including traveling, smoking, use of glazed ceramics, and distance of residence from the road and working or living near factories/industries (Hernandez-Avila *et al*., 1996).

The research protocol was approved by the Kenyatta National Hospital Ethics and Research Committee and the relevant Medical Officers in the study areas. All participants were explained of the study objectives and procedures and counseled on the lead exposure reduction procedures, and their willingness to participate sort. Blood samples, 5 ml, was collected from each subject into lead free vacutainer tubes containing 5 drops of EDTA anticoagulant by a qualified laboratory technician. The blood was stored in a cool box and transported to either Nyamira District Hospital or Kenyatta National Hospital for the preservation. Analysis for blood lead was carried out at Kenyatta University, Department of Chemistry laboratory using an AAS procedure.

2.2 Laboratory Procedures

To 5 ml of whole blood sample 10 ml of concentrated nitric acid was added in a beaker and digested slowly below boiling point for 3 hours on a hot plate in a fume chamber. When the volumes had been reduced to about a third, 5 ml of 30 % hydrogen peroxide solution was added, evaporated at the same temperature and then the residues were dissolved in 10 ml of 1 % nitric acid and filtered. The digested blood samples were placed in 10 ml plastic vacutainer tubes which were free from lead and taken to Kenyatta University for analysis. The treatment [by wet digestion] of blood was done at Nyamira District Hospital for samples collected in Nyamira while those collected in Nairobi were treated at Kenyatta National Hospital. Strict precautions were taken when handling the blood samples to minimize

HIV infection including disinfecting working area with a 5 % phenol.

The lead levels in digested samples were determined in triplicate by AAS (Buck Scientific Model 210 VGP) and DPASV (Buck Scientific Model 780 ZPV) procedures, which were validated using calibration, co-efficiency of variation and recovery methods. Freshly prepared standard solutions, together with a blank solution were used to construct the calibration curve and its regression equation used to determine concentration in samples. The relationships between the blood lead levels and the risk factors were determined by correlation coefficient and linear regression. Further linear regression equations were used where applicable to enable prediction or estimation of the blood lead levels. The t-test was carried to determine the contribution of the environmental risk factors on the lead levels in the human blood.

3. Results

3.1 Method Validation

The regression equation from the calibration curves for lead standards for AAS and DPASV were Y = 0.123X-0.007 and Y = 0.23X+0.047 respectively, where Y= absorbance of lead and X = concentration. The intercepts were low, close to zero, suggesting that there was minimum matrix interference. The Spearson's correlation factor, r^2 was 0.998, indicating that 99.8% of absorbance correspond to the concentration and therefore indicate linearity. Six standard solutions of lead containing 20 µg/l were added to different portions of a blood sample and then analyzed. The co efficiency of variation was 0.403 % indicating high reproducibility for the element. The detection limit of AAS was 0.02 µg/l while that of DPASV was 0.01 µg/l while the quantification limits were 80 µg/dl and 93 µg/l respectively.

The results of the levels of blood lead from the two techniques (Table 1) were compared using the student t-test and the results indicate that there was no significant difference ($P < 0.01$) between the two methods in each study area. A regression curve for DPASV against AAS gave r^2 value of 0.98194, indicating strong correlation between the two methods (Table 2). The regression equation Y = 0.977669X - 0.064545, (where Y = DPASV and X = AAS) gave the slope of 0.977669 which was close to unit and the intercept close to the origin, implying that the two methods gave similar results. The results obtained by AAS technique was however used in this study.

3.2 Level of environmental risk factor exposure

A questionnaire was used to determine the involvement of subjects in risk factors of traveling, place of residence, smoking, exposure to cigarette smoke, use of glazed ceramics, working in factories, living/working near factories releasing lead were investigated and the results are given in Table 2. From the table 64 % of the subjects in Nyamira Town and Nairobi City Centre and 10 % of Nairobi Suburban subjects were frequent travelers. Thirty percent of Nairobi City Centre, 36 % of Nyamira Town, 78 % of Nairobi Suburban and 18 % of Nyamira Rural subjects were occasional travelers. The majority (82 %) of Nyamira Rural subjects traveled rarely. Most of the subjects in the study areas were non smokers; with only 18 % in Nairobi City Centre, 14 % in Nyamira Town, 10 % in Nairobi Suburban and 2 % in Nyamira Rural being smokers. Most subjects recruited were frequent users of glazed ceramics with 48 % in Nairobi City Centre, 60 % of Nyamira Town, 21 % of Nairobi Suburban and 20 % of Nyamira Rural subjects being users. Thirty percent of Nairobi City Centre, 22 % of Nyamira Town, 32 % of Nairobi Suburban and 20 % of Nyamira Rural subjects were occasional users of glazed ceramics while 2 % of Nairobi City Centre and 32 % of Nairobi Suburban subjects used glazed ceramics rarely.

Most subjects had their residence near roads except those from Nyamira Rural. All (100 %) of Nairobi City Centre, 88 % of Nyamira Town and 80 % of Nairobi Suburban subjects had their residence within 0-50 meters from the roads. Only 10 % of Nairobi Suburban subjects had their residence within 51-100 meters from the roads. Roads were constant source of lead pollution due to the leaded fuels which were used in vehicles. The levels of exposure depended on the extent of the use of the roads with some roads extremely busy while others were not and this could be the case presently (Ankrah *et al*., 1996; *Kim et al*., 2005; Mbaria, 2007). Thirty percent of Nairobi City Centre, 2% of Nyamira Town and 14% of Nairobi Suburban subjects lived near busy roads while 68% of Nairobi City Centre, 56% of Nyamira Town and 82% of Nairobi Suburban subjects stayed near moderately busy roads. All Nyamira Rural subjects lived near roads not busy with traffic. Most subjects recruited were non factory workers with only 16% of Nairobi city centre, 6% of Nyamira Town and 6% of Nairobi Suburban subjects being factory workers. Twenty six percent of Nairobi city centre, 10% of Nyamira Town and 16% of Nairobi Suburban subjects lived/worked near factories.

3.3 Environmental exposure and lead levels

The relationship between the environmental factors studied and the mean BPb levels of the subjects were investigated and the results are presented in Tables 4 - 9. The mean BPb levels of the study subjects in different traveling categories were determined and results are given in Table 4. The mean BPb levels are influenced by the frequency of traveling. The frequent travelers had the significantly higher ($P < 0.0\ 1$) mean BPb level in Nairobi City Centre, Nyamira Town and Nairobi Suburban with means of 33.10±23.31, 38.12±20.26 and 28.5±13.36 µg/l, respectively. The subjects who traveled rarely had the lowest mean BPb levels of 22.31±7.27, 18.14±5.33, 21.70±4.82 and 21.90±6.69 µg/l in Nairobi City Centre, Nyamira Town and Nairobi Suburban, respectively. The difference between the mean BPb levels of the frequent and the rarely travelers were statistically significant in each study area ($P < 0.01$). The frequency of traveling exposed subjects to varying levels of lead from the vehicle exhausts, with frequent travelers exposed to higher levels of lead than those who rarely traveled. In a large number of developing countries like Kenya, the use of gasoline with high lead content (frequently exceeding 0.8 g/litre) is a still standard practice (KMOL, 2004; Link *et al*., 2007; Mbaria, 2007). Without significant changes in public policies, leaded gasoline creates large health damages in these countries as urbanization and motorization increases (World Bank, 1995). The use of leaded gasoline has not been eliminated completely in Kenya (Mbaria, 2007) and accounts for the high lead levels for the individuals who work in areas with high vehicular emissions such as petrol stations, driving/conducting of public vehicles and street hawking.

Towns have high vehicular and industry densities which discharged more amounts of lead to the environment. The lead levels in Nyamira Town were not expected to be higher than those of Nairobi Suburban. This was because Nairobi City hosted a higher number of vehicles than Nyamira Town. The higher BPb levels in Nyamira Town could either be due to poor feeding habits or may be the vehicles could be using petrol from Uganda which may have higher lead levels. Nairobi City Commission (1996) estimated that over 500,000 cars entered the City Centre daily. The current number could be even higher while those which enter Nyamira Town could rarely reach 500 cars. The Nairobi City is therefore likely to have high concentrations of atmospheric lead assuming not all cars have started using unleaded fuels (Mbaria, 2007).

The Nairobi Suburban subjects however had lower mean BPb level than Nyamira Town subjects because they had better protective feeding habits (Njoroge& UNEP, 2005).The Nairobi Suburban subjects had lower mean BPb level than Nyamira Town subjects even though the level of pollution of the later was lower as the former had better feeding habits. The higher BPb level observed in Nairobi Suburban subjects than the Nyamira Rural subjects was probably due to the long time they spend in traffic traveling to their working places, the nature of air they inhale and the water they drink. There has been a lot of lead deposited into the environment by vehicles and other industries in the Nairobi City while in Nyamira Rural the lead exposure is limited.

The mean BPb level of the study subjects and the frequency of use of glazed ceramics in the study areas were investigated and results are given in Table 7. The frequent users of glazed ceramics had higher BPb level in Nairobi City Centre, Nyamira Town, Nairobi Suburban and Nyamira Rural with means of 35.88±12.15, 32.25±12.70, 34.5±16.81 and 25.27±7.34 µg/l while the non users had the lowest values of 21.4±9.37, 17.67±3.77 and 18.06±5.84 µg/l in Nairobi City Centre, Nyamira Town and Nairobi Suburban subjects, respectively. The difference between the BPb level among the frequent and non users of glazed ceramics was statistically significant in the four study areas ($P < 0.01$). The results agree with those of other studies (Lagerkvist *et al*., 1996; Njoroge& UNEP, 2005) who found that use of glazed ceramics in cooking ware resulted in high BPb level among the users. Mbaria (2007) reported that the lead levels of most glazed ceramic materials in Kenya contained 1.0 µg/g. Thus, the use of glazed ceramics was one of the main contributors of the BPb level among children and adolescents (Njoroge & UNEP, 2005). The main uses of glazed ceramics in Kenya are to prepare and serve food (cooking pots).

The mean BPb levels and distance of residence of the subjects from the road was investigated and results are given in Table 5. The individuals who stayed up to 50 M away from the roads had a high BPb level in Nairobi City Centre, Nyamira Town and Nairobi Suburban with means of 29.68±23.51, 26.86±18.84 and 26.16±18.07 µg/l while those who stayed between 51-100 M from the roads had lower mean BPb levels of 26.13±4.43, 23.6±18.9 and 23.14±5.83 µg/l respectively. The results show that the mean levels of BPb levels decrease with increase of distance of residence from the roads. All Nyamira rural residence stayed at a distance of more than 101 M from the roads. The difference between the mean blood lead level of those who stayed 51-100 M and 0-50 M from the roads were statistically significant in Nairobi City Centre and Nairobi Suburban ($P < 0.01$).

The other factor which was correlated to the BPb level other than residing within 50m near roads busy with vehicle traffic was working/living near factories/industries with possible lead emissions which has been shown to be a source of lead pollution (Lagerkvist *et al.*, 1996). The mean BPb level and working/living near factory/industry which possibly used lead was investigated and the results are presented in Table 9.

The subjects who worked/lived near factories/industries had high BPb levels in Nairobi City Centre, Nyamira Town and Nairobi Suburban with means with BPb levels of 39.3±21.14, 37.71±17.78 and 36.5±18.10 µg/l while those who stayed away had lower mean BPb levels of 24.1±19.2, 25.87±13.46 and 26.4± 10.91 µg/l, respectively. All the Nyamira Rural subjects did not work or live near factory/industry. However, the difference between the mean BPb level of those who worked/lived near factory/industry and those who stayed away were not statistically significant ($P < 0.01$).

The higher BPb levels of the subjects in towns compared to that of Nyamira Rural could also be due to the possible lead poisoning from the food and water used or from the air. Elevated levels of lead in water are principally from industrial discharge, highway runoff and weathering process in areas with natural lead mineralization. Lead could be discharged into the environment by automobiles which still use leaded petrol in Kenya. The lead is then absorbed into the human body through the water and food s consumed by the residents. Since lead is bioaccumulative in the body, the blood lead level of the individual increases with time accounting for the high BPb levels of the town dwellers.

4. Discussion

The study showed that traveling, place of residence, smoking, exposure to cigarette smoke, use of glazed ceramics, working in factories, living/working near factories releasing lead exposed subjects to lead (Lagerkvist et al, 1996; Hwang et al., 2004; Wright et al., 2003; Njoroge & UNEP, 2005; USEPA, 2005; Martin et al., 2006; Kim, 2005). Traveling exposes people to motor vehicle fumes that may contain high levels of lead (Onyari *et al*., 1991; Smargiassi *et al*., 2002; Coyle *et al*., 2005; Mbaria, 2007). Even though Kenya has banned the use of leaded fuel, some may be finding its way to the country especially from western Kenya where it may be smuggled from Uganda; where leaded fuel is in use (Roh *et al*., 2000; Mbaria, 2007). Factories could be using leaded fuels making such areas to have high levels of lead exposure (Lagerkvist *et al*., 1996; Kim *et al*., 2005; USEPA, 2005). Areas near busy roads have been shown to have high vehicular lead emissions (Onyari *et al*., 1991; Oyaro, 2000). Lead is used in glazed ceramics and some of these ceramics are used to prepare or serve food for human beings hence exposing them to lead (Lagerkvist *et al*., 1996; CDC, 2005). Cigarette smoke contains high levels of lead and thus smoking is a source of lead (Kyle, 1992; Mitei & Murungi, 1999; Lagerkvist *et al*., 1996).

A study by Annest and Mahaffey (1984) showed that the centres of large urban areas were found to have mean BPb level of 14.9 µg/dl while the rural residents had 13.0 µg/dl (Kim *et al*., 2005). The concentration of lead in the atmosphere near highways of large cities where there is heavy traffic using leaded gasoline is high and causes lead pollution. Recent studies from different environmental materials sampled along motorways and roundabouts in Nairobi showed high levels of lead contamination in the City (Ankrah *et al*, 1996; Oyaro, 2000; Mutuku & UNEP, 2003; KMOL, 2004; Njoroge& UNEP, 2005;Mbaria,2007).

Cigarette smoking has been reported to be a contributor to high lead levels in blood by many authors (Lagerkvist *et al*., 1996; Mitei & Murungi, 1999; Fewtrell *et al*., 2003; USEPA, 2005). Cigarette tobacco in Kenya contains high amounts of lead of about 8.6 µg per cigarette (Mitei & Murungi, 1999). Some studies have reported that smokers have higher lead in their blood than non smokers (Mitei& Murungi, 1999; Coyle *et al*., 2005; Fewtrell *et al*., 2003; CDC, 2005). A smoker is exposed to about 10 µg per packet of cigarette smoked (Mitei & Murungi, 1999)Non smokers who stay or live with smokers are exposed to tobacco combustion products and become passive smokers with an equivalent of 0.1 – 1.0 cigarette per day (Kyle, 1992). Studies showed that the concentration of lead in blood of children whose parents were non smokers was 30 µg/l. The mean BPb level of children with one parent smoker was 39 µg/l while those of children with both parents who were smokers was 47 µg/l (CDC, 2005). These findings agree with our findings which show that smokers had higher BPb level than non smokers.

Road sides are among the highly polluted environment with lead. Mutuku & UNEP (2003) reported lead levels of 265,918 µg/Kg in soils taken from road sides in Nairobi central business district while that of Thika Highway was 133,790 µg/Kg. This means that the subjects in towns are exposed to high lead levels than those from the rural. The mean BPb levels usually decrease with increase in distance from the busy roads. The results agree with other studies which showed that the BPb levels varied inversely with the distance from the road due to lead deposition from fuel emission (Ankrah *et al*., 1996; Dioka *et al*., 2004; Oladele& Timothy, 2007).

The high BPb levels of those living close to or working in factory/industry or working near factory suggest that some factories emit lead to the environment. The mean BPb levels of subjects working in various Korean industries ranged from 55.40 µg/l for those who worked in plastic product industries to 123.00 µg/l for those who worked in radio and television broadcasting apparatus (KMOL, 2004; Kim *et al*., 2005). The work place is the primary source of lead exposure to adult workers in many industries including bridge building, house painting, battery manufacturing and radiator repair (CDC, 2005). Paints and paint varnishes are known to contain a lot of lead (KMOL, 2004). Two subjects from Nyamira Town who had very high lead levels (117.0 µg/l) worked with paints daily. The two subjects also resided within a range of 50 M from the moderate roads and were frequent users of glazed ceramics. The relative high BPb level of the subjects who lived in towns than those who lived in rural could be that the subjects from town resided in painted buildings while those in Nyamira Rural reside in muddy houses.

5. Conclusion

The study has shown that those individuals who were environmentally exposed to lead had high levels of blood lead than those who were not. Smoking, frequent travelling, using of glazed ceramics, living close to busy roads, working / living near factories or industries have been identified as the main environmental risk factors to elevated blood lead levels. Reduction of the exposure from these sources will lower the lead levels in the human blood.

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Competing interests

The authors declare that there are no competing interests whatsoever.

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Table 1: Spearman's correlation coefficient and regression equation for the blood lead levels for AAS against DPASV for the study areas

Study area	r^2	Regression equation
Nairobi City Centre	0.98194	Y = 0.977669x-0.064545
Nyamira Town	0.99893	Y = 0.983948x-0.1888
Nairobi Suburban	0.98980	Y = 0.974987x+0.235347
Nyamira Rural	0.86557	Y = 0.916247x+0.559856

Table 2: The mean values of lead determined by AAS and DPASV techniques in each study area and their t-test value.

Technique	Mean concentration of lead (µg/dl)			
	Nairobi City Centre	Nyamira Town	Nairobi Suburban	Nyamira Rural
AAS	29.80±16.92	28.1±29.3	26.44±17.78	24.20±7.07
DPASV	29.03±16.7	25.37±31.8	25.7±17.8	23.00±7.1
t-test value	0.037	0.019	0.041	0.0019

Table 3: The percentage distribution of the subjects in different age groups per sex in the four study areas

Age group(years)	Percentage distribution							
	Nairobi City Centre		Nyamira Town		Nairobi Suburban		Nyamira Rural	
	Male	Female	Male	Female	Male	Female	Male	Female
Less than 20	14	14	10	10	14	14	12	12
21-30	12	12	12	12	12	12	14	14
31-40	14	14	16	16	14	14	14	14
Above 40	10	10	12	12	12	12	10	10

Table 4: The frequency of exposure (percentage) of subjects to risk factors in the four study areas

Risk factor	Percentage distribution			
	Nairobi City Centre	Nyamira Town	Nairobi Suburban	Nyamira Rural
Traveling				
Frequently	64	64	10	-
Occasionally	30	36	78	18
Rarely	6	-	12	82
Smoking	18	14	10	2
Use of glazed ceramics				
Never	14	68	42	6
Rarely	18	-	50	10
Occasionally	22	32	2	78
Often	46	-	-	6
Distance of residence from the road (m)				
Less than 50	100	88	80	-
51-100	12	20	-	-
Above 100	-	-	-	100
How busy is the road?				
Not busy	2	42	14	100
Moderately	68	56	82	-
Very busy	30	2	4	-
Working in the factory	16	6	6	-
Working/living near the factor	26	10	16	-

Table 5: The mean and the range of BPb levels (µg/l) of the subjects in different traveling frequency

	Mean Lead Concentration (range) (µg/l)			
	Nairobi City Centre	Nyamira Town	Nairobi Suburban	Nyamira Rural
Frequently	33.1±23.31 (22-107)	38.12±20.26 (10-117)	28.5±13.36 (0-82)	- -
Occasionally	28.67±8.7 (15-50)	20.08±12.36 (1-63)	26.33±11.47 (12-68)	24.25±3.89 (15-32)
Rarely	22.31±7.27 (10-47)	18.14±5.33 (0-34)	21.7±4.82 (0-32)	21.9±6.69 (8-40)

Table 6: The mean and the range of BPb levels (µg/l) of smokers and non smokers in the study areas

	Mean lead concentration (range) (µg/l)			
	Nairobi City Centre	Nyamira Town	Nairobi Suburban	Nyamira Rural
Always	31.42±12.40 (23-107)	29.67±14.48 (0-117)	28.83±11.16 (10-82)	25.86±3.89 (15-33)
None	24.23±18.52 (10-99)	18.19±14.82 (20-88)	21.59±11.70 (0-68)	20.59±8.12 (8-40)

Table 7: The mean and the range of BPb level (µg/l) of the subjects in different frequencies of use of glazed ceramics

	Mean Lead Concentration (range) (µg/l)			
	Nairobi City Centre	Nyamira Town	Nairobi Suburban	Nyamira Rural
Never	21.4±9.37 (0-49)	17.67±3.77 (0-23)	18.06±5.84 (0-38)	13.23±4.23 (10- 20)
Rarely	- -	- -	24.67±7.43 (0-42)	- -
Occasionally	31.18±12.8 (15-100)	27.6±9.45 (23-54)	28.31±11.89 (15-62)	21.6±4.11 (15-30)
Frequently	35.88±12.15 (30-107)	32.25±12.70 (23-117)	34.5±16.81 (29-82)	25.27±7.34 (8-40)

Table 8: The mean and the range of BPb level (µg/l) of the subjects in various groups of distance of residence from the road

	Mean Lead Concentration (range) (µg/l)			
	Nairobi City Centre	Nyamira Town	Nairobi Suburban	Nyamira Rural
Less than 50	29.68±13.51 (20-107)	26.86±18.84 (5-117)	26.16±18.07 (0-82)	- -
51-100	26.13±4.43 (10-33)	23.6±18.9 (0-83)	23.14±5.83 (15-48)	- -
Above 100	- -	- -	- -	24.20±7.07 (8-40)

Table 9: The mean and the range of BPb level (µg/l) of the subjects working/living within 50M from a factory/industry using lead

	Mean Lead Concentration (range) (µg/l)			
	Nairobi City Centre	Nyamira Town	Nairobi Suburban	Nyamira Rural
Yes	39.3±11.14 (20-87)	37.71±17.78 (20-117)	36.5±18.10 (20-82)	- -
No	24.1±19.2 (10-99)	25.87±13.46 (0-67)	26.4±10.91 (0-52)	24.57±7.28 (8-40)