"EVALUATION OF LEAD AND CADMIUM IN SELECTED KENYAN POPULATION AND SOURCES INCLUDING DETERMINATION OF TRACE ELEMENTS IN CONSUMABLE CLAYS USING ATOMIC ABSORPTION METHOD"

By

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A thesis submitted in part fulfilment for the Degree of Master of Science in the Department of Chemistry, University of Nairobi.

DECLARATION

This thesis is my original work and has not been presented for a degree in any other University.

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DEDICATION

This work is dedicated to my hard working mother, Mrs. Grace Wanjiku Wanjie and to Miss Lillian Wangui Kabuagi, my wife-to-be.

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ABSTRACT

The analysis was done by using Atomic Absorption Method. The evaluation of lead and cadmium in the general Kenyan population was done using blood samples collected from Nairobi Hospital, Kiambu Hospital and Chemelil Sugar Factory's Dispensary. Only 5% of the Nairobi samples, 2% of the Kiambu and Chemelil samples showed the presence of lead, with highest value of 256.70 μgdl^{-1}. For the majority of the samples (96%), the lead levels were below 20 μgdl^{-1}, which actually lies within the 'normal' levels of lead with upper limit of about 40 μgdl^{-1}.

On the other hand, 32% of the Nairobi samples, 18% of the Kiambu samples and 35% of the Chemelil samples indicated the presence of cadmium (highest 32.30 μgdl^{-1}), suggesting that the metal is becoming more abundant in the environment. The rest of the samples had levels below 1 μgdl^{-1}.

The mean lead levels ranged from 16-46 μgg^{-1} in the pots and 16-36 μgg^{-1} in the soils (used to prepare the pots); cadmium levels ranged from 0.50-0.90 μgg^{-1} in the pots and also the same amount in the soils. Therefore, levels of these metals in the pots and soils were similar, suggesting that heating during pot preparation and also cooking does not affect the levels of the metals (Pb, Cd) in the pots significantly.

Studies done on the leaching of these metals during cooking of acidic (eg. pH 2.0) food stuffs showed that very little amounts get removed. Therefore, the use of local pottery in cooking does not contribute significantly to lead and cadmium toxicity in this country.

Clays consumed by pregnant women in Kenya, that is, volcanic tuff and mahti, contain very high levels of aluminium (30,156-49,803 mg kg^{-1}) and iron (19,117-40,655 mg kg^{-1}) and also appreciable amounts of cadmium (0.46-0.78 $mgkg^{-1}$), copper (4.32-26.26 $mgkg^{-1}$), cobalt (4.87-15.61 $mgkg^{-1}$), Chromium (7.34-117.27 $mgkg^{-1}$), lead (20.41-24.52 $mgkg^{-1}$), manganese (687.1-974.44 $mgkg^{-1}$), nickel (20.16-23.38 $mgkg^{-1}$) and zinc (38.57-102.39 $mgkg^{-1}$).

Evaluation of lead and cadmium in cigarettes showed that cigarette tobacco contains high levels of these metals. The lead levels ranged from 6.52-8.82 ugg^{-1} and cadmium levels from 0.84-1.25 ugg^{-1}. Therefore smoking is an important source of lead and cadmium in the environment.

CHAPTER ONE

INTRODUCTION

1.1. BIOLOGICAL ACTIVITY AND TOXICITY OF METALS

Metals are as important as vitamins to the body and are an integral component of the environment and of living matter. Many of them are essential to life, even though they occur only in trace amounts in the body tissues. But metals can be toxic. A metal can be regarded as toxic if it interferes with growth or metabolism of cells when it is present above a given concentration (1). Almost all metals are toxic at high concentrations and some are severe poisons even at very low concentrations. Copper, for example, is a micronutrient, a necessary constituent of all organisms, but if the copper intake is increased above the proper level, it becomes highly toxic. Like copper, each metal has an optimum range of concentration, in excess of which the element is toxic. The toxicity of a metal depends on its route of administration and the chemical compound with which it is bound. The combining of a metal with an organic compound may either increase or decrease its toxic effects on cells. On the other hand, the combination of a metal with sulphur to form a sulphide results in a less toxic compound than the corresponding hydroxide or oxide, because the sulphide is less soluble in body fluids than the oxide (1). Toxicity generally results (a) when an excessive concentration is presented to an organism over a prolonged period of time, (b) when the metal is presented in an unusual biochemical form or (c) when the metal is presented to an organism by way of an unusual route of intake. Less well understood, but perhaps of equal significance, are the carcinogenic and tetratogenic properties of some metals (1).

Toxic effects may appear at the molecular level (biochemical damage) or at cellular and higher levels of organization.

With more advanced damage, the organism as a whole may be affected, leading to impairment of essential life functions and eventually to death.

In assessing the potential impact of levels of a metal in the environment or in the target itself (e.g. human), the terms ´critical concentration´, ´threshold´ (concentration, dose, level) as well as ´no detected effect level´ are often used (2, 3, 4, 5, 6). The first two refer to the lowest level of exposure which is necessary to produce a detectable adverse effect, and the last to the highest level of exposure at which no adverse effects can be detected. To estimate the

´critical´ or ´threshold´ level, use is made of ´dose-response relationships´. These show how the frequency of various effects in a population increase with dose (exposure level), and through proper mathematical calculation, allows the ´apparent threshold´ for each of the effects to be established at a selected level of probability (3,5,6).

1.2. HEAVY METALS OF SPECIAL CONCERN

Heavy metals are arbitrarily defined as those metals having a density at least five times greater than that of water. Such metals occur naturally in the earth´s crust in different concentrations, and in some locations in highly concentrated form, consituting ore deposits. Although metals have many physical properties in common, their chemical reactivity is quite diverse, and their toxic effects on biological systems are even more diverse (1). Only a few are important environmentally. Those likely to cause concern are listed in Table 1, where some data relevant to the assessment have been listed.

Table 1: Some heavy metals of potential environmental concern

Metal	Essential in mammals	Daily intake in adults(mg)	Approx. human body content (mg)
Copper (cu)	Yes	0.07-5.0	100
Cadmium (cd)	No	0.01-0.05	9-40
Mercury (Hg)	No	0.001-0.3	13
Tin (Sn)	Yes	1-40	17
Lead (Pb)	No	0.1-0.5	120
Antimony (Sb)	No	0.01-0.12	8
Vanadium (V)	Yes	1-4	18
Chromium (Cr)	Yes	0.03-0.1	6
Molybdenum (Mo)	Yes	0.1-0.5	9
Manganese (Mn)	Yes	2-9	12
Cobalt (Co)	Yes	0.005-0.004	1.2
Nickel (Ni)	Yes	0.2-0.6	10

References: (7) (8) (9,10) (11)

Man has been exposed more and more widely to metallic contaminants in his environment, resulting from the products of industry. Smelting of ores and refining of metals has been going on for a long time, introducing metals into air and water, but human exposures were usually local: during the past 50 years, they have become fairly general. Exposures to lead have occured in circumscribed areas of the world for 3,000 years or more and were high among the Roman upper classes; the use of lead pipes in soft water areas have lead to sporadic episodes of lead poisoning in persons drinking this water, but not until 1924, when alkyl lead was put into gasoline as an antiknock agent, were whole populations exposed to lead at annual increasing rate (1).

Cadmium was an industrial curiosity in 1900, but today its use is sharply increased with resultant contamination of air, water and food. Mercury has been widely used for amalgamation of gold from crushed ore, but discovery of its catalytic and fungicidal properties has resulted in considerable local contamination from seeds and from the dumping of effluents into stagnant lakes. Currently, man is exposed to metals in amounts exceeding those to which his forbearers were exposed. The earth is rapidly becoming a place where few human beings can be found who are exposed only to background environmental levels. As a result, the human body burden of many metals has considerably increased over that of primitive man (1). In order to comprehend the dangers associated with each metal, data on environmental occurrence, distribution, dietary intake and toxicity to humans is paramount. This is discussed in the following section:

1.3 THE BACKGROUND, HUMAN AND ENVIRONMENTAL IMPACT OF DIFFERENT METALS

1.3.1 ALUMINIUM

1.3.1.1 BACKGROUND

Aluminium is the most abundant of the metallic elements in the earth's crust. It is estimated that aluminium constitutes 8.13% of the igneous rocks; the most abundant aluminium minerals are the aluminosilicates which are inert to further reactions (12,13).

Aluminium is an excellent conductor of both heat and electricity. The high thermal conductivity of the metal, together with its light weight and corrossion resistance, accounts for its general use in the manufacture of cooking utensils.

1.3.1.2 HUMAN AND ENVIRONMENTAL IMPACT

The role of aluminium in the body is not well understood, however, aluminium has been implicated in the analysis encephalopathy (14), where aluminium gels provided a source of Al^{3+} cation. Higher concentrations of aluminium have been found in patients suffering from azheimers diseases which is a form of senile dementia (15). It has been shown further that aluminium inhibits yeast or brain hexokinases and that activation can be restored by various ligands such as phosphate or carboxylate (16). Contrary to popular belief that aluminium is not an environmental hazard, there is sufficient evidence that shows that it is an environmental hazard, for instance: in plants, at concentration <0.1mg/l in nutrient solution it is good for normal plant growth but at concentrations between 0.1-30mg/l it is quite toxic (17). In fish, concentration of 0.07mg/l is lethal (18). In rat, aluminium at 60-220mg/day has been found to be lethal and in man, 2-45mg/day is considered normal but toxic at 5000mg/day (19,9). Therefore, due to preponderance of aluminium cookware, aluminium is ingested by a large proportion of the population. However, no official limit has been established by FAO/WHO.

1.3.2 CADMIUM

1.3.2.1 BACKGROUND

Cadmium occurs in zinc-copper ores: the ratio of cadmium to zinc is usually between 1:100 and 1:1000, depending on the source (20). Zinc ores, therefore, consitute the main industrial source of cadmium and the metal is fractionated during the smelting or electrolytic processes employed for the refining of zinc. World production of refined cadmium began in the late 19th century and increased steadily until 1969 when it reached a peak of over 17,000 tonnes. Since then world production figures have flactuated between 15,000 and 18,000 tonnes per year (21). An insight into the impact of human activities on the global cadmium cycle may be gained when it is noted that atmospheric emissions from man-made sources of the 7,000 tonnes per year exceed those of natural sources by about an order of magnitude (22).

The marked increase in cadmium use during the last three decades has caused a corresponding increase in environmental contamination and in problems caused by exposure at different stages. Cadmium is now used industrially as antifriction agent, as a rust proofer, in plastics manufacture, in alloys, as an orange colouring agent in enamels and paints, in alkaline storage batteries (Nickel-cadmium and silver cadmium) and other purposes (1,23).

Cadmium is released into the air as a result of incineration or disposal of cadmium containing products (for example, rubber tyres and plastic containers) and as a by-product in the refining of other metals, primarily zinc. Rubber tyres can contain 20-90 ug of cadmium due to the use of zinc compounds such as zinc oxide and zinc diakyl carbamates in the vulcanisation process. The abrasion of tyres on road adds cadmium to street dust and mean levels of 2 ugg^{-1} and higher have been reported (25).

The total concentration of cadmium in non-polluted agricultural soils range from 0.01-0.7 ugg^{-1}(25). However, the use of phosphate rock fertilisers containing cadmium (concentration ranging from 1-100 ugg^{-1}) and of sludge from combined industrial and domestic treatment works (concentrations upto 30 ugg^{-1}), are major sources of soil contamination by cadmium (26).

In fresh waters not known to be contaminated, most cadmium levels are below 1 ugl^{-1} (27,20). In contaminated areas, dissolved cadmium levels are mainly dependent upon pH. Concentrations upto 10 ugl^{-1} are found in some mining areas (28).

Cereals such as wheat and rice contain less than 0.1 ugg^{-1}, other food items less than 0.05 ugg^{-1} (29). Concentrations higher by one order of magnitude or more are found in sea food (e.g. shellfish, cattlefish and crabs). Liver and, in particular, kidneys of domestic animals contain high concentrations of cadmium.

1.3.2.2 **HUMAN AND ENVIRONMENTAL IMPACT**

The main pathways of cadmium to man are via inhalation or food intake. Dietary intake is the predominant source of cadmium exposure in the general population but tobacco can be a more important source in smokers due to the high concentration of cadmium in tobacco smoke. Plant-based foodstuffs, particularly cereal products, usually make the largest contribution to dietary intake. Thus, the transfer of cadmium from soil to crop plants is the critical exposure pathway for the general population (22).

The absorbed cadmium is stored mainly in the liver and kidney where it accumulates with age, reflecting the long residence time of the metal in humans. The biological half life of cadmium in human kidneys is over 10 years (22,30). In humans not occupationally or environmentally exposed to a significant degree, the cadmium content of kidneys rises with age upto 40-50 years. This is due to the binding of cadmium to a low molecular weight protein, metallothionein, which is extremely rich in sulphydryl groups and is induced by excess tissue cadmium (30).

There is a limit to the renal storage of cadmium (200-400 $\mu g g^{-1}$) of renal cortex, wet weight), above which renal demage prevents further metal accumulation and results in a decrease in kidney cadmium (30). The amount of cadmium needed to be retained daily to cause impaired kidney function after 50 years is about 10-15 μg (22).

The excretion of cadmium is usually low. In humans with a body burden of 10-60 mg cadmium, the concentration in urine maybe about 0.5-2.0 $\mu g l^{-1}$. Urinary excretion increases with renal damage and therefore the urinary cadmium level in humans is influenced by both the body burden and the degree of kidney impairment (31).

In addition to renal effects, large cadmium body burdens have been associated with effects on bone structure. In one area in Japan, a syndrome termed itai-itai disease had been identified, mainly in females with poor nutritional status. The effects were severe and painful bone damage. Bones were easily fractured and twisted, and the effects took around 5-10 years (and in some cases upto 30 years), to manifest themselves. Symptoms in this particular group were characterized by renal dysfunction and osteomalacia (22). The women had been eating rice grown on rice fields which had been irrigated with cadmium polluted river water. A possible reason why older women were mainly affected was that they also suffered from a deficiency of vitamin D (from a lack of sunshine). This, together with the high cadmium intake, gave rise to the very painful and often fatal disease. Over a 20 year period around 100 people (mostly older women) had died from the disease (24). Elderly females from a city in Belgium have been found to have larger cadmium burdens and a higher prevalence of renal dysfunction compared with an age-matched control population (22).

Hypertension has been atributed to cadmium though the topic is controversial. Respiratory and pulmonary damage is reported to occur from the breathing of cadmium vapour or particulates. Cadmium, unlike mercury and lead, does not affect the central nervous system (24).

1.3.3 COPPER

1.3.3.1 BACKGROUND

Copper is mainly associated with sulphur in its ore minerals, examples are chalcocite, CU_2S, chalcopyrite, $CUFeS_2$ and bornite CU_5FeS_4Pv (24). During the smelting of these ores and refining of the metal, considerable environmental contamination is likely to occur. World production of copper in 1971 stood at 310 x 10^6 tonnes (24). It is largely used by man in the electrical industry in such alloys as brass, in chemical catalysts, and in algicides, wood preservatives and antifouling paints, Insecticides (copper arsenites) and fungicides ($CuSO_4.5H_2O$) (13,24).

1.3.3.2 HUMAN AND ENVIRONMENTAL IMPACT

Since copper is essential for all forms of life, problems appear when it is deficient or in excess. For man, food is the main source of copper intake. Some sources rich in copper are, shell-fish, kidneys, liver and nuts. Poor sources are dairy products, sugar and honey. Soft water, or water with a low pH can leach appreciable amounts of copper from pipes, while carbonated drinks, in the presence of copper can become highly contaminated (24).

The daily human consumption of copper is around 2-5mg, while the required amount for a child is 1 to 1.6mg per day, and for adults 2mg day^{-1} while less than 0.3mg day^{-1} produces deficiency. Approximately 32% of the copper consumed is absorbed, but this varies, for example high calcium and iron intakes reduce copper absorption. Copper is mainly distributed in the liver (storage), kidneys and intestines (24).

Copper deficiency means reduced protein and enzyme activity. Signs of this are anaemia, loss of hair pigment and reduced growth. Menkes kinky hair disease in children is due to a deficiency of cytochrome oxidase, and is fatal by the age 3-5 years. Wilson's disease occurs with excess copper (24).

In order to be toxic, single intakes of copper must be in gram amounts, or continual intakes in excess of 250mg day^{-1}. One effect of copper toxicity is irritation of the gastro-intestinal tract (24).

There are wide variations in the toleration of copper by animals. Trace concentrations one tenth to one twentieth of those accepted in drinking water can kill fish in areas where the water is very soft (low in calcium and magnesium). Exposure to copper may also make fish more prone to die from disease, since it is known to reduce production of certain antibodies. In mammals, ruminants like sheep are poisoned by 20-100 mg/kg body weight copper sulphate (single dose) and cattle by 200-800 mg/kg, whereas swine and rats will tolerate five times as much (1).

1.3.4 COBALT

1.3.4.1 BACKGROUND

Cobalt compounds are found fairly distributed in nature. It has been estimated that the quantity of cobalt in the earth´s crust amount to about only one quarter of nickel. Cobalt is usually obtained as a by-product in the extraction of other metals, particularly copper, nickel and gold (1,13)

Cobalt is not of major industrial importance, since the total annual production of the world does not exceed 3000 tonnes. The most important use of the metal is in the manufacture of a series of alloys known as stellites. These are alloys composed of cobalt and one or more of the metals tungsten, iron, nickel, chromium, molybdenum; these are extremely hard and resistant to corrosion (13).

1.3.4.2 HUMAN AND ENVIRONMENTAL IMPACT

Cobalt is an essential element to all organisms except perhaps green algae and seed plants (32). Its natural compounds include corrins - vitamins B12 and some enzymes (33). Vitamin B12 is a cofactor in a number of enzymes (34). The human adult body contains 2 to 5mg. Deficiency of cobalt leads to pernicions anaemia while in excess, it results in coronary failure and polycythaemia (35).

1.3.5 CHROMIUM

1.3.5.1 BACKGROUND

The chief chromium ore is chromite $FeO.Cr_2O_3$ from which chromium metal is obtained. Chromium is an important industrial metal. It is mainly used in alloys, refractory bricks, electroplating, tanning, paint and wood persevatives (1,13,24).

1.3.5.2 HUMAN AND ENVIRONMENAL IMPACT

Chromium is an essential trace element in both man and animals hence problems appear when it is deficient or in excess. Chromium forms an essential part of the glucose torelance factor, which together with insulin controls the removal of glucose from the blood.

Chromium deficiency leads to incorrect glucose metabolism (36).

Hexavalent chromium has been stated to cause lung cancer after a few years of industrial exposure (1). There is no evidence of hazard from non-occupational exposure. The lifetime of chromium (VI) in the aqueous environment is limited as it is readily reduced to chromium (111) by organic material (24).

1.3.6 IRON

1.3.6.1 BACKGROUND

Iron is the second most abundant element in the earth's crust, being only surpassed by aluminium, with typical concentrations of over 50,000ugg^{-1} in primary igneous rocks. Iron is by far the most important of all the industrial metals. Although it was not the first metal used by man, it has been known and utilized for more than 5000 years. The world s production of iron and steel annually runs to well over a hundred million tonnes (1,37).

1.3.6.2 HUMAN AND ENVIRONMENTAL IMPACT

Iron is very essential for all forms of life. Natural compounds are the porphyrins where over 70 metalloproteins and enzymes that require iron are known (38). In human diet, a level of 6-40mg/day is recommended but levels of 200mg/day is considered toxic (9,39). Deficiency of iron leads to anaemias, while in excess amounts, it causes haemochomatosis and haemosiderosis (35). Acute toxic poisoning leads to vomiting, pallor, shock, haematemesis, circulatory collapse and coma (39).

1.3.7 LEAD

1.3.7.1 BACKGROUND

Lead is relatively abundant in the environment. Whereas the average content of lead in soil and rocks is about $20 \mu g g^{-1}$, in certain even uncontaminated areas the levels can be higher by one order of magnitude. In surface water as well as drinking water lead levels are usually below $10 \mu g l^{-1}$. However, much higher levels can be found in certain soft water areas where lead pipes are still in use (40,41,6).

The major sources of anthropogenic lead in the environment that are of significance arise from the industrial and other technological uses of lead. About half of the lead consumed annually is for the manufacture of storage batteries, about 7 per cent for alkyl lead fuel additives. 15 percent for chemicals, 7 percent for alloys and the rest for various other industries (42).

Worldwide atmospheric lead emissions from human activities have been estimated to total 450,000 tonnes per year compared with just 25,000 tonnes from natural sources. Inorganic lead, produced from combustion of alkyl lead in automobiles, accounts for over half of the man-made emissions. however, in countries where unleaded petrol is being introduced, emissions from this source are rapidly declining. Other major sources include the smelting and refining of the metal itself and certain other metal ores, coal combustion and refuse incineration as well as production of lead-based products (22).

1.3.7.2 HUMAN AND INVIRONMENTAL IMPACT

Humans are exposed to lead via food, air and water: in children, dust, paint and soils may also be important. Food is the main source of lead intake for humans living in rural areas unless specific sources of exposure exist. Dietary intake range from 100-500 μgd^{-1} (43,5). Processed and canned food can contribute significantly to the intake, since food items such as processed milk and fruit juices in lead-soldered cans have been shown to contain high lead levels (43,6,44). Improperly glazed ceramics and other consumer products may contribute to the total lead intake to a varying degree. Poisonous concentrations of lead are found in foods allowed to stand in lead-glazed containers for as little as 1 hour. In 1970, a two-year old child in Montreal died from drinking apple juice kept in a leadglazed jug (45). In adults, lead intake from water is about 10μgdl^{-1} but exposure increases in soft water areas with lead plumbing, and bottle-fed infants can ingest large amounts from this source. Lead intake from the ingestion of dust is considered to be an important source of exposure in certain infants. In adults, the uptake of lead from the gastro-intestinal tract is about 10 percent, in children it is probably much higher. The uptake may increase in cases of low dietary calcium (5).

Uptake of lead from lungs is about 50 percent in adults. Respiratory uptake was reported to account for about 30 percent of total uptake in adults for some urban populations, but is the main source of lead in occupational exposure (22).

Lead taken into the body enters the blood from where it is redistributed to soft tissues and the skeleton. Skeletal tissue is the long-term storage site for lead and contains most of the body burden of the metal. Lead in blood is biologically active and is used not only as an indicator of recent exposure but also to evaluate the likelihood to health effects (22). Blood lead levels less than 80ug/100ml usually indicate very low lead exposure, whereas levels between 80 and 100u g/ml would be consistent with moderate lead exposure, and levels greater than 100 indicate more chronic lead exposure. The values can reach as high as 2000 ug/100ml and correlate exponentially with lead levels (46).

The following manifestations of clinical lead poisoning occur in adults occupationally exposed to high levels of lead: abdominal colic, anaemia, renal damage, neuropathy and, rarely encephalopathy. Recent studies in males indicate a casual relationship between lead exposure and increased blood pressure, although no threshold lead-in-blood level for this effect was evident. Some effects in individuals may be found at lead levels below 60ug/100ml. The toxic effects of lead on the human foetus have prompted restrictions in employment of females of child-bearing age in lead-using industries (22).

Lead induces a variety of biological effects, of which the disturbance of the haem synthesis pathway is best characterized. These include: inhibition of the porphyrin synthesis enzyme, δ-amino-levulinic acid dehydratase (ALA-D):inhibition of iron incorporation into the porphyrin which results in elevated levels of free erythrocyte protoporphyrins (FEP): other changes in the porphyrin metabolism resulting in increased levels of corproporphyrin have also been reported (6).

1.3.8 MANGANESE

1.3.8.1 BACKGROUND

Manganese, an essential trace metal, is one of the more abundant elements in the earth´s crust and in soils, waters and living things. Mining of manganese ores, metallurgical processing and other industrial uses can cause pollution with fumes, dust and aerosols, chiefly of manganese oxides. Some environmental contamination can also come through the use of manganese compounds in making linoleum, matches, fireworks and dry cells, through the use of organo-manganese fuel additives and from the use of the metal in fertilizers and fungicides (1).

1.3.8.2 HUMAN AND ENVIRONMENTAL IMPACT

Humans are exposed to manganese via inhalation and food intake. The daily manganese requirement for man is estimated at about 3 mg, and this is probably covered by food intake (47).

In view of the relatively small quantity of manganese in food, oral manganese intake is only very rarely the cause of chronic manganese poisoning (47). Manganese poisoning especially as a result of high-speed drilling of alloys, which produces large amounts manganese dioxide dust is a potential industrial hazard. Excessive inhalation has caused pneumonia among industrial workers and inhalation and ingestion of heavily contaminated water have also been reported as associated with chronic and irreversible brain disorder resembling parkinson's disease (1).

1.3.9 NICKEL

1.3.9.1 BACKGROUND

Nickel is widely distributed throughout the earth's crust and is a relatively plentiful element. It occurs in marine organisms, is present in the oceans and is a common consituent of plant and animal tissues (48).

Nickel is frequently used as a catalyst and in nickel plating. Its most important use is in the manufacure of special alloy steels and cast irons (13).

1.3.9.2 HUMAN AND ENVIRONMENTAL IMPACT

Man may take in nickel through contaminated food. Foods can be contaminated with nickel during handling, processing and cooking by utensils containing large quantities of nickel. Nickel usually is not readily absorbed from the gastro-intestinal tract except as nickel carbonyl, $Ni(CO)_4$, which is a higly toxic industrial product. Nickel at high concentration is a potent carcinogen in that it has been implicated in hypersensitivity reactions, cancer of the nasal passages and sinuses (1,48).

1.3.10 ZINC

1.3.11 BACKGROUND

The principal ore of zinc is the sulphide, zinc blende, Zns, from which zinc is extracted. A large proportion of the world's production of the primary and secondary zinc finds its way into the industry in the metallic form, as in various types of brass, rolland zinc sheet, die-casting alloys and as a protective coating an iron and steel. Important quantities of the metal are also used in the production of white pigments such as zinc oxide and lithopone (1,49).

1.3.12 HUMAN AND ENVIRONMENTAL IMPACT

Zinc is an essential element with a wide margin of safety betwen the levels in diet and those that might cause cumulative toxic effects. It is found in over 80 metalloproteins/enzymes. Its main functions include catalytic as in peptidases and anhydrases and in the stabilization of coiled ribosomes (50). There is no maximum acceptable daily intake recommended by FAO/WHO. However, Ochiai reported that levels between 150-600mg/day is toxic to man and only 5-40 mg/day should be the recommended daily intake (51). In Kenya for instance, the maximum limit in fish products is 150mg/kg

(52). Zinc deficiency in man and animal cause skin-lession, dwarfism and hupogonadism. Higher levels on the other hand cause pulmonary disorder, metal fume fever and drowsiness (35).

1.4 REVIEW OF THE TWO COMMONLY USED ANALYTICAL TECHNIQUES

The two most commonly used analytical methods for environmental contaminants are the atomic absorption spectroscopy and X-ray fluorescence. The following is a brief review of each of these methods.

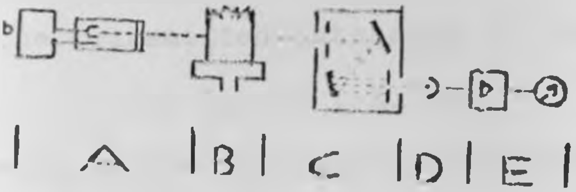
1.4.1 ATOMIC ABSORPTION SPECTROSCOPY

Atomic absorption spectroscopy is a common analyical tool used in many laboratories due to its high sensitivity, accuracy and reproducibility, the ease of sample preparation which incorporates less human error and the comparatively low cost. Recently, environmental contamination by heavy metals has been given serious debate and the introduction of atomic absorption spectroscopy was welcomed by so many researchers (53).

The principle of atomic absorption spectroscopy and the essential components of an atomic absorption spectrometer are discussed in the next section.

1.4.1.1 ATOMIC ABSORPTION SPECTROSCOPY USING A FLAME

The essential components of an atomic absorption spectrometer are shown below:



A is a hollow cathode lamp; B a flame or electrothermal device, C a grating monochromator, D a photomultiplier and E a signal processor.

The hollow cathode lamp emits radiation characteristic of the cathode material, usually a single element (Analyte). This beam, consisting largely of resonance radiation, is electronically or mechanically pulsed. Analyte atoms are produced thermally in the atom reservior. Ground state atoms which predominate under experimental conditions, absorb resonance radiation from the lamp, reducing the intensity of the incident beam. The mono chromator isolates the desired resonance line and allows this radiation to fall on the photomultiplier. An electrical signal is generated.

The electronics of the unit are designed to respond selectively to the pulsed radiation emanating from the radiation source. Signal processing occurs, which results in electronic output proportional to the absorption by the analyte atoms (54). If the part of the radiant energy of the incident light beam absorbed is I_o, the transmitted intensity, I, may be written:

$$I = I_o \exp(-K_v cd)$$

Where K_v is the absorption coefficient and d the average thickness of the absorbing medium, that is, the path length of the flame horizontally (55).

1.4.1.2 ACCURACY AND SENSITIVITY OF ANALYSIS

The analytical methodology of atomic absorption spectroscopy is comparatively easy and the human error is small. The accuracy of analysis is very good since the ground state, which has a steady electron configuration is measured. However, there is variability in accuracy between different instruments and different elements. That of the single beam type depends on the stability of the light emission from the lamp: the noise level is higher and the accuracy lower than in the double beam type. The criteria governing the accuracy are (1) the stability of the light source (hollow cathode lamp), which depends on an appropriate current, (2) smooth nebulization and (3) the cleanliness of the burner. The senstivity is defined by the concentration of the metal solution showing 1% absorbance and is expressed in g/ml/1%. The factors affecting sensitivity are (1) the state of the flame, (2) selection of burning gas, (3) efficiency of the nebulizer, (4) working condition of the light source (5) optical system and (6) dispersion ability of the diffraction grating (53).

1.4.2 X-RAY FLUORESCENCE ANALYSIS

X-ray fluorescence analysis has been widely employed at the quality control stage of manufacturing processes. Recently, the kind of environmental contaminants have become very diversified, and it has become necessary not only to measure the density of a certain element by atomic absorption analysis, but also to measure the density of many elements as possible and to measure their chemmical states. X-ray fluorescence analysis by which both quantitative and qualitative analysis can be made without destroying the specimen has been highly estimated and widely used for the analysis of environmental contaminants at various laboratories (53).

1.4.2.1 ADVANTAGES

1. The method provides absolute measurements.
2. The form of the specimen does not affect the measurement that is liquid, powder or lumps can be used directly.
3. Qualitative and semi-quantative analysis are easy to perform.
4. The method is non-destructive, so that the specimen can later be re-analyzed by another method or stored indefinitely.
5. Elements which have a large atomic number than that of fluorine are quantitatively analyzable.
6. Sufficiently strong X-rays give a comparative accuracy of 0.3%. An accuracy of 2-3% is easily attained.
7. Measurement is rapid and easy to make (53).

1.4.2.2 DISADVANTAGES

1. The equipment is rather expensive, so that ordinary investigational facilities and industrial companies are not easily able to afford it.
2. The equipment is too large to carry around.
3. As a rule, the sensitivity is lower than that of other analytical methods such as atomic absorption

analysis (53).

For the present work, analysis of blood and soil samples, the atomic absorption method was more appropriate than the X-ray fluorescence analysis because of the following reasons:

1. The method is more sensitive as stated earlier on.
2. It would not have been possible to analyse cadmium in blood and soil samples using X-ray fluorescence analysis bacause cadmium is used as a source for production of X-rays.

The other methods available for analysis of heavy metals are the polarography and dithizone method (56). These two methods were not used for the analyses of the samples, especially the blood samples because the handling errors would have been greater. For example, the dithizone method involves three extraction stages to avoid various metal interferences and this would have increased chances of contamination. Blood samples are very sensitive to contamination since the levels of the metals being determined is very small (57).

1.4.3 THE PURPOSE OF THE PRESENT STUDY

This was mainly to understand the following:

1. The levels of lead and cadmium in the blood of the general Kenyan population, as a yardstick of the envrionmental pollution by these two metals. The fact that accumulation of cadmium and lead in humans may have different sources means that the best way to estimate total exposure and risks is through biological monitoring. This is possible as we have enough information on metabolism to relate concentrations in certain indicator media and tissues to exposure (dose) and risk to health effects. For this purpose, blood samples were collected from Nairobi Hospital, Kiambu District Hospital and Chemelil Sugar Company´s dispensary. They were obtained from the hospitals because it was easier to get them from there than from other sources. The donors were not suffering from any special disease.

2. The levels of lead and cadmium in pottery since earthenware can be a source of lead poisoning especially when used to prepare or store acidic foodstuffs (45). In our country, pottery is widely used, especially in the rural areas, to

prepare soup from bones, which is acidic.

3. The levels of most of the trace elements in consumable clays in Kenya, particularly volcanic tuff and mahti. These are consumed by pregnant women due to deficiency of minerals in their bodies.

We wish to give a general background and justification for our interest in studying volcanic tuff and mahti as source of trace metals in the human body. It is a well known fact that craving for certain types of things or foods in pregnant women is not abnormal. We have observed many instances in rural areas and urban centres like Nairobi, expectant mothers eating soil from many sources which may include new construction sites, quarries, mud houses and anthills, just to mention a few. It is believed that the eating of earth by pregnant women is probably due to a deficiency of iron and other elements in the body. However, the consumption of soil can be addictive leading to continual post pastrum use.

Since soils contain both toxic and non-toxic organic and inorganic substances which can be quite harmful not only to the health of the mother but also to the infant, we decided to carry out heavy metal analysis in volcanic tuff and mahti (soils)sold in Nairobi's city markets. Before this study was initiated, a preliminary survey at Gikomba market showed that a substantial amount of this special clay was being consumed. We found that between 50-100kg of the tuff was consumed weekly.

4. The levels of lead and cadmium in some local brands of cigarettes since tobacco smoke is an important source of cadmium as it has been already stated earlier on in the introduction.

CHAPTER TWO

EXPERIMENTAL PROCEDURE

2.1 APPARATUS

All apparatus were thoroughly washed with tap water, rinsed with dilute nitric acid and then with deionized water and dried.

2.2 CHEMICALS

These were purchased from the British Drug Houses (B.D.H.), Hopkin and Williams Ltd., E. Merck and Darmstadt, F.R. Germany and Kel Chemicals Ltd. and were used without further purification.

2.3 PREPARATION OF STANDARDS

Standards were prepared from the analytical grade of the salt of the metal. Some were bought already prepared. The following table gives a summary of how the standards were prepared.

Table 2

Metal	Salt or Metal Solution	Diluent 250 ml	Concentration (ppm)
Pb	$Pb(NO_3)_2$	1%V/V HNO_3	1000
Cd	$CdCl_2 2\frac{1}{2}H_2O$	1%V/V HCl	1000
Mn	$MnSO_4.H_2O$	H_2O	1000

Zn	$Zn(NO_3)_2.6H_2O$	H_2O	1000
Co	$Co(NO_3)2.6H_2O$	H_2O	1000
CU	$CUSO_4.5H_2O$	H_2O	1000
Ni	$Ni(NO_3)_2.6H_2O$	H_2O	1000
Fe	$Fe(NO_3)_3$ Standard solution	-	1000
Al	$Al(NO_3)_3$	-	1000
Cr	K_2CrO_4	H_2O	1000

2.4 INSTRUMENTS

Spectrophotometer: A Perkin-Elmer Model 2380 Atomic Absorption spectrophotometer

pH-Measurements: These were done with a pye unicam model 292 MK 2 pH meter.

Muffle furnace: N3A SIMON MULLER

2.5 SAMPLING

Blood samples were collected from Nairobi Hospital, Kiambu Hospital and Chemelil Sugar Company's dispensary. Pottery and soil samples were collected from the following areas, especially from Kisumu, Kakamega and Muranga because that is where most of the pottery in this country is made.

The blood was got from the person using hypodermic needles and syringes and put in vials previously treated with a anti-coagulant. Those from Chemelil had to be stored in a fridge since they could not be analysed on the same day they were donated.

Pot Samples	Where Collected
P1	Kisumu
P2	Kisumu
P3	Muranga
P4	Kisumu
P5	Taita-Taveta
P6	Mombasa
P7	Museum
P8	Kakamega
P9	Kakamega
P10	Kakamega
P11	Muranga

Soil Sample	Where Collected
S1	West Nyakach Saangoro
S2	Rakwaro Awach River
S3	Kasae South Nyanza border
S4	Jimo Olwalo
S5	Kasae West Nyakach

S6	West Nyakach Oduogo Kasae
S7	Rateng Kisogo River Agoro

Volcanic tuff samples were bought from Gikomba Market in Nairobi and mahti from one of the shops in the city. Cigarette brands were obtained from the local shops.

2.6 TREATMENT AND DIGESTION OF SAMPLES

Pot and soil samples, volcanic tuff and mahti were first thoroughly ground to fine powder using a pestle and mortar. They were then dried in an oven for one hour at temperatures between 100°C and 105°C. After cooling, they were stored in clean, dry plastic containers ready for digestion. Cigarette tobacco was first dried at the same temperatures before grinding in a mortar. This was ashed immediately after weighing.

2.6.1 DIGESTION OF SAMPLES

BLOOD SAMPLES

Each sample was drawn from the vial using a micro-litre pipette into a clean 100 ml conical flask. To the sample (2 ml) was added 6ml of concentrated nitric acid, 2 ml of concentrated sulphuric acid and 2 ml of concentrated perchloric acid. The mixture was heated over a hot plate to almost dryness and the residue dissolved in 4 ml of 2M hydrochloric acid by heating (58). After cooling, the solution was transfered into a 10 ml volumetric flask. After several rinsings of the conical flask with de-ionized water, the volume of the sample solution was made up to 10 ml. This was ready for analysis.

2.6.2 BLANK SAMPLES

2 ml of de-ionized water was treated similarly as the blood sample.

2.6.3 POTTERY, SOIL SAMPLES, TUFF AND MAHTI

The amounts of each of the above substances weighed varied between 2 and 3gm. To the weighed amount of each sample was added 15ml of concentrated nitric acid and 45ml of concentrated hydrochloric acid in a round-bottomed flask. After putting boiling chips, the mixture was refluxed for 2 to 3 hours (59). After cooling and settling down of the residue, the liquid portion was filtered (using filter paper No.42) into a 150ml beaker. After several rinsings of the residue in the flask with de-ionized water, the final volume in the beaker came upto about 125ml. This was then evaporated to about 10ml on a hot plate. After cooling, the solution was transferred into a 50ml volumetric flask. After several rinsings of the beaker, the final volume in the flask was made upto 50 ml. This was ready for analysis.

2.6.4 CIGARETTE TOBACCO

2.0 gm of the grounded tobacco was weighed in a silica crucible and dry ashed in a muffle furnace at about 500°C. This was done by gradually raising the voltage from 0 to 110 volts in steps of 10 volts and then held at final voltage for 3 hours. After the ashing was over and cooling of the ash and crucible for about 10 minutes, it was transferred into a beaker, added 2 ml of concentrated nitric acid and 1 ml of 30% hydrogen peroxide. This was then evaporated to dryness on a hot plate, with the beaker covered by a watch glass. The procedure was repeated with 2 ml of nitric acid only (60). After cooling, the beaker and the residue were washed with de-ionized water and the solution filtered into a 25 ml volumetric flask. This was done several times and the volume made upto the mark. This was ready for analysis.

2.7 LEACHING OF LEAD AND CADMIUM FROM POTTERY

Acidic solutions of different pH values were prepared using analar nitric acid (70%) and de-ionized water. For example, solutions of the pH values quoted below were made in the manner described alongside:

pH(2.1) - Pipetted 1 ml of the nitric and made up to 2 litres in a 2-litre flask using de-ionized water.

pH(4.1) - Pipetted 10 microlitres of the same nitric acid and made upto 2 litres.

pH(5.8) - Measured 16 ml of the acidic solution of PH(4.1) and then diluted to 2 litres.

Acidic blank solutions were obtained from each of the above prepared solutions, that is, 25ml of each solution was reserved as a blank in a 25 ml volumetric flask.

After measuring the pH of each solution and reserving 25 ml as a blank, the remainder was boiled in the pot until 40-50 ml of the solution remained. This solution was transferred into a clean 100 ml beaker using a clean pipette. After cooling, the pH was measured. It remained the same within limits of experimental error. The solution was then evaporated on a hot plate until the volume was about 15 ml. After cooling, it was transferred by filtering into a 25 ml volumetric flask. After several rinsings of the beaker and filter paper with de-ionized water, the final volume was made up to the mark. This was ready for analysis.

For each pot, the analysis was done in duplicate. Different PH values were used because the leaching effect of the acid depends on its PH value.

CHAPTER THREE

RESULTS AND DISCUSSION

3.1 LEAD CONCENTRATION IN BLOOD

Majority of the samples (96%) had levels below 20 μgdl^{-1} which was the detection limit of the instrument. It would be logical to say that majority of the blood samples contained the ´normal´ values of lead. The full details are given in the Tables below: Each value is an average of two replicates.

TABLE 3: Levels of lead in blood (μgdl^{-1}) from Nairobi Hospital

Sample No	Lead Conc. Mean	S.D.	Occupation
BN1	n.d	-	-
BN2	n.d	-	-
BN3	112.5	0	-
BN4	n.d	-	-
BN5	110.5	-	-
BN6	n.d	-	-
BN7	118.5	0	-
BN8	n.d	-	-
BN9	n.d	-	-
BN10	n.d	-	-
BN11	n.d	-	-
BN12	n.d	-	-
BN13	n.d	-	-
BN14	n.d	-	-
BN15	n.d	-	-
BN16	n.d	-	-
BN17	n.d	-	-
BN18	n.d	-	-
BN19	n.d	-	-
BN20	n.d	-	-

BN21	n.d	-	-
BN22	n.d	-	-
BN23	n.d	-	-
BN24	n.d	-	-
BN25	n.d	-	-
BN26	n.d	-	-
BN27	n.d	-	-
BN28	n.d	-	-
BN29	n.d	-	-
BN30	n.d	-	-
BN31	n.d	-	-
BN32	n.d	-	-
BN33	n.d	-	-
BN34	n.d	-	-
BN35	n.d	-	-
BN36	n.d	-	-
BN37	n.d	-	-
BN38	n.d	-	-
BN39	n.d	-	-
BN40	n.d	-	-
BN41	n.d	-	-
BN42	n.d	-	-
BN43	n.d	-	-
BN44	n.d	-	-
BN45	n.d	-	-
BN46	n.d	-	-
BN47	n.d	-	-
BN48	n.d	-	-
BN49	n.d	-	-
BN50	n.d	-	-
BN51	n.d	-	-
BN52	n.d	-	-
BN53	n.d	-	-
BN54	n.d	-	-
BN55	n.d	-	-
BN56	n.d	-	-
BN57	248.0	0	-
BN58	n.d	-	-
BN59	n.d	-	-
BN60	n.d	-	-
BN61	n.d	-	-
BN62	n.d	-	-
BN63	n.d	-	-
BN64	n.d	-	-
BN65	n.d	-	-
BN66	n.d	-	-
BN67	n.d	-	-
BN68	n.d	-	-
BN69	n.d	-	-
BN70	n.d	-	-
BN71	n.d	-	-

BN72	n.d	-	-
BN73	n.d	-	-
BN74	n.d	-	-
BN75	n.d	-	-
BN76	n.d	-	-
BN77	n.d	-	-
BN78	n.d	-	-
BN79	n.d	-	-
BN80	n.d	-	-
BN81	256.7	0	-
BN82	n.d	-	-
BN83	n.d	-	-
BN84	n.d	-	-
BN85	n.d	-	-
BN86	n.d	-	-
BN87	n.d	-	-
BN88	n.d	-	-
BN89	n.d	-	-
BN90	n.d	-	-
BN91	n.d	-	-
BN92	224.7	0	-
BN93	n.d	-	-
BN94	n.d	-	-
BN95	n.d	-	-
BN96	n.d	-	-
BN97	n.d	-	-
BN98	n.d	-	-
BN99	n.d	-	-
BN100	n.d	-	-
BN101	n.d	-	-
BN102	n.d	-	-
BN103	n.d	-	-
BN104	n.d	-	-
BN105	n.d	-	-
BN106	n.d	-	-
BN107	n.d	-	-
BN108	n.d	-	-
BN109	n.d	-	-
BN110	n.d	-	-
BN111	n.d	-	-
BN112	n.d	-	-
BN113	n.d	-	-
BN114	n.d	-	-
BN115	n.d	-	-

Table 4: Levels of lead in $\mu g dl^{-1}$ from Kiambu Hospital

Sample No.	Lead Conc. Mean	S.D	Occupation
BK1	n.d	-	Farmer
BK2	n.d	-	Labourer
BK3	n.d	-	Student
BK4	n.d	-	Student
BK5	n.d	-	Student
BK6	n.d	-	Student
BK7	n.d	-	Student
BK8	159.4	0	Student
BK9	n.d	-	Student
BK10	n.d	-	Student
BK11	n.d	-	Business man
BK12	n.d	-	-
BK13	n.d	-	Farmer
BK14	n.d	-	-
BK15	n.d	-	Teacher
BK16	n.d	-	House wife
BK17	n.d	-	House wife
BK18	n.d	-	Clerk
BK19	n.d	-	Farmer
BK20	n.d	-	House wife
BK21	n.d	-	Clerk
BK22	n.d	-	-
BK23	n.d	-	Business man
BK24	n.d	-	House wife
BK25	n.d	-	House wife
BK26	n.d	-	House wife
BK27	n.d	-	House wife
BK28	n.d	-	Policeman
BK29	n.d	-	Student
BK30	n.d	-	House wife
BK31	n.d	-	Tailor
BK32	n.d	-	Business man
BK33	n.d	-	Prisoner
BK34	178.0	-	Business man
BK35	n.d	-	Farmer
BK36	n.d	-	Policeman
BK37	n.d	-	Student
BK38	n.d	-	House wife
BK39	n.d	-	-
BK40	n.d	-	Student
BK41	n.d	-	Student
BK42	n.d	-	Student
BK43	n.d	-	Student

BK44	n.d	-	Student
BK45	n.d	-	Student
BK46	n.d	-	Student
BK47	n.d	-	Student
BK48	n.d	-	Student
BK49	n.d	-	Student
BK50	n.d	-	House wife
BK51	n.d	-	House wife
BK52	n.d	-	House wife
BK53	n.d	-	House wife
BK54	n.d	-	-
BK55	n.d	-	-
BK56	n.d	-	House wife
BK57	n.d	-	House wife
BK58	n.d	-	Civil servant
BK59	n.d	-	Civil servant
BK60	n.d	-	Farmer
BK61	n.d	-	House wife
BK62	n.d	-	House wife
BK63	n.d	-	Civil servant
BK64	n.d	-	House wife
BK65	n.d	-	Civil servant
BK66	n.d	-	House wife
BK67	n.d	-	Farmer
BK68	n.d	-	House wife
BK69	n.d	-	-
BK70	n.d	-	Labourer
BK71	n.d	-	-
BK72	n.d		Student
BK73	n.d	-	Civil servant
BK74	n.d	-	Civil servant
BK75	n.d	-	Civil servant
BK76	n.d	-	House wife
BK77	n.d	-	House wife
BK78	n.d	-	House wife
BK79	n.d	-	Student
BK80	n.d	-	Student
BK81	n.d	-	Student
BK82	n.d	-	Student
BK83	n.d	-	Student
BK84	n.d	-	Student
BK85	n.d	-	Student
BK86	n.d	-	Student
BK87	n.d	-	Student
BK88	n.d	-	Student
BK89	n.d	-	Student

Table 5: Levels of lead in blood (Ugdl^{-1}) from Chemelil Dispensary

Sample No.	Lead Conc. Mean	S.D	Occupation
BC1	n.d	-	F. Worker
BC2	n.d	-	F. Worker
BC3	n.d	-	F. Worker
BC4	n.d	-	F. Worker
BC5	n.d	-	F. Worker
BC6	n.d	-	F. Worker
BC7	n.d	-	House wife
BC8	n.d	-	F. Worker
BC9	n.d	-	F. Worker
BC10	n.d	-	F. Worker
BC11	n.d	-	F. Worker
BC12	n.d	-	F. Worker
BC13	n.d	-	F. Worker
BC14	n.d	-	House wife
BC15	n.d	-	Barmaid
BC16	n.d	-	-
BC17	n.d	-	F. Worker
BC18	n.d	-	House wife
BC19	n.d	-	F. Worker
BC20	n.d	-	F. Worker
BC21	n.d	-	Barmaid
BC22	n.d	-	F. Worker
BC23	n.d	-	-
BC24	n.d	-	F. Worker
BC25	n.d	-	F. Worker
BC26	n.d	-	F. Worker
BC27	n.d	-	F. Worker
BC28	n.d	-	F. Worker
BC29	n.d	-	F. Worker
BC30	n.d	-	F. Worker
BC31	n.d	-	F. Worker
BC32	n.d	-	F. Worker
BC33	n.d	-	F. Worker
BC34	n.d	-	House wife
BC35	n.d	-	House wife
BC36	n.d	-	-
BC37	n.d	-	F. Worker
BC38	n.d	-	F. Worker
BC39	232.4	0	F. Worker
BC40	n.d	-	F. Worker
BC41	n.d	-	F. Worker

BC42	n.d	-	F. Worker
BC43	n.d	-	F. Worker
BC44	n.d	-	F. Worker
BC45	n.d	-	F. Worker
BC46	n.d	-	F. Worker
BC47	n.d	-	F. Worker
BC48	n.d	-	F. Worker
BC49	n.d	-	Student
BC50	n.d	-	Farmer
BC51	n.d	-	F. Worker
BC52	n.d	-	F. Worker

From the tables it can be seen that nine samples indicated high values of lead (over 100 ugdl^{-1}). Six of these were from Nairobi, two from Kiambu and one from Chemelil. Nairobi, had the highest percentage of samples which showed lead (5%) whereas the other smaller towns had lower percentages (2%). The mean lead levels were as follows: 9.3 ugdl^{-1} for the Nairobi samples; 3.7 ugdl^{-1} for the Kiambu samples and 1.8u gdl^{-1} for the Chemelil samples.

It is interesting to note that seven out of these nine samples which indicated high levels of lead also indicated high levels of cadmium. Therefore these samples were rather exceptional cases. However, it was not unusual to have obtained such values as lead body burdens as high as 2000 ugdl^{-1} have been reported (46). Since the blood samples studied were not from people occupationally exposed to lead, food intake and inhalation were most probably the contributing factors to the high levels of lead in the blood.

To compare the values that we obtained with those found in other countries, we have reported the latter in the tables that follow.

Table 6: Blood lead concentrations ($\mu g dl^{-1}$) reported from Belgium, Malta, Mexico and Sweden, (1981-1983) (61).

Country	Year	n	Mean	S.D
Belgium	1981	50	16.5	3.9
	1983	25	13.7	1.9
Malta	1981	195	30.7	11.9
	1983	36	24.3	7.0
Mexico	1981	21	26.9	7.7
	1983	19	13.5	4.8
Sweden	1981	31	8.3	3.8
	1983	27	5.9	3.1

n - Number of subjects

S.D.- Standard deviation

Table 7: Lead in blood (μgdl^{-1}) in adults as reported from other countries (62).

Area	Population	n	Mean
France	R	95	27.8
Italy	(Milan)	142	24-46
Japan	U(Hokkaido) U(Tokyo, Okinawa)	308	7
Nepal	R	60	4
Netherlands	U(Amsterdam)	145	14
Papua Guinea	R(Children, 7-10 years)	100	5
U.K.	U(London)	50	29
	U(Glasgow)	30	13.5
	U(Birmingham)	78	29-45
U.S.A.	U(Newyork)	15	15
	U(Chicago)	747	20-48
	U(Chicago, 10-14 years)	746	23.5
	U(San Diego)	86	27

R = Rural U = Urban

The Tables show that lead levels in the blood of general populations are usually less than 40 μgdl^{-1}. Thus the values that we obtained for majority of the samples suggest low exposures to the metal. Therefore the lead levels in blood of the general Kenyan population are low and measures should be taken to maintain such low levels of the metal in the environment as in Sweden which is a developed nation.

3.2 Cadmium Concentration in Blood

The levels in the samples from Nairobi, Kiambu and Chemelil are given in the following tables: As in the case of lead analysis, each value is an average of two replicates.

Table 8: Levels of Cadmium in blood ($ugdl^{-1}$) from Nairobi Hospital.

Sample No	Cadmium Conc.		Occupation
	Mean	S.D	
BN1	n.d	-	-
BN2	n.d	-	-
BN3	n.d	-	-
BN4	n.d	-	-
BN5	22.5	2.5	-
BN6	n.d	-	-
BN7	25.5	2.5	-
BN8	n.d	-	-
BN9	17.5	2.5	-
BN10	n.d	-	-
BN11	n.d	-	-
BN12	17.5	2.5	-
BN13	n.d	-	-
BN14	n.d	-	-

BN15	n.d	-	-
BN16	n.d	-	-
BN17	n.d	-	-
BN18	12.5	-	-
BN19	n.d	-	-
BN20	15.0	5.0	-
BN21	n.d	-	-
BN22	n.d	-	-
BN23	n.d	-	-
BN24	n.d	-	-
BN25	n.d	-	-
BN26	n.d	-	-
BN27	n.d	-	-
BN28	n.d	-	-
BN29	n.d	-	-
BN30	n.d	-	-
BN31	n.d	-	-
BN32	n.d	-	-
BN33	n.d	-	-
BN34	n.d	-	-
BN35	n.d	-	-
BN36	n.d	-	-
BN37	n.d	-	-
BN38	n.d	-	-
BN39	n.d	-	-
BN40	n.d	-	-
BN41	n.d	-	-
BN42	n.d	-	-
BN43	n.d		-
BN44	n.d	-	-
BN45	n.d	-	-
BN46	n.d	-	-
BN47	n.d	-	-
BN48	n.d	-	-
BN49	n.d	-	-
BN50	13.9	1.1	-
BN51	14.0	0	-
BN52	n.d	-	-
BN53	n.d	-	-
BN54	n.d	-	-
BN55	n.d	-	-
BN56	18.4	0	-
BN57	16.7	0	-
BN58	n.d	-	-
BN59	n.d	-	-
BN60	n.d	-	-
BN61	29.4	3.8	-
BN62	18.4	0	-
BN63	n.d	-	-
BN64	n.d	-	-
BN65	n.d	-	-

BN66	n.d	-	-
BN67	7.0	4.8	-
BN68	8.1	4.2	-
BN69	n.d	-	-
BN70	n.d	-	-
BN71	29.5	0	-
BN72	n.d	-	-
BN73	21.7	7.9	-
BN74	21.7	0	-
BN75	26.9	4.5	-
BN76	10.7	2.5	-
BN77	18.3	3.8	-
BN78	11.3	1.9	-
BN79	15.1	5.1	-
BN80	9.0	1.9	-
BN81	21.0	3.7	-
BN82	20.4	0	-
BN83	23.0	0	-
BN84	n.d	-	-
BN85	18.5	2.1	-
BN86	14.8	2.1	-
BN87	n.d	-	-
BN88	n.d	-	-
BN89	n.d	-	-
BN90	10.9	1.6	-
BN91	23.3	2.2	-
BN92	20.0	2.8	-
BN93	n.d	-	-
BN94	n.d	-	-
BN95	n.d	-	-
BN96	n.d	-	-
BN97	n.d	-	-
BN98	n.d	-	-
BN99	n.d	-	-
BN100	n.d	-	-
BN101	n.d	-	-
BN101	n.d	-	-
BN102	n.d	-	-
BN103	n.d	-	-
BN104	n.d	-	-
BN105	n.d	-	-
BN106	n.d	-	-
BN107	19.3	3.2	-
BN108	21.4	2.1	-
BN109	18.9	0	-
BN110	28.3	1.6	-
BN111	16.9	3.1	-
BN112	n.d	-	-
BN113	n.d	-	-
BN114	n.d	-	-
BN115	9.4	1.6	-

Table 9: Levels of Cadmium in blood (μgdl^{-1}) from Kiambu Hospital

Sample No.	Cadmium Conc.		Occupation
	Mean	S.D	
BK1	n.d	-	Farmer
BK2	n.d	-	Labourer
BK3	n.d	-	Student
BK4	n.d	-	Student
BK5	n.d	-	Student
BK6	12.8	0	Student
BK7	n.d	-	Student
BK8	20.2	1.6	Student
BK9	10.0	0	Student
BK10	n.d	-	Student
BK11	n.d	-	Business man
BK12	n.d	-	-
BK13	n.d	-	Farmer
BK14	11.9	0	-
BK15	10.9	1.8	Teacher
BK16	n.d	-	House wife
BK17	n.d	-	House wife
BK18	n.d	-	Clerk
BK19	n.d	-	Farmer
BK20	n.d	-	House wife
BK21	17.3	1.7	Clerk
BK22	6.4	1.7	-
BK23	16.3	0	Business man
BK24	n.d	-	House wife
BK25	n.d	-	House wife
BK26	n.d	-	-
BK27	7.5	1.4	House wife
BK28	12.4	1.6	Policeman
BK29	n.d	-	Student
BK30	19.7	2.7	House wife
BK31	22.4	0	Tailor
BK32	16.0	1.6	Business man
BK33	n.d	-	Prisoner
BK34	16.0	1.6	Business man
BK35	14.2	0	Farmer
BK36	n.d	-	Policeman
BK37	n.d	-	Student
BK38	n.d	-	House wife
BK39	n.d	-	-
BK40	n.d	-	Student
BK41	n.d	-	Student

BK42	n.d	-	Student
BK43	n.d	-	Student
BK44	n.d	-	Student
BK45	n.d	-	Student
BK46	n.d	-	Student
BK47	n.d	-	Student
BK48	n.d	-	Student
BK49	n.d	-	Student
BK50	n.d	-	House wife
BK51	n.d	-	House wife
BK52	n.d	-	House wife
BK53	n.d	-	House wife
BK54	n.d	-	-
BK55	n.d	-	-
BK56	n.d	-	House wife
BK57	n.d	-	House wife
BK58	13.7	2.0	Civil servant
BK59	n.d	-	Civil servant
BK60	n.d	-	Farmer
BK61	n.d	-	House wife
BK62	n.d	-	House wife
BK63	10.2	0	Civil servant
BK64	n.d	-	House wife
BK65	n.d	-	Civil servant
BK66	n.d	-	House wife
BK67	n.d	-	Farmer
BK68	n.d	-	House wife
BK69	n.d	-	-
BK70	n.d	-	Labourer
BK71	n.d	-	-
BK72	n.d	-	Student
BK73	n.d	-	Student
BK73	n.d	-	Civil servant
BK74	n.d	-	Civil servant
BK75	n.d	-	Clerk
BK76	n.d	-	House wife
BK77	n.d	-	House wife
BK78	n.d	-	House wife
BK79	n.d	-	Student
BK80	n.d	-	Student
BK81	n.d	-	Student
BK82	n.d	-	Student
BK83	n.d	-	Student
BK84	n.d	-	Student
BK85	n.d	-	Student
BK86	n.d	-	Student
BK87	n.d	-	Student
BK88	n.d	-	Student
BK89	n.d	-	Student

Table 10: Levels of cadmium in blood (μgdl^{-1}) from Chemelil Dispensary

Sample No.	Cadmium Conc.		Occupation
	Mean	S.D	
BC1	n.d	-	F. Worker
BC2	n.d	-	F. Worker
BC3	n.d	-	F. Worker
BC4	n.d	-	F. Worker
BC5	n.d	-	F. Worker
BC6	n.d	-	F. Worker
BC7	n.d	-	F. Worker
BC8	n.d	-	F. Worker
BC9	n.d	-	F. Worker
BC10	14.7	1.9	F. Worker
BC11	16.7	3.4	F. Worker
BC12	n.d	-	F. Worker
BC13	n.d	-	F. Worker
BC14	n.d	-	House Wife
BC15	17.6	4.7	Barmaid
BC16	12.3	2.1	-
BC17	22.3	2.1	F. Worker
BC18	n.d	-	House Wife
BC19	n.d	-	F. Worker
BC20	25.3	2.9	F. Worker
BC21	21.1	1.7	Barmaid
BC22	n.d	-	F. Worker
BC23	32.3	2.1	F. Worker
BC24	n.d	2.1	-
BC25	5.3	0	F. Worker
BC26	n.d	-	F. Worker
BC27	n.d	-	F. Worker
BC28	n.d	-	F. Worker
BC29	n.d	-	F. Worker
BC30	n.d	-	F. Worker
BC31	10.2	2.8	F. Worker
BC32	n.d	-	F. Worker
BC33	n.d	-	F. Worker
BC34	n.d	-	House wife
BC35	n.d	-	House wife
BC36	n.d	-	-
BC37	n.d	-	F. Worker
BC38	20.0	2.0	F. Worker
BC39	5.4	2.8	F. Worker
BC40	n.d	-	F. Worker
BC41	21.5	0	Teacher
BC42	15.1	0	F. Worker

BC43	10.8	2.6	F. Worker
BC44	n.d	-	F. Worker
BC45	n.d	-	F. Worker
BC46	n.d	-	F. Worker
BC47	n.d	-	F. Worker
BC48	n.d	-	F. Worker
BC49	n.d	-	Student
BC50	7.3	1.5	Farmer
BC51	12.7	4.1	F. Worker
BC52	6.0	2.0	F. Worker

Majority of the samples (72%) that were analyzed for cadmium had levels below 1 ug/100 ml which was the detection limit of the instrument. However, some samples indicated higher levels of cadmium (over 1ugdl^{-1}) implying that there is an increasing amount of the metal in the environment. The mean cadmium levels were as follows: 5.8 ugdl^{-1} for the Nairobi samples; 2.7u gdl^{-1} for the Kiambu samples and 5.3 ugdl^{-1} for the Chemelil samples.

The percentages of the samples from Nairobi, Kiambu and Chemelil which indicated the presence of cadmium were 32%, 18% and 35% respectively. The percentage for Nairobi, an industrial city was almost the same as that of Chemelil. The latter is a small uncountry town situated about 430 km from Nairobi where Chemelil sugar industry is situated. Kiambu town, though situated about 13 km from Nairobi, and surrounding areas had the lowest percentage. The observed trend in percentages seem to imply that most of the cadmium in the blood of

Kenyans is most probably airborne. This deduction is added more weight when it is observed that majority of students (93.8%) and house wives (92.9%) who are less exposed to air-borne cadmium showed little or no cadmium in their blood.

The increasing levels of cadmium in the environment can be attributed to the fact that our country has experienced a rapid industrial development, especially in the manufacture of plastics. Disposing of used plastic materials like plastic paper is also another problem. Plastic, as is well known is of a non-biodegradable material. When burnt, it emits toxic fumes containing cadmium which contribute to air pollution. Its continued use poses a real threat as an environmental pollutant. Similar burning of sugar cane after harvesting in Chemelil Sugar Factory areas increases particulate matter in the air which may attribute to high cadmium levels.

Another possible contributing factor to the increased levels of cadmium is the abrasion of tyres of motor vehicles on the Kenyan roads. It is well known that the volume of traffic, especially in the urban areas is increasing rapidly every year. The consequent abrasion of tyres on the roads increases the amounts of cadmium in the urban environment.

To compare the values that we obtained with those obtained in other countries, we have included the following table.

Table 11: Cadmium in blood (μgdl^{-1}) in adults as reported from different countries (62)

Year	Area	Population	n	Mean
1976	Belgium	U(Liege)	20	0.41
1973	Denmark	U(Aarhus)	110	0.11
1982	India	U,R(Ahmedabad)	36	0.15
1980		U(Ahmedabad)	204	0.81
1979	Japan	U(Hokkaido)	308	0.34
1979	Sweden	U(Stockholm)	39	0.38
1980	U.K.	U(Birmigham)	88	8-1.1
1976	U.S.A.	U(New York)	97	3.3
1974		U(Ann Arbor)	47	1.71
1968		U(19 locations)	243	1.77
1976		U(Philadelphia)	27	0.34-1.11
1972	West Germany	Normals (Serum)	29	22.8
-	Netherlands	U(Arnhem)	138	0.04

R = Rural U = Urban

From the table, it is clear that majority of the samples had levels below 1 μgdl^{-1}. But some had higher levels (over 1 μgdl^{-1}), for example those of the 29 West Germans analyzed in 1972. Our conclusion is that the cadmium levels in the blood of Kenyans are within the range of the levels obtained in other countries and measures need to be taken to control its emission into the environment. However, no sufficient data are at present available for setting limit values for cadmium concentration in blood and for the various indicators of effect (47).

But since the developed countries have started to express concern about the increasing levels of cadmium in their environments, it´s also very important for this country to take similar precautionary measures to protect our precious environment.

Following now is a report on the studies done on some of the sources of lead and cadmium in the environment.

3.3 LEAD AND CADMIUM IN POTTERY

As it had been mentioned in the introduction, pottery can be a source of lead and cadmium poisoning. The following tables show the levels of lead and cadmium in some local pottery and in some of the soils used for pot making. Duplicate analysis of each sample was done.

Table 12: Levels of lead and cadmium (μgg^{-1}) in some local pottery

Pot sample Number	Lead (μgg^{-1})		Cadmium (μgg^{-1})	
	Mean	S.D.	Mean	S.D.
P1	24.27	1.41	0.75	5.5×10^{-2}
P2	37.98	1.21	0.81	2.5×10^{-2}
P3	20.24	0.63	0.91	0
P4	46.29	1.41	0.72	6.3×10^{-2}
P5	16.38	0.98	0.61	7.3×10^{-2}
P6	23.48	0	0.57	2.0×10^{-2}
P7	20.36	0.98	0.67	2.0×10^{-2}
P8 (T)	20.93	0	0.45	2.5×10^{-2}
P8 (B)	28.89	0.58	0.45	2.5×10^{-2}
P9	27.75	1.48	0.55	2.4×10^{-2}
P10 (T)	17.94	0	0.81	2.4×10^{-2}
P10 (B)	17.94	0	0.84	2.4×10^{-2}
P11 (T)	26.49	1.89	0.77	0
P11 (B)	31.40	0	0.93	7.5×10^{-2}

T - Top

B - Bottom

Table 13: Levels of lead and cadmium in some local soils used for pot making. Duplicate analysis of each sample was done.

Soil Sample	Lead (ugg^{-1})		Cadmium (ugg^{-1})	
	Mean	S.D.	Mean	S.D.
S1	26.55	0.95	0.79	$3.6x10^{-2}$
S2	36.33	0.58	0.79	0
S3	25.17	0	0.42	$2.5x10^{-2}$
S4	31.17	0.30	0.91	$1.1x10^{-2}$
S5	16.08	0	0.54	0
S6	30.54	0.58	0.77	$2.5x10^{-2}$
S7	17.73	1.17	0.48	$2.5x10^{-2}$

From the above results, it is clear that the levels of lead and cadmium in some of the locally used pottery are what can be termed as the naturally occurring levels: in normal non-contaminated soil lead content ranges, according to Shacklette (1971), from less than 10 ugg^{-1} to 70 ugg^{-1} (77). The total concentration of cadmium in non-polluted agricultural soils ranges form 0.01-0.7 ugg^{-1} (63).

It is important to note that out of the 11 pots analyzed, only two pots (No.8 and No.10) had been previously used for cooking purposes. The levels of lead and cadmium in them are within the range of those in some other pots, for example pots No.1, 5 and 6, which had not been used for cooking purposes. So it seems that heating does not significantly affect the levels of the metals in the pots.

For the two pots which had been used in cooking, we analyzed the top and bottom parts of the pots. The purpose of doing this was to find out whether there was any consistent pattern in the values of the metals in these two areas of the pots and hence get more evidence as to whether heating affects the levels of the metals in the pots. For pot No.8, the level of lead in the bottom part was higher than in the top part whereas the cadmium levels were the same. For pot No.10, the levels of lead were the same in the top and bottom parts whereas the cadmium levels were different, so it seems that heating does not significantly affect the levels of the metals in the pots.

Though heating does not seem to significantly affect the levels of lead and cadmium in the pots, we did studies to investigate how much of these metals get leached into food during cooking of acidic foodstuffs. The results are shown in the following table.

Table 14: Levels of Lead and Cadmium Leached from Pottery.

PH	Lead	Cadmium
2.1	n.d	n.d
4.1	n.d	n.d
5.8	n.d	n.d

It was found that very little of these metals get into food during cooking. This can be explained for in two ways: first, the levels of lead and cadmium in the pots are low. Secondly, the pots are not glazed. In conclusion, it can be said that the use of local pottery does not contribute much to lead and cadmium toxicity in this country.

The other important source of trace metals which aroused our interest are the consumable clays: volcanic tuff and mahti. These are soils consumed by pregnant women in Kenya due to deficiencies of minerals in the body.

3.4 TRACE ELEMENTS IN CONSUMABLE CLAYS

The levels of trace elements in volcanic tuff, mahti, and geosphere are given in the following tables.

Table 15: The levels of trace elements in Indian tuff (mahti) in (mg/kg) from duplicate analysis of each sample

Metal	Mean	Standard Deviation
Aluminium	49,803	3762.10
Cadmium	0.78	0.16
Copper	26.26	0.71
Cobalt	15.61	0.93
Chromium	117.27	8.30
Iron	19.117	1044.70
Lead	24.52	2.99
Nickel	28.38	2.50
Manganese	406.76	18.72
Zinc	38.57	9.65

TABLE 16: THE LEVELS OF TRACE ELEMENTS IN THREE TUFF SAMPLES IN MG/KG

Metal	Sample Number 1		Sample Number 2		Sample Number 3	
	Mean	S.D.	Mean	S.D.	Mean	S.D.
Aluminium	30,258	5212.10	31,322	1299.20	28,889	733.91
Cadmium	0.44	$2.2x10^{-2}$	0.35	$3.1x10^{-2}$	0.58	$3.0x10^{-2}$
Copper	5.65	0.42	3.76	0.57	3.55	0.30
Cobalt	3.62	0.22	4.82	$9.7x10^{-2}$	6.18	0.23
Chromium	5.97	1.14	7.43	0.62	8.63	1.09
Iron	24,693	1771.30	40,655	2749.60	34,335	1457.30
Lead	20.55	0.81	21.00	0.38	19.69	0
Nickel	26.08	7.25	15.27	0.62	19.12	1.15
Manganese	457.57	52.03	974.44	78.42	629.29	13.26
Zinc	93.14	9.05	109.35	9.48	104.67	7.97

TABLE 17: TRACE ELEMENTS IN GEOSPHERE

	CONCENTRATIONS (mg/kg)					
Metal	Granite	Basalt	Soil	Shale	Limestone	Sandstone
Al	77,000	87,600	71,000	88,000	9,000	43,000
Cd	0.09	0.13	0.35	0.22	0.028	0.05
Cr	4	90	70	90	11	35
Co	1	35	8	19	0.1	0.3
Cu	13	90	30	39	5.5	30
Fe	27,000	56,000	40,000	48,000	17,000	29,000
Pb	24	3	35	23	5-7	10
Mn	400	1,500	1,000	850	620	460
Ni	0.5	150	50	68	7	9
Zn	52	100	90	120	20	30

References: 64, 65, 66, 67, 68, 69

3.4.1 Aluminium

The average concentration found in volcanic tuff (30,156 ± 1219.7) and mahti (49,803 ± 3762.10) in mg/kg is very high as compared to that found in plants: 30-530mgkg-1 and edible vegetables: 0.1-2.00mgkg-1 (70). But relatively low when compared to that found in the geosphere (Table 17). It can be said therefore that those women who ingest large amounts of volcanic soil (from Gikomba market) and also mahti may be at risk from excessive aluminium exposure.

3.4.2 Cadmium

The values obtained in tuff (0.35-0.53) and mahti (0.78±0.16) in mg/kg are higher than those in the uncontaminated geosphere (Table 17). The values however, fall within the range of cadmium in land plants (0.1-2.4mgkg-1) and edible vegetables (0.05-0.9mgkg-1) (69). As for toxicity, the values indicate that consumption of tuff and mahti may increase the chances of cadmium toxicity to the consumer, since the recommended daily intake should not exceed 0.015mg day-1 (71).

3.4.3 Copper

The highest concentration found in volcanic soil was 5.65mgkg-1 and 26.26mgkg-1 in mahti. These values are quite low when compared to the values of sediment soils found in the Winam Gulf of Lake Victoria (72) and in geosphere (Table 17). But fall within the range found in land plants: 5-15mgkg-1 and edible vegetables: 4-2mgkg-1 (73). In human diet, the levels of 6mg/day are considered toxic (39).

3.4.4 Cobalt

The three volcanic tuff samples analyzed showed cobalt levels ranging from 3.62-6.18 mg/kg. The level in mahti was 15.61 mg/kg. These values are much lower than those obtained in basalt, soil and shale but are relatively higher than those found in granite, limestone and sandstone (Table 17). They are higher than those found in land plants: 0.005-1 mg/kg and edible vegetables: 0.01-4.6 mg/kg (74). The toxic levels in human diet has been reported at 500mg/day (39), therefore consumption of tuff and mahti may not pose serious threat to normal body function due to cobalt.

3.4.5 Chromium

Our values of 5.97-8.63 mg/kg in volcanic tuff are lower than those found in the geosphere with the exception of granite. (Table 17). The value of 117.27 mg/kg found in mahti was higher but close to those found in basalt and shale (90 mg/kg). However, the values with the exception of the value in mahti, are within the range reported in land plants (0.03-10mg/kg) and edible vegetables: 0.016-14mg/kg (74).

3.4.6 Iron

The three tuff samples showed big variations in the iron content unlike the other elements. These may be attributed to local geological differences. The values ranged from 24,693 to 40,655 mg/kg. The value in mahti was lower, 19,117 mg/kg. These values are quite high as expected for contaminated soils. For instance, the high level of 40,655 mg/kg represents a level of about 4.3%. It is quite comparable to those values obtained in the sewage sludges (40,088 mg/kg) in Kariobangi and values of 41,775 and 15,620 mg/kg obtained in manure and fertiliser respectively (75). The values also fall within those obtained in the geosphere (Table 17). They are, however, many orders of magnitude than those found in land plants 70-700 mg/kg and edible vegetables : 2-250 mg/kg (39).

3.4.7 Lead

The three tuff samples showed an average concentration of lead of 20.41 mg/kg and that in mahti being 24.52 mg/kg. These concentrations are similar to those obtained in uncontaminated soils (72), in geosphere (Table 17) and fall within those found in land plants: 1-13 mg/kg and edible vegetables: 0.2-20 mg/kg (39).

3.4.8 Manganese

In the three tuff samples that we analyzed, concentrations of 457.57, 974.44 and 629.29 mg/kg were obtained. The value in mahti was 406.76 mg/kg. They are within the range obtained in the geosphere (Table 16) and the values found in land plants: 20-700 mg/kg and edible vegetables: 0.3-1000 mg/kg (76). The variation of the manganese content found in this study can be attributed to local geological differences.

3.4.9 Nickel

The levels reported here in of 15.27-26.08 mg/kg in tuff and 28.38 mg/kg in mahti are quite low as compared to those found in basalt, soil and shale but are relatively higher than those in limestone, sandstone and granite. This may be attributed to its high adsorption on the soil particles limiting its availability. However, the values reported in this study are about five times those determined in land plants: 1-5 mg/kg and edible vegetables. 0.02-4 mg/kg (74, 39).

In human diet, the normal level is 0.03 mg/day but becomes toxic at 50mg/day and lethal at 30mg/day (39). It is thus possible that consumption of tuff and mahti may increase the nickel intake to toxic levels since only trace amounts are required for normal biological functions.

3.4.10 Zinc

Our results show no big variation in the three tuff samples. The average value in tuff was 102.39 mg/kg and that in mahti 38.57 mg/kg. These values are comparably as high as those obtained in the geosphere (Table 17) and from plants (59-233.mg/kg) and in sludge soils of Kariobangi (75).

Let's now look at cigarettes as an important source of cadmium.

3.5 LEAD AND CADMIUM IN CIGARETTES TOBACCO

As it had been mentioned earlier on in the introduction, cigarettes smoking is an important source of cadmium in the human body (for smokers) and in the environment. We, therefore, considered it is very important to understand the levels of cadmium and lead in some local brands of cigarettes and compare these values with those obtained in other countries.

The following tables show the values of lead and cadmium in some local brands of cigarettes and in some cigarettes from the developed countries.

Table 18: Levels of cadmium and lead in some local brands of cigarettes in μgg^{-1}.

Cigarette intials	Cadmium (μgg^{-1})		Lead (μgg^{-1})	
	Mean	S.D.	Mean	S.D.
S.M.	0.84	3.6×10^{-2}	6.52	0
T.C.	0.94	0	7.37	4.0×10^{-2}
E.C.	0.81	1.8×10^{-2}	6.52	0
S.C.	0.79	3.6×10^{-2}	6.52	0
W.C.	1.01	5.6×10^{-2}	6.81	0
Unprocessed Tobacco	1.25	5.6×10^{-2}	8.82	0

As the table shows, those who smoke unprocessed tobacco are likely to inhale larger amounts of lead and cadmium than those who smoke processed tobacco. This is probably due to the fact that some amounts of these metals are lost during industrial processing, for example when drying the leaves.

The mean cadmium levels were $0.94 \pm 0.16 \mu gg^{-1}$ whereas the mean lead levels were $7.09 \pm 0.83 \mu gg^{-1}$.

To compare the values of the metals in the local cigarettes with those obtained in other countries, we have included the following table.

Table 19: The mean contents of trace elements in filter cigarette tobacco as reported from different countries (77).

Sampling time and place	Number of different brands	Cd ($\mu g g^{-1}$) Mean	Cd ($\mu g g^{-1}$) S.D	Pb ($\mu g g^{-1}$) Mean	Pb ($\mu g g^{-1}$) S.D
1920's Finland	2	1.4	0.4	3.4	1.1
1940's Finland(+)	1	1.0		2.2	
1966-67 Finland	5	1.7	0.4	3.3	1.5
1978 Finland	1	1.3		2.2	
1980-82 Finland	4	1.9	0.6	1.7	0.6
1984 Finland	1	0.7		1.3	
1980's England	11	-		5.3	
1957 U.S.A.	3	-		46	31
1975 Yugoslavia	10	2.2	1.0	-	-
1977 E. Germany	15	1.7	0.8	3.3	1.2
1978 W. Germany	15	1.5	0.3	3.3	0.6
1979-80 Finland	44	1.4	0.4	0.8	0.4

*Duplicate determinations were made from separate digests of each brand.

+ Pipe tobacco sample contains also other substances than tobacco leaves.

Comparing Table 18 with Table 19 shows that the levels of lead and cadmium in the local cigarettes are within the range of values obtained in other countries.

The values are quite high and therefore, we can conclude and say that cigarette smoking is an important source of cadmium in our environment and measures to restrict it, especially in public places, need to be taken seriously. It has been shown that smoking may double the body burden of cadmium (78). According to the results of this study, a one-pack-a-day smoker inhales about 14.1ug of cadmium daily, of which 5-10% is retained. Chronic smokers bear greater risks for lung cancer and arteriosclerosis more commonly associated with use of tabacco products (79).

It should be noted that smoking in public areas and facilities has been restricted or banned altogether in developed countries of Europe and Americas.

3.6 CONCLUSIONS AND RECOMMENDATIONS

In this work, the levels of lead and cadmium in the blood of the general Kenyan population and in some of the sources of these metals, for example, local pottery and cigarettes, have been determined using atomic absorption spectrophotometry. In addition, the levels of trace elements in clays consumed by pregnant women in Kenya were determined.

The levels of lead in blood in most of the samples (96%) were found to be low, below 20 ugdl^{-1}. Therefore these samples contained the ´normal´ level of lead since upper limit ´normal´ level is about 40 ugdl^{-1} for adults. It may be concluded, therefore, that lead pollution is not yet a great problem in this country. However, the emission of the metal into the environment is bound to increase as the country develops and more and more vehicles move on the roads releasing lead-laden gases from their exhaust systems.

Regarding cadmium, it was found that 32% of the Nairobi samples, 18% of the Kiambu samples and 35% of the Chemelil samples showed the presence of cadmium, suggesting that cadmium pollution is on the increase in this country. The mean levels ranged from 0 to 29.5u gdl^{-1} for the Nairobi samples, 0 to 22.4 ugdl^{-1} for the

Kiambu samples and 0 to 32.3 μgdl^{-1} for the Chemelil samples. It may be concluded that the rising cadmium pollution is due to the rapid industrialization, which the country is undergoing, especially in the manufacture of cadmium containing products like plastics, x-ray sources and rubber tyres. Plastic, as is well known is made of a non-biodegrable material and most people tend to burn it after use, thereby releasing toxic fumes containing cadmium into the air and polluting the environment. Of late, due to the failure of urban authorities to collect garbage regularly, urban residents, especially in Nairobi, have resorted to burning uncollected garbage, which contains plastic products among many other things, and thereby polluting the environment tremendously.

On the other hand, some urban residents burn rubber tyres in order to get the steel wires inside. This also may contribute to cadmium pollution. I recommend that the National Environmental Secretariat create awareness in the urban residents, especially in the major urban centres, of the dangers of burning refuse and cadmium containing plastic products. This can be done using the media. In addition, the secretariat and the Ministry of Health should ban the smoking of cigarettes in public places and facilities since smoking is an important source of cadmium in the environment. The general conclusion on cadmium pollution in this country is that it is more due to air pollution than to eating of cadmium containing foods such as cereals. This is so because majority of the blood samples from housewives (92.9%) and students (93.8%) who are less exposed to air-polluted cadmium showed very low levels of cadmium, below 1 μgdl^{-1}.

In case of cigarettes, it was found that cigarette tobacco contains high levels of lead and cadmium. The mean lead values ranged from 6.52 to 8.82 μgg^{-1} and cadmium values from 0.84 to 1.25 μgg^{-1}. Therefore smoking is an important source of cadmium in the environment and measures to restrict it or ban it in public places should be encouraged as it has been done in some developed countries of Europe and America.

Regarding the clays consumed by pregnant women in Kenya, it was found that the soils contain very high levels of aluminium and iron and also appreciable amounts of the other trace metals. The following were the respective concentrations in volcanic tuff and mahti in $mgkg^{-1}$: aluminium (30,156 ± 1005.91; 49,803 ± 3762.10), iron (33228 ± 6561.64; 19,117 ± 1044.70), cadmium (0.46 ± 0.077; 0.78 ± 0.16), copper (4.32 ± 0.94; 26.26 ± 0.71), cobalt (4.87 ± 1.06; 15.61 ± 0.93), chromium (7.34 ± 1.11; 117.27 ± 8.30), lead (20.41 ± 0.66; 24.52 ± 2.99), nickel (20.16 ± 4.46; 28.38 ± 2.50), manganese (687.10 ± 214.93; 406.76 ± 18.72) and zinc (102.39 ± 6.76; 38.57 ± 9.65).

Therefore, prolonged consumption of clays may cause health problems to the mother and foetus, especially by metals like aluminium, lead and cadmium which are not required for normal body functions. I recommend that the women be discouraged from eating the soils and instead be encouraged to buy mineral containing tablets, for example, iron tablets. In addition, studies should be done on laboratory animals like rats, which have been fed on the soils in order to predict the physical and biological effects of eating the soils in human beings.

On pottery, it was found that very little amounts of lead and cadmium get leached during cooking of acidic food stuffs. This is most probably because the pots contain very low amounts of the metals and they are also not glazed with lead containing compounds. Therefore, the use of pottery does not contribute significantly to lead and cadmium poisoning in this country.

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APPENDIX

LIST OF FIGURES

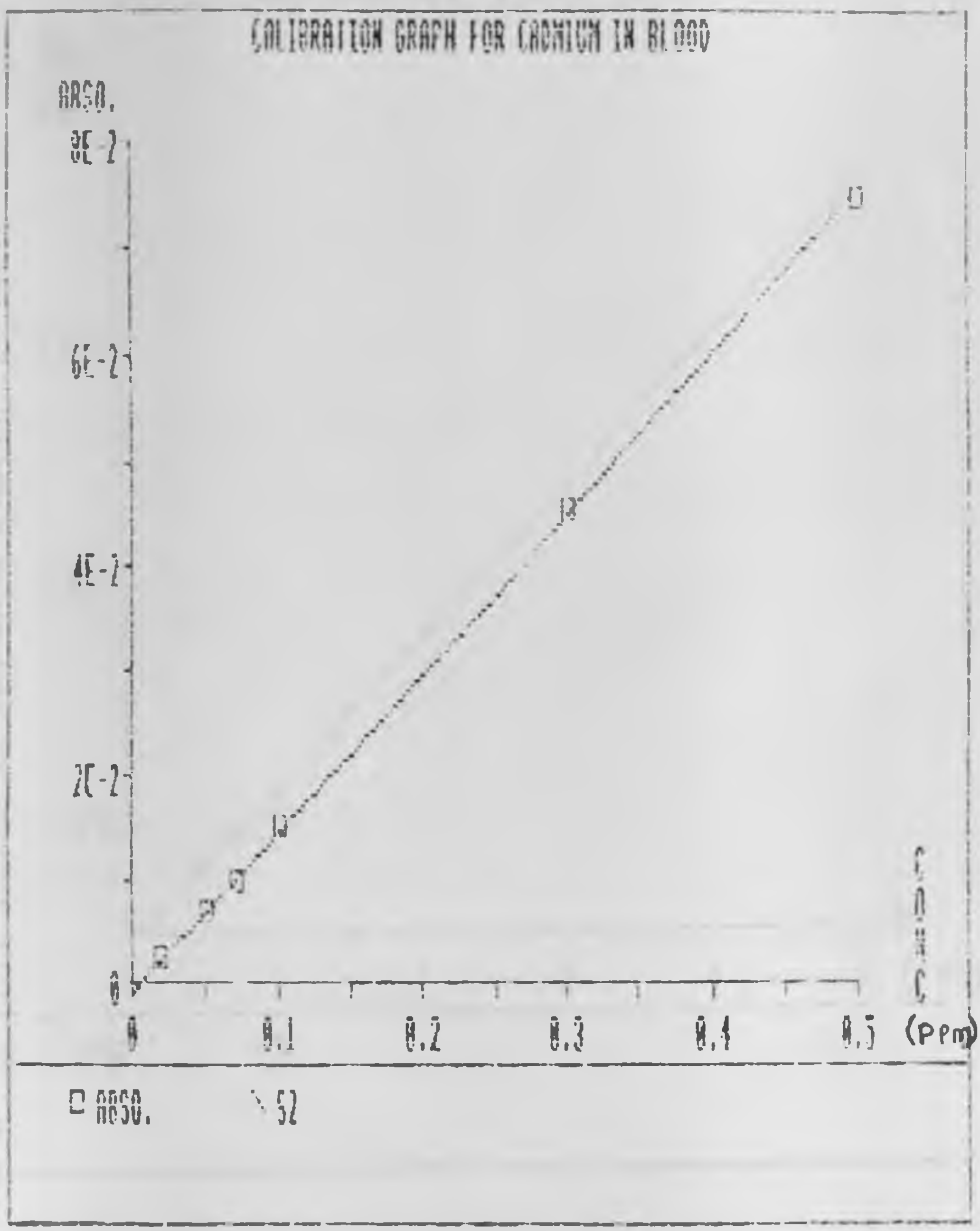

Fig. 1 Calibration graph for cadmium determination in blood.

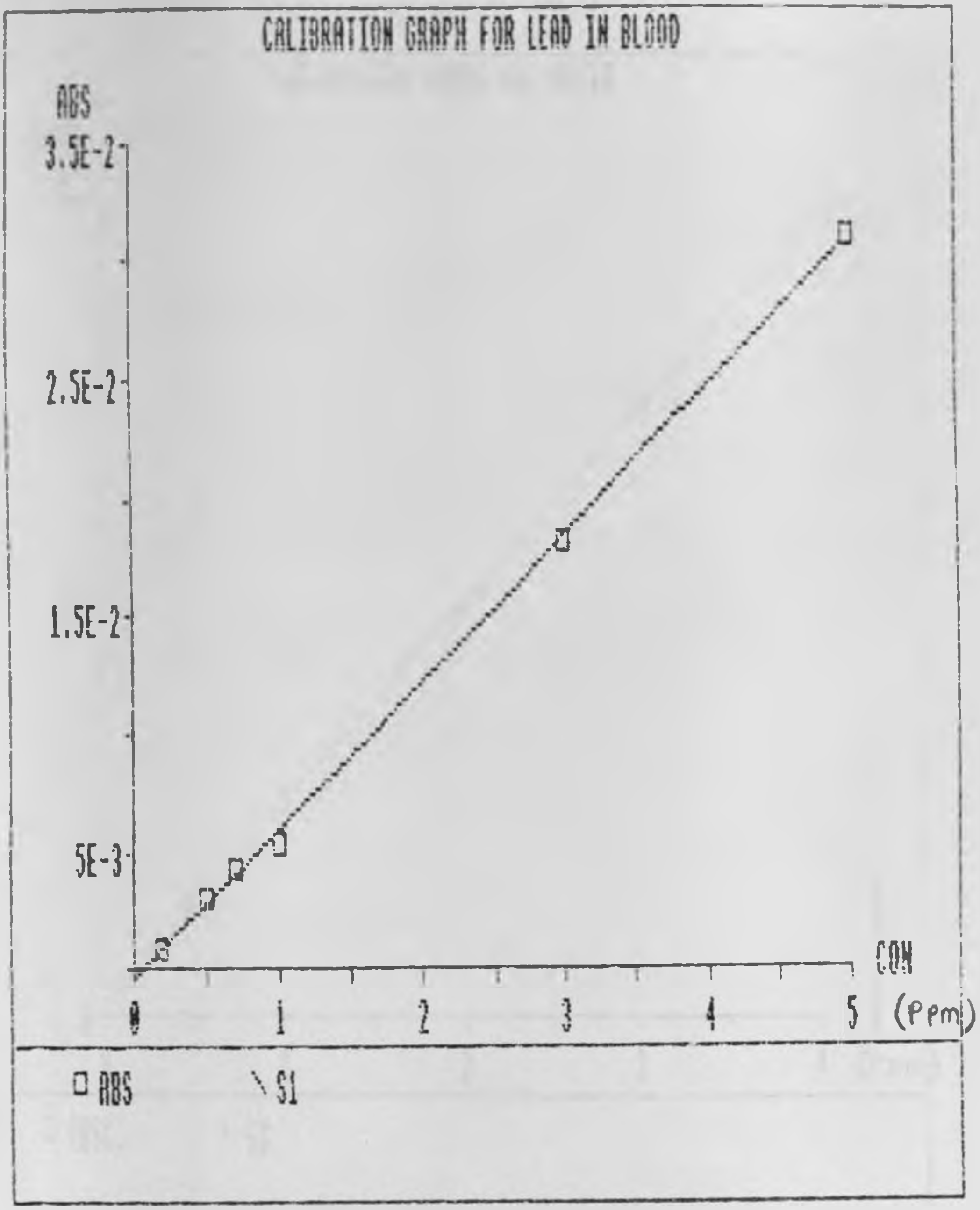

Fig. 2 Calibration graph for lead determination in blood.

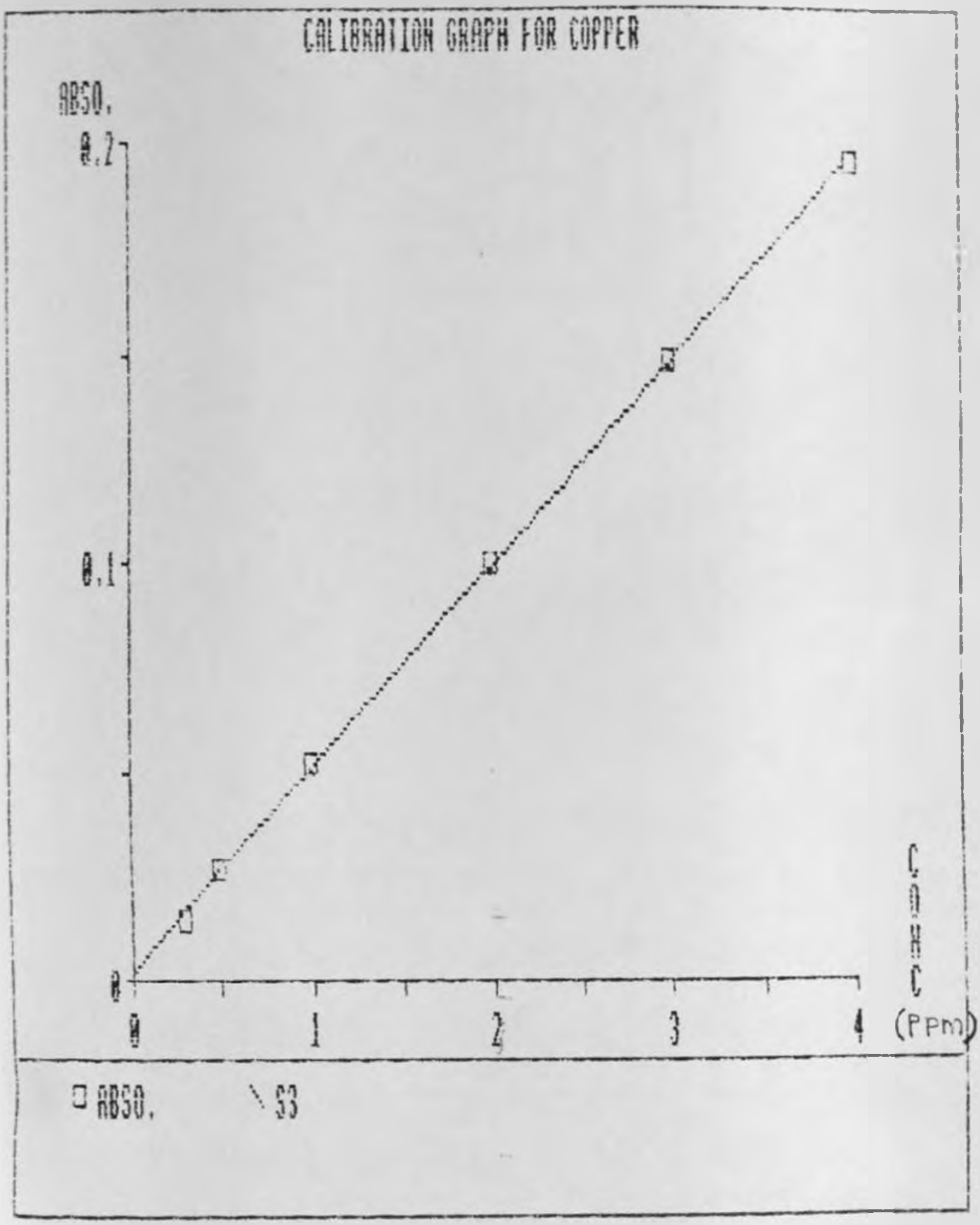

Fig. 3 Calibration graph for copper determination in tuff.

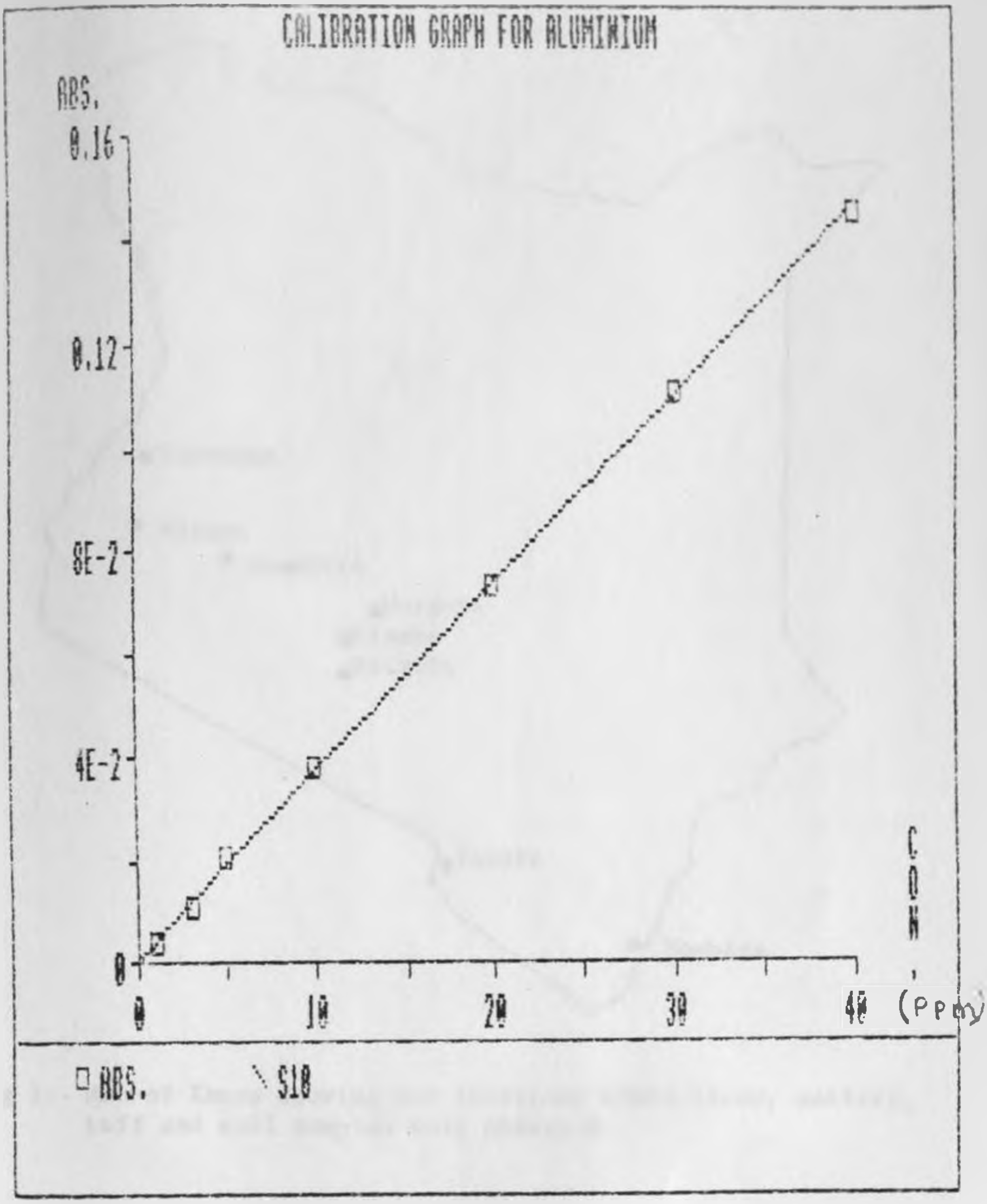

Fig. 4 Calibration graph for aluminium determination in tuff.

Fig 5: Map of Kenya showing the locations where blood, pottery, tuff and soil samples were obtained.