

**INVESTIGATION OF HEAVY METALS CONCENTRATION IN THE SOIL:
A CASE STUDY OF MINNA METROPOLIS**

BY

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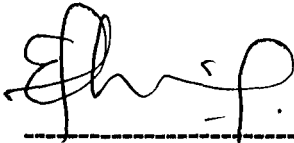
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CERTIFICATION

I hereby certify that this project was written by OYEBANJI, KAYODE DAVID of the Chemical Engineering Department of the Federal University of Technology Minna, Nigeria.



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DEDICATION

This work is dedicated to my Maker, the God of the whole earth and to my parents Mr. And Mrs. J. A. Oyebanji.

ACKNOWLEDGEMENT

First and foremost I thank my God for his abundant blessings, good health, knowledge and strength accorded me throughout the period of my stay on FUT campus.

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I appreciate the Alade's for their help and support, my God will definitely not forget the labour of your love.

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I thank my colleagues, to them I say VICTORIA ASCERTA. And to my ALMAMATER, I DOFF MY HAT.

ABSTRACT

This project investigates the concentrations of four different heavy metals in the soil around Minna, Nigeria. These metals are chromium (Cr), Copper (Cu), Lead (Pb) and Iron (Fe). Four different sites, in four different locations i.e (Mobil, Bosso, Kpakungu and Chanchaga) were used as the study sites. Each of the sites is basically a varse piece of land. The highway was taken as a reference point and soil samples were collected from both sides of the road at regular interval for analysis.

From the study site at Chanchaga, the highest concentrations of Pb, Cu, Fe and Cr were $117.00\mu\text{g/g}$, $13.20\mu\text{g/g}$, $59.00 \times 10^2\mu\text{g/g}$ and $20.10\mu\text{g/g}$ respectively. At Kpakungu study site, the highest concentrations of Pb, Cu, Fe and Cr were $85.00\mu\text{g/g}$, $14.40\mu\text{g/g}$, $52.00 \times 10^2\mu\text{g/g}$ and $42.50\mu\text{g/g}$ respectively. Also, the result shows that at Mobil study site, the highest concentrations of Pb, Cu, Fe and Cr were $168.80\mu\text{g/g}$, $35.20\mu\text{g/g}$, $68.50 \times 10^2\mu\text{g/g}$ and $35.20\mu\text{g/g}$ respectively. From the study site at Bosso, the highest concentrations of Pb, Cu, Fe and Cr were $81.20\mu\text{g/g}$, $11.20\mu\text{g/g}$, 51.00×10^2 and $20.20\mu\text{g/g}$. In all the sites of study, the levels of Cu and Pb were relatively low except at the site in Mobil. This can be attributed to the heavy automobile activities, farming activities and the various industrial activities within the region.

The results obtained show a correlation between distance and concentration for Lead (Pb) and Copper (Cu). High variations were however observed for Iron (Fe) and chromium (Cr). A regression analysis was used to relate concentration of element to distance from highway, for Pb and Cu. The obtained expressions were further used for prediction.

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CHAPTER ONE

1.0 INTRODUCTION

1.1 BACKGROUND OF STUDY

Pollution of water, air, soil, atmosphere, etc means, to make them dirty, impure and dangerous for people and animal to live in or to use. This can be by means of poisonous chemicals. Pollution could make human and animal existence very unbearable if not controlled (Odigure, 1998).

Chemical pollution in the environment is understood to mean a high level of chemical substance that adversely affects the natural environment. Pollution can be thought of as being the presence of too high concentration of resources or materials in the wrong place at the wrong time. This emphasizes the view that pollution involves the misuse of resources (Atoyebi, 2002). However, pollution is a by-product of human activities starting from the primitive agricultural farming technique to today's high technology industrial activities. Industrialization is highly desirable for the sustenance of a nation's economy and the enhancement of the citizenry's well being. However, the negative impacts precipitated by the introduction of its unwanted by products into the ecological systems may be catastrophic, if allowed to build up and uncontrolled (Odigure, 1998). Oil spillage and high level of toxic metals in soil which includes the four in the subject analysis of this work are all examples of the environmental pollution. Gaseous pollutants like sulphur dioxide, carbon monoxide, nitrogen monoxide, exhaust of industrial engines and household waste both in liquid and solid forms pollute the soil and water (Peter, 1985). Part of these water are effluents which contains toxic substances of heavy metals, high hydrogen concentration (pH), and some other non biodegradable substances (Purves,1985). Heavy metals are considerable environmental concern due to their toxicity and accumulative behaviour (Ongbu,1992). Trace quantities of certain heavy elements are

essential to animal and plant growth. However, they are easily assimilated and accumulated in ecological materials (Numberg, 1984).

Heavy metal is generally a collective term applying to the group of metals and metalloids with an atomic density greater than 6g/cm. Although it is only a loosely defined term, it is widely recognized and usually applied to the elements such as cadmium (Cd), arsenic (As), Chromium (Cr), Mercury (Hg), Nickel (Ni), Copper (Cu), Lead (Pb) and Zinc (Zn), which are commonly associated with pollution and toxicity problem (Alloway and Ayres, 1997). Since industrial revolution the production of heavy metals such as lead, zinc, copper, cadmium and scandium has increased exponentially. Between 1950 and 1990, production of this metals increased nearly to 10-folds, with emissions rising in high levels (Alloway, 1990). At normal or natural concentration, heavy metals are important in several ways, many are used industrially in technologically advanced countries. Some are physiologically essential for plants and thus have a direct bearing on health and agricultural productivity and many are significant as pollutants of ecosystems throughout the world (Alloway, 1990). Heavy metals are natural constituents of the earth's crust and are present in varying concentrations in all ecosystems. Natural sources of heavy metals, arise from chemical and physical weathering of igneous and metamorphic rocks. Other contributions include the decomposition of plant and animal detritus, precipitation or atmospheric deposition of airborne particles from volcanic activity, wind erosion, forest fire smoke, plant exudates and oceanic spray (Kennish, 1992)

Anthropogenic sources of heavy metals are various industrial sources, including present and former mining activities, foundries, smelters and diffuse sources such as piping, constituents of products, combustion by-products, traffic etc. Living organisms require trace amounts of some heavy metals, most heavy or trace metals occupy a central position in the biological system as functional component of metalloproteins and metalloenzymes (Kumar and Krishnaswany, 1997). Some of these elements are required in small but critical concentration for

normal healthy growth by most living organisms (Alloway and Ayres, 1997). The essential trace metals are so important that their absence or deficiency may lead to disease or death of the concerned organism (Kumar and Krishnaswany, 1997). The only way living organism get this element is through food intake, which then depends on the type of soil these foodstuffs are planted.

With day-to-day depositions and reactions that take place, heavy metals are deposited and this pollutes the soil. pollution of soil constitutes a major environmental problem because many of the elements will persist and still remain in the soil for many years to come.

This study is expected to provide a response for comprehensive studies of suspected areas of pollution and for complimentary investigations of chemical behaviour of the heavy metals in the soils in Minna, Niger State, Nigeria.

1.2 OBJECTIVES OF THE STUDY

The aims and objectives of this research project are:

1. To determine the concentration of the selected heavy metals in soil in and around Minna, Niger State.
2. To see if the level of heavy metals concentration encountered in this area can cause toxicity to animals, plants and human beings around the area.
3. To know the level of depositions of the heavy metals and the factors responsible for various depositions of the various metals.
4. To generate a relation between the source of emission and reception. i.e. Establish emission-reception concept.
5. To make appropriate recommendations both preventive and corrective measures to advert toxicity of the natural habitat of animals, plants and human beings.

1.3 METHOD AND SCOPE OF STUDY

The work focuses on analysing the concentration of heavy metals in Minna soils, covering Bosso, Chanchaga, Kpakungu and Mobil locations. The heavy metals analysed for determination of concentrations are copper (Cu), Chromium (Cr), lead (Pb) and iron (Fe). The major highway in each of the locations was taken as the reference point, and samples were collected at distances zero meter (reference point), 50m, 100m, 150m, and 200m away from both sides of the road. The top soils were collected from a uniform depth of between 7.5 to 10cm into the ground. The analysis was done using the Atomic Absorption Spectrophotometer (AAS) after acid digestion using perchloric acid and nitric acid, which serve as extractant.

1.4 RELEVANCE OF STUDY

Monitoring the level of accumulation of the heavy metals in soil is of great importance. Since their continuous deposition in the soil can cause severe environmental degradation and toxicity. A good knowledge of the changes in the concentration of the soil in Minna would assist in environmental management. Due to the expansion of industrial and urban society, with the introduction of more vehicles on our roads, the heavy metals are being accumulated in the soil on a daily basis. Therefore, it is obligatory to monitor the level of accumulation of these toxic pollutants in the soil so that they do not exceed the acceptable limits, hence posing threat to the survival of plants, animals and human beings within Minna and it's environs.

CHAPTER TWO

2.0 LITERATURE REVIEW

2.1 SOIL FORMATION

Soil formation is the differentiation of the surface volume of the landmass into horizons of soil profiles. In other words it is the progressive organization of the system. Initially, the rocks and minerals of the land mass determine the nature of the soil (Clarence, 1982).

Soil formation proceeds in stages, but these stages may grade indistinctly from one into another. The first stage is the accumulation of unconsolidated rock fragment, the parent material. Parent material may be accumulated by deposition of rock fragments moved by glaciers, wind, gravity or water. It may accumulate more or less in place from physical and chemical weathering of hard rocks. The second stage is the formation of horizons. This stage may follow or go on simultaneously with the accumulation of parent material. Soil horizons are as a result of dominance of one or more process over others, producing a layer, which differs from the layers above and below. (Smith, 1982).

The major processes in which promote horizon differentiation are gains, loses, transfers and transformations of organic matter, soluble salts, carbonates, silicate clay minerals sesquioxides and silica (Smith, 1982).

Gains consist normally of additions of organic matter and of oxygen and water through oxidation and hydration. Loses are chiefly of material dissolved or suspended in water percolating through the profile or running off the surface. Transfers of both minerals and organic materials are common in soils.

Water moving through the soil picks up materials insolution or suspension. These materials may be deposited in another horizon if the water is withdrawn by plant roots or evaporation, or if the minerals are precipitated as a result of difference in pH (degree of acidity),the salt concentration or other conditions in deeper horizons, (smith, 1982).

2.2 THE SOIL PROFILE

The interactions within the soil system produce visible changes in the soil mass. Vertical sections of most soils reveal a succession of layers called horizons each having distinctive properties such as color and thickness each approximating the curvature of the land surface. The total vertical pattern including all horizons is called the soil profile. Horizontal variation, which may integrate very gradually, are identified as kinds of soil, with each kind having similar profiles through out its extent. Soil profiles then, are the major identifying features of kinds of soils and they reflect a particular history of natural process that has taken place at the profile site. (Clarence, 1982).

Two commonly recognized major soil horizons are surface soil and subsoil. However, close inspection reveals more layers in many soils. Scientists identify them chiefly by the letters A, B and C from the top downward, and then often subdivide them, as A₁, A₂, A₃, B₁, B₂, B₃, C. (Clarence, 1982).

The "A" horizons are parts of the surface soil, and the B horizons are parts of the subsoil. The C horizons are made up of rock fragments called the parent material of the soil.

2.3 ELEMENTAL COMPOSITION OF SOIL

The elemental composition of soil varies over a wide range, permitting only a few general statements to be made. Those soils that contain less than 12-20% organic carbon are termed mineral (Garrison, 1982).

All other soils are termed organic. Carbon, oxygen, hydrogen, nitrogen, phosphorus and sulphur are the most important constituents of organic soils. The number of organic compounds into which these elements are incorporated in soil is very large, and the elucidation of the chemistry of soil organic matter is a challenging problem (Garrison, 1982).

Besides oxygen, the most abundant elements found in mineral soils are silicon, aluminium and iron. The distribution of chemical elements will vary

considerably from soil to soil and in general, will be different in a specific soil from the distribution of elements in the crustal rocks of the earth. Often this difference may be understood in terms of pedogenic weathering processes and the chemical reactions that accompany them.

The most important micro or trace elements in soil are boron, iron, copper, manganese, molybdenum and zinc, since these elements are essential in the nutrition of green plants. Also important are; cobalt, which is essential in animal nutrition and selenium, chromium, lead, nickel and cadmium which may accumulate to toxic levels in soil.

The average distribution of trace elements in soil is not greatly different from that in crustal rocks. This indicates that the total content of a trace element in soil usually reflects the content of that element in the soil parent material and, generally, that the trace element contents of soil often is not affected substantially by pedochemical processes. (Sposito, 1982).

The elemental composition of soil varies with depth below the surface because of pedochemical weathering (Garrison, 1982). The principal processes of this type that result in the removal of chemical elements from a given soil horizon are: soluviation (ordinary dissolution in water), cheluviation (complexation by organic or inorganic ligands), reduction and suspension.

2.4 TEXTURE AND TEXTURAL CLASSIFICATION

The mineral composition of a soil with respect to size and size distribution of the primary particles is referred to as soil texture. The textural classification of soil is based upon the relative quantities of clay, silt and sand found in a sample. Descriptive names are given to soil materials with different ranges of particle composition, in the most common textural classification of soil. The names are intended to be suggestive of the physical behaviour of soils of different composition (Walter, 1982)

2.5.0. SOURCES OF HEAVY METALS

There are various sources of heavy metals, these sources are categorized into two broad groups namely; non point and point sources. Non point sources are further categorized into natural and anthropogenic sources.

2.5.1 NON POINT SOURCES

- 1. NATURAL:-** Chemical and physical weathering of igneous and metamorphic rocks and soils often release heavy metals into the sediment and into the air. Other contributions include; the decomposition of plant and animal detritus, precipitation or atmospheric deposition of airborne particles from volcanic activity, wind erosion, forest fire smoke, plant exudates and oceanic spray (Kennish, 1992).
- 2. ATHROPOGENIC:-** Surface run off from mining operations usually has a low pH and contains high levels of metals. The combustion of fossil fuel pollutes the atmosphere with metal particulates that eventually settle to the land surface (Connell et al, 1984).

2.5.2 POINT SOURCES

Domestic wastewater effluent contains metals from metabolic wastes, corrosion of water pipes and consumer products. Individual effluents and waste sludges may substantially contribute to metal loading (Connell et al, 1984)

2.6 SOILS OF TRAFFIC AREAS

Roadside soils are impacted by traffic – derived contaminants, for example heavy metals and polyaromatic hydrocarbons PAH (Jacks et al, 1998). These contaminants are usually adsorbed strongly to the soil. Environmental exposure of domestic and terrestrial animals to lead and other trace or heavy metals as a result of naturally occurring soil and water elements and traffic – derived contaminants has been on the increase over the past twenty years (Jamie 2001).

The dominating source of particles in urban air is road traffic. For these particles the dispersion conditions are expected to be like for gases and the particle concentrations in a street canyon can be calculated using dispersion models developed for gaseous pollutants (Wahlin, 2001). The inorganic contamination of top soils ear roadside is very high and confirms the major role of vehicular movement as source of soil pollution (Wahlin, 2001).

Although, the theoretical background of contamination mapping in urban areas are still unknown for the most part, there is always a spatial variability of soil contamination of an examined site (Suitma, 2003).

2.7 REVIEW OF HEAVY METALS OF INTEREST

2.7.1 CHROMIUM

It has the symbol Cr, a metallic element with atomic number 24 and atomic weight 51.996. It is a transition element found at the top of group VIB of the periodic table (Hubert, 1982).

A hard, brittle silver – gray metal. Chromium is a naturally occurring element, obtained primarily from chromite an ore containing a mixture of ferrous and chromite oxides. The main sources of chromium in the environment includes; industrial and urban sewage waste, chromium also originates from electroplating bath, corrosion inhibitors from heat exchange system, trade effluents from tanning processes and technology used in food processing (Cabrera-vigue et al, 1997).

Chromium is best known as an alloying element in stainless steels and in electroplating, as a decorative and corrosion resistant surface for other metals. Chromium is one of the essential trace elements in the human body, as it appears to play a role in the metabolism of glucose and some lipids. However, adverse effects may occur at higher concentration, excessive amount of chromium especially Cr (VI) which is more toxic may be involved in the spread of some diseases such as lung and gastrointestinal cancers (Cabrera-vigue et al, 1997).

2.7.2 COPPER

It has the symbol Cu, a metallic chemical element with atomic number 29 and atomic weight 63.54 (Hopkins, 1982). Copper is found at the head of group IB of the periodic table. It is soft, heavy, malleable, ductile and relatively strong (Hopkins, 1982).

Copper occurs naturally as ores in the soil, binding strongly to organic compounds as metal organic complexes and the commonest ores are those of sulphide oxide and carbonate salts (Hopkins, 1982). These copper compounds have low mobility in soil. Industrial activities, heavy vehicular movement, electroplating and electrochemical processes, as well as agricultural activities are other ways by which copper is released to the environment. These activities release metal particulates that eventually settle to the land surface.

Copper is best known for its use in coins, art objects and electrical equipment. Large production of the world's copper output is used in the electrical industries principally as wire (Hopkins, 1982).

Copper is one of the essential trace elements required by the body for proper and healthy growth, it is essentially required in enzymes for them to perform effectively, by reducing bioaccumulation in terrestrial ecosystem which includes man (Famgmeier et al, 2001).

At high concentration, copper becomes toxic. A dose of 100g is reported to have resulted in liver and kidney damage.

2.7.3 IRON

Iron has the symbol Fe, a metallic chemical element with atomic number 26 and atomic weight 55.847. Iron is found in group VIII B of the periodic table (Hopkins, 1982).

In the native state, it is a gray-white lustrous solid that is soft, ductile and tough. It occurs in the native state in limited quantities in rocks and in meteorites, which are generally more than 90% iron (Hopkins, 1982). Through

other anthropogenic sources, iron particulates are released to the atmosphere which eventually settle to the land surface.

In man, iron is found in haemoglobin, which is a pigment in red blood cells, the muscles, the bone marrow, the liver and the spleen. As the blood containing oxyhaemoglobin circulates through the body, oxygen is released to the tissues for cellular respiration. Iron is therefore necessary to the respiration mechanism and also for the formation of new red blood cells. Generally, iron is an essential element for all vertebrates, many invertebrates and some plants.

2.7.4 LEAD

Lead has the symbol Pb, a metallic chemical element with atomic number 82 and atomic weight 207.19. Lead is in group IVA of the periodic table, pure lead is silvery white, but on exposure to air it becomes bluish gray. It is soft, dense, malleable and readily fusible (Hopkins, 1982). Occurrence of lead in soil is natural, they are widely distributed in nature but is rarely found in the native or uncombined state. The most important lead ore is galena, which is lead sulfide, PbS ((Hopkins, 1982).

The best known uses of lead are in electrical storage batteries, in soldering alloys and as the compound tetraethyl lead, in gasoline. Lead is also released to the environment through various industrial and human activities. The emission of aerosolic $PbCl_2$, $PbBr_2$ and PbO from combustion of petrol containing lead tetraethyl is a major source of lead to the environment (Hopkins, 1982). Lead is well known for its toxicological properties. One of such is the irreversible reduction in intelligence quotient in children leading to poor school performance (Klein and Snodgrass, 1997). Lead in human causes inhibition of enzymes involved in the synthesis of haemoglobin, leading to anaemia. In addition, it is toxic to the nerves therefore causing neurological effects. Concentration increases as one grows old, making the control of lead intake imperative.

CHAPTER THREE

3.0 EXPERIMENTAL METHODOLOGY

3.1 SOIL SAMPLING

Samples of soils were collected during the dry season, from four major locations within Minna, Niger State, Nigeria. These locations were selected based on the fact that roadside soils are impacted by traffic derived contaminants for example heavy metals and polyaromatic hydrocarbons (PAH). These locations are notable for their high flow of traffic within Minna metropolis and they are; Chanchaga, Kpakungu, Mobil and Bosso areas.

From each of the selected locations, the major highway (Federal road) passing through, was taken as the reference point. From each of these locations samples of soils from ten different points were collected, five soil samples were collected from either sides of the road, the sum of which gives ten samples for a single location. The first sample on each occasion was taken from the immediate road side, after which an interval of fifty metres was given between successive samplings. The top soils were collected from a uniform depth of between 20 to 40 centimetres into the ground. Conventional sampling materials like soil sampling probe, shovel, measuring tape and plastic sleeves were used for the sampling operation.

3.2 SAMPLE LABELLING

Sample labeling was considered to be very important. Samples were labelled based on the following; location of collection, road side from which collection was made and the collection point.

The first figure stands for the location of collection, numbering 1,2,3,4 i.e. Chanchaga, Kpakungu, Mobil and Bosso respectively. The first letter stands for the side of the road from which collection was made;

At Chanchaga, along Minna – Abuja road, the right side of the road is tagged A and left side B.

At Kpakungu, along Minna – Bida road, the right side of the road is tagged A and the left B.

At Mobil, along Mobil – Tunga road, the right side of the road is tagged A and the left side B.

At Bosso, along Bosso – Maikunkele road, the left side of the road is road is tagged A and the left side B.

The second figure stands for the point of collection numbering 1,2,3,4,5. The immediate road side soil sample was tagged point 1, 50 metres intervals were given between successive points and were attributed accordingly.

3.3 SAMPLE TREATMENT

The soil samples were air dried in the laboratory for fifteen days to ensure that the moisture content is totally removed or reduced to the nearest minimum. After drying, the samples were collected and sieved with 0.5mm sieve to obtain five particles.

3.4 DIGESTION OF SOIL SAMPLES

The sieved soil was properly ground using an agate mortar; this mortar enhances oxidation of the soil samples. 1.0g of the finely ground soil was accurately weighed, then transferred to a digestion tube. 10ml volume of the acid mixture (two parts HNO_3 : one part HClO_4) was added and digested at 150°C . The digestion was carried out until clear fumes appeared. The digest was then washed into a 50ml standard volumetric flask and with distil water made up to the mark.

3.5 INSTRUMENTATION

To determine the concentration of heavy metals in soil samples, the unicam 929 AAS was used. The principle of atomic absorption makes use of the free atom of an element absorbing lights and wavelengths characteristics of that

element. Each element has different wavelengths. The extent of that absorption is a measure of the number of atoms in the light path.

The principle of operation of Unicam 929 AAS involves the following;

- i. A light source of cathode lamps. Each element has its own working condition. The light from the lamp will allow electrons to be emitted as a spectrum. The wavelength depending on each element.
- ii. A monochromatic device, which will isolate the required wavelength. It should be noted that a standard wavelength of each element has been programmed into the AAS memory.
- iii. An energy source, i.e. air acetylene flame is used to decompose the sample into its constituent atoms.
- iv. A photo multiplier detector, which controls the radiation signal into a form that can be easily detected.
- v. Read out device, where results are displayed. The light source of AAS is the hollow cathode lamps (HCLS). They are high intensity; stable light sources that emit the elements specific spectral lines required for AAS measurements. The hollow cathode emits very narrow spectral lines, this means that the absorption measurement is made at the maximum of the absorption, when the signal is at maximum. The hollow cathode lamp thus essentially performs the monochromation and the monochrome is only required to accept the desired line. Each element has its own lamp of specific wavelength as shown below.

ELEMENT	WAVELENGTH (nm)
Copper	324.8
Lead	217.0
Chromium	357.9
Iron	248.3

Table 3.1 wavelengths of elements

Table 3.1 wavelengths of elements

The Unicam 929 AAS energy source is supplied by the combustion of the acetylene flame, the flame is ignited with the aid of the solar switch. Oxygen gas passed through a compressor to support the combustion. For each of the element reading the AAS is calibrated. Each of the cathode tubes has its own band pass and the maximum current that should be used to operate the tubes. All parameters were entered into the computerized data system of the AAS.

3.6 QUALITY CONTROL TECHNIQUE

In nearly all spectrochemical techniques, a blank measurement is required. A reagent blank was prepared for the digestion that was carried out on the soil samples. A reagent blank contains the solvent plus all reagents used in the sample preparation procedure at the same concentrations as in the analytical sample. The ideal blank is identical to the sample except that the analyte concentration is zero. The instrumental response from the blank is then subtracted from that of the sample in order to compensate for the effects of concomitants.

3.7 ATOMIC ABSORPTION SPECTROPHOTOMETER, (AAS) ANALYSIS

Atomic absorption spectrometry has widely been used for trace elemental analysis. It can be used to determine most of the metals in the periodic table in the microgram – per – milliliter to nanogram – per – milliliter range (Winefordner, 1976). The atomic absorption spectrophotometer was switched on and was allowed to warm up for at least 15 minutes. In each case of heavy metal analysis, the hollow cathode lamps of metallic ions to be investigated must be inserted or fixed into the instrument and allowed to stabilize for 10 minutes. This was done at their standard wavelength and current at which the lamp glows. Oxyacetylene gas must be provided for ignition of flame at the burner, air pump must also be supplied to provide complete combustion.

Working standard of each element was prepared to calibrate or standardise the instrument. Distilled and deionised water was used to set the

machine to zero and to flush ion residue that may be present in the burning flame. This was done each time reading was taken to avoid contamination of lens, hence wrong readings. The instrument was adjusted to read absorbance of the aspirated sample solutions. Results obtained from the standards were used to plot a standard graph of absorbance versus concentration, from which the concentrations of samples of soils analysed were traced out by interpolations.

CHAPTER FOUR

4.0 EXPERIMENTAL RESULTS

Table 4.1 Heavy metal concentrations at Chanchaga (Along Minna – Abuja road)

(a) Right hand side of the road - A

LOCATION	DISTANCE (m)	CONCENTRATION OF ELEMENT ($\mu\text{g/g}$)			
		Pb	Cu	Fe	Cr
Chanchaga	0	110.20	13.20	58.00×10^2	7.60
	50	108.10	12.90	52.00×10^2	12.30
	100	104.20	12.60	57.00×10^2	12.00
	150	100.50	12.10	53.00×10^2	12.40
	200	100.50	11.70	56.00×10^2	20.10

(b) Left hand side of the road - B

LOCATION	DISTANCE (m)	CONCENTRATION OF ELEMENT ($\mu\text{g/g}$)			
		Pb	Cu	Fe	Cr
Chanchaga	0	117.00	11.90	54.00×10^2	18.20
	50	115.30	11.40	59.00×10^2	19.30
	100	112.50	11.00	52.00×10^2	16.90
	150	109.90	10.60	54.00×10^2	15.00
	200	107.20	10.30	58.00×10^2	15.00

Table 4.2 Heavy metal concentrations at Kpakungu. (Along Minna-Bida road)

(a) Right hand side of the road - A

LOCATION	DISTANCE (m)	CONCENTRATION OF ELEMENT ($\mu\text{g/g}$)			
		Pb	Cu	Fe	Cr
Kpakungu	0	18.10	14.40	47.00×10^2	42.50
	50	80.80	13.50	42.00×10^2	30.50
	100	80.60	12.50	38.00×10^2	33.20
	150	80.30	11.70	41.00×10^2	20.10
	200	79.00	10.80	45.00×10^2	20.50

(b) Left hand side of the road - B

LOCATION	DISTANCE (m)	CONCENTRATION OF ELEMENT ($\mu\text{g/g}$)			
		Pb	Cu	Fe	Cr
Kpakungu	0	85.00	13.80	48.00×10^2	40.30
	50	84.00	13.30	52.00×10^2	35.40
	100	83.20	12.70	50.00×10^2	25.30
	150	82.00	12.00	51.00×10^2	25.30
	200	81.50	12.00	47.00×10^2	20.20

Table 4.3 Heavy metal concentrations at Mobil (Along Mobil -Tunga road)

(a) Right hand side of the road - A

LOCATION	DISTANCE (m)	CONCENTRATION OF ELEMENT ($\mu\text{g/g}$)			
		Pb	Cu	Fe	Cr
Mobil	0	168.80	35.20	68.50×10^2	32.30
	50	165.00	34.60	62.00×10^2	35.20
	100	161.50	34.00	63.00×10^2	30.50
	150	157.90	33.80	63.50×10^2	30.50
	200	154.40	33.10	60.00×10^2	29.30

(b) Left hand side of the road - B

LOCATION	DISTANCE (m)	CONCENTRATION OF ELEMENT ($\mu\text{g/g}$)			
		Pb	Cu	Fe	Cr
Mobil	0	165.20	34.00	67.00×10^2	20.20
	50	164.00	33.50	66.00×10^2	33.40
	100	162.50	32.90	68.00×10^2	30.20
	150	160.50	32.10	66.00×10^2	18.30
	200	158.60	31.40	62.00×10^2	19.60

Table 4.4 Heavy metal concentrations at Bosso (Along Bosso-Maikunkele road)

(a) Right hand side of the road - A

LOCATION	DISTANCE (m)	CONCENTRATION OF ELEMENT ($\mu\text{g/g}$)			
		Pb	Cu	Fe	Cr
Bosso	0	76.50	10.50	45.00×10^2	12.50
	50	76.00	9.50	48.50×10^2	13.00
	100	75.20	8.70	47.00×10^2	15.50
	150	74.30	8.00	48.50×10^2	15.00
	200	73.60	8.00	47.00×10^2	17.50

(b) Left hand side of the road - B

LOCATION	DISTANCE (m)	CONCENTRATION OF ELEMENT ($\mu\text{g/g}$)			
		Pb	Cu	Fe	Cr
Bosso	0	81.20	11.20	51.00×10^2	15.60
	50	80.40	11.00	49.00×10^2	18.00
	100	79.80	10.70	48.50×10^2	20.20
	150	72.10	10.50	44.00×10^2	19.20
	200	70.30	10.00	46.00×10^2	17.10

CHAPTER FIVE

5.0 DISCUSSION OF RESULTS AND CONCLUSION

5.1 DISCUSSION OF RESULTS

From the results shown in chapter four . it could be observed that the concentrations of Lead (Pb) and Copper (Cu) decreased with distance away from the active or reference site, except for a few instances where a constant value is observed for two successive samples. This could be attributed to the fact that roadside soils are impacted by traffic derived contaminants, for example heavy metals and polyaromatic hydrocarbons in an emission-reception concept (Jack, 1998). The highest concentration value obtained in the study was $68.50 \times 10^2 \mu\text{g/g}$ of Iron (Fe) obtained from soil at Mobil site. This could be attributed to the fact that Iron ores, constitutes up to 10% of the earth's crust and in addition to this, heavy automobile activities and a few industrial activities that take place at Mobil can cause an increment in the concentration levels of Iron metals. From the result, the highest concentration of lead (Pb) was $168.80 \mu\text{g/g}$ obtained from soil at Mobil site. The concentration of lead here decreases at various distances away from the reference point. A general increment in concentration of lead is noticed at Mobil study site. This could be attributed to the fact that exhaust was given off into the environment by heavy-duty vehicles and automobiles (Atoyebi, 2002 and Awoyale, 2000). Generally, the level of copper detected in the soil samples were very low. The range was between $8 \mu\text{g/g}$ and $35.20 \mu\text{g/g}$. The highest level was $35.20 \mu\text{g/g}$ obtained at Mobil site. This could be attributed to the fact that copper is a constituent of most alloys used in automobile parts. When discarded as scraps these parts corrode and then copper is deposited into the soil (Adeniyi et al, 2002). The highest concentration of chromium (Cr) was $42.5 \mu\text{g/g}$ obtained from soil sample at Kpakungu study site. Chromium is obtained primarily from chromite ore, chromium also originates from electroplating bath, corrosion inhibitors form heat exchange system, trade

effluents from tanning processes and technology used in food processing (Cabrera-Vigue et al, 1997).

From the analysis carried out, the highest concentration levels for lead, copper and iron were obtained from soil samples at Mobil site, while the highest concentration level for chromium was obtained from soil at Kpakungu study site. The results obtained for Mobil study site are logical since pollutants are also generated from the various activities of inhabitants ranging from farming, automobile works to transportation. The nature of the results propelled the decision to test for correlation, graphs of concentrations versus distances were plotted for each of the heavy metals and for each of the locations. Negative and highly correlated graphs were obtained for copper and lead, while correlation was not established based on graph type, for iron and chromium. The linear regression analysis was then used to generate relations for cases where correlations were established. The relations were further subjected to test; hence predicted values of concentration were obtained.

5.2 CONCLUSIONS

On the basis of the investigations carried out on the various soil samples collected from Mobil, Chanchaga, Bosso and Kpakungu, the following conclusions can be drawn.

- (a) The highest concentration levels for lead, copper and iron were 168.8 $\mu\text{g/g}$, 35.20 $\mu\text{g/g}$ and 68.5 x 10² $\mu\text{g/g}$ respectively obtained from soil samples at Mobil site.
- (b) The highest concentration level for chromium was 42.5 $\mu\text{g/g}$ obtained from soil sample collected from Kpakungu study site.
- (c) The observed concentration levels for Pb, Cu and Fe at Mobil study site is traceable to various activities of inhabitants ranging from farming, automobile works to industrial activities.

- (d) Various anthropogenic sources of emission may substantially contribute to metal loading.
- (e) The concentration of the heavy metals in all the locations of study are within the set limits by federal environmental protection agency.

5.3 RECOMMENDATION

- ❖ In order to reduce the threat to humans, local planning and soil protection authorities should check and improve the buffer capacity of the soils for inorganic soil contaminants e.g heavy metals, and perform action against the soil acidification.
- ❖ Risk estimation for an increased transport of colloids carrying heavy metals to the ground water as a result of highway run off infiltration in roadside soils should be investigated.
- ❖ It is recommended that model development and discrimination be emphasized so as to understand the emission-reception concept for heavy metals better.
- ❖ Soil sampling procedures should be varied and the resulting models compared.
- ❖ Also, inter-comparison study on the models and the input data is also recommended.

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APPENDIX

CORRELATION COEFFICIENT

In order to establish whether there is a linear relationship between two variables x_1 and y_1 the Pearson's correlation coefficient r is used.

$$r = \frac{n\sum x_1 y_1 - \sum x_1 \sum y_1}{\sqrt{[n\sum x_1^2 - (\sum x_1)^2][n\sum y_1^2 - (\sum y_1)^2]}} \quad (1)$$

where n is the number of data points.

The value of r must lie between +1 and -1: the nearer it is to +1, or in the case of negative correlation to -1; then the greater the probability that a definite linear relationship exists between the variables x and y . Values of r that tend towards zero indicate that x and y are not linearly related (they may be related in a non-linear fashion). It is a sound practice to represent the relationship between the two variables by plotting a graph of y_1 versus x_1 .

LINEAR REGRESSION

Once a linear relationship has been shown to have a high probability by the value of the correlation coefficient (r), then the best straight line through the data points has been estimated. This can often be done by visual inspection of the plotted graph but in many cases it is far better practice to evaluate the best straight line by linear regression (method of least squares). The equation is;

$$y = ax + b \quad (2)$$

where y , the dependent variable, is plotted as a result of changing x , the independent variable.

To obtain the regression line 'y on x', the slope of the line (a) and the intercept on the y - axis (b) are given by the following equations.

$$a = \frac{n\sum x_1 y_1 - \sum x_1 \sum y_1}{n\sum x_1^2 - (\sum x_1)^2} \quad (3)$$

$$\text{and } b = \bar{y} - a\bar{x}$$

where \bar{x} is the mean of all values of x_1 and \bar{y} is the mean of all values of y_1

Analysis of copper (Cu),

1. Mobil – 'Roadside A'

c (µg/g)	d (m)	cd (µg/g.m)	d ² (m ²)
35.20	0	0	0
34.60	50	1730	2,500
34.00	100	3400	10,000
33.80	150	5070	22,500
3.10	200	6620	40,000
$\Sigma c = 170.70$	$\Sigma d = 500$	$\Sigma cd = 16,820$	$\Sigma d^2 = 75,000$

Considering the regression equation (2); and taking equations (3) and (4) into cognisance.

$$a = \frac{5 \times 16820 - 500 \times 170.7}{5 \times 75,000 - (500)^2}$$

$$a = -0.01$$

$$\bar{c} = 170.7/5 = 34.14$$

$$\bar{d} = 500/5 = 100$$

$$b = 34.14 - (-0.01) \times 100$$

$$b = 35.14$$

$$\underline{CCuMbA = 35.14 - (E - 2) D}$$

2. Mobil – 'Roadside B'

c (µg/g)	d (m)	cd (µg/g.m)	d ² (m ²)
34.00	0	0	0
33.50	50	1675	2,500
32.90	100	3290	10,000
32.10	150	4815	22,500
31.40	200	6280	40,000
Σc = 163.70	Σd = 500	Σcd = 16,060	Σd ² = 75,000

$$a = \frac{5 \times 16,060 - 500 \times 163.9}{5 \times 75,000 - (500)^2}$$

$$a = -0.0132$$

$$\bar{c} = 163.90/5 = 32.78$$

$$\bar{d} = 500/5 = 100$$

$$b = 32.78 - (-0.0132) \times 100$$

$$b = 34.1$$

$$\underline{CCuMbB} = \underline{34.1 - (1.32 \text{ E} - 2) D}$$

3. Bosso – 'Roadside A'

C (µg/g)	d (m)	cd (µg/g.m)	d ² (m ²)
10.50	0	0	0
9.50	50	475	2,500
8.70	100	870	10,000
8.00	150	1200	22,500
8.00	200	1600	40,000
Σc = 44.7	Σd = 500	Σcd = 4145	Σd ² = 75,000

$$a = \frac{5 \times 4145 - 500 \times 44.7}{5 \times 75,000 - (500)^2}$$

$$a = -0.013$$

$$\bar{c} = 44.7/5 = 8.94$$

$$\bar{d} = 500/5 = 100$$

$$b = 8.94 - (-0.013) 100 = 10.24$$

$$b = 10.24$$

$$\underline{CCuBsA = 10.24 - (1.3E - 2) D}$$

4. Bosso 'Roadside B'

C (µg/g)	d (m)	Cd (µg/g.m)	d ² (m ²)
11.20	0	0	0
11.00	50	550	2500
10.70	100	1070	10,000
10.50	150	1575	22,500
10.00	200	2,000	40,000
Σc = 53.4	Σd = 500	Σcd = 5, 195	Σd ² = 75,000

$$a = \frac{5 \times 5, 195 - 500 \times 53.4}{5 \times 75,000 - (500)^2}$$

$$a = - 5.8 \times 10^{-3}$$

$$\bar{c} = 53.4/5 = 10.68$$

$$\bar{d} = 500/5 = 100$$

$$b = 10.68 - (- 5.8 \times 10^{-3}) \times 100$$

$$b = 11.26$$

$$\underline{CCuBsB} = \underline{11.26 - (5.8 \text{ E} - 3) D}$$

5. Chanchaga - 'Roadside A'

C (µg/g)	d (m)	Cd (µg/g.m)	d ² (m ²)
13.20	0	0	0
12.90	50	645	2,500
12.60	100	1260	10,000
12.10	150	1815	22,500
11.70	200	2340	40,000
Σc = 62.5	Σd = 500	Σcd = 6060	Σd ² = 75,000

$$a = \frac{5 \times 6060 - 500 \times 62.5}{5 \times 75,000 - (500)^2}$$

$$a = - 7.6 \times 10^{-3}$$

$$\bar{c} = 62.5/5 = 12.5$$

$$\bar{d} = 500/5 = 100$$

$$b = 12.5 - (- 7.6 \times 10^{-3}) \times 100$$

$$b = 13.26$$

$$\underline{CCuChgA} = 13.26 + (-7.6 \text{ E-3})D$$

G. Chanchaga - 'Roadside B'

C (µg/g)	d (m)	Cd (µg/g.m)	d ² (m ²)
11.90	0	0	0
11.40	50	570	2500
11.00	100	1100	10,000
10.60	150	1590	22,500
10.30	200	2060	40,000
Σc = 55.20	Σd = 500	Σcd = 5320	Σd ² = 75,000

$$a = \frac{5 \times 5320 - 500 \times 55.20}{5 \times 75,000 - (500)^2}$$

$$a = - 8 \times 10^{-3}$$

$$\bar{c} = 55.20/5 = 11.04$$

$$\bar{d} = 500/5 = 100$$

$$b = 11.04 - (- 8 \times 10^{-3}) \times 100$$

$$b = 11.84$$

$$\underline{CCuChgB} = 11.84 - (8 \text{ E-}3)D$$

7. Kpakungu - 'Roadside A'

c (µg/g)	d (m)	Cd (µg/g.m)	d ² (m ²)
14.40	0	0	0
13.50	50	675	2,500
12.50	100	1250	10,000
11.70	150	1755	22,500
10.80	200	2160	40,000
Σc = 62.9	Σd = 500	Σcd = 5840	Σd ² = 75,000

$$a = \frac{5 \times 5840 - 500 \times 62.9}{5 \times 75,000 - (500)^2}$$

$$a = -0.018$$

$$\bar{c} = 62.9/5 = 12.58$$

$$\bar{d} = 500/5 = 100$$

$$b = 12.58 - (-0.018) \times 100$$

$$b = 14.38$$

$$\underline{CCuKpA = 14.38 - (1.8 \text{ E-}2)D}$$

8. Kpakungu - 'Roadside B'

C (µg/g)	d (m)	Cd (µg/g.m)	d ² (m ²)
13.80	0	0	0
13.30	50	655	2,500
12.70	100	1270	10,000
12.00	150	1800	22,500
12.00	200	2400	40,000
Σc = 63.8	Σd = 500	Σcd = 6135	Σd ² = 75,000

$$a = \frac{5 \times 6135 - 500 \times 63.8}{5 \times 75,000 - (500)^2}$$

$$a = - 9.8 \times 10^{-3}$$

$$\bar{c} = 63.8/5 = 12.76$$

$$\bar{d} = 500/5 = 100$$

$$b = 12.76 - (- 9.8 \times 10^{-3}) \times 100$$

$$b = 13.74$$

$$\underline{CCuKpB} = \underline{13.74 - (9.8 \text{ E-}3)D}$$

Analysis of Lead (Pb)

1. Mobil - 'Roadside A'

C ($\mu\text{g/g}$)	d (m)	Cd ($\mu\text{g/g. m}$)	d ² (m ²)
168.80	0	0	0
165.00	50	8250	2500
161.50	100	16150	10,000
157.90	150	23685	22,500
154.40	200	30,880	40,000
$\Sigma c = 807.60$	$\Sigma d = 500$	$\Sigma cd = 78,965$	$\Sigma d^2 = 75,000$

Considering the regression equation (2), and taking equation (3) and (4) into cognisance.

$$a = \frac{5 \times 78,965 - 500 \times 807.6}{5 \times 75,000 - (500)^2}$$

$$a = - 7.18 \times 10^{-2}$$

$$\bar{c} = 807.6/5 = 161.52$$

$$\bar{d} = 500/5 = 100$$

$$b = 161.52 - (-0.0718) \times 100$$

$$b = 168.7$$

$$\underline{\text{CPbMbA}} = \underline{168.7 - (7.18 \text{ E-}2)\text{D}}$$

2. Mobil - 'Roadside B'

C (µg/g)	d (m)	Cd (µg/g.m)	d ² (m ²)
165.20	0	0	0
164.00	50	8200	2500
162.50	100	16,250	10,000
160.50	150	24075	22,500
158.60	200	31720	40,000
Σc = 810.80	Σd = 500	Σcd = 80245	Σd ² = 75,000

$$a = \frac{5 \times 80245 - 500 \times 810.8}{5 \times 75,000 - (500)^2}$$

$$a = - 3.34 \times 10^{-2}$$

$$\bar{c} = 810.8/5 = 162.16$$

$$\bar{d} = 500/5 = 100$$

$$b = 162.16 - (-0.0334) \times 100$$

$$b = 165.5$$

$$\underline{CPbMbB} = \underline{165.5 - (3.34 \text{ E-}2)D}$$

3. Bosso - 'Roadside A'

C (μg/g)	d (m)	Cd (μg/g.m)	d ² (m ²)
76.50	0	0	0
76.00	50	3800	2500
75.20	100	7520	10,000
74.30	150	11145	22,500
73.60	200	14720	40,000
Σc = 375.6	Σd = 500	Σcd = 37,185	Σd ² = 75,000

$$a = \frac{5 \times 37,185 - 500 \times 375.6}{5 \times 75,000 - (500)^2}$$

$$a = - 1.5 \times 10^{-2}$$

$$\bar{c} = 375.6/5 = 75.12$$

$$\bar{d} = 500/5 = 100$$

$$b = 75.12 - (-0.015) \times 100$$

$$b = 76.62$$

$$\underline{\text{CPbBsA}} = \underline{76.62 - (1.5 \text{ E-}2)\text{D}}$$

4. Bosso - 'Roadside B'

C (µg/g)	d (m)	Cd (µg/g.m)	d ² (m ²)
81.20	0	0	0
80.40	50	4020	2500
79.80	100	7980	10,000
72.10	150	10815	22,500
70.30	200	14,060	40,000
Σc = 383.8	Σd = 500	Σcd = 36,875	Σd ² = 75,000

$$a = \frac{5 \times 36,875 - 500 \times 383.8}{5 \times 75,000 - (500)^2}$$

$$a = - 0.0602$$

$$\bar{c} = 383.8/5 = 76.76$$

$$\bar{d} = 500/5 = 100$$

$$b = 76.76 - (-0.0602) \times 100$$

$$b = 82.78$$

$$\underline{CPbBsB} = \underline{82.78 - (6.02 \text{ E-}2)D}$$

5. Chanchaga - 'Roadside A'

C (µg/g)	d (m)	Cd (µg/g.m)	d ² (m ²)
110.20	0	0	0
108.10	50	5405	2500
104.20	100	10,420	10,000
100.50	150	15,075	22,500
100.50	200	20,100	40,000
Σc = 523.5	Σd = 500	Σcd = 51,000	Σd ² = 75,000

$$a = \frac{5 \times 51,000 - 500 \times 523.5}{5 \times 75,000 - (500)^2}$$

$$a = -0.054$$

$$\bar{c} = 523.5/5 = 104.70$$

$$\bar{d} = 500/5 = 100$$

$$b = 104.7 - (-0.054) \times 100$$

$$b = 110.10$$

$$\underline{\text{CPbChgA}} = \underline{110.10 - (5.4 \text{ E-}3)\text{D}}$$

6. Chanchaga - 'Roadside B'

C (μg/g)	d (m)	Cd (μg/g.m)	d ² (m ²)
117.00	0	0	0
115.30	50	5,765	2500
112.50	100	11,250	10,000
109.90	150	16,485	22,500
107.20	200	21,440	40,000
Σc = 561.90	Σd = 500	Σcd = 54,940	Σd ² = 75,000

$$a = \frac{5 \times 54,940 - 500 \times 561.9}{5 \times 75,000 - (500)^2}$$

$$a = -0.05$$

$$\bar{c} = 561.9/5 = 112.38$$

$$\bar{d} = 500/5 = 100$$

$$b = 112.38 - (-0.05) \times 100$$

$$b = 117.38$$

$$\underline{CPbChgB} = \underline{117.38 - (5 \text{ E-}2)D}$$

7. Kpakungu - 'Roadside A'

C (μg/g)	d (m)	Cd (μg/g. m)	d ² (m ²)
81.10	0	0	0
80.80	50	4,040	2500
80.60	100	8,060	10,000
80.30	150	12,045	22,500
79.00	200	15,800	40,000
Σc = 401.80	Σd = 500	Σcd = 39,945	Σd ² = 75,000

$$a = \frac{5 \times 39,945 - 500 \times 401.8}{5 \times 75,000 - (500)^2}$$

$$a = - 9.4 \times 10^{-3}$$

$$\bar{c} = 401.80/5 = 80.36$$

$$\bar{d} = 500/5 = 100$$

$$b = 80.36 - (-0.0094) \times 100$$

$$b = 81.30$$

$$\underline{CPbKpA = 81.3 - (9.4 E-3)D}$$

8. Kpakungu - 'Roadside B'

C (μg/g)	d (m)	Cd (μg/g. m)	d ² (m ²)
85.00	0	0	0
84.00	50	4200	2500
83.20	100	8320	10,000
82.20	150	12,300	22,500
81.50	200	16,300	40,000
Σc = 415.7	Σd = 500	Σcd = 41,120	Σd ² = 75,000

$$a = \frac{5 \times 41,120 - 500 \times 415.7}{5 \times 75,000 - (500)^2}$$

$$a = - 0.018$$

$$\bar{c} = 415.7/5 = 83.14$$

$$\bar{d} = 500/5 = 100$$

$$b = 83.14 - (-0.018) \times 100$$

$$b = 84.94$$

$$\underline{CPbKpB = 84.94 - (1.8 \text{ E-}2)D}$$

PREDICTION

(a) Prediction of concentrations for copper

(1) Mobil - 'Roadside A'

$$\text{Model} - \text{CCuMbA} = 35.14 - (E - 2) D$$

D(m)	Predicted concentration ($\mu\text{g/g}$)
0	35.14
50	34.64
100	34.14
150	33.64
200	33.14

(2) Mobil - 'Roadside B'

$$\text{Model} - \text{CCuMbB} = 34.1 - (1.32E - 2) D$$

D(m)	Predicted concentration ($\mu\text{g/g}$)
0	34.10
50	33.44
100	32.78
150	32.12
200	31.46

(3) Bosso - 'Roadside A'

Model - CCuBsA = $10.24 - (1.3E - 2) D$

D(m)	Predicted concentration ($\mu\text{g/g}$)
0	10.24
50	9.59
100	8.94
150	8.29
200	7.64

(4) Bosso - 'Roadside B'

Model - CCuBsB = $11.26 - (5.8E - 3) D$

D(m)	Predicted concentration ($\mu\text{g/g}$)
0	11.26
50	10.97
100	10.68
150	10.39
200	10.1

(5) Chanchaga - 'Roadside A'

Model - $CCuChgA = 13.26 - (7.6E - 3) D$

D(m)	Predicted concentration ($\mu\text{g/g}$)
0	13.26
50	12.88
100	12.50
150	12.12
200	11.74

(6) Chanchaga - 'Roadside B'

Model - $CCuchgB = 11.84 - (8E - 3) D$

D(m)	Predicted concentration ($\mu\text{g/g}$)
0	11.84
50	11.44
100	11.04
150	10.64
200	10.24

(7) Kpakungu - 'Roadside A'

Model - CCuKpA = $14.38 - (1.8E - 2) D$

D(m)	Predicted concentration ($\mu\text{g/g}$)
0	14.38
50	13.48
100	12.58
150	11.68
200	10.78

(8) Kpakungu - 'Roadside B'

Model - CCuKpB = $13.74 - (9.8E - 3) D$

D(m)	Predicted concentration ($\mu\text{g/g}$)
0	13.74
50	13.25
100	12.76
150	12.27
200	11.78

(b) Prediction of concentrations for Lead

(1) Mobil - 'Roadside A'

$$\text{Model} \quad - \quad \text{CPbMbA} \quad = \quad 168.7 - (7.18\text{E} - 2) D$$

D(m)	Predicted concentration ($\mu\text{g/g}$)
0	168.70
50	165.11
100	161.52
150	157.93
200	154.34

(2) Mobil - 'Roadside B'

$$\text{Model} \quad - \quad \text{CPbMbA} \quad = \quad 165.5 - (3.34\text{E} - 2) D$$

D(m)	Predicted concentration ($\mu\text{g/g}$)
0	165.50
50	163.83
100	162.16
150	160.49
200	158.82

(3) Bosso - 'Roadside A'

$$\text{Model} - \text{CPbBsA} = 76.62 - (1.5E - 2) D$$

D(m)	Predicted concentration ($\mu\text{g/g}$)
0	76.62
50	75.87
100	75.12
150	74.37
200	73.62

(4) Bosso - 'Roadside B'

$$\text{Model} - \text{CPbBsB} = 82.78 - (6.02E - 2) D$$

D(m)	Predicted concentration ($\mu\text{g/g}$)
0	82.78
50	79.77
100	76.76
150	73.75
200	70.74

(5) Chanchaga - 'Roadside A'

Model - CPbChgA = $110.10 - (5.4E - 3) D$

D(m)	Predicted concentration ($\mu\text{g/g}$)
0	110.10
50	109.83
100	109.56
150	109.29
200	109.20

(6) Chanchaga - 'Roadside B'

Model - CPbChgB = $117.38 - (5E - 2) D$

D(m)	Predicted concentration ($\mu\text{g/g}$)
0	117.38
50	114.88
100	112.38
150	109.88
200	107.38

(7) Kpakungu - 'Roadside A'

$$\text{Model} - \text{CPbKpA} = 81.3 - (9.4E - 3) D$$

D(m)	Predicted concentration ($\mu\text{g/g}$)
0	81.3
50	80.83
100	80.36
150	79.89
200	79.42

(8) Kpakungu - 'Roadside B'

$$\text{Model} - \text{CPbKpB} = 84.94 - (1.8E - 2) D$$

D(m)	Predicted concentration ($\mu\text{g/g}$)
0	84.94
50	84.04
100	83.14
150	82.24
200	81.34

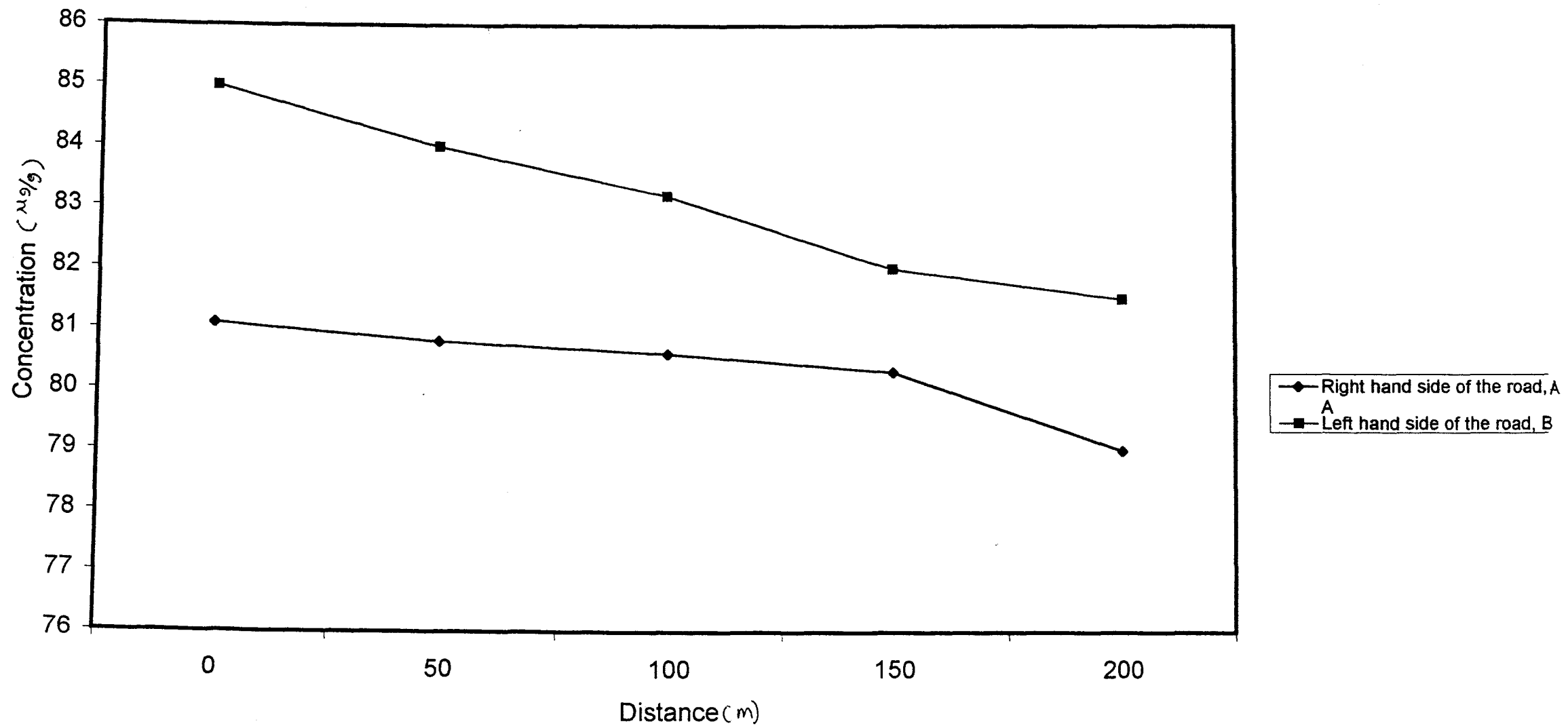


Fig. 1: Concentration of Lead (Pb) versus distance at Kpakungu

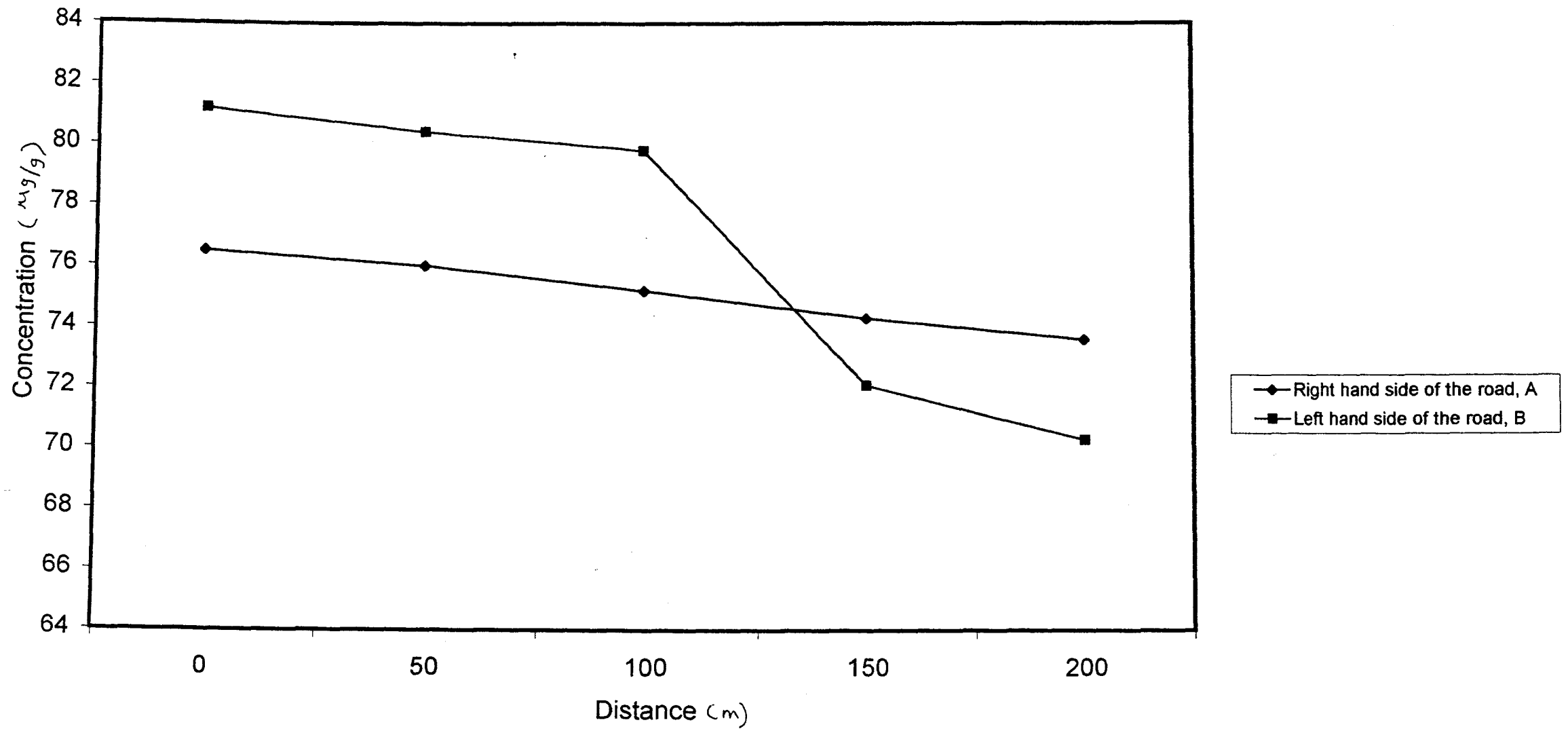


Fig. 2: Concentration of Lead (Pb) versus distance at Bosso

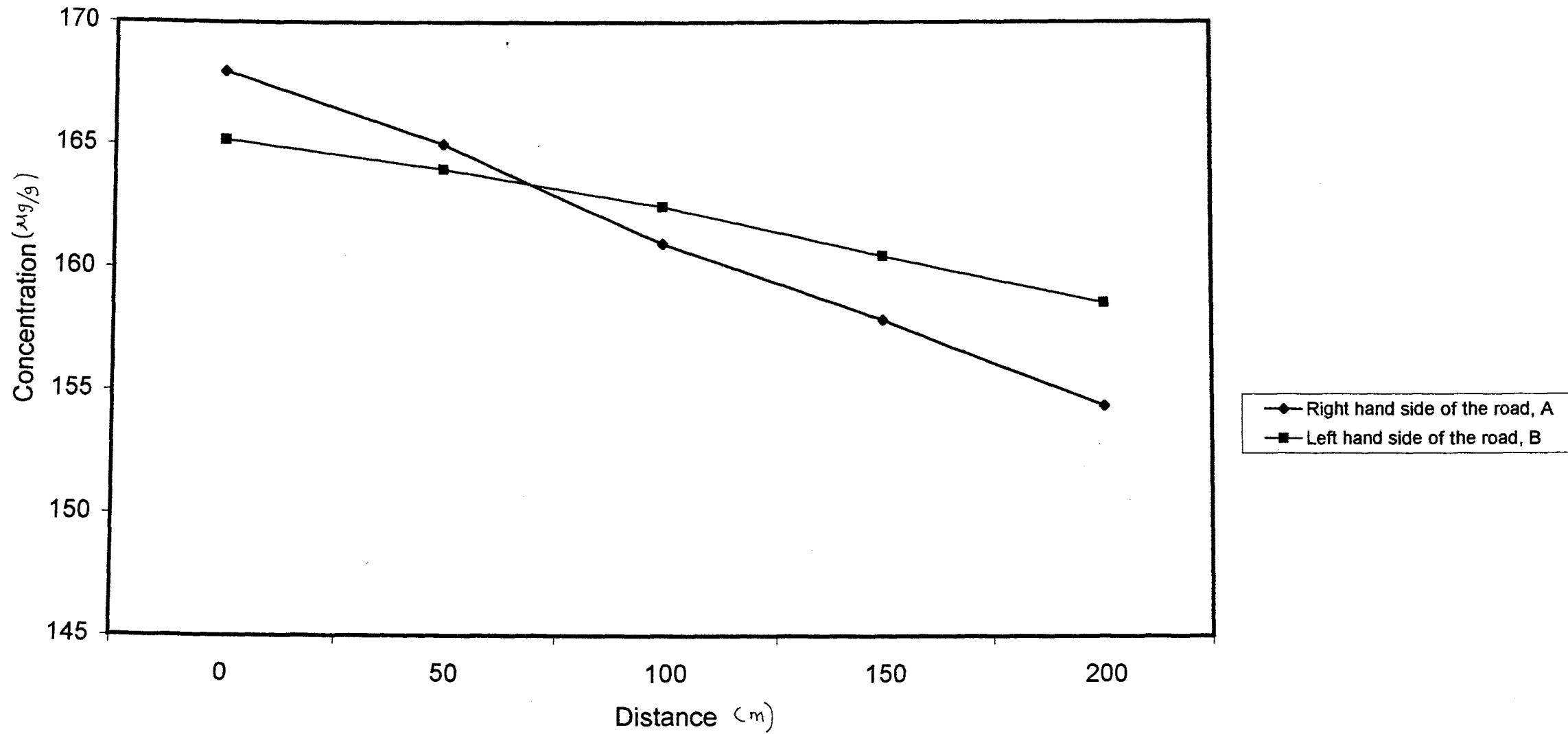


Fig. 3: Concentration of Lead (Pb) versus distance at Mobil

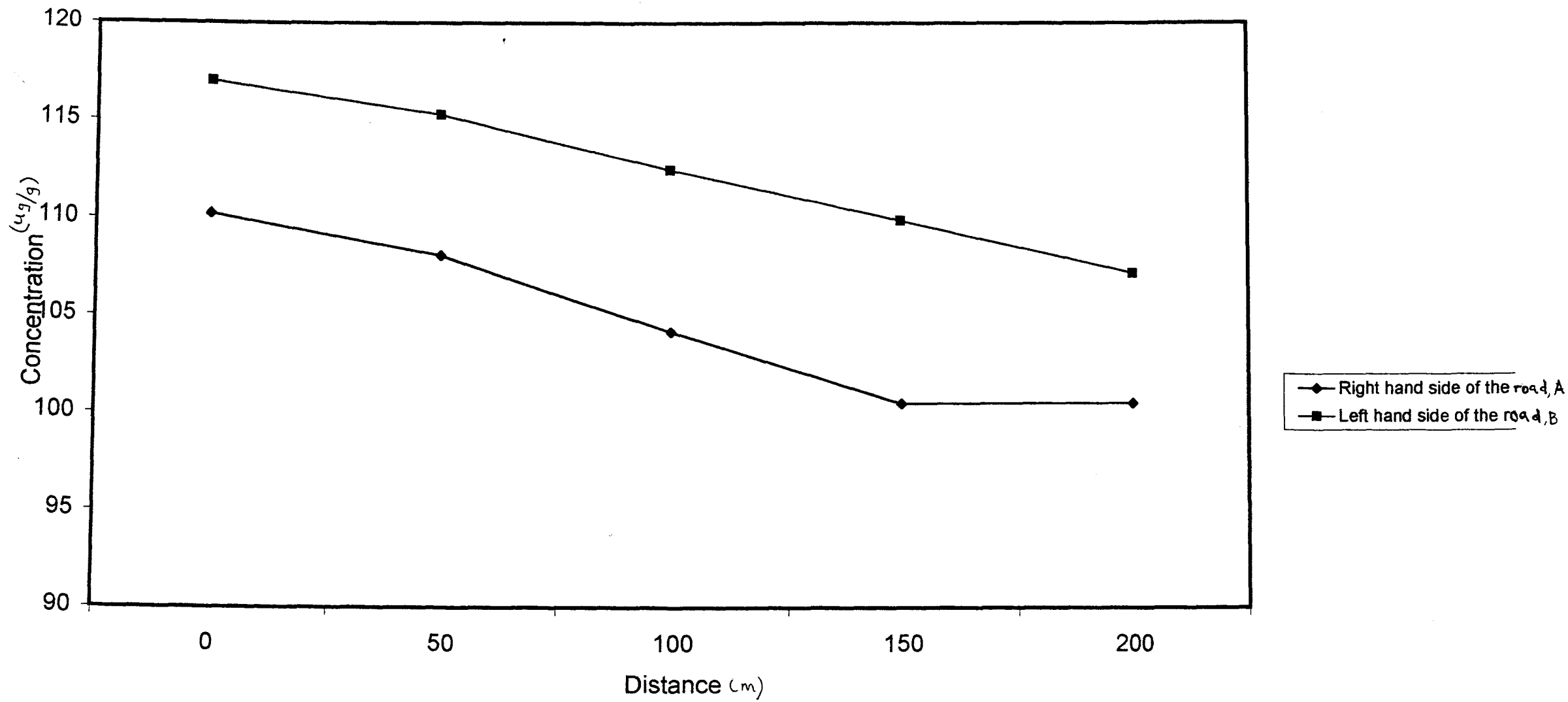


Fig. 4: Concentration of Lead (Pb) versus concentration at Chanchaga

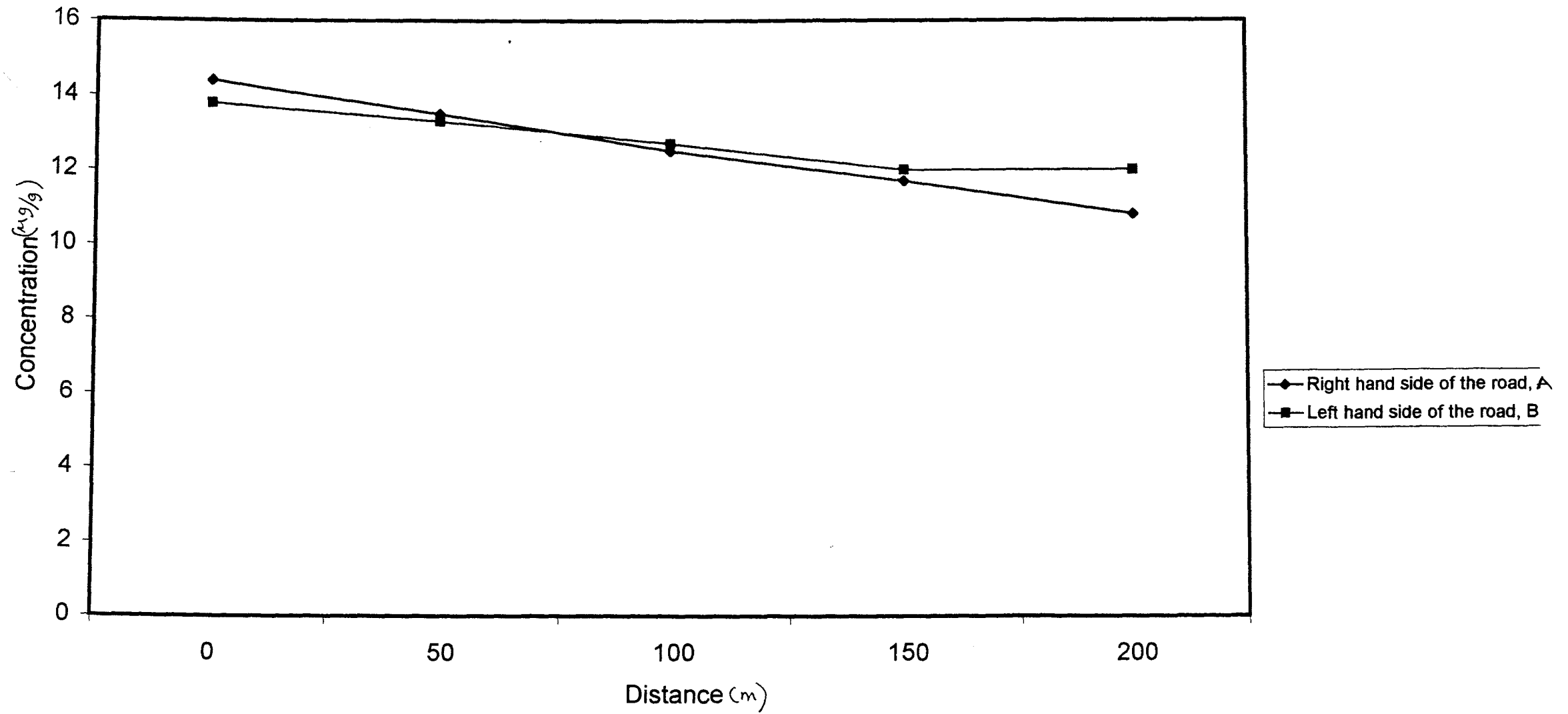


Fig. 5: Concentration of Copper (Cu) versus distance at Kpakungu

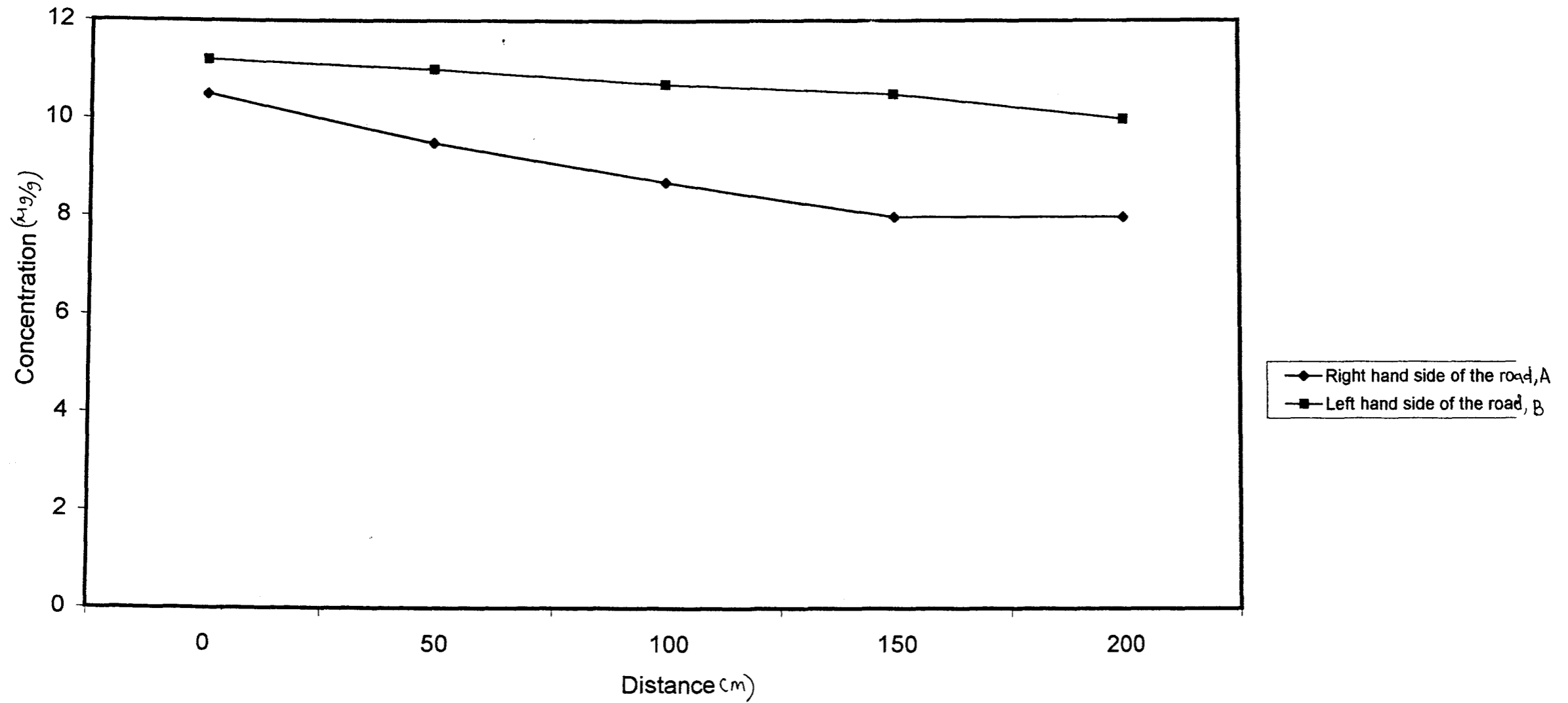


Fig. 6: Concentration of Copper (Cu) versus concentration at Bosso

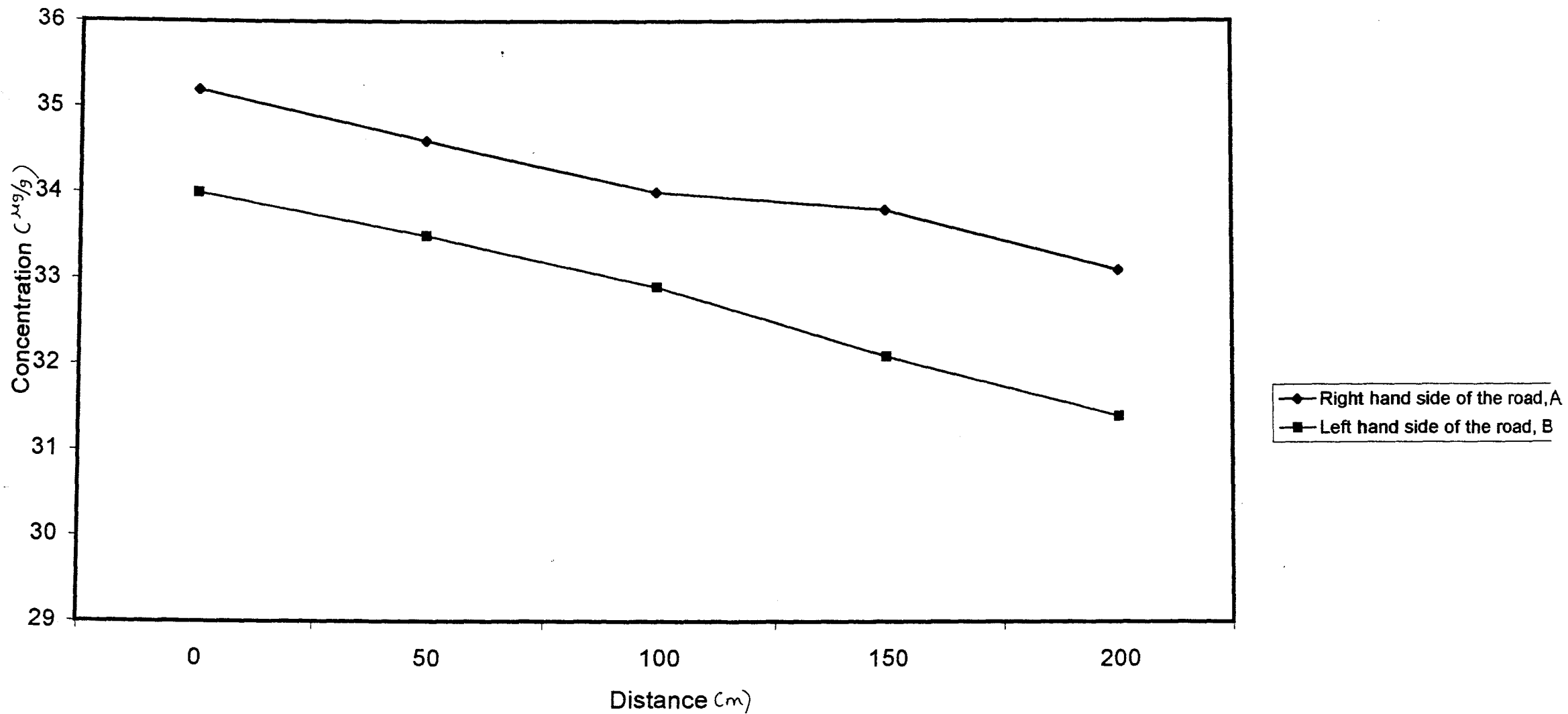


Fig. 7: Concentration of Copper (Cu) versus distance at Mobil

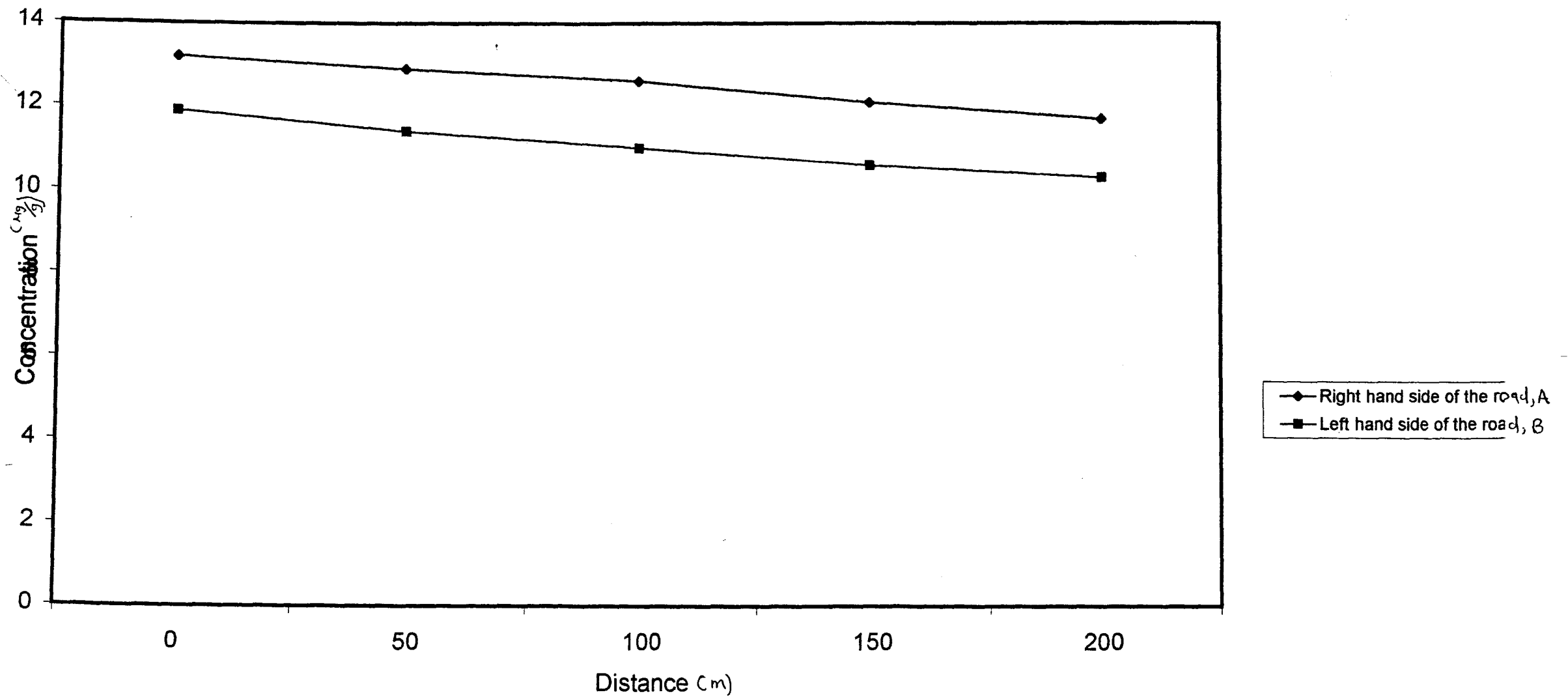


Fig. 8: Concentration of Copper (Cu) versus distance at Chanchaga

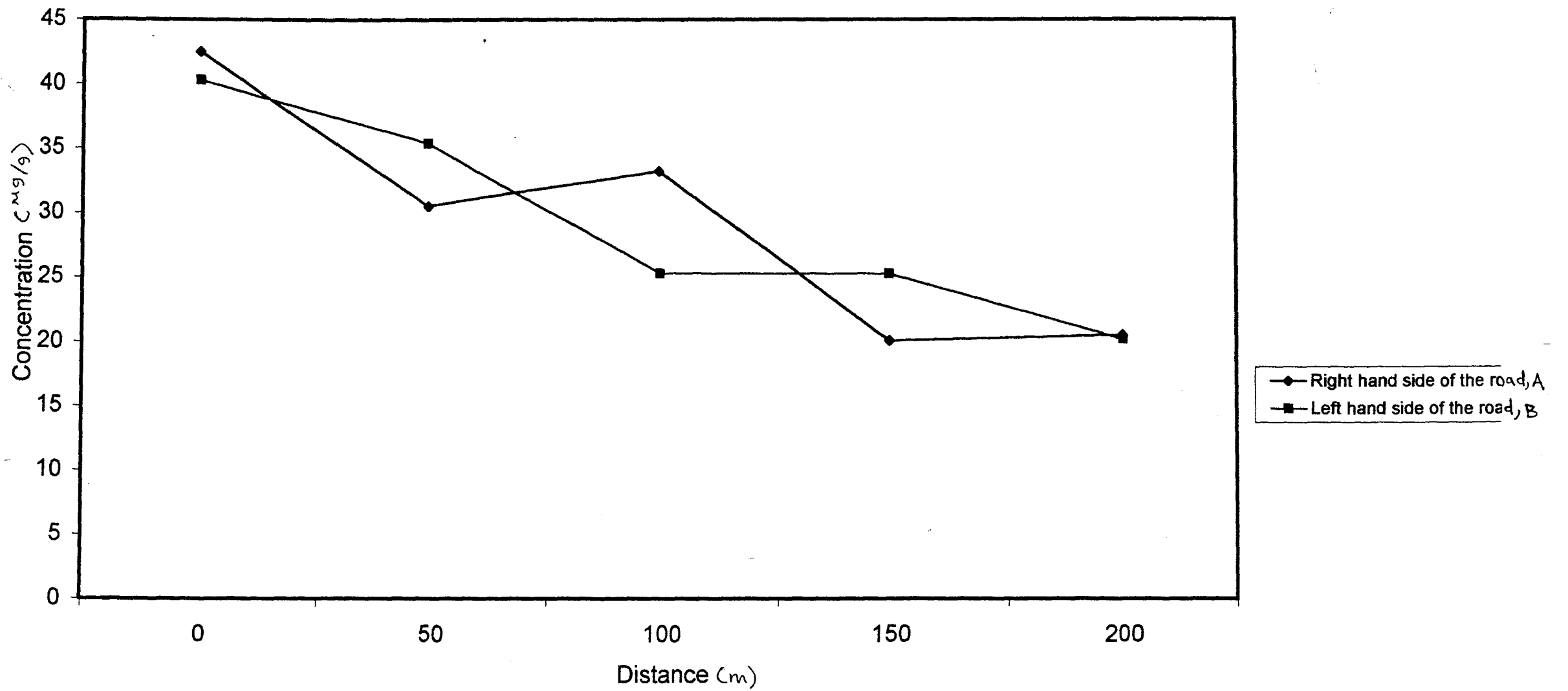


Fig. 9: Concentration of Chromium (Cr) vesus distance at Kpakungu

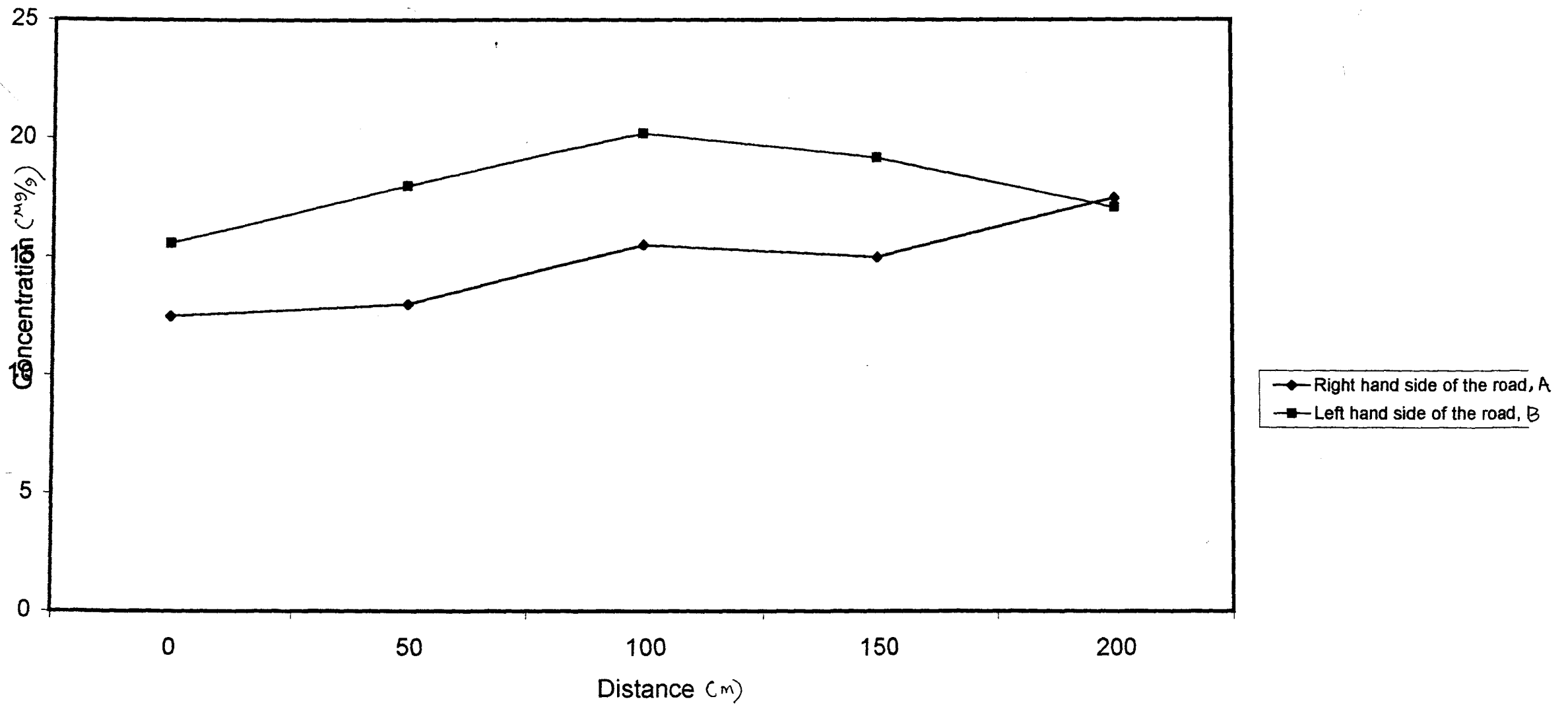


Fig. 10: Concentration of Chromium (Cr) versus distance at Bosso

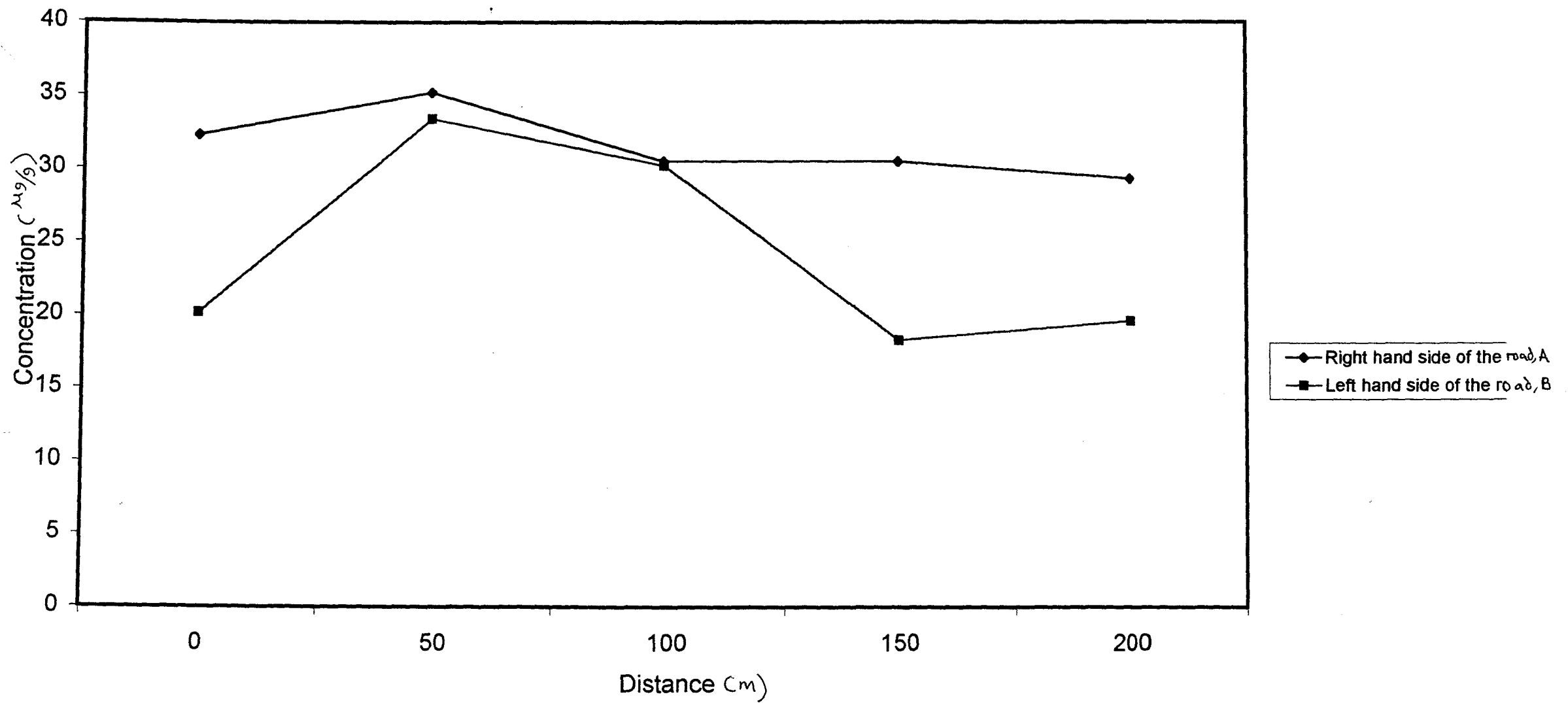


Fig. 11: Concentration of Chromium (Cr) versus distance at Mobil

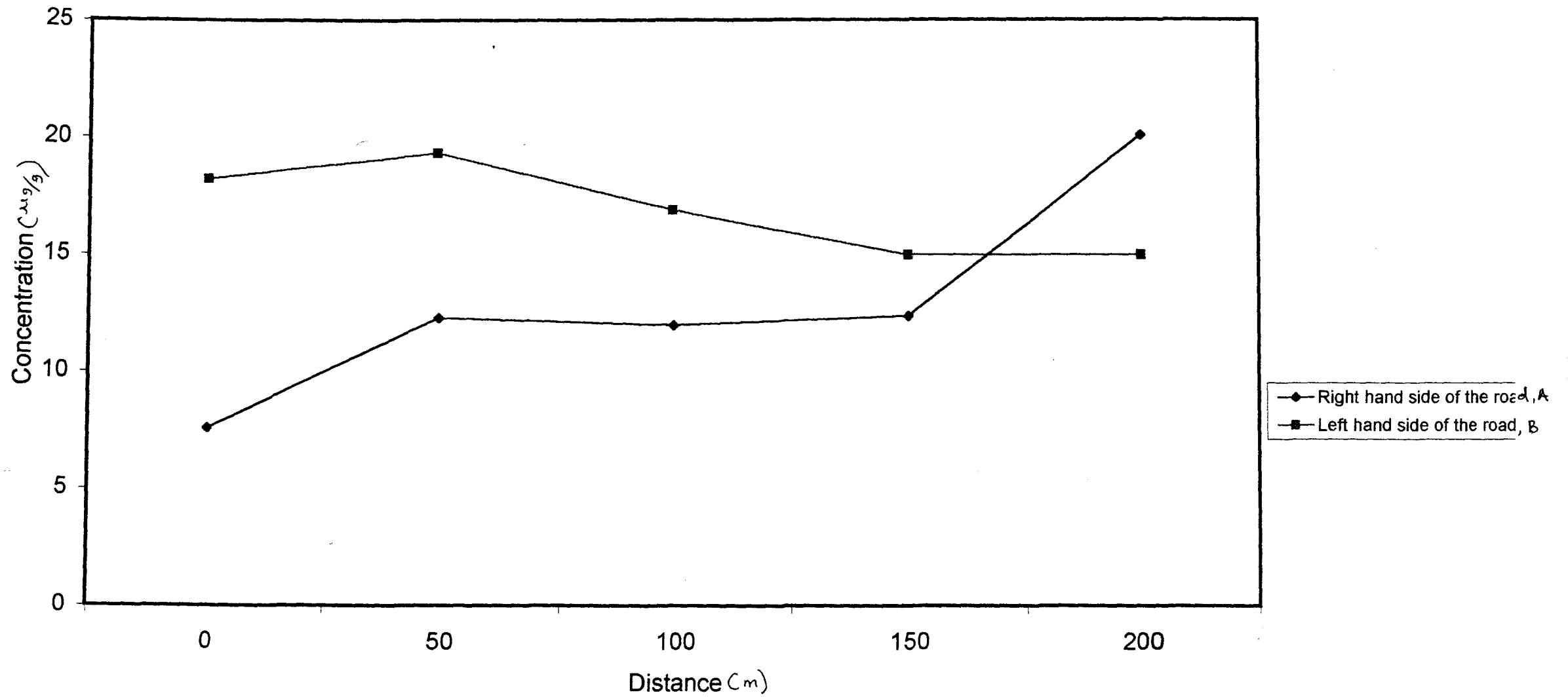


Fig. 12: Concentration of Chromium (Cr) versus distance at Chanchaga

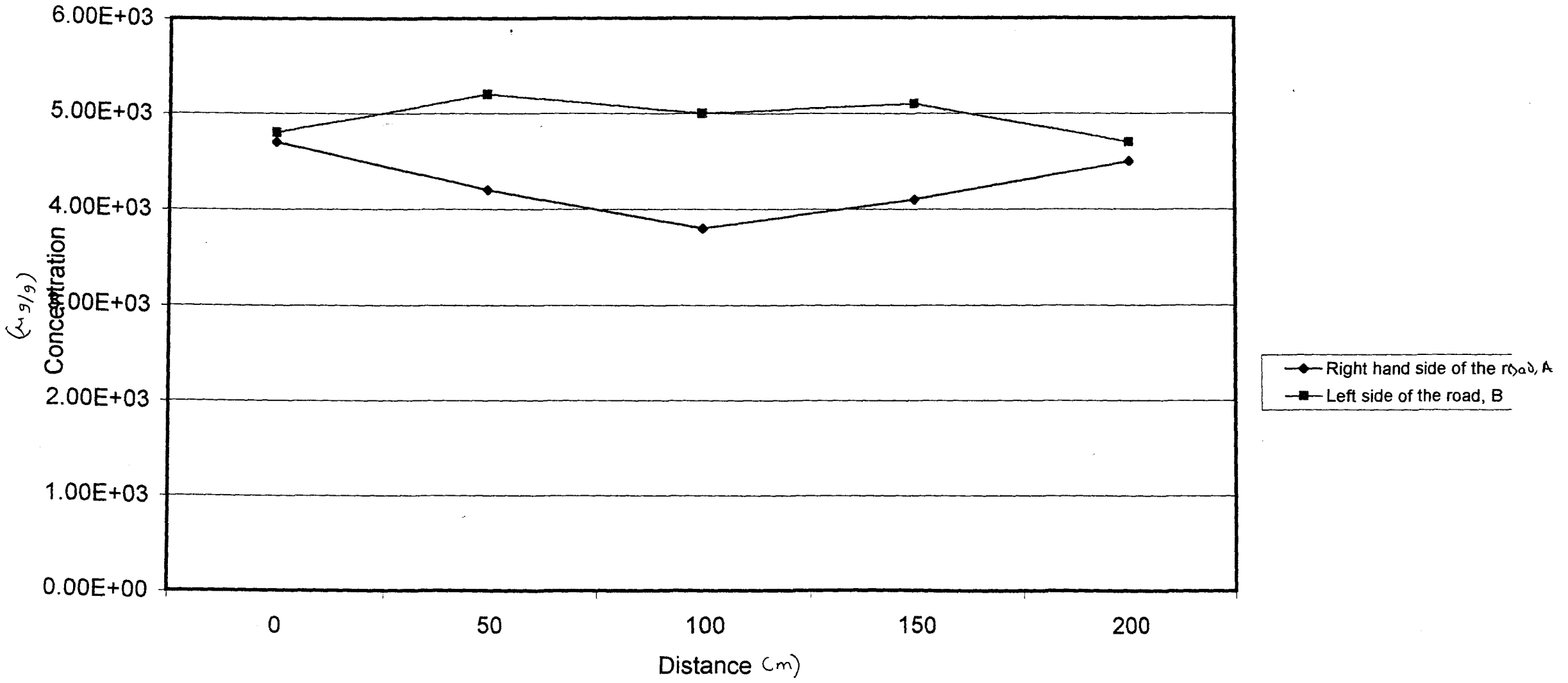


Fig. 13: Concentration of Iron (Fe) versus distance at Kpakungu

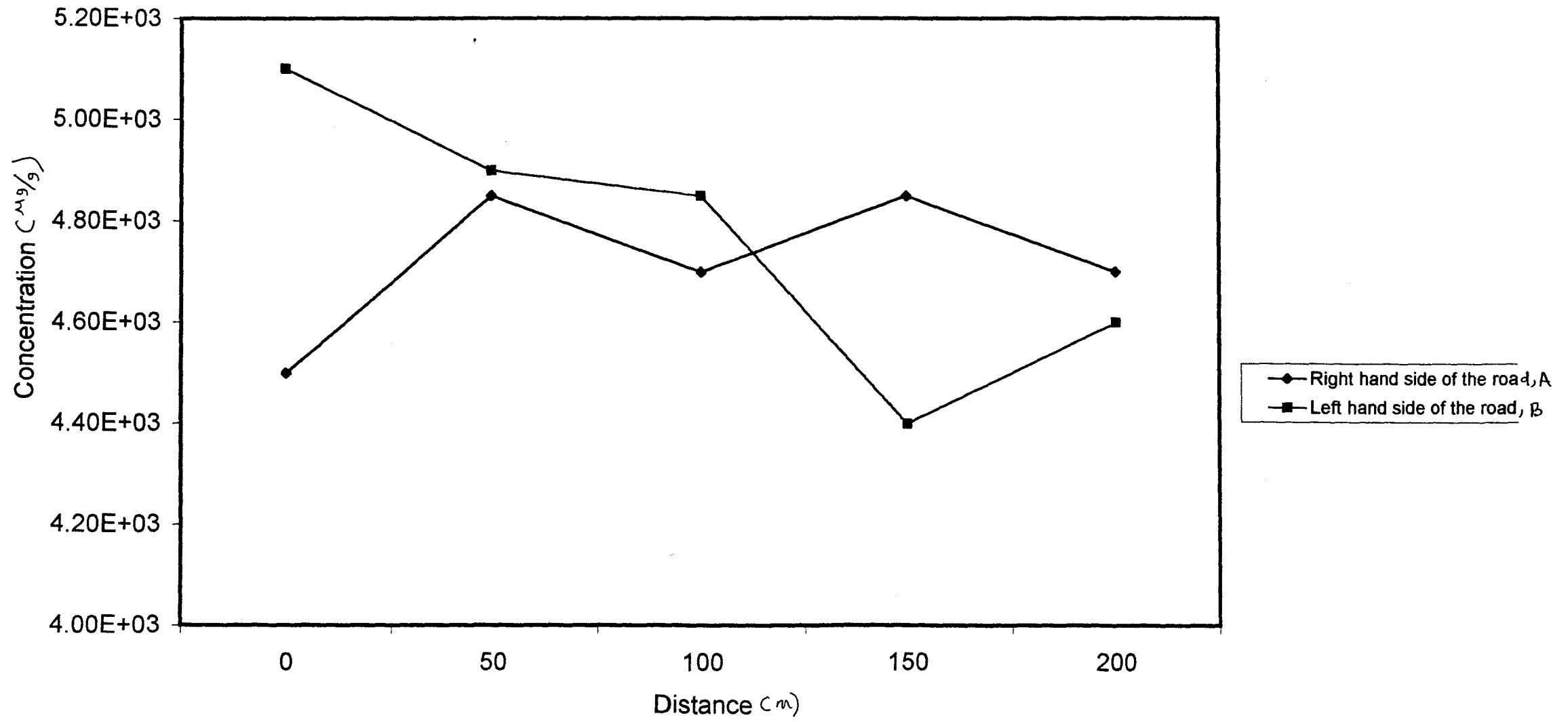


Fig. 14: Concentration of Iron (Fe) versus distance at Bosso

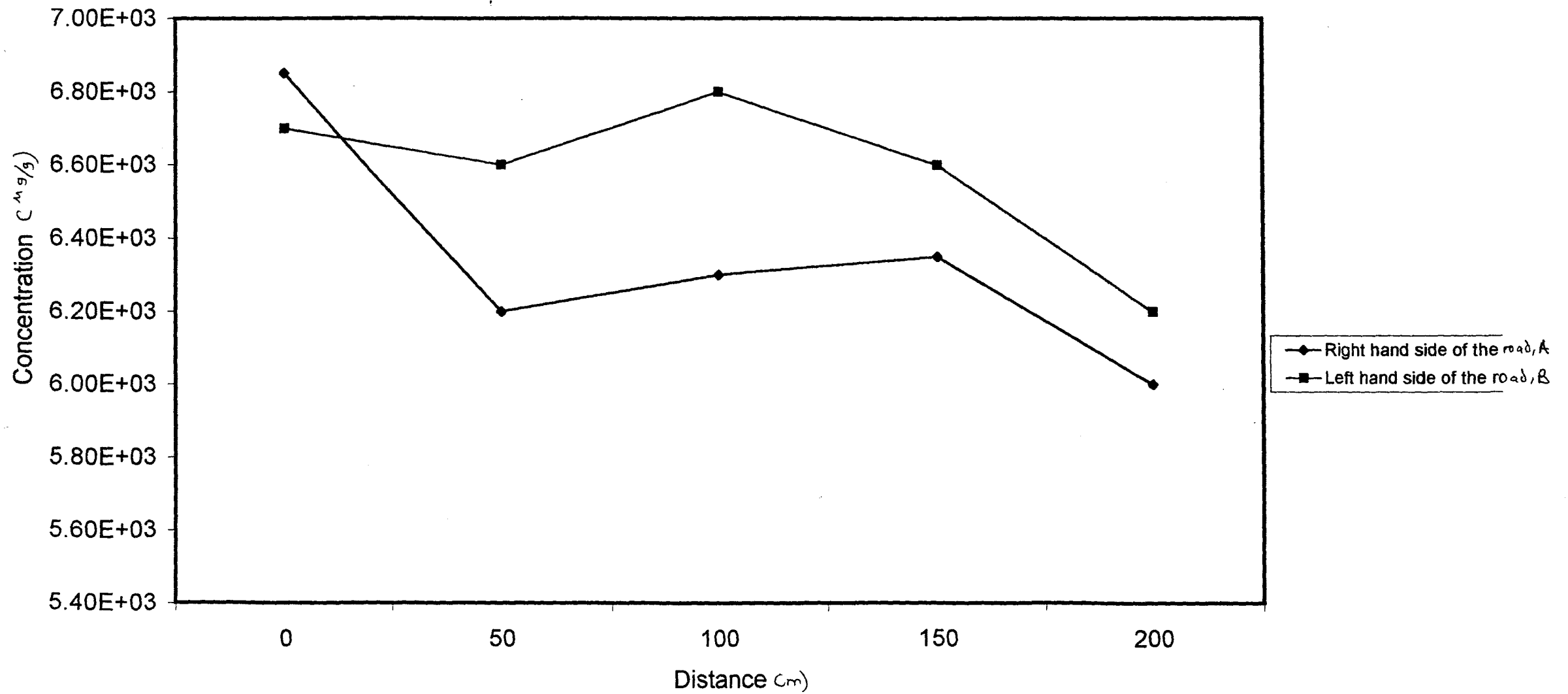


Fig. 15: Concentration of Iron (Fe) versus distance at Mobil

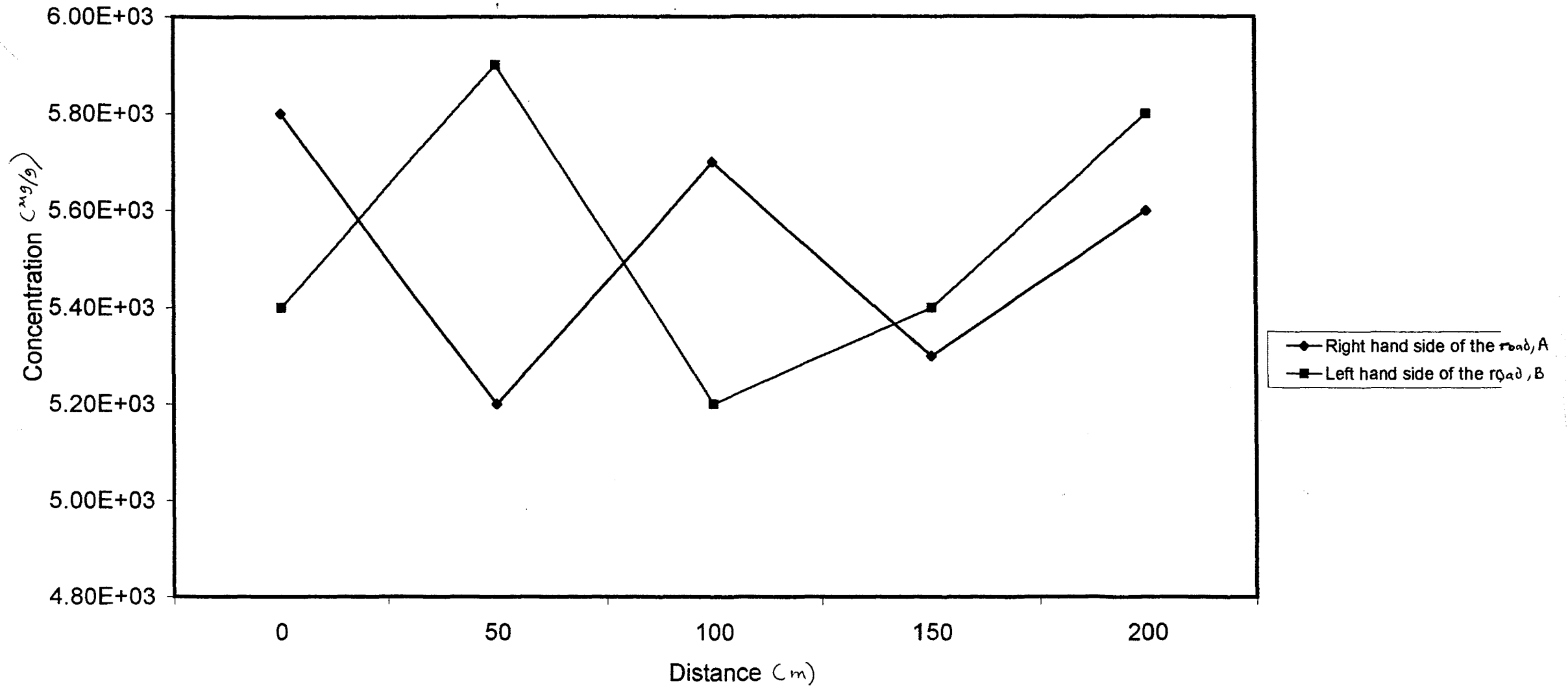


Fig. 16: Concentration of Iron (Fe) versus distance at Chanchaga