

Green Leaves as Indicator for Air Pollution

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Dedication

To my family

Mother, father, sister and brothers

and relatives,

I gladly present this work

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Abstract

Green leaves of Ficus (*Ficus penegalensis*) and Neem (*Azadirachta indica*) were analyzed for their trace metals (Pb, Zn and Cd) contents. The samples were collected and washed according to Metal Analysis Standardization.

Solutions of the samples for analysis were obtained by wet-digestion method using Nitric-perchloric acid mixture.

The trace elements lead, zinc and cadmium were determined by Atomic Absorption Spectroscopic Technique (AAS) for the 18 samples collected from Khartoum (Sharia elneel), Omdurman (Ombadda), and Khartoum North (Kadaro) as heavy-traffic, low-traffic areas and distal area, respectively. The species Ficus and Neem samples were collected each randomly from such areas. The samples were taken from the tips, mids and bottoms of each tree.

ملخص البحث

تم تحليل الأوراق الخضراء لأشجار اللبخ والنيم لتحديد تركيز ومستويات الفلزات / العناصر الثقيلة فيها (الرصاص ، الخارصين والكاديوم). تم جمع العينات وغسلت حسب ما جاء في معيار تحليل الفلزات.

حضرت محاليل العينات بواسطة التفكيك اللين باستخدام خليط من حامض النتريك المركز والبيركلوريك.

تم تحديد تراكيز الرصاص ، الخارصين والكاديوم باستخدام طريقة طيف الامتصاص الذري للثمانية عشر عينة والتي جمعت من الخرطوم جنوب (شارع النيل) ، أم درمان (أمبدة) وبحري (الكدرو) لمناطق معرضة لحركة سيارات ومركبات كثيفة ، ومنخفضة ولمناطق بعيدة على التوالي. وقد جمعت عينات أوراق اللبخ والنيم كل على حدة بطريقة العينة العشوائية من كل منطقة ، حيث أخذت العينات من أعلى الشجرة ومن وسطها وأدنى الفروع.

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CHAPTER ONE

1. INTRODUCTION

The burning of the fossil fuels, the emissions from chemical plants, the wide use of chemicals and other human activities release into the environment large quantities of toxic elements, which are found in a relatively low concentrations in a plant organisms (Dean, *et al.*, 1944).

The pollution of the air, soil and water, the contamination of microorganisms, plants and animals is certainly growing into real hazards (Dean, *et al.*, 1944). These toxic elements and hazardous substances may be transferred from organism to another organism in the ecosystem.

It is necessary to determine the initial concentrations of trace elements in plant green leaves and the extent of contaminations in areas where these elements are expected to show high concentrations (Raymond, 1998). Attention should be paid to those elements, which play no physiological role, which are particularly abundant in the environment, and have high toxicity (Pb, Cd, Zn, Hg, Etc) (Ibrahim, 1986).

In plants, toxic elements either ingested or absorbed from the atmosphere (environmental) can be accumulated. Green leaves (Gabriela, 2002) incorporate trace elements into their structures during growing and later essentially during photosynthesis process. These incorporated trace elements are separated from the continual metabolic activity of the plant organs.

Green leaves are generally discarded, easily removed, rapidly collected, conveniently transported and easily preserved.

Trace elements concentrations are higher in green leaves than in other organs (and tissues) e.g., branches, stems, roots and consequently,

leaves' samples of lower mass can be analyzed with better precision and accuracy, less interferences are also encountered in most leaves elemental measurement techniques (Noble, 1955).

Neem (*Azadirachta indica*) and ficus (*Ficus penegalenesis*) species widely employed for ornamentation and shadow in the Sudan, have been successfully used here for monitoring the metal toxicity of various trace elements to the air by the analysis of their concentrations in green leaves.

To amplify knowledge about their suitability as bio-indicator species, their capacity for accumulating trace elements from urban air pollution was evaluated (Noble, 1955).

The adult and newer leaves of these two species were collected. They were washed with distilled water, dried by the sun light, and ground by means of mortar and then were ready for analysis. Characterization of element levels was carried out by Atomic Absorption Spectroscopy (AAS) and X-ray fluorescence (XRF) (Eliane, 2003).

Plants have played an important role in the biomonitoring of air pollution. Neem and ficus are the plant's species employed to detect the concentrations of several air pollutants by several of spectroscopic methods. The determination of levels of trace elements in these plant's green leaves, using (AAS), Neutron Activation Analysis (NAA) or (XRF) to indicate their potential as accumulators plants for the evaluation of environmental (air) pollution (Eliane, 2003).

There are many sources from which trace elements are incorporated into the green leaves:

- a. **Natural Sources:** these sources are aerosol, water, emission of vehicle exhausts, forest fires, ... etc. Trace elements accumulating from these sources are called natural trace elements (Stern, 1968).
- b. **Anthropogenic Sources:** these sources are the man made and comprise; refineries, smelters, chemical plants, refuse burnings, etc. Trace elements from these sources are called anthropogenic trace elements (Joseph, *et al.*, 1973).

In order to remove natural trace elements, the washing agents, solubility and solvent, adsorption efficiency of the metals (Pb, Cd, and Zn) from solution into leaves and their elution had been tried, and beside these, the site from which the green leaves collected has great effects on the results of analysis of the samples.

Plants trace elements content is affected by agricultural activities (fall blowing, crop dusting) (Noble, 1955). Trace elements concentrations in the leaves are known to vary according to seasons, wind direction, currents, range of exposure of plants to air pollution from site expected to be with higher or lower levels of trace elements.

Trace elements content in green leaves is affected by both the lifetime and the site of the plants, or by geographical location and by the colours of the leaves.

Determination of heavy toxic elements concentration in plant green leaves had been used as a monitor for air exposure to toxic heavy metals (Tee, *et al.*, 1991).

Trace elements analysis of green leaves had found application in agriculture, medicine, health and other aspects. Green leaves trace elements analysis had been performed to establish baseline data for air pollution

monitored by plant. Leaves analysis also was related to the nutritional status of the plants and the degree of contamination (Herkule, 2003).

Most of the analytical methods used for trace elements determination in environmental samples, such as plants, require decomposition of the sample. Hence, when the analytical methods require dissolution of the sample, preparation (in addition to sampling) is the analysis step that has the greatest effect on uncertainty of the final results. This especially important in the determination of trace elements in plants, because plant materials are, as a rule, not homogeneous and they usually contain soil and / or mineral fractions, thus making them difficult to dissolve. Air-borne particulate matter also represents a very complex matrix for analysis. It may contain a large number of elements of widely different concentrations, as well as variable amounts of organic materials and silicate base dust (Mohammed, 1986). (The activated charcoal was used here to bleach the organic colouration of the samples after the hot digestion).

During the last two decades great progress has been made in analytical instrumentation, but both sample preparation and sampling are still the major factors contributing to the uncertainty of the final results (Herkule, 2003).

To be effective, sample digestion methods must efficiently decompose the sample matrix so that the analysis of interest are completely released and solubilized i.e., "total decomposition of the sample", and are in a form compatible with the analytical method of choice. The widely used sample decomposition procedures do not always ensure complete decomposition (Herkule, 2003).

Now a days, a microwave oven is widely used for the total decomposition of environmental samples (Herkule, 2003). There are many advantages in using the microwave digestion for the decomposition of environmental samples, and include decreased digestion times, smaller amounts of acid required, reduced contamination during the digestion procedure and the avoidance of using perchloric acid (HClO_4) (Herkule, 2003).

For the determination of trace elements in environmental samples e.g., plant materials, both in the microwave assisted extraction (leaching) and total digestion techniques have been used for sample preparation (Herkule, 2003). In addition, alkali fusion with sodium carbonate and boric acid has been used especially for the decomposition of atmospheric particles containing chromium. The pressure bomb digestion method also has been used (Herkule, 2003).

In wet digestion (wet-chemical) methods, HF (hydrofluoric acid) is needed for dissolution of the silicate matrix in plants (Herkule, 2003).

After the sample has been decomposed and dissolved, the trace elements are usually determined by atomic absorption spectrometry (AAS) in flame mode (FAAS) or with graphite furnace device (GFAAS), or by inductively coupled plasma atomic emission spectrometry (ICP-AES) (Herkule, 2003).

Although (AAS) is still often used, simultaneous multi-elemental analysis is not possible with this technique. Therefore, (ICP-AES) has become a well established analytical tool for multi-elemental analysis (Herkule, 2003).

Low detection limits, a wide linear dynamic range, relative freedom from chemical interferences and above all, its high sample throughput makes (ICP-AES) a powerful analytical tool for many applications (Herkule, 2003).

Neutron Activation Analysis (NAA) and especially X-ray Fluorescence (XRF) are often applied in trace elements determinations of plants (Herkule, 2003).

1.1 Motor Vehicle Emissions and Air Pollution, at a Glance

It is generally recognized that the motor vehicle in its various forms – cars, buses, trucks, motor cycles, and mopeds – makes a significant contribution to society throughout the world, because of the exceptional mobility, it provides and the vital part it plays in economic growth in energy sector of activity.

It also contributes to the overall development of the less privileged members of the world community in at least two ways – it improves access and transport facilities and it creates a wide range of employment opportunities.

Conversely, it is also recognized that the mounting volume of motor traffic, especially in areas without adequate infrastructures, is associated with certain negative environmental impacts, such as air pollution, noise, congestion and accidents, adversely affecting certain aspects of the quality of life (Geis, 1984).

1.2 Air Pollution and Automobile Emissions

The mix and growth in motor vehicle population in any city determines the contribution of auto emission to the overall air pollution in that city.

As the pollution load attributable to auto exhausts depends on the vehicle kilometers traveled and the growth with time therein, for assessing the need for improvement in the vehicular emissions and fuel quality to contain pollution from auto exhausts, it is necessary to study the growth trends of motor vehicles and the changes in the air quality (motor vehicles – MVG – URTAP).

The growth trends are reviewed in the major cities (Khartoum, Omdurman and Khartoum North). The pollutants from vehicular emissions in any city are attributed not only by the private owned vehicles and the public transport vehicles used by the residents of the city, but also by the private and the public transport determine ambient air quality. However, to know the extent of contribution of auto exhausts to the overall air pollution is a complex exercise. Whereas, the pollution load from vehicular emissions can be known to a fair degree of accuracy, there is hardly any reliable data available in the country, even for the major cities, on air pollution source inventories (motor vehicles – MVG – URTAP).

1.3 Nature of Air Pollutants

Air pollutant is substance presents in gaseous, liquid or solid state that causes an extreme change in the ratios of components, which lead to hazardous – direct and / or indirect – effects on the living organisms and other non-living ones, or it is – the air pollutant – the agent, which causes / makes the conditions unsuitable for the living, otherwise, causing material defeats (Alawdat, 1984).

Air pollutants are those of atomic radiations, increased CO₂, decreased Ozone, NO₂, NO, SO₃ and hydrocarbons, besides other pollutants.

- Air pollutants are those as a result of fuel combustion of transport means, warmness and industry.
- Pollutants due to industrial pollution.
- Pollutants of combustion and burning, rework and waste products and industrial garbage (Detrie, 1973).

The air pollutants due fuel combustion are considered of the most effective agents on the components of the ecosystem, there are essential five pollutants: CO, hydrocarbons, sulphur compounds, nitrogen oxides and molecules (Alawdat, 1984).

1.3.1 Air Pollutants

A chemical species foreign to the composition / contents of the clean atmosphere is said to be a “contaminant”. A contaminant that can cause an adverse effect to a receptor and, which occurs in the atmosphere in concentration sufficiently high to cause the adverse effect is called a “pollutant” (Geis, 1984). Table (1.1) indicates some of the air pollutants.

Table (1.1) Air Pollutant's Compounds and their Examples

Compound / Group	Examples
Solids	Carbon fly ash, ZnO, PbCl ₂
Sulphur Compounds	SO ₂ , SO ₃ , H ₂ S, Mercaptans
Organic Compounds	Aldehydes, hydrocarbons, tars
Nitrogen Compounds	NO, NO ₂ , NH ₃
Oxygen Compounds	O ₃ , CO, CO ₂
Hydrogen Compounds	HF, HCl, HBr
Radioactive Compounds	Radioactive gases, aerosols, ... etc.

(Stern, 1968)

Air pollutants are classified into two categories: primary and secondary pollutants. Primary pollutants are those emitted directly from sources, e.g., CO, NO, NO₂, SO₂, particulates and various hydrocarbons.

Secondary pollutants are those formed by chemical processors in atmosphere e.g., photochemical oxidants and sulphate.

The pollutants most commonly encountered (CO, NO, NO₂, SO₂, hydrocarbon particles and photochemical oxidants) are those associated with sources that involve combustion (automobiles, trucks, fossil fueled electric generation power plants and boilers) (Geis, 1984).

1.3.2 Sources of Air Pollutants

Many agents found naturally or due to man introduction in the nature are considered *sources* of soil, vegetation, under water, seawater pollution and besides all *air pollution* by particles of mine, sulphur gases relevant to high temperatures at the summer time beside motor vehicle emission of matter particulates.

These agents come from many sources other than the domestic industrial effluents, atmosphere, runoff and lithosphere (Stern, 1968).

To far extent, the mix and growth in motor vehicle population in any area determines the contribution of auto-emission to the overall air pollution in that area.

An air pollutant source is defined as any vehicle, facility, physical plant, installation or activity that emit primary air pollutants into atmosphere (Geis, 1984).

For modeling purposes, sources are classified according to the following geometric configuration: *point, line, and area*. Examples of *point* sources are fossil-fueled electric power generating plants and large

municipal incinerators. Roadways and airports flight patterns are classified and modeled as *line* sources. Oil refineries and residential tracts are typical *area* sources (Geis, 1984).

1.3.3 Major Air Pollutants

The important air pollutants are those produced from fuel combustion, burning of waste products and other industrial pollutants and besides these natural ones. There are several of the extremely affecting pollutants on the components of the ecosystem of which are CO, SO₂, SO₃, H₂S, hydrocarbons, NO₂, NO and particulates (Detrie, 1973).

While any smoke, soot, fly ash, dust, cinders, dirt, noxious or obnoxious acids, fumes, oxides, gases, vapors, odors, toxic or radioactive substances, waste, solids, liquids and gaseous substances are considered of the famous air pollutants (Faith, 1959).

1.3.4 Minor Air Pollutants

These are pollutants, which produced due to natural and anthropogenic activities, but their concentrations in the atmosphere have relations to the nature of the pollutants. Of these are the very famous ones; lead, cadmium, zinc, copper and others. Some of them have significant roles in plants, animals and human, although they considered trace elements. On the other hand, several of these trace elements concentrate in living organisms due to some processes leading to hazardous adverse and negative effects not encountered even in same levels of the major elements.

1.4 Health Aspects of Air Pollution

1.4.1 Air Pollution Episodes

It is very difficult to demonstrate chronic effects caused by continued exposure to air pollution. However, air pollution episodes with extremely

high concentrations have been found to cause acute sicknesses and death. It is therefore, reasonable to presume that a prolonged exposure to small concentrations will also result in adverse effects. From a community health point of view, the chronic effects may be the more important. However, it was the major air pollution disasters with their thousands of excess deaths that finally resulted in some control measures (Bobrov, 1952 and Bach, 1972).

1.4.2 Lessons from Air Pollution Disasters

Several disasters were observed in the winter months in the northern temperatures zones with dense population and heavy industrialization. Adverse meteorological conditions such as stagnating air masses under shallow inversions with impeded ventilation and dispersion probably played a decisive role.

A combination of two or more gas aerosol mixtures in moist and cold weather could possibly cause synergistic damage to health. Air pollution disasters at the time of their occurrence have never been fully appreciated. Therefore, guidelines for protection were never issued. Air pollution disasters have proven that pollutants in certain combinations and concentrations are detrimental to health and often lethal (Bach, 1972).

1.5 Economic Aspects of Air Pollution

There is no longer doubt that air pollution places a grave burden up on the national economy as well as the economy of individual families. Air pollution affects soils and erodes buildings surfaces, corrodes metals, weakens textiles, deteriorates works of art and more importantly, it damages vegetation and crops and kills animals. In these ways it drastically interferes with well being of people. The existence of all these adverse

effects should provide enough incentive for reducing the pollution of the atmosphere (Bach, 1972).

Many analysts of the economic aspects of air pollution discussed only the cost of damages caused by pollution and the amounts spent by polluters for control equipment. A more useful assessment of the economic importance of air pollution, however, can be obtained if the cost of damages and control efforts are related to the value of the benefits to be gained by control of pollution (Geis, 1984).

Air pollution is an indirect effect of not dealing with e.g., metal contamination; it results in a loss of the aesthetic value (s) and loss of economic wealth.

1.5.1 Cost of Air Pollution Damages

Per capita annual costs for outside and inside maintenance of houses, laundry and dry cleaning, hair and facial care were higher in polluted areas than unpolluted (Geis, 1984).

Traffic: pollution episodes with dense fogs reduce visibility, slow down traffic, and cause costly accidents. It is well known that increased air pollution results in decreased visibility. Thus, to a large extent, air pollution is responsible for the traffic industry's extra costs (Geis, 1984).

Agriculture: valuable plants such as cotton, beans, vegetables ... etc, are very susceptible to smog and emissions damages. Crop dusting, fall plowing, nearer to pulp and paper mills, iron and steel mills, oil refineries, smelters and chemical plants all cause great damages to agriculture. The automobile emissions adversely affect the road-side vegetation and even the distal plants in the heavily polluted areas (Thomas and Hendricks, 1956).

Health: in order to assess the total cost to the community from diseases such as chronic bronchitis, emphysema, cancer, damage of nervous system, kidney and reproductive systems ... etc, leading to morbidity and mortality. "Bates" has suggested the acquisition of the following information:

1. An assessment of the loss of productive working hours in industry in workers with chronic bronchitis compared to workers without this disease.
2. An assessment of the loss of working potential as a result of the crippling power of emphysema, bronchitis and damaged nervous system.
3. An assessment of welfare compensations caused by these diseases (Geis, 1984 and EPA, 2003).

1.5.2 The Cost of Cleaner Air

Two contrasting opinions existed it comes to the question, *WHO is to pay for cleaner air?* (Bach, 1972).

One group argues that if the total air pollution control costs are not lower than the total benefits resulting from controlling air pollution, then investing in control devices could not be sound economics either from the company's or the public stand point.

The second group states bluntly that the cost of pollution should be imposed on the pollutor. It is argued that if the pollutors were forced to internalize their external social pollution costs, they would develop methods of controlling the pollution (Geis, 1984 and Lombi, *et al.*, 1998).

1.5.3 Cost-Benefit Analysis of Air Pollution

Air pollution is a classical example of an external diseconomy. Whenever market forces are insufficient to make an individual bear the

private and social costs resulting from his actions, such as polluting the atmosphere. The external diseconomies can be eliminated, if the social costs can be internalized, i.e., if industry, which is producing the pollution is also required to be its elimination or removal (Geis, 1984).

The optimum economic level of air pollution control, which does not necessarily coincide with the optimum health level of air pollution control, can be assumed by a cost-benefit analysis (Bach, 1972).

1.5.4 Cost-Benefit Model

The purpose of this cost-benefit effectiveness analysis is to determine the maximum net benefit from air pollution control. The difference between the costs of air pollution control and the benefits from a reduction in air pollution constitutes the net benefit to a community.

The total net benefit (P_T) is related to the total benefit (B_T) and the total cost of control (CCT) as follows (Bach, 1972):

$$P_T = B_T - CCT \dots\dots\dots(1)$$

Where CCT: total cost of control is the summation of the individual costs of control from the net emitters:

$$CCT = \sum_{j=1}^n CCT \dots\dots\dots(2)$$

B_T : the total benefit is the summation of the benefit (B_{ji}) received in the i^{th} of m receptor areas due to the control of j^{th} of the n emitter. Thus:

$$B_T = \sum_{i=1}^m \sum_{j=1}^n B_{ji} \dots\dots\dots(3)$$

Combining equation (1) and (3) yield the net total benefit (P_T):

$$P_T = \sum_{i=1}^m (\sum_{j=1}^n B_{ji} - C_j) \dots\dots\dots(4)$$

1.5.5 Benefits of Air Pollution Control

The major benefits from air pollution control lie in the *sale or reuse* of reclaimed effluent, in reduced damage to materials and equipments, and

in an improved environment. Health and social welfare, and not mere economic considerations, should ultimately determine the optimum air quality.

The other benefits from air pollution control are tangible, i.e., the cleaner air, is the cleaner atmospheric substances (O_2 , O_3 and others), this will save vegetation, animals and human life.

1.6 Air Pollution Problems in Sudan

From the previous discussion, one gets the impression that air pollution problems are only restricted to industrialized communities of the world. The situation in the countries like Sudan and probably many developing countries is based mainly on agricultural produced (now, post petroleum, the vast pollution problems threatening the future of Sudan), the most of which is exported as raw material or in partially processed form.

Most of the industries present are only light (now, Giad, oil refineries) and are to a certain extent concentrated in certain localities or states. With these ideas in mind, air pollution of the pattern that characterizes the industrialized societies is practically absent.

However, this should not generate optimism in one's mind that we will not be having the problem in the near or foreseeable future. We have vast potentialities for development particularly in agriculture, forestry and animal resources.

With the expansion of agriculture, oil refineries, vast increased cars, buses, small and light industries, workshops, furnaces, smelters, tannany, wood burning and using of leaded-petroleum as a main fuel for transport and goods carrying vehicles and other activities, we are bound to be forced to process our products locally first for our consumption and secondly for

export. These operations are likely to call for one kind of industry or another (Geis, 1984).

The last decade in the twentieth century witnessed several kinds of pollution in Sudan; livestock farms, meat, eggs; in Khartoum and the fearful burst in cancer-diseased patients in Northern and Gezira states, besides pulmonary tuberculosis in East and Kidney failure in whole Sudan. Besides, the pollution approached by the prolonged war in the Southern states.

1.6.1 Air Pollution Sources in Khartoum State

Air pollution in Sudan resulting from the various activities of the Sudanese people is expected to be in general terms appreciably negligible, and if any at all may be limited to the major cities within the country.

Compared to other towns in Sudan, however, Khartoum is expected to have the worst problem. Here, the industrialized areas / zones of Khartoum, Khartoum North and Omdurman are the main areas producing gaseous wastes, which are discharged into the air.

Motor vehicles were used to be the second rate, (but now the vast increase in imported and locally made cars, vehicles, trucks ... etc, are the main contributors of air pollution in Khartoum State), producers of the wastes a part from engine exhaust's wastes. The oil refineries are the top rate today.

The unexpected expansion in Khartoum building and architecture, increased in population need to meet the demands of establishing industries and supply of the fuel for transport, house, markets and other activities are the main sources of the pollution of the air in Khartoum State.

1.7 Reasons for the Choice of the Topic

There are certain few chemicals that are ubiquitous in our present environment and whose toxicity in the form and quantity in which they are sometimes found in our ecosystems is proven beyond question (Hemphill, 1974).

There are certain few elements, i.e., lead (Pb), cadmium (Cd) and zinc (Zn), which are expected to be emitted in quantities more than other chemicals to atmosphere and through time settle down and precipitate in the ecosystem whether in plants, soil, water or stay there in the air.

In any case, the plant leaves are the easier tools to be used to indicate the pollutants from air entering the ecosystem and to estimate their effect on human life and how and when to meet the needs and costs to deal with such problem.

Harmful effects or acute poisoning in man, animals and plants due to excessive exposure to lead, cadmium and zinc are well documented (UNEP, 1978).

The increase in Pb, Cd and Zn concentrations in ambient air during the past 20 years has been attributed primarily to industrial emissions and the inclusion of, i.e., lead alkyls – $\text{Pb}(\text{CH}_2\text{CH}_3)_4$ and $\text{Pb}(\text{CH}_3)_4$ in gasoline – cadmium and zinc compounds emitted into the air near the major highways in large urban areas is dependent on the traffic density can vary from (4) microgram to (50) micrograms per centimeter (Stringer, 1974).

The conclusion that combustion of automotive fuel containing Pb anti-knock fluids and the smelters of Zn and Cd, Fe, Cu, ... etc, are the major contributors to these heavy metals concentration in plant as

indicators for ambient air pollution. The petrol used in the Sudan is leaded by type (Geis, 1984).

1.8 Hypothesis

There is a relationship between the concentrations of Pb, Zn, Cd, Cu, Fe and others in roadside air, soil and plants on one hand and traffic flow on the other.

There is a relationship between the concentrations of heavy metals on plant's green leaves and the degree of air pollution in Khartoum due to natural and manmade activities, which cause the accumulation of these metals on vegetation and later on cause problems to man and animals and even disrupt the ecosystems.

1.9 Objectives of the Study

The aims of this study are:

1. To have a baseline information of Pb, Zn and Cd pollution from automobile emissions near roadside (air and soils) in plants at various positions in Khartoum State.
2. To assess Pb, Zn and Cd concentrations in roadside air (plants) resulting from automobile emissions at various places through the year. Here this work is carried out in July, August and September.
3. To assess Pb, Zn and Cd concentrations in roadside plants as a function of distance from heavy traffic roads in Khartoum State.
4. To give recommendation and suggestion of methods to protect people, animals and plants against hazards resulting from Pb, Zn and Cd pollution from automobile emissions.

CHAPTER TWO

2. LITERATURE REVIEW

2.1 Heavy Metal Pollution

2.1.1 Lead (Pb)

Lead (Pb) naturally occurring bluish-gray or bluish silvery-gray soft metal found in small amounts in the earth's crust, with a melting point of 3275.5° C and a boiling point at atmospheric pressure of 1740° C. It has four normally occurring isotope, atomic weights: 208, 206, 207 and 204 in order of abundance (ATSDR, 1999).

The isotopic ratios differ for various mineral sources, this property has been used in non-radioactive tracers studies to investigate the environmental and metabolic pathways of lead.

Lead can be found in all parts of our environment. Much of it comes from human activities, including burning fossil fuel, mining and manufacturing.

Lead has many different uses. It used in the production of batteries, ammunition, metal products (solders and pipes) and devices to shield X-rays.

Because of health concerns, lead from gasoline, paints and ceramic products, caulking and pipe solders have been dramatically reduced in recent years.

Lead (II) in inorganic compounds, i.e., nitrate, chlorate and chloride, while lead (III) salts have poor solubility in water.

Lead abundance by weight, crust 13 ppm (35%), ocean 0.03 ppb (46%) and air unknown.

The two major use of lead are in lead acid storage batteries (from motor vehicles) and as lead alkyl compounds added to petrol (O'Neill, 1995).

Organic lead compounds such as tetra-ethyl lead and tetra-methyl lead (anti-knock) used as fuel activities. They both are colourless liquids with boiling point of 114° C and 200° C respectively. Since their volatility is lower than that of most petrol components, the evaporations of petrol tends to concentrate lead tetra-methyl and tetra-ethyl. Both compounds are decomposed at boiling point as well as by ultraviolet light and trace chemicals in air such as halogens, acids or oxidizing agents.

The lead compounds in the exhaust emissions are trapped on the catalyst surface and prevent the catalyst reacting with other compounds in the other exhaust gases.

The majority of the lead used in batteries is recycled and only causes problems when the battery – disposal and recycling process – are not effectively controlled.

In contrast, about 75% of the lead added to petrol is emitted through the exhaust and dispersed as an aerosol in the atmosphere. As a consequence, it is unlikely that there is any where left on the earth's surface that has natural levels of lead (O'Neill, 1995).

Results from Greenland ice cores indicated that there has been a 400-fold increase in lead deposition in the ice between 800 BC and 1965. The average anthropogenic emission rate in the later half of the nineteenth century was 22×10^6 kg per area, due mainly to the smelting of lead ores and turning of coal. Nowadays, the rate is about 20 times higher, at 450×10^6 kg per area.

Approximately 94% of the lead in the atmosphere is derived from anthropogenic sources, with an even higher proportion in urban areas where there is heavy metal traffic (O'Neill, 1995 and WHO, 1985).

Soil surface reports indicated that surface contamination by atmospheric lead causing much higher levels in the top layers of soil (were absorbed by plants) were actually misinterpretations of the natural biogeochemical concentrating effects. The increase in aerial dispersion from anthropogenic emissions has increased the atmospheric flux, leading to higher levels of lead in plants, soil and rivers and some lead falling directly on the sea (O'Neill, 1995).

The wide spread distribution of lead from motor vehicles exhausts increases the atmospheric levels by factors of 20 (much more in urban areas) (O'Neill, 1995).

When lead enters the environment, itself does not breakdown, but its compounds are changed by sunlight, air and water when released to the air it may travel long distances before settling to the ground.

Once lead falls onto soil, it usually strikes to soil particles. Movement of lead from soil into ground water will depend on the type of lead compound and the characteristics of the soil. Much of the lead in inner city soil comes from old houses painted with lead-based paints.

2.1.2 Cadmium and Zinc

2.1.2.1 Cadmium (Cd)

Cadmium (Cad'me – um) is a natural element in the earth's crust. It is usually found as a mineral cadmium with other elements such as oxygen (cadmium oxide), chloride (cadmium chloride), or sulfur (cadmium sulfate and cadmium sulfide).

Cadmium (Cd) is a soft silver-white metal. It has a relatively high vapour-pressure. In the air the vapour is rapidly oxidized to cadmium oxide. Many inorganic cadmium compounds are soluble in water (e.g., CdSO_4 , $\text{Cd}(\text{NO}_3)_2$ and CdCl_2), whereas CdS and CdO are almost insoluble in water.

Cd occurs together with zinc in nature, the ratio being generally, 1 : 100 – 1 : 1000. Cd is obtained as a by-product in the refining of Zn, in certain zinc ores the Cd concentration may be about 5% (UNEP, 1984).

All soils and rocks, including coal and mineral fertilizers, contain some Cd. Most Cd used in United States of America is extracted during the production of other metals like Zn, Pb and Cu. Cd does not corrode easily and has many uses including batteries, pigments, metal coatings and plastics (ATSDR, 1999).

Cadmium (Cd) enters air from mining, industry and burning coal and household before falling to the wastes. Its particles in air can travel long distances before falling to the ground or water. It enters water and soil from waste disposal and spills or leaks at hazardous waste sites. It binds strongly to soil particles. It does not break in the environment, but it can change form.

Plants and animals take up Cd from the environment and it stays in the tissues a very long time and can build up from many years of exposure to low levels (ATSDR, 1999).

In Europe, estimations have been made of the atmospheric Cd emissions from different sources there. The steel industry, waste incineration, volatile action (Mount Etna) and zinc production seem to account for the largest emissions.

Tobacco contains Cd and smoking contributes significantly in the uptake of Cd (EHC, 1976).

In United Kingdom, the average addition of Cd to crop lands is $0.4\text{mg/m}^2/\text{area}$ (air deposition 41%, phosphate fertilizers 54% and sewage sludge 5%).

The uptake of Cd is similar to Zn, both are readily taken up by plants and enter the edible portions. This is an important difference from lead (Pb), which is not easily accumulated by plants.

Cadmium concentrations in plants are much closer to soil levels, through this varies very much from species to species, and the relative uptake of Cd is reduced as the concentration of cadmium in the soil increases.

The aerial pollution from cadmium-containing fumes and particulates, plus water pollution due to Cd, Zn-containing sediments and mine waste.

Because of its lower boiling point, cadmium is more concentrated, relative to zinc, in the atmospheric emission from zinc smelters than it is in the ore or in zinc metal (O'Neill, 1995).

2.1.2.2 Zinc (Zn)

Zinc (zingk) is one of the most common elements in the earth's crust. It is found in air, soil and water and presents in all foods. Pure zinc is a bluish-white shining metal (ATSDR, 1999).

Zinc abundance be weight: crust 70 ppm (24%), oceans 11 ppm (22%). It is an essential element. Its cycle is very closely interrelated with cadmium, because natural zinc-minerals and most anthropogenic fluxes contain small amounts of cadmium.

The mobilization of Zn by human activities outweighs natural cycling processes (O'Neill, 1995). Zinc has many commercial uses as coatings to prevent rust, in dry cell batteries and mixed with other metals to make alloys like BRASS and bronze. A zinc and copper alloy is used to make pennies in the United States of America (AQC,).

Zinc combines with other elements to form zinc compounds. Common zinc compounds found at hazardous waste sites include ZnCl_2 , ZnS , ZnO , and ZnSO_4 . Zinc compounds are widely used in industry to make paint, rubber, dyes, wood preservatives and ointments (ATSDR, 1999).

Zinc is released into the environment by natural processes, but most comes from activities of people like mining, steel production, coal burning and burning of wastes.

Zinc attaches to soils sediments and dust particles in the air. Rain and snow remove zinc dust particles from the air. Its compounds can move into water and into lakes, streams and rivers. Most of Zn in soil stays bound to soil particles it builds up in fish and other organisms, but it does not build up in plants (ATSDR, 1999).

2.2 Mechanisms of Transport and Accumulation of Metals in Plant Green Leaves

Most of the studies conducted on plants green leaves have focused on mechanisms of trace elements concentrations. These plants also reported as accumulators for trace elements.

The uptake of the trace elements and their transport into the plant organs (leaves, roots, stems, buds, ... etc) are found to be similar to some extent.

The large potential for biomonitoring air pollution by plant green leaves is highlighted by the selection of the plant population (species) (Lasat, *et al.*, 1999).

Plants of two different species or more concentrated different amounts of Pb, Cd and Zn, but closer amounts may encountered in several, fewer cases (Schwartz, *et al.*, 1999).

Currently, different experiments are ongoing to investigate mechanisms of uptake and transportation of metals, fate of accumulated metal when plants are exposed in polluted air, and fate of chelating agents in plants when used in chemically –assisted biomonitoring (McLaughlin, *et al.*, 1999).

2.3 Lead, Cadmium and Zinc and Roadside Vegetation

Pb, Cd and Zn are concentrated by the vegetative components of roadside ecosystems from both, the atmospheric and soil compartments. Contamination of above ground parts from the atmospheric compartments may be via gravity settling, impaction or precipitation.

The relative importance of these transfer mechanism is unclear, but the first is generally considered the most important. Contamination from atmospheric compartment is also generally considered to be topical (superficial) in nature and largely susceptible to removal by washing. Little evidence of plant Pb, Cd and Zn uptake from surface deposits has been provided.

Transfer of Pb, Cd and Zn from soil compartment to the below ground portions of plants is via root uptake from the soil solution. Since much of the Pb, Cd and Zn is presumed to be present in the soil is non – or slightly soluble forms, much of these heavy metals in this compartment are

thought to be unavailable to roadside plants. Nevertheless, there is ample evidence that plants do take up soluble heavy metal through their roots. The uptake is favoured by low soil pH. Translocation of Pb, Cd and Zn absorbed by the roots to above ground portion of plants is controversial as the evidence is variable.

Plants that have received the greatest attention in the roadside environment include grasses, agricultural crops and woody plants (Smith, 1976).

2.4 Concentration of Lead, Cadmium and Zinc in Green Leaves of Plants

Areas moderately contaminated by trace heavy metals, but a level exceeding the critical levels for food production, are widespread in the world, could be utilized for i.e., fiber production.

Plants can be used for landscape improvement and an environmentally sound and cost effective air reclamation, using imported (exotic) and indigenous (local) tree species, i.e., ficus and neem (Gunthardt, *et al.*, 2002 and Sumita, *et al.*, 2003).

Before considering contaminated tree's green leaves, more should be known about the potential of our native trees provenances (Sumita, *et al.*, 2003). Small quantities of mobile heavy metals (Cu, Zn) are essential for plants, because they are cofactors of important enzymes. In higher concentrations, however, mobile as well as less mobile non-essential heavy metals (Pb, Cd) can include acute tissue and cell injury and damage (Gunthardt, *et al.*, 2002 and Sumita, *et al.*, 2003).

Results obtained with tree's green leaves showed that within the cell, the formation of free radicals and reactive oxygen species is stimulated,

which can result in an oxidative burst (Faith, 1959 and Gunthardt, *et al.*, 2002). Biomonitoring refers to the use of plant's green leaves to determine air pollutants or to determine the risk (s) associated with their presence in the environment (Sumita, *et al.*, 2003).

The concentration of heavy metals in plant's leaves is the matter of health, as well as an important factor defining air pollution problem (Mohammed, A. H., 1986).

Success in controlling heavy metals concentration through the choice of trees has been reported using major parameters for evaluating air pollution degree and its consequences on human life and the surroundings (Letchamo, *et al.*, 2002 and Mohammed, A. H., 1986).

Interactions between the atmospheric (or hydrospheric) pollutants and bio-organisms are always of major concern (Faith, 1959).

Bioaccumulation of trace elements is mostly a passive process and this enables to use some of bio-organisms as indicators of atmospheric (or hydrospheric) pollution. However, there always are critical biological processes and micro-environmental conditions, which affect levels of the trace elements. At the same time heavy metals migrate from one ecosystem to another, so the task is to define pathways and their quantitative parameters (life-time, adsorption or accumulation coefficients) as well as distribution between different physical and chemical forms (Colbeck and Morison, 2003).

Man being at the top of the food chain, is at a great risk of suffering from health hazards associated with heavy metals because bioaccumulation (Lawtheg, *et al.*, 1962). The primary source of heavy metals in plants are soil, sediments, surface and ground water and air. However, the

bioavailability and mobility of the heavy metals in the environment strongly depends on the chemical forms (speciation and compounds) of the respective metals, which all have different properties. Solubility will differ dramatically. This is important when considering how much of each metal is transferred from soil, sediments, water and air into the plants and therefore into the animals and human bodies (Sumita, *et al.*, 2003).

The key-point is to analyze how much is the concentration of geoassimilated and atmospheric heavy metals to bioassimilated heavy metals in plants (Sumita, *et al.*, 2003).

CHAPTER THREE

3. MATERIALS AND METHODS

Ficus and neem have been used as ecological bioindicators in Sudan, mainly the urban areas, Khartoum State and the three main cities, Khartoum North, Khartoum South and Omdurman. The specimens were collected from the sites, Sharie enneel – Khartoum South, Ombada residential area – Omdurman and the control area, the farms of Kadaro – Khartoum North.

Several chemical analysis methods have been applied to investigate and / or to estimate the concentrations of heavy metals Pb, Cd, Zn and Cu in the three sites.

The aim of the present study was to determine the concentrations of toxic trace elements (Pb, Zn and Cd) in the green leaves of Ficus (*Ficus penegalensis*) and Neem (*Azadirachta indica*) as a bio-monitor for air pollution in urban areas i.e., Khartoum and areas around.

Air pollution by toxic metals is one of the serious problems of the environment. Plants have been frequently used as indicators (monitors) in the search for metal pollution and accumulation of air, or as bio-accumulators for the monitoring the effects of natural and anthropogenic damage on the living organisms and their surroundings.

The aim of this study was to select accumulator species for determination of air pollutant metals. The used species Ficus and Neem that offer ranges of trace element accumulator plants. The collection and washing of the samples were due to metal analysis standardization (MAS) for the 18 samples from the three different sites.

3.1 Study Area

3.1.1 Physical Setting

Khartoum, the national capital of Sudan, is composed of the three cities of Khartoum South, Khartoum North and Omdurman. The three cities are situated around the confluence of the Blue Nile and White Nile at latitude 15° 36' North and longitude 32° 31' East. On a featureless plain having an average altitude of 380 m above sea level.

In the case of both Khartoum South and Khartoum North the plain increases slightly in height from west to east, whereas at Omdurman, the land gains in altitude towards the north west reaching the highest point in the three cities area over the *Markhiyat Hills* that rise between 50 m above the general level of the plateau, giving rise to only significant relief feature in the vicinity of the urban complex. The simplicity of relief has minimized the possibility of climatic modification under the rather unpleasant conditions of semiarid tropical climate (Elbushra, 1976).

3.1.2 Selection of the Area

The main reason for the selection of Khartoum State as an area of the study was to see the effect of the sharp increase in automobiles on the environment. During the last two decades (1984 – 2003), the records have shown that the total number of vehicles licensed in Khartoum State and National Capital increased from about 84,980 in 1984 to hundred thousands or even uncounted number at present time (2003).

Also the fuel used in Sudan is leaded fuel. Therefore, it was decided to study the lead, cadmium and zinc pollution from automobile emissions in Khartoum State.

3.1.2.1 Heavy Traffic Site (Sharie enneel)

This was selected to represent the heavy traffic site. During most crowded hours of the day, the flow of traffic is directed towards this road from the three cities (Khartoum South, Khartoum North and Omdurman).

3.1.2.2 Low Traffic Site (Ombada)

This was selected as a residential area, some avenues and garden trees were selected from the first, fifth, seventh and ninth blocks in order to represent low traffic site.

3.1.2.3 Kadaro Site (Farms and Campus of Juba University)

This area was selected as control area. The reason was the fact that there are no private vehicle running in that area, or even if, they are less than fifty vehicles. Only about two buses, five minibuses and twenty-three private cars (and not daily) are working there. It is also far from industrial locations, so it is not affected by industrial emissions.

Ficus and neem, three samples from each of, were collected from the above mentioned three sites and were treated following the previously mentioned methods for analysis of trace elements content.

3.2 Plants Of The Study

The extensive distribution of Ficus and Neem tree in the state of Khartoum makes them a potential bio indicator tool for monitoring existing levels of different pollutant metals in the atmosphere (Qatar Univ-sci-J-, vol.k, NO.1. 1995).

The present study illustrates the importance of the two widely distributed species of plants (Neem and Ficus) in depicting the levels of some toxic heavy metals along the Nile Road, in Ombadda and Khartoum area. A similar monitoring scheme using these identified species could very

will be extended to other areas in the state of Khartoum in order to form a comprehensive monitoring plan for the country (Sudan). This field study also highlights the potential for removal of pollutants by increasing afforestation of woody trees as they wash the soil and clean the air in large quantities in the Sudan (Qatar Univ-sci-J-, 1995).

The use of biological indicator organism is a very attractive tool to identify and demarcate areas of atmospheric contamination (Phillips, D, 1980, Qanti-Aqu-Biol-Indi).

Some of these organism not only accumulate certain contaminants from the surrounding milieu, allowing inexpensive and relatively simple contaminant analysis, but they may also represent a moving time-averaged or integrated value of the relative biological availability of these chemicals at each site studied. However, the use of indicator organisms introduces biological variables which are not present in physico-chemical studies of water, sediments and air. These variables merit consideration in as much as they affect the result of indicator surveys for trace pollutants like metals (Phillips, D.1977).

3.2.1 Ficus

Family: Moraceae

Latin Name: *Ficus pengalensis*

English: Java fig, weeping fig

Arabic: Ficus

Smallish, evergreen, strangling fig tree reaching to above 10m in Sudan. Leaves are simple, ovate, taper to a sharp point at the tip, and are Lime-green in colour, covering singly and alternately from each other, and

measure 5-8 cm long by 3 cm wide in some areas this may reach up to 20 cm long by 8 cm wide.

This species is found naturally in India, Malaya and the East Indies. It has now been introduced throughout the tropics, grown outside in frost-free areas as on or namerilal, and else where indoors as a potted plant.

It is used in full wood, amenity (pleasantness), Dune (sand hills) control, charcoal, shade, Timber, shelter belt, pesticide, fruit, medicine, Agroforesry Hedging (fence).

The tree is fairly wordy, to lerating high terps and some drought. It is requires fairly frequent irrigation of planted in the semi-arid to arid areas of Sudan. It also thought to be leant of most types of soils, at any altitude, at any rainfall, even at high temp. It is fast growing tree specially if given regular watering. It requires protection from lives lack. It is in no inlayed an ornamental, with its attractive Lime-green drooping foliage (Kees Vogt, 1995).

3.2.2 Neem

Family: Maliaceae

English: Neem

Arabic: Neem

An evergreen tree reaching a maximum height of 20 m. Its leaflets enable easy recognition; they are seriate and have a very bitter, quinine-like taste. It is universally known by its Indian name, Neem. It originates from Asia, in particular North East India and Burma, and is now widely established and naturalized throughout the tropics, including Sudan.

It is used in fuel wood, Amenity, Dune control, Honey, charcoal, shade, shelter belt, oil, Timber, pesticide, Hedging, fruit, Medicine, Agroforestry.

Neem can be regarded as a true multi purpose tree. It is universally regarded as an amenity and shade tree of great value and often provides the central meeting place in a village. Leaves contain an insect repellent which is useful for protective stored grains and meats and can be put on crops.

Neem tree requires a rainfall of 1200 mm. It grows in a wide-range of condition, from sandy to heavy clay soils, and on stony and nutrient poor sites, and it grows at altitude from 1-2000 m. It is tolerant of very high Temp, but sensitive to cold. This tree is becoming increasingly popular in the state of Khartoum due to its many benefits. However, most of these are still not known and should be more widely publicized (Kees Vogt, 1995 and (Hamza, 1990).

3.3 Data Collection

Since there is poorer information available about air pollution in Sudan and in Khartoum State in particular and only two dissertations had

been introduced to cover such problem (Geis, 1984 and Mohammed, A. H., 1986), the data collected for this study were resourced from the two dissertations, from Sudan Library (University of Khartoum), Library of Environmental Studies Institute, Main Library of Khartoum University, personal communications, Library of National Research Center (main, of Amarat Street 57 and of Shambat) and from Internet.

Although, there is no, however, data available for Pb, Cd and Zn pollution resulting from air pollution to the green leaves of plants.

3.3.1 Data Collection for Lead, Cadmium and Zinc Concentrations in Green Leaves

The field work survey for Pb, Cd, and Zn concentrations in green leaves from air was carried out during the period (August to September 2003).

Some data were first collected from Internet, and from different libraries on the quantity of emissions in atmosphere in Sudan and in Khartoum State in particular, types of emitted pollutants in Sudan and Khartoum State.

Data were then collected directly from the field including leaves samples from the three different sites for neem and ficus species green leaves.

3.4 Sampling Procedure

3.4.1 Leaves Sampling

Leave's samples were taken from the three sites (Sharie enneel, Ombada and Kadaro) from ficus and neem trees, from the tip, bottoms and the mids branches' leaves.

In the distal area (control area), the samples were taken from the tips bottoms and middle to tree leaves.

The sampling period for each point / site was half an hour. The all study was usually carried out during 12:00 to 3:00 pm. Sampling was done continuously two times. For all sites, measurements were taken in different neem and ficus trees.

3.4.2 Sampling Techniques

3.4.2.1 Leaves Sampling Technique

The leave-samplers (the writer and his fellow) were constructed to collect leaves from neem and ficus trees, cutting them manually from different parts of the tree, from different trees (of neem and ficus) and at different areas within the main three sites.

3.5 Analytical Methods in the Field

The increased interest for the measurement and control of environmental pollution leads to the need for improved methods of analyzing environmental samples (here these are leaves of neem and ficus).

Physico-chemical analytical procedures have been adopted very successfully in trace elements determination of particular samples. These methods depend upon fundamental properties of elements such as the unique behavior extra-nuclear electrons of atoms when excited in some way.

Under ideal circumstances these properties can be exploited through appropriate resolution techniques to prevent interference effect, and hence make possible quantitative analysis of small quantities of substances in the presence of larger amounts of other materials.

Among the most widely used methods embodying the principles (Butler, 1979) are:

- a. Neutron Activation Analysis.
- b. X-ray Fluorescence Analysis (X-RF).
- c. Atomic Absorption Spectroscopic Analysis (AAS).
- d. Atomic Spectroscopy, and
- e. Mass Spectroscopy.

For leaves samples two methods were used, AAS and X-RF analysis.

3.5.1 Preparation of the Leave's Samples

3.5.1.1 Sample Collection

18 samples were collected from 3 different sites in Khartoum State, Sharie enneel, Ombada and Kadaro areas. The samples were gathered from twigs (at tips, mids and bottoms) from different ficus and neem trees. These were gathered manually and then were preserved in plastic bags.

3.5.1.2 Sample Washing

All the samples collected were washed using tape water. This was done three times to ensure the cleanness and purity of the leaves' samples.

Then the washed samples were laid down flat on wood table to dry by sunlight for 8 hours.

3.5.1.3 Sample Digestion Steps

The dried leaves' samples were then grounded in mortars. The powders were then sieved and stored in labeled plastic bags, ready to next analysis steps.

The samples prepared were labeled as follows: AI, CIII and EV, were ficus leaves of Sharie enneel, Ombada and Kadaro respectively, and

BII, DIV and FVI were neem leaves of Sharie enneel, Ombada and Kadaro, respectively *and each was divided into three.*

0.5g of each sample was weighed by a sensitive balance and was then placed on 100 ml beaker. Acid mixture (4 ml concentrated HNO_3 and 1 ml HClO_4) was added to the sample powder, heated on hot plate at 120°C , the beakers were covered by watch glasses under fume ~~hude~~ hood. This was proceeded until all the white / brown fumes were evaporated and the residue became colourless.

To each beaker 5 ml of distilled H_2O were added. The obtained products were pale yellow solutions.

To each beaker 0.5g activated charcoal was added and the beakers were heated on hot plate for 5 minutes and the hot beaker contents were filtered leaving behind colourless solution.

These colourless solutions were then transferred to 25 ml volumetric flaks and each was then completed up to the mark by adding ~~distilled~~ distilled water. The sample's solutions were now ready for analysis by Atomic Absorption Spectroscopy (AAS).

3.6 Recovery Study

Sometimes, pretreatment required for the collected samples prior analysis, for most analytical methods it is necessary to destroy organic matters associated with the samples and, as a dissolved samples are normally required to render the samples soluble.

Wet-ashing with acids ($\text{HNO}_3 + \text{HClO}_4$) is frequently a suitable procedure (Kumetani, 1972) as ~~a~~ dry-ashing in a hot plate with dissolution in the strong acids ($\text{HNO}_3 + \text{HClO}_4$) mixture. Losses, assumed to be a result of volatilization, ~~may~~ occur with some metals (Pb, Zn and Cd)

under such dry-ashing conditions (120°C for 1 hour) (Thompson, 1970) reported a low temp ashing procedure for wet-digestion (dry-ashing).

3.7 Atomic Absorption Spectroscopic (AAS)

3.7.1 Equipment

Atomic Absorption Spectroscopic (AAS) model GBC932 plus consisting of:

1. Hollow-cathode lamp
2. Monochromator
3. Nebulizer
4. Spray chamber and,
5. Burner.

3.7.2 Measuring Principle

After the sample solution prepared, which is desired to determine an element concentrations on it. The hollow cathode lamp is selected according to which element concentrations are searched in same, because each element has specific hollow lamp.

The acetylene cylinder was opened and the compressor adjusted the ratio of inlet 2:8 unites for acetylene and air.

The software was provided with parameters such as element, which is searched, wavelength and number of samples with labels.

The burner was ignited to create a satiable flame of air-acetylene. Through this flame, the electromagnetic radiation from hollow cathode is passed. The sample solution was provided to the instrument through the sample capillary tube. When the sample reached the flame it is changed into gaseous state and then brought to its atomic state (free atom form) in the flame.

Element in ground state absorbs radiation predominantly of wavelength (λ) corresponds to transitions from ground state to upper excited states.

These free atoms absorb a part of the radiation, by knowing the intensity of electromagnetic radiation from the source and the intensity of which has transmitted part of the radiation, which is absorbed, can be calculated and because atomic absorption follows the same quantitative laws as other spectrometry methods:

$$A = \log P_i/P_e \dots\dots\dots (1)$$

Where P_i is incident radiation, P_e is transmitted radiation and A is absorption.

By estimating the absorbed radiation, the concentrations of the element can be determined (Butler, 1979) according to Beer's Law:

$$A = XC + b \dots\dots\dots (2)$$

Where A is absorption, C is concentration and b is another absorption factor (molar absorptivity).

Atomic absorption measurements are relative measurements, which means that the bases are standards characteristics of unknown composition and concentrations.

Chapter Four

4. Results and Discussion

Heavy metals concentrations were determined in two plant species Ficus and Neem from Khartoum State three sites.

Samples from Sharia elneel, Ombadda and Kadaro have been divided each into 18 groups. As can be seen from tables (1 – 18).

The lead (Pb) concentrations / levels in Sharia elneel and Ombadda ficus were very close to each other, but Pb in Ficus of Kadaro is higher than formal two sites, although the dissolved and dispersed values of total concentrations did not show any significant increase throughout the study. In fact, dispersed and dissolved petroleum-added lead and other metals values monitored through the three sites of Khartoum State (Tables, 1 – 18).

The levels of Pb showed significant difference between the levels of Pb in Ficus and Neem trees. The concentrations of Pb in Neem species was found to be greater than that in Ficus species (see histogram, fig (25)). The same results obtained for Zn. Zn in Neem was found to show greater values than in Ficus (fig (26)).

The levels of Cd did show high significant difference between Sharia elneel Ficus and the two other sites Ficus and Neem species (fig (24)). This increase in Cd at Sharia elneel Ficus could be attributed to an input of some dissolved fractions in between sampling procedures.

Pb, Zn and Cd were analyzed in the two common tree species, Ficus and Neem from three different localities throughout Khartoum State.

The sampling period was roughly four days (July, 2003), and the sites covered were Sharia elneel, Ombada and Kadaro, where the

maximum, minimum and rare impact of automobile emission was felt respectively. It is interesting to note that levels of Pb and Zn in the two species not varied significantly between the three sites (table 5). While the levels of Cd revealed high significant difference comparing the levels of Cd in Sharia elneel to that in the two other sites (table 6).

It is evident that the highest levels of Pb were recorded in Neem of Ombada followed by Kadaro and Sharia elneel. This because the lead-battery factory used to get rid of waste products there in Kadaro area in last century's mid decades.

Sharia elneel Neem showed lower values in Pb mainly because of the fact that this area is opened and is easily washed and it's soil exposed to cleaning when the Nile floods, also affected by wind and current movement.

Zn levels were recorded to show very closer values in the two species in the three sites. This attributed to similar mechanism of and adsorption of Zn by the automobile emissions and other agents.

Cd levels were found to be highest at Sharia elneel. It was found to be increase by 300 folds that in Ficus of Kadaro and 130 folds that of Ficus of Ombada. While Cd levels in Neem at Sharia elneel showed increase by 50 folds that in Ombada and 20 folds that in Kadaro.

It is important to mention here that all three sites have different environmental characteristics and peculiarities, which have a very significant effect on the heavy metal levels found there.

Tables (1 – 18) depict the values of Pb, Zn and Cd in the three sites throughout Khartoum State. It is interesting to note that while there is no significant difference between the levels of Pb and Zn found in Ficus and

Neem in all the three sites, but samples of Ficus showed lower levels than Neem.

Samples from Ficus at Sharia elneel showed increase in values of Cd 9 folds that in Neem and consequently depicted marked decrease in the levels of Cd in the two other sites.

It is quite clear that these values are influenced largely by the outfalls of Khartoum city, which is heavily industrialized and number of motor vehicles using the lead-added petrol has increasing vastly and due to lack of environmental awareness amongst people.

Concentration factors were computed using measured levels of dissolved heavy metals and other pollutants. While the concentration factors for heavy metals are generally low reaching a maximum of 0.9 microgram, the factors for Pb, Zn and Cd are generally very low (table 19).

Concentration factors in Sharia elneel and / or nearby areas were not significantly differ from those observed for samples collected from Ombada and Kadaro areas.

It is important to note that while Ficus accumulate lower Pb and Zn in Sharia elneel, it accumulates higher Cd. While Neem in Sharia elneel des the reverse (table 19).

The species Ficus and Neem respond primarily to dissolved or soluble species of pollutants in the surrounding milieu.

There are many factors affecting variability of metals Pb, Zn and Cd content in the two species Ficus and Neem:

- Distance with respect to rate of automobile emissions.
- Part of tree from which leaf samples collected (tips, bottoms and mids.

- Dusting (fertilizers, pesticides and insecticides).
- Exposure to motor vehicle exhausts, emissions from factories, factory-waste products, furnaces, ... etc.
- Bleaching.
- Seasonal variation in trace elements content of leaf.
- The age of the tree.
- The density of trees and density of pollution.
- Geographical location (soil, topography, current movement, ... etc).
- Colour of the leaf (effects of organic matters, i.e., chlorophyll).
- Adsorption of gases and humidity.
- Temperature.
- Rainfall, dryness, drought and soil erosion.
- Absorption (root-system efficiency) of nutrients, diet, water, salts and minerals.
- Sun, fogs, ... etc.

Heavy metal analysis of *Ficus penegalenesis* and *Azadirachta indica* indicated a high Cd content compared to Pb and Zn (tables 1 - 18).

The concentration of Pb in the plants studied, which is close to the average of 0.48 $\mu\text{g/ml}$. However, Zn concentration was reported to be closer to that of Pb with average of 0.39 $\mu\text{g/ml}$.

Although Cd is considered to be a non-essential element for plants, it is effectively absorbed by both roots and leaves systems.

Mean Cd content of plants from the different three places in Khartoum State was lower in Neem than in Ficus, this could be due to several factors i.e., exposure rate, smelter and other emissions.

Although Pb occurs naturally in all plants, it has not been shown to play any essential roles in their metabolism (Broyer, 1954).

The great variation of Pb contents in plants is influenced by several environmental factors, ranging from 0.1 $\mu\text{g/ml}$ to 10 $\mu\text{g/ml}$ (Cannon, 1976). In the present study, Pb ranged from 0.3 $\mu\text{g/ml}$ to 0.6 $\mu\text{g/ml}$.

Zn has an estimated role in the metabolism of higher plants (Lindsay, 1972) and is found in the range of 0.3 $\mu\text{g/ml}$ to 0.5 $\mu\text{g/ml}$. The results yielded a range of Zn in Ficus and Neem, which is somewhat lower than the normal concentrations reported from other plants (Shaclette, 1980).

Although the concentration of Zn has been reported to be as high as 300 $\mu\text{g/kg}$ in some plants (Davis, 1978) but concentration range of 300 – 400 $\mu\text{g/kg}$ is toxic to most plants.

Pollution of the air and plants by Pb, Zn and Cd metals occurs due to industrial wastes, application of fertilizers, corrosion of sheeting, wires, pipes and burning of coal and wood, and before all by automobile emissions.

Biological and chemical factors also contribute heavy metal pollution. The importance of these agents reflected in results.

The abundance of these heavy metals pollutants in air and later in plants and soil varies with soil types, plant species efficiency to accumulate heavy metals and to the climatic conditions.

The effect of Pb, Zn and Cd on soil, air and plants (here Ficus and Neem) may generally toxic at high concentrations. But, some plant species appeared to benefit from accumulation of some metals. In the present study the leaves of Pb, Zn and Cd were found to be lower than the toxic and lethal range, but these still act as pollutants. They may inhibit absorption of

macro elements such as Ca, K and Mg, and this could affect the density of vegetation in some studied sites with time.

Table (1) Concentration of lead in Ficus at Sharia Elneel

NO	Concentration ($\mu\text{g/ml}$)	Absorbance
1	0.377	0.0082
2	0.36	0.0072
3	0.357	0.0044
4	0.363	0.0073
5	0.344	0.0068

Table (2) Concentration of Lead in Neem at Sharia Elneel

NO	Concentration ($\mu\text{g/ml}$)	Absorbance
1	0.354	0.0077
2	0.404	0.0091
3	0.4	0.0085
4	0.329	0.0069
5	0.303	0.0052

Table (3) Concentration of Zinc in Ficus at Sharia Elneel

NO	Concentration ($\mu\text{g/ml}$)	Absorbance
1	0.332	0.1226
2	0.322	0.1169
3	0.292	0.1129
4	0.286	0.1085
5	0.283	0.1141

Table (4) Concentration of Zinc in Neem at Sharia Elneel

NO	Concentration ($\mu\text{g/ml}$)	Absorbance
1	0.398	0.133
2	0.387	0.129
3	0.386	0.135
4	0.393	0.134
5	0.382	0.132

Table (5) Concentration of Cadmium in Ficus at Sharia Elneel

NO	Concentration ($\mu\text{g/ml}$)	Absorbance
1	0.909	0.0668
2	0.903	0.0663
3	0.889	0.0666
4	0.885	0.0642
5	0.906	0.0662

Table (6) Concentration of Cadmium in Neem at Sharia Elneel

NO	Concentration ($\mu\text{g/ml}$)	Absorbance
1	0.103	0.0077
2	0.1	0.0072
3	0.097	0.0052
4	0.1	0.0072
5	0.101	0.0075

Table (7) Concentration of Lead in Ficus at Ombada

NO	Concentration ($\mu\text{g/ml}$)	Absorbance
1	0.414	0.009
2	0.413	0.0088
3	0.09	0.0081
4	0.404	0.0076
5	0.4	0.0068

Table (8) Concentration of Lead in Neem at Ombada

NO	Concentration ($\mu\text{g/ml}$)	Absorbance
1	0.657	0.016
2	0.629	0.0129
3	0.629	0.0129
4	0.609	0.0111
5	0.536	0.006

Table (9) Concentration of Zinc in Ficus at Ombada

NO	Concentration ($\mu\text{g/ml}$)	Absorbance
1	0.34	0.1134
2	0.327	0.1106
3	0.326	0.1069
4	0.325	0.1044
5	0.334	0.1082

Table (10) Concentration of Zinc in Neem at Ombada

NO	Concentration ($\mu\text{g/ml}$)	Absorbance
1	0.489	0.1622
2	0.488	0.1522
3	0.404	0.147
4	0.399	0.1371
5	0.371	0.1289

Table (11) Concentration of Cadmium in Ficus at Ombada

NO	Concentration ($\mu\text{g/ml}$)	Absorbance
1	0.0095	0.0007
2	0.0091	0.00056
3	0.0075	0.00038
4	0.0062	0.0001
5	0.0048	0.00011

Table (12) Concentration of Cadmium in Neem at Ombada

NO	Concentration ($\mu\text{g/ml}$)	Absorbance
1	0.021	0.0016
2	0.02	0.0014
3	0.019	0.0013
4	0.0146	0.0012
5	0.0143	0.0008

Table (13) Concentration of Lead in Ficus at Kadaro

NO	Concentration ($\mu\text{g/ml}$)	Absorbance
1	0.616	0.0128
2	0.613	0.0124
3	0.612	0.0119
4	0.609	0.0109
5	0.603	0.01

Table (14) Concentration of Lead in Neem at Kadaro

NO	Concentration ($\mu\text{g/ml}$)	Absorbance
1	0.607	0.0128
2	0.568	0.0117
3	0.534	0.0115
4	0.544	0.0116
5	0.571	0.0118

Table (17) Concentration of Cadmium in Ficus at Kadaro

NO	Concentration ($\mu\text{g/ml}$)	Absorbance
1	0.005	0.0004
2	0.0039	0.00036
3	0.0032	0.00028
4	0.0026	0.00018
5	0.0017	0.00012

Table (18) Concentration of Cadmium in Neem at Kadaro

NO	Concentration ($\mu\text{g/ml}$)	Absorbance
1	0.011	0.0008
2	0.009	0.0006
3	0.007	0.00052
4	0.006	0.00046
5	0.0022	0.00028

Table (19) Total Concentrations of Pb, Zn, and Cd in Ficus and Neem at the Three Sites

Sample	Locations			
Species	Metal	Total metal concentration (µg/ml)		
		Sharia elneel	Ombada	Kadro
Ficus	Pb	0.4	0.4	0.6
	Zn	0.3	0.3	0.4
	Cd	0.9	0.007	0.003
Neem	Pb	0.3	0.6	0.5
	Zn	0.4	0.4	0.5
	Cd	0.1	0.002	0.005

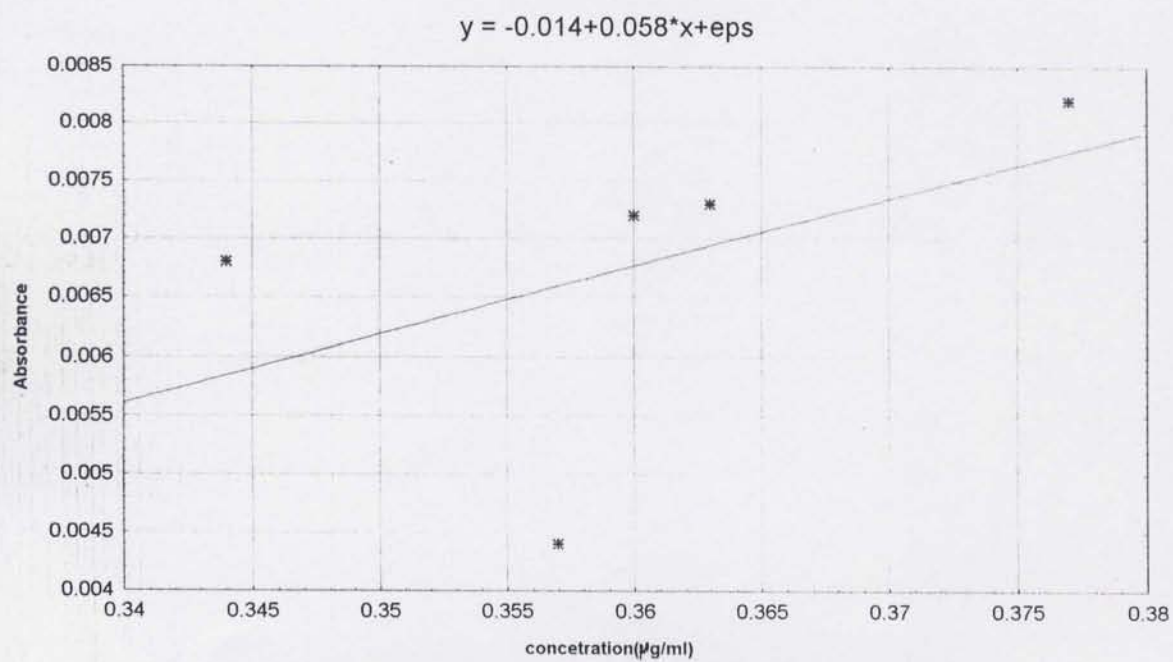


fig.(1): Concentration vs absorbance (Sharia ElNeel Ficus Pb)

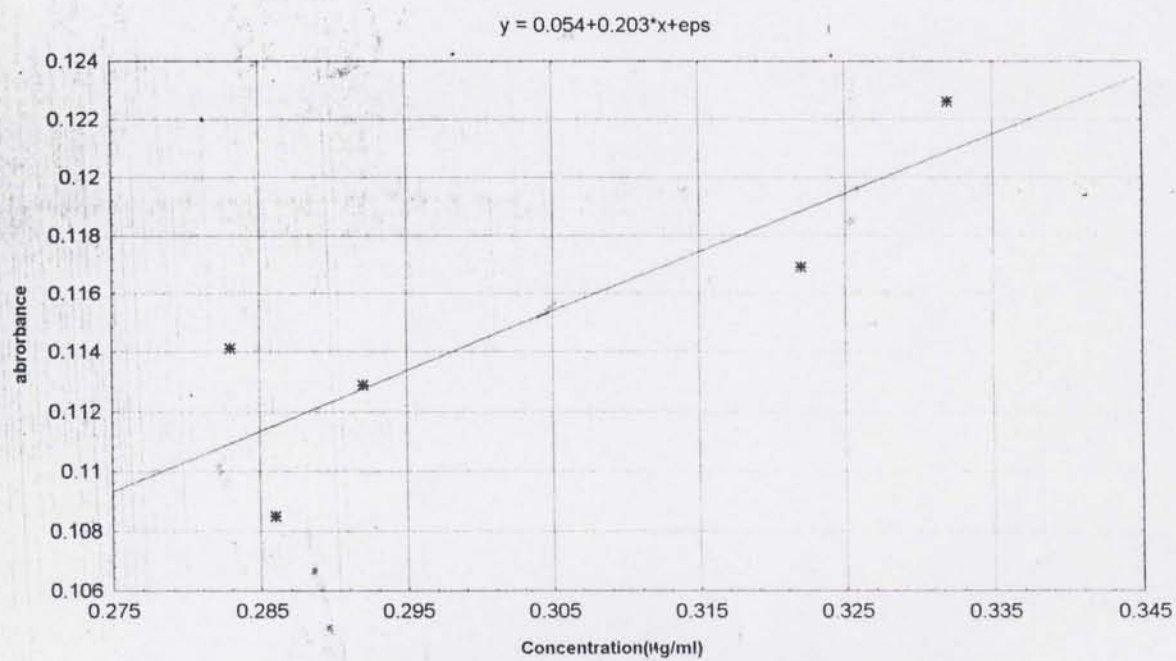


Fig.(2): Concentration vs absorbance (Sharia El Neel Ficus Zn)

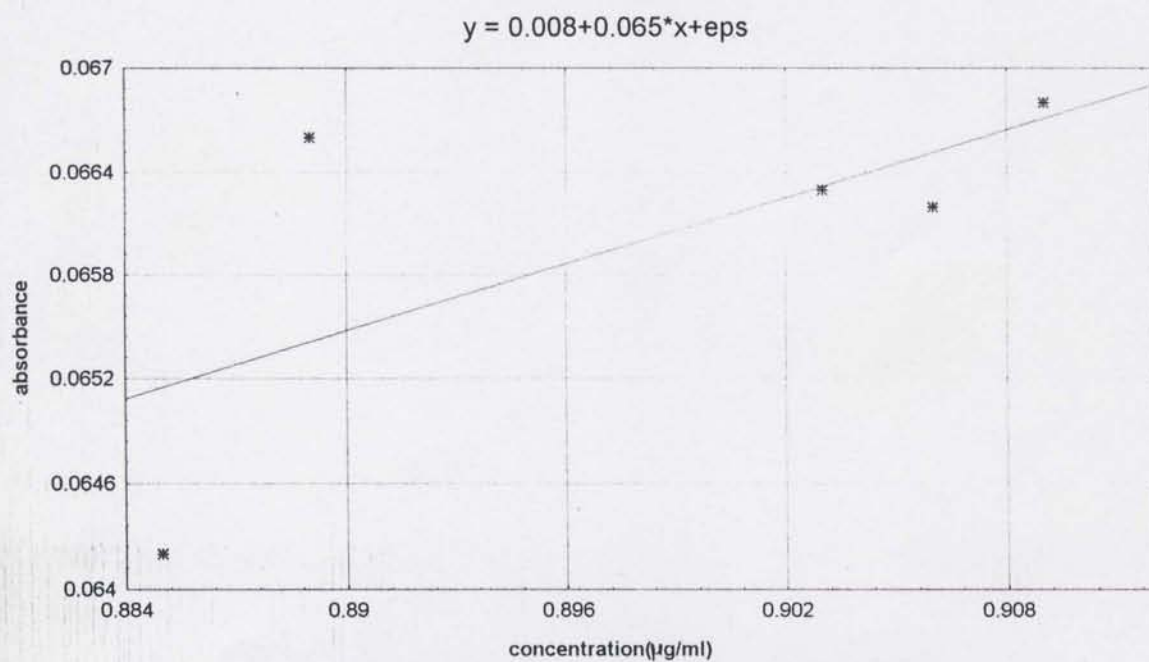


fig.(3): Concentration vs absorbance (Sharia EINneel ficus Cd)

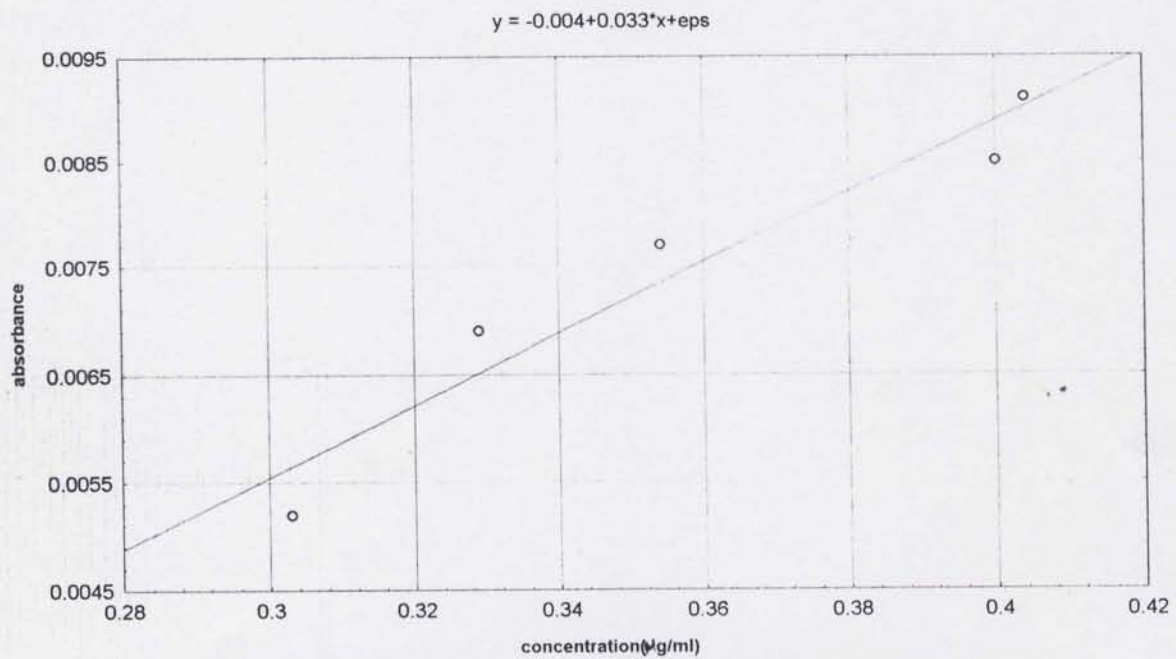


fig.(4): Concentration vs absorbance(Sharia ElNeel Neem Pb)

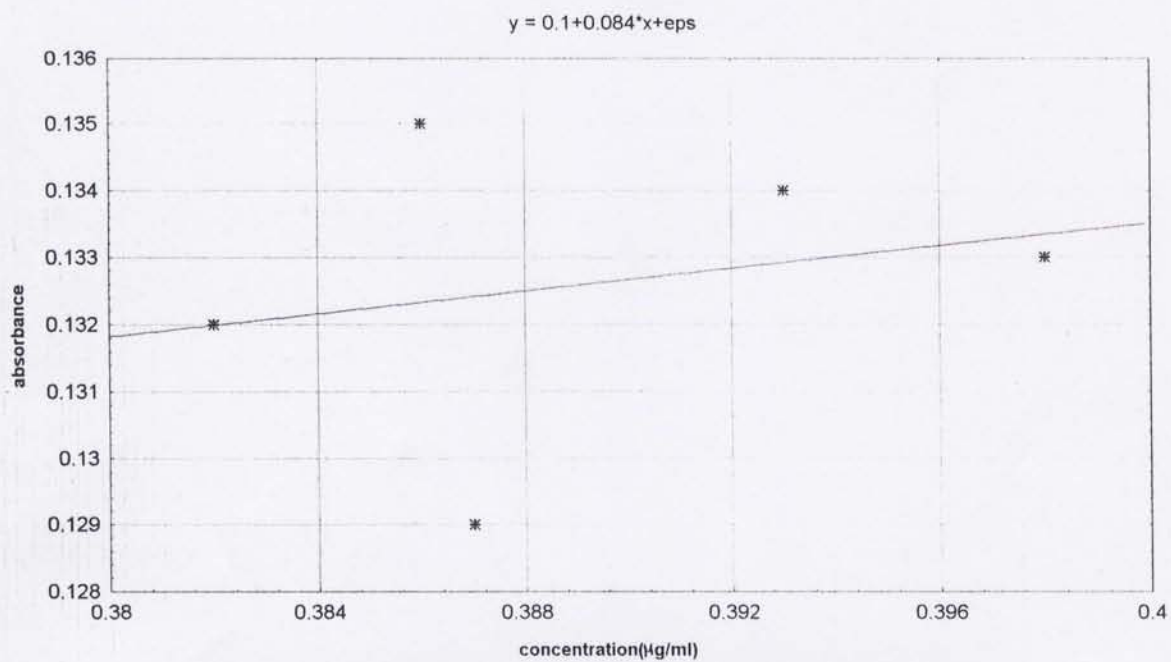


fig.(5):Concentration vs absorbance(Sharia ElNeel Neem Zn)

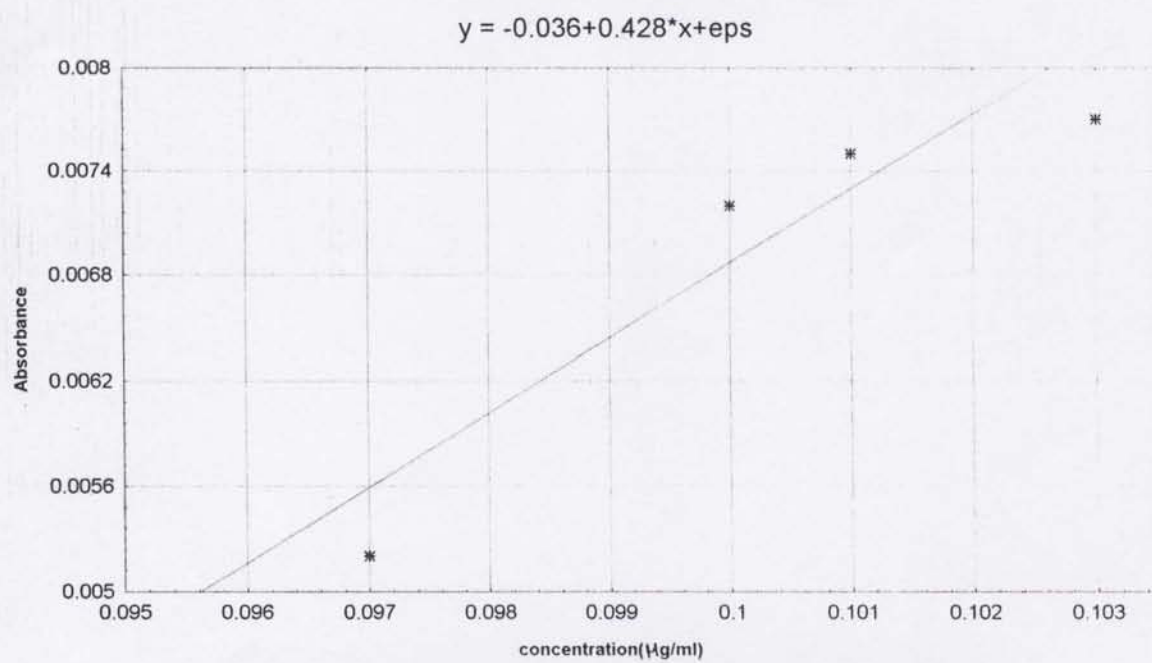


fig.(6) concentration vs absorbance (Sharia El Neel Neem Cd)

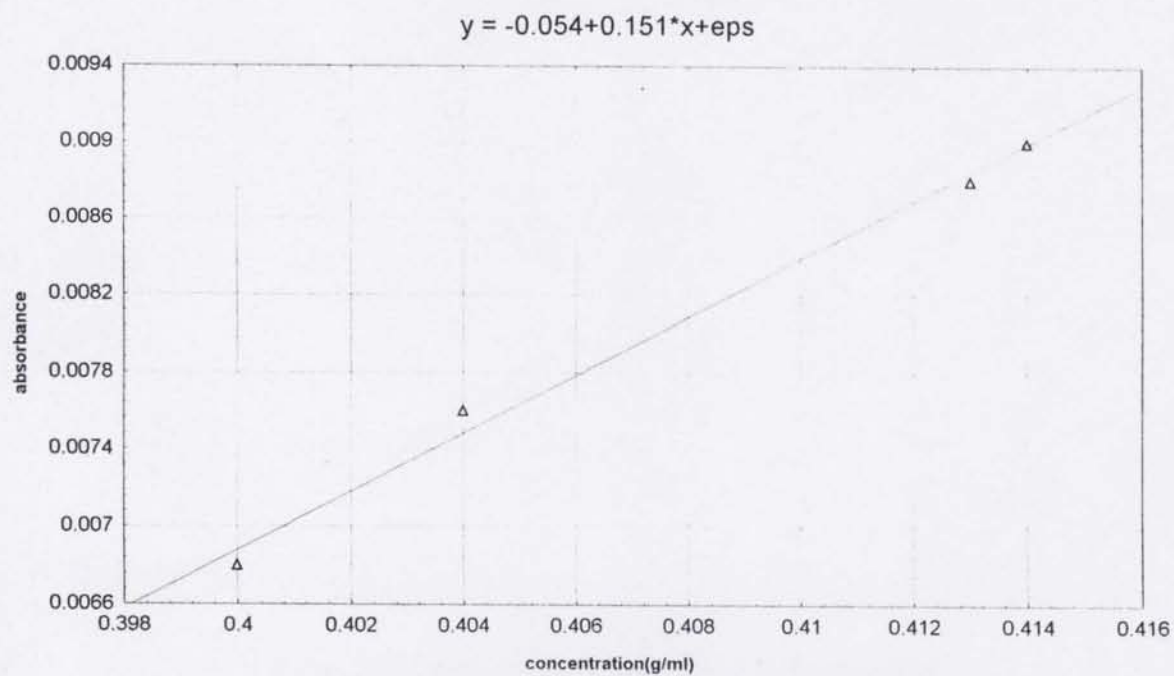


fig.(7):Concentration vs absorbance(Ombada ficus Pb)

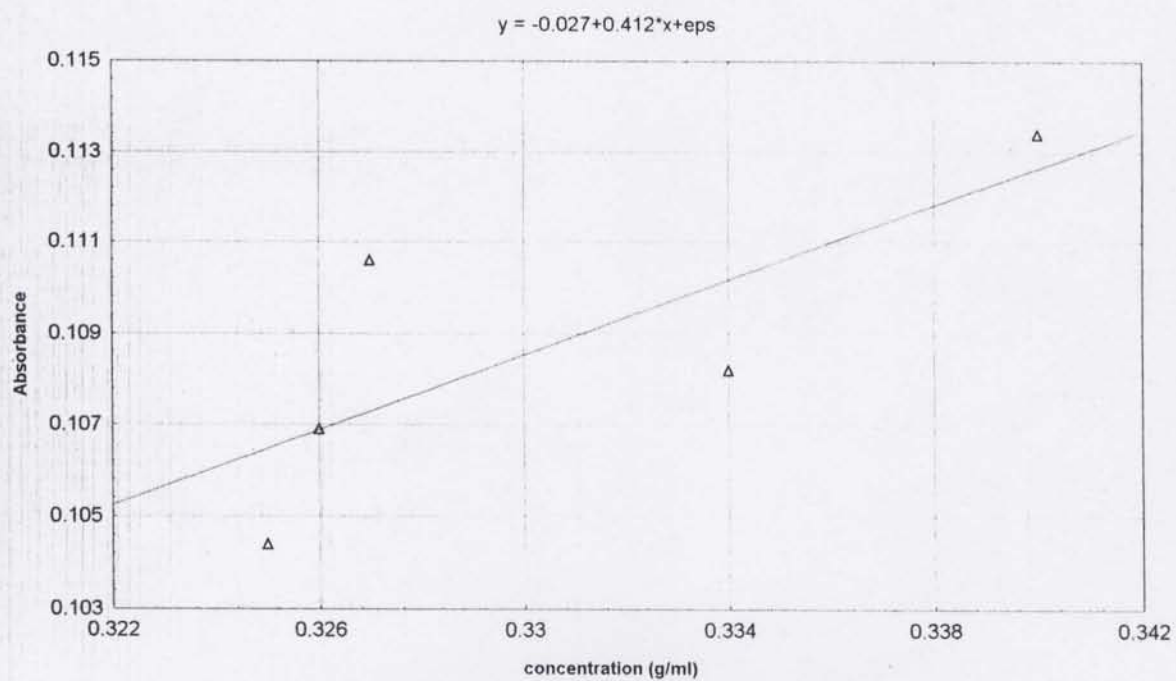


fig.(8):Concentration vs absorbance(Ombada ficus Zn)

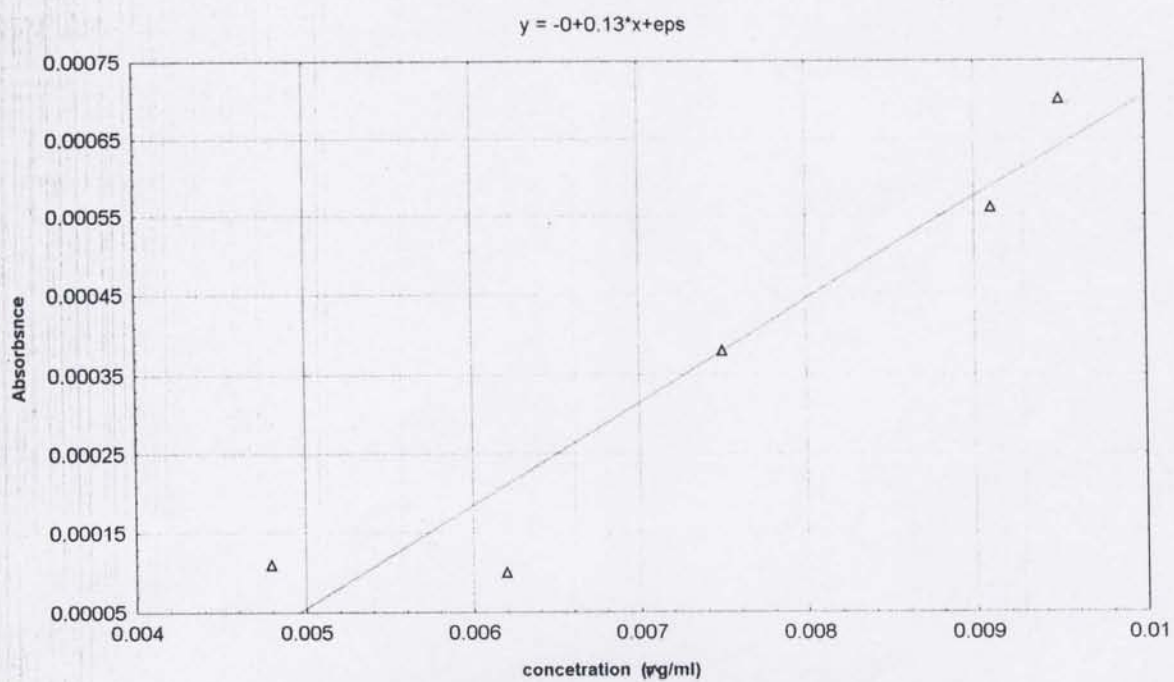


fig.(9):Concentration vs absorbance(Ombada ficus Cd)

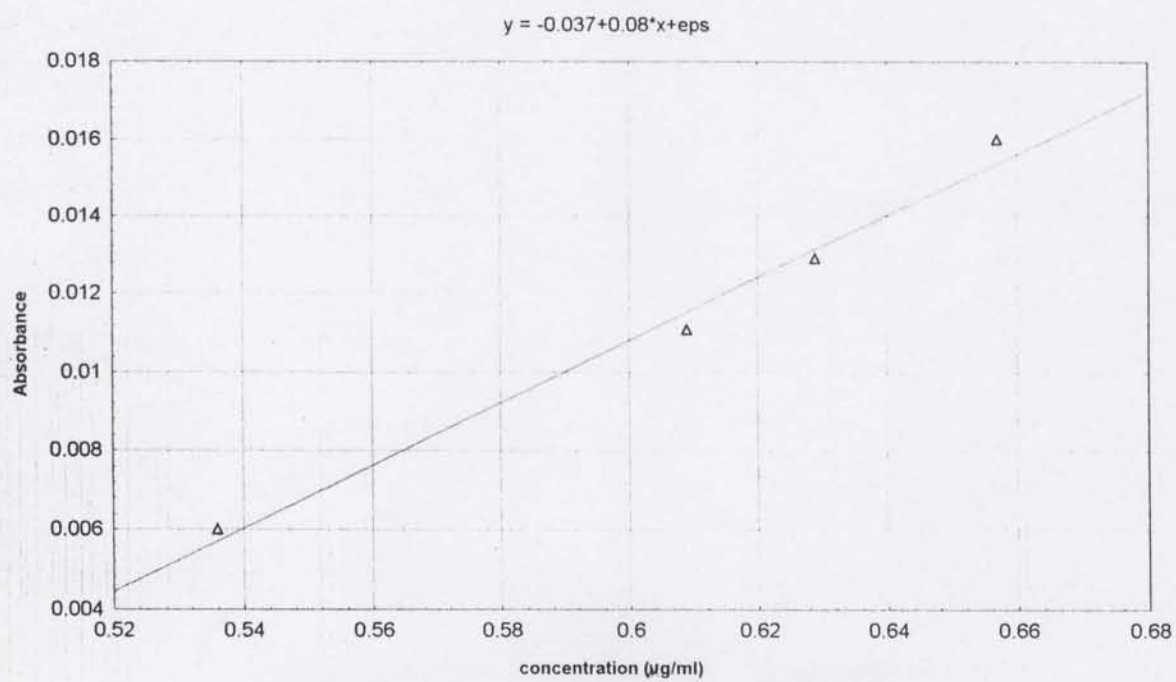


fig.(10):Concentration vs absorbance(Ombada Neem Pb)

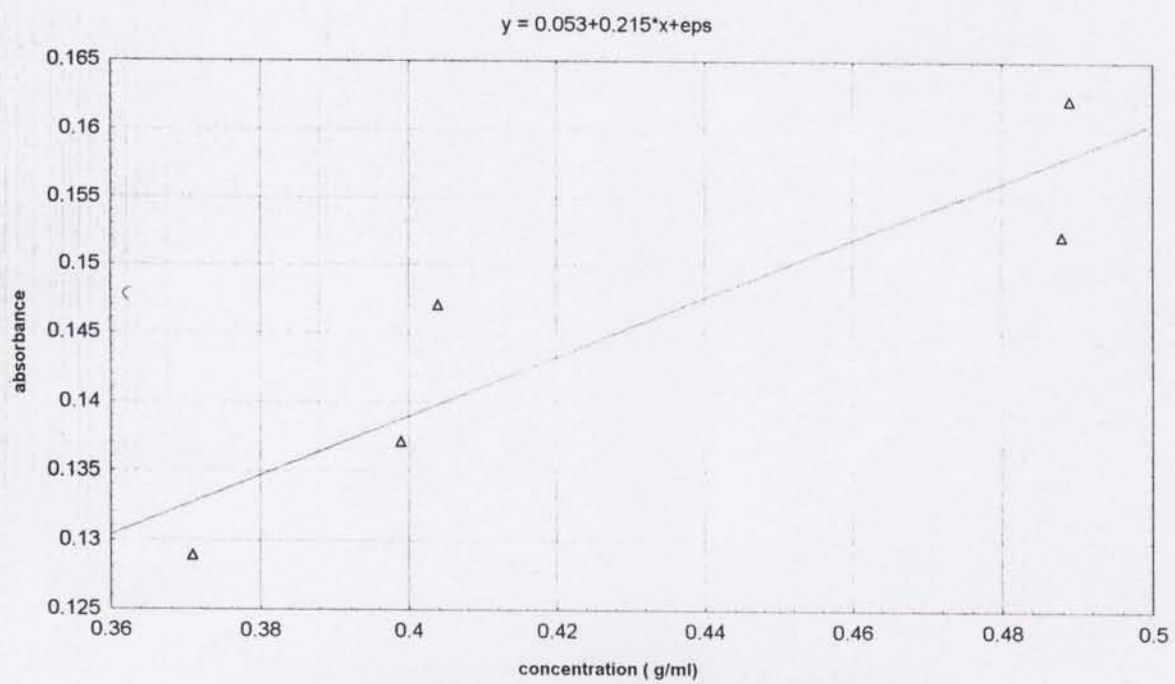


fig.(11):Concentration vs absorbance(Ombada Neem Zn)

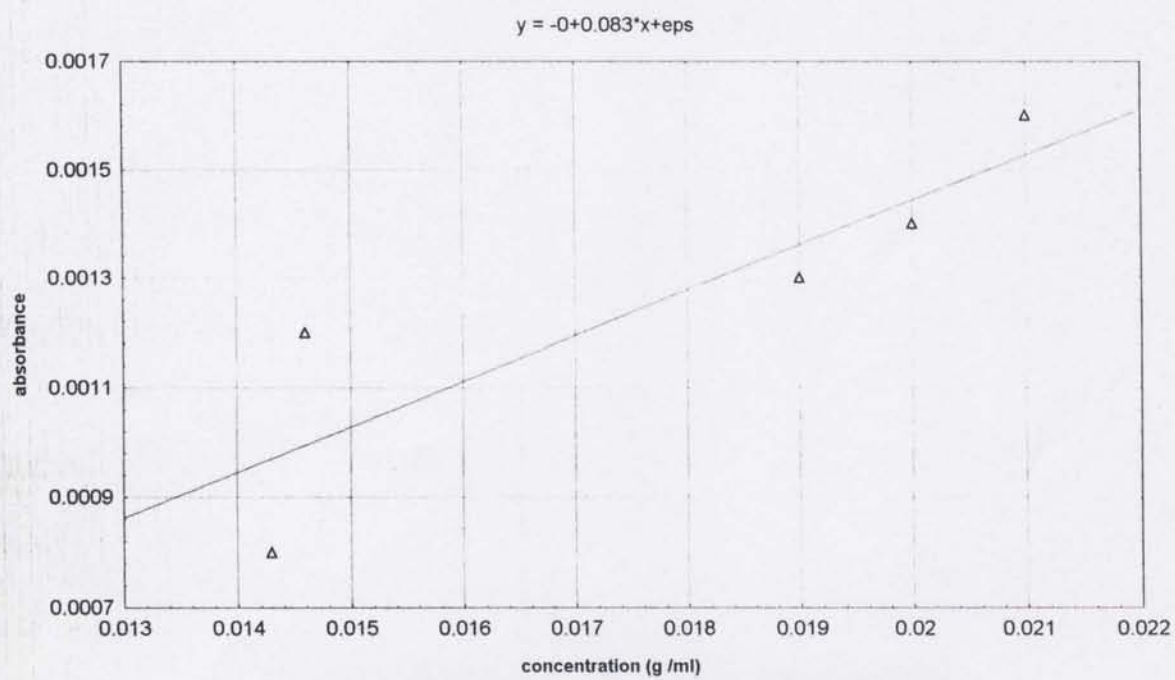


fig.(12):Concentration vs absorbance(Ombada Neem Cd)

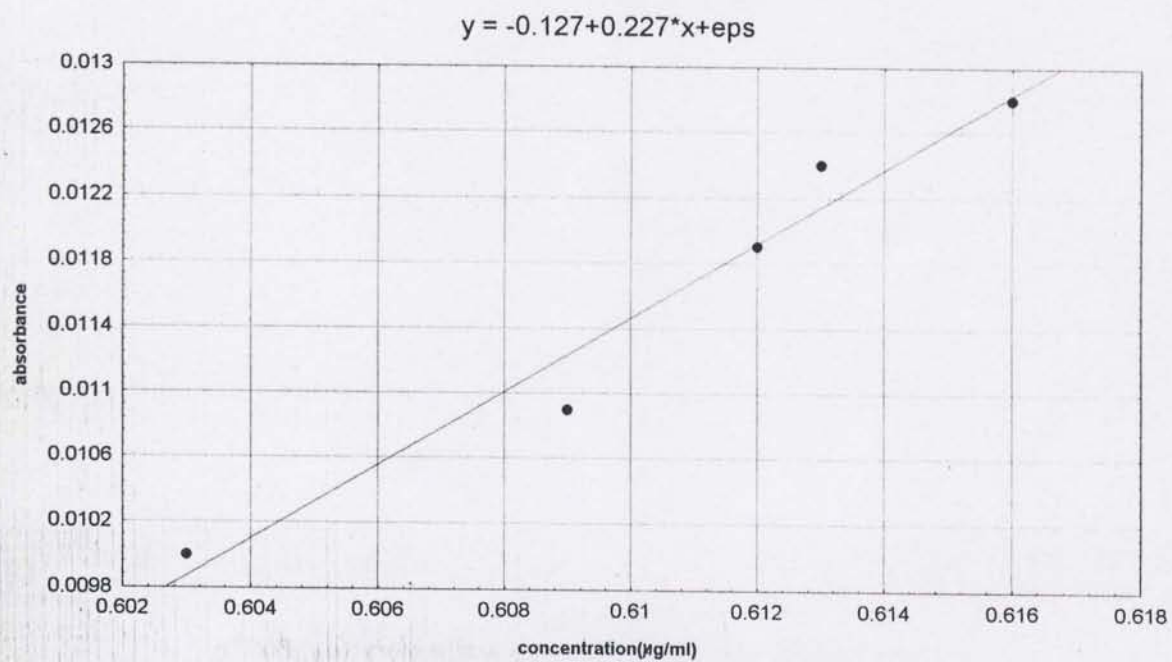


fig.(13): Concentration vs absorbance(Kadro ficus Pb)

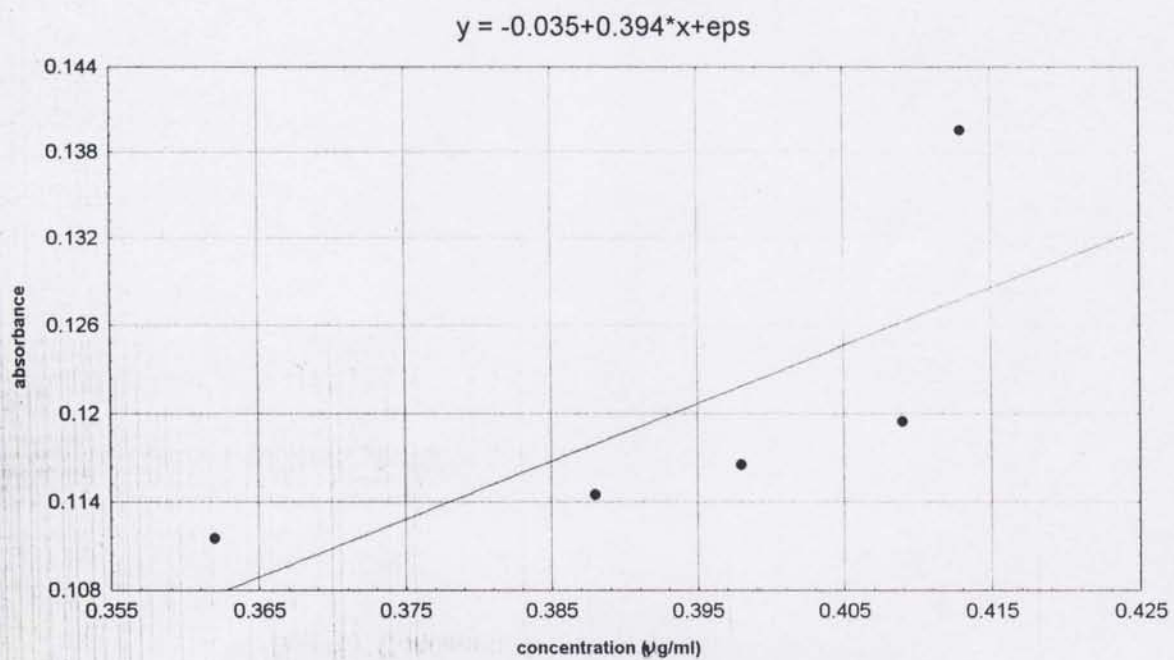


fig.(14): Concentration vs absorbance(Kadro ficus Zn)

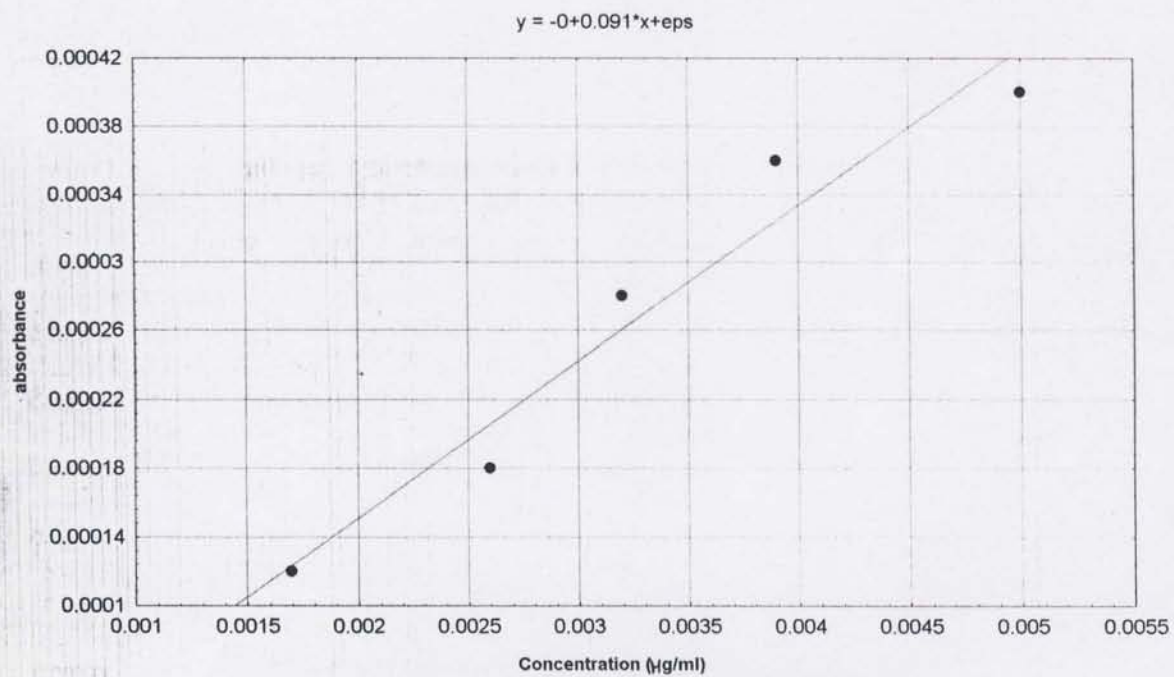


fig.(15): Concentration vs absorbance (Kadro ficus Cd)

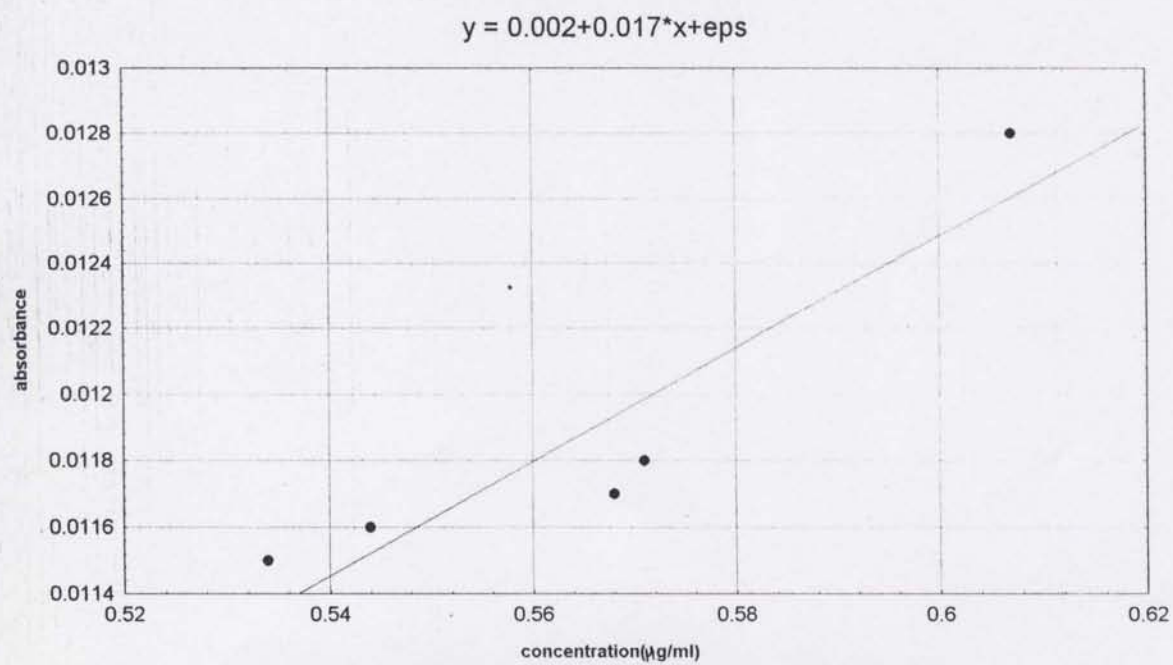


fig.(16): Concentration vs absorbance(Kadro Neem Pb)

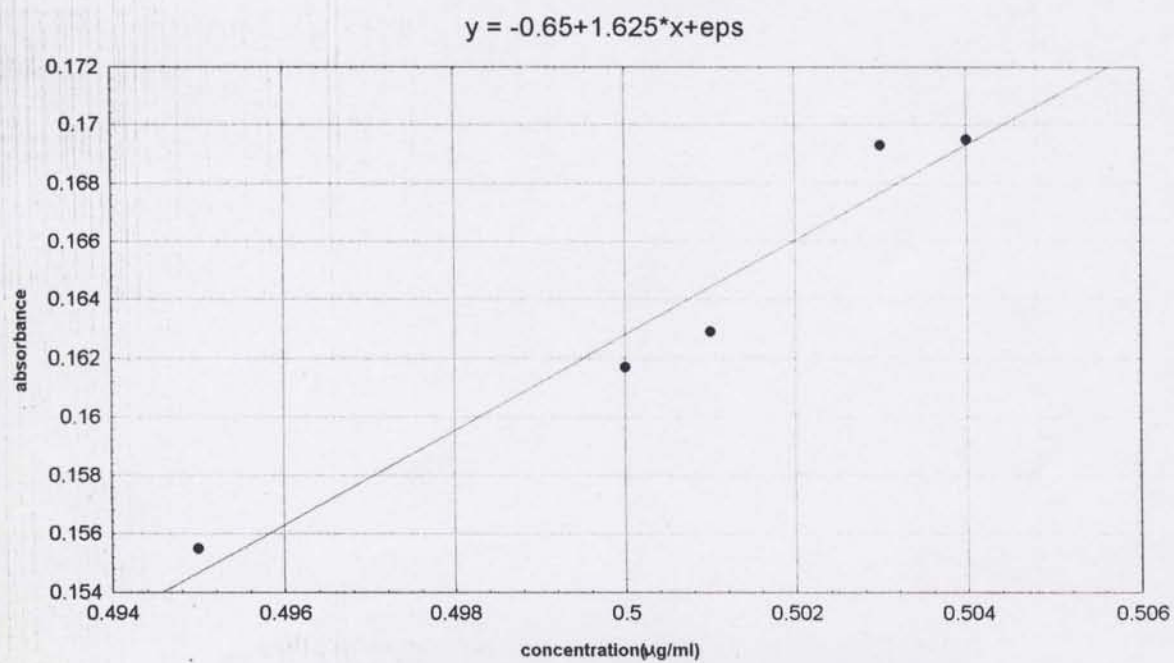


fig.(17): Concentration vs absorbance(Kadro Neem Zn)

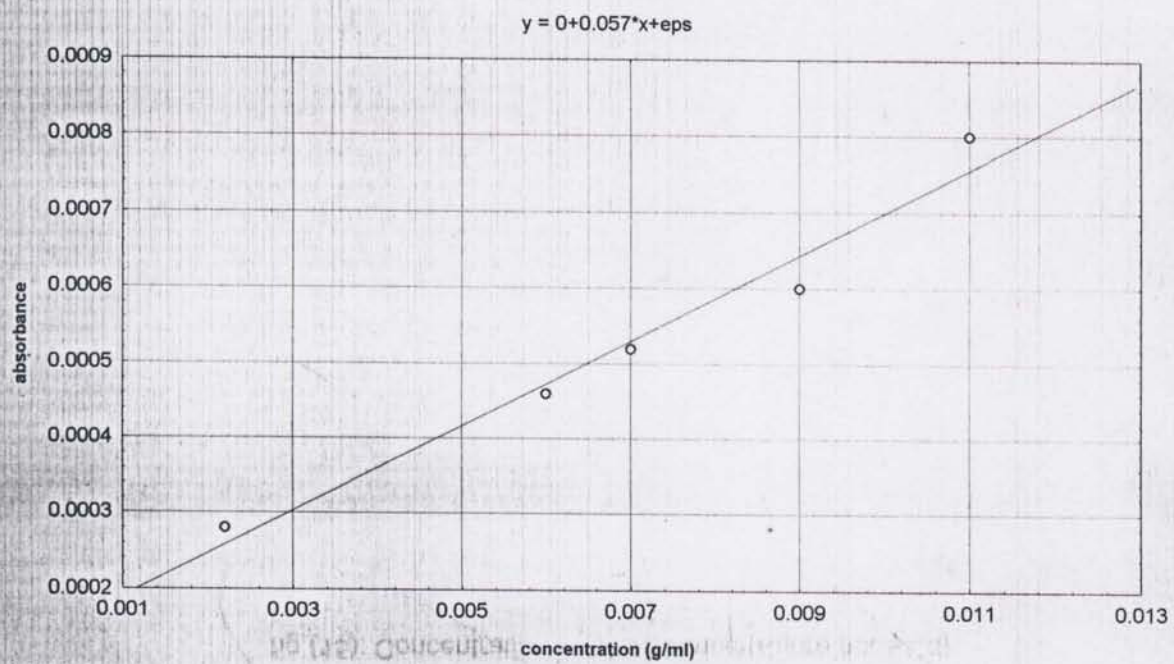


fig.(18): Concentration vs absorbance(Kadro Neem Cd)

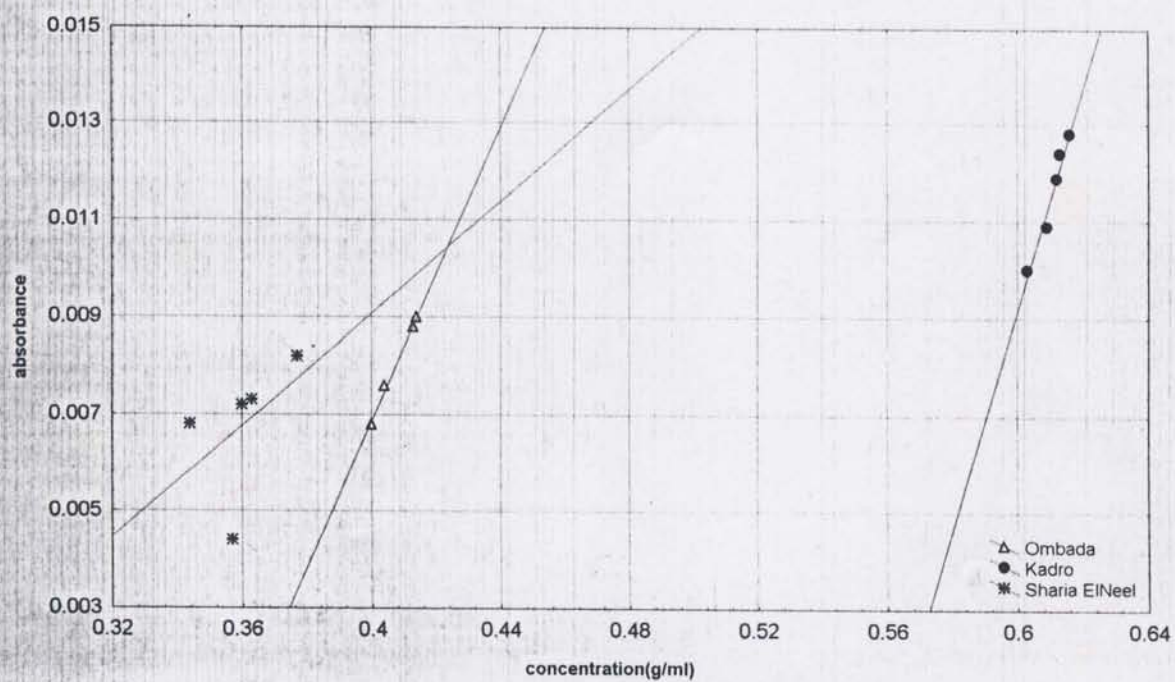


fig.(19):Concentrations of Pb in ficus at the three sites

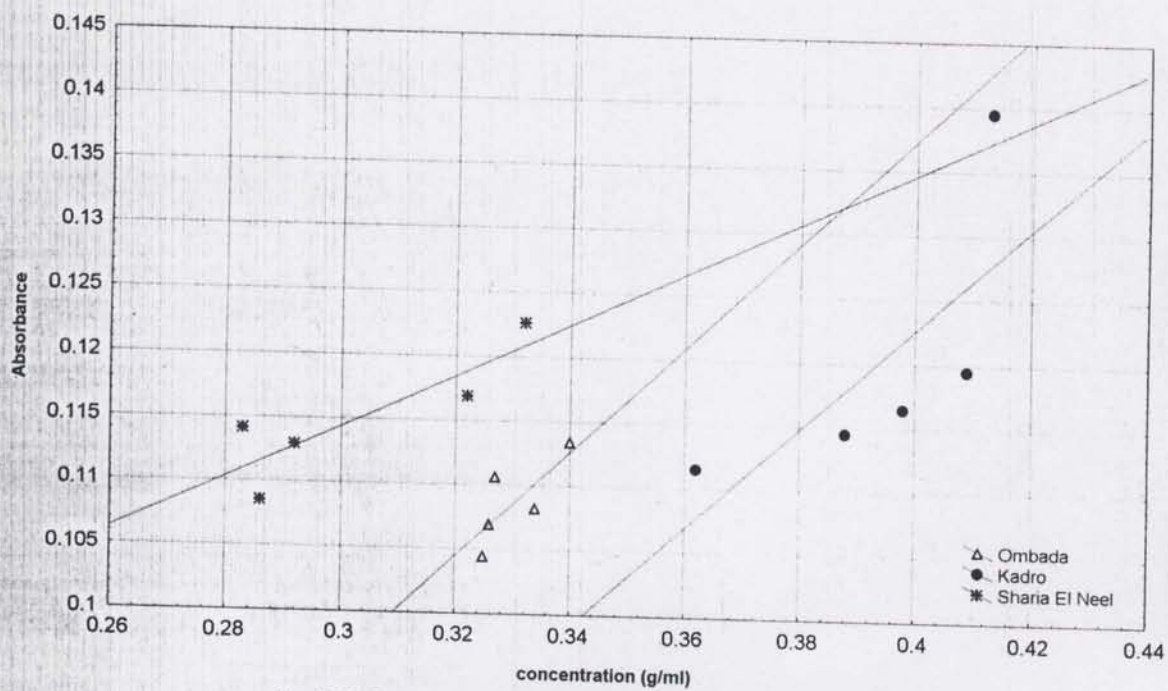


fig.(20):Concentrations of Zn in ficus at the three sites

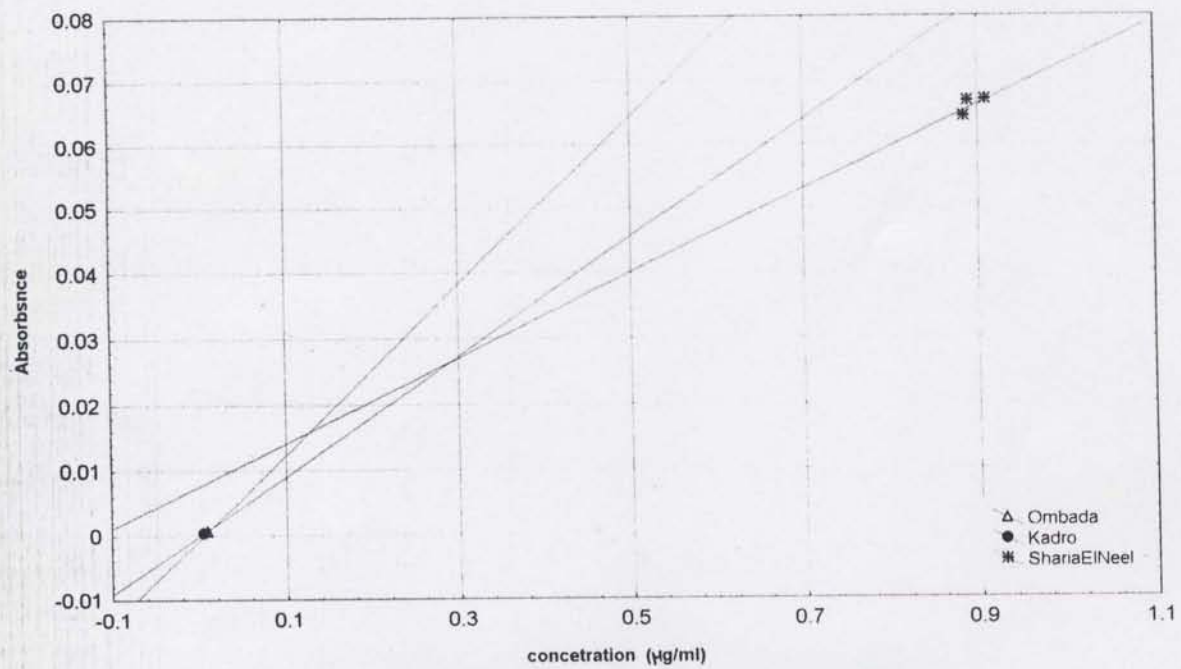


fig.(21):Concentrations of Cd in ficus at the three sites

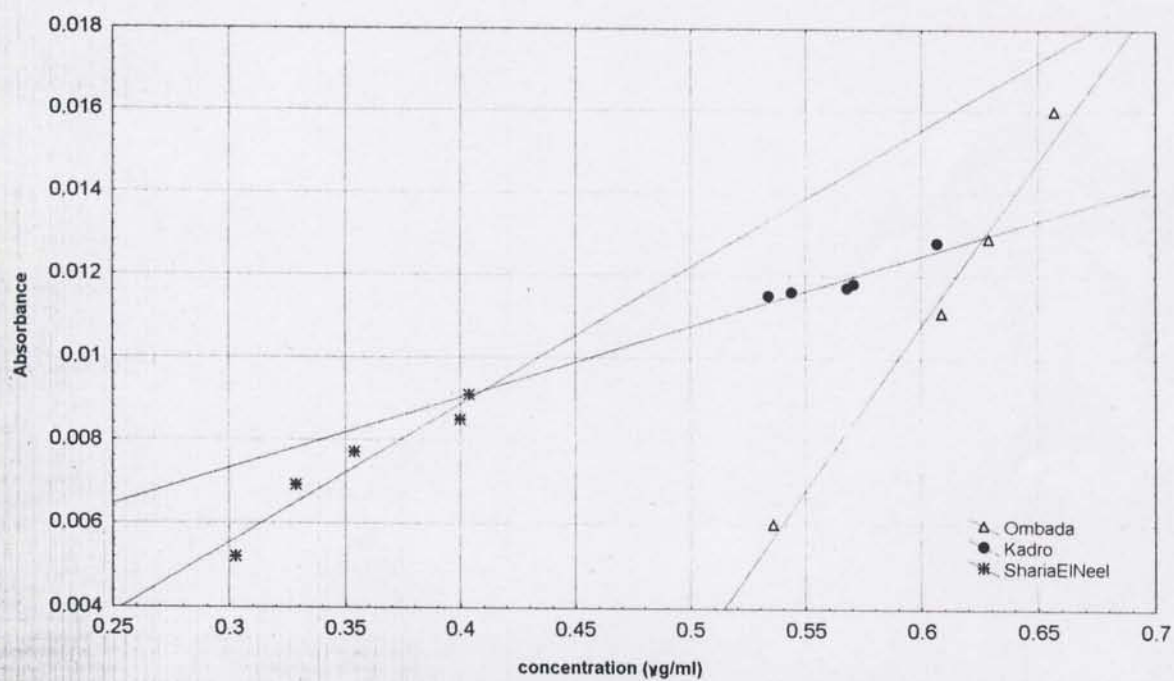


fig.(22):Concentrations ofPb in Neem at the three sites

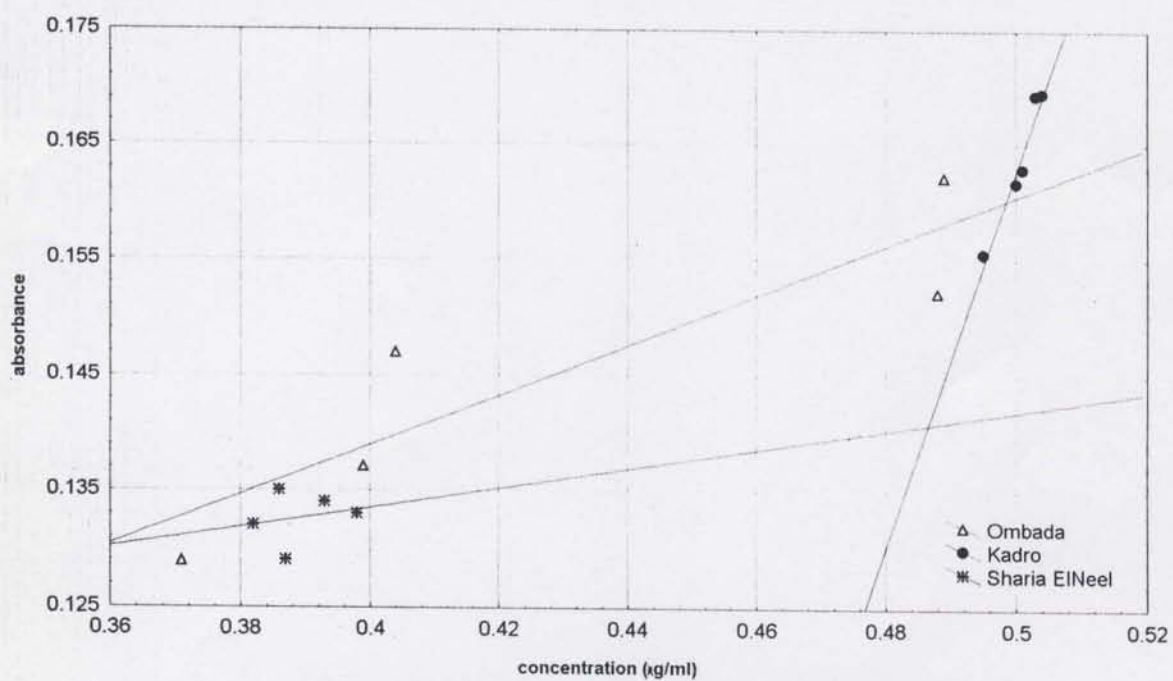


fig.(23):Concentrations of Zn in Neem at The three sites

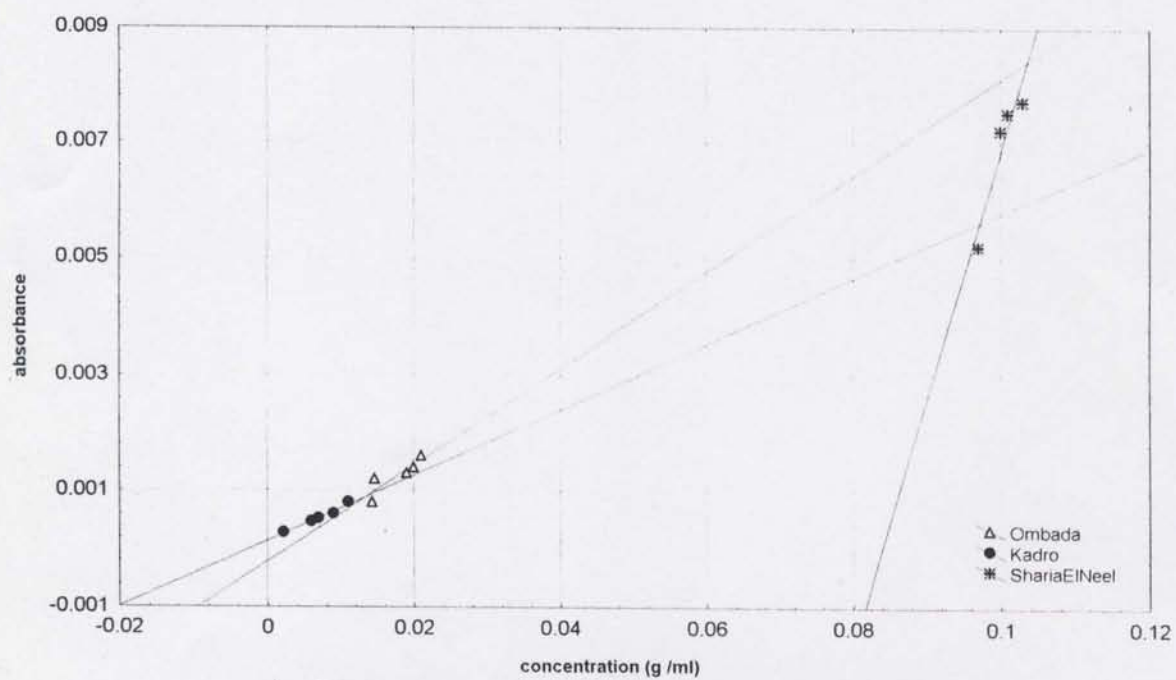


fig.(24):Concentrations of Cd in Neem at the three sites

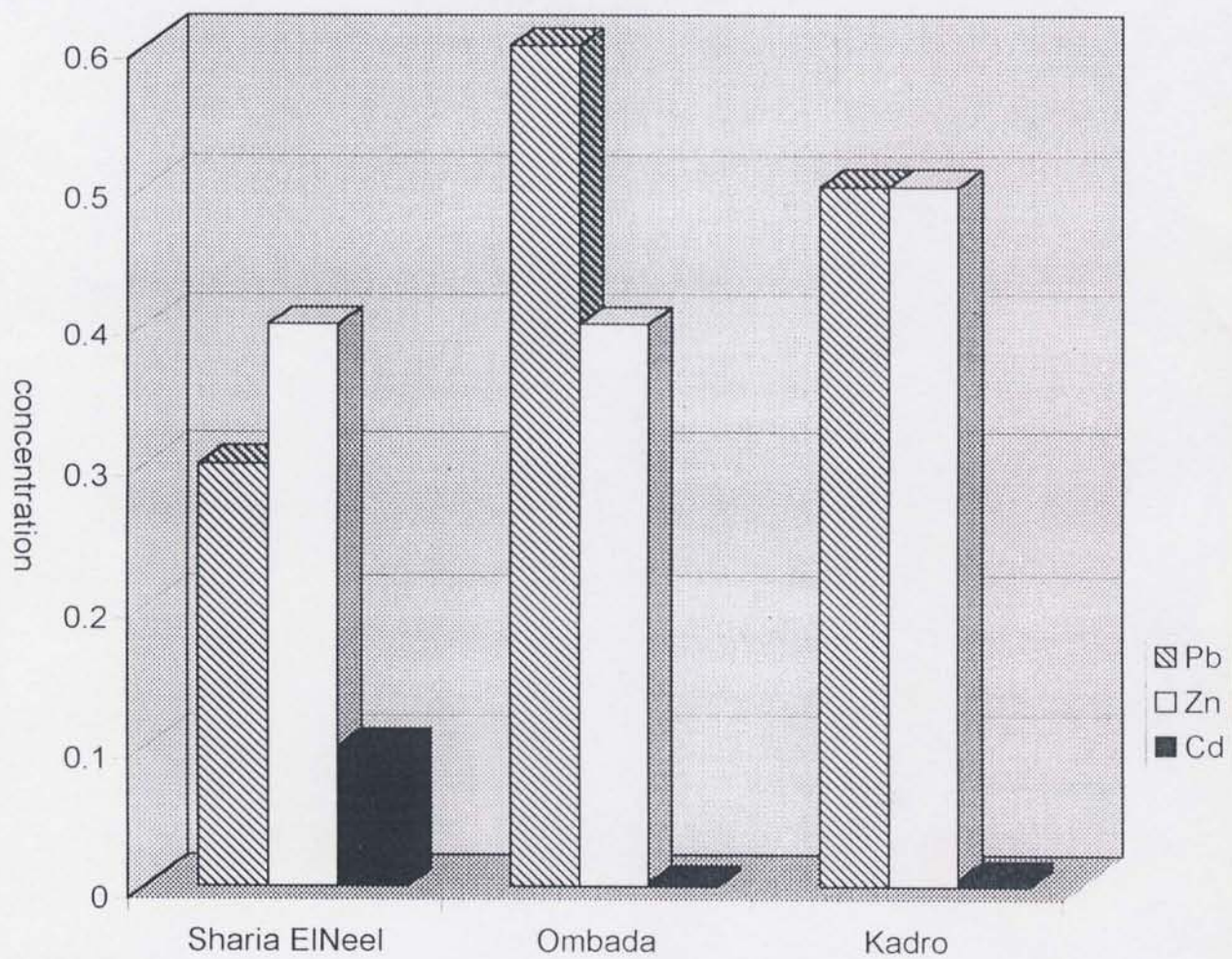


fig.(25):comparison between concentration of(Pb,Zn andCd)in Neem at the three sites

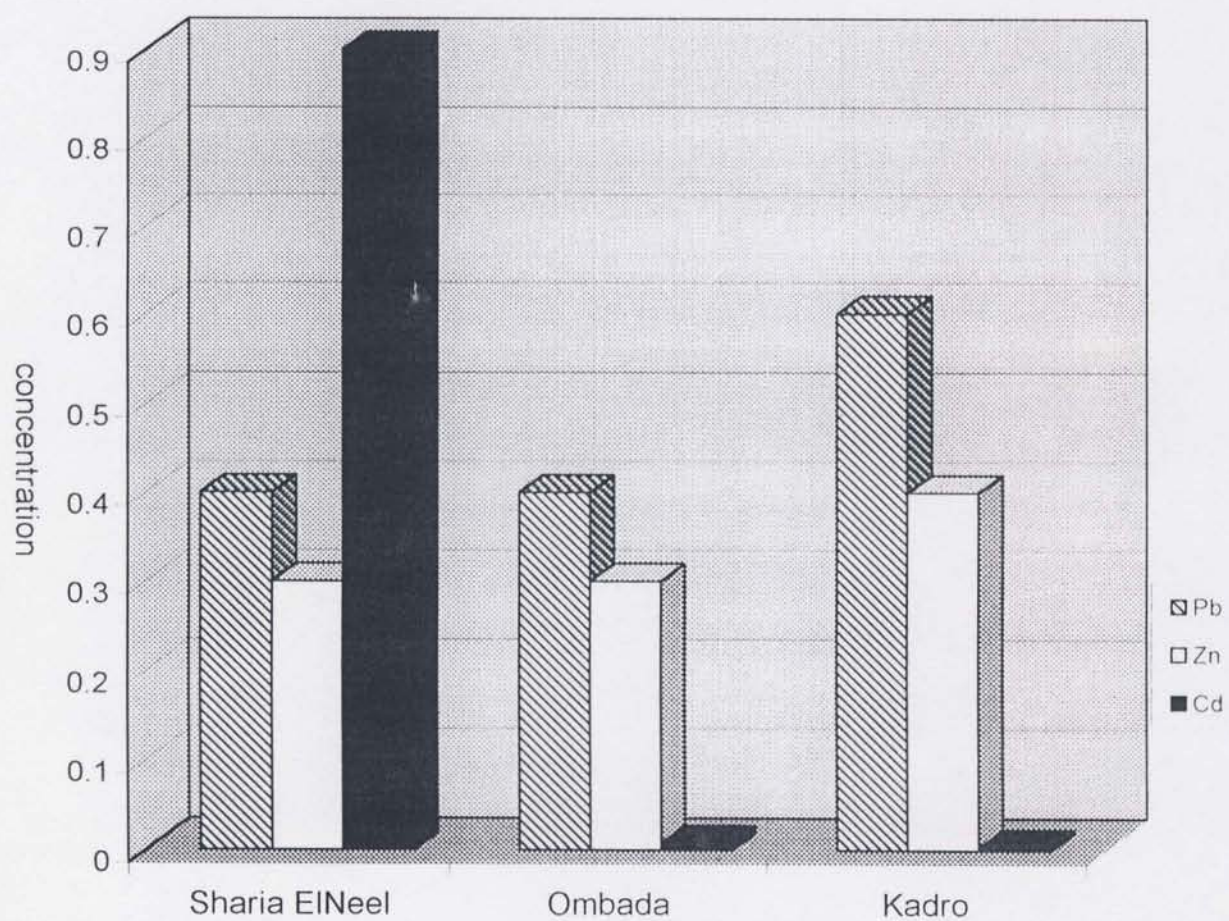


fig.(26):Comparison between concentration of (Pb,Zn and Cd) in Ficus at the three sites

Conclusion

Air pollution involves the loss of resources, degrades the environment, and destroys health. Methods presently known to control pollution cost money, time and effort.

The results of lead, Zinc and Cadmium concentration in plants green leaves of Ficus and Neem showed metal pollution from automobile emission and other incinerations are not yet a threat to human, animals and plants health in Khartoum State (Sudan).

But, we have keep aware of environment, the development of new technology necessary for really adequate control of pollution carries a high price.

Nevertheless, it appears that we really have no choice but to pay the necessary price in any currency and inconvenience.

The challenge now facing human is to fight pollution and how to protect the environment at present and tomorrow from rapid change. Not being able to predict the direction and extend of changes is difficult for any individual to accept, but it seems clear that the pace at which it occurs will be decided primarily by changes in industrial technology.

In last decades of last century, advances in industry and technology have altered the way human behave and the manner in which is thought to bring a head their environment.

Pollution problem remains the keystone. If any thing, it is more important than ever as a vehicle for stopping pollution, for simple reason that it means in human life. Moreover, it is significant and more effective on earth and universe as whole. What follows is a result of human existence and development.

Recommendations

To announce strict air quality standards, to go into effect in last century. In part, these standards have been postponed several times and at the present time they are still not fully in effect.

The standards establish limits for the amount of SO_2 , SO_3 , particulate matters and hydrocarbons, CO, Photochemical oxidants, heavy metals and NO, NO_3 that can safely exist in the air.

Full enforcement of the limits would undoubtedly cause a large number of changes, such as closing some sections of large cities to automobile traffic at certain hours, a greater use of public transportation and car pools, and very significant changes in fuels used by electric generating plants and other industries. Hence, there has been considerable controversy.

To bring healthy and cleaning to our atmosphere, some recommendations have to be headed and activated:

- **Priority for sufficient vehicles:** we have to allow the sufficient vehicles to use the roads and only those vehicles, which were found to cause the huge pollution, have to be forbidden.
- **Lead-Free Petrol:** it is safe and health-supporting to use petrol, which is recently modified to safe the environment. Petrol of Sudan must be lead-free petrol so as to safe air, soil and water from being polluted by deposited Pb and other metals.
- **Plantation:** by increasing the number of plants on roadsides and round residential and industrial areas, we can refresh air and ensure soil with few metals that contaminate ecosystems.

- **Agriculture and Industry:** it is better to build industrial areas in far distal sites from residential and agricultural areas.
- **Town Planning:** when the cities and towns were planned and constructed, this keep flow of air and ensure rapid cycle of smoke, fumes, fogs and other wastes to outside the atmosphere, besides avoidance of crowd-ness.

References

1. Al awdat, Mohd, (1984), Air pollution. *King Khalid Military Journal*, issue 6, vol.2.
2. Agency for Toxic Substances and Diseases Registry (ATSDR), (1999). Atlanta. (GA 30333). U.S.A.
3. Ashida, J., (1965). Adaptation of Fungi to Metal Toxicants. *Am. Rev. Phytopathol.* 3: 153 – 174.
4. Bach, w.(1972). Atmospheric Pollution. Mc Grow-Hill CO.New York (U.S.A) pp30-35.
5. Bob rov, R.A.(1952), Phytopathology, In: *proceedings of the 2nd National Air pollution symposium, los Angeles (Stand ford Research Institute)*, p, 129.
6. Broyer, T. C., A. B. Carlton, C. M. Johnson and P. R. Stout (1954). A Micronutrient Elements of Higher Plants. *Plant Physiology.* 29: 526 – 532.
7. Butler, J, (1979). A.P.chem.. Academic press London (U.K) pp, 193-204.
8. Cannon, H. I. (1976). Lead in Vegetation. In: *Lead in the Environment*. (Lovering, T. G. ed) *US. Geol. Surv. Prof. Pap.* 957, 23.
9. Col beck, I., and Morison, J (2003). Uptake of Heavy Metals by Plants. (*Col bi @ essex-ac-uk and moris j @ essex-ac-uk.*).
- 10.Davis, R. D. (1978). Critical Levels of Twenty Potentially Toxic Elements in Young Spring Barley. *Plant Soils.* 49: 395 – 402.
- 11.Dean, R.S., et-al.(1944). "Report Submitted to the trail Smelter Arbitrol Tribunal", *U.S.Bur. Mines Bull*, 453.

12. Detrie, J-(1973). Atmosphere must be clean, Paris. In: *El muhandis, A.A., (1988). Features of Air poll: in K.D.S., King Sand Univ., Geology Dept., Reyadh.*
13. Elbushra, E., (1976). An Atlas of Khartoum conurbation. Khartoum Univ.press, pp, 15-45.
14. Eliane, T.J., (2003). Laboratory of Experimental Air Pollution, Sao Paulo (Brazil).
15. Environment Protection Agency (EPA) (2003). Reports about Taiwan, Belgium, and Poland.
16. Faith, W.L., (1959). Air poll. Control. John Wiley and sons, inc., London, Chapman & Hall, Ltd.
17. Gabriela, M-Gaspar & Attila, A., (2002). Heavy Metal Uptake by two radish varieties, vol.46 (3-4), Hungaria.
18. Ghies, G.A.H., (1984). Investigation of lead poll. from Automobile Emissions in Khartoum. Khartoum Univ. pres. Inst of Environ studies.
19. Giinhardt, M.S., (2002). Cellular injury, heavy metal uptake & growth of Poplar, willow & spruce influenced by heavy metal & soil acidity, Birmensdorf, Switzerland, in: *cost action 837, WGZ toxic metal work shop, Bordeaux, France, 25-27 April, 2002.*
20. Hemphils, D. (1974). Road side Pb contamination in the Missouri Lead Belt. *Arch Environ Health.*
21. Herkufes, Oulu University Library (2002). Assessing Industrial pollution by means of environmental samples in the kemi-Torino. Chapter (1). Introduction in: *Methods for the dissolution and analysis of environmental samples* (June, 2003).

22. Ibrahim, S.M., (1986). Methods of Control gaserus pollutions emitted by motor-rehicle exlausts, Univ. king Sand, K.S.A.
23. Joseph, M.M., (1973). "Introduction to Environmental Science", Boston, little Brown CO., pp, 147-205.
24. Kumetrai, T.Y. ,Bove, J.L., Nathanson, B., siebenberg, s, and Magyar, M, (1972) *Environ. Sci. Technol.* 6 (7), 617-620.
25. Lawther, P.J, et-al (1962). Epidemiology of Air poll. (*Report on a symposium*), WHO, Geneva, (Public Health Papers. 15).
26. Letchamo, W., et-al (2002). Heavy metal accume in sea Buckthorn cultivators in Siberia. Alexandria, VA, pp, 399-401. In *Janick, J, et-al. "Trands in new crops and new uses."* ASHS press, Alexandria, VA.
27. Lindsay, W. L. (1972). Zinc in Soil and Plants Nutrition. *Adv. Agron.* 24: 147 – 153.
28. Lombi; E., Wenzel, w.w., & Adriano, D.C., (1998). Trace elements contamination, Tisks assessment, and remediation, 6: 1-15.
29. Mc Laughlin, M.J, et-al (1999). "Pridiction of Cadmium Conc: in potato tubers (sol-tuberosum) by pre-plant soil and irrigation water analysis". *Australian Journal of soil Research*, 137: 191-207.
30. Mitchell, R., (1993). Environmental Microbiology, John Wiley and Sons, Inc, Publication, New York.
31. Mohd, A.H.T, (1986). "Trace elements content of some selected Sudanese population". Univ.of Khartoum-Sudan Library (Khartoum). Motor Vehicles-MVG-URTAD.
32. Noble, W., (1955), *Agric. & Food chem.*, 3: 330.

33. O'Neill, p, (1995), *Environmental chem.*, 2nd ed, Madras, Chapman & Hall pp, 193-221.
34. Phillips, D.J.H, (1977). The use of Biological indicator organisms to monitor trace metal pollution in Marine and Estuarine environments: A review. *Environmental Metal Pollution*, 13, 281-317.
35. Phillips, D.J.H, (1980). Quantitative Aquatic Biological Indicators. Their Use to monitor Trace Metal and Organo chlorine pollution, pp, 488, *Applied Science Publ. Ltd*, London, U.K.
36. Qatar Univ (1995). *Sci-J-*, vol. 15, No. 1, pp, 11, 215-221.
37. Rothamsted (U.K.). LASAT, M.M, et-al (1999). Molecular physiology of Zinc transport in the Zn Hyper accumulator *Thlaspi caerulescens*-J-EXP. Bot.
38. Ryamond, C. (1998). *Chemistry*. 6th. Boston (U.S.A), McGraw-Hill c, pp, 692-716.
39. Sc.F.C.T., (1970). The Handling of Experimental Data. *Prepared by the science foundation course team*. The Open Univ. Press.
40. Schwartz, c. et-al (1999). Phytoextraction of Cd & Zn by the hyper accumulator plant *Thlaspi caerulescens* as effected by plant size and origin (submitted) in: *Lombi E., (1999)*.
41. Shacklette, H. T. (1980). Elements in Fruits and Vegetables from Areas of Commercial Production in the Conterminous United States. *US Geol. Surv. Prof. Pap.* 1178, 149.
42. Smith, H. (1976). Lead contamination of the Road side ecosystem. *J-Air Poll-control Assoc*, 26, 753-764.
43. Stringer, c. (1974). Lead conc: in *Human lung samples*. *Arch Environ. Health*. 29, 268-270.

44. Sumita, M.E., (2003). Laboratory of Experimental Air Poll., Univ. of Sao Paulo, Sao Paulo (Brazil) in: *Boom in characterization of Air poll. & its effects*, Academic press, New York, vol, 1, 2nd ed (U.S.A).
45. Tea, T.W. & Khan, R.M. (1991). "Removal of lead, cadmium and zinc by waste Tea leaves". *Environ. Technol. Lett*, pp, 829-835.
46. Thomas, M.D., Hendricks, R.H. (1956)) effected of air pollution on plants, in: *Masi U, P.L, et-al. Air poll. Handbook*, New York, section 9, p, 1.
47. Thomson, R.J., Morgan, G.B, and Purdue, L.J (1970). At. Absorp. Newsl. 9 (3) 53-57.
48. UNEP, (1978). Lead: Evaluation Technique for one of the priority pollutions: effects and control, *New York, UN (Air pollution series)*, No-1