ASSESSMENT OF LEVEL OF HEAVY METAL IN SOIL AND THEIR ENVIRONMENTAL EFFECTS FROM THREE MECHANIC VILLAGES IN ABUJA

BY

EKEOCHA CHRISTOPHER IKECHUKWU

(B.Tech FUTO)

REG No: 20124763678

**A THESIS SUBMITTED TO POST GRADUATE SCHOOL
FEDERAL UNIVERSITY OF TECHNOLOGY, OWERRI, IMO STATE**

IN PARTIAL FULFILLMENT FOR THE REQUIREMENTS FOR THE AWARD OF MASTER OF SCIENCE DEGREE (M.Sc) IN ENVIRONMENTAL CHEMISTRY

MAY, 2019

CERTIFICATION

This is to certify that this work "Assessment of level of heavy metal concentration in soil and their environmental effects from three major mechanic villages in Abuja" was carried out by Ekeocha Christopher Ikechukwu (20124763678) in partial fulfillment for the award of the degree of Master of Science (M.Sc) in Environmental Chemistry in the Department of Chemistry of the Federal University of Technology Owerri.

.... 15/5/19 ....
Dr. C.I.A Nwoko Date
(Principal Supervisor)

Enenebeaku .... 07/09/19 ....
Dr. C. Enenebeaku Date
(Co -Supervisor)

.... 07/09/19 ....
Prof. M.O.C Ogwuegbu Date
(Head of Department)

.... 07/09/2019 ....
Prof. A. M Ette Date
(Dean, School of Physical Sciences)

....
Prof. (Mrs) N.N. Oti Date
(Dean, Postgraduate School)

.... 15/5/2019 ....
Prof. S.A Odoemenam Date
(External Examiner)

DEDICATION

This research work is dedicated to Almighty God the creator of the Universe and to my late Dad Ekeocha Livinus who did not live to see his most cherished dream come true.

ACKNOWLEGEMENTS

I wish to acknowledge the unquantifiable assistance of an erudite scholar and renowned professor of Chemistry, Prof. C.I Anunuso who started the supervision of this work for his fatherly advice and constructive criticisms throughout the period of the research work. Big thanks to my supervisor Dr. C.I.A Nwoko and co-supervisor Dr. C. Enenebeaku, for their assistance and supervision of this work. Special thanks to the following persons; Prof M.O.C Ogwuegbu (HOD), Prof. U. Egereonu and Dr (Mrs) C.E Ogukwe. This research would not have been complete without the assistance and support of Staff of Sheda Science and Technology Complex [SHETSCO] Abuja whose laboratories were used for the analyses. Not forgetting my fellow students Ndukwe Reginald, Ugwu-Ojo Ogochukwu, Anoruo Obinna and my colleagues in the office; Okorie Okike, Onyeke Lynda, Modebei Mark, Okoh Beatrice and Mbagwu Dominic.

More so, special thanks to my Angelic Mother, Ezinne Roseline Ekeocha for her tender love and care and my siblings: Ogechi, Uchechi and Chima for their supports and encouragement. My lovely wife Joy and daughter Christabel, for their understanding, love, care and support throughout the period of this programme. Thank you all.

TABLE OF CONTENTS

Title page i

Certification ii

Dedication iii

Acknowledgement iv

Table of content v

List of Tables xii

List of Figures xiv

Abstract xvi

CHAPTER ONE

1.1 Introduction 1

1.2 Background 1

1.2 Problem Statement 3

1.3 Objectives of the research work 4

1.4 Justification of the study 4

1.3. Scope of the Study 5

CHAPTER TWO

2.0. Literature Review 6

2.1. Definition of Heavy Metal 7

2.2 Sources of Heavy Metal 7

2.2.1 Atmosphere to soil pathway 8

2.2.2 Solid wastes to soil pathways 8

2.2.3 Agricultural supplies to soil pathway 8

2.2.4 Sewage to soil pathway 9

2.3 Characteristics of Heavy Metal Contamination in Soil 9

2.3.1 Wide distribution 9

2.3.2 Complex heavy metal contamination 10

2.3.3 Irreversibility and remediation problem 10

2.3.4 Strong latency 10

2.4. Heavy Metal Toxicity 11

2.5. Effects of Heavy Metals 11

2.5.1 Effects of Heavy Metals on Soil Microorganism and Enzymatic Activities 11

2.5.2 Effects of Heavy Metals on Plants 12

2.5.3 Effects of Heavy Metals on Humans 13

2.6. Heavy Metal Poisoning 13

2.6.1. Cadmium Poisoning 13

2.6.2. Chromium poisoning 14

2.6.3 Lead Poisoning 14

2.6.4 Mercury poisoning 15

2.6.5 Arsenic Poisoning 15

2.6.6 Silver Poisoning 16

2.6.7 Zinc poisoning 16

2.6.8 Copper poisoning 17

2.7. Bioaccumulation of Heavy Metals 18

2.8.0 Review of Analytical Method 18

2.8.1 Atomic Absorption Spectrophotometer 19

2.8.2 X-Ray Fluorescence 19

CHAPTER THREE

3.0. Materials and Method 21

3.1 Description of Study Area 21

3.2 Methodology 22

3.2.1 Preparation of stock solution 22

3.2.2 Standard working solution 23

3.3 Sample Collection and Sample Treatment 23

3.3.1 Sample Collection 23

3.3.1. Sample Treatment 24

3.3.2. Sample Digestion 24

3.3.3 Calibration Curve 25

3.4. Physicochemical Analysis of Soil 27

3.4.1. pH Determination 27

3.4.2. Determination of Specific Gravity 27

3.4.3. Determination of Bulk Density 28

3.4.4. Determination of True Density and Percentage Porosity 28

3.4.5. Determination of Particle Size Distribution 29

3.4.6. Determination of Moisture Context 30

3.4.7. Determination of Electrical Conductivity 30

3.4.8. Determination of Organic Matter 31

3.4.9 Soil Microbial Analysis (Total Coliform) 32

3.5.0 Analysis of Phosphate (PO_4^{2-}) 32

3.5.1 Analysis of Sulphate (SO_4^{2-}) 33

3.6 Instrumentation 33

3.7. Statistical Analysis 34

3.8. Pollution Indices Assessment 34

3.8.1. Single Indices 34

3.8.1.1 Contamination factor 35

3.8.1.2 Ecological risk factor 36

3.9. Integrated Indices 36

3.9.1 Degree of Contamination 37

3.9.3 Potential Ecological Risk 37

CHAPTER FOUR

4.0 Result and Discussion 38

4.1 Physicochemical Contents of Studied Soil 38

4.2 Results of Anionic Contents of Studied Soil 40

4.3 Levels of heavy metals in soil 41

4.3.1 Iron 42

4.3.2 Zinc 42

4.3.3 Copper 43

4.3.4 Nickel 43

4.3.5 Lead 44

4.3.6 Chromium 44

4.3.7 Cadmium 44

4.4 Pearson's Correlation Analysis 46

4.5 Analysis of Variance (ANOVA) 49

4.6 Test for Homogeneity (Levene's Test) 50

4.7 Post Hoc Tests 51

4.8 Effect size (Eta- Square) 51

4.9 Results of Ecological Risk Index Assessment of Heavy Metals in Soil 53

CHAPTER FIVE

CONCLUSION AND RECOMMENDATION

5.0 Conclusion and Recommendation 56

5.1 Conclusion 56

5.2 Recommendation 56

5.3 Contribution of the research work to knowledge 57

REFERENCES 58

Appendix 80

LIST OF TABLES

Table 1 Pre-industrial reference level (μg/g) and Toxic- Response Factor by Håkanson 35

Table 2 Physiochemical Properties of Soil samples from Investigated mechanic villages 38

Table 3 Heavy metal concentration in soils (mg/kg) in investigated mechanic villages 41

Table 4 Pearson’s Correlation Coefficient of Heavy Metals in Apo Mechanic village 46

Table 5 Pearson’s Correlation Coefficient of Heavy Metals in Kugbo Mechanic village 47

Table 6 Pearson’s Correlation Coefficient of Heavy Metals in Zuba Mechanic village 48

Table 7 Values and classes of contamination factor and degree of contamination of soil samples from studied sites 53

Table 8 Ecological Risk Factor, Potential Ecological Risk Index and Pollution Classes of Soil in the Studied Sites 55

Table 9 Levels of Fe (mg/Kg) in different sub–layers of the soil in the three major mechanic villages in Abuja 90

Table 10 Levels of Zn (mg/Kg) in different sub–layers of the soil in the three major mechanic villages in Abuja 91

Table 11 Levels of Cu (mg/Kg) in different sub–layers of the soil in the three major mechanic villages in Abuja 92

Table 12 Levels of Ni (mg/Kg) in different sub–layers of the soil in the three major mechanic villages in Abuja 93

Table 13 Levels of Pb (mg/Kg) in different sub–layers of the soil in the three major mechanic villages in Abuja 94

Table 14 Levels of Cr (mg/Kg) in different sub–layers of the soil in the three major mechanic villages in Abuja 95

Table 15 Levels of Cd (mg/Kg) in different sub–layers of the soil in the three major mechanic villages in Abuja 96

LIST OF FIGURES

Fig: 1 Map of sampling sites of major Mechanic Villages in Abuja 21

Fig: 2 Hypothetical Models of Sources, Wastes and Pollutants from Activities of Auto Mechanics in Mechanic Villages 26

Fig 3: Calibration curve for Lead 80

Fig 4: Calibration curve for Cadmium 80

Fig 5: Calibration curve for Nickel 81

Fig 6: Calibration curve for Copper 81

Fig 7: Calibration curve for Zinc 82

Fig 8: Calibration curve for Chromium 82

Fig 9: Graph showing comparison of DPR Background value of (Fe) with soil samples from the three investigated Mechanic Villages in Abuja 83

Fig 10: Graph showing comparison of DPR Background value of (Zn) with soil samples from the three investigated Mechanic Villages in Abuja 84

Fig 11: Graph showing comparison of DPR Background value of (Cu) with soil samples from the three investigated Mechanic Villages in Abuja 85

Fig 12: Graph showing comparison of DPR Background value of (Ni) with soil samples from the three investigated Mechanic Villages in Abuja 86

Fig 13: Graph showing comparison of DPR Background value of (Pb) with soil samples from the three Mechanic Villages in Abuja 87

Fig 14: Graph showing comparison of DPR Background value of (Cr) with soil samples from the three investigated Mechanic Villages in Abuja. 88

Fig 15: Graph showing comparison of DPR Background value of (Cd) with soil samples from the three investigated Mechanic Villages in Abuja. 89

ABSTRACT

This research work is aimed at assessment of levels of heavy metal in soils and their environmental effects from three Mechanic Villages in Abuja namely; Apo, Kugbo and Zuba. To achieve the set target, soil samples were collected from five sampling points in each of the mechanic villages to a depth range of 0 - 15 cm with a stainless hand dug auger. A control sample was also taken from a point approximately 100 km where neither industrial nor commercial activities take place. Results of analyses of physicochemical properties: pH, % porosity, electrical conductivity, particle size distribution, sulphate, chloride, nitrate and microbial contents of the soil samples indicate that most of the values exceeded those of control values. Levels of heavy metals in soils were determined using Automated Atomic Absorption Spectrophotometer (AAS). Results of the analysis revealed a decreasing in trend of heavy metal contents (mg/kg) in soil in the three studied automobile repair sites as follows; Apo site: Cu (7668) > Zn (5360) > Cr (1174) > Fe (467) > Pb (333) > Ni > (196) > Cd (10.6); Kugbo site: Zn (1587) > Cu (1043) > Cr (783) > Ni (234) > Fe (217) > Pb (170) > Cd (9.47) and Zuba site: Zn (1190) > Cr (767) > Cu (512) > Fe (279) > Pb (250) > Ni (127) > Cd (10.4). Comparative analysis reveals that values of the studied heavy metals exceeded those of control and background values of some international regulatory bodies. Pearson's correlation analyses reveal that some of the heavy metals had very strong correlations with one another and with some of the physicochemical properties of the soil. These indicate that the studied heavy metals have the same origin, mutual dependence and identical behaviors. Multiple ecological risk indices models explored in the study showed various ecological risk level associated with heavy metal contamination of soils from the investigated sites with classes ranging from low to very high ecological risks. This could be traceable to anthropogenic activities like indiscriminate discharge of heavy metal containing waste in soil and poor waste management practice in the mechanic villages. This calls for urgent measure in curtailing indiscriminate waste discharge and the introduction of environmental friendly waste management in the mechanic villages so as to avert epidemics and environmental degradation due to heavy metal pollution.

Keywords: Atomic absorption spectrophotometer (AAS); heavy metals; soil; mechanic villages; physicochemical properties; pollution indices, statistical analysis.

sCHAPTER ONE

1.0 Introduction

1.1 Background Information

Environmental pollution is an unfavorable alteration of the environment due to indiscriminate disposal of waste usually from anthropogenic or geogenic activities. Pollution of environment by heavy metal is a serious problem due to the adverse effects such contamination have on human begins and the environment. Soil which serve as repositories for dumping of anthropogenic waste undergoes certain biochemical processes which mobilize these chemical substances, pollute water supplies and impact food chains, thereby causing great harm to humans (Abechi et al., 2010). Uncontrolled waste from industrial and human activities have contributed immensely in raising the level of heavy metal concentration in soil as when compared with ones from geogenic processes (Basaram et al., 2010). Huffon, M and Simon, C (1986) reported that the environmental pollution associated with heavy metals at even low level could result to long-term cumulative health effects and is among the leading health concerns all over the world.

Heavy metals refer to metallic chemical elements that have relative high density and are toxic or poisonous at low concentration. They are natural components of the earth's crust and cannot be degraded nor destroyed completely. Some heavy metals like copper, calcium, selenium, manganese, iron, zinc are all important for metabolism activities of the human body. Some researchers observed that that high concentration of heavy metals can lead to poisoning of the ecosystem (Udosoro et al., 2010; Skorbilowicz et al., 2018). Some examples of heavy metals are lead, cadmium, mercury, chromium, cobalt, nickel, manganese, copper, arsenic, selenium, iron, zinc etc. The major concern of heavy ersist in the soil coupled with their ability to accumulate, destroy soil organisms as well as move along the food chain. Recent study reported that one of the major sources of increased heavy metal concentration in the ecosystem in Nigeria is from the activities of automobile mechanic workshops (Adewale et al., 2010).

However, it is a common practice in Nigeria especially in the cities and towns where large areas of lands are mapped out and allocated for auto mechanic activities with branded name “Mechanic Villages”. In these mechanic villages, various forms of vehicle repairs are performed and there are some environmental threats associated with such practices. Some of the activities performed by these auto mechanics in the mechanic villages that lead to environmental pollution are; welding and soldering, battery charging, automobile body work, spraying of paints, spilling of oil, greases, petrol and hydraulic fluids, diesel and lubricating oils, gear box recycling, panel beating of automobile bodies, piecing of faulty vehicles into spare parts etc. Wastes from these activities include: metal scraps, worn-out parts, spent lubricants and hydraulic fluids, used electrolytes, stripped oil sludge, discarded cans, packaging materials etc (Pam et al., 2013; Adelakan et al., 2011).

Furthermore, certain chemicals like chlorofluorocarbon (CFC) a greenhouse gas usually used as air conditioner gases are allowed to escape in large amount in the atmosphere during maintenance of vehicles air conditioner. This green house gas encourages climate change, depletion of the ozone layer and global warming (Bassuer, G., 1987). Also, fumes from exhaust pipes, spent solvents and chemicals may also lead to the formation of ground layer ozone/smog formation, global warming and climatic change. Further reactions between these chemicals and rain could result in the formation of acid rain which kills crops, corrodes roofing sheets and possess health threats to humans (Wikipedia 2011).

As the population of human on earth increases especially in the developing countries of the world, the quest for importation of fairly used vehicles also increases. As such, urban areas where the mechanic village concepts were not in practice will react to the increased supply with the establishment of more mechanic villages. This may amount to greater soil and environmental pollution especially if the present poor waste management and indiscriminate discharges of auto mechanic wastes are allowed to continue (Nwachukwu et al., 2010). Hence, these activities should be checkmated by relevant authorities with a view to encouraging more environmental friendly practice in other to curtail the level of waste discharge emanating from various mechanic villages.

1.2 Problem Statement

The problem of environmental pollution which could be traced back to anthropogenic and geogenic activities especially pollutants from automobile workshops has been a serious environmental problem to the government, Environmental Protection Agency (EPA), National Environmental Regulatory and Safety Agency and other stakeholders. In recent times, efforts have been made in the developed countries to curtail the volume of waste and the rate of environmental pollution resulting from indiscriminate release of heavy metal and other industrial wastes into the environment. But the case is different in Nigeria and some other third world countries because of indiscriminate establishment of the automobile workshops, unguided discharge of wastes materials as well as ignorant of the health threat these wastes posses to the environment and its habitants.

1.3 Objectives of the Research Work

The primary aim of this study is to assess the level of heavy metal contents in soils in three major mechanic villages in Abuja (Nwoko et al., 2018) as well as its environmental effects. The following objectives were set in order achieve the set target.

1. Assess levels of some heavy metals in investigated soils together with their environmental effects.
2. Evaluate the extent of environmental pollution associated with observed heavy metal contamination of soil in studied mechanic villages using ecological risk models.
3. Provide a data base on heavy metal pollution from major automobile workshop in Abuja. The data collected would give an insight on the pollution level of heavy metals in soil which would further help in the designing of remediation process.

1.4 Justification of the study

The problem of climate change, global warming, ozone layer depletion and other environmental challenges has been a major concern due to the adverse effects they have on the environment. Heavy metal pollution is known to be a major contributing factor to the pollution of the environment and their origin could be traced from geogenic and anthropogenic activities. Thus, it is important to assess the concentration of heavy metal in soil samples from selected mechanic villages together with their environmental effects. Hence the study serves as a veritable tool that will assist in the following ways:

1. Assess the level of heavy metals contents in the major mechanic villages in Abuja and possible health risks associated with such contamination when compared to established international permissive limit.
2. Provide information on the level of pollution attributed to heavy metal in soils in the affected mechanic villages as well as generate data which could be used in modeling and simulation.
3. Identify gaps in knowledge and opportunities for further works especially in designing tools for remediation processes of polluted areas.

1.5 Scope of the Study

This research work is targeted at evaluating various levels of heavy metal in soil drawn from three major mechanic villages in Abuja the Federal capital territory as well as assessing their environmental effects. To achieve this task, soil samples from these mechanic villages and their controls will be randomly sampled and a total of Three Hundred and Sixty (360) analyses will be done on the eighteen soil samples collected. The result obtained will be statistically analyzed to ascertain their degree of contamination.

CHAPTER TWO

2.0 Literature Review

Several works have been conducted by some activities in auto mechanic workshops and their environmental effects (Onweremadu et al., 2007; Iwegbue et al., 2007; Liu, et al., 2007). A researcher observed that activities of artisans in auto repair workshops are capable of producing pollutants which can be used to determine the growth of microorganisms of the environment surrounding where they operate (Wang et al., 1985). Ipeaiyea et al., (2005) investigated heavy metal contamination at the vicinities of reclaimed auto mechanic workshops in Iwo, Nigeria. These researchers observed that lead was the dominant contaminant and was quite mobile. Heavy metals are serious pollutants to the environment due to their toxicity, non bio-degradable nature and bioaccumulation properties (Yuan, et al., 2004; Nwuche et al., 2008 and Mohiuddin et al., 2010).

Recent research works reveals that activities of artisans in mechanic villages have contributed immensely in increasing the rate of heavy metal load in the environment in Nigeria (Olayiwola, O.A, 2011; Nwachukwu et al., 2010; Ipediyeda et al., 2008; Adewoyin et al., 2013). Some of the wastes materials produced in mechanic villages during the course of vehicle repairs which contributes towards heavy metal pollution in soil include: electroplating, indiscriminate discharge of used car batteries and electrolytes, panel beating, wiring of cars, discharge of condemned petroleum products, engine and gear box recycling, welding, fabrication and soldering, combustion process, scrapping and painting etc. Reports from previous studies also showed that some heavy metals are essential to body metabolism at low concentration but can be toxic to the same body at high concentration. They include metals like copper, selenium, manganese, zinc and iron (Ouyang et al., 2002). Non-essential heavy metals like cadmium, lead, mercury, chromium, arsenic, arsenic etc are also highly toxic even at low concentrations (Ouyang et al., 2002).

Recent reports also reveal that absorption and accumulation of heavy metals in human can lead to serious health problems like liver and kidney damage neurotoxic effects in children (Nwoko et al., 2018) bone and fractures damage, destruction of nerve tissues, circulatory, nerve tissues, heart and reproductive system (Ayangbero et al., 2017; Gupta et al., 2017; Malik et al., 2016; Pam et al., 2013; Jarup, L., 2003).

2.1 Definition of Heavy Metal

Heavy metals are elements that have relatively high densities and are poisonous even at low concentration. Heavy metal originated with the reference to the adverse effect of cadmium, mercury and lead which are denser than iron (Kumar et al., 2013; Sengupta et al., 2002; Dufus, J.H 2002). They noted some criteria for the description of a heavy metal as its density, atomic weight, atomic number or position on the periodic table. The term “heavy metal” has been in use since 1817 when Gmelin grouped known meals into three groups namely; non-metals, light metals and heavy metals with the light metal of density range (0.860 – 5.00) gm/cm^3 and that of heavy metal 5.308gm/cm^3 – 22.00gm/cm^3 (Habashi et al., 2009).

2.2 Sources of Heavy Metal

Researchers like Zhang et al., 2011; Khan et al., 2008; Krewski et al., 2007; Yokel et al., 2008 all reported that heavy metal in soil could be from atmospheric deposition, sewage, irrigation, improper stacking of industrial solid waste, mining activities, pesticides and fertilizer applications, sludge or municipal compost, emission from municipal waste incinerators, smelting industries, spillage of petroleum and petrochemicals products, coal combustion residues, paints productions and applications.

2.2.1 Atmosphere to soil pathway

Presence of heavy metals in the atmosphere are traceable to gases and dust particles usually produced by energy, transport, metallurgical sector as well as in the production of construction materials. With the exception of mercury, heavy metals are introduced into the atmosphere inform of aerosol and are subsequently deposited in the soil through natural sedimentation and precipitation. Pollution in a downtown central Sweden lead had been reported be have emanated from urban industrial copper plant, sulphuric plant and paint factory in and around the area (Lin et al., 1998). Wind as an agent of transportation helps in circulation and deposition of heavy metals from industrial waste heap to surrounding areas.

2.2.2 Solid wastes to soil pathways

Some solid wastes have complex composition of which mining and industrial solid waste contamination is the most serious. When these wastes pill up, heavy metals contents in them can move easily due to facilitation of sunlight and rain. At such, they deposit on soil and are also leached to the surrounding water.

2.2.3 Agricultural supplies to soil pathway

Fertilizers, mulch, pesticide and herbicides are very important agricultural inputs for agricultural production (Zhang et al., 2007). However, long-term excessive applications of these farm inputs have led to contamination of soil by heavy metals. The vast majority of pesticides contain organic compounds with only a few containing inorganic. In a research conducted on heavy metal contamination of agricultural soil and counter measures in Japan reported that some pesticides contain heavy metals like Hg, Ag, Cu, Zn (Arao et al., 2010). Contents of heavy metals in fertilizer are generally phosphate, potash, nitrogen (Arao et al., 2010). Boya et al., (2010) observed an increase in the available content of cadmium in soils due to application of large amount of phosphate and compound fertilizers in soil. This has also increased metal uptake of cadmium by plants. In recent years, mulch has been promoted and used in large areas, which resulted in wide pollution of soils. This is as a result of heat stabilizers which contain calcium and lead usually added in the course of production of mulch. This also increases the level of heavy metal contamination of soils (Satarug et al., 2003).

2.2.4 Sewage to soil pathway

Wastewater is divided into groups namely; several categories, namely: sanitary sewage, chemical wastewater, industrial mining wastewater and urban mining mixed sewage. Heavy metals are brought to the soil by irrigative sewage and are fixed in the soil in different ways resulting in the accumulation of heavy metals in soil. Sewage irrigation is a feasible way to solve the problem of crop irrigation in the arid area. It is important to pay much attention to heavy metal contamination caused by sewage irrigation because of its environmental effects. Thus, quality of irrigative sewage must be strictly controlled by way of treatment to fall within the national quality standard set for irrigation water.

2.3 Characteristics of Heavy Metal Contamination in Soil

2.3.1 Wide distribution

With the development of economy and society, heavy metal contamination has become increasingly common in the world. In the world's ten top environmental events, two events have been related to heavy metal contamination (Yang et al., 2009).

2.3.2 Complex heavy metal contamination

In the past, soil contaminations were mainly caused by single heavy metal. However, in recent years more cases of soil contamination are found to have been caused by varieties of heavy metals (Zhou et al., 1995). The complex contaminations caused by varieties of these heavy metals always amplify the contamination by heavy metals separately. This was clearly shown in a report on study of the influence of combined pollution of heavy metals on soil respiration (Qin et al, 2008).

2.3.3 Irreversibility and remediation problem

If air and water are polluted, the pollution problem can be reversed certainly by dilution and self-purification after switching off the sources of pollution. It is difficult to use dilution or self-purification techniques to eliminate heavy metal contamination in soil. Soil contamination by heavy metal can take up to one or two hundred years to be naturally remediated (Wood et al., 1974).

2.3.4 Strong latency

Heavy metal contamination is always difficult to be noticed due to its colour. It does not explicitly destroy the environment in a short period. Nevertheless, when its concentration or value exceeds that of the environmental tolerance, heavy metals in soil may be activated and this will cause serious ecological damages. Thus, heavy metal contamination is usually a chemical time bomb (Wood et al., 1974).

2.4 Heavy Metal Toxicity

Heavy metal toxicity or metal poisoning is a term used to explain the toxic effect of some heavy metals in different forms. Some metals are said to be toxic when they form certain toxic soluble compounds. A report by “A Metal Prime (2012)” has it that certain metals have no biological role. In the case of lead and cadmium any measurable amount may have negative health effects of human and ecosystem (CDC 2012).

Interestingly not all heavy metals are toxic; some are essential to human like cobalt, copper, iron, calcium, manganese, molybdenum, selenium and zinc (Goyer et al., 2001). While Manganese is cited as nutritionally essential metal, evidence is limited to its role in non-human animal species. According to a report by NAS/IOM (2003) manganese is regarded as essential for human nutrition because it is an activator and constituent of many enzymes present in humans. Toxic metals sometimes initiate the action of an essential element in the body, interfering with the metabolic process to cause illness. Toxic metals include cadmium, lead, Arsenic, mercury and radioactive metals of which the later have both radiological and chemical toxicity. Metals in an oxidation state abnormal to the body may also become toxic to the same system.

2.5 Effects of Heavy Metals

2.5.1 Effects of Heavy Metals on Soil Microorganism

Microbial and enzymatic activities in soil can sensitively reflect the quality of the soil. Aceves et al., (1999) and Lee et al., (1996) reported that an important indicator for the determination of degree of soil contamination is the microbial biomass of the soil. Presence of heavy metals in soil can greatly inhibit the activities of these soil microbes. Kandeler et al., (1997) also reported that soils contaminated by heavy metals such as copper, zinc, lead and other heavy metals were greatly inhibited. The soil's microbial biomass near the mine was significantly lower than that far away from the mine and the effects of different concentrations of heavy metals on soil microbial biomass were different.

Chander et al., (1995) studied the effect of different concentration of heavy metals on soil microbial biomass and found out that concentration of heavy metals in the soil were three times above the environmental standard established by the European Union which could also inhibit microbial biomass. He also observed that activities of almost all enzymes in the soil were significantly reduced by 10 to 50 times as concentration of heavy metals in the soil increases Chander et al., (1995). Microbial growth in soil can be greatly simulated at low concentration of heavy metal and are also reduced at high concentration (Fliepbach et al., 1994).

2.5.2 Effects of Heavy Metals on Plants

Low concentration of heavy metals in soil may not have much adverse effects on growth of plants grown on it. However, the plant could die if the concentrations of heavy metals in soil are high, such that the content enriched by these plants exceeds those of tolerance threshold. A study in Florida observed that if the copper content in soil was more than 50 mg/kg, it would affect seeds of citrus crops. Also, if the level of copper content is up to 200 mg/kg, it would affect wheat (Zhang et al., 1989).

Research has also found out that growth of cabbage and bean seedling under cadmium concentration of 30 mol/L was inhibited. The root length decreased and the plant height and leaf area dropped (Qin et al., 1994; Acar et al., 1993). Cadmium may also interfere with crop photosynthesis and protein synthesis, and may cause membrane damage. Research findings showed that irrespective of the origin of the metals in soil, excessive levels of many metals can result in soil quality degradation, crop yield reduction, poor quality of agricultural products, posing significant hazards to human, animals and ecosystem at large (Long et al., 2002).

2.5.3 Effects of Heavy Metals on Humans

Research has reported that skin absorption and inhalation of heavy metals contaminated air are sure way these heavy metals in urban soils may go into the human body (Chao et al., 2014). This cause direct damage to the health of human beings especially children. They also affect the urban environmental quality and damage human health indirectly through polluting of food, water and atmosphere. Heavy metals have also been observed to bind to vital cellular components such as structural protein (Zhong et al., 2017), enzymes, nucleic acids etc and can also interfere with their function (Landis et al., 2000). Recent research observed that symptoms and effects of these heavy metals may vary according to the metal or metal-compound, and the doses involved (Nielen et al., 2008).

2.6. Heavy Metal Poisoning

2.6.1. Cadmium Poisoning

Cadmium is a very toxic metal and can be found in certain amount in soils, rocks, coal, minerals, fertilizers and other chemical products. Cadmium is mainly used in the production of batteries, pigments, metal coating and plastics. Cadmium is bio persistent and once absorbed by an organism remains resident for many years. Cadmium is also found in some industrial paints and may represent a hazard when sprayed. Operations involving the removal of Cadmium paint by scrapping or blasting usually by panel beaters and car painters helps in introducing the metal to the soil. This also poses serious health risk to humans.

2.6.2 Chromium poisoning

Chromium is mainly found in rocks, animals, plants and soil. Chromium compounds bind to soil and are more likely to migrate to ground water where they are very persistent in sediment in water. Chromium is used in metal alloys and pigments for paints, cement, paper, rubber etc. Toxicity and carcinogenic properties of Chromium VI have been known since the late 19th century (Barceloux et al., 1999). Low level of exposure to chromium can irritate the skin and cause ulceration while long term exposure results in destruction of human organs. According to a report by National Research Council (1974) similar cases were reported in 1963, where over 60 automobile factory workers in England who had been wet-sanding chromate-based primer paint that had been applied to car bodies showed various degrees of chromium infection.

2.6.3 Lead Poisoning

Lead can be exposed to the environment as a result of anthropogenic activities like mining, burning of fossil fuel, manufacturing of batteries, ammunitions, pipes, x-ray shielding devices, leaded gasoline, paints, pipe solder etc. Different scientific reports from ATSDR (1999) and WHO-IPCS (2002) have it that in humans, exposure to lead can result in a wide range of biological effect. Lead has been observed by scientist to produces tumors in experimental animals. It also affect the development of the nervous system and other organs in human body most especially children. Thus, causing permanent learning and behaviour disorders. Symptoms of lead poisoning include; abdominal pains, confusion, headache, anemia, irritability, seizures, coma and even death. In 2013, the World Health Organization (WHO) estimated that lead poisoning resulted in 143,000 deaths and contributed to 600,000 new cases of children with intellectual disabilities (WHO, 2013).

2.6.4 Mercury poisoning

Mercury poisoning is a disease caused by exposure to mercury or its compounds. Mercury as a heavy metal occurs in several forms and can produce toxic effects in high doses. Research work published by Zhao et al., (2006) has it that sixty workers died from the gliding of main dome during the construction of Saint Isaac's Cathedral as a result of exposure to mercury through the use of gold amalgam an alloy of mercury. They also reported that the first emperor of unified China, Qin Shi Huang died of ingesting mercury pills in quest of giving him external life (Zhao et al., (2006). More than 600 people had also died due to mercury exposure in what became known as Minamata disaster (Zhao et al., (2006). In twenty two documented cases as reported by Davidson et al., (2004) it was noted that pregnant women who consumed contaminated fish showed mild or no symptoms but gave birth to infants with severe developmental deformities. Some other toxic effects of mercury include; damage to the brain, kidney and lungs, vision, hearing or memory loss.

2.6.5 Arsenic Poisoning

Arsenic occurs naturally in the environment in small quantity and can be released in large quantities to the environment through geogenic activities like volcanic eruption, erosion of rocks, forest fires and anthropogenic activities. Arsenic is also found in paints, dyes, drugs, soaps and semi-conductors, pesticides, copper smelting, mining, coal burning etc. Arsenic is odourless, tasteless but can cause cancer of the skin, lungs, liver and bladder. A study conducted by Ravens C., (2007) found out that over 137 million people in more than 70 countries are probably affected by Arsenic poisoning from drinking water. Ingestion of high level of arsenic can possibly result to death while long-term low level exposure can cause darkening of the skin and the appearance of small “Corns” or “Warts” on the plants. Norman, N., (2014) also noticed that ground water contaminated by Arsenic as at 2014 is still poisoning millions of people in Asia continent till today.

2.6.6 Silver Poisoning

Silver usually combines with other elements like sulphide, chloride and nitrate. Silver is used in making jewelries, silverware, electronic equipment, dental fillings, electrical contacts, conductors, brazing alloys, solders and mirrors. James et al., (2006) observed that inappropriate exposure to chemical compounds of silver element or silver dust leads to disease called *“Argyrosis”* with symptoms like turning of skins of affected person to blue or bluish grey. Local argyria shows in limited regions of the body like patches of skin, parts of the mucous membrane or the conjunctiva.

2.6.7 Zinc poisoning

Zinc is one of the essential minerals needed for a healthy body, yet it has its limitations and side effects. Zinc can be harmful and toxic when consumed in excess and such toxicity level has been seen to occur at ingestion of greater than 225mg. Also excessive absorption of zinc can suppress copper and iron absorption by the body (Fosmire et al., 1990; Rout et al., 2003; Brita et al., (2006) in their separate studies observed and reported that zinc ion in solution is highly toxic to bacteria, plants, invertebrates and even in vertebrates fishes.

Zinc occurs naturally in rocks, soils, plants and animals and it can enter into the environment through atmospheric deposition from any of the processes below:

- The application of sewage or sludge to land
- Mining activities or processes
- Burning of coal and other fossil fuels

Zinc ion is held by cation exchange on soil clay minerals and becomes more mobile and bio available under acidic soil condition (Ross et al., 1994). Interestingly, under acidic condition, zinc can be leached from soil in soluble organic complexes.

2.6.8 Copper poisoning

Copper occurs naturally in rocks, soil, plants and animals and sometimes in sulphide mineralization. Copper can enter the environment

- Incineration of heavy metal containing waste
- Burning of wood and fossil fuels.
- In atmospheric deposition from mining, metal smelting and metal processing industries

Exposure to high dose of copper can cause anemia, liver and kidney damage, stomach and intestinal irritation. Copper poisoning can occur from eating of foods cooked in uncoated cookware or from drinking water that has been exposed to copper pipes or additives designed in pipes to control algal growth.

2.7 Bioaccumulation of Heavy Metals

Bioaccumulation is the process by which organism accumulate substances or chemicals in their system. There are some plants that can absorb heavy metals easily from the surrounding soils. These plants are known as hyper accumulators. When these crops are harvested from heavy metal contaminated areas for human use, exposure to certain harmful levels of heavy metals occurs. Metal uptake by plants is a function of pH of the soil. Thus, the higher the acidity, the more soluble and mobile the metals become and vice versa. Changes in dissolved metal concentration and species greatly influenced metal uptake by plants. Plants uptake was primarily related to the concentrations of metals in the soil solution rather than total metal concentration.

However, several studies have shown that the characteristics of heavy metal contamination in urban soil and agricultural soils are different (Babula et al., 2008). Heavy metals in urban soils like that of mechanic villages, parks, roads sides and industrial sites may go into the body directly through digestion, skin contact, inhalation etc. Heavy metals in agricultural soil are absorbed and accumulated by crops, and will find their way into the body when human beings consume these crops or animals that had fed on these crops. Ingesting heavy metals through the soil-crop system is a major way of damaging human health (Aeliona et al., 2008).

2.8 Review of Analytical Method

In analytical chemistry, several techniques are implored for the determination of various concentrations of elements in a sample. Some of these techniques include: Atomic absorption spectroscopy (AAS), X-ray fluorescence (XRF), Neutron Activation Analysis (NAA) etc.

2.8.1 Atomic Absorption Spectrophotometer

This is an instrument used in the quantitative determination of chemical elements using the absorption of optical radiation (light) by free atoms in the gaseous state. Atomic absorption spectrophotometer (AAS) can be used in the determination of over seventy elements in solution, soil, sediment and water samples. The technique is used in pharmacology, biophysics and toxicology research. Some of the uses of AAS machine in modern research work are as follows;

- Water analysis: Determination of metal contents in water samples
- Clinical analysis: Analyses of metals contents in biological fluids and tissues such as whole blood, plasma, urine, saliva, brain tissue, liver, semen etc
- Pharmaceuticals: Determination of level of catalyst remaining in final products.

The technique makes use of absorption spectrometry to assess the concentration of an analyte in a sample. It requires standards with known analyte concentration to be used to establish a relationship between the measured absorbance and the analyte concentration. This technique relies on Beer- Lambert law.

2.8.2 X-Ray Fluorescence

X-ray fluorescence is the emission of characteristics “Secondary” (or fluorescent) x-ray from a material that has been excited by bombarding with high energy x-rays or gamma rays. The phenomenon is widely used for elemental and chemical analysis, especially in the investigation of metals, glass, ceramics and building materials and for research in geochemistry, forensic science and archaeology. The techniques are based on ionization of atoms as a result of bombardment of certain rays (x-ray or gamma ray) to the material. This process results in the ejection of one or more election(s) from the atom. The removal of an electron in such way makes the electronic structure of an atom unstable, and electrons in higher "fall" into the lower orbital to fill the hole left behind. In falling, energy is released in the form of a photon, the energy of which is equal to the energy difference of the two orbital involved. Thus, the material emits radiation which has energy characteristics of the atoms present. In principle, the lightest element that can be analyzed is beryllium but due to instrumental limitations and low x-ray yields for the light elements, it is often difficult to quantify element lighter than sodium, unless background corrections and very comprehensive inter- element corrections are made.

CHAPTER THREE

3.0 Materials and Method

3.1 Description of Study Area

Abuja located in the Central Region of Nigeria on latitude 9°40^{1}N and 9°29^{1}E and it falls within the Guinean – Savannah Mosaic Zone in West Africa sub- region (Ekeocha et al., 2017, Nwoko et al., 2018). Abuja has a land mass of 713 km^{2} and a population of over 776,298 according to 2006 census population count (Abuja – Wikipedia 2015). Abuja is bordered with five states namely: Benue, Kaduna, Kogi, Nassarawa and Niger States. Three mechanic villages were selected for the study and they were Apo in Gudu district, Zuba in Madalla and Kugbo in Kugo district Nwoko et al., 2018).

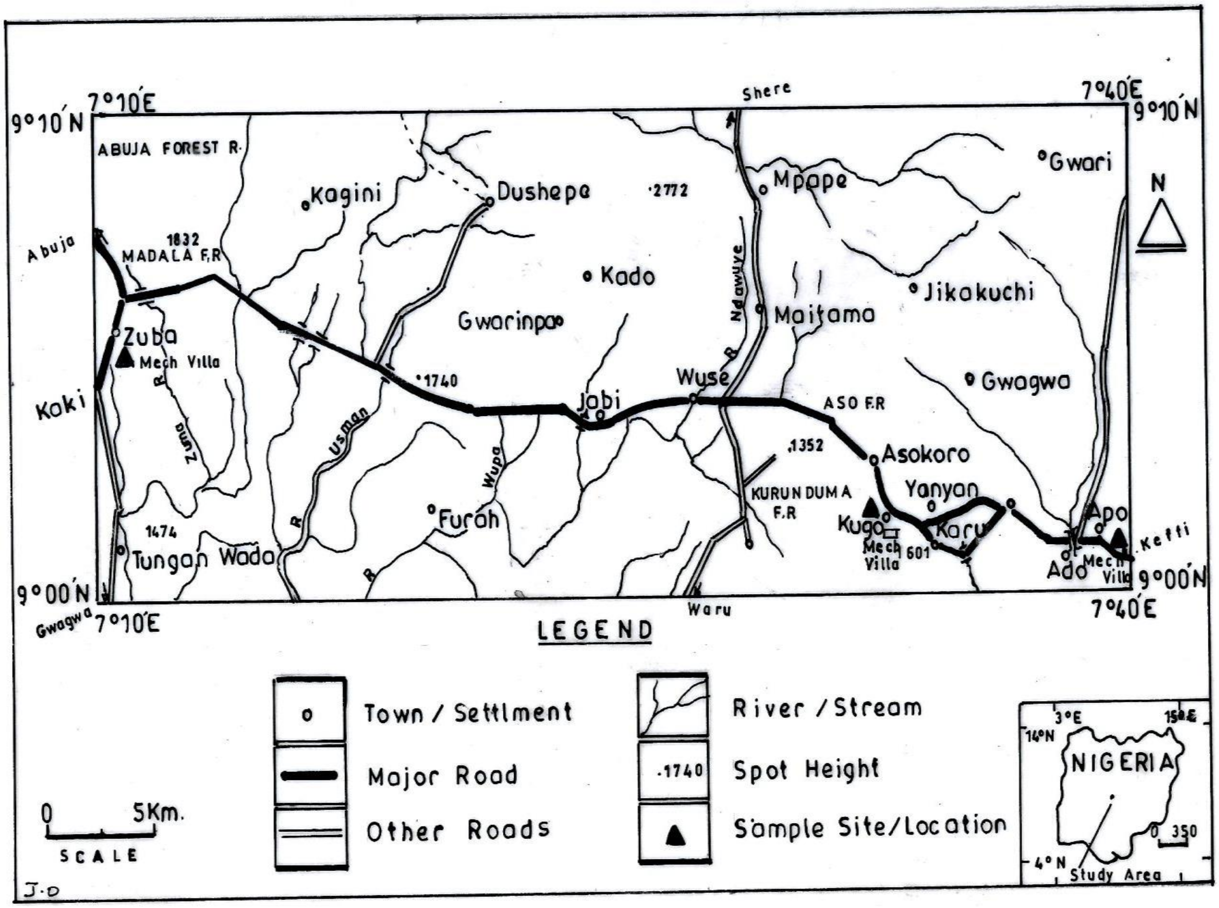


Fig. 1 Map of sampling sites of major Mechanic Villages in Abuja (Ekeocha et al., 2017, Nwoko et al., 2018)

3.2. Methodology

3.2.1. Preparation of Stock Solutions

1. Lead stock solution was prepared by dissolving 1.5985 g of $Pb(NO_3)_2$ in 50 ml of distilled deionized water and made up to1 litre giving 1000 mgL^{-1} lead solution.

2. Cadmium stock solution was prepared by dissolving 2.7442 g $Cd (NO_3)_2.4H_2O$ in 50 ml of distilled deionized water and made up to 1 litre giving 1000 mgL^{-1} cadmium solution.

3. Nickel stock solution was prepared by dissolving 4.9434 g $Ni(NO_3)_2.6H_2O$ in 50 ml of distilled deionized water and making up to 1 litre giving 1000 mgL^{-1} nickel solution.

4. Zinc stock solution was prepared by dissolving 0.1g Zinc Powder in 20ml 1:1 HCl and making up to 1 litre with distilled deionized water giving 1000 mgL^{-1} zinc solution.

5. Copper stock solution was prepared by dissolving 0.1 g copper metal in 15 ml 1:1 Concentrated HNO_3 and making up to 1 litre with distilled deionized water giving 1000 mgL^{-1} copper solution.

6. Chromium stock solution was prepared by dissolving 2.8289 g $K_2Cr_2O_7$ in 50 ml of distilled deionized water and making up to 1 liter giving 1000 mgL^{-1} chromium solution.

3.2.2. Standard Working Solution

Using serial dilution formula:

$$C_{\text{stock solution}} \times V_{\text{stock solution required}} = C_{\text{standard working solution}} \times V_{\text{standard working solution}} \quad - \quad - \quad \text{equation (1)}$$

$$V_{\text{stock solution required}} = \frac{C_{\text{standard working solution}} \times V_{\text{Vstandard working solution}}}{C_{\text{stock solution}}} \quad - \quad - \quad - \quad - \quad \text{equation (2)}$$

Standard working solutions of various concentrations were prepared from 1000 mgL^{-1} of each metal stock solution using serial dilution approach. All solutions were prepared in deionized water.

3.3 Sample Collection and Treatment

3.3.1 Sample Collection

According to a researcher, surface soils are the locus of inputs of heavy metals (Abechi et al., 2010). These heavy metals tend to accumulate on a relatively long term basis (Ogunmodede et al., 2015). These pollutants normally contaminate the upper layer of the soil at a depth range of 0 – 40 cm (Ogunmodede et al., 2015). This implies that high concentration of heavy metals could be at this depth if assessed (Ogunmodede et al., 2015), Krishma et al., 2007; Kakulu et al., 1993). Ten sampling points were initially mapped out in each of mechanic villages out of which five points where randomly selected. Soil samples were collected with a stainless hand auger at a depth of 0 -15 cm, enclosed in new polyethylene bags and were labeled accordingly. Control samples were also collected at an approximate distance of 100 km away from each of the mechanic villages where neither auto repairs non commercial activities were carried out. The samplings were done in November 2014, the ending of rainy season.

3.3.1 Sample Treatment

The three soil samples drawn from each depth were homogenized to make a composite sample of that point. In all a total of sixteen sample points were sampled with five points drawn from each of the mechanic villages investigated plus a control sample. The soil samples were enclosed in different clean dry polyethylene bags, labeled and transported to the laboratory for analysis. All the soil samples were air dried to prevent microbial degradation (Edgell K., 1998). They were further made stones and particles free, crushed in an acid pre-washed mortar and pestle and further sieved (Isioma et al., 2015) to $\leq 120\mu m$ with a laboratory test sieve (Endecott's limited, London, England. serial number 489479).

3.3.2. Sample Digestion

Complete digestion of the soil samples was carried out according to methods by (Edgell K., 1988; Kimbrough et al., 1989). 10 mL 1:1 HNO_3 were added to 1 g of each of the soil samples in separate beakers, mixed and covered with a watch glass. The mixtures were heated up in an oven at 95 $°C \pm 5$ °C without boiling and refluxed for 30 min until no brown fumes were seen. The samples were later heated for extra 2 hours and allowed to cool. Later 2 ml of water and 3 ml of 30% H_2O_2 were added, covered and warmed until effervescence subsides.

More so, 10 ml of concentrated H_2SO_4 were added to each sample and the beakers heated up until clear solutions were observed and fumes ceased. Later the digested materials were filtered by gravitation with whatman No.41 filter paper and the respective solutions made up to 100 ml in a volumetric flask with deionized water. (Nwachukwu et al., 2018, Kimbrough et al., 1989; Ogbonna et al., 2009; Chalem et al., 2008)

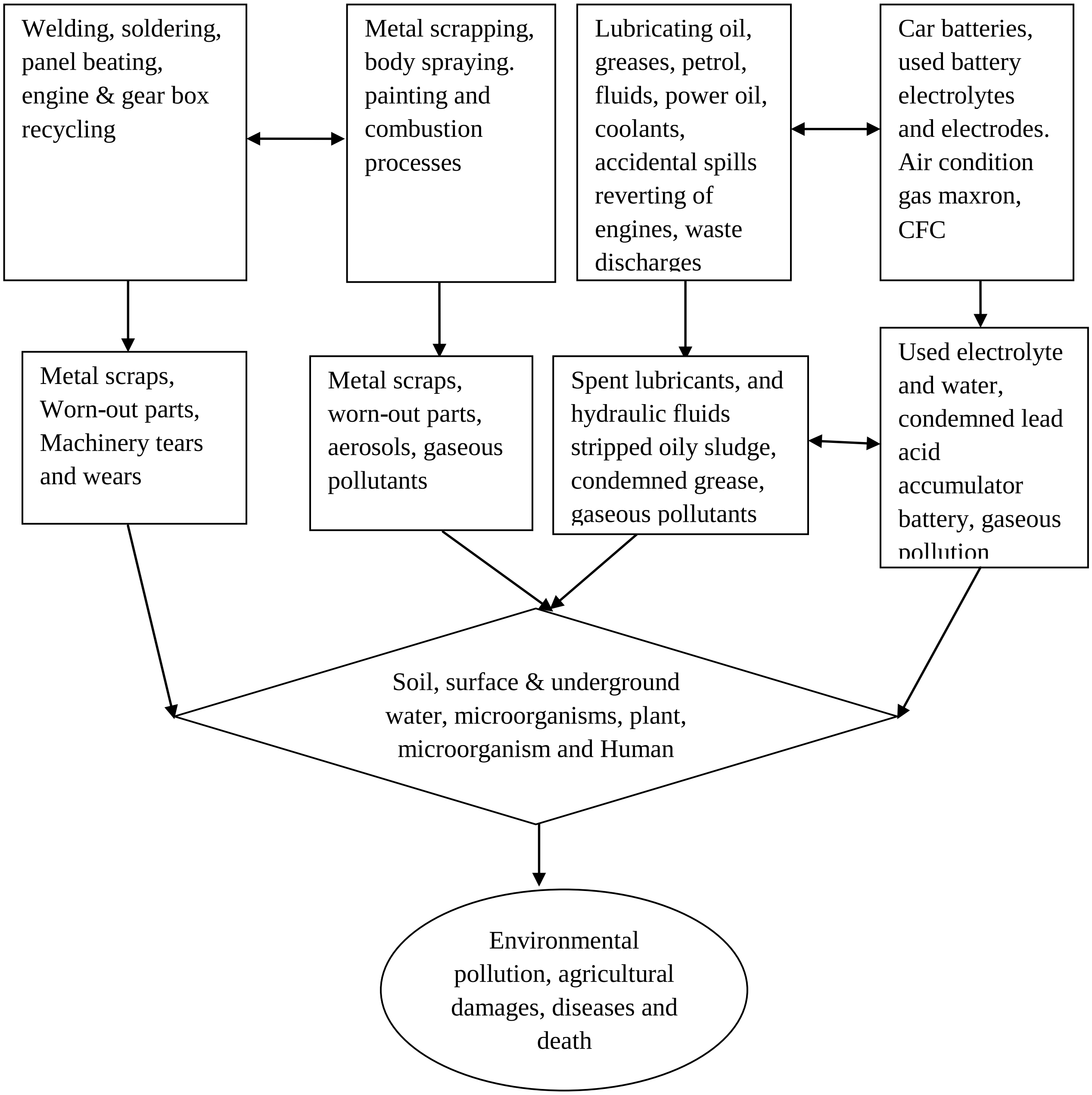
3.3.3 Calibration Curve

A calibration curve of absorbance against concentration for each heavy metal investigated was prepared for each heavy metal (Fe, Pb, Cd, Ni, Cu, Zn and Cr) as shown in appendices I-VIII which yielded good linearity. The calibration curves were used for the determination of heavy metal concentration in the samples (Eva et al., 2016). The actual concentration of various heavy metals in the sample was determined as (Eva et al., 2016);

$$\text{Amt. of metal in vol. of digested solution} = \frac{\text{vol. of digest solution x conc. of metal in sample solu from calib curve}}{1000} \quad - \quad \text{equation (3)}$$

$$\text{Amt. of metal } (\mu g g^{-1}) = \frac{\text{amount of metal in volume of digested solution}}{\text{weight of sample digested (g)}} \quad - \quad - \quad - \quad - \quad - \quad - \quad \text{equation (4)}$$

Figure 2 Hypothetical Models of Sources, Wastes and Pollutants from Activities of Auto Mechanics in Mechanic Villages



3.4 Physicochemical Analysis of Soil

3.4.1. pH Determination

The pH values were determined using pH/conductivity meters (Jenway model 430). Prior to analysis, pH meter was calibrated with standard buffer solution of pH 4, 7 and 9. 1g of investigated soil samples was weighed into 100 ml beaker and 10 ml of deionized water were added to the respective samples. The mixture were stirred several times and allowed to cool for about 30 min to allow sediments to settle. The electrode of the pH meter was inserted into the settled suspension and the pH of the sample measured. This procedure was repeated for all other samples (Chalem et al., 2008).

3.4.2. Determination of Specific Gravity

Mass of empty and dry pycometer was initially weighed. Exactly 125 g of sieved soil samples and the weight determined. Distilled water was then added up to half of the pycometer containing the soil and was allowed for 10 minutes. Entrapped air in the pycometer was removed by the application of a partial vacuum to the content for 10 minutes. After which the vacuum was stopped and carefully removed from the pycometer and later filled up with distilled water to the mark. The weight of pycometer and content was then determined. The pycometer was later was then emptied, cleaned, filled up to mark with distilled water, weighed and recorded (Estefan et al., 2013). Mathematically,

$$\text{Mathematically, specific gravity} = \frac{W_o}{W_{ot}\,(W_A - W_B)} \quad - \quad - \quad - \quad \text{equation (5)}$$

where $W_o = W_t$ of sample of oven - dry soil

$W_A = W_t$ of pycometer filled with water

$W_B = W_t$ of pycometer filled with water and soil

3.4.3. Determination of Bulk Density

Bulk density of the soil samples were determined by ratio of oven dryness of the soil to bulk volume of the soil using bulk density apparatus (Miller et al 2001). An ovenproof container was washed air dried and weighed on an electronic balance (W_1). The soils to be analyzed was carefully transferred into the dry container and further dried for 2 hours in an oven at 105 ^oC. The sample was brought out, allowed to cool, weighed and recorded. The volume of the soil was determined by measuring the height of the ring with a ruler in centimeter together with the diameter of the ring whose half gives the radius of the ring (NLWRA, 2001). Mathematically,

Ring volume (cm^3) = $3.142r^2$ . . . . . . equation (6)

Bulk density (g/cm^3) = Weight of dry soil (g)/ volume of soil (cm^3) . equation (7)

BD = Bulk density (g/cm^3)

W = Weight of oven-dry soil (g)

V = Volume of soil sample (cm^3)

3.4.4. Determination of True Density and Percentage Porosity

Percent pore space (PS) is the ratio of the volume of voids in a soil to the total volume (bulk volume) of the soil times 100. Texture and structure are the main factors governing the amount of PS in soil. The OM affects pore space indirectly by improving structure. If the aggregation of a particular soil is increased, the TPS increases, and the weight per unit volume or BD of the soil decreases. A medium textured mineral soil that is in good structural condition for plant growth has a PS of about 50 %. This PS is important for gas exchange (O_2 and CO_2) between the soil and the atmosphere, and water storage and movement. The PS is filled with air and water.

Depending on pore size, pore spaces are given the name macro-pores (large) or micro-pores (small). There is no sharp line of demarcation between the two pore sizes. (Estefan et al., 2013)

Calculation

$$\text{Pore Space (\%)} = \frac{\text{PD-BD}}{\text{PD}} \times 100 \quad . \quad . \quad . \quad . \qquad \text{equation (8)}$$

Where: PD = Particle density (g/cm^3)

BD= Bulk density (g/cm^3)

3.4.5. Determination of Particle Size Distribution (Hydrometer Method)

The hydrometer method of silt and clay measurement relies in the effect of particle size on the differential settling velocities within a water column. By this method (using Hydrometer with Bouyoucous scale in (g/L) after 40 second all sand-sized particles (0.02 mm and larger) settle out of the suspension and after 4 hours, particles larger than clay (0.002 mm) settle out of the suspension (Estefan et al., 2013). Theoretically, the particles are assumed to be spherical having a specific density of 2.65 g/cm^3. If all other factors are constant, then the settling velocity is proportional to the square of the radius of the particle (Stoke's Law).

Mathematically, $$V = \frac{2r^2\left(\rho_{dp} - \rho_{dl}\right)}{9\eta} . \quad . \quad . \quad . \quad . \quad . \qquad \text{equation (9)}$$

V = Velocity of fall (cm/sec)

r = "equivalent" radius of the particle (cm)

ρdp = Density of particle (g/cm3), 2.65 is a (usual) good approximation

ρdl = Density of liquid (g/cm3), for water this is ~1.0

g= Acceleration of gravity (cm/sec), value at the sea level is 981

η= Viscosity of liquid (g/cm/sec)

3.4.6. Determination of Moisture Context

This method is based on removing soil moisture by oven-drying the soil sample until the weight remains constant. 30 g of soil sample was weighed in a weighing tin and covered with lid. After which the lid was removed and the tin with content was dried in an oven to a constant weight between $105^0c \pm 5^0c.$ The lid was replaced and the whole container placed in a desiccators to cool after which the tin and content were weighed. The moisture content of the soil as a percentage of the dry soil weight was calculated for all the samples using the formula below (Standard Association of Australia, 1997).

$$MC\% = \frac{W_2 - W_0}{W_3 - W_1} \times 100 \qquad - \quad - \quad - \quad - \quad - \qquad \text{equation (10)}$$

Where; $W_0 \equiv W_3 - W_1$ = weight of dry soil (g)

W_1 = weight of tin (g)

W_2 = weight of moist soil + tin (g)

W_3 = weight of dried soil + tin (g)

$$\text{Moisture Factor} = \frac{\text{Wet soil (g)}}{\text{Dry soil (g)}} \quad - \quad - \quad - \quad - \quad - \quad - \quad – \qquad \text{equation (11)}$$

3.4.7. Determination of Electrical Conductivity

Exactly 250g of the dried soil samples were weighed into separate 400 ml flask and were mixed with deionized water until the soil is glisten (Nwachukwu et al ., 2018). The mixtures were covered with paraffin and left to sit overnight. The next day, 50 g of the paste were weighed and transferred into 50 ml beaker while taking into account the initial weight of the empty beaker and the final weight of the beaker with paste. Later the various beakers were left in an oven overnight to dry. The next day, samples were brought out, allowed to cool, filtered (Buckner funnels, filter papers and Erlenmeyer flasks attached to the vacuums). The filtrates were taken and the electrical conductivity determined electronically with a calibrated electrical conductivity meter 430 Multi-Parameter by Jenway (Richard L.A., 1954).

3.4.8. Determination of Organic Matter

Exactly 2 g of dried sample of mesh size < 60 mesh was weighed into a 500 ml Erlenmeyer flask with the addition of 10 ml of 0.167 M $K_2Cr_2O_7$. It was followed by the addition of 20 ml conc.H_2SO_4 swirled and allowed to stand for 30 minutes in an insulation pad. The mixture was further diluted with 200 ml of deionized water and 10 ml 85% H_3PO_4 and 0.2 g NaF were all added simultaneously. Prior to the filtration, 10 drops of ferroin indicator was added to avoid deactivation by adsorption onto clay surfaces. Later the solution was mixed with 0.5 M Fe^{2+} to a burgundy endpoint (Walkdey and Black 1934). A blank sample used in standardization of Fe^{2+} solution was also ran using the procedure above. Calculations of percentage organic matter for each of the samples were done with the following formula:

$$\%\text{ Carbon} = \frac{(\text{B-S})\times \text{M of Fe}^{2+}\times 12\times 100}{\text{soil(g)}\times 4000} \qquad - \quad - \quad - \quad - \text{ equation (12)}$$

$$\%\text{ Organic Matter} = \frac{\%\text{ Total C}\times 1.72}{0.58} \qquad - \quad - \quad - \quad - \text{ equation (13)}$$

Where B = mL of Fe^{2+}solution used to titrate blank

S = mL of Fe^{2+}solution used to titrate sample

$\frac{12}{4000}$ = milli equivalent weight of C in g.

3.4.9 Soil Microbial Analysis (Total Coliform)

Exactly 1.0 g of crushed soil samples were mixed with 20 ml of distilled water in 100 ml volumetric flask and made up to the mark with deionized water in triplicates to give a dilution factor of 10^2. The diluted samples were filtered through membrane filter with a vacuum pump. The filter membrane was placed in the m-HPC agar plate and incubated using an incubator pre-set to $28 \pm 2^0 C$ for 24 hours. Observation was made for colony development on the filter membrane and colonies were counted as colony forming unit per 100 g (Ogbonna et al., 2009).

3.5.0 Analysis of Phosphate (PO_4^{2-})

Extraction solution for phosphate: 42.00 g of $NaHCO_3$ was dissolved and adjusted to pH of 8.5 with 50% NaOH and acetic acid. Standard solution of ammonium molybdate was prepared by dissolving 12.7 g of the salt in 250 ml of distilled water. Antimony potassium tartarate was prepared by dissolving 0.291 g in 100 ml of distilled-deionized water. Both reagents prepared above were added into 100 ml of 5 m H_2SO_4, mixed thoroughly, made to 200 ml with deionized water and were stored in a Pyrex glass bottle in a dark compartment.

Preparation of colour developing reagents: Stock phosphate solution (1000 gm/L): 4.40 g of the oven dried KH_2PO_4 salt was dissolved in deionized water, 1 mL of conc. H_2SO_4 added and the solution further diluted to 1 L in a volumetric flask. From the prepared solution above, 10 mL aliquot was placed in a 50 mL measuring flask and certain amount of deionized water was added. 10 mL of the colour developing reagent was also added, stirred and allowed to stand for 15 mins. It was later measured at 880nm by using Spectronic 21D UV/Visible Spectrophotometer and glass cells. Prior to the analysis, standard calibration curve was prepared by taking volumes of 0.00 - 12.00 mL from the standard solution ofKNO_3 (Mussa et al., (2009).

3.5.1 Analysis of Sulphate (SO_4^{2-})

50 g of each of the investigated soil samples were weighed (Nwachukwu et al ., 2018) and transferred to different 250 ml conical flask followed by the addition of exactly 50 ml of distilled water (1:1 ratio) with agitation. The agitation was done using mechanical shaker for 10 minutes. The sample mixture was left for 30 minutes and filtered with Whatman No. 42 filter paper into a Buchner funnel. After the extraction of the sample, conditional reagent was prepared by mixing 50 ml glycerol with a solution containing 30 ml conc. HCl, 300 ml deionized water, 100 ml (95%) ethanol and 75 g NaCl. Standard sulphate 0.1 M was also prepared by drying Na_2SO_4 at 110 ^oC in an oven for about 2 hours followed by cooling in a desiccator after which 7.10 g from it was dissolved in 1.0 L of de-ionized water. Also, 3 mL of the sample was taken out of the stock and further diluted to 100 mL in a 250 mL conical flask. 5 ml conditional reagents were also added while stirring followed by a spoonful of $BaCl_2$ crystals. After stirring for about 4 minutes, the solution was poured into a 4 cm sample silica cell and the absorbance was measured at 420 nm by using Jena Model UV-VIS Spectrophotometer (Mussa et al 2009). Prior to analysis, a standard calibration curve was prepared at 5.0 ml interval.

3.6. Instrumentation

Contents of heavy metals (Fe, Zn, Cd, Cr, Pb, Cr, and Ni) in all the soil samples from the investigated mechanic villages were determined using the method of the Association of Official Analytical Chemists (AOAC 1990). Prior to analysis, working standard solutions of the heavy metals were prepared from their various stock solutions of 1000 ppm in 2 M HNO_3 (Onojake et al.,2015) and the respective absorbencies of the heavy metals were measured using AAS machine (Unicam 969 Solar). After that, calibration curves were obtained for concentration versus absorbance. The filter membrane was placed in the m-HPC agar plate. Observations were also made for colony development on the filter membrane (Chalem, et al 2008).

3.7 Statistical Analysis

Descriptive Statistics were used to determine the mean and standard deviation where appropriate (Nwoko et al., 2018). Inferential Statistics were also conducted to determine one – way analysis of variance (ANOVA) among the measured parameters. Post hoc comparison using Turkey's tests and test for homogeneity of variance was used in identification of significant difference in measured parameters among the sampling points (Hassan et al., 2018). Pearson's correlation analyses were further implored to evaluate the potential relationships among variables and Eta square (η^2) was also conducted to assess how much the independent variables have affected the dependent variable. IBM SPSS statistics software 16.0 was used for the statistical analyses.

3.8 Pollution Indices Assessment

Pollution index model is an important tool for processing, analyzing and conveying raw environmental information to decision markers, managers, technicians and the public (Caeiro et al., 2005). In this study, four population indices were used for the environmental assessment of level and effects of investigated heavy metals contamination in three major mechanic villages in Abuja (Nwoko et al., 2018). Models used were contamination indices, ecological risk indices, degree of contamination and potential ecological risk index (Qingjie et al., 2008).

3.8.1 Single Indices

Single indices are indicators used to calculate only one metal contamination in soil sediment and water. They include: contamination factor, enrichment factor, ecological risk index and index of geo-accumulation (Qingjie et al., 2008)

3.8.1.1 Contamination Factor

Contamination factor $\left(C_f^i\right)$ is a diagnostic tool for the assessment of levels of heavy metal contamination in sediment, water, sludge and soil. Contamination factor can also be used to differentiate sources of heavy metal contamination. It can also be used to determine the degree of anthropogenic influence (Caeiro et al., 2005; Håkanson .L., 1980). Mathematically, it is expressed as;

$$C_f^i = \frac{C_i}{C_{ri}} \qquad - \quad - \quad - \quad - \quad - \quad - \quad - \quad - \quad - \qquad \text{equation (14)}$$

C_f^i: Contamination factor; C_i : content of metal i instead of mean content from at least 5 sample sites; C_{ri}: reference value, baseline level, or national criteria of metal i.

The following terminologies are used to describe the contamination factor; $C_f^i < 1$, low contamination factor; $1 \le C_f^i < 3$, moderate contamination factors; $3 \le C_f^i < 6$, considerable contamination factors; and $C_f^i \ge 6$ very high contamination factor (Qingjie et al., 2008). Table 2 shows the pre-industrial reference level determined from various European and American lakes (Qingjie et al., 2008).

Table 1 Pre-Industrial Reference Level (µg/g) and Toxic- Response Factor by Håkanson (1980)

Heavy metal	Hg	Cd	As	Cu	Pb	Cr	Zn
Pre-industrial reference level	0.25	1.0	15	50	70	90	175
Toxic-response factor	40	30	10	5	5	2	1

3.8.1.2 Ecological Risk Factor

This is a component of pollution indices used for assessing the ecological risk associated with heavy metal contamination in soil and sediments (Qingjie et al., 2008, Bawa-Allah et al., 2017).

$$E_r^i = T_r^i \times C_f^i \quad - \quad - \quad - \quad - \quad - \quad - \quad - \quad \text{equation (15)}$$

E_r^i : Ecological risk factor

C_f^i : Contamination Factor

T_r^i : Toxic - response factor for a given substance.

Toxic - response factors of heavy metals are shown in Table 1 (Qingjie et al., 2008). The following terminologies are used to describe the risk factor: $E_r^i < 40$, low potential ecological risk; $40 \leq E_r^i < 80$, moderate potential ecological risk; $80 \leq E_r^i < 160$, considerable potential ecological risk; $160 \leq E_r^i < 320$, high potential ecological risk; and $E_r^i \geq 320$, very high ecological risk (Qingjie et al., 2008).). Although the risk factor was originally used as a diagnostic tool for the purpose of controlling water pollution, it was successfully used for assessing the quality of sediments and soils in environment by heavy metals.

3.9 Integrated Indices

Integrated indices are indicators used to calculate more than one metal contamination, which were based on the single indices. Each kind of integrated index might be composed by the above single indices separately. According to algorithm, eight integrated methods were illustrated as following.

3.9.1 Degree of Contamination

Degree of contamination (C_d) was originally defined as the sum of all contamination factors (Qingjie et al., 2008)

$$C_d = \sum_{i=1}^{m} C_f^i \quad - \quad - \quad - \quad - \quad - \quad - \quad - \quad \text{equation (16)}$$

Where C_f^i is the single index of contamination factor, and m is the count of the heavy metal species. For the description of contamination degree, the following terminologies have been used: $C_d < m$, low degree of contamination; $m \leq C_d < 2m$, moderate degree of contamination; $2m \leq C_d < 4m$, considerable degree of contamination; and $C_d > 4m$, very high degree of contamination (Caeiro et al., 2005; Pekey et al., 2004, (Qingjie et al., 2008)).

3.9.2 Potential Ecological Risk

The potential ecological risk index (RI) was in the same manner as degree of contamination defined as the sum of the risk factors

$$PERI = \sum_{i=1}^{m} E_r^i \quad - \quad - \quad - \quad - \quad - \quad - \quad \text{equation (17)}$$

Where Er^i is the single index of ecological risk factor, and m is the count of the heavy metal species. The following terminology was used for the potential ecological risk index: RI < 150, low ecological risk; 150 ≤ RI < 300, moderate ecological risk; 300 ≤ RI < 600, considerable ecological risk; and RI > 600, very high ecological risk (Håkanson, L., 1980, (Qingjie et al., 2008)

.

CHAPTER FOUR

4.0 Result and Discussion

4.1 Physicochemical contents of studied soil

Table 2 Physiochemical Properties of Soil samples in Investigated mechanic villages (Ekeocha et al., 2017)

Sample points	pH	Percentage Porosity (%)	Electrical Conductivity (µs/cm)	Particle Size Distribution (µm)	Sulphate (mg/g)	Chloride (mg/g)	Nitrate (mg/g)	Total Coliform count (cfu/g)
A_1	7.20	59.6	388	511	0.60	0.05	0.15	230
A_2	7.19	62.1	391	568	0.51	0.11	0.25	210
A_3	7.22	60.1	386	561	0.63	0.13	0.15	140
A_4	7.39	60.9	369	576	0.68	0.12	0.09	110
A_5	7.31	59.7	388	596	0.68	0.08	0.12	120
$\bar{x}$±SD	7.26±0.09	60.5±1.04	384±8.79	562±31.7	0.51±0.2	0.10±0.34	0.15±0.58	162±54.5
Range	7.19-7.39	59.6-60.9	369-391	511-596	6	0.05-0.11	0.09-0.25	110-230
K_1	7.49	59.8	219	459	0.51-0.68 0.57	0.06	n.d	360
K_2	7.88	63.4	230	349	0.29	n.d	n.d	590
K_3	7.77	66.4	310	458	0.40	0.11	0.07	450
K_4	7.41	59.8	289	474	0.18	0.09	0.11	180
K_5	7.19	60.2	355	400	0.34	n.d	n.d	90
$\bar{x}$±SD	7.55±0.28	61.9±2.92	281±56.6	428±525	0.35±0.1	0.87±0.3	0.09±0.35	334± 202
Range	7.19 -7.88	59.8-66.4	219-355	349-474	4	0.06-0.11	0.07-0.11	90-590
Z_1	7.10	59.3	389	527	0.18-0.57 0.45	0.11	0.02	140
Z_2	7.19	56.8	388	556	0.58	0.15	0.09	250
Z_3	7.19	60.8	367	587	0.65	0.13	n.d	80
Z_4	7.24	59.7	391	600	0.62	0.09	n.d	80
Z_5	7.33	60.4	380	610	0.59	0.11	0.11	90
$\bar{x}$±SD	7.20±0.09	159±1.57	383±9.87	576±34.2	0.58±0.7	0.12±0.23	0.07±0.49	128 ±72.6
Range	7.19-7.33	56.8-60.8	367-291	527-610	7	0.09-0.15	0.02-0.11	90-250
Control	7.29	56.6	206	366	0.45-0.65 0.16	n.d	n.d	160

A: Apo automobile repair sites; K: Kugbo automobile repair sites; Z: Zuba automobile repair sites; n.d: not determined; n.l no limit.

Heavy metal accumulation in sediments had been reported to be controlled directly or indirectly by redox conditions either through a change in the redox state or speciation (McKay et al., 2007). The result of the study showed that maximum and minimum pH values of 7.88 and 7.10 were detected in soil samples drawn from Kugbo and Zuba mechanic villages respectively. A decreasing trend in the mean values of pH in the investigated automobile repair site were observed to follow the sequence of Kugbo site (7.548) > Apo site (7.26) > Zuba site (7.20). The results of the pH as recorded were also found to be higher than those reported by (Adewoyin et al., 2013; Iwegbue et al., 2006). Importantly, pH is vital in solute concentration and in sorption and desorption of contaminants in soil (Elliot et al., 1986).

Results of percentage porosity of soil samples (Table 2) reveal that all the values of percentage porosity in the investigated soils were above average with least and highest values of 59.8% and 66.4% recorded in Zuba and Kugbo automobile repair sites, respectively. A decreasing order of mean values of % porosity in all the sites can be written as Zuba site (61.9%) > Apo site (60.5%) > Kugbo site (59.4%). High % porosity in soil could be traceable to some automobile repair activities like welding and fabrication, panel beating of automobile parts, indiscriminate discharge of metal scraps, lubricants, hydraulics, battery electrolytes and petroleum products. Electrical conductivity recorded mean values of 281 µs/cm, 383 µs/cm and 384 µs/cm in Kugbo, Zuba and Apo mechanic villages. These mean values also exceeded that of control site (206 µs/cm) which possibly indicates anthropogenic influence on the quality of the soil. High values of electrical conductivity could be traced to deposit of heavy metals which are also good electrical conductors. In addition, the research findings from the study reveals that values of particle size distribution in all the sites ranges from (349 - 596) µm as shown in Table 2. Mean values of particle size distribution in the investigated sites were observed to follow a decreasing order of Zuba site (576 µm) > Apo site (563 µm) > Kugbo site (428 µm) respectively (Nwoko et al., 2018). These results also exceeded that of control value and thus depict anthropogenic influence (Nwoko et al., 2018). High particle size distribution could also be linked to some automobile repair activities like scrapping and refurbishment of vehicles, spraying and painting.

4.2 Results of Anionic Contents of Studied Soil

Results of anionic contents in investigated soil as shown in Table 2 reveal that values of sulphate fluctuated between 0.51 – 0.68 mg/g, 0.18 – 0.57 mg/g and 0.45 – 0.65 mg/g in Apo, Kugbo and Zuba automobile repair sites, respectively. High sulphate content is soil could be attributed to automobile repair sites activities like indiscriminate discharge of lubricants, electrolytes, oil sludge and used petroleum products. Chloride contents in investigated soils recorded a decreasing mean values in the order of Apo site (0.110 mg/g) > Zuba site (0.097 mg/g) > Kugbo site (0.033 mg/g). Some automobile repair activities that could have added to chloride content in soil include: Changing and repair of automobile air condition gases, radiator coolants etc. Nitrates contents in investigated soil fluctuated between 0.09 – 0.25 mg/g in Apo site, 0.09 – 0.35 mg/g in Kugbo site and 0.02 – 0.11 mg/g in Zuba site. Total coliform count unit (cfu/g) as shown in Table 2 recorded some values that exceeded those of control 160 cfu/g and standard acceptable count of 100 cfu/g. comparatively the values of total coliform count unit in all the sites fluctuate between 110 – 230 cfu/g in Apo site, 90 – 590 cfu/g in Kugbo site and 90 – 250 cfu/g in Zuba site respectively.

4.3 Levels of heavy metals in soil

Table 3 Heavy metal concentration in soils (mg/kg) in investigated mechanic villages (Ekeocha et al., 2017; Nwoko et al., 2018)

Mechanic village	**Cr**	**Fe**	**Ni**	**Cu**	**Zn**	**Cd**	**Pb**
A_1	1117	561	238	1677	8200	12.5	96.4
A_2	1173	426	212	22000	5288	11.5	357
A_3	1916	423	402	12830	8421	10.6	967
A_4	814	411	48.6	219	847	8.90	194
A_{p-5}	848	512	80.5	1616	4045	8.90	51.7
Average	1174	467	196	7668	5360	10.5	333
Mean ±SD	1174±444	467±66.4	196±141	7668±9488	5360±3144	10.5±1.59	333±373
Range	814-1916	411-561	48.6-402	219-22000	847-8421	8.94-12.5	51.7-967
K_1	911	203	195	3144	2869	1.20	89.6
K_2	288	320	370	407	719	10.2	201
K_3	726	259	110	340	2016	15.2	316
K_4	915	145	178	1017	1441	1.50	15.7
K_5	1074	157	318	306	890	19.2	225
Average	783	217	234	1043	1587	9.47	170
Mean ±SD	783±303	217±73.3	234±107	1043±1210	1587±879	9.47±8.07	170±118
Range	288-1074	145-320	110-370	340-3144	719 - 2869	1.20-19.2	15.7- 316
Z_1	830	302	187	686	410	10.2	199
Z_2	764	331	148	351	976	12.5	58.3
Z_3	1120	195	127	956	1010	9.50	249
Z_4	630	306	126	352	1710	8.80	443
Z_5	491	260	48.0	217	1845	11.1	298
Average	767	279	127	512	1190	10.4	250
Mean ±SD	767±236	279±53.4	127±50.7	512±302	1190±589	10.4±1.41	250±140
Range	491-1120	195-331	48.0-187	217-956	410-1845	8.84-12.5	58.3-443
C_T	1108	2.45	108	37.3	73.4	na	102
B_T	100	5000	35.0	36.0	140	0.80	85.0
I_V	380	nl	210	190	720	17.0	530
CEPA	61.0	nl	26.0	23.0	100	0.10	26.0
USEPA	26.0	nl	31.0	16.0	110	0.60	31.0
EUSTD	180	nl	300	140	300	3.00	300
UKSTD	6.40	Nl	70.0	63.0	200	1.40	70.0
FAO/ISRIC	250	nl	150	50.0	175	5.00	150

A_p: Apo auto mechanic village; K_u: Kugbo auto mechanic village; Z_u: Zuba auto mechanic village; C_T: control sample; B_T: background values of DPR (2002); I_V: intervention value of DPR (2002). n.a: not available; n.l: no limit, (Ekeocha et al., 2017; Nwoko et al., 2018)

4.3.1 Iron

The concentration of iron in sampled soils in the mechanic villages when compared with values of nickel and cadmium were high. Iron fluctuated between 144.96 mg/kg and 561.39 mg/kg in the three sites. These values were seen to be lesser than the values reported in soils around auto mechanic spare parts market and soil in oil field in Nigeria (Iwegbue et al., 2006). When compared with the tolerance value set by DPR (2002) the values of iron were found to have fallen below this tolerance value (Table 3). Low concentration of iron can be attributed to geogenic activities. Also the geographical location of Abuja and the availability of this metal especially in its ore form in the soil are believed to have been a major factor which contributes to the low concentration of iron recorded. This result fitted with the common range found in unpolluted soils and iron is ranked fifth abundance element in the study. The mean values of iron were seen to follow the sequence of site A (466.74mg/kg) > site Z (278.56mg/kg) > site K (216.83mg/kg).

4.3.2 Zinc

Results of heavy metal contents in (Olarenwaju, et al., 2015) investigated soil samples are shown in Table 3. Values of zinc fluctuated between (847 – 8421 mg/kg) in Apo, (719 – 2869 mg/kg) in Kugbo and (410 – 1845 mg/kg) in Zuba mechanic villages respectively. These values are higher than the tolerance values by DPR (2002) and those of the pre – industrial reference value by (Hakanson L., 1980; Iwegbue et al., 2013). Also concentration level of zinc from the study (Table 3) reveals that values of zinc are greater than the tolerance values of certain regulatory agencies in the world such as FAO/ISRIC (2004) (500mg/kg), USEPA (1999) (110 mg/kg), UKSTD (2000) (200 mg/kg), CEPA (1990) (100 mg/kg) and EUSTD (1983) (300 mg/kg). Site A from the graph of Figure 4 recorded the highest concentration in all the five sample points. The main source of pollution is anthropogenic like scrapping and panel beating of vehicle body parts, attrition of vehicle tires, lubricating oil that contain zinc additives like zinc dithiophosphates (Jaradat et al., 1999).

4.3.3 Copper

Results of the study showed that copper is the second most abundant metal among the investigated heavy metals (Table 3). Although copper which serves as an essential element both to humans and animals at low concentration can also be toxic at high concentration. Their concentration (mg/kg) in investigated soils ranges from (219 – 22000) in Apo mechanic village, (340 – 3144) in Kugbo mechanic village and 217 – 22000 in Zuba mechanic village respectively. The mean values of copper content in the sites are as follows: Apo mechanic village (7668.38 mg/kg) > Kugbo mechanic village (1042.84 mg/kg) > Zuba mechanic village (512.40 mg/kg). The level of copper found in all the sites were above that reported by (Gungshik, J.R., 2008; Iwegbue et al., 2013; Osakwe et al., 2008) and some international regulatory bodies (Table 3).

4.3.4 Nickel

Level of nickel as observed ranges from (48.0 - 402.4) mg/kg with an average abundance of 185.89 mg/kg which is far higher than the tolerance value (Haciyaakupoglu et al., 2014) or maximum permissible limits provided by DPR (2002) 35 mg/kg, USEPA (1999) 16 mg/kg, FAO/ISRIC (2004) 100mg/kg, CEPA (1990) 26.90 mg/kg. Nickel in soil is usually present in organically bound form, which under acidic and neutral conditions increases its mobility and bio availability (Kabata - Pendias et al., 1999). Nickels in soils are majorly from diesel and spent lubricating oil and grease.

4.3.5 Lead

Mean concentration of lead in soil samples in Kugbo, Zuba and Apo mechanic villages are in the ranges of (15.70 – 315.8) mg/kg, (58.3 – 443.1) mg/kg and (51.7 – 966.9) mg/kg respectively. All the mean values of lead from the sites exceeded the standard limit of by UKSTD (70 mg/kg), CEPA (26.0 mg/kg), USEPA (31.0 mg/kg) and DPR (85.0 mg/kg). High level of lead in soil in the sites can be attributed to anthropogenic components like exhaust gases from petrol engine, used petroleum products, emissions from welding and soldering, dry cell batteries (lead acid accumulator), car paints, leaded gasoline etc. The trend of decrease is in the mean concentration of lead from the sites are; site A (333.08mg/kg) > site Z (249.54mg/kg) > site A (196.40 mg/kg).

4.3.6 Chromium

The levels of chromium observed from the study among the three sites shows that it ranges from 287.5mg/kg to 1915.8 mg/kg with an average of 976.29 mg/kg. These values were far higher than the values reported by some researchers like; Umoren, I.U and Onianwa, P.C; (2005), Hong, et al., (2014) and Adaikpoh, E.O., (2013). These values also exceeded the tolerance values established by DPR (2002) 100 mg/kg, USEPA (1999) 26mg/kg, EUSTD (1983) 180mg/kg, CEPA (1990) 61mg/kg, FAO/ISRIC (2004) 250 mg/kg etc. Chromium can enter the soil through coloured polyethylene, empty and scrapped vehicle paints, discarded plastic materials, lead-chromium batteries etc

4.3.7 Cadmium

Results of the investigation showed that cadmium contents were in the range of 1.23 – 19.2mg/kg. The mean values in the sites were as follows; site A (11.088mg/kg) > site Z (10.414 mg/kg) > site K (9.47mg/kg). Notably, observed values of cadmium were higher than the values reported by Japtap et al., (2010), Babatunde and Steve (2014), Hakanson (1980), DPR (2002), USEPA (1999), FAO/ISRIC (2004) and CEPA (1990). The trend of decrement can be written as site A (11.088mg/kg) > site Z (10.44 mg/kg) > site K (9.47 mg/kg). Lead in soil is majorly through artificial activities like scrapping and spraying of vehicles, wear of automatic tyres, condemned car batteries, metal coating, etc.

4.4.0 Pearson's correlation analysis

Correlation analysis is a statistical tool used in measuring and analysis of degree of relationship between two or more variables. This gives us clue on the degree and direction of the relationship between measured variables. At such, sources and relationship between variables can be determined using correlation analyses. Mathematically, Karl Pearson's correlation coefficient can be stated as:

$$r = \frac{N\sum XY - \sum X \sum Y}{\sqrt{N\sum X^2 - \left(\sum X\right)^2}\sqrt{N\sum Y^2 - \left(\sum Y\right)^2}} \quad - \quad - \quad - \quad - \qquad (18)$$

where N = number of samples; X,Y are the single samples indexed;

Table 4 Pearson's Correlation Coefficient of Heavy Metals in Apo Mechanic Village (n=5) (Ekeocha et al., 2017)

	Fe	Zn	Cu	Ni	Pb	Cr	Cd	pH	EC	%P	PSD	SO_4^{2-}	Cl^-	NO_3^-
Fe	1.00													
Zn	0.40	1.00												
Cu	-0.49	0.33	1.00											
Ni	-0.07	0.88*	0.53	1.00										
Pb	-0.57	0.48	0.55	0.83	1.00									
Cr	-0.28	0.75	0.52	0.96**	0.94*	1.00								
Cd	0.38	0.76	0.41	0.60	0.12	0.37	1.00							
pH	-0.27	-0.87	-0.65	-0.76	-0.35	-0.59	-0.88*	1.00						
EC	0.44	0.72	0.52	0.49	0.11	0.34	0.59	-0.85	1.00					
%P	-0.69	-0.36	0.71	-0.10	0.11	-0.07	0.06	-0.08	-0.07	1.00				
PSD	-0.51	-0.64	0.07	-0.46	0.01	-0.24	-0.86	0.56	-0.21	0.26	1.00			
SO_4^{2-}	0.08	-0.41	-0.82	-0.41	-0.16	-0.26	-0.77	0.80	-0.59	-0.64	0.38	1.00		
Cl^-	-0.61	0.30	0.69	0.62	0.68	0.63	0.48	-0.44	-0.03	0.59	-0.33	-0.62	1.00	
NO_3^-	-0.14	0.41	0.91*	0.43	0.24	0.31	0.64	-0.80	0.70	0.64	-0.16	-0.96**	0.53	1.00

EC: Electrical Conductivity; %P: Percentage Porosity; PSD: Particle Size Distribution; Significant /r/*($p < 0.05$); ** ($p < 0.01$)

Results of correlation analyses of heavy metals and physiochemical properties of investigated soils are shown in tables 4, 5 and 6 below. The results shown in Table 4 indicate that strong positive correlation exist between the following metals (Nwoko et al., 2018) Pb/Cr (r = 0.94) evidencing that in 94 % of cases, the correlation of both heavy metals increases simultaneously (Nwoko et al., 2018). Other strong positive correlation were seen among Zn/Ni (r = 0.88) (Uluturhan et al. 2009), Cr/Ni (r = 0.96), Cr/Zn (r = 0.75), Cd/Zn (r = 0.76), Ni/Cd (r =0.60) and Cu/Pb (r = 0.55) respectively. This indicates that the studied heavy metals have identical behavior, are mutually dependent and are also from the same source. Strong negative correlations also exist between some physicochemical properties of the soil samples and some heavy metals as follows: Cd/pH (r = - 0.88), SO_4^{2-}/NO_3^- (r = - 0.96), Zn/pH (r = - 0.87), Cd/PSD (r = - 0.86), Cu/SO_4^{2-} (r = - 0.82), Cd/SO_4^{2-} (r = - 0.77), Ni/pH (r = - 0.76), Fe/%P (r = - 0.69), Cu/pH (r = - 0.65) and Cr/pH (r = - 0.59). This strong negative correlation indicates that the sources of the metal were from different origin.

Table 5 Pearson's Correlation Coefficient of Heavy Metals in Kugbo (Adomoko et al., 2008) Mechanic Village (n= 5) (Ekeocha et al., 2017)

	Fe	Zn	Cu	Ni	Pb	Cr	Cd	Ph	EC	%P	PSD	SO_4^{2-}	Cl^-	NO_3^-
Fe	1.00													
Zn	-0.14	1.00												
Cu	-0.22	0.81	1.00											
Ni	-0.27	-0.72	-0.28	1.00										
Pb	-0.53	-0.20	-0.58	0.05	1.00									
Cr	-0.93*	0.33	0.28	-0.37	-0.27	1.00								
Cd	0.18	-0.51	-0.74	0.28	0.87	0.00	1.00							
pH	0.93	0.00	-0.17	-0.02	-0.38	-0.91*	-0.04	1.00						
EC	-0.50	-0.38	-0.63	-0.10	0.39	0.56	0.71	-0.55	1.00					
%P	0.73	-0.06	-0.51	- 0.24	0.80	-0.58	0.47	0.77	0.06	1.00				
PSD	-0.13	0.74	0.49	-0.87	-0.40	-0.11	-0.69	0.21	-0.35	0.08	1.00			
SO_4^{2-}	0.08	0.79	0.70	-0.27	0.17	0.23	-0.09	-0.02	-0.31	-0.01	0.18	1.00		
Cl^-	-0.20	0.61	0.19	-0.97**	-0.14	0.23	-0.38	0.13	0.03	0.27	0.92*	0.06	1.00	
NO_3^-	-0.36	0.06	-0.19*	-0.65	-0.33	0.18	-0.32	-0.02	0.24	0.08	0.66	-0.54**	0.79	1.00

EC: Electrical Conductivity; %P: Percentage Porosity; PSD: Particle Size Distribution; Significant /r/*($p < 0.05$);** ($p < 0.01$)

Analyses of correlation coefficient among variables in Kugbo mechanic village as shown in Table 5 reveals that strong positive correlations exist among heavy metals in the sampled soils as follows; Pb/Cd (r = 0.87), Zn/Cu (r = 0.81) and Pb/Zn (r = 0.53) (Tokalioglu et al., 2002). Also among metals and physiochemical properties like Fe/pH (r = 0.93), Pb/%P (r = 0.80), Fe/%P (r = 0.73), Zn/ SO_4^{2-} (r = 0.79), PSD/ Zn (r = 0.74), Cu/ SO_4^{2-} (r = 0.70) and Zn/Cl^- (r = 0.61). Strong negative correlation also occurred between heavy metals like Fe/Cr (r = -0.93), Ni/Zn (r = -0.72), Cd/Cu (r = -0.74) and Pb/Cu (r = -0.58) and with physiochemical properties of soil like Cr/pH (r

= -0.91), Ni/PSD (r = -0.87), PSD/Cd (r = -0.69), Ni/NO_3^- (r = -0.65) and Cu/EC (r = -0.63) (Tokalioglu et al., 2002).

Table 6 Pearson’s Correlation Coefficient of Heavy Metals (Sallah et al., 2012) in Zuba Automobile Repair Sites (n = 5)

	Fe	Zn	Cu	Ni	Pb	Cr	Cd	pH	EC	%P	PSD	SO_4^{2-}	Cl^-	NO_3^-
Fe	1.00													
Zn	-010	1.00												
Cu	-0.63	-0.64	1.00											
Ni	0.37	-0.87	0.59	1.00										
Pb	-0.22	0.65	-0.14	-0.39	1.00									
Cr	-0.53	-0.65	0.95*	0.53	-0.32	1.00								
Cd	0.41	-0.18	-0.40	-0.05	-0.84	-0.21	1.00							
pH	-0.04	0.94*	-0.75	-0.94*	0.43	-0.75	0.10	1.00						
EC	0.96*	-0.03	-0.61	0.35	0.03	-0.60	0.16	-0.02	1.00					
%P	-0.80	0.34	0.36	-0.44	0.69	0.12	-0.73	0.22	-0.59	1.00				
PSD	-0.42	0.94*	-0.35	-0.88*	0.65	-0.37	-0.30	0.85	-0.36	0.53	1.00			
SO_4^{2-}	-0.48	0.66	-0.03	-0.58	0.34	0.09	-0.20	0.52	-0.53	0.66	0.82	1.00		
Cl^-	-0.02	-0.45	0.24	0.24	-0.89*	0.49	0.72	-0.32	-0.29	-0.59	-0.36	0.11	1.00	
NO_3^-	0.26	0.32	-0.69	-0.55	-0.43	-0.59	0.83	0.60	0.10	-0.38	0.17	0.00	0.33	1.00

EC: Electrical Conductivity; %P: Percentage Porosity; PSD: Particle Size Distribution; Significant /r/*($p < 0.05$);** ($p < 0.01$) (Wei et al., 2013)

Strong positive correlations were seen (Wei et al., 2013) among some heavy metals in Zuba site as follows: Cu/Cr (r = 0.95), Pb/Zn (r = 0.65), Cr/Ni (r = 0.53) and with some physiochemical properties; Fe/EC (r = 0.96), Zn/pH (r = 0.94), Zn/PSD (r = 0.94), Pb/%P (r = 0.69), Pb/PSD (0.65), Zn/ SO_4^{2-} (r = 0.66). Major strong negative correlation among heavy metals like Ni/Zn (r = -0.87) , Cd/Pb (r = -0.84), Cr/Zn (r = -0.65), Cu/Zn (r = -0.64) and Cu/Fe (r = -0.63). Also between heavy metals and some physiochemical properties; Ni/pH (r = -0.94), Pb/Cl^- (r = -0.89), Ni/PSD (r = -0.88), Fe/%P (r = -0.80), Cr/pH (r = -0.75), Cu/pH (r = -0.75), Cd/%P (r = -0.74), Cu/NO_3^- (r = -0.65) and Cu/EC (r = -0.61) respectively. The correlation coefficients between concentrations of various heavy metals and those of physiochemical properties of the soil samples show strong linear relationship between the variables, which probably indicate common origin and mutual dependence. Heavy metals in investigated soils could be attributed to (Olarenwaju et al., 2015) indiscriminate discharge of heavy metal containing wastes generated from various automobile activities in soils in and around the studied mechanic villages.

4.5 Analysis of Variance (ANOVA)

Analysis of variance was conducted to compare the mean among groups and within groups. Test for homogeneity of variance [Levene's Statistic], mean plots, post hoc test [Turkey HSD] were also conducted. Prior to the statistical analysis of the data, a research hypothesis was set for the study as:

Question: Is there any difference in the mean values of the dependent variables in the three mechanic villages.

Research Hypothesis: There is a difference in the mean values of the dependent variables in the three mechanic village.

Null Hypothesis [H_o]: There is no difference in the mean values of the dependent variables in the three mechanic village

Mathematically, [Ho]: = $\mu_{siteK} = \mu_{siteZ} = \mu_{siteA}$ - - equation (19)

Where μ represent the mean values of dependent variables α-level = 0.05. Analysis of variance was conducted to check the validity of the null hypothesis. The results of ANOVA conducted at α-level of 0.05, showed that the variables had significant difference greater than α – level of

0.05. That is [p-value > 0.05]; Fe [p = 0.376], Ni [p= 0.308], Pb [p = 0.574], Cd [p = 0.862], Cu [p = 0.115], Cr [p = 0.147], OM [p = 0.653], TVC [p = 0.055], PP [p = 0.180] and BD [p = 0.089]. With these results, null hypothesis is said NOT to be rejected and there are insufficient evidences to claim that some of the mean values may be different from each other. Thus there is no significant difference among the mean value of the dependent variables (heavy metals) of the three sites studied.

However, at α-level = 0.05, the following variables had p-values < α - level. They are; Zn [p= 0.009], SO_4^{2-} [p= 0.003], EC [p= 0.000], pH [p=0.020], NO_3^- [p= 0.003], TD [P= 0.000], SG [p= 0.000], PMC [p= 0.003] and PSD [p= 0.000]. The result implies there is a significant difference among the mean values of these sets of dependent variables. Hence, test for homogeneity of variance and post hoc test will be conducted to validate this claim.

4.6 Test for Homogeneity [Levene's Test]

Levene's test was used to test for the homogeneity of the variance among the dependent variables at α-level = 0.05 such that $\sigma^2_{SiteK} = \sigma^2_{SiteZ} = \sigma^2_{SiteA}$. The test showed that Ni [P = 0.131], Pb [p = 0.152], Cr [p = 0.641], Cl [p = 0.107], BD [P = 0.080], SO_4^{2-} [P = 0.342], NO_3^- [p = 0.631], TD [p = 0.191], SG [p = 0.169], OM [p = 0.033], PMC [p = 0.253] and PSD [p = 0.231]. Null hypothesis [H_o] is said NOT be rejected because all the p-values are greater than α-level of 0.05. Thus, there is a little evidence to show that the variances are not equal and the homogeneity of variance assumption may be reasonably satisfied.

Nevertheless, some of the dependent variables gave p-values less than the α-level of 0.05. They include; Fe [p= 0.022], Cd [p= 0.002], Cu [p= 0.000], TVC [p= 0.021], PP [p= 0.049], Zn [p= 0.026], EC [p= 0.003] and pH [p= 0.015]. In this case, null hypothesis [H_o] that the variances are equal is also rejected for these sets of dependent variables. Since the F ratio is statistically significant in some of the results of the variables, multiple comparisons test [Post Hoc tests] is further conducted for these sets of variables.

4.7 Post Hoc Tests

The post hoc tests or multiple comparisons test were conducted from these sets of variables using Turkey HSD. The results obtained are as shown below; Fe [p = 0.594], Zn [p = 0.943], Cu [p = 0.143], Ni [p = 0.287], Pb [p = 0.545], Cr[p = 0.184], Cd [p = 0.851], TVC [p = 0.062], Nitrate [p = 0.928 & 1], pH [p = 0.862 & 0.059], EC [p = 1.00 & 0.998], Cl [p = 0.154 & 0.785], Sulphate [p = 1.00 & 0.819] and OM [p = 0.678],

The result of the Post Hoc Tests showed that all the p- values for comparing the mean values of the variables are greater than the α-level of 0.05. Conclusively, **Null hypothesis [H_0] is NOT rejected** and this implies that it is unlikely that the mean values of the variables are different.

4.8 Effect size [Eta- Square]

Effect size [Eta square] is a value that enables us to see how independent variables [treatment effect] have affected the dependent variables [DV] in an experimental study. Mathematically effect square [η^2] = the sum of square between Groups/Total sum of square. Eta Square [η^2] were also conducted to enable us see how much the independent variables (IV) have affected the dependent variable (DV) using Cohen's guideline (1988). Small effect was seen in Cd [η^2 = 2.03%], Medium effect in Fe [η^2 = 8.78%], Pb [η^2 = 8.83%] and OM [η^2= 7.53%]. Large effect were also seen in Ni [η^2 = 17.83%], Cu [η^2 = 30.27], Cr [η^2 = 27.36%], Cl [η^2 = 39.24%], TVC [η^2 = 54.62%], PP [η^2 = 24.84%], BD [η^2 = 33.25%], Zn [η^2 = 54.62%], SO_4^{2-} [η^2 = 61.90%], EC [η^2 = 72.38%], pH [η^2 = 47.81%], NO_3^- [η^2 = 63.29%], TD [η^2 = 77.01%], SG [η^2 = 79.11%], PMC [η^2 = 62.26%] and PSD [η^2 = 77.32%]. The statistics of the results of Eta-square values above reveals that over 80% of the dependent variables showed large effect of Eta- value, a conclusion can also be made that the variances seen could have been caused by the independent variables (treatment effect).

Cohen's guidelines (1988)

0.01 – 0.058 small effect

0.059 – 0.137 medium effect

> 0.137 large effect

4.9 Results of Ecological Risk Index Assessment of Heavy Metals in Soil from investigated Mechanic Villages.

Table 7 Values and classes of contamination factor and degree of contamination of soil samples from studied mechanic villages (Ekeocha et al., 2017)

Mechanic village		**Fe**	**Zn**	**Cu**	**Ni**	**Pb**	**Cr**	**Cd**	**C_{Dclass}**
Kugbo	C_f	0.0400	11.3	29.0	6.70	2.00	7.90	11.8	68.8
	C_i	216	1587	1043	234	169	789	9.40	
	C_{ri}	5000	140	36.0	35.0	85.0	100	0.800	
	Class	l	vh	vh	vh	m	m	vh	vh
Zuba	C_f	0.0600	8.50	14.2	3.63	2.94	7.67	13.0	50.0
	C_i	278	1190	512	127	250	767	10.4	
	C_{ri}	5000	140	36.0	35.0	85.0	100	0.80	
	Class	l	vh	Vh	C	m	vh	vh	vh
Apo	C_f	0.0900	38.3	213	5.61	3.92	11.7	13.9	287
	C_i	467	5360	7668	196	333	1173	11.1	
	C_{ri}	5000	140	36.0	35.0	85.0	100	0.800	
	Class	l	vh	m	c	c	vh	vh	vh

C_i : Concentration of heavy metal in soil; C_{ri}: background value for each heavy metal adopted from DPR (2002); C_f^i: contamination factor; C_D :Degree of contamination; l: low contamination; m: moderate contamination; c: considerable contamination and vh: very high contamination.

The results of contamination factor and degree of contamination models (Table 7) revealed that 71.0% of the heavy metal (Zn, Cu, Ni, Cr and Cd) in Kugbo mechanic village were in the class of very high contamination, whereas iron and lead were in the class of low and moderate contamination respectively. In Zuba mechanic village, 54.1% of the heavy metals (Zn, Cu, Cr, Cd) in soil were in the level of very high contamination. Apo mechanic village also had 42.9% of its soil in the level of very high contamination and the metal responsible for this are; Cr, Cd and Zn. Ni and Pb were found to be in class of considerable contamination, whereas Cu and Fe had moderate and low contamination. Comparatively Zn, Cd and Cr had very high contamination factor in all the sites which could be attributed to anthropogenic processes. Fe had low contamination factor too in all the sites and this low contamination factor signifies that the pollution is from geogenic process as it dominates approximately 1.50% of the earth's crust (Tippie V.K., 1984). Also the three sites had very high degrees of contamination and a trend of increase in degree of contamination can be deduced as Zuba site (50) < Kugbo site (68.8) < Apo site (287). This could be attributed to some anthropogenic activities carried out in the studied mechanic villages and indiscriminate discharges of heavy metal containing waste in and around the mechanic villages.

However results in Table 7 reveals that 66.7% of soil samples from Kugbo mechanic village though contaminated but are of low ecological risk to the environment. The remaining 33.3% of soil samples possess considerable ecological risk as a result of mild contamination. In Zuba mechanic village, 83.3% of soil samples indicated low ecological risk and copper which covers 16.7% showed moderate ecological risk. Copper because of its high content recorded high ecological risk in Apo mechanic village, cadmium showed moderate ecological risk and other heavy metals in soil in Apo site possess low ecological risk (Liu et al., 2014). Comparing the Potential Ecological Risk Index [PERI] (Wei et al., 2013) on the three sites investigated, Kugbo and Zuba mechanic villages were in the class of moderate potential ecological risk while Apo with PERI value of 1216 falls in the class of very high potential ecological risk index (Li et al., 2012). These results also indicated that soil in Apo mechanic village with the highest value of PERI possess more environmental trait to health of humans, organisms and ecosystem at large. Thus urgent steps have to be taken so as to avert the outbreak of an epidemic and series of health related problems caused by heavy metals in that area.

Table 8 Ecological Risk Factor, Potential Ecological Risk Index and Pollution Classes of Soil in the Studied Sites (Ekeocha et al., 2017, Nwoko et al., 2018)

Mechanic village		**Zn**	**Cu**	**Ni**	**Pb**	**Cr**	**Cd**	**PERI**
Kugbo	E_r	11.3	145	33.4	10.0	15.8	35.5	251
	C_f	11.3	29.0	6.70	2.00	7.90	11.8	
	T_r	1.00	5.00	5.00	5.00	2.00	3.00	
	C_{ri}	5000	140	36.0	35.0	85.0	100	0.80
	Class	lp	cp	lp	lp	lp	cp	mp
Zuba	E_r	8.50	71.2	18.2	14.7	15.3	39.0	167
	C_f	8.50	14.2	3.60	2.90	7.70	13.0	
	T_r	1.00	5.00	5.00	5.00	2.00	3.00	
	C_{ri}	5000	140	36.0	35.0	85.0	100	0.80
	Class	lp	mp	lp	lp	lp	cp	mp
Apo	E_r	38.3	1065	28.1	19.6	23.5	41.6	1216
	C_f	38.3	213	5.60	3.90	11.7	13.9	
	T_r	1.00	5.00	5.00	5.00	2.00	3.00	
	C_{ri}	5000	140	36.0	35.0	85.0	100	0.80
	Class	lp	vhp	lp	lp	lp	mp	vhp

E_r : Ecological risk factor; C_f: Contamination factor; T_r: Toxic response factor for a given metal; PERI: Potential Ecological Risk Index; $PERI_{class}$: Classification of Potential Ecological Risk Index; l: Low potential ecological risk; m: Moderate potential ecological risk; C_p: Considerable potential ecological risk and v_{hp}: Very high potential ecological risk (Li et al., 2012)

CHAPTER FIVE

5.0 Conclusion and Recommendation

5.1 Conclusion

The results obtained from the study supply valuable information on various levels of heavy metal contents in soils drawn from three major mechanic villages in Abuja, Nigeria. The results also showed the distribution pattern of the studied heavy metals whose values in all the sites with the exception of iron were found to have exceeded the background or pre-industrial reference value(s) provided by some world regulatory bodies. The high values recorded could be attributed to anthropogenic activities like indiscriminate discharge of heavy metal containing wastes generated from various auto-mechanic practices. Correlation analyses revealed that these heavy metals had strong correlation with each other and with some of the physicochemical properties of the soil. Some of them showed a high approximation to perfect correlation indicating a strong linear relationship between the measured variables. Different useful pollution indices models used for the assessment showed that soil samples from investigated mechanic villages has various degrees of pollution.

5.2 Recommendations

Based on the findings of this research work, it is therefore suggested that systematic investigation should be conducted so as to determine the rate of heavy metal loading as well as changes in the quality of soil in and around these automobile repair sites. Indiscriminate discharge of heavy metal containing wastes generated from auto mechanic repairs on soil in particular and environment at large should be totally stopped. Better still, these wastes should be collected, recycled and properly disposed in order to save our environment from harmful pollutants. Also, adequate sensitization on the damages of indiscriminate discharge of waste in the environment should be made by relevant authorities and a more environment friendly automobile mechanic village concept and proper waste management encouraged.

5.4 Contribution of the Research Work to Knowledge

- This research work provided four different useful tools [single and integrated] for calculating pollution indices. This model can be used in assessing the environmental impact of heavy metal contamination in soil and sediments and water (Hu et al., 2014).
- The study also gave a holistic method of analyses for environmental impact assessment of heavy metal contamination in soil. This could be adopted by relevant authorities to checkmate the level of heavy metal contamination caused by anthropogenic activities and the ecological risk associated with it.

REFERENCES

Abechi, E.S., Okunola, O.J., Zubairu S.M.J., Usman, A.A and Apene E. (2010). Evaluation of Heavy Metals in Roadside Soils of Major Streets in Jos Metropolis, Nigeria. J. Environ. Chem. Ecotoxicol. 2 (6): 98 – 102.

Abuja - Wikipedia https://en.m.wikipedia.org > wiki >Abuja (Retrieved 26 October 2015)

Adaikpoh, E.O; (2013) "Distribution and enrichment of heavy metals in soils from waste dump sites within Imoru and Environs, Southwest Nigeria" Journal of Environment and Earth Science Vol 3 (14) ISSN 2224 – 3216 (paper)

Acar, Y.B; and Alshawabkeh, A.N. (1993). Principles of Electro Kinetics Remediation. J. Environ. Sci. Tech. 27(13): 2638 – 2647

Aceves, M.B; Grace, C; and Anosorena, J. (1999). Soil microbial biomass and organic Compound in a gradient of zinc concentration in soils around a mine soil top. J. Soil Bio. Biochem. 31(6): 867–876

Adelakan, B.A and Adegunde, K.D. (2011). Heavy metal contamination of soil and groundwater at automobile mechanic villages in Ibadan, Nigeria. Int'l. J. Phy. Sci. 6 (5):1045–1058.

Adewale, M.B and Uchegbu, L.U (2010). Properties of soils and plants uptake within the vicinity of selected automobile workshops in Ile-Ife Southern, Nigeria. Ethiopian J. Environ. Stud. Manag. 3:(3)

Adewoyin, O.A; Hassan, A.T. and Aladesida, A.A., (2013). The impact of auto mechanic workshops on soil and ground water in Ibadan Metropolis. African J. Environ. Sci. Tech. 7(9):891–898 Doi: 10.5897/AJEST2013.1462

Aeliona, C.M., Davis, H.T., and McDermott, S. (2008). Metal concentration in rural topsoil in South Carolina: Potential for human health impact. Sci. Tot. Environ. 402: 149-156

A metal primer (2012) (http/www.darmouth.edu/~toxmetal/toxic-metals/metals-primer.html) Dartmouth Toxic Metals Superfund Research Program, Retrieved 2014-11-20

Abuja - Wikipedia https://en.m.wikipedia.org > wiki >Abuja (Retrieved 26 October 2015)

Adomako D., Nyarko BJ., Dampare SB., Serfor-Armah, Y., Osae, S., Fianko, J.R., Akaho, E.H., (2008). Determination of toxic elements in waters and sediments from River Subin in the Ashanti Region of Ghana. Environ Monit Assess.141(1-3):165-175.

ASTM D 854-00 Standard Test for Specific Gravity of soil and solids by water pyconometer.

Arao, T.; Ishikawa, T., Murakam, I.M., et al., (2010). Heavy metal contamination of agricultural soil and counter measures in Japan: Paddy and Wat. Environ. 8(3): 247 – 257

ATSDR Agency for Toxic Substances and Disease Registry (1999). ATSDR Substance Priority List. https://www.atsdr.cdc.gov (Accesses May 7th , 2014)

Ayangbero, A.S., Babalola O.O.(2017). A New strategy for heavy metal polluted environments: A review of microbial Biosorbents. Int. J. Environ. Res. Pub. Health. 14: 94- 101.

Babatunde, O.A., Oyewale, O.A, Steve, P.I, (2000). Bioavailability of Trace elements in soil around NNPC Oil Depot, Jos, Nigeria. J. Environ. Toxicity and Food Technol. 8(1): 47-56

Babula, P., Adam, V., Opatrilova, R., Zhenalek, J., Havel, l., Kisek R., (2008). Uncommon heavy metals Metalloids and their plant toxicity: A Review Environ. Chem. Lett. 6: 189 – 213 DOI:10.1007/s10311-008-0159-9

Bleser, P., Zimmermann, S; and Luster, J. (2000). Critical examination of trace element enrichments and depletions in soils: As, Cr, Cu, Ni and Zn in Swiss forest soil. J. Environ. Sci. 259: 257-280

Barceloux, D.G; and Barceloux, D. (1999). Chromium. J. Clinical Toxicol. 37(2): 173–194

Basaram , B., Satyanarayanan, M, Sudarshan V; and Keshav K.A. (2010). Assessment of Soil contamination in Patancheru Industrial Area, Hyderabad, Andhra Pradesh, India. J. Environ. Earth Sci.3: 214 – 220.

Bassuer, G. (1987). The endangered ozone layer and new theories of ozone depletion. J. Environ. Sci. 29(1): 20–27.

Bawa-Allah, K.A., Saliu, J.K., Otitoloju, A.A. (2017): Integrated assessment of the heavy metal pollution status and potential ecological risk in the Lagos Lagoon, South West, Nigeria, Human and Ecological Risk Assessment: An International Journal, 24(2): 377–397 DOI: 10.1080/10807039.2017.1384694

Boya, R.S. (2010). Heavy metal pollutants and chemical ecology, exploring new frontiers. J. Chem. Ecol.36: 46–58

Brita, T. A., Schamphelaere, D; and Karnel, A.C. (2006). Mechanism of Chronic Waterborne Zinc Toxicity in Daphnia Magna. J. Aqua. Toxicol. 77(4): 393–401

Bouyoucous G.J. (1962). Hydrometer Method Improved for Making Particle-Size Analyses of Soils. Agronomy Journal; 54: 464–465

Caeiro, S., Costa, M.H., and Ramos, T.B. (2005). Assessing Heavy Metal Contamination in Sado Estuary Sediment: An Index Analysis Approach. J. Ecological indicators 5: 151–169

CDC (2012).Centre for Disease Control and Prevention Global Health Strategy. Available at http://www.cdc.gov/globahealth/pdf/HHS one page factsheet press quality.pdf

CEPA [Chinese Environmental Protection Administration] (1990). Elemental Background Of Soils In China. (GB15618-1995). Environmental Science Press of China, Beijing

Chao, S.U., Jiang, L.Q., and Zhang, W.J. (2014). A review of heavy metal contamination in the soil worldwide: situation, impact and remediation techniques. J. Environ. Skeptics and Critics 3(20):24–38

Chakravarity, M and Patrgiri, A.D., (2009). Metal pollution assessment in sediments of the Dikrong River, N.E India, J. Hum. Ecol, 27 (1), 63 - 67

Chalem, R., Pandda, T., Herbert, B., and Sakait, C. (2008). Effect of pH on the mobilization of copper and iron by pyoverdin I in artificially contaminated soils. Journal of Science Asia

Chander, K., Brookes, P.C., and Harding, S.A. (1995). Microbial biomass dynamics following addition of metal enriched sewage sludge to a sandy loam. J. Soil Bio. Biochem. 27(11): 1409–1421

Chatterjee, M., Silva, F.E.V., and Sarkar, S.K. (2007). Distribution and possible source of trace elements in the sediment cores of a tropical macro tidal estuary and their ecotoxicological significances. Environ. Int. 33:346–356

Cheng, J L., Shi, Z., and Zhu, Y.W. (2007). Assessment and Mapping of Environmental Quality in Agricultural Soils of Zhejiang Province, China. J. Environ. Sci.19:50–54

Chinese Environmental Protection Agency CEPA (1990)

Davidson, P.W., Myers, G.J., and Weiss, B. (2004). Mercury exposure and Child development outcomes. J. Pediatrics, 113(4):1023–1029

Duce, R.A., Hoffmann, G.L., and Zoller, W.H., (1975). Atmospheric Trace Metals at Remote Northern and Southern Hemisphere Sites: Pollution or Natural? J. Sci. 187:59–61

Duffus, J.H. (2002). Heavy Metals -A meaningless Term. J. Pure and Appl. Chem. 74(5):79–807

Department of Petroleum Resources (DPR, 2002). Environmental Guidelines and Standards for the Petroleum Industry in Nigeria (Revised Edition) Department of Petroleum and Natural Resources Abuja, Nigeria.

Edgell, K. (1988). USEPA method study 37-SW-846 method 3050 acid digestion of sediments, sludge and soils. EPA contract No. 68-03-3254

Ekeocha CI, Ogukwe CE, Nikoro JO. (2017). Application of multiple ecological risk indices for the assessment of heavy metal pollution in soils in major mechanic villages in Abuja, Nigeria. British J. Appl. Sci. Tech. 19(2):1-10. DOI: 10.9734/BJAST/2017/30779 26.

Elliot H.A., Liberati M.R., Huang C.P., (1986). Competitive Adsorption of Heavy Metals in soils. J. Environ. Qual. 15: 214–219.

Estefan S., Sommer R., Rayn J., (2013). Methods of soil, plants and Water Analysis: A manual for the West Africa and north Africa region 3rd edition pg 26 -74

FAO/ISRIC Food and Agricultural Organization and International Soil Reference and Information Centre (2004). Guiding Principle for the quantitative assessment of soil degradation with a focus on soil salinization, nutrient decline and soil pollution. (Accessed *10th November 2014)* Available at ftp://ftp.fao.org/agl/agll/docs/misc36e.pdf

Fliepbach, A., Martens, R., and Reber, H. (1994). Soil microbial biomass and activity in soils treated heavy metals contaminated sewage sludge. J. Soil Bio. Biochem. 26:1201–1205

Fosmire, G.J. (1990). Zinc Toxicity. American J. Clin. Nutri. 51(2): 225–227

Goyer, R.A., and Clarkson, T.M. (2001). Toxic effects of metals. Casarett and Doull’s Toxicology. New York: McGraw-Hill, Chapter 23: 811–868

Gungshik, J.R, and Mohammed, J.D. (2007). Impact of mining of trace metal contents of soils. African J. Natural Sci.10: 21–24.

Guo W., Huo S., Xi, B. Zhang J., Wu, F, (2015). Heavy Metal Contamination in Sediments from Typical Lakes in the Five Geographic Regions of China: Distribution, Bioavailability, and Risk. J. Ecological Engineering 81:243-255 DOI: 10.1016/j.ecoleng.2015.04.047

Gupta, V., Malik, D.S., Dinesh, D.K.(2017). Risk assessment of heavy metal pollution in middle stretch of River Ganga: An Introspection. Int. Res. J. Environ. Sci. 6(2):62-71.19.

Habashi, F.; (2009) “Gmelin and his handbook” Bulletin for the History of Chemistry" 34(1): 30-31**.** DOI:10.2298/JMMB0901001H

Hakanson, L. (1980). An Ecological Risk Index for Aquatic Pollution Control. A Sedimentological Approach. J. Wat. Res.14: 975–1001.

Hassan I, F., Walid, A., (2018). Effect of site on sedimentological characteristics and metal pollution in two semi-enclosed embayment's of great freshwater reservoir: Lake Nasser, Egypt. Journal of African Earth Sciences, Volume 141, p. 194-206. DOI: 10.1016/j.jfrearsci.2018.02.012

Hong, A.H; Law, P.L and Onni, S.S; (2014) "Environmental burden of heavy metal contamination levels in the soil from sewage irrigation area of Geriyo Catchment, Nigeria" Journal of Civil and Environmental Research Vol 6 No. 10 ISSN 2224 -5790 (paper) ISSN 2225 – 6514.

Hu, Y., Wang, D., Wei, L., Song, B, (2014). Heavy metal contamination of urban top soils in a typical region of Loess Plateau, China J Soils Sediments (2014) 14:928–935 DOI 10.1007/s11368-013-0820-1

Huffon, M. and Simon C. (1986). The quantities of cadmium, lead, mercury and arsenic entering the UK environment from human activities. J. Sci. Tot. Environ. 57:129–150

Ihejirika C.E.,Njoku-Tony R.F., Ebe T.E., Enwereuzoh U.O., Izunobi L.C.,, Asheigbu, D.,Verla, N, (2016). Anthropogenic Impact and Geo-accumulation of Heavy Metal Levels of Soils in Owerri, Nigeria. British J. App.Sci.& Tech. 12(1):1 – 9 Doi DOI: 10.9734/BJAST/2016/19357

Iwegbue, C.M.A., Isirimah, N.O., Igwe, C., and Williams, E.S. (2006). Characteristics levels of heavy metals in soil profile of automobile mechanic waste dumps in Nigeria. Int'l. J. Environ. Sci. Tech. 26:123-128 Doi: 10.1007/s10669-006-7482-0

Iwegbue, C.M. (2007). Metal fractionation in soil profiles at automobile mechanic waste dumps around Port Harcourt. Journal of Waste Management Resources 25(6):585–593.

Iwegbue C.M.A, Bassey, F.I, Tesi, G.O, Nwajei, G.E and Tsafe, A.I (2013). Assessment of heavy metal contamination in soils around cassava processing mills in sub-urban areas of Delta State, Southern Nigeria. J. Basic and Appl. Sci. 21(2): 96–104

Iwegbue, C.M.A., Egobueze, F.E., and Opuene, K. (2006). Preliminary assessment of heavy metals in soils of an oil field in the Niger Delta, Nigeria" Int'l. J. Environ. Sci. Tech. 3(2):167–172.

Iwegbue, C.M.A., Isirimah, Igwe, N.O., Williams. E.S. (2006). Characteristics levels of heavy metal in soil profiles of automobile mechanic waste dumps in Nigeria. Environmentalist 26:123-128

Ipediyeda, A.R., Dwodu, M. (2008). Heavy metal contamination of top soil and dispersion in the vicinities of reclaimed auto repairs workshop in Iwo, Nigeria. Bull. Chem. Soc. Ethiopia 22(3):339-348

Isioma E. Arinze, O. Igwe, C .O. Una, (2015). Analysis of heavy metals' contamination in soils and water at automobile junk markets in Obosi and Nnewi, Anambra State, Southeastern Nigeria Arabian Journal of Geosciences 8(12): 10961-10976 DOI: 10.1007/s12517-015-2001-6

Japtap, M.N., Kulkarni, M.V., Puranik, P.R, (2010). Flux of heavy metals in soils irrigated with urban wastewaters. America-Eurasian J. Agric. Environ. Sci. 8(5): 487–493.

James, W.D., Berger, T.G., Elston, D.M., and Odom, R.D. (2006). Andrews diseases of the skin. J. Clinical Dermatology. Saunders Elsevier pp 858 ISBN 0721629210

Jaradat, Q.M., and Momami, K.A. (1999). Contamination of roadside soils, plants and air with heavy metals in Jordan: A Comprehensive Study. Turkish Journal of Chemistry 23: 209–220.

Jarup L. (2013). Hazards of heavy metals contamination. The British Medical Bull. 68:167-182.

Kabata-Pendias, A; and Pendias, H; (1999) "Biogeochemistry of trace elements" 2nd edition. Wyd Nauk PWN Warszawa

Kakulu, S.E., (1993). Biological monitoring of atmospheric trace metal deposition in North Eastern Nigeria. J. Environ. Monit. Assess. 28: 137-143

Kannan K., Agusa, T., Perrotta, E., Thomas, N.J., Tanabe, S.(2006). Comparison of trace element concentrations in livers of diseased, emaciated and non-diseased southern sea otters from the California coast. J. Chemosphere. 65(11):2160-7

Kandeler, E; Lurienegger, G. and Schwarz, S; (1997) "Influence of heavy metals on the functional diversity of soil microbial communities" Journal of Soil Biology and Biochemistry, 27(11): 1409-1421

Khan, D.K., Gupta, N., Santra, S.C. (2008). An assessment of heavy metal contamination in vegetables grown in wastewater-irrigated areas of Titagarh, West Bengal, India. Bull. Environ. Cont. Toxicol. 80 (2), 115 – 118

Kimbrough, D.E., Wakakuwa, J.R., (1989). Acid digestion for sediments, sludge's, soils and solid wastes. A Proposed Alternative to EPA SW 846 Method 3050. J. Environ. Sci.Technol. 23:898- 907

Krishma, A.K., and Govil, P.K. (2007). Soil contamination due to heavy metals from an Industrial Area of Surat, Gujarat, Western India. Environ Monit Assess. 124: 263–275

Krewski, D., Yokel, R.A., Nieboer, E., Borchelt, D.,Cohen, J., Harry, J., Kacew, S., Lindsay, J., Mahfouz, A.M., Rondeau, V. (2007) Human Health Risk Assessment for Aluminum, Aluminum Oxide and Aluminum hydroxide. J. Toxicol. Environ. Health, Part B, 10:1-269. DOI: 10.1080/10937400701597766

Kumar, V., Abbas, A.K and Aster, J.C. (2013). Environmental and Nutritional Diseases. Robbins Basic Pathology. 9th edition Elsevier Philadelphia, PA, ISBN9781437717815

Koirtyoham, S.R; (1991). A History of Atomic Absorption Spectroscopy. Analytical Chemistry 63(2) 1924A- 1031A

Kwon, Y.T., Lee, C.W., Ahn, B.Y. (2001). Sedimentation pattern and sediments bioavailability in a waste discharging area by sequential metal analysis. Microchem. J. 68 (2–3), 135–141

Kwon YT, Lee CE. (1998) Application of multiple ecological risk indices for the evaluation of heavy metal contamination in a coastal dredging area. The Science of the Total Environment, 214:203-210

Landis, W.G., Sofield, R.M., and Yu, M.H., (2000). Introduction to Environmental Toxicology. Molecular Substructures to Ecology Landscapes. 4th edition, CRC Press, Boca Raton, Florida ISBN 9781439804100

Lee, D.H., Zo, Y.G., and Kim, S.J. (1996). Nonradioactive methods to study genetic profiles of natural bacterial communities by PCR-Singled-Strand-Conformation Polymorphism. J. Appl. Environ. Microbio. 62(9): 3112–3120

Li, L., Zhang, R,S., Wang, X, Y, (2012). Potential Ecological Risk Assessment and Sources Analysis of Heavy Metals in the Corn Farmland Soil from the Xinxiang City. Conference: Remote Sensing, Environment and Transportation Engineering (RSETE), 2012 2nd International Conference on DOI: 10.1109/RSETE.2012.6260659 2012 - ieeexplore.ieee.org

Liu, Z.Y. (1998). The source and fate of Pb in Central Sweden. Sci. Tot. Environ. 209(1): 47–58.

Liu, C., Zhang, Y., Zhang, F., Zhang, S., Yin, M. et al., (2007). Assessing pollutions of soil and plant by municipal waste dump. J. Environ. Geo. 52(4), 641–651.

Liu, W.H., Zhao, J.Z., Ouyang, Z.Y., et al (2005). Impacts of sewage irrigation on heavy metal distribution and contamination in Beijing China. Environment International 31: 805–812

Liu, M., Yuyi, Y., Xiaoyan, Y., Miaomiao, Z, Qing X. L., Jun, W, (2014). Distribution and ecological assessment of heavy metals in surface sediments of the East Lake, China. *Ecotoxicology 2014, 23 (1): 92-101*

Long, X.Y; Yang, X.E; and Ni, W.E. (2002). Current status and prospective on Phytoremediation of heavy metal polluted soils. J. Appl. Ecolo.13:757-762

Malik, Q.A, Khan, M.S., (2016). Effect on human health due to drinking water contaminated with heavy metals. J. Pollut. Eff. Cont. 5:179-189.

McKay,G., Gerente C., Lee V.K.C., Cloirec P.L. (2007). Application of chitosan for the removal of metals from wastewaters by adsorption-mechanism and models review. Critical reviews in Environ. Sci. Technol. 37 (10, 41 – 127, 2007

Miller, R.E., Hazard, J., and Howes, S. (2001). Precision, accuracy and efficiency of four tools for measuring soil bulk density or strength. Res–Paper PNW-RP-532: U.S Department of Agriculture, Forest Service, Pacific Northwest Research Station, Portland.

Mohiuddin, K.M., Zakir, H.M., Otomo, K., Sharmin, S., and Shikazono, N. (2010). Geochemical distribution of trace metal pollutants in water and sediments of downstream of an urban river. Int. J. Environ. Sci. Tech. 7(1): 17–28.

Mucha, A.P, Vasconcelos, M.T.S and Bordalo, A.A (2003). Macrobenthic community in the Doura Estuary. Relation with trace metals and natural sediments characteristics. Environ. Poll. 121:169–180

Mussa, B. A., Elferjanis, H.S., Haroun, A.F., and Abdelnabi, F.F. (2009). Determination of available nitrate, phosphate and sulphate in soil samples. Int'l. J. Pharma. Tech. Res. 1(3): 598–604

NAS/IOM (National Academy of Sciences/ Institute of Medicinal) (2003). Dietary reference intakes for vitamin A , vitamin K. arsenic, boron, chromium, copper, iodine, iron, manganese, nickel, silicon, vanadium and zinc. Food and Nutrition Board, Institute of Medicine, Washington, D.C, ISBN 030972794

NAS/NRC (National Academy of Science/National Research Council) (2000). Toxicological effects of methyl mercury. Washington, D.C

National Research Council, Committee on Biological effect of Atmospheric Pollutants Chromium, (1974) National Academy of Sciences, Washington DC

Nielen, M.W.F., and Marvin, H.J.P. (2008). Challenges in chemical food contaminants and residue analysis in Y. Pico (ed). Comprehensive Analytical Chemistry, 51: 1–28. *Elsevier, Amsterdam ISBN 0080931928*

NLWRA (2001). Australian Agricultural Assessment. National Land and Water Resources Audit.

Norman, N. (2014). Digging Deep for Safer Water. Journal of Chemistry World 11(4) 54–57

Nwachukwu, M.A., Feng, H., and Alinor, I.J. (2010). Assessment of heavy metal pollution in soil and their implications within and around mechanic villages. Intl J. Environ. Sci. Tech 7(2): 347–358.

Nwachukwu, A.M., Feng, H. Achilike, K. (2010). Integrated study for automobile wastes management and environmentally friendly mechanic villages in Imo River Basin, Nigeria. African J. Environ. Sci. Technol. 4(4):234 – 294

Nwachukwu, J.N., Ubani, C.S., Osuji, C.A., Biomarkers in *Achatina achatina* as Ecological Risk Assessment Models of Mining Activities. Research J. Environ. Toxicol. 12(2): 63 – 72. DOI: 10.3923/rjet.2018.63.72

Nwoko, C.I., Enenebeaku, C.K., Ekeocha, C.I., (2018). Use of integrated pollution indices in assessing heavy metals pollution in soils of three auto mechanic villages in Abuja . African J. Environ. Sci. Tech. 12(10): 370 – 376 DOI: 10.5897/AJEST2018.2548

Nwuche, C.O., Ugorji, E.O. (2008). Effect of heavy metal pollution on the soil microbial activity. Int. J. Environ. Sci. Tech. 5(3):409–414.

Ogbonna, J.F., and Amajuoyi, C.A. (2009). Physicochemical characteristics and Microbial Quality of an Oil polluted site in Gokana, Rivers State. J. Appl. Sci. Environ. Manage. 13(3): 99–103

Ogunmodede, O. T., Adewole, E., Ojo, A. A, (2015). Quantitative changes in soil properties and plant uptake of metals on municipal solid waste dumpsite in Nigeria.
Int'l. Lett. of Chem. Phys.& Astron. 52: 152-162

Olanrewaju L., Bankole S.A., Udeh I.I. (2015). Assessment of automobile workshops and heavy metal pollution in a typical Sub-Saharan African urban Environment. Environmental Research, Engineering and Management, 71(1), 27-35 http://dx.doi.org/10.5755/j01.erem.71.1.9303

Olayiwola, O.A. (2011). An assessment of soil heavy metals pollution by various allied artisans in Automobile Workshop in Osun State, Nigeria. Electrical J. Environ. Agric. Food Chem.10 (2): 1881-1886

Onojake, M. C., Sikoki, F. D., Omokheyeke, O., Akpiri, R. U. (2015). Surface water characteristics and trace metals level of the Bonny/New Calabar River Estuary, Niger Delta, Nigeria. Appl. Wat. Sci. 7(2):951-959

Onweremadu, E.U., and Doruigbo, C.J. (2007). Assessment of Cadmium concentration of crude oil arable soil. Int. J. Environ. Sci. Tech. 4(3):409–412.

Osakwe, S.A., and Egharevba, F. (2008). Sequential fractionation of cadmium, copper, lead and chromium in soils around municipal solid waste dumps in Agbor Nigeria. J. Chem. Soc. Nigeria, 33(2): 139–147.

Ouyang, Y., Higman, J., Thompson, J., O'Toole, T., Campbell, D ., (2002). Characteristics and spatial distribution of heavy metals in sediment from cedar and Ortega Rivers Sub-basin. J. Contamin. Hydrol. 54(1-2):19-35

Pam, A.A., Rufus, S. and Offem, J.O. (2013). Contribution of automobile mechanic sites to heavy metals in soil: A case study of North bank mechanic village Makurdi, Benue State, Central Nigeria. J. Chem. Biol. and Phys. Sci. 3:2337–2347

Pam, A.A., Rufus, S. and Offem, J.O. (2013). Evaluation of heavy metals in soil around auto mechanic workshop clusters in Gboko and Makurdi Central Nigeria. J. Environ. Chem. Ecotoxicol. 5(11):298–306.

Pala, E.M.,, Dey, S. (2016). Microscopy and Microanalysis of Blood in a Snake Head Fish, Channa Gachua Exposed to Environmental Pollution. Microsc. Microanal. 22(1):39-47. Doi: 10.1017/S1431927616000519.

Pekey H. (2004). Heavy metal pollution assessment in sediments of Izmit Bay, Turkey. Environ. Monit. Assess. 123: (1-3), 219–231

Qin, T.C., Wu, Y.S., Wang, H.X. (1994). Effect of cadmium, lead and their interactions on the physiological and biochemical characteristics of Brassica Chinensis, Acta Ecological Sinica 14(1): 46–49

Qin, Y.S., Zhao, J., and Lin, Z.Q. (2008). Study on the influence of combined pollution of heavy metals; Cu and Pb on soil respiration. J. Anhui Agric. Sci. 36(3): 1117–1128

Qingjie, G, Jun D, Yunchuan X, Qingfei W, Liqiang Y. Calculating pollution indices by heavy metals in ecological geochemistry assessment and a case study in parks of Beijing. J. China Uni. of GeoSci. 2008; 9(3):230-241. DOI:10.1016/S1002-0705(08) 60042- 4.2008

Ravens croft, P. (2007). Predicting the global distribution of arsenic pollution in groundwater. Paper presented at Arsenic, The Geography of a Global Problem in Royal Geographic Society arsenic conference held at Royal Geographic Society, London, England. Page 6

Reiman, C., and De Caritas, P (2005). Distinguishing between natural and anthropogenic sources for elements in the Environment: Regional Geochemical survey versus enrichment factors. The science of the total environment 337:91–107

Richard, L.A. (1954). Diagnosis and improvement of saline and alkali soils. U.S salinity laboratory U.S dept. Agric. HBK. 60, pp 160.

Ross, S.M. (1994). Retention, transformation and mobility of toxic metals in soil: In toxic metals in soil-plant systems pp 64 –152 Chichester: John Wiley and Sons.

Rout, G.R., and Premananda, D. (2003). Effect of metal toxicity on plant growth and metabolism. J. Agronomy 23(1):3–11

Salah,M., Emad A., Zaidan,T.A., Al-Rawi,A.S., (Assessment of Heavy Metals Pollution in the Sediments of Euphrates River, Iraq, (Journal of Water Resource and Protection Volume 4(12): 1009 – 1023 DOI: 10.4236/jwarp.2012.412117

Satarug, S., Baker, J.R., and Urbenjaplo, S. (2003). A global perspective on cadmium pollution and toxicity in non-occupational exposed population. Toxicology letters, 137:65–83.

Sengupta, M. and Bishayi, B. *(2002)* Effect of lead and arsenic on marine macrophage response. Drug and Chemical Toxicology, 25, 459-472.

Standards Association of Australia. (1997) AS 1289 B1-1-1997 Determination of moisture content of a soil: oven drying method (Standard method).

Sutherland, R.A (2000). Bed sediment associated trace metals in an urban stream. Oahu, Hawaii. J. Environ. Geol, 36: 611-627

Tippie, V. K., (1984). An environmental characterization of Chesapeake Bay and a frame work for action. In: Kennedy, V (Ed), The Estuary as a filter. Academic press, New York, pp 467–487

Tokalioglu, S., Kartal, S. (2002). Atomic Absorption Spectrometric Determination of Heavy Metal Contents of Soils around Different Highways in Turkey and Statistical Interpretation of the Data. Journal of Trace and Microprobe Techniques Volume 20(1):127-140 https://doi.org/10.1081/TMA-120002466

Turekian, K.K; and Wedepohl, K.H. (1961). Distribution of the element in some major units of the earth's crust J. Geol. Am 72, 175-192

Uluturhan, E., (2010). Heavy metal concentrations in surface sediments from two regions (Saros and Gökova Gulfs) of the Eastern Aegean Sea. Environ Monit Assess. 165(1-4): 675-84. DOI: 10.1007/s10661-009-0978-6

Umoren, I.U., and Onianwa, P.C., (2005). Concentrations and distribution of some heavy metals in urban soils of Ibadan, Nigeria" Pakistan Journal of Science and Industrial Research, 48 (6) 397 – 403

Udousoro, I., Umoren, I.U., and Asuquo, E.O. (2010). Survey of some heavy metal concentration in selected soils in South Eastern Part of Nigeria. World J. App. Sci. Technol. 2 (2):139–148.

USEPA [United States Protection Agency] (1999). Screening level ecological risk assessment protocol for hazardous waste combustion facilities, vol 3, Appendix E: Toxicity Reference Values EPA 530-D99-001C

Wang, M.H.,and Lau, W. (1985). Root growth of dicotyledonous and Eleusine India collected from motorways at different concentrations of lead. J. Environ. Res. 36(2):257-67

Walkdey, A., and Black, I.A. (1934). An examination of Degtjareff method for determining soil organic matter and a proposed modification of the chromic acid titration method. Soil Sci. 37:29–37

Wei, X., Haoping, W., Beibei, H., Wenmin, H., Guihua, L, (2013). Bioaccumulation of Heavy Metals by Submerged Macrophytes: Looking for Hyper accumulators in Eutrophic Lakes Environ. Sci. Technol. 47(9): 4695 – 4703 https://doi.org/10.1021/es303923w

WHO/IPCS (2002). The WHO Recommended Classification of Pesticides by Hazard and Guidelines to Classification 2000 – 2002 pg 1- 60

Wikipedia (2011). Auto mechanics free encyclopaedia. accessed online at en. Wikipedia/org./wiki/auto mechanic (Accessed 27th November, 2014)

Wood, J.M. (1974). Biological Cycle for Toxic Elements in the Environment. 183:1049–1052

World Health Organization (2013). Stop lead poisoning in children in children. (http://www.who.int/mediacentre/news/notes/2013/lead - 2013-10-18/en/).

Yang, Y.B., and Sun, L.B. (2009). Status and control counter measures of heavy metal pollution in urban soil. J. Environ. Protec. Sci. 35(4):79–81

Yokel, R.A.; Hicks, C.L.; and Florence, R.L.; (2008). Aluminium bioavailability from basic sodium aluminium phosphate, an approved food additive emulsifying agent, incorporated in cheese J. Food Chem. Toxicology 46: 2261 – 2266.

Yuan, C.J., Shi, B., He, J., Liu, L., and Jiang, G. (2004). Specialization of heavy metals in marine sediments from the East China Sea by ICP-MS with sequential extraction. Environ. Int. 30(6):769–783.

Zakir, H.M; Shikazono, N., and Otomo, K. (2008). Geochemical distribution of trace metals and assessment of anthropogenic pollution in sediments of old Nakagawa River, Tokyo Japan. Am. J. Environ Sci. 4(6): 661-672

Zhang, l. P., Ye, X., Feng, H., et al (2007). Heavy metal contamination in western Xiamen Bay sediment and its vicinity, China. J. Marine Pollution Bulletin 54:974–982

Zhang, W.J., Jiang, F.B., and Ou, J.F. (2011). Global pesticide consumption and pollution: with China in focus. Proceeding of the Int'l. Academy of Eco. Environ. Sci. 1(2):125–144

Zhang, W.J., and Zhang, X.Y., (2007). A forecast analysis of fertilizers consumption worldwide. J. Environ. Monit. Assess. 133:427–434.

Zhang, Z.J., Lu, Q.F., and Fang, F. (1989). Effect of mercury on growth and physiological function of wheat seedlings" Chinese J. Environ. Sci. 10(4):10–13

Zhao, H.L., Zhu, X., and Sui, Y. (2006). The short-lived Chinese Emperors. J. American Geriatrics Soc. 54(8) 1295–1296

Zhou, Q.X. (1995). Ecology of Compound Pollution. China Environmental Science Press, Beijing, China

Zhong , T., Xue, D., Zhao, L., Zhang, X., (2017). Concentration of heavy metals in vegetables and potential health risk assessment in China. Environ Geochem Health. 2018 Feb;40(1):313-322. DOI: 10.1007/s10653-017-9909-6

Zoller, H.H., Gladney, E.S., and Duce, R.A. (1974). Atmospheric concentration and sources of trace metals at the South. Pole. J. Sci. 183:198–200

APPENDIX

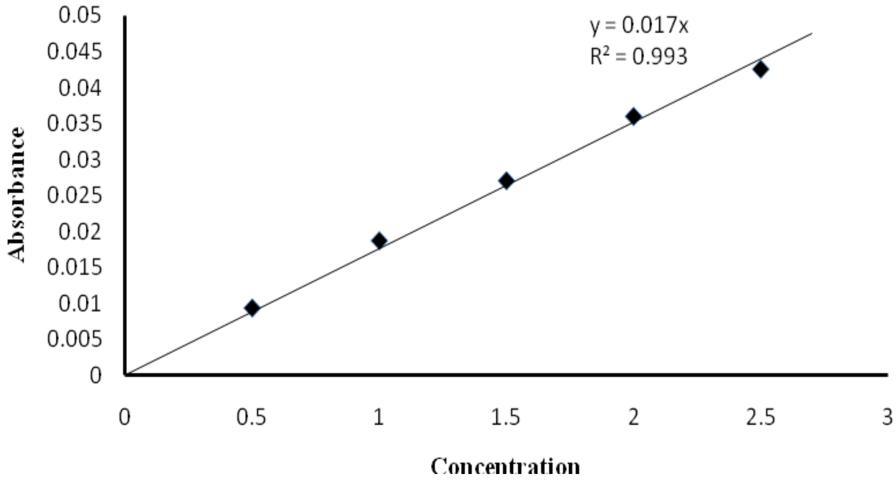


Fig 3: Calibration curve for Lead

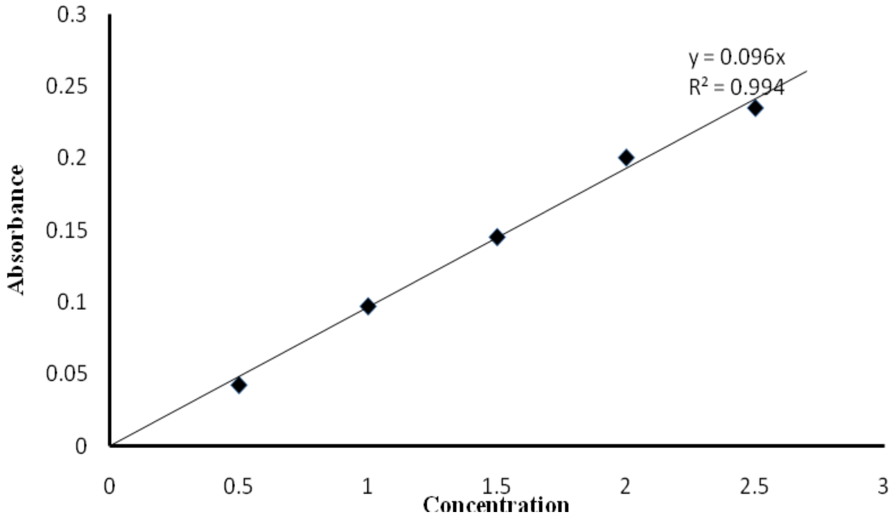


Fig 4: Calibration curve for Cadmium

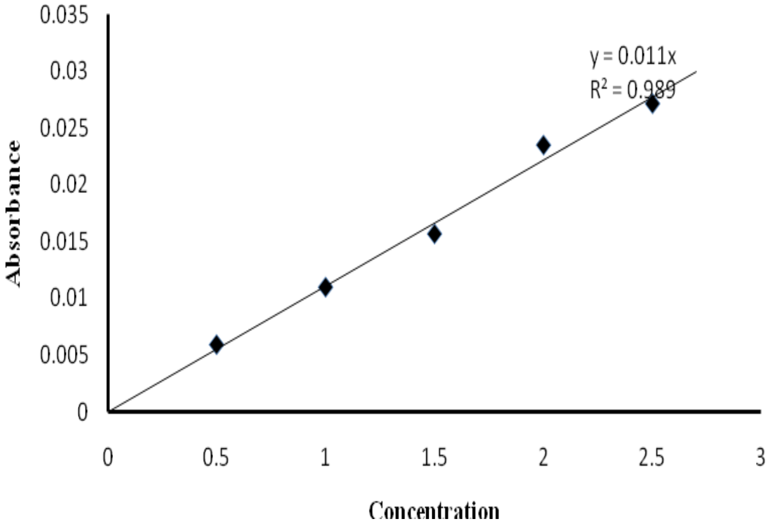


Fig 5: Calibration curve for Nickel

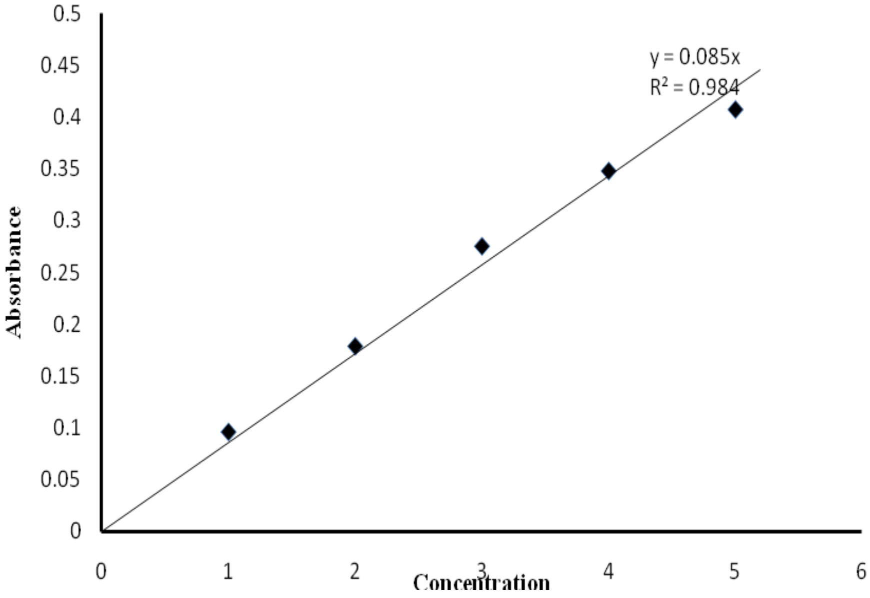


Fig 6: Calibration curve for Copper

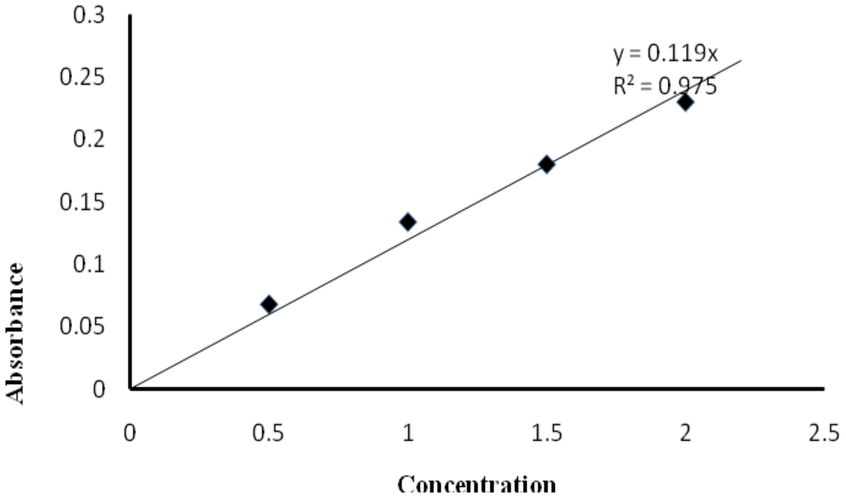


Fig 7: Calibration curve for Zinc

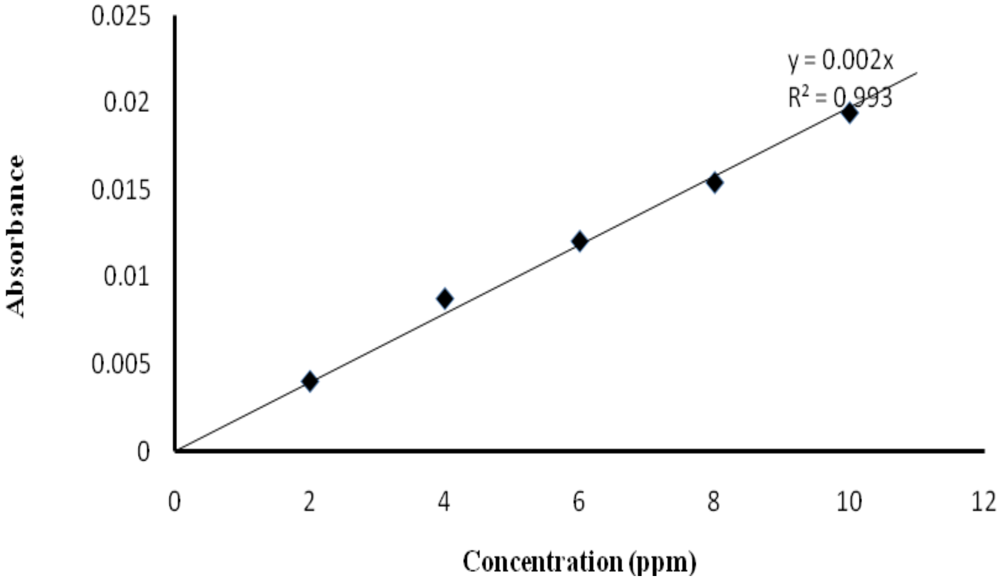


Fig 8: Calibration curve for Chromium

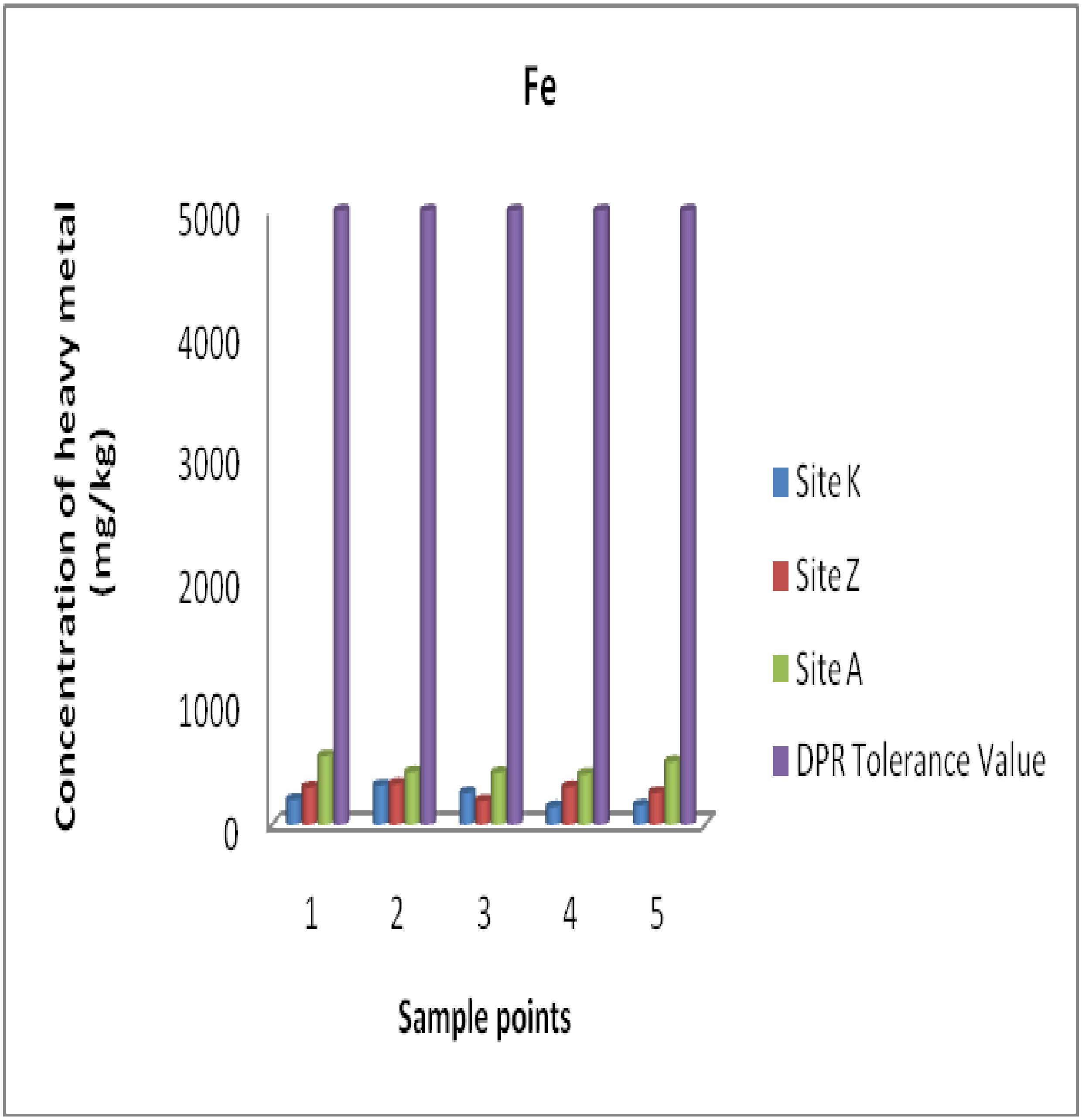


Fig 9: Graph showing comparison of DPR Background value of [Fe] with soil samples from the three investigated Mechanic Villages in Abuja

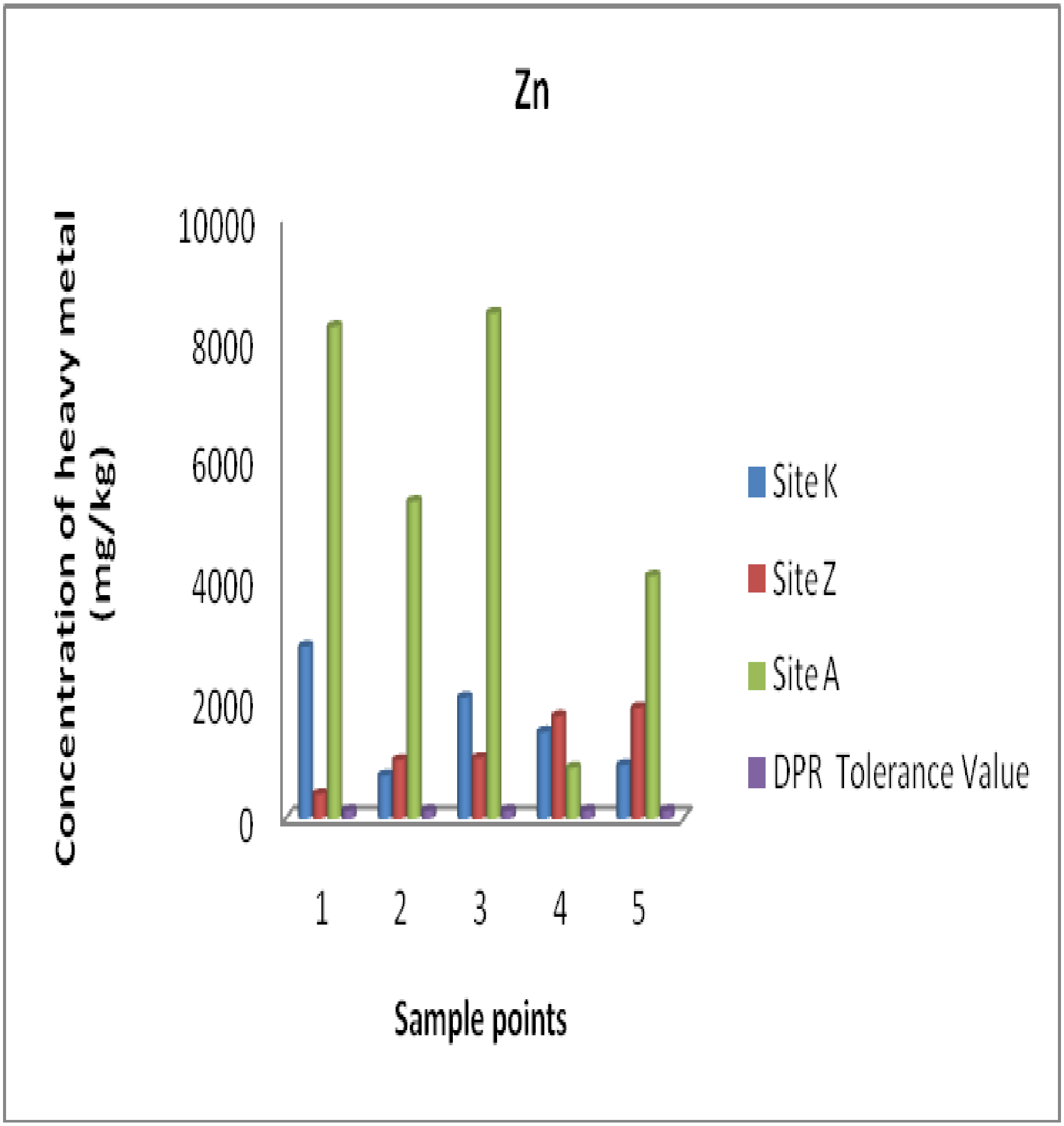


Fig 10: Graph showing comparison of DPR Background value of [Zn] with soil samples from the three investigated Mechanic Villages in Abuja.

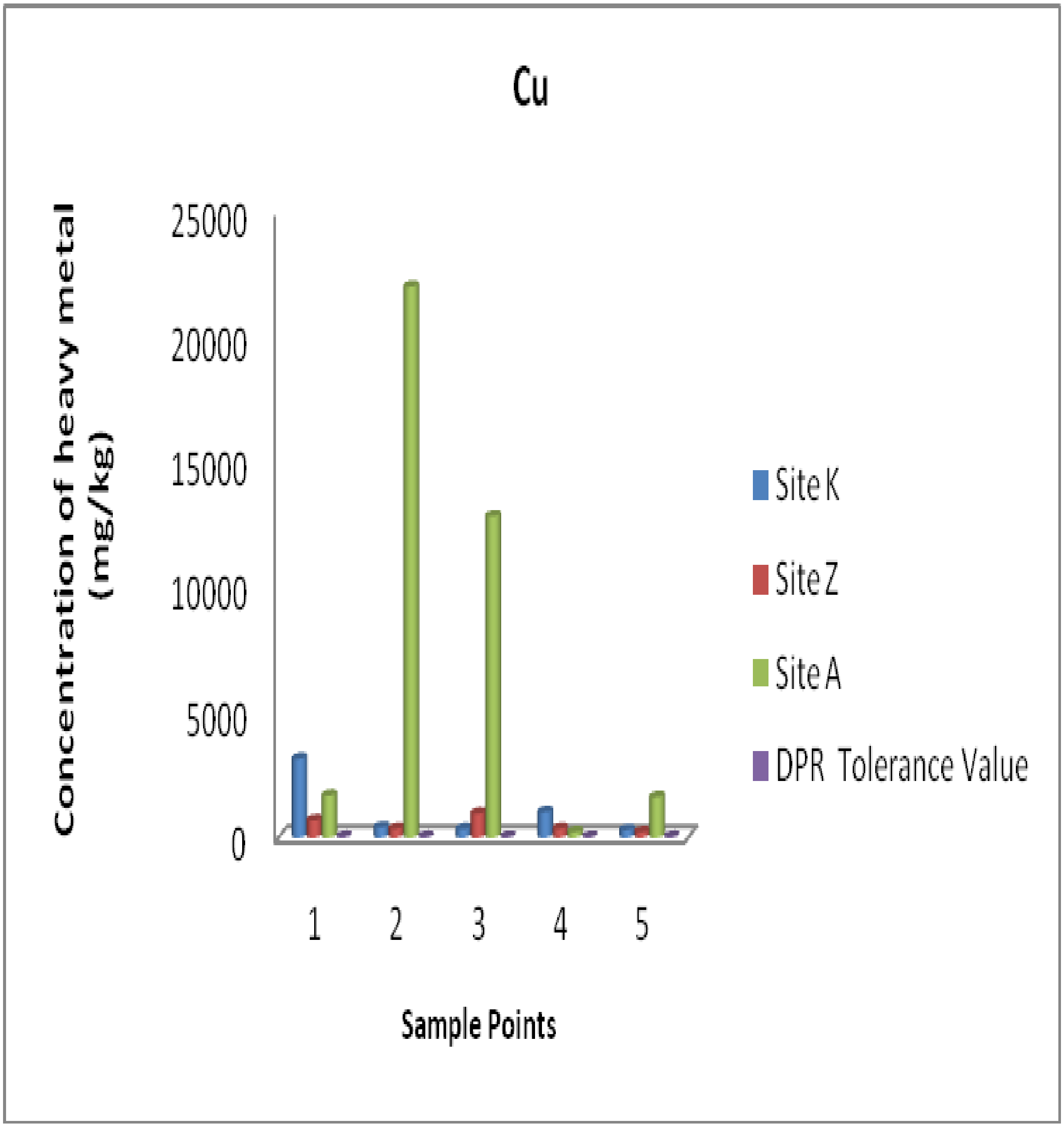


Fig 11: Graph showing comparison of DPR Background value of [Cu] with soil samples from the three investigated Mechanic Villages in Abuja**.**

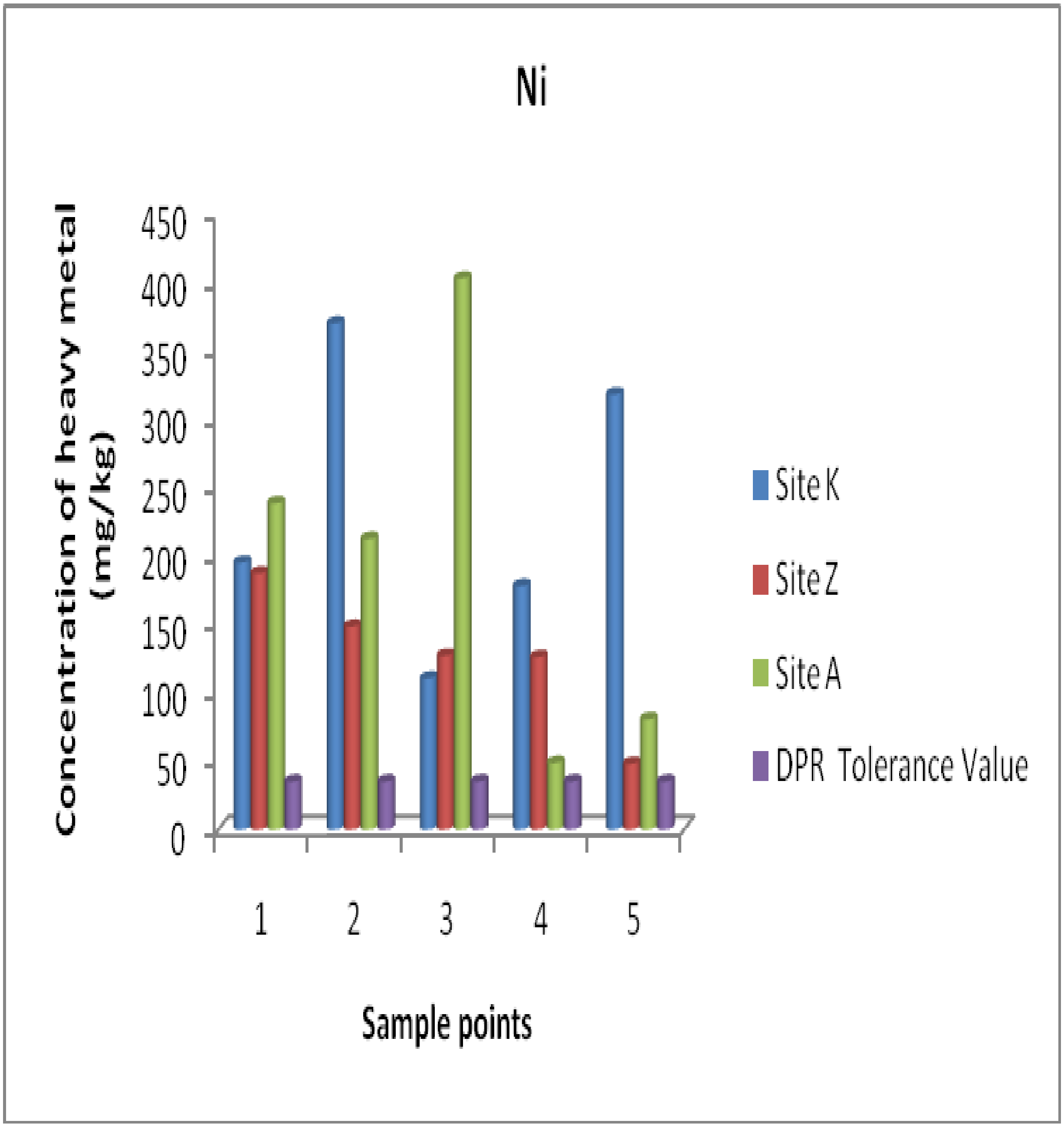


Fig 12: Graph showing comparison of DPR Background value of [Ni] with soil samples from the three investigated Mechanic Villages in Abuja.

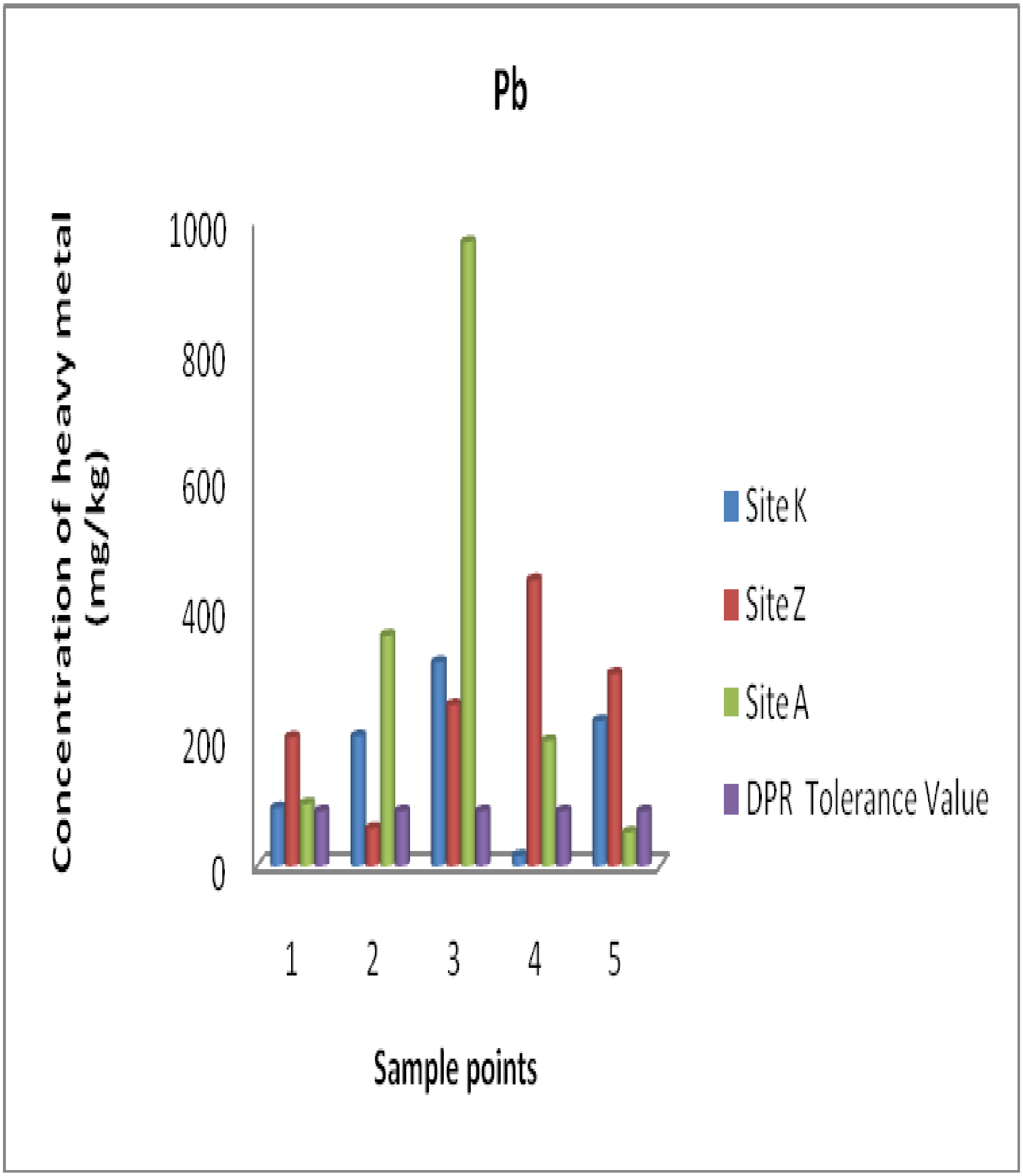


Fig 13: Graph showing comparison of DPR Background value of [Pb] with soil samples from the three Mechanic Villages in Abuja**.**

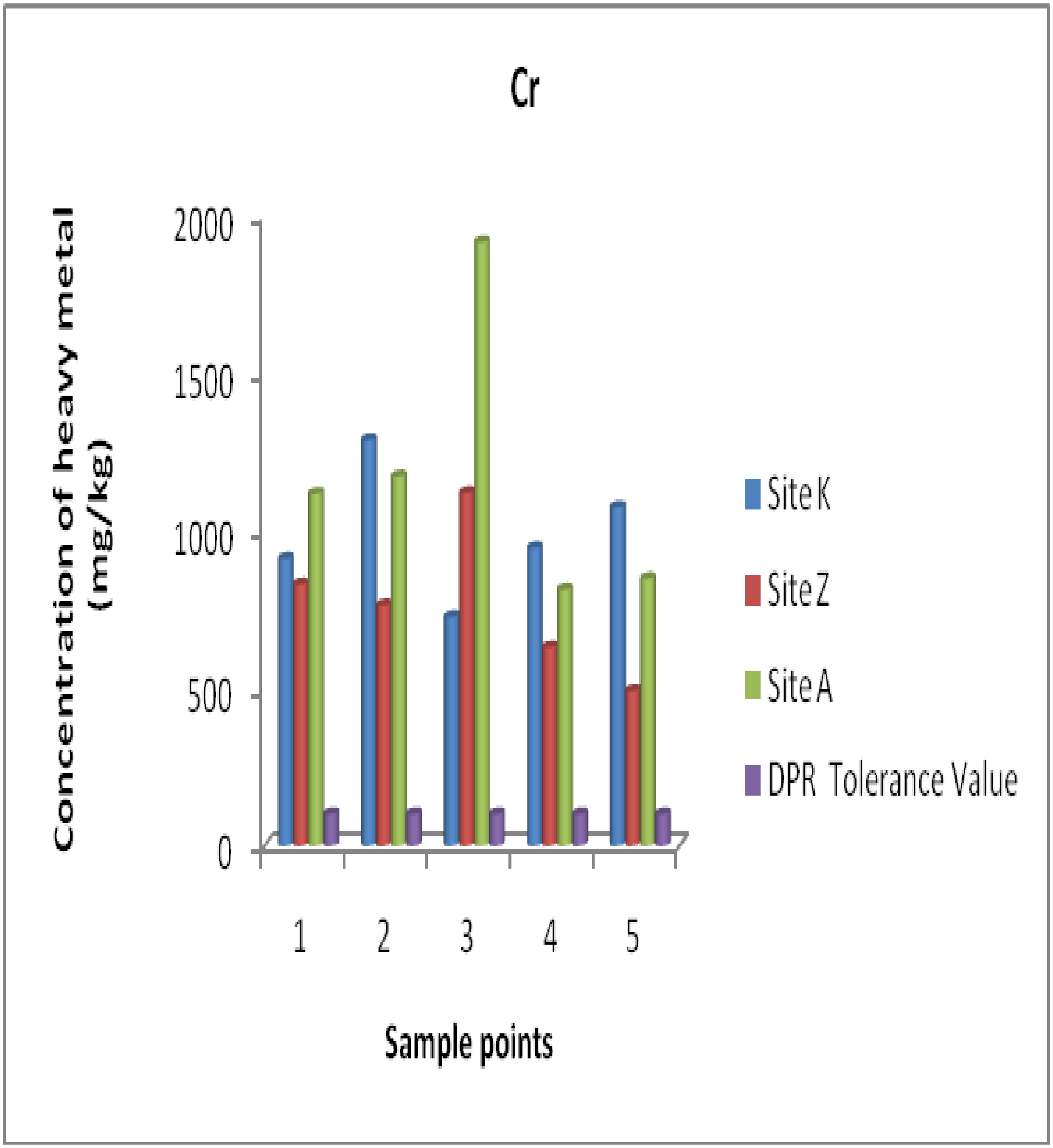


Fig 14: Graph showing comparison of DPR Background value of [Cr] with soil samples from the three investigated Mechanic Villages in Abuja.

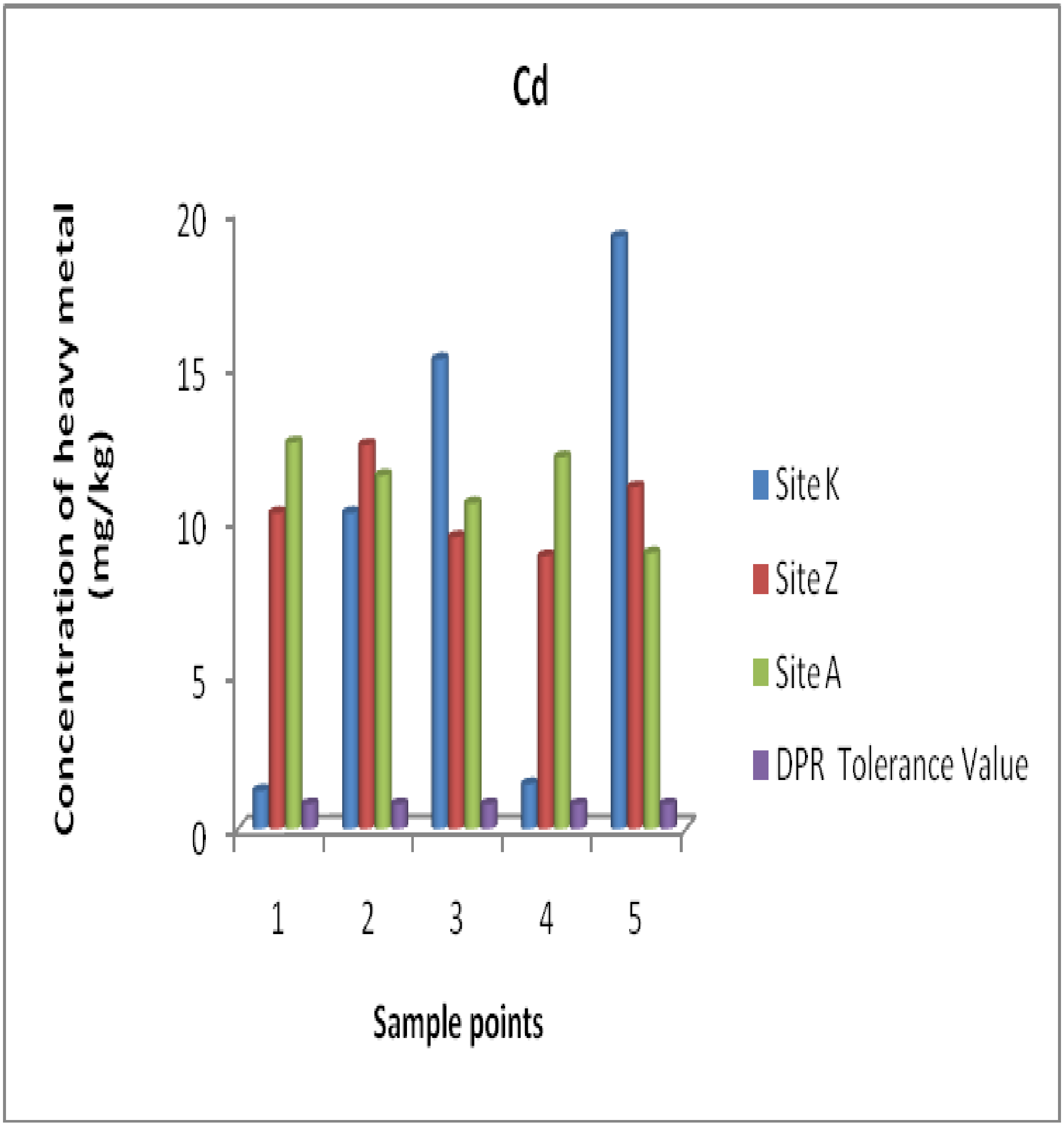


Fig 15: Graph showing comparison of DPR Background value of [Cd] with soil samples from the three investigated Mechanic Villages in Abuja.

Table 9 Levels of Fe (mg/Kg) in different sub–layers of the soils in three major Mechanic Villages in Abuja

S/N	Depth of Site K (cm)			Depth of Site Z (cm)			Depth of Site A (cm)		
	0 -5	6 -10	11 -15	0 -5	6 -10	11 -15	0 -5	6 - 10	11-15
S_1	120.86	55.45	26.81	179.48	82.35	39.81	334.03	155.26	72.10
S_2	190.49	87.40	42.26	196.79	90.29	43.66	253.73	116.41	56.28
S_3	154.36	70.82	34.24	115.80	53.14	25.69	251.62	115.45	55.82
S_4	86.25	40.57	18.13	182.15	84.57	34.41	245.34	112.11	52.21
S_5	93.11	42.72	20.65	154.50	70.89	34.28	304.84	139.87	67.63
Range	86.25–190.49	40.57–87.40	18.13–42.26	115.80–196.79	53.14–90.29	25.69–43.66	245.34–334.03	112.11–155.26	52.21–72.10
$\bar{X}$	128.92	59.39	28.41	165.74	76.24	35.57	277.91	127.82	60.80
SD	43.43	19.77	9.93	31.79	14.72	6.78	39.41	18.89	8.56

Table 10 Levels of Zn (mg/Kg) in different sub–layers of the soil in the three major Mechanic Villages in Abuja

S/N	Depth of Site K (cm)			Depth of Site Z (cm)			Depth of Site A (cm)		
	0 -5	6 -10	11 -15	0 -5	6 -10	11 -15	0 -5	6 - 10	11 -15
S_1	1707.06	783.24	378.71	243.74	113.83	52.07	4879.12	223.91	1082.42
S_2	427.98	196.36	94.95	580.60	269.39	125.81	3146.18	1443.54	697.98
S_3	1199.28	550.26	266.06	600.77	275.65	133.28	5010.26	2298.83	1111.51
S_4	857.51	393.45	190.24	1017.63	466.91	225.76	503.97	234.23	108.80
S_5	529.25	242.83	117.41	1097.59	503.60	243.50	2406.60	1104.20	533.90
Range	427.98–1707.06	196.36–783.24	94.95–378.71	243.74–1097.59	113.83–503.60	52.07–243.50	503.97–5010.26	223.91–2298.83	108.80–1111.51
$\bar{X}$	944.22	433.23	209.47	708.07	325.88	156.08	3189.20	1060.90	706.92
SD	522.78	239.86	115.98	350.32	159.81	78.66	1870.61	875.31	416.07

Table 11 Levels of Cu (mg/Kg) in different sub–layers of the soil in the three major Mechanic Villages in Abuja

S/N	Depth of Site K (cm)			Depth of Site Z (cm)			Depth of Site A (cm)		
	0 -5	6 -10	11 -15	0 -5	6 -10	11 -15	0 -5	6 - 10	11 -15
S_1	1870.86	858.39	415.05	418.17	187.28	80.55	1017.58	457.71	201.31
S_2	242.10	111.08	53.71	218.84	95.82	36.33	13140.24	5991.11	2869.05
S_3	202.06	95.71	41.83	568.82	260.99	126.19	7633.85	3502.59	1693.56
S_4	605.12	277.64	134.24	219.38	96.07	36.45	130.54	59.89	28.96
S_5	192.31	83.65	30.44	129.17	59.27	35.79	961.16	441.00	213.23
Range	192.31–1870.86	83.65–858.39	30.44–415.05	129.17–568.82	59.27–260.99	35.79–126.19	130.54–13140.24	59.89–5991.11	28.96–2869.05
$\bar{X}$	622.49	285.29	135.05	310.88	139.89	63.06	4576.70	2090.50	1001.20
SD	718.55	329.94	161.75	178.82	82.57	40.18	5661.01	2584.52	1242.39

Table 12 Levels of Ni (mg/Kg) in different sub–layers of the soil in the three major Mechanic Villages in Abuja

S/N	**Depth of Site K (cm)**			**Depth of Site Z (cm)**			**Depth of Site A (cm)**		
	0 -5	6 -10	11 -15	0 -5	6 -10	11 -15	0 -5	6 - 10	11 -15
S_1	115.96	53.21	35.73	121.27	51.05	14.68	141.79	65.06	31.46
S_2	239.91	90.90	38.79	93.18	35.46	19.56	126.26	57.93	28.01
S_3	65.63	30.11	14.56	75.50	34.64	16.75	249.43	104.86	48.11
S_4	105.79	48.54	15.54	74.91	34.37	16.62	30.92	12.27	5.42
S_5	189.03	86.73	41.93	28.56	13.10	6.34	47.89	21.98	10.63
Range	65.63–239.91	30.11–90.90	14.56–41.93	28.56–121.27	13.10–51.05	6.34–19.56	30.92–249.43	12.27–104.86	5.42–48.11
$\bar{X}$	143.26	61.89	29.31	78.68	33.72	14.79	119.26	52.42	24.73
SD	70.02	20.09	13.21	33.51	13.51	5.03	87.18	37.01	17.13

Table 13 Levels of Pb (mg/Kg) in different sub–layers of the soil in the three major Mechanic Villages in Abuja.

S/N	Depth of Site K (cm)			Depth of Site Z (cm)			Depth of Site A (cm)		
	0 -5	6 -10	11-15	0 -5	6 -10	11-15	0 -5	6 -10	11-15
S_1	58.31	20.46	7.83	118.59	54.40	26.30	37.36	26.32	12.72
S_2	125.83	52.98	22.98	34.69	15.91	7.69	212.23	97.38	47.08
S_3	187.90	86.21	41.68	148.39	68.08	32.92	595.31	253.96	117.63
S_4	11.34	3.28	1.08	263.64	120.97	58.49	125.25	47.88	20.56
S_5	133.64	61.32	29.63	177.07	81.24	39.28	33.76	12.11	4.82
Range	11.34–187.90	3.28–86.21	1.08–41.68	34.69–263.64	15.91–120.97	7.69–58.49	33.76–595.31	12.11–253.96	4.82–117.63
$\bar{X}$	103.40	44.85	20.64	148.48	68.12	32.94	200.78	87.53	40.56
SD	69.04	33.06	16.40	83.55	38.34	18.54	232.43	98.49	45.92

Table 14 Levels of Cr (mg/Kg) in different sub–layers of the soil in the three major mechanic villages in Abuja

S/N	Depth of Site K (cm)			Depth of Site Z (cm)			Depth of Site A (cm)		
	0 -5	6 -10	11-15	0 -5	6 -10	11-15	0 -5	6 -10	11-15
S_1	541.98	248.68	120.24	493.73	226.54	109.53	684.38	304.91	127.31
S_2	171.06	78.49	37.95	474.40	198.49	90.81	708.05	320.28	144.86
S_3	431.91	198.17	95.82	696.28	285.71	137.81	1139.90	523.01	252.89
S_4	562.10	247.90	134.70	374.61	171.88	83.11	494.15	212.14	107.41
S_5	649.03	283.20	141.76	302.26	134.09	54.84	524.50	231.47	101.93
Range	171.06–649.03	78.49–283.20	37.95–141.76	302.26–696.28	134.09–285.71	54.84–137.81	494.15–1139.90	212.14–523.01	101.93–252.89
$\bar{X}$	471.22	211.29	106.09	468.26	203.34	95.22	710.20	318.36	146.88
SD	184.75	80.18	41.95	149.17	57.30	30.88	258.10	123.39	61.65

Table 15 Levels of Cd (mg/Kg) in different sub–layers of the soil in the three major mechanic villages in Abuja

S/N	Depth of Site K (cm)			Depth of Site Z (cm)			Depth of Site A (cm)		
	0 -5	6 -10	11 -15	0 -5	6 -10	11 -15	0 -5	6 - 10	11 -15
S_1	0.73	0.33	0.16	7.09	2.29	0.85	8.46	3.42	1.15
S_2	6.09	2.79	1.35	7.41	3.40	1.64	6.82	3.13	1.51
S_3	9.06	4.66	1.51	5.63	2.58	1.17	6.28	2.88	0.89
S_4	8.60	3.96	1.91	5.26	2.41	1.17	7.17	3.29	1.59
S_5	11.42	5.24	2.53	6.59	3.03	1.46	5.32	2.44	1.18
Range	0.73–11.42	0.33–5.24	0.16–2.53	5.26–7.41	2.29–3.40	0.85–1.64	5.32–8.46	2.44–3.42	0.89–1.59
$\bar{X}$	7.18	3.39	1.49	6.39	2.74	1.26	6.81	3.03	1.26
SD	4.07	1.94	0.87	0.93	0.46	0.3	1.16	0.39	0.29