

**LEVELS OF POLYCYCLIC AROMATIC HYDROCARBONS AND HEAVY
METALS IN SURFACE SOIL AT AUTO-MECHANIC WORKSHOPS WITHIN
THE ACCRA METROPOLIS, GHANA**

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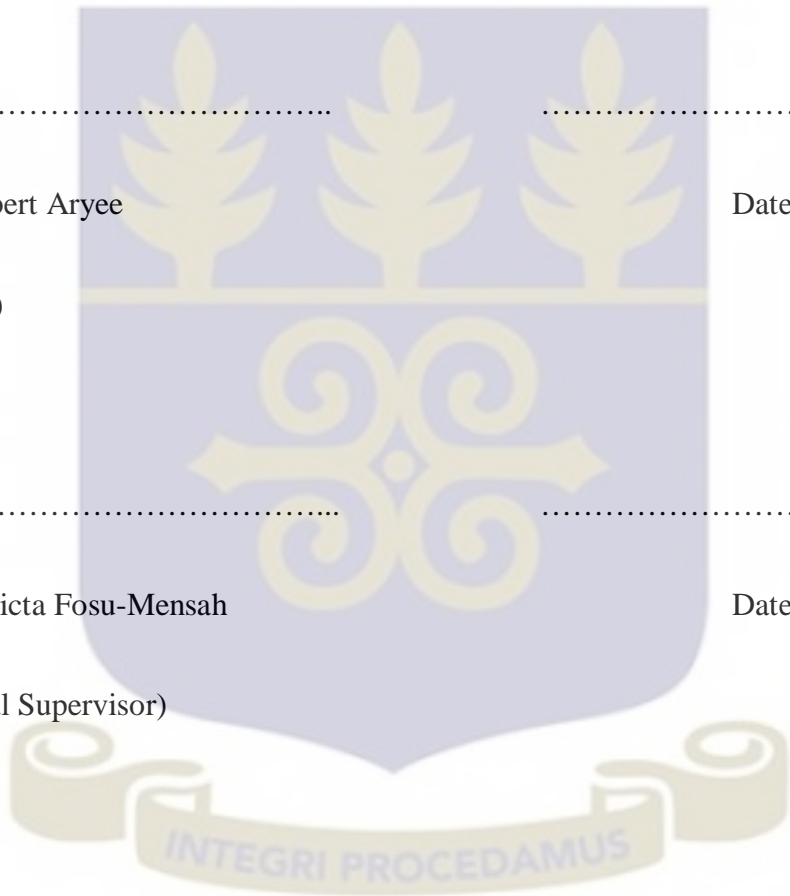
**THIS THESIS IS SUBMITTED TO THE UNIVERSITY OF GHANA, LEGON IN
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DECLARATION

I hereby declare that except for references of other people's work which have been cited and duly acknowledged, this work is the result of my own research and initiative conducted under supervision, and that this thesis has neither in whole nor in part been presented for an award of a degree elsewhere.



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ABSTRACT

This study investigated the concentrations of Polycyclic aromatic hydrocarbons (PAHs) and five selected heavy metals (Pb, Cd, Ni, Zn and Cu) in water and soil at some selected auto-mechanic shops within the Accra Metropolis. In all 57 soil samples and 36 water samples were collected between December 2015 and February 2016 from eighteen (18) selected auto-mechanic workshops, three (3) hand-dug wells and two (2) control sites. The samples were extracted and analyzed for PAHs (naphthalene, acenaphthalene, acenaphthene, fluorene, phenanthrene, anthracene, fluoranthene, pyrene, benzo (a) anthracene, chrysene, benzo (b) flouranthene, benzo (k) fluoranthene, benzo (a) pyrene, indeno (1,2,3-c,d) pyrene, dibenzo (a,h) anthracene, benzo (g,h,i) perylene) and heavy metals (Pb, Cd, Ni, Zn and Cu) using the Gas chromatography equipped with combiPal autosampler and Ni electron capture detector (ECD) and the Atomic Absorption Spectroscopy (AAS) respectively. Physicochemical properties of soil and water were determined to evaluate the quality of soil and drinking water. In addition, two hundred and thirty (230) respondents (made up of 150 auto-mechanics and 80 household' representatives) were randomly selected and interviewed using a structured questionnaire. Information on knowledge of chemical hazards, occupational habits and health related risks associated with handling of used engine oil were sought. The results obtained showed that soil and water samples analyzed from the various sites recorded concentrations of PAHs below 0.01 $\mu\text{g/g}$ and 0.01 $\mu\text{g/L}$ detection limit respectively. The ranges of heavy metal concentration in water samples analyzed were: <0.001 – 0.03 mg/L for Cu, <0.001 – 0.21 mg/L for Pb, <0.002 mg/L for Cd, <0.001 – 0.03 mg/L for Ni and <0.001 – 0.08 mg/L for Zn The mean concentrations of metals in soil samples were in the

ranges Pb (33.03 – 150.26 mg/kg), Cd (<0.002 – 0.29 mg/kg), Ni (34.02 – 87.59 mg/kg), Cu (58.40 – 102.07 mg/kg), Zn (63.92 – 187.92 mg/kg). Similarly the results of physicochemical analysis of water samples from wells over the study period were in the ranges; pH (6.17 – 6.87), temperature (27.8 – 29.8 °C), EC (106.20 – 172.60 μ S/cm), turbidity (0.56 – 0.71 NTU), alkalinity (72.6 – 150.83 mgCaCO₃/L), TH (244.0 – 610.2 mgCaCO₃/L), TDS (64.10 – 103.40 mg/L). In addition results of physicochemical analysis of soil samples were in the ranges; pH (6.31 – 8.68), CEC (4.08 – 16.32 cmol/kg), %OM (6.05 - 15.30%), EC (103 – 1065 μ S/cm). The survey showed that majority of auto-mechanics were aware of the health risks associated with handling of used engine oils however only 50.7% of artisans use full Personal Protective Equipment (PPE) when working. Safety and hygienic practices among artisans were generally low. Household's also indicated their unhappiness about the siting and activities of auto-mechanics in residential areas but added that they are unable to do anything about it as they perceived it is the responsibility of the government to regulate the activities of auto-mechanics. Due to the adverse effect of heavy metals on human health it is recommended that there is regularly training for these artisans to minimize their exposure to these chemicals.

DEDICATION

I dedicate this thesis to the Almighty God for His providence throughout my studies and to my parents for their love and support.



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Finally to my colleagues: Azantilow, Myers, Carl, Fahad, Emma, Thelma, Lois and Jemima (Mama G), my buddies Mustapha Quayson and Amoako Ofori and to all who in diverse ways have helped me and contributed to the successful completion of this course, may grace and favour locate you.

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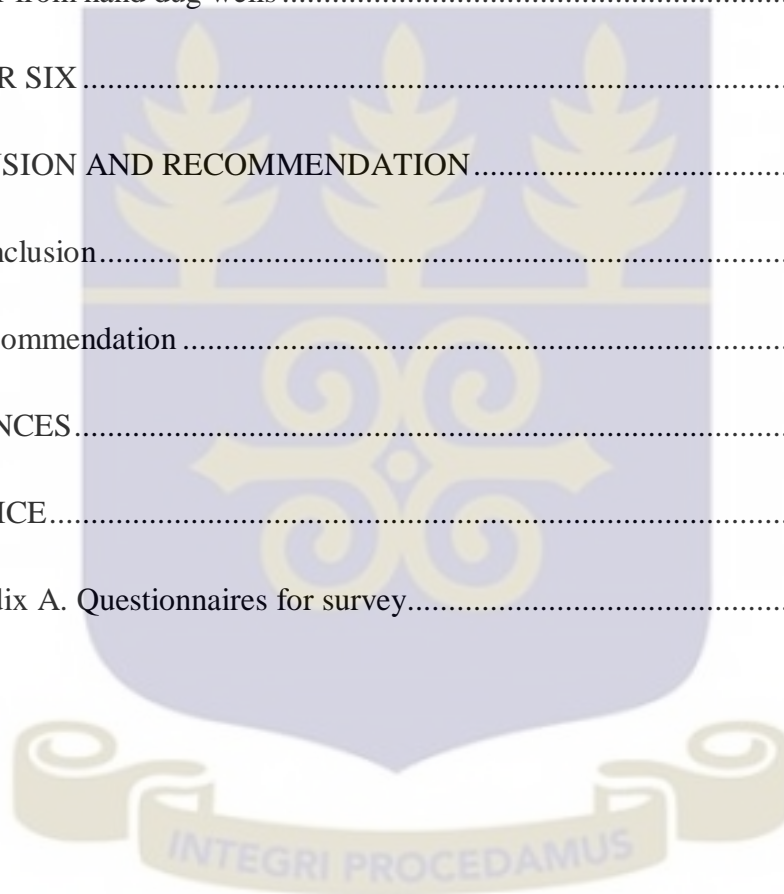
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LIST OF ABBREVIATIONS

Cd	Cadmium
Pb	Lead
CEC	Cation exchange capacity
WHO	World Health Organization
IAEA	International Atomic Energy Agency
AAS	Atomic Absorption Spectroscopy
GC	Gas Chromatography
PAH	Polycyclic Aromatic Hydrocarbons
PPE	Personal Protective Equipment
Ni	Nickel
Zn	Zinc
Cu	Copper
EC	Electrical conductivity
ANOVA	Analysis of Variance
LSD	Least significant difference

CHAPTER ONE

INTRODUCTION

1.1 Background to study

In recent years there has been an increase in the amount of waste generated across the globe partly as a result of urbanization and population growth. Studies have shown that the activities of artisans in the automobile industry (which include mechanics, welders and sprayers) generate varieties of waste such as used engine oil (American Chemical Society, 2004).

Used engine oil, which is popularly referred to as “dirty oil” among local artisans is usually obtained after servicing and subsequently draining from automobile engines. This is made up of a mixture of different chemicals including petroleum hydrocarbons, chlorinated biphenyls, chlorodibenzofurans, additives, decomposition products and heavy metals that come from engine parts as they wear away (Wang *et al.*, 2000).

According to Alloway and Ayres (1997), the chemicals found in used engine oil vary according to the brands and types of engine used, the mechanical condition of the engine that it comes from, the sources (automobile, airplanes, trains, ships, tractors or lawn mowers) and the mileage driven between oil changes. Studies have shown that used oil is less viscous than unused oil; and when disposed off into the soil, it adsorbs to the soil particles, reducing porosity and therefore reduces aeration of soil (Alloway and Ayres, 1997; Shukry *et al.*, 2013). Pollution of the soil with used engine oil leads to a buildup of metals in the soil and the eventual translocation into plant tissues such as leaves (Vwioko *et al.*, 2006). Olugboji and Ogunwole (2008) found that used engine oil easily migrates

into the environment and eventually seeps into water bodies. Waste oil has severe adverse environmental and health impacts and is more toxic than virgin oil due to the presence of degraded additives and other contaminants (UNEP, 2013).

Heavy metals are defined as metallic elements that have high density, specific gravity or atomic weight. Although heavy metals are naturally occurring elements that are found throughout the earth's crust, most environmental contamination and human exposure result from anthropogenic activities such as mining and industrial production. Reported sources of heavy metals in the environment include geogenic, industrial, agricultural, pharmaceutical, domestic effluents, and atmospheric sources (He *et al.*, 2005).

Heavy metals can be toxic; their toxicity depends on several factors including the dose, route of exposure, and chemical species, as well as the age, gender, genetics, and nutritional status of exposed individuals. Because of their high degree of toxicity, arsenic, cadmium, chromium, lead, and mercury rank among the priority metals that are of public health significance (ATSDR, 2015). These metallic elements are considered systemic toxicants that are known to induce multiple organ damage, even at lower levels of exposure (Ali, 2013). According to the U.S. Environmental Protection Agency, and the International Agency for Research on Cancer, water sources (groundwater, lakes, streams and rivers) can be polluted by heavy metals leaching from industrial and consumer waste. Heavy metals, such as Pb, Zn, Cu, Cr, Ni and Cd have been found to be contained in used engine oil in appreciable amounts (Vazquez-Duhalt, 1989; Zali *et al.*, 2015).

Another major pollutant found in used engine oil in appreciable quantities is polycyclic aromatic hydrocarbons (PAHs). PAHs represent a group of chemical compounds that are

formed during the incomplete combustion of coal, oil, gas, wood, garbage, or other organic substances, such as tobacco and charbroiled meat. PAHs can either be synthetic or occur naturally (found in the air, water and soil) (Voulvoulis *et al.*, 2015)

There are more than 100 different PAH compounds with varying levels of toxicity. PAHs that contain up to four benzene rings are known as light PAHs (l-PAHs) and those containing more than four benzene rings are known as heavy PAHs (h-PAHs). The h-PAHs are known to be more stable and toxic than the l-PAHs (ATSDR, 1994). PAHs have low solubility in water but are highly lipophilic. In water or when adsorbed on particulate matter, PAHs can undergo photodecomposition in the presence of ultraviolet light from solar radiation. In the atmosphere, PAHs can react with ozone, nitrogen-oxides and sulphur dioxide to give diones, nitro- and dinitro-PAHs, and sulphonic acids, respectively (Srogi, 2007; Tham *et al.*, 2008).

Although PAHs are described as carcinogenic, only the following are considered as possible human or animal carcinogens: benz(a)anthracene, benzo(a)pyrene, benzo(b)fluoranthene, benzo(k)fluoranthene, chrysene, dibenz (a,h)anthracene, indeno(1,2,3-cd)pyrene (ATSDR, 1995). Humans may be exposed to these compounds by inhalation of the compounds in tobacco smoke and contaminated air, as well as ingestion of contaminated food. Populations living in the vicinity of hazardous waste sites may be at greater risk of potential exposure to PAHs than the general population through inhalation, ingestion and direct contact with contaminated media (ATSDR, 1995)

1.2 Problem Statement

In recent times, concerns have been raised regarding the activities of automobile mechanics in Darkuman, a suburb of Accra, Ghana. A survey of Darkuman indicates that apart from Kokompe (A well-known spare parts market) there are several other automobile workshops scattered all over the town from which used engine oils, lubricating oils and other solvents containing petroleum hydrocarbons are indiscriminately dumped or spilled on every available space by artisans in the business of auto-repairs. The number of mechanic shops in Darkuman has increased in recent years owing to the fact that there has been an upsurge in the number of vehicles in recent times. These vehicles as well as other machine parts require servicing when they develop a fault. Though there are well established companies in this business such as Mechanical Lloyd and Japan Motors, some people cannot afford their services resulting in high demand for the services of these local artisans who deal in the sale of spare parts and servicing. Each of these workshops usually hosts a variety of artisans such as mechanics, welders, auto-electricians, sprayers and vulcanisers. The activities at the mechanic workshop generate wide varieties of wastes that are indiscriminately dumped on soils thereby contaminating the soil and underground water and its environs. While these waste substances could contain hazardous chemicals such as PAHs and heavy metals which can be deleterious to humans even at low concentrations, the levels of these contaminants are not known. In addition, these contaminants have the potential of getting into water sources through infiltration and runoff. Hand dug wells popularly referred to as “bura” in the community are of great service to the inhabitants especially when there is disruption in water supply from the Ghana Water Company Ltd. Inhabitants use water

from these sources for various purposes such as in their domestic and economic activities. In addition to their toxicity and health effects, several of these chemicals present in these motor repair workshops (e.g. petrol and solvents) are flammable. The present study would therefore advance the evidence base and make significant contribution to understanding the levels and effect of discharge of used engine oil on the environment.

1.3 Justification

Darkuman in recent times has become a hub for artisans in the business of auto repairs and sale of spare parts. The siting of workshops in this town is largely unregulated and as a result they are located haphazardly around street corners and directly in front of residential houses. The activities of these artisans generate various kinds of waste of which they indiscriminately dispose them off onto the soil and every available space. This exposes residents directly to soil contaminants. According to Odjegba and Sadiq (2002), used engine oils pose environmental threat to the health of humans found in such environment.

Heavy metals, such as Pb, Zn, Cu, Cr, Ni and Cd, and PAHs such as benzo[a]pyrene, (which is known for its carcinogenicity) have been found to be contained in used engine oil in appreciable amounts (Vazquez-Duhalt, 1989).

These contaminants have been of interest to researchers in recent years. PAHs found in used engine oils are of concern because they are persistent and can stay in the environment for long periods of time due to their inability to burn easily. They are also known to be carcinogenic and mutagenic in humans hence their presence in the environment even in minute concentrations is a cause for concern.

Heavy metals have also been shown to persist for a long time in the environment because they are non-degradable and therefore can be translocated to different components affecting the biota (Obodai *et al.*, 2011; Rajaganapathy *et al.*, 2011). The persistence of heavy metals can result in bioaccumulation and biomagnifications causing heavier exposure for some organisms than is present in the environment alone (Adelekan and Abegunde, 2011). The toxicity of heavy metals is one of the major current environmental health concerns and potentially dangerous because of bio-accumulation through the food chain (Rajaganapathy *et al.*, 2011). The presence of heavy metals in water degrades their quality, which eventually affects human health (Rajaganapathy *et al.*, 2011). Due to the high level of contamination of the soil with used engine oils as a result of the activities of mechanics and local spare parts dealers, there is the need to research the impact of these activities on the environment in order to create awareness on the hazards of exposure to these oils and environmental impacts (soil and water) of these oils. The research also seeks to help agencies such as the Environmental Protection Agency (EPA) to formulate policies to regulate the activities of these artisans and also create a useful database for effective monitoring of PAH emissions and the release of heavy metals into the environment from used engine oils.

Darkuman was selected as the study area because there are relatively many auto mechanic workshops in that town. Results obtained from this study will therefore provide substantive and accurate information to draw relevant conclusion and make appropriate recommendations.

1.4 Aim

To determine the concentrations of PAHs and heavy metals (Cu, Cd, Zn, Ni, Pb) in surface soil and water (from hand-dug wells) at auto mechanic shops in Darkuman within the Accra metropolis.

1.5 Objectives

- i. To determine physicochemical properties of soil (organic matter content, pH, electrical conductivity and cation exchange capacity) and water samples (turbidity, total dissolved solids, pH, electrical conductivity, colour and total hardness) collected from various auto-mechanic shops in Darkuman.
- ii. To study the distribution of the metals and PAHs in the soil and assess the extent of contamination of the soil using indices of pollution.
- iii. Assess the level of knowledge and perception of artisans and residents respondents on hazards associated with waste engine oils.



CHAPTER TWO

LITERATURE REVIEW

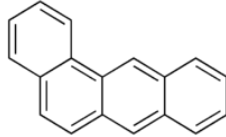
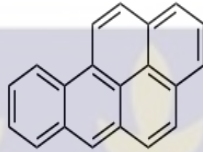
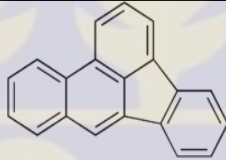
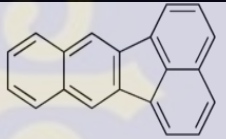
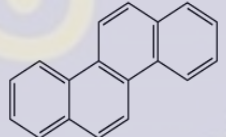
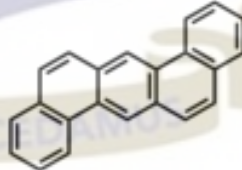
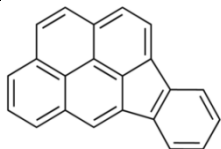
2.1 Polycyclic Aromatic Hydrocarbons (PAHs)

Polycyclic aromatic hydrocarbons (PAHs) are a large group of organic compounds that are made up of two or more fused aromatic rings. PAHs are weakly volatile and dissolve weakly in water- the solubility decreases with an increase of the number of aromatic rings (Moeckel *et al.*, 2013). PAHs dissolve well in organic solvents and are lipophylic. All PAHs are solid and have high melting and boiling points. PAHs are chemically inactive but bond to particulate matter when adsorbed at the surface of dust. They belong to the group of persistent organic pollutants (POPs). These are organic contaminants that are resistant to degradation, can remain in the environment for long periods, and have the potential to cause adverse environmental effects (Zhao *et al.*, 2014).

Due to their relative chemical stability and resistance to biodegradation, PAHs can remain in the environment for longer periods once released into the environment. Reports have shown that exposure of human body to the environment containing PAHs may induce some fatal diseases such as lung and skin cancers (Wang *et al.*, 2013). PAHs have been extensively researched into because of their carcinogenicity and mutagenicity in animals (Anyakora *et al.*, 2006). In 2015, PAHs ranked 9th on the list of most threatening compounds to human health (Agency for Toxic Substances and Disease Registry (ATSDR, 2015).

Table 1 below shows the name, acronym, chemical structure and molecular mass of some PAHs that are considered as possible human or animal carcinogens (Kim, 2013).

Table 2.1 Names and chemical structures of some PAHs

Name	Acronym	Chemical Structure	Molecular mass
Benz(a)anthracene	BaA		228
Benzo(a)pyrene	BaP		252
Benzo (b)fluoranthene	BbF		252
Benzo(k)fluoranthene	BkF		252
Chrysene	CHR		228
Dibenz(a,h)anthracene	DhA		278
Indeno(1,2,3-cd)pyrene	IcP		276

2.2 Naming of PAHs

The nomenclature of PAHs and their derivatives has undergone substantial changes over the last century. The most common recommended nomenclature is the International Union of Pure and Applied Chemistry's (IUPAC) nomenclature. The IUPAC nomenclature uses trivial and semi-trivial name systems for naming a set of parent compounds. The naming strategy for a PAH follows several steps: Structures are typically oriented such that (i) the greatest number of rings in a row are aligned horizontally, (ii) the maximum number of rings is positioned in the upper right quadrant and (iii) the least number of rings is positioned in the lower left quadrant. Numbering begins with the uppermost ring the furthest to the right; the most counterclockwise carbon atom is not involved with ring fusion. The numbering proceeds clockwise around the structure with hydrogenated carbon atoms. The numbering of anthracene and phenanthrene are 'retained exceptions' to this rule. Numbering of atoms engaged in ring fusion are given letters, such as *a*, *b* and *c*, after the number of the preceding atom. If multiple identical ring substituents are added they are labeled with "di", "tri", "tetra", etc. before the substituent name to indicate their multiplicity. Figure 2.1 shows examples of how PAHs are named according to IUPAC.

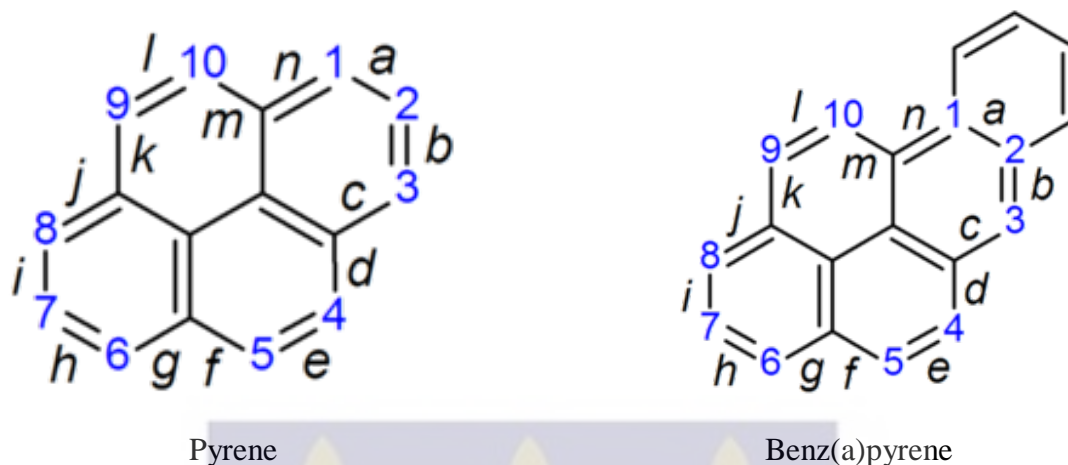


Figure 2.1 Examples showing IUPAC's nomenclature of PAHs

2.3 Classification of PAHs

Polycyclic aromatic hydrocarbons have been classified in two classes: *peri* and cata-condensed PAHs. Peri-condensed PAHs can be defined as those systems whose graph, or lines which connect the ring centers, form cycles. They have rings that are connected to each other by more than one face and also have carbon atoms that are not on the periphery of the molecule. Peri-condensed PAHs are the most thermodynamically stable class of PAH therefore the most commonly found PAHs. These can be subdivided into alternant and non alternant PAHs. Alternant PAHs are commonly fused aromatic ring systems which contain only benzoid (six-membered rings) and fused-benzoid rings; these include the arenes and phenes and linear molecules, such as biphenyl and terphenyl. In molecules of this type, the conjugated atoms can be divided into two groups, such that each atom is directly linked only to atoms of the opposite group. Conjugate molecules of this type are readily dealt with by the pertubational orbital theory. Examples of alternant PAHs are Chrysene and Benz(a)anthracene.

Non-alternant PAHs on the other hand contain odd-membered rings and not amenable to treatment by the simple perturbational molecular orbital method. Examples of non-alternant PAHs are fluoranthene and fluorene. . Examples of alternant and non alternant PAHs are shown in figure 2.2 and figure 2.3 respectively.

Cata condensed PAHs can be defined as those systems whose graphs do not form cycle. This can further be classified as branched or not branched, the former being thermodynamically more stable and chemically less reactive than non branched systems of the same size. Cata-condensed PAHs are always alternant systems.



Chrysene

Benz(a)anthracene

Figure 2.2 Examples of alternant PAH



Floranthene

Flourene

Figure 2.3 Examples of non-alternant PAH

2.4 Sources of PAHs in the environment

Polycyclic aromatic hydrocarbons (PAHs) are ubiquitous in nature as a consequence of synthesis in terrestrial vegetation, microbial synthesis, and volcanic activity. It has been shown that quantities formed by these natural processes are small in comparison with those produced from forest and prairie fires and anthropogenic sources. Most PAHs released to the environment are emitted to the atmosphere. Anthropogenic sources of PAHs such as the burning of common fuels, such as coal, oil, gas, and wood, and other organic materials, such as garbage, tobacco, and grilled meat have been shown to release significantly more PAHs than natural sources such as volcanic eruptions (Zhao *et al.*, 2014).

PAHs are mainly derived from anthropogenic activities related to pyrolysis and incomplete combustion of organic matter. Emission sources of PAHs affect their characterization and distribution, as well as their toxicity. As reported by Lee (2010), the major sources of PAH emissions may be divided into four classes: stationary sources (including domestic and industrial sources), mobile emissions, agriculture activities, and natural sources.

2.5 Environmental fate processes

Studies have been carried out on PAHs due to their ubiquitous nature in the environment. This is partly because they are transported over long distances without significant degradation. PAHs are sparingly soluble in water but an affinity for sediment, soil, and biota (Moeckel *et al.*, 2013).

As cited in the Canadian soil quality guideline for potentially carcinogenic PAHs (CCME, 2010), PAH compounds are generally found adsorbed to particulate matter when found in air and water. Thus, although most PAHs are emitted to the atmosphere, sediments and soils are the major environmental sinks for these compounds. In addition to direct deposition to soils, PAHs can be deposited onto or absorbed by plants, from which they can be washed by rain, oxidized, or be deposited into soil as a result of plant decay. Removal of PAHs from the environment is normally associated with biodegradation or photodegradation processes. The rates of degradation vary and generally decrease with increasing numbers of aromatic rings (Zhang *et al.*, 2015).

2.6 Exposure routes in man

Polycyclic aromatic hydrocarbons can have deleterious effect on humans when they are exposed. Due to this, several researches have been carried out to ascertain its routes of exposure in humans. Studies have shown that humans are exposed to PAHs via air and drinking water, but mostly by intake of food (Ding *et al.*, 2013).

In ambient air, human beings are exposed to PAH vapor or PAHs contained in dust and other particulate matter outdoors or indoors at the home or workplace. Sources of human exposure to PAHs include cigarette smoke, vehicle exhaust, residential heating, agriculture burning, waste incineration, and emissions from industrial processes. According to the United States Agency for Toxic Substances and Disease Registry (ATSDR, 2015), main exposures of the U.S. population to PAHs include the inhalation of tobacco smoke, wood smoke, and ambient air with PAHs from traffic emissions and consumption of food containing PAHs.

Predominant sources of PAH pollution at home include residential heating, tobacco smoking, and cooking. Vehicle emissions are also main sources of PAHs in many cities. Intake of PAHs from contaminated soil may occur via ingestion, inhalation or dermal (skin) exposure to contaminated soil/dust.

According to Xia et al., (2013), people who live or work in the vicinity of an active or inactive facility that recycles used mineral-based crankcase oil may either breathe fumes found near the facility or come in contact with contaminated soil, sludge, or sediment.

2.7 Occurrence of PAHs

2.7.1 Occurrence of PAHs in water

As cited in the Canadian soil quality guidelines' document (CCME, 2010), researchers have shown that the sources of PAHs that enter water and soil are varied and may include

- ✓ Dispersion from creosoted materials
- ✓ Accidental oil spills;
- ✓ Precipitation and atmospheric deposition;
- ✓ Industrial processes (creosote, coal tar, asphalt, land-farming)
- ✓ Municipal effluents; and
- ✓ Disposal (burial) of wastes containing PAHs

Leaching through soil and surface run-offs have been observed to be the major ways through which polycyclic aromatic hydrocarbons reach groundwater, fresh and marine surface waters (Hu *et al.*, 2016). The concentrations of PAHs in water according to a report by the ATSDR (1994) tend to be low (around 100 ng/L) due to their weak solubility. Research carried out by Dhananjayan and Muralidharan (2012) to investigate

the occurrence of PAH in water and sediments along harbor line, Mumbai, India, showed that the mean total concentrations of 15 PAHs (Σ PAHs) in water ranged from 8.66 $\mu\text{g/L}$ to 46.74 $\mu\text{g/L}$ with the highest concentration of 104.07 $\mu\text{g/L}$ being recorded at the site where oil intrusion was clearly visible. A concentration of 66.74 $\mu\text{g/L}$ was also recorded at a site close to a sewage outlet.

Fluoranthene (FA), phenanthrene, pyrene (PY), and anthracene are the PAHs detected in high concentrations in drinking water. Of the six PAHs usually measured in water for regulatory purposes, FA is the only PAH that is detected to any significant extent. Some PAHs are known carcinogens, but many of these have not been measured in drinking-water, have not been detected in drinking-water (e.g. dibenzo[*a,e*]pyrene, dibenzo[*a,h*]pyrene, chrysene), or have been found in relatively low concentrations in drinking-water (WHO, 2003)

2.7.2 Occurrence of PAHs in soil

PAHs are found in all surface soils as a result of natural processes and also due to it acting as a sink for anthropogenic sources of PAHs. Due to anthropogenic activities being the main sources of PAHs, researches have been carried out in urban and metropolitan areas to ascertain the levels of PAHs in their soils (Teaf 2008; Wang *et al.*, 2013; Peng *et al.*, 2011). Metropolitan areas have higher PAH concentrations than forest and agricultural areas because of the many sources of fossil fuel combustion. Hung *et al.*, (2015) reported that the majority of urban soil concentrations fall in the 600– 3000 $\mu\text{g/kg}$ range with expectant higher values near areas of heavy transportation and industrialization.

PAHs have been shown to adsorb strongly to the organic fraction of soils and also not to penetrate deeply into most soils, therefore limiting both leaching to groundwater and availability for uptake by plants (Ahangar, 2010; Owabor *et al.*, 2010). A research carried out by Bortey-Sam *et al.*, (2014) to determine the concentration of PAHs in the surface soils of 36 communities within the Kumasi Metropolitan Assembly (KMA) showed that the mean concentrations of total PAHs in the soil samples ranged from 14.78 at Ahinsan to 2084 ng/g (dw) at Adum, with a mean value 442.5 ± 527.2 ng/g (dw). The mean concentrations of BaP in soil samples from the communities ranged from 0.5939 ± 0.3284 (Ahinsan) to 259.5 ± 38.37 ng/g (dw). However, the mean value of BaP throughout the 36 communities was 32.59 ± 51.90 ng/g (dw).

The concentrations of PAH in soil contaminated with used engine oil in some communities have also been measured. Studies by Obini *et al.*, (2013) to determine the levels of polycyclic aromatic hydrocarbons in soil contaminated with spent motor Engine oil in Abakaliki Auto-Mechanic Village in Nigeria showed that the highest total concentrations of PAHs in the studied area to be 0.1385 ± 0.2 mg/Kg. The results also showed that phenanthrene and benzo[b]fluoranthene PAHs constituted the largest group of compounds with high concentrations in a typical soil sample contaminated with used engine oils, with the low molecular weight phenanthrene being more dominant with relatively lower concentrations compared to benzo[b]fluoranthene.

2.8 Toxicity of PAHs in humans

Human exposure to PAHs has been associated with an increased risk of developing cancer in a variety of tissues, including the lung, bladder, stomach, and skin (including the scrotum), depending on the mode of exposure and the form of PAH. Excess

incidences of lung cancer have been associated with PAH exposure in a variety of occupational settings, including coal gasification, coke production, paving and roofing, and various occupations involving exposure to creosote or soot (IARC, 2006).

The toxicity of PAHs is structurally dependent, with isomers (PAHs with the same formula and number of rings) varying from being nontoxic to being extremely toxic. Benzo[*a*]pyrene, is notable for being the first chemical carcinogen to be discovered (and is one of many carcinogens found in cigarette smoke). The ATSDR has classified seven PAH compounds as probable human carcinogens: benzo[*a*]anthracene, benzo[*a*]pyrene, benzo[*b*]fluoranthene, benzo[*k*]fluoranthene, chrysene, dibenz(ah)anthracene, and indeno(1,2,3-*cd*)pyrene.

PAHs known for their carcinogenic, mutagenic and teratogenic properties are benzo[*a*]anthracene and chrysene, benzo[*b*]fluoranthene, benzo[*j*]fluoranthene, benzo[*k*]fluoranthene, benzo[*a*]pyrene, benzo[*ghi*]perylene, coronene, dibenz(ah)anthracene (C₂₀H₁₄), indeno(1,2,3-*cd*)pyrene (C₂₂H₁₂) and ovalene. (WHO, 2000).

Benzo [a] pyrene (BaP) has been the most extensively studied PAH and is the usual marker for carcinogenic levels of PAHs in environmental studies. However uncertainties about the suitability of BaP as a cancer risk indicator have also been discussed (Bostrom *et al.*, 2002).

2.9 Analytical Methods

PAH are extracted using different techniques prior to clean up and purification. Solvent extraction techniques include Soxhlet, Ultrasonication, Mechanical shaking and

Supercritical Fluid Extraction (SFE). Though each of these extraction techniques has its own advantages, the choice of extraction according to Banjoo and Nelson (2005), depends on factors such as operating cost, simplicity of operation and the sample matrix. The USEPA recommends the Soxhlet extraction method as the standard method for extracting semi-volatile and non-volatile organics from solid matrices because it is an easily standardized technique with high recoveries as compared to the other techniques. This procedure however is cumbersome as it requires large amounts of organic solvents, longer extraction time and a higher probability of labile compounds being degraded.

The Solid Phase Extraction technique (SPE) is used when analyzing PAHs in contaminated soil samples. This is due to the fact that there may be other components which may interfere with the determination of PAHs and also the inability of PAHs to be analyzed directly in the extraction solution due to their lower concentrations. SPE has been shown to be a faster, more cost-effective sample preparation method with dramatic time savings over many liquid/liquid extraction techniques (Simpson, 2000).

PAH are most often identified and quantified using either gas chromatography (GC) with flame ionization detection (FID) or coupled to mass spectrometry (MS) or high performance liquid chromatography (HPLC) with ultraviolet or fluorescence detection.

2.10 Heavy metals

Heavy metals are naturally occurring elements that are found throughout the earth's crust. Many different definitions have been proposed, some based on parameters such as density and toxicity. The term heavy metal may refer to any metallic chemical that has a relatively high density and is toxic at low concentrations. Although heavy metals are

naturally occurring elements that are found in the Earth's crust, most environmental contamination and human exposure result from anthropogenic activities such as mining and smelting operations, industrial production and use, and domestic and agricultural use of metals and metal-containing compounds (Herawati *et al.*, 2000 and He *et al.*, 2005),

2.10.1 Sources of heavy metals in the environment

Metals are naturally found in the environment (but rarely at toxic levels), especially in the Earth's crust, where they contribute to the balance of the planet (Obodai *et al.*, 2011). The most important sources of heavy metals in the environment are the anthropogenic activities such as mining, smelting procedures, steel and iron industry, chemical industry, traffic, agriculture as well as domestic activities (Herawati *et al.*, 2000 and He *et al.*, 2005). Contamination of the environment with heavy metals can also occur through metal corrosion, atmospheric deposition, soil erosion of metal ions and leaching of heavy metals, sediment re-suspension and metal evaporation from water resources to soil and ground water (Khan *et al.*, 2008). According to Shayley *et al.*, (2009), the distribution of contaminants released to soils by human activities is related to how and where they are added. Contaminants may be introduced into drinking water via runoff or leached from the soil into groundwater.

2.10.2 Heavy metal mobility

Metals do not normally travel downward from the soil surface to any great extent thereby will stay at the soil surface when added to the soil. Movement to groundwater, surface water, or the atmosphere is minimal as long as the retention capacity of the soil is not exceeded. Thus, when metals are introduced at the soil surface, downward transportation does not occur to any great extent unless the metal retention capacity of the soil is

overloaded, or metal interaction with the associated waste matrix enhances mobility (Morris & Jackson 2016).

At the same time, metals participate in chemical reactions with the soil solid phase. The concentration of metals in the soil solution, at any given time, is governed by a number of interrelated processes, including inorganic and organic complexation, oxidation/reduction reactions, precipitation/dissolution reactions, and adsorption/desorption reactions (Kabata-Pendias, 1993).

Metal mobility in the soil may be enhanced by changes in soil environmental conditions over time, such as the degradation of the organic waste matrix, changes in pH, redox potential, or soil solution composition, due to various remediation schemes or to natural weathering processes. Metals associated with the aqueous phase of soils are subject to movement with soil water, and may be transported through the vadose zone to groundwater. Metals, unlike the hazardous organics, cannot be degraded. However, some metals, such as Cr, can be transformed to other oxidation states in soil, reducing their mobility and toxicity (Kabata-Pendias, 1993)

Adsorption processes are also affected by the form of the metal added to the soil and by the solvent introduced along with the metal. These interactions can either increase or decrease the movement of metals in soil water. Soils with heavier textures and higher pH are effective in attenuating metals, while sandy soils and/or soils with low pH do not retain the metals effectively (McLean & Bledsoe, 1996).

2.11 Selected heavy metals

Some heavy metals are nutritionally essential for a healthy life whereas large amounts of any of them may cause acute or chronic toxicity (Coen *et al.*, 2001). However, some others (like As, Cd, Pb, and methylated forms of Hg) have been reported to have no known bio-importance in human biochemistry and physiology and consumption even at very low concentrations can be toxic (Jomova & Valko, 2010, Tokar *et al.*, 2011).

The activities of auto-mechanics generate waste products such as waste engine oils which are known to contain significant concentrations of Pb, Cd, As, Cu and Zn (Vazquez-Duhalt, 1989; Odoh *et al.*, 2011).

2.11.1 Lead

Lead is a bluish-white lustrous metal. It is very soft, highly malleable, ductile, and a relatively poor conductor of electricity. It is very resistant to corrosion but tarnishes upon exposure to air. Lead isotopes are the end products of each of the three series of naturally occurring radioactive elements (Lenntech, 2014). It has an atomic number of 82, density of 11.34 gcm^{-3} at 20°C , melting point of 327°C and a boiling point of 1755°C .

It has many beneficial uses in compounds as well as in its metallic form, but is toxic at almost any level in the body (Young, 2005). Lead is a major constituent of the lead-acid battery used extensively in car batteries. It is used as a coloring element in ceramic glazes, as projectiles, in some candles to treat the wick. It is the traditional base metal for organ pipes, and it is used as electrodes in the process of electrolysis. One of its major uses is in the making of the glass of computer and television screens, where it shields the

viewer from radiation. Other uses are in sheeting, cables, solders, lead crystal glassware, ammunitions and as weight in sport equipment

Lead (Pb) is the least mobile of all heavy metals. A high soil pH may precipitate Pb as hydroxide, phosphate or carbonate. The metal forms Pb^{2+} though its oxidation state is +4. The natural Pb content is strongly related to the bedrock and this is supported by the relatively low concentration in natural soil solutions. For instance, in a study of heavily Pb polluted soils, the formation of pyromorphite, $Pb_5Cl(PO_4)_3$, was observed. It was also observed that the concentration of the mineral was mainly close to the grass (*Agrostis capillaris*) and hence indicated an influence of the rhizosphere on the process of its formation (Kabata-Pendias & Pendias, 2000). Therefore, natural systems are known to contribute to the formation and distribution of Pb.

2.11.1.1 Effects of lead on human health

Lead is one out of four metals that have the most damaging effects on human health. It can enter the human body through uptake of food (65%), water (20%) and air (15%). (Lenntech, 2014). Lead has no known biological role. It can accumulate in the body and cause serious health problems. It is toxic, teratogenic (disturbs the development of an embryo or foetus) and carcinogenic. The effects of lead on humans depend on the level and the duration of exposure. Some of the effects of lead on human health are: a rise in blood pressure, brain damage, declined fertility of men through sperm damage and damage to the nervous system and the brains of unborn children since it can enter a foetus through the placenta of the mother (Sharma & Agrawal, 2005).

2.11.2 Cadmium

Cadmium (Cd) is naturally occurring in the Earth's crust. It is a lustrous, silver-white, ductile, very malleable metal. Its surface has a bluish tinge and the metal is soft enough to be cut with a knife, but it tarnishes in air. It is soluble in acids but not in alkalis. It is similar in many respects to zinc but it forms more complex compounds (Lenntech, 2014). It has an atomic number of 48, density of 8.7 g cm^{-3} , melting point of 321°C and a boiling point of 767°C .

Cadmium is used to manufacture pigments and batteries and in the metal-plating and plastics industries.

During weathering, Cd goes directly into soil solution and, although known to occur as Cd^{2+} , it may also form complex ion such as $[\text{CdCl}]^+$, $\text{Cd}(\text{OH})^+$, CdCl^{3-} and $\text{Cd}(\text{OH})^{3-}$. Oxidation potential and pH are the principal factors controlling Cd ion mobility in soil. Under conditions of strong oxidation, Cd is however, likely to form CdO and CdCO_3 , and is likely to be accumulated in phosphate and in biolith deposits (Kabata-Pendias & Pendias, 2000).

2.11.2.1 Effects of Cadmium on human health

The principal route of cadmium in humans is through the uptake of food. Foodstuffs such as mushrooms, shellfish and cocoa powder are rich in Cadmium hence can greatly increase the cadmium concentration in human bodies (Lenntech, 2014). The effects of Cadmium on human health are based on the level of exposure. Acute inhalation exposure to high levels of cadmium in humans may result in effects on the lung, such as bronchial and pulmonary irritation. A single acute exposure to high levels of cadmium can result in

long-lasting impairment of lung function (Figuroa, 2008). Chronic inhalation and oral exposure of humans to cadmium results in a build-up of cadmium in the kidneys that can cause kidney disease, including proteinuria, a decrease in glomerular filtration rate, and an increased frequency of kidney stone formation (Neeti & Prakash, 2013). Other health effects that can be caused by Cadmium include; diarrhea, stomach pains and severe vomiting, psychosocial disorders and damage to the immune system.

2.11.3 Zinc

Zinc (Zn) is a lustrous bluish-white metal. It is brittle and crystalline at ordinary temperatures, but it becomes ductile and malleable when heated between 110°C and 150°C. It releases hydrogen when it is reacted with dilute acids. Zinc has an atomic number of 30, density of 7.11 gcm⁻³, a melting point of 420°C and a boiling point of 907°C.

Uses of Zinc include: die-casting in the automobile industry; Zinc oxide as a white pigment in water colours or paints, and as an activator in the rubber industry. As a pigment, zinc is used in plastics, cosmetics, photocopier paper, wallpaper, printing inks etc, while in rubber production its role is to act as a catalyst during manufacture and as a heat disperser in the final product.

Zinc accumulates in surface soils as it is easily adsorbed by mineral and organic components. On weathering, Zn²⁺ is released. However, ZnO²⁻, ZnO²⁻, Zn(OH)³⁻, ZnCl⁺ and ZnHCO³⁺ are some of the other ionic species in which Zn may exist in the soil. Though the factors controlling the mobility of Zn are similar to that of Cu, the metal appears to occur in more readily soluble forms (Kabata-Pendias & Pendias, 2000).

2.11.3.1 Effect of Zinc on human health

Zinc is called an “essential trace element” because very small amounts of zinc are necessary for human health. Zinc is used for treatment and prevention of zinc deficiency and its consequences, including stunted growth and acute diarrhea in children, and slow wound healing. It is also used for boosting the immune system, treating the common cold and recurrent ear infections, and preventing lower respiratory infections. It is also used for malaria and other diseases caused by parasites. Low levels of zinc in the human body may result in symptoms such as loss of appetite, slow wound healing and skin sores (Sharma *et al.*, 2005).

Although humans can handle proportionally large concentrations of zinc, too much zinc can still cause eminent health problems, such as stomach cramps, skin irritations, vomiting, nausea and anaemia. Very high levels of zinc can damage the pancreas and disturb the protein metabolism, and cause arteriosclerosis. Extensive exposure to zinc chloride can cause respiratory disorders (Afshan *et al.*, 2014).

2.11.4 Nickel

Nickel (Ni) is silvery-white hard, malleable, and ductile metal. It is a fairly good conductor of heat and electricity. It dissolves slowly in dilute acids but, like iron, becomes passive when treated with nitric acid. It also has the ability to resist corrosion even at high temperatures. Nickel has an atomic number of 28, density of 8.9gcm^{-3} at 20°C , a boiling point of 2913°C and a melting point of 1453°C .

The major use of nickel is in the preparation of alloys. Nickel alloys are characterized by strength, ductility, and resistance to corrosion and heat. Nickel is easy to work and can be

drawn into wire. It resists corrosion even at high temperatures and for this reason it is used in gas turbines and rocket engines.

Nickel is easily mobilized during weathering and then is co-precipitated mainly with Fe and Mn oxides (Kabata-Pendias, 2000). However, unlike Mn^{2+} and Fe^{2+} , Ni^{2+} is relatively stable in aqueous solutions and is capable of migration over a long distance.

2.11.4.1 Effects of Nickel on human health

The major source of nickel exposure in humans is through oral consumption as nickel is found in both food and water. Other forms of exposure include breathing (polluted air from nickel metal refining, fossil fuel combustion, and tobacco smoking). Skin contact with nickel-contaminated soil or water may also result in nickel exposure. In small quantities nickel is essential, but when the uptake is too high it can be a danger to human health. Some adverse effects of Nickel on human health are: asthma and chronic bronchitis, respiratory failure, heart disorders and higher chances of development of lung cancer, nose cancer, larynx cancer and prostate cancer (Kim *et al.*, 2013)

2.11.5 Copper

Copper (Cu) is a reddish metal with a face-centered cubic crystalline structure. It is malleable, ductile, and an extremely good conductor of both heat and electricity. Copper has low chemical reactivity. In moist air it slowly forms a greenish surface film called patina; this coating protects the metal from further attack. It has an atomic number of 29, a density of 8.9 g cm^{-3} , melting point of 1083°C and a boiling point of 2595°C .

The major applications of copper are in electrical wires (60%), roofing and plumbing (20%) and industrial machinery (15%) (Lenntech, 2014). Copper is mostly used as a pure

metal, but when a higher hardness is required it is combined with other elements to make an alloy (5% of total use) such as brass and bronze. Copper is ideal for electrical wiring because it is easily worked, can be drawn into fine wire and has a high electrical conductivity.

When Cu ends up in the soil, it strongly attaches to organic matter and soil minerals. As a result, it does not travel very far after release and it hardly ever enters groundwater. It does not break down in the environment and because of that it can accumulate in plants and animals when it is found in soils (Pattnaik and Reddy 2011).

Copper forms quite easily soluble minerals in weathering processes and release Cu ions, especially in acid environments. These Cu ions can readily precipitate with various anions such as sulphide, carbonate and hydroxide. The metal is therefore rather immobile in soils and shows relatively little variation in total content in soil cores. The common characteristic of Cu distribution in soil cores is its accumulation in the top horizon. Its accumulation in surface soils thus reflects the bioaccumulation of the metal and also recent anthropogenic sources of the element (Kabata-Pendias & Pendias, 2000).

2.11.5.1 Effects of Copper on human health

Copper is an essential trace element in humans and can be found in many kinds of food, in drinking water and in air. Although humans can handle proportionally large concentrations of copper, too much copper can still cause eminent health problems. Long-term exposure to copper can cause irritation of the nose, mouth and eyes and it causes headaches, stomachaches, dizziness, vomiting and diarrhea. Intentionally high uptakes of copper may cause liver and kidney damage and even death. Excessive

exposure to copper has been linked to cellular damage leading to Wilson disease in humans (Gaetke *et al.*, 2014).

2.12 Engine oils

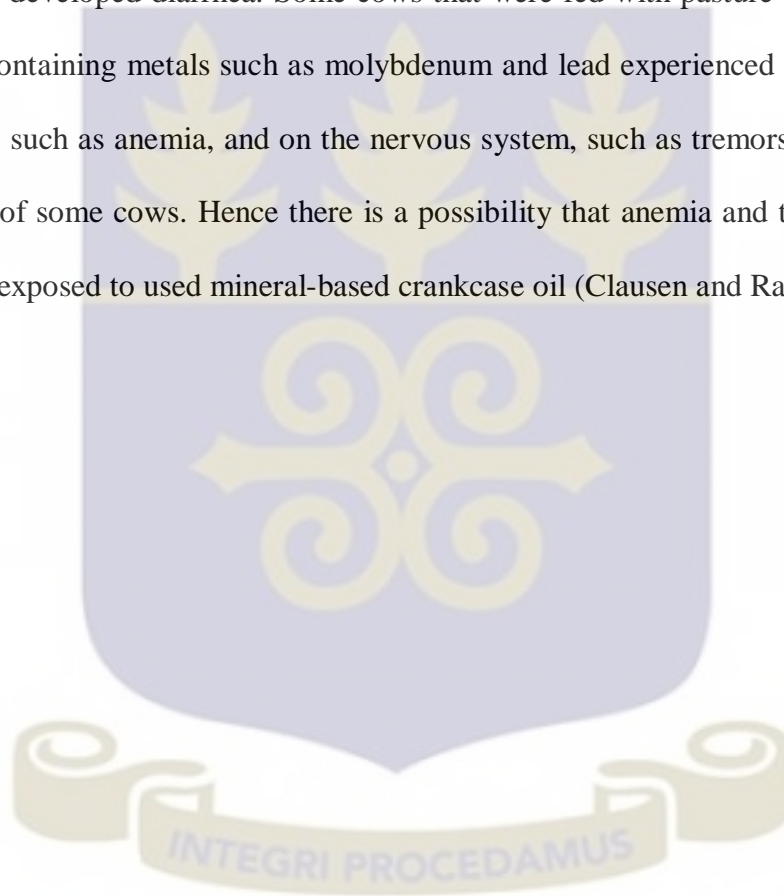
Kirk-Othmer (1981) observed that mineral-based crankcase oils are manufactured using highly refined base oils which can contain up to 20% of a variety of additives such as viscosity index improvers, detergents/dispersants, anti-wear additives, pour-point depressants, and antioxidants. During use, the high temperatures and friction cause changes such as oxidation and nitration. There is also the accumulation of contaminants such as fuel (petrol or diesel), water, antifreeze and insoluble particles in the oil (Vazquez-Duhalt, 1989). The degree of chemical change and accumulation of contaminants in the oil increases with use and varies depending on the type of fuel used and the mechanical properties of the engine.

2.12.1 Effect of used engine oil on human health

Used engine oils can have a deleterious effect on humans when they are exposed. The level of harm caused is dependent on factors such as the route of exposure and the duration. An example is a research by Dautrebande and Capps (1950), who observed that volunteers experienced nose and throat irritations when they were exposed to aerosols and used mineral-based crankcase oil for some few minutes. Studies carried out by Clausen and Rastogi (1977) have shown that the effect of used engine oils on human health may include: respiratory diseases, gastrointestinal diseases, hematological diseases and hepatic diseases.

Mechanics and other auto workers who are exposed to used engine oil and other chemicals from a large number of motor vehicles have experienced effects on the skin (rashes), blood (anemia), and nervous system (headaches and tremors) (Clausen and Rastogi (1977) , American Chemical Society (2004)).

Studies have shown that animals that ate food contaminated with large amounts of used engine oil developed diarrhea. Some cows that were fed with pasture contaminated with used oil containing metals such as molybdenum and lead experienced harmful effects on the blood, such as anemia, and on the nervous system, such as tremors which resulted in the death of some cows. Hence there is a possibility that anemia and tremors may occur in people exposed to used mineral-based crankcase oil (Clausen and Rastogi, 1977)



CHAPTER THREE

MATERIALS AND METHODS

3.1 Study area

This study was conducted in Darkuman in the Accra Metropolitan Assembly (AMA) in the Greater Accra region. It lies within Lat. $5^{\circ}34'59.3''\text{N}$ (5.5831400°) and long. $5^{\circ}34'59.3''\text{N}$ (5.5831400°). It is a settlement with a population of about 61,562 people (Ghana Statistical Service, 2010). Darkuman is influenced by urbanization or urban sprawl whereby smaller communities have merged together.

There are several businesses that take place in Darkuman, notable among them is the Kokompe spare parts market, a well known market for the sale and repair of vehicle parts. Apart from this market, there are several other automobile workshops scattered all over the town from which used engine oils, lubricating oils and other solvents containing petroleum hydrocarbons are indiscriminately dumped or spilled on every available space by artisans in the business of auto-repairs.

Siting of these workshops is not regulated, and as a result they are located at random, around street corners or directly in front of residential and commercial houses. This exposes residents, including infants with pica-habits to soil contaminants.

3.1.1 Climate and Vegetation

The Greater Accra Region where Darkuman is located has two rainy seasons with an average annual rainfall of about 730 mm. The major season begins in May and ends in mid-July. The minor season begins in mid-August and ends in October.

There is little variation in temperature throughout the year with the mean monthly temperature ranging from 24.7°C in August (the coolest) to 28°C in March (the hottest) with an annual average of 26.8°C.

Relative humidity is generally high varying from 65% in the mid-afternoon to 95% at night. The predominant wind direction in Accra is from the West South West (WSW) to North North East (NNE) sectors. Wind speeds normally range between 8 to 16 km/hr.

3.1.2 Geology and Soils

The geology of the AMA consists of Precambrian Dahomeyan schists, granodiorites, granites gneiss and amphibolites to late Precambrian Togo series comprising mainly quartzite, phillites, phylitones and quartz breccias. Other formations found are the palaeozoic accraian sediments - sandstone, shales and interbedded sandstone-shale with gypsum lenses

The soils in the metropolitan area can be divided into four main groups: drift materials resulting from deposits by wind-blown erosion; alluvial and marine mottled clays of comparatively recent origin derived from underlying shales; residual clays and gravels derived from weathered quartzites, gneiss and schist rocks, and lateritic sandy clay soils derived from weathered Accraian sandstone bedrock formations.

3.1.2 Activities at the study site

Activities carried out at the study sites include the disassembly and assembly of machine spare parts, changing of oil in vehicles, and the repair of vehicle parts. Through these activities, engine oils, lubricating oils and other solvents containing petroleum

hydrocarbons are indiscriminately dumped or spilled on every available space. Materials that are considered to be waste are either sold as scraps or burnt which exacerbates the emission of PAHs and other pollutants. Artisans can be seen carrying out these activities with little or no protective equipment. Plate 3.1 below shows some images taken at the site.



Plate 3.1 Images from the study sites

3.2 Selection of study sites

A reconnaissance visit was made to the study area in October, 2015. In order to select suitable sites for the study, a list of all the sites where auto-mechanic workshops were located was made. The sites were named using the name of a landmark around that site. Each site was made of maintenance, welding and spraying workshop. The names were written on a piece of paper and folded into a small box. Six sites were randomly selected. The selected sites were Darkuman Junction (DJ), Cable and Wireless (CW), Datus School (DS), Kokompe (KP), Alafia (AL), Global church (GB) and were coded as S1, S2, S3, S4, S5, S6 respectively. A Global Positioning System (GPS) device (Model, GARMIN etrex 20) was used to take all the coordinates of the selected sites.

3.2 Soil sampling

Soil samples were collected from the workshops in December 2015. Each workshop was sub divided into three quadrants. Three soil samples from sampling spots of about 10 - 30 m apart from each other were collected from each quadrant and homogenized into a composite sample. The samples were collected with a soil auger at a depth of 0 – 15 cm after the removal of the exposed surface according to MCPA method (2008). This depth was chosen because organic matter which is the major sorptive material of pollutants is found in significant quantities in surface soils hence the accumulation of pollutants at that region. Soil samples were collected at the control sites which were observed not to be under the influence of auto-mechanic shops. The control for this research was taken from Korle Gonno (about 4 km from study sites) where no auto mechanic shops or activities were observed. This was coded as CS. Table 3.1 and Figure 3.1 below show the name

and location of sampling sites and the map of the Accra metropolitan assembly and sampling sites respectively.

Table 3.1 Sampling sites

Name	Location Code	Coordinates
Suro Nipa House's well	W1	(5°35'30.174", -0°14'52.807")
Kokompe Well	W2	(5°34'45.066, -0°15'.9.511")
Well at Alafia	W3	(5°35'31.495", -0°14'.59.5")
Darkuman Junction	S1	(5°34'44.089, -0°15'21.37")
Cable and Wireless	S2	(5°35'4.3115", -0°14'52.67")
Datus School	S3	(5°35'0.640, -0°14'31.812")
Kokompe Spare Parts' Market	S4	(5°34',44.026, -0°15'7.11")
Alafia	S5	(5°35'31.9884", -0°14'54.60")
Global church	S6	(5°34'40.62", -0°14'57.419')
Korle Gonno (Control site for soil analysis)	CS	(5°44'63.215", -0°17'.96.511")
Korle Gonno(Control site for water samples)	CW	(5°44'56.456", -0°16'.76.234")

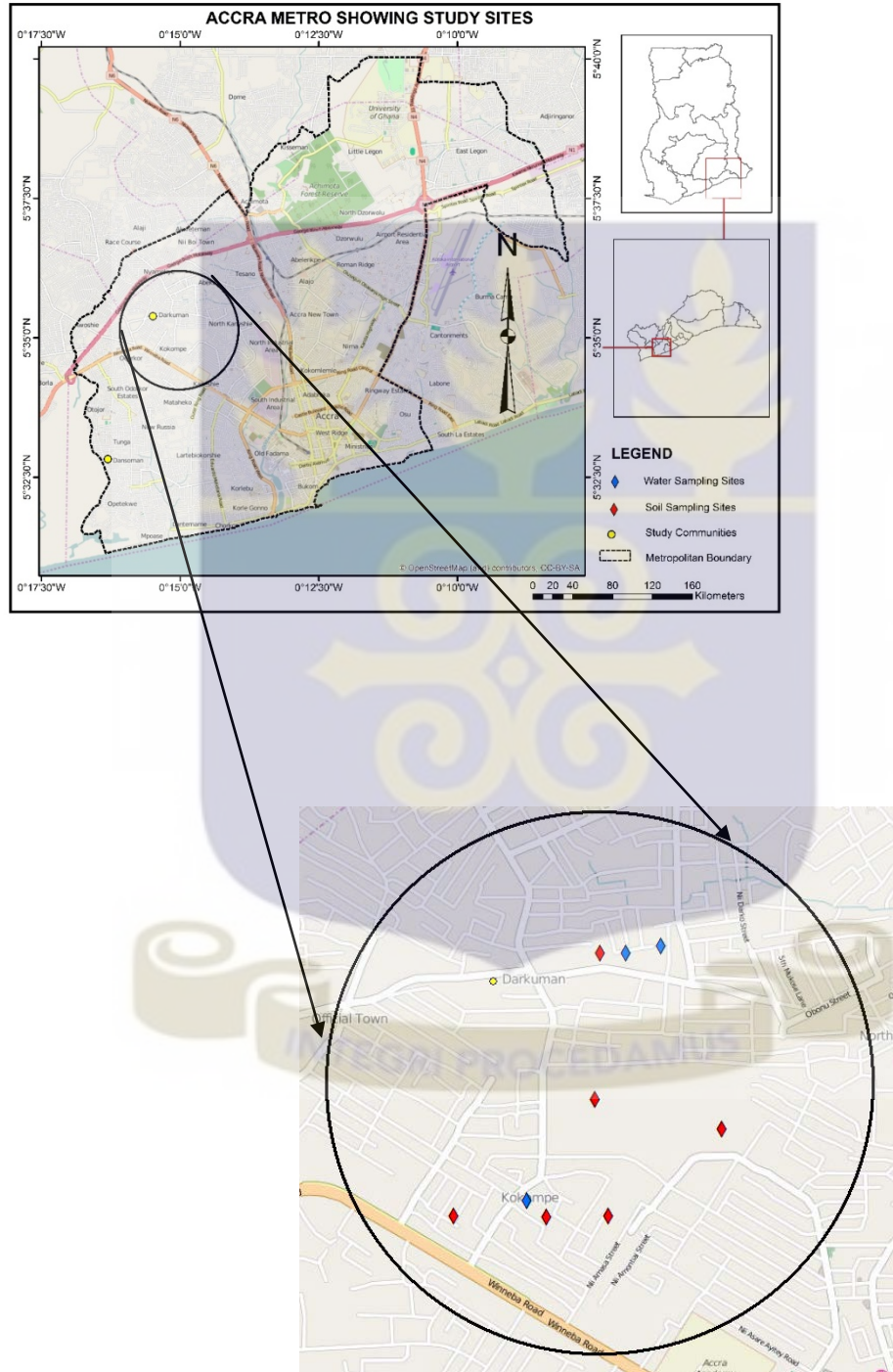


Figure 3.1 Map of the study area

3.2.1 Soil sample preparation

The composite soil samples were air-dried at room temperature for three (3) weeks. They were then disaggregated using porcelain pestle and mortar, and sieved with a 2-mm nylon mesh to give the fine earth fraction. The fine earth fraction (< 2 mm) was then used for the various analytical determinations.

3.3 Soil Analysis

The soil physico-chemical analysis was carried out at the University of Ghana Ecological Laboratory. Physico-chemical parameters measured were soil pH, conductivity, soil organic carbon/organic matter and soil cation exchange capacity.

3.3.1 Soil pH

The pH of the soil sample was determined in a 1:1 soil to distilled water ratio (McLean, 1982; McKeague, 1978). A 10 g soil was weighed into a beaker and 10 mL of distilled water added, stirred vigorously and allowed to stand for 30 minutes. A microprocessor pH 213 meter was calibrated, and then inserted into the supernatant of the soil solution and the pH read. A buffer solution of pH 4 and pH 7 was used to standardize the pH meter. Triplicate pH values were taken.

3.3.2 Soil Organic Matter

The organic carbon content of the soil was determined using the wet combustion method (Walkley and Black, 1934). Ten millilitres of 0.167 M potassium dichromate ($K_2Cr_2O_7$) solution and 20 ml of concentrated sulphuric acid (H_2SO_4) were added to a 0.5 g soil which had been passed through a 2mm sieve in a 250 Erlenmeyer flask. The flask was then swirled to ensure full contact of the soil with the solution after which the mixture

was allowed to stand for 30 minutes. The unreduced $K_2Cr_2O_7$ remaining in solution after the oxidation of the oxidizable organic material in the soil sample was titrated with 0.2 M ferrous ammonium sulphate solution after adding 10 mL of orthophosphoric acid and 2 mL of barium diphenylamine sulphonate indicator. A colour change from a dirty brown colour to a bright green indicates the end point. A standardization titration of the $K_2Cr_2O_7$ with the ferrous ammonium sulphate was done and the amount of oxidizable organic carbon calculated by subtracting the moles of unreduced $K_2Cr_2O_7$ from that of $K_2Cr_2O_7$ present in the standardized titration. The titre value was used to calculate the percent carbon (% C) as:

$$\%OC = \frac{[(0.3 \times (10 - aM))]}{W} \times 1.33 \text{----- [1]}$$

Where M = Molarity of the ferrous ammonium sulphate (0.2M)

a = Titre value of the ferrous ammonium sulphate

W = Weight of the soil sample

Additionally, % Organic C is converted to organic matter using the following equation:

$$\% \text{ Organic Matter (OM)} = \% \text{ Organic carbon} \times 1.724.$$

3.3.3 Cation Exchange Capacity (CEC)

Five grams of the soil sample was weighed into an extraction bottle and 50 mL of 1.0 M ammonium acetate at pH 7.0 added. The contents were then shaken for 30 minutes and filtered through a Number 42 Whatman filter paper. The filtrate was collected with a well labelled high density polypropylene container and reserved for the determination of

exchangeable bases. The soil mass on the filter paper was then leached with methanol to wash off the non-adsorbed NH_4^+ and the NH_4^+ saturated soil leached four times with acidified 1.0 M KCl. A 10 mL aliquot was transferred into a distillation flask and distilled to liberate NH_3 into boric acid. The ammonium ion concentration (mol/L) in the KCl filtrate was determined by titration of the solution with 0.01 M HCl and the CEC of the soil in cmol/kg estimated (Horneck *et al.*, 1989; Schollenberger and Simon, 1945). For quality control purposes, two blank tests in which the same procedure was performed without the soil were carried out to ensure accuracy and to detect any contamination during the analytical procedure.

$$\text{CEC (cmol/kg)} = \text{NH}_4 - \text{N} \left(\frac{\text{mol}}{\text{L}} \right) \times 10\text{mL} \times \frac{100}{5g} \text{-----} [2]$$

where $\text{NH}_4\text{-N}$ in distillate was determined from the titration

3.3.4 Electrical Conductivity

The conductivity of the soil samples were determined using PHWE electrical conductivity meter. The instrument was initially calibrated by rinsing with potassium chloride (KCl) solution. The conductivity of this standard is known to be 1413 $\mu\text{S/cm}$; the electrode was rinsed with distilled water and then immersed in a soil: water suspension (1:2) for the actual reading. Triplicate values were taken.

3.4 Water Sampling

Three hand-dug wells in Darkuman, within a 100 m radius away from auto-mechanic workshops were purposively selected for water sampling. All the wells were shallow which represents unconfined aquifers. A water sampler was used to collect water samples into 1 L plastic bottles and field filtration was carried out through filter papers (0.45 μm)

to remove suspended solids. The bottles were rinsed with distilled water and again with water from the hand dug wells. Three (3) samples were taken from each sampling site for analysis. The collection of the water samples were done once in a month over a three month period (December 2015 - February 2016). The control for this experiment was taken from a hand dug well at Korle gonno using the same procedure. Three replicates were collected from each well making a total of 36 water samples. The samples were transported to the laboratory in an ice chest and kept in a refrigerator

3.5 Physicochemical parameters of water samples

Physicochemical parameters measured were temperature, pH, turbidity, total dissolved solids, electrical conductivity, total hardness and alkalinity. All analyses were determined using appropriate certified and acceptable international procedures outlined in the standard methods for the examination of water and waste water (APHA, 2005).

3.5.1 Temperature

The temperature was determined using a portable pH meter that also measures temperature while measuring the pH on the site.

3.5.2 pH

The pH values of the samples were measured using a portable pH meter (HANNA pH 209, U.S.A). The instrument was calibrated using buffer solutions of 7.00 and the probe stored in a 4 M KCl solution. It was then used to measure the pH of each sample by dipping the probe into about 50 mL of the sample in the beaker. The pH was read and recorded after which the probe was rinsed in deionized water. The procedure was repeated for each of the samples and their pH values recorded.

3.5.3 Conductivity

The conductivity meter model PHYWE was used for conductivity determination. The conductivity meter was calibrated using a 0.01 M KCl solution with corresponding conductivity of 1413 $\mu\text{S}/\text{cm}$ at 25°C. 100 mL of the sample was poured into a beaker and the electrode was gently dipped into it and a stable reading recorded. The probe of the conductivity meter was rinsed with deionized water after each reading.

3.5.5 Alkalinity

A 25 mL aliquot of the water sample was pipetted into a round bottom flask and two drops of methyl orange was added. The resulting solution was titrated with 0.01 M HCl standard solution to a pale pink end point. The Alkalinity of the water sample in mg CaCO_3/L was computed as below:

$$\text{Alkalinity} \left(\frac{\text{mgCaCO}_3}{\text{L}} \right) = \frac{A \times M \times 50 \times 1000}{\text{Vol. of water sample (mL)}} \text{-----} [3]$$

Where A = vol. of acid used (mL)

50 = equivalence of CaCO_3

M = Molarity of standard acid used

3.5.6 Total Hardness

A 25 mL aliquot of the water sample was pipetted into a 250 mL conical flask and 2 mL of ammonium chloride- ammonium hydroxide (NH_4Cl - NH_4OH) buffer was added to monitor the pH around 10. Two drops of Eriochrome Black T indicator were added. The content in the conical flask was titrated against standard EDTA solution (0.01 M) until the contents of the flask changed from wine- red to blue at end point.

Titration was repeated until a consistent titre was obtained. The value of the average titre was recorded.

Calculation

$$\text{Total Hardness (mgCaCO}_3) = \frac{A \times B \times 1000}{\text{Volume of sample (mL)}} \text{----- [4]}$$

Where A = Titre value

B = 1 = mg of CaCO₃ equivalent to 1 mL of EDTA titrant

3.5.7 Total Dissolved Solids (TDS)

Total Dissolved Solids (TDS) was determined using gravimetric method. An empty beaker was cleaned and oven dried at a temperature of 103°C and weighed to a constant weight. 100 mL of the water was filtered into the weighed beaker, heated and evaporated at a temperature of 105 °C to dryness. The dried sample was cooled in a desiccator and weighed. Drying and weighing between the weight of the empty beaker and the beaker with its contents is the weight of the dry residue. The Total Dissolved Solids in mg/L was computed as follows:

$$\text{TDS (mg/L)} = \frac{\text{wt. of dry residue (mg)}}{\text{Vol. of sample (mL)}} \times 1000 \text{----- [5]}$$

3.5.8 Turbidity

Turbidity was measured using the HACH DR 2010 Spectrophotometer with the wavelength set to display “NTU TURBITY” units. Two sample cells were obtained, one filled with deionized water and the other with the sample. The deionized water (blank) was used to zero the Spectrophotometer followed by the sample readings. The results in

Nephelometric Turbidity Units (NTU) were displayed and the values recorded. The procedure was repeated for the other samples and the blank.

3.6 Heavy metal Analysis

3.6.1 Containers and Cleaning Process for analysis of heavy metals

All glassware and high density polyethylene containers used in the analytical determinations were immersed in a warm liquid soap bath for two days. They were then rinsed with deionised-water (DI-water) and left immersed in 10% HNO_3 at room temperature for three days. Flasks were again rinsed three times with DI-water and afterwards immersed in 50% HNO_3 bath at 90 °C for 24 hours. They were further rinsed with DI-water several times and placed overnight in a clean oven at 60 °C, then removed from the oven and allowed to cool down. They were then double bagged in new polyethylene bags and stored under room temperature.

3.6.2 Water sample preparation for analysis of heavy metals

The water samples were filtered using a Whatman No 42 filter, 9 cm. 100 ml of the filtrate was then measured into a beaker. In addition, 15 ml concentrated nitric acid solution and 10 ml of 50% concentrated hydrochloric acid solution were added. The content was evaporated to almost dryness on a hot plate and 7 ml of 50% concentrated hydrochloric acid added and heated for 10 minutes. The solutions were allowed to cool, and then distilled water added to each and filtered into a 100 ml Pyrex volumetric flask using a Whatman No 42 filter, 9 cm. This was then made up to the mark with distilled water. The 100 ml each of the water samples was used for the heavy metal determination using VARIAN AA240FS-Flame Atomic Absorption Spectrometer model.

3.6.3 Digestion of soil samples

A 1.5 g of each of the soil samples were weighed with a digital weighing balance model: METTLER TOLEDO XS603S into 125 ml beakers. The samples were digested with 30 ml aqua-regia (3ml 65% HNO₃; 1ml 35% HCl) for 3 hours on a hot plate (45 °C). This was done to reduce the interference of organic matter. The digested samples were allowed to cool at room temperature. The sides of the beakers were washed with de-ionised water and diluted to a volume of 25 ml and transferred into the appropriate test tube.

3.6.4 Determination of heavy metals in soil

A series of calibration solutions (standards) containing known amounts of analyte elements was prepared and used to calibrate the VARIAN Atomic Absorption Spectrometer AA240FS. Blanks were then atomized followed by the standards and calibration graphs plotted showing the response from the AAS. The concentrations were calculated based on the absorbance obtained using the Beer Lambert law. Responses of standard were then used to establish accurate performance of machine and accurate concentration values of element. The machine was calibrated after every three analysis.

Using the AAS, light was generated from a hollow cathode lamp at a wavelength characteristic to each analyte. Each analyte was then atomized using an atomizer to create free atoms from the samples. Air-acetylene gas was used as the source of energy for the production of free atoms for the elements Zinc (Zn), Lead (Pb), Copper (Cu), Nickel (Ni), Cadmium (Cd). The samples were then introduced as an aerosol into the flame and the burner aligned in the optical path to allow the light beam pass through the flame where the light was absorbed. The light was then directed into a monochromator which then

isolated the specific analytical wavelength of the light emitted by the hollow cathode lamp from the non-analytical. The sensitive light detector then measured the light and translated the response into analytical measurements.

Calculation of concentration of heavy metals was done using

$$\text{Final conc. } \left(\frac{\text{mg}}{\text{kg}} \right) = \frac{\text{Conc. (analytical measurement)} \times \text{Nominal volume}}{\text{weight (g)}} \text{----- [6]}$$

Where nominal volume= final volume of digest sample solution

3.7 Indexes of Pollution

3.7.1 Enrichment factor (EF)

Enrichment factor (EF) of an element in the studied samples is based on the standardization of a measured element against a reference element. A reference element is often one characterized by low occurrence variability such as Al, Fe, Ti, Si, Sr, K, Sn etc (Sezgin *et al.*, 2003; Ahiamadjie *et al.*, 2011). It is used to differentiate heavy metals originating from human activities and those of natural sources. This is determined by the relation:

$$EF = \frac{[C_x/C_{ref}]_{\text{sample}}}{[C_x/C_{ref}]_{\text{background}}}$$

Where C_x is the element of interest

C_{ref} is the concentration of reference element for normalization.

Five contamination categories are recognized on the basis of the enrichment factor: $EF < 2$ states deficiency to minimal enrichment, $EF = 2 - 5$ moderate enrichment, $EF 5 - 20$ significant enrichment, $EF = 20 - 40$ very high enrichment and $EF > 40$ extremely high

enrichment (Sezgin *et al.*, 2003; Duzgoren- Aydin *et al.*, 2007; Ahiamedjie *et al.*, 2011). The crustal abundance data of Krauskopf and Bird (1995) were used for all EF values.

3.7.2 Contamination factor

The contamination factor (C_f) which gives an indication of the level of contamination is computed for soil samples using the measured concentrations of the toxic elements and their corresponding values in rock samples. It is calculated according to the equation below:

$$C_f = \frac{C_x}{C_n}$$

where C_f = contamination factor

C_x = Concentration of the heavy metal in the sample

C_n = Concentration of the heavy metal in the continental crustal average/ baseline concentrations.

A value of $C_f < 1$, $1 \geq C_f \leq 3$, $3 > C_f \leq 6$, $C_f > 6$ represents low, moderate, considerate and very high contaminations respectively. The crustal abundance data of Krauskopf and Bird (1995) were used for all CF values.

3.7.3 Pollution Index (PI)

Pollution Index is commonly used to assess the quality of the environment (dos Anjios *et al.*, 2000). This is obtained by using the equation below. The PI of each element is and classified as either low ($PI \leq 1$), middle ($1 < PI \leq 3$) or high ($PI > 3$).

$$PLI = \sqrt[n]{Cf_1 \times Cf_2 \times Cf_3 \dots Cf_n}$$

Where Cf = contamination factor of a studied heavy metal

3.7.4 Index of geoaccumulation

The index of geoaccumulation (Igeo) is widely used in the evaluation of contamination by comparing the levels of heavy metal obtained to a background level originally used with bottom sediments (Muller, 1969; Atiemo, 2011). It is calculated using the equation: $I_{geo} = \log_2[(C_n / 1.5B_n)]$ where C_n is the measured concentration of the heavy metal in soil being studied and B_n is the geochemical background concentration of the heavy metal (crustal average) (Taylor and McLennan, 1985). The constant 1.5 is introduced to minimize the effect of possible variations in the background values which may be attributed to lithologic variations in the sediments (Lu *et al.*, 2009; Atiemo, 2011).

Igeo values <0 = practically unpolluted, 0-1 = unpolluted to moderately polluted, 1-2 = moderately polluted, 2-3 = moderately to strongly polluted, 3-4 = strongly polluted, 4-5 = strongly to extremely polluted and >5 = extremely polluted. According to the crustal abundance data of Krauskopf and Bird (1995) the reference samples Zn: 70, Ni: 75, Al: 8.23, Pb: 12.5, Cu: 55 and Cd: 0.2 were used as reference samples for the various calculations.

3.8 Quality control and quality control assurance

The following control and quality assurance techniques were used during analysis. Analytical blanks were used to check contamination during sample preparation where as duplicates were made to check the accuracy and the reproducibility of the method used. The standards were also used to check the efficiency of the equipment used. Reference standards used for the elements of interest, blanks and duplicates of samples were

digested under the same condition as samples. These served as internal positive controls.

The Standard Reference Material used was the IAEA-SOIL-7.

3.9 PAHs Analysis

3.9.1 Extraction of PAHs from water samples

The extraction technique employed in this work was the United States' Environmental Protection Agency (USEPA) Method 3510 for aqueous matrix for the analysis of semi-volatile and non-volatile organics. After filtration, 1000 ml portion of the water sample was transferred into a 2 L capacity glass-separating funnel. Then 30 ml of saturated sodium chloride (NaCl) was added to produce a salt out effect. It was thoroughly mixed by inverting the flask three to four times. 100 ml of Dichloromethane as extraction solvent was added and this was vigorously shaken manually for 2-3 minutes and releasing the pressure intermittently. The phases were then allowed to separate for 5 minutes and the Dichloromethane extract (organic layer) was separated or collected from the aqueous layer. The extraction was repeated with 100 ml of Dichloromethane and the organic layers were put together and dried over anhydrous magnesium sulphate. The extracts from water samples were then concentrated on rotary vacuum evaporator to about 2 ml and subjected to clean up.

3.9.2 Clean-Up of extract (purification using Silica SPE cartridge)

One gram of silica gel that previously had been activated at 130 °C for 10 hours was carefully packed into 10 mL polypropylene cartridge column and 6 mL Dichloromethane was used to condition the cartridge. The concentrated extract was then loaded onto the column and 50 mL pear shape flask was placed under the column to collect the eluate. A 10 mL dichloromethane was used to elute the column afterwards, and the total filtrate

collected concentrated to just dryness using the rotary evaporator set at 38°C. The residue was re-dissolved in 1 mL methanol and transferred into a 2 mL standard vial prior to quantification by Gas Chromatography.

3.9.3 Extraction of PAHs from soil samples

A ten gram soil sample was weighed and quantitatively transferred into a 250 mL separating funnel. A 10 mL of acetonitrile was added to the soil sample in the funnel and ultra-sonicated for 2 minutes. An additional 10 mL portion of acetonitrile was added, and the separating funnel closed tightly and placed on a horizontal shaker. It was then set to shake continuously for 30 minutes at 300 mot/min and finally allowed to stand for 5 minutes to sufficiently separate the phases. A 10 mL of the supernatant was carefully taken and dried over 2 g anhydrous magnesium sulphate through filter paper into 50 mL round bottom flask. This was then concentrated to about 1mL using the rotary evaporator, and made ready for silica clean up step.

3.10.4 Clean-up of extract (extraction purification using silica gel)

One gram of silica gel that previously had been activated at 130 °C for 10 hours was carefully packed into 10 mL polypropylene cartridge column and 6 mL acetonitrile was used to condition the cartridge. The concentrated extract was then loaded onto the column and a 50 mL flask was placed under the column to collect the eluate. A 10 mL acetonitrile was used to elute the column afterwards, and the total filtrate collected concentrated to just dryness using the rotary evaporator set at 38°C. The residue was re-dissolved in 1 mL methanol and transferred into a 2 mL standard vial prior to quantitation by Gas Chromatography.

3.9.5 Gas Chromatographic conditions for PAHs determination

The final extracts were analyzed by Gas Chromatograph-Varian CP-3800 (Varian Association Inc. USA) equipped with combiPal autosampler and Ni electron capture detector (ECD) that allowed the detection of contaminants even at trace level concentrations (in the lower $\mu\text{g/g}$ and $\mu\text{g/kg}$ range) from the matrix to which other detectors do not respond. The GC conditions used for the analysis were capillary column coated with VF-5 (30 m + 10 m EZ guard column x 0.25 mm internal diameter, 0.25 μm film thickness). The injector and detector temperature were set at 270 °C and 300 °C respectively. The oven temperature was programmed as follows: 70 °C held for 2 min, ramp at 25 °C/ min to 180 °C, held for 1 min, and finally ramp at 5 °C/ min to 300 °C. Nitrogen was used as carrier gas at a flow rate of 1.0 mL/ min and detector make-up gas of 29 MI min⁻¹. The injection volume of the GC was 1.0 μL . The total run time for a sample was 31.4 min.

3.9.6 Quantification of PAH residues.

The residue levels of PAHs were quantitatively determined by the external standard method using peak area. Measurement was carried out within the linear range of the detector. The peak areas whose retention times coincided with the standards were extrapolated on their corresponding calibration curves to obtain the concentration

3.9.7 Limit of detection of PAHs

The limit of detection of the PAHs determined was based on the extract of the fortified samples that were serially diluted by factor of two to give different concentrations. One out of each concentration that gave a response three times the standard deviation of the least fortified sample was noted. This was used to estimate the statistical significance of

differences between low level analyte responses and the combined uncertainties in both the analyte and the background measurement (Frimpong *et al.*, 2012).

3.9.8 Analytical quality assurance and quality control

Proper quality assurance procedures and precautions were taken to ensure the reliability of the results. The samples were carefully handled to avoid any external influences that could interfere with the integrity of the sample and hence contaminate it. Glasswares were properly cleaned, and reagents were of analytical grades. Deionized water was used throughout the study. For the spectrophotometric analysis, reagent blank determinations were used to correct the instrument readings. For validation of the analytical procedure, repeated analysis of the samples against internationally certified/standard reference material (SRM-1570) of National Institute of Standard and Technology were used.

Additionally, the quality of PAH residues was assured through the analysis of solvent blanks, procedural matrix blanks and duplicate samples. All reagents used during the analysis were exposed to same extraction procedures and subsequently run to check for interfering substances. In the blank for each extraction procedure, no PAH was detected. Sample of each series was analyzed in duplicates. All extracts were kept frozen until quantification was achieved. Recalibration curves were run with each batch of samples to check that the correlation coefficient was kept around $r^2=0.99$. The method was optimized and validated by fortifying the samples with 500 μL of 1 μg m/L standards mixture before analysis to evaluate the recovery of compounds. The recoveries of internal standards ranged between 70% and 119% for most of the PAHs analyzed.

$$\text{Recovery (\%)} = \frac{\text{Concentration of PAH recovered from fortified sample} \times 100}{\text{Concentration of PAH added to the sample}}$$

3.10 Survey

3.10.1 Research Design

The survey employed the random sampling method and purposive techniques to select 230 respondents where questionnaires were administered. The respondents included mechanics (65), spare parts dealers (48), welders (37) and households (80) to assess their knowledge and perception of health risks associated with used engine oils.

The structured questionnaires included open and close ended questions. Interviews were also conducted with some executive members of the Greater Accra Spare Parts' Dealers Association (GASDA)-Kokompe branch.

The data collection took the form of hand delivery questionnaires and interviews. There were interviews with some of the key informants which also informed the restructuring of questions in the questionnaire. Due to the nature of some questions as well as the educational background of some respondents, the questions were not self-administered but took the form of an interview. For the literates who understood the questions, copies of the questionnaire were given to them for self-administration. The survey was conducted from December, 2015 to March, 2016. There was a 100% response rate. Copies of the questionnaires used for this study are presented in Appendix A.

3.10.2 Ethical Considerations

The respondents were assured of confidentiality of their responses and that results of the study would be reported in aggregate forms without identifying any particular person. Ethical clearance was sought from the College for Basic and Applied Science- University of Ghana before the commencement of the study.

3.12 Data Analysis

Data obtained from soil and water samples were subjected to analysis using the Statistical Package for Social Science (SPSS) 20.0 and Microsoft Excel 2010 software. One-way Analysis of variance (ANOVA) was used to test for the significant differences and similarities between the physico-chemical properties of water and soil as well as the heavy metal content in water and soil for the various sampled sites. The least significant difference (LSD) method at 5% significance level was used to determine the difference in the heavy metals detected at the various sites. A Pearson correlation analysis was also carried out to establish the degree of relationship between the physico-chemical parameters of water and soil and the heavy metals detected in water and soil samples.

Besides the statistical analysis of data, concentrations of heavy metals were compared with values of heavy metals for soils and water obtained from other studies.

The Stata software where the probit model was used to examine the factors influencing artisans' knowledge of occupational health risk, factors influencing artisans' decision to wear protective clothing, artisans' knowledge on the safety and hygienic practices during work, and factors influencing artisans' knowledge of impact of their activities on water quality from hand dug wells among others.

CHAPTER FOUR

RESULTS

4.1 Physico-chemical parameter of water samples

A summary of the mean and standard deviation of the physical parameters of water samples is presented in Table 4.1.

4.1.1 pH

The pH of the water samples over the study period were fairly similar and did not vary significantly ($p > 0.05$). The mean pH values of the water samples ranged from 6.54 to 6.98 in December, 6.37 to 6.87 in January and 6.17 to 6.87 in February. Analysis of variance (ANOVA) results showed no significant differences ($p > 0.05$) in pH with respect to the month in which sampling was done. The least significant difference (LSD) test however showed a significant difference ($p < 0.05$) in pH between sites W1 and W2, W1 and W3 and W2 and W3.

4.1.2 Temperature

The mean temperature recorded at W1, W2 and W3 in December were found to be higher than for the other months and that of the control. The mean temperature recorded during the study period was in the range of 28.63 – 29.37 °C with the highest temperature (29.37 °C) recorded at W1 and the lowest temperature (28.63 °C) recorded at W2. Although ANOVA revealed that there were no significant differences ($p > 0.05$) in temperature in relation to the month of sampling, the LSD test showed a significant difference between sites W1 and W2.

4.1.3 Total Dissolved Solids (TDS)

The levels of total dissolved solids (TDS) did not follow any particular trend. The mean TDS levels of the different water samples ranged from 64.1 to 103.4 mg/L. The highest TDS value (103.4 mg/L) was recorded at W2 and the lowest TDS (71.9 mg/L) value being recorded at W1. Analysis of variance results and LSD test showed there was no significant difference ($p > 0.05$) in TDS values with respect to the different months and sites respectively.

4.1.4 Conductivity

The mean conductivity levels of the water samples over the study period were found to be higher at all the sites than those of the control sites. Mean conductivity levels recorded in December, January and February ranged from 129.3 to 172.6 $\mu\text{S}/\text{cm}$, 115.6 to 164.4 $\mu\text{S}/\text{cm}$ and 106.2 to 155.8 $\mu\text{S}/\text{cm}$ respectively. The conductivity of water recorded during the sampling period did not show any statistically significant difference among the different sampling months ($p > 0.05$). The results of the LSD test revealed a significant difference ($p < 0.05$) between sites W1 and W2 and W2 and W3.

4.1.5 Alkalinity

The highest mean alkalinity level (250.6 mgCaCO_3/L) was recorded at W2 in December with the lowest mean value (72.6 mgCaCO_3/L) recorded at W1 in February. The mean alkalinity values of samples in December were found to be higher as compared to the other months. There was a significant difference ($p < 0.05$) in the alkalinity value recorded among all the sites in relation to the month sampled. LSD test revealed a significant difference ($p < 0.05$) between sites W1 and W2, W1 and W3 and W2 and W3.

4.1.6 Total Hardness

The study revealed significant differences ($p < 0.05$) in total hardness of water for the different sampling months. There were also significant site differences ($p < 0.05$) for total hardness. Total hardness of water sampled within the various months decreased in the order: December > January > February. The mean values for total hardness recorded in December, January and February varied from 295.2 to 610.20 mgCaCO₃/L, 254.6 to 578.7 mgCaCO₃/L and 244.0 to 532.3 mgCaCO₃/L respectively.

4.1.7 Turbidity

The mean turbidity recorded for all samples were found to be less than 1 NTU. The mean turbidity values for all the samples were found to range from 0.59 to 0.65 NTU. Analysis of variance (ANOVA) showed no significant differences ($p > 0.05$) in turbidity in relation to the months sampled and also among the different sites.

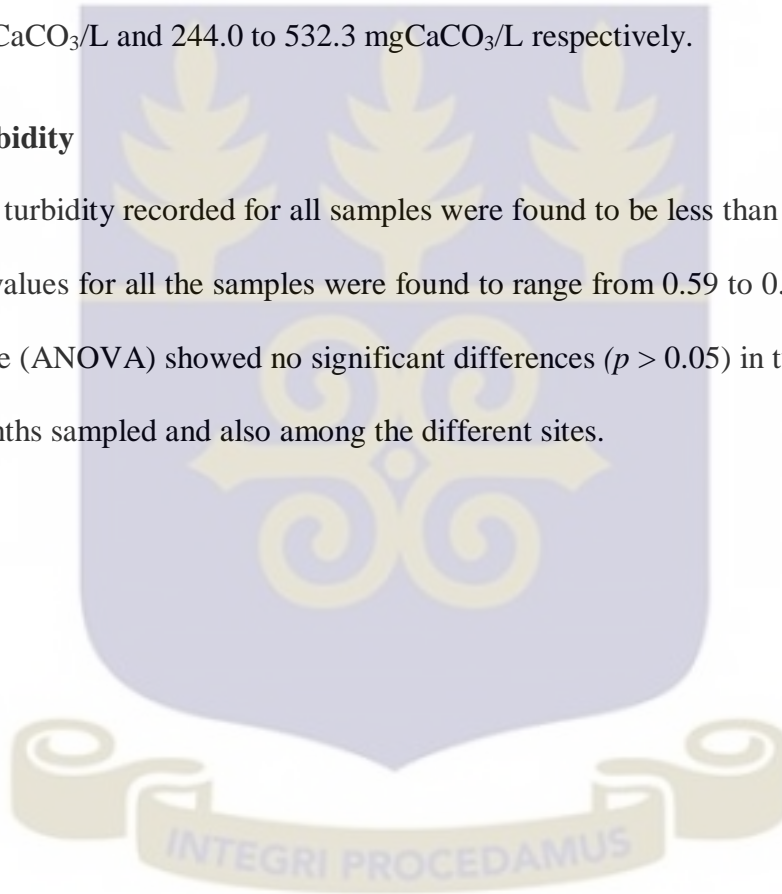


Table 4.1 Physicochemical parameters of water samples over the studied period

Parameters	December				January				February			
	W1	W2	W3	CW	W1	W2	W3	CW	W1	W2	W3	CW
pH	6.98	6.54	6.77	6.97	6.87	6.37	6.64	6.91	6.17	6.58	6.53	6.87
Temp (°C)	30.1	28.4	29.6	29.10	29.8	28.8	29.3	29.00	27.8	28.4	28.63	28.70
EC (µS/cm)	129.3	172.6	139.8	87.20	115.6	164.4	121.7	85.60	155.8	114.1	125.37	83.30
Turbidity (NTU)	0.61	0.71	0.63	0.34	0.58	0.69	0.59	0.38	0.64	0.56	0.65	0.38
Alkalinity (mgCaCO₃/L)	82.5	250.6	119.4	112.60	75.8	240.2	105.3	88.80	231.3	100.5	134.80	87.50
Total hardness (mgCaCO₃/L)	295.2	610.2	315.0	372	254.6	578.7	303.8	101.70	532.3	292.9	356.40	258.70
TDS (mg/L)	90.5	103.4	89.2	87.2	71.9	97.6	73.6	80.35	93.7	98.5	76.43	82.35

W1= Suro Nipa House W2= Well at Kokompe W3= Well at Alafia CW= Control site

Source: Author's field survey

4.2 Concentration of heavy metals in water samples

Activities of mechanics at auto-mechanic shops in Darkuman generate waste that can affect water quality from hand dug wells within the vicinity.

Figure 4.1 presents the concentrations of heavy metals for the sampling period.

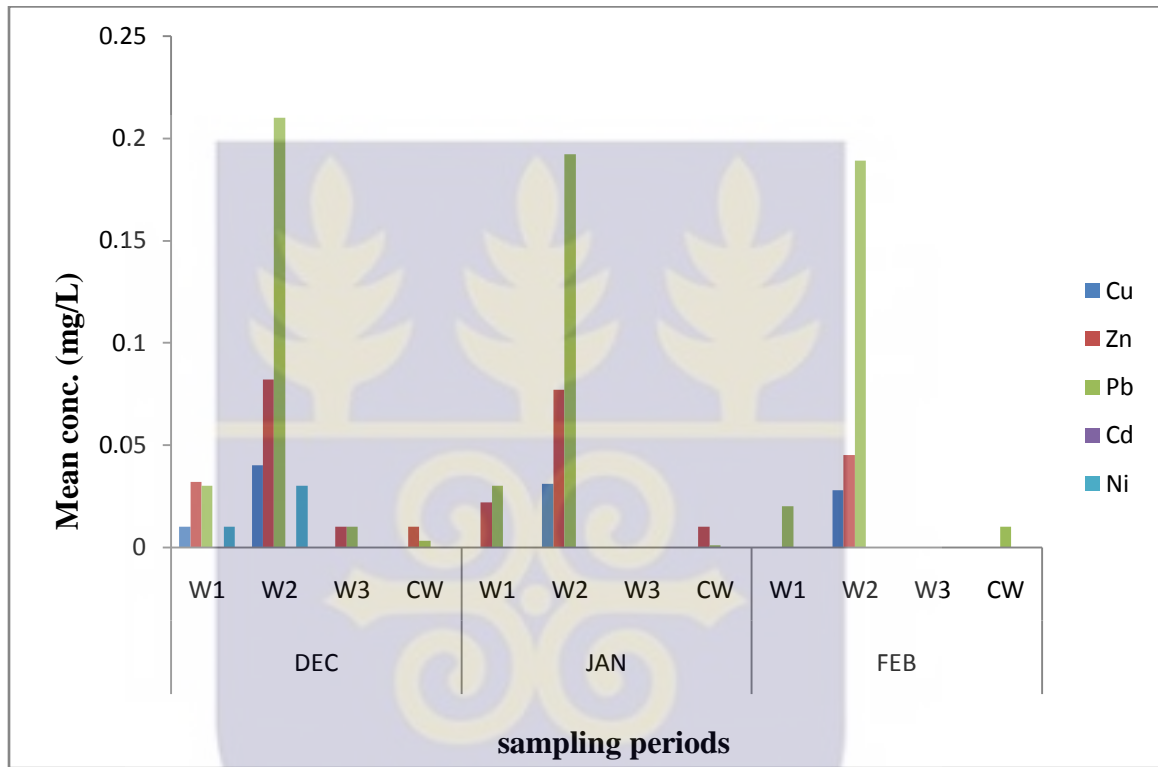
Results of water samples recorded in December revealed that the mean concentration of cadmium at W1, W2, W3, CW (control site) were <0.002 mg/L (below detection limit).

The mean concentration of Cu, Ni, Zn and Pb recorded at W1 were 0.01, 0.01, 0.03 and 0.03 mg/L respectively. W2 recorded mean concentrations of 0.04, 0.08, 0.21 and 0.03 mg/L for Cu, Ni, Zn and Pb respectively. The mean concentration of Zn and Pb recorded at W3 were 0.01 and 0.01 mg/L respectively. The mean concentration of Cu and Ni at W3 were however < 0.001 mg/L (below detection limit).

In January, W1 recorded mean concentrations of 0.02 and 0.03 mg/L for Zn and Pb respectively. The mean concentrations of Cu, Cd and Ni were however below detection limits. The mean concentrations of Cu, Zn and Pb at W2 were found to be 0.03 mg/L, 0.08 mg/L and 0.19 mg/L respectively. The mean concentrations of Cd and Ni at W2 were however found to be below detection limits. The mean concentration of Cu, Cd, Ni, Pb and Zn at W3 were all found to be below detection limits.

With the exception of Pb which recorded a mean concentration value of 0.02 mg/L, the mean concentrations of Cu, Zn, Cd and Ni recorded at W1 in the month of February were all below detection limit. W2 however recorded mean concentrations of 0.03, 0.05 and 0.19 mg/L for Cu, Zn and Pb respectively. The mean concentrations of Ni and Cd were however found to be below detection limits.

Analysis of Variance (ANOVA) results showed that there was no significant difference ($p < 0.05$) in the concentration of the heavy metals recorded among the sites in the various months.



W1 = Suro Nipa House' well **W2**= Well at Kokompe **W3**= Well at Alafia **CW**= Control site

Figure 4.1 Mean concentrations of heavy metals in water samples

4.3 Correlation between heavy metal concentration and physicochemical parameters

A Pearson's product moment correlation was used to investigate the association, strength and direction of the physico-chemical properties and heavy metal concentrations measured in the water samples. Tables 4.2 to 4.4 show some observations made in terms

of significant positive relationship between water physicochemical parameters and heavy metal concentrations in water during the study.



Table 4.2 Pearsons’s product moment correlation coefficient between water physico-chemical parameters and heavy metal concentrations in December

Elements	pH	Temp (°C)	EC(μS/cm)	Turbidity (NTU)	Alkalinity (mgCaCO3/L)	Total hardness (mgCaCO3/L)	TDS (mg/L)
Cu (mg/L)	-0.739	-0.861	0.888	0.908	0.899	0.956	0.987
Zn (mg/L)	-0.697	-0.829	0.859	0.881	0.871	0.936	0.976
Pb (mg/L)	-0.832	-0.928	0.947	0.961	0.955	0.989	1.000**
Cd (mg/L)	-	-	-	-	-	-	-
Ni (mg/L)	-0.674	-0.812	0.843	0.866	0.856	0.925	0.969

** Correlation is significant at 0.01 (2-tailed)

Table 4.3 Pearsons’s product moment correlation coefficient between water physico-chemical parameters and heavy metal concentrations in January

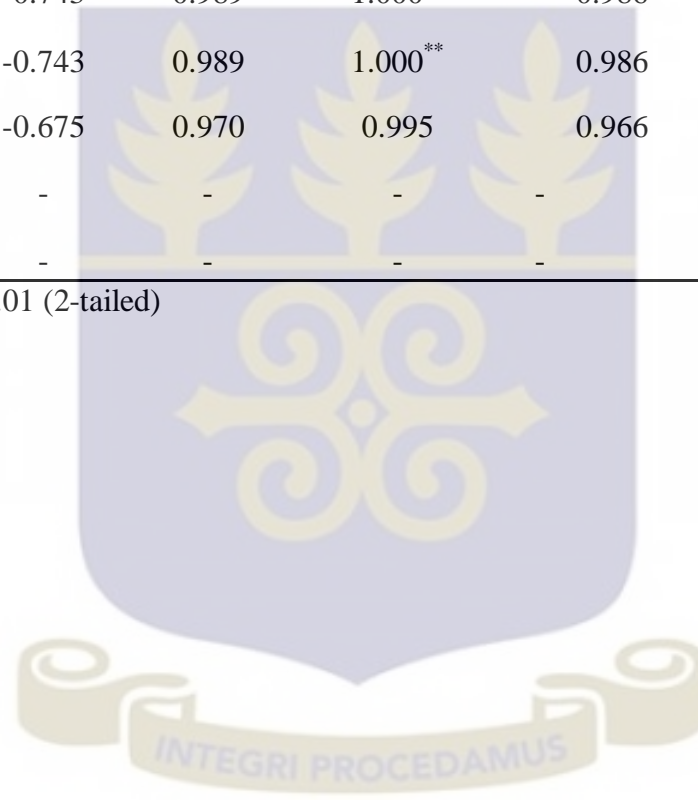
Element	pH	Temp (°C)	EC(μS/cm)	Turbidity (NTU)	Alkalinity (mgCaCO3/L)	Total hardness (mgCaCO3/L)	TDS (mg/L)
Cu (mg/L)	-0.888	-0.866	0.993	0.997	0.986	0.990	0.998*
Zn (mg/L)	-0.726	-0.693	0.923	0.935	0.900	0.912	0.943
Pb (mg/L)	-0.812	-0.784	0.966	0.974	0.951	0.959	0.979
Cd (mg/L)	-	-	-	-	-	-	-
Ni (mg/L)	-	-	-	-	-	-	-

* Correlation is significant at 0.05 (2-tailed)

Table 4.4 Pearsons’s product moment correlation coefficient between water physico-chemical parameters and heavy metal concentrations in January

Elements	pH	Temp (°C)	EC(μS/cm)	Turbidity (NTU)	Alkalinity (mgCaCO3/L)	Total hardness (mgCaCO3/L)	TDS (mg/L)
Cu (mg/L)	-0.923	-0.743	0.989	1.000**	0.986	0.987	0.971
Zn (mg/L)	-0.923	-0.743	0.989	1.000**	0.986	0.987	0.971
Pb (mg/L)	-0.882	-0.675	0.970	0.995	0.966	0.968	0.943
Cd (mg/L)	-	-	-	-	-	-	-
Ni (mg/L)	-	-	-	-	-	-	-

**Correlation is significant at 0.01 (2-tailed)



4.4 Concentrations of PAHs in water samples

Results from the GC-MS showed that the levels of naphthalene, acenaphthalene, acenaphthene, fluorene, phenanthrene, anthracene, fluoranthene, pyrene, benzo (a) anthracene, chrysene, benzo (b) flouranthene, benzo (k) fluoranthene, benzo (a) pyrene, indeno (1,2,3-c,d) pyrene, dibenzo (a,h) anthracene, benzo (g,h,i) perylene in water samples were found to be below the detection limit (0.01 $\mu\text{g/L}$) of the instrument used (Varian CP – 3800 GC with a CP – 8400 Autosampler and saturn 2000).

4.5 Physicochemical parameters of soil samples

4.5.1 pH of soils

The pH of soils from maintenance shops, welding shops and spraying shops varied from 6.31 - 8.68. Analysis of variance (ANOVA) showed there were significant differences ($p < 0.01$) in pH values among the sites. The mean pH values from maintenance workshops ranged from a minimum of 7.08 recorded at S5 to a maximum of 8.68 recorded at S4. Mean value of pH from welding workshops ranged from a minimum of 6.84 recorded at S1 to a maximum of 8.15 recorded at S4. Similarly pH values for spraying workshops ranged from a minimum of 6.31 recorded at S2 to a maximum of 7.33 recorded at S3.

4.5.2 Cation Exchange Capacity (CEC)

The mean Cation Exchange Capacity (CEC) of soil sampled within the study area ranged from a minimum of 4.08 cmol/kg to a maximum of 16.32 cmol/kg. The highest CEC value (16.32 cmol/kg) was recorded at S4 and the least value (4.08 cmol/kg) recorded at S1. Analysis of variance (ANOVA) showed there were significant differences ($p < 0.01$) in CEC of soil among the various sites.

4.5.3 Organic matter content in soils

The mean percentage of organic matter contents in soils from maintenance shops, welding shops and spraying shops varied from 6.65 to 15.30%, 6.05 to 11.47%, 5.62 to 8.41% respectively. Analysis of variance (ANOVA) showed there were significant differences ($p < 0.01$) in the soil organic matter contents at the different workshops. The mean value for percentage organic matter contents in soils from the various workshops were found to decrease in the order maintenance workshops > welding shops > spraying shops.

4.5.4 Electrical conductivity in soils

Table 4.5 presents a summary of the physicochemical parameters of the soil samples from the various sites. The mean conductivity of soil sampled within the study area ranged from a minimum of 103 $\mu\text{S}/\text{cm}$ at S1 to a maximum of 1065 $\mu\text{S}/\text{cm}$ recorded at S4. The mean conductivity levels recorded at the sites revealed that the mean conductivities at maintenance workshops were found to be generally higher as compared to the mean conductivity recorded at spraying and welding workshops. Analysis of variance (ANOVA) showed there were significant differences ($p < 0.01$) in the electrical conductivity in soils among the various sites.

Table 4.5 Physicochemical parameters of soil parameters of the study area

Site	Statistics	pH			EC ($\mu\text{S}/\text{cm}$)			%OM			CEC (cmol/kg)		
		MW	WS	SS	MW	WS	SS	MW	WS	SS	MW	WS	SS
S1	Min	7.02	6.78	6.45	256	112	89	6.43	5.98	5.98	5.53	5.00	3.98
	Max	7.18	6.89	6.76	312	186	127	6.98	6.10	6.54	5.98	5.40	4.21
	Mean	7.11	6.84	6.65	285	144.33	103	6.65	6.05	6.21	5.76	5.16	4.08
	SD	0.08	0.06	0.17	28.05	37.87	20.88	0.29	0.06	0.29	0.23	0.21	0.12
S2	Min	7.14	7.02	6.14	398	315	213	7.15	7.87	5.89	7.67	7.21	5.89
	Max	7.87	7.12	6.54	579	397	328	7.89	7.98	6.70	8.09	7.98	6.12
	Mean	7.55	7.07	6.31	461	365.33	272.67	7.52	7.92	6.23	7.91	7.51	6.03
	SD	0.37	0.05	0.20	101.74	44.07	57.62	0.37	0.06	0.42	0.22	0.41	0.13
S3	Min	7.79	8.00	7.13	89	118	89	7.87	7.17	6.68	4.09	6.12	5.14
	Max	7.87	8.30	7.65	152	198	129	8.98	7.76	7.54	5.00	6.64	5.91
	Mean	7.83	8.14	7.33	115	150	107	8.28	7.42	7.07	4.65	6.40	5.64
	SD	0.40	0.15	0.28	32.75	42.33	20.30	0.61	0.31	0.43	0.49	0.26	0.43
S4	Min	8.51	8.00	7.13	986	707	301	14.92	10.87	7.99	15.98	13.87	10.65
	Max	8.98	8.30	7.65	1132	809	362	15.98	12.01	8.89	16.65	14.65	11.53
	Mean	8.68	8.15	7.24	1064.67	753.67	325	15.30	11.47	8.41	16.32	14.20	11.20
	SD	0.26	0.15	0.17	73.66	51.55	32.51	0.59	0.57	0.45	0.34	0.40	0.48
S5	Min	6.98	7.37	7.13	498	128	89	7.87	6.83	4.98	8.12	5.98	4.14
	Max	7.23	7.54	7.43	517	234	138	8.90	7.12	6.00	8.32	6.23	4.87
	Mean	7.08	7.48	7.24	507.33	183	116	8.44	6.95	5.62	8.19	6.07	4.59
	SD	0.13	0.09	0.17	9.50	53.11	24.88	0.52	0.15	0.56	0.11	0.14	0.39
S6	Min	7.65	7.06	6.26	208	152	142	7.02	6.16	5.09	5.14	7.08	7.58
	Max	8.02	7.32	6.98	304	198	210	7.98	6.90	5.98	6.98	7.32	7.87
	Mean	7.88	7.17	6.67	265	175	180.33	7.38	6.61	5.61	6.03	7.18	7.77
	SD	0.20	0.13	0.37	50.47	23.00	34.82	0.52	0.39	0.46	0.92	0.12	0.16

**S1= Darkuman Junction, S2= Cable and Wireless, S3= Datus School S4= Kokompe S5= Alafia S6= Global church
MW= Maintenance workshop, WS= Welding workshop, SS= Spraying workshop**

Source: Author's field survey

4.6 Concentration of heavy metals in soils

4.6.1 Validation of Atomic Absorption Spectrometry

IAEA-SOIL-7 was used as a standard reference material (SRM) for the validation of the analytical results. The results of the IAEA-SOIL-7 obtained are shown in Table 4.6

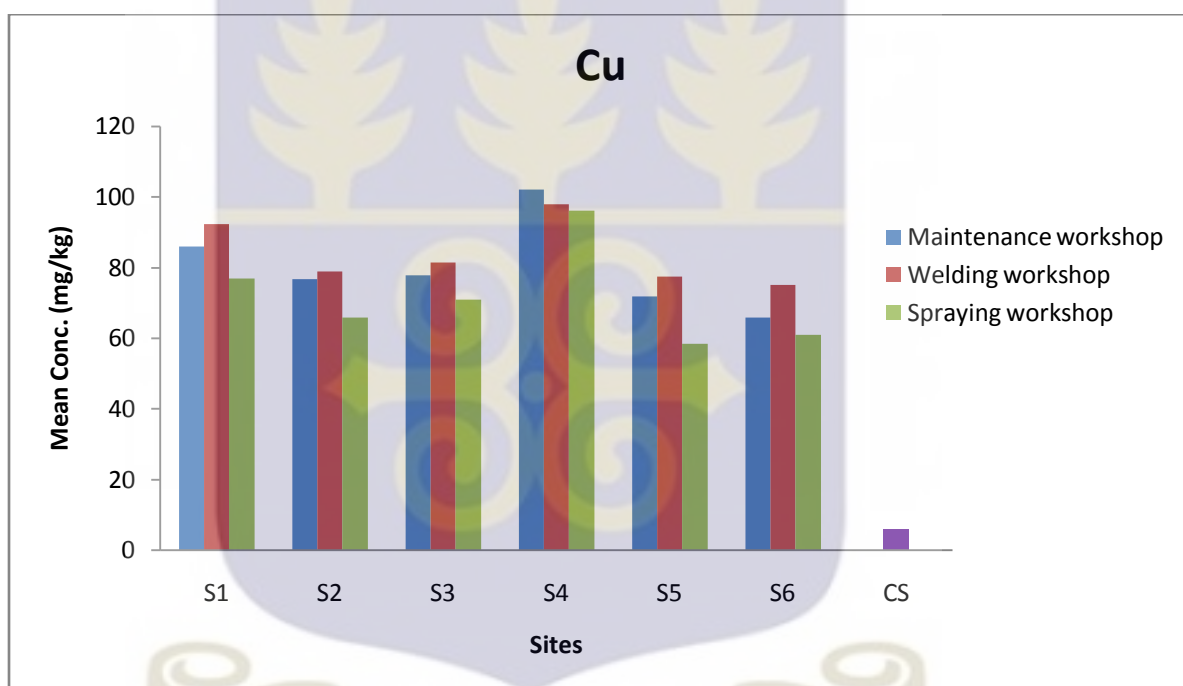
Table 4.6 Analytical results of IAEA – Soil – 7 certified values (mg/kg)

Elements	This Study (mg/kg)	IAEA Values (mg/kg)	95% Confidence Level	% Recovery
Cu	10.98	11	11-13	99.82
Cd	1.15	1.3	1.1 - 2.7	88.46
Zn	103.96	104	101 – 113	99.96
Ni	22.02	26	21 – 37	84.69
Pb	61.85	60	55 – 71	103.08

4.6.2 Concentration of copper (Cu) in soil samples

The mean concentration of copper in the soil samples ranged from 58.40 to 102.07 mg/kg. The highest mean concentration (102.07 mg/kg) was recorded at S3 while the lowest mean concentration (58.40 mg/kg) was recorded at S5. The mean concentration of Cu recorded at maintenance workshops ranged from 65.90 mg/kg recorded at S6 to 102.07 mg/kg recorded at S4 with a total mean of 80.07 mg/kg. The mean concentrations of Cu recorded at welding workshops ranged from 75.10 mg/kg at S6 to 97.92 mg/kg at S4 with a total mean of 83.87 mg/kg. The mean concentration of Cu at spraying workshops ranged from 60.91 mg/kg at S2 to 96.05 mg/kg recorded at S4 with a total mean of 71.70 mg/kg. Similarly, the mean concentration of Cu at CS (control) was found to be 6.24 mg/kg.

The total mean concentrations of copper from the workshops was in the order of Welding workshops (WS) > Maintenance workshops (MS) > Spraying workshops (SS). The mean concentration of copper recorded at the various workshops is illustrated in Figure 4.2. Analysis of variance (ANOVA) results showed significant differences ($p < 0.05$) in the concentrations of Cu among the different workshops. The least significant difference (LSD) test revealed significant difference ($p < 0.05$) in the concentration of copper between S1 and S4; S1 and S5; S1 and S6; S2 and S4 and S3 and S4.



S1= Darkuman Junction, S2= Cable and Wireless, S3= Datus School S4= Kokompe S5= Alafia S6= Global church CS= Control site

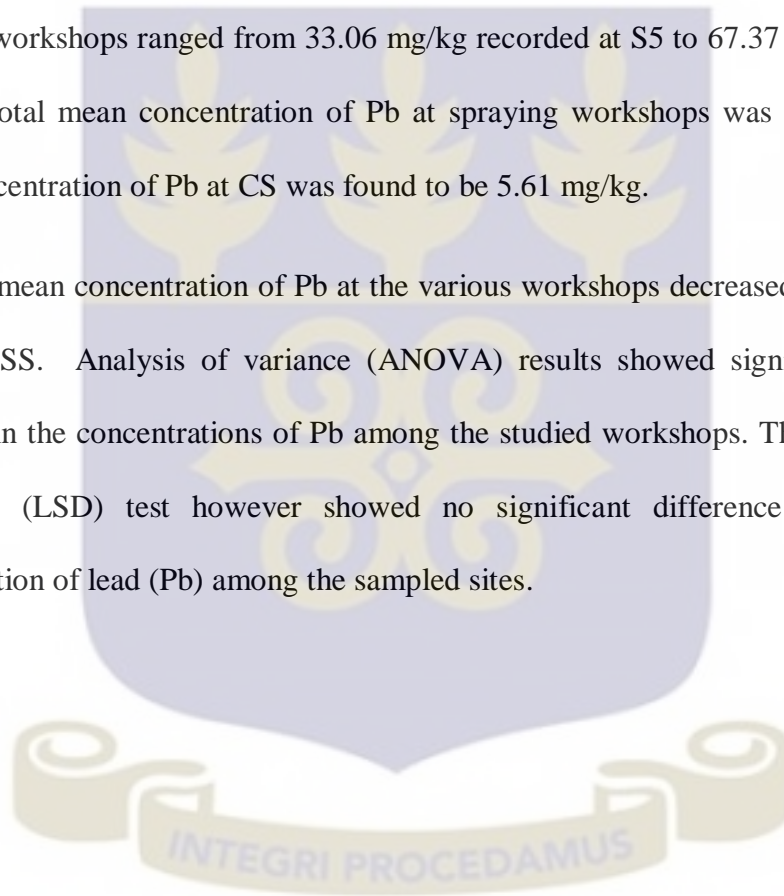
Figure 4.2 Mean concentration of copper recorded at the study sites.

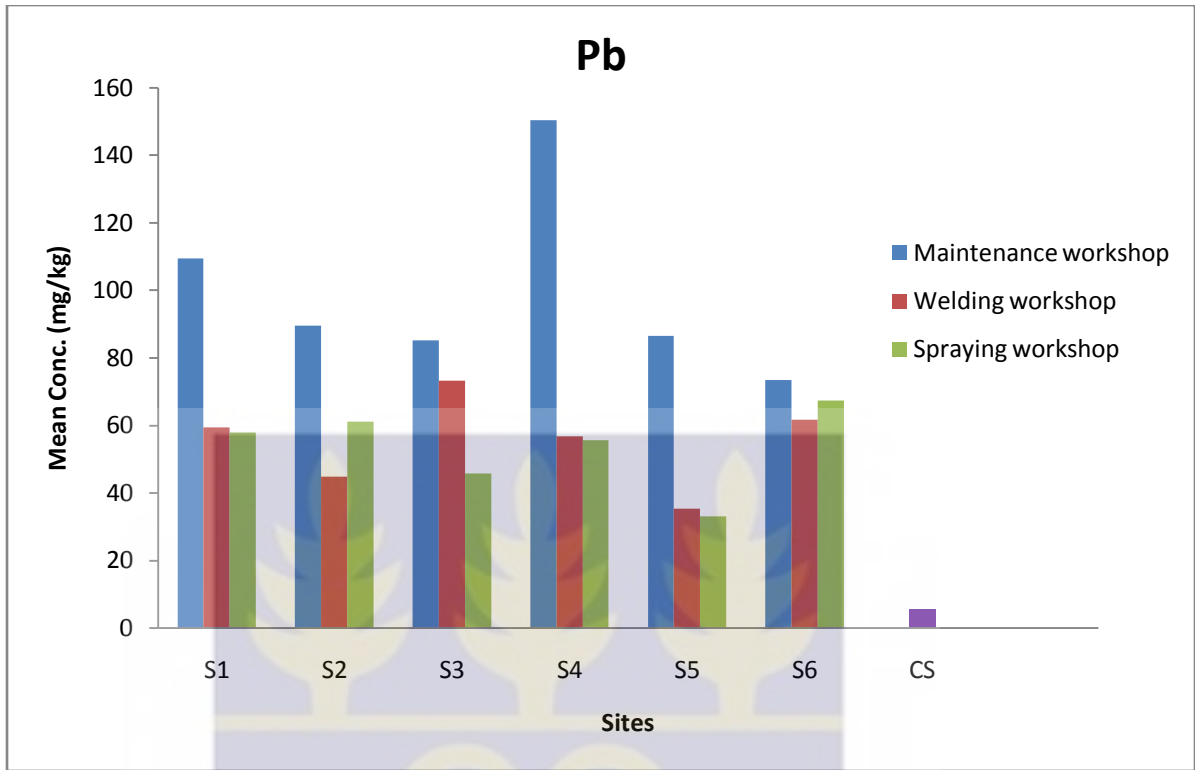
4.6.3 Concentrations of Lead (Pb) in soil samples

The mean concentration values of lead (Pb) in the soil from the study sites ranged from 33.06 to 150.26 mg/kg with the highest mean value (150.26 mg/kg) and lowest mean value (33.06 mg/kg) recorded at the maintenance workshop at S4 and spraying workshop

at S5 respectively. The mean concentration values of Pb recorded at maintenance workshops ranged from 73.45 mg/kg recorded at S6 to 150.26 mg/kg recorded at S4. The total mean concentration of Pb at maintenance workshop was 99.04 mg/kg. The mean concentration values of Pb at welding workshops ranged from 35.18 mg/kg recorded at S5 to 73.12 mg/kg recorded at S3. The total mean concentration of Pb at welding workshops was found to be 55.07 mg/kg. The mean concentration of Pb recorded at spraying workshops ranged from 33.06 mg/kg recorded at S5 to 67.37 mg/kg recorded at S6. The total mean concentration of Pb at spraying workshops was 53.40 mg/kg. The mean concentration of Pb at CS was found to be 5.61 mg/kg.

The total mean concentration of Pb at the various workshops decreased in the order MW > WS > SS. Analysis of variance (ANOVA) results showed significant differences ($p < 0.05$) in the concentrations of Pb among the studied workshops. The least significant difference (LSD) test however showed no significant difference ($p < 0.05$) in the concentration of lead (Pb) among the sampled sites.





S1= Darkuman Junction, S2= Cable and Wireless, S3= Datus School, S4= Kokompe
S5= Alafia, S6= Global church, CS= Control site

Figure 4.3 Mean concentration of lead recorded at the study sites

4.6.4 Concentration of Nickel (Ni) in soil samples

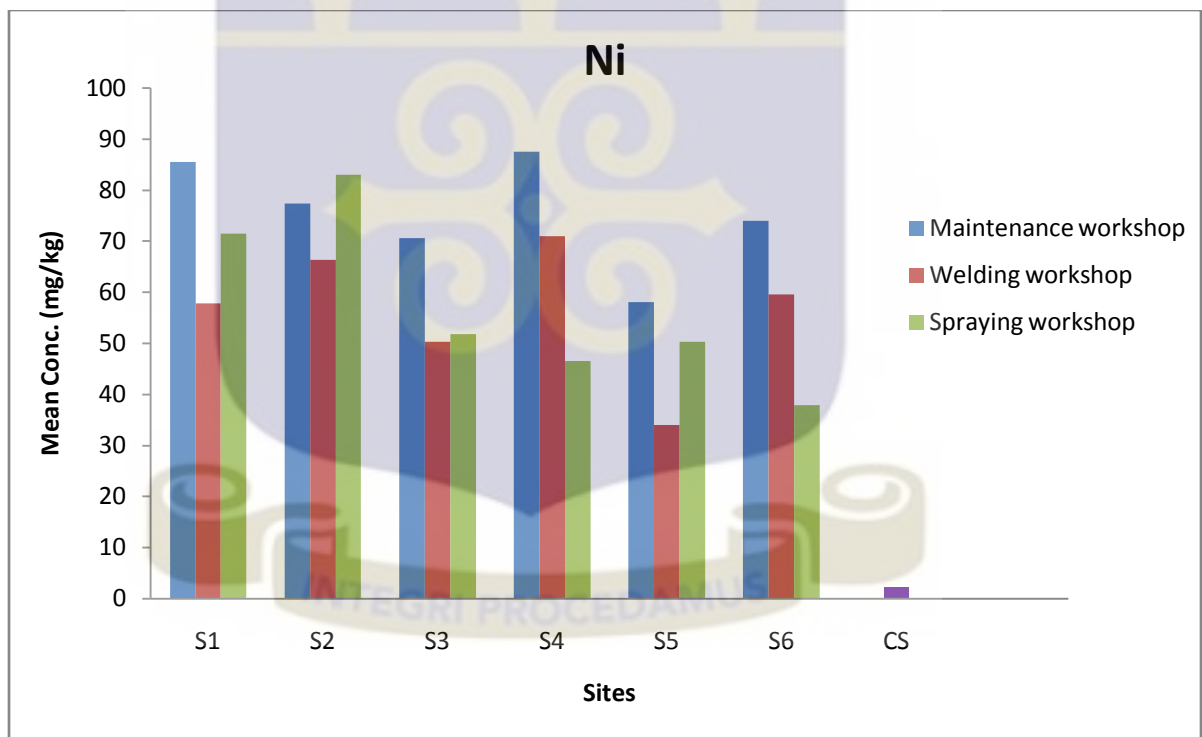
Nickel (Ni) was found in the soils from all sites due to its wide applications in auto mechanics. The mean concentrations of Ni recorded were within the range 34.02 mg/kg recorded at S5 to 87.59 mg/kg recorded at S4.

In Figure 4.4 it could be seen that the highest mean concentration of Ni for each site were recorded from the maintenance workshops except S2 which had its highest value being recorded at the spraying workshop.

The mean concentration of Ni recorded at maintenance workshops ranged from 58.18 mg/kg at S5 to 87.59 mg/kg at S4. The total mean concentration of Ni at maintenance

workshops was 75.55 mg/kg. The mean concentration of Ni recorded at welding workshops ranged from 34.02 mg/kg at S5 to 71.05 mg/kg at S4 while mean concentration of Ni at welding workshops was found to be 56.55 mg/kg. The mean concentration of Ni at spraying workshops ranged from 37.88 mg/kg recorded at S6 to 83.09 mg/kg recorded at S2. The total mean concentration of Ni at spraying workshops was 56.88 mg/kg. The mean concentration value of Ni at CS was 2.14 mg/kg.

Analysis of variance (ANOVA) results showed no significant differences ($p < 0.05$) in the concentrations of Ni among the sites. The least significant difference (LSD) test revealed a significant difference ($p < 0.05$) in the concentration of Ni between sites S2 and S5.



S1= Darkuman Junction, S2= Cable and Wireless, S3= Datus School, S4= Kokompe
S5= Alafia, S6= Global, CS= Control site

Figure 4.4 Mean concentration of Ni in soil samples

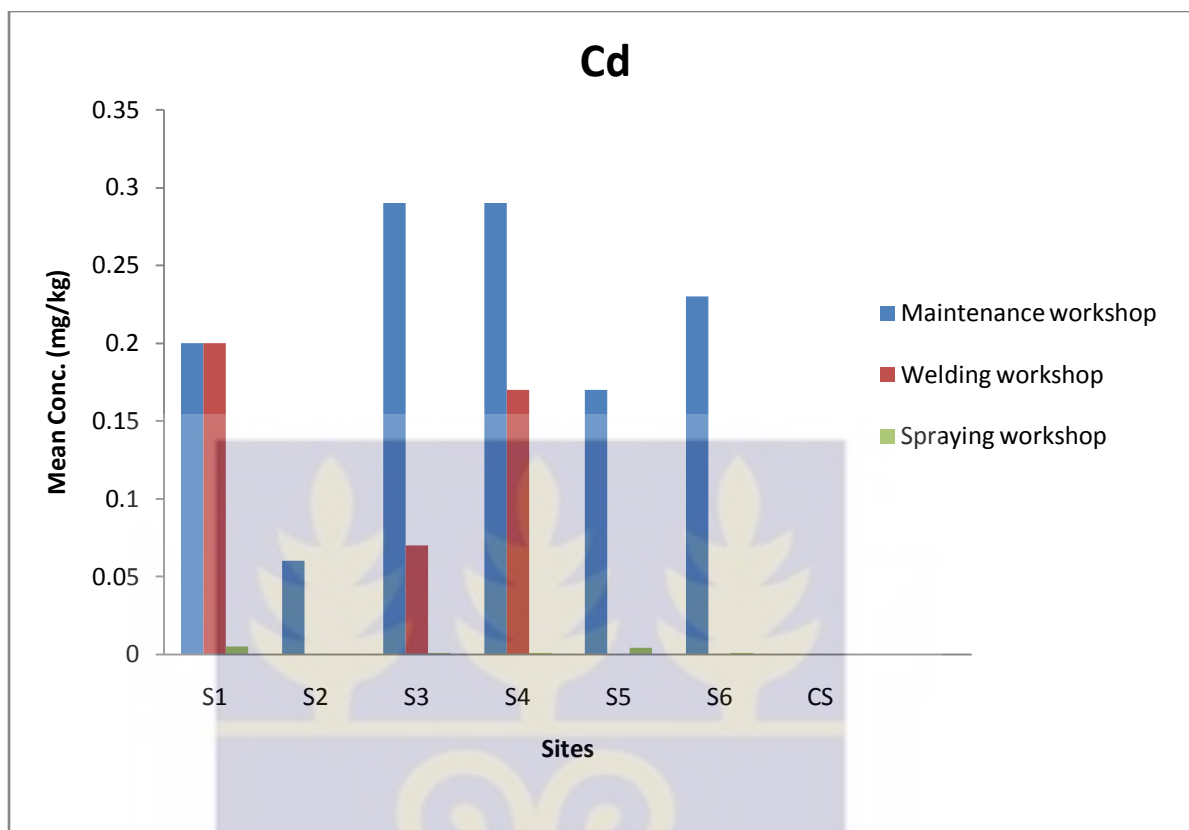
4.6.5 Concentrations of Cadmium (Cd) in soils

Cadmium had the least mean concentrations in all the studied soils. It ranged from concentrations < 0.002 mg/kg (below detection limit) to 0.29 mg/kg.

The mean concentration of Cd at maintenance workshops ranged from 0.06 mg/kg recorded at S2 to 0.29 mg/kg recorded at S4 and S3 with a total mean of 0.17 mg/kg.

The mean concentration of Cd at welding workshops ranged from < 0.002 mg/kg recorded at S2, S4, S5 and S6 to 0.17 mg/kg recorded at S4 with a total mean of 0.04 mg/kg

The total mean concentration of Cd recorded at spraying workshops was lower (0.002 mg/kg to 0.01 mg/kg) than soils from the other workshops. . The concentration of Cd recorded at S2, S3, S4, S5 and S6 were found to be < 0.002 mg/kg. It was also found to be < 0.002 at CS (control). From Figure 4.5 it could be seen that both the welding and maintenance workshops at S1 recorded a mean value of 0.2 mg/kg. Analysis of variance (ANOVA) results showed no significant differences ($p < 0.05$) in the concentrations of Cd among the different workshops. The least significant difference (LSD) test also revealed no significant difference ($p < 0.05$) in the concentration of Cd between the sites.



S1= Darkuman Junction, S2= Cable and Wireless, S3= Datus School, S4= Kokompe
S5= Alafia, S6= Global church, CS= Control site

Figure 4.5 Mean concentrations of Cd in soil samples

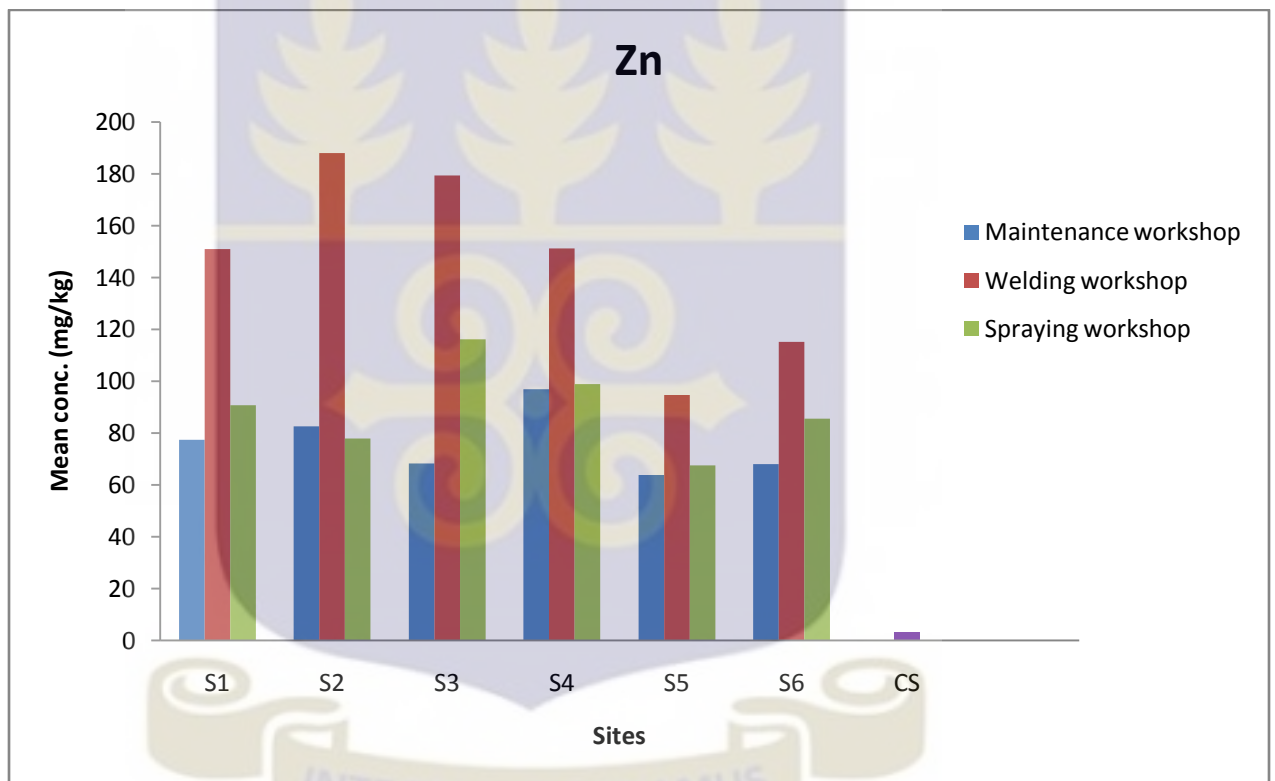
4.6.6 Concentration of Zinc (Zn) in soil samples

The mean concentration of zinc (Zn) across the workshops ranged from 63.92 mg/kg recorded at the maintenance workshop at S5 to 151.16 mg/kg at the welding workshop at S4.

The mean concentration of zinc recorded at maintenance workshop ranged from 63.92 mg/kg at S5 to 96.90 mg/kg at S4. The total mean concentration of Zn recorded at maintenance workshops was 76.21 mg/kg. The total mean concentration of Zn (146.57 mg/kg) at welding workshops was found to be higher than the other workshops. The mean concentration of Zn at these workshops ranged from 94.82 mg/kg at S5 to 187.92

mg/kg at S2. The mean concentrations of Zn at spraying workshops ranged from 37.88 mg/kg at S6 to 83.09 mg/kg at S2. The total mean concentration of Zn at spraying workshops was 89.50 mg/kg.

The distribution of zinc across the workshops of the various sites was in the order of WS > MS > SS as shown in Figure 4.6. Analysis of variance (ANOVA) results showed no significant differences ($p < 0.05$) in the concentrations of Zn among the different sites.



S1= Darkuman Junction S2= Cable and Wireless S3= Datus School area S4= Kokompe
S5= Alafia S6= Global Area CS= Control site

Figure 4.6 Mean concentration of Zn in soil samples

4.7 Geo-accumulation Index (Igeo)

The values of Geo-accumulation index (Igeo) of soils at maintenance workshops, welding workshops and spraying workshops are presented in Tables 4.7, 4.8 and 4.9 respectively.

The Igeo values of heavy metals recorded at maintenance workshops are shown in Table 4.7. Igeo of Pb ranged from 1.97 to 3.00 with a mean value of 2.36. Nickel ranged from -0.95 to -0.36 with a mean of -0.59. Copper had values in the range of -0.32 – (-0.31 with a mean of -0.06 while Cd recorded values in the range of 3.55 - 5.91 with a mean of 4.76. Zn values ranged from -0.72 – (-0.12 with a mean of -0.48. The mean values of Igeo decreased in the order of Cd > Pb > Cu > Zn > Ni.

Table 4.7 Mean Igeo values of soil at maintenance workshops

Site	Cu	Zn	Pb	Cd	Ni
S1	0.06	-0.44	2.54	5.33	-0.40
S2	-0.10	-0.35	2.26	3.55	-0.54
S3	-0.08	-0.62	2.18	5.91	-0.67
S4	0.31	-0.12	3.00	5.03	-0.36
S5	-0.20	-0.72	2.20	5.14	-0.95
S6	-0.32	-0.63	1.97	5.58	-0.60
CS	-6.37	-5.25	-6.55	-	-4.53

S1= Darkuman Junction, S2= Cable and Wireless, S3= Datus School, S4= Kokompe
S5= Alafia S6= Global church CS= Control site

The Igeo values of heavy metals at the welding workshops are presented in Table 4.8: Cu recorded Igeo values ranging from -0.90 to 0.25 with a mean of -0.12. Zinc recorded values which ranged from -0.15 to 0.84 with a mean value of 0.44. Igeo values of Ni and Cd were within the ranges of -1.17 and -0.66 and -2.20 and 5.58 with means -0.94 and 2.55 respectively. The Igeo values for Pb ranged from 1.08 to 1.84 with a mean of 1.47. The mean Igeo values for heavy metals at welding workshops decreased in the order of Cd > Pb > Zn > Cu > Ni.

Table 4.8 Igeo of soil at welding workshops

Site	Cu	Zn	Pb	Cd	Ni
S1	0.16	0.52	1.70	4.05	-0.96
S2	-0.07	0.84	1.48	3.55	-0.76
S3	-0.02	0.77	1.28	-2.20	-1.16
S4	0.25	0.53	1.84	-0.80	-0.66
S5	-0.90	-0.15	1.08	5.14	-1.17
S6	-0.14	0.13	1.44	5.58	-0.92
CS	-9.37	-5.08	-6.55	-	-4.53

S1= Darkuman Junction, S2= Cable and Wireless, S3= Datus School, S4= Kokompe
S5= Alafia S6= Global church CS= Control site

Table 4.9 shows the Igeo values for heavy metals recorded at spraying workshop. Igeo values of Cu ranged from -0.50 to 0.22 with a mean value of -0.23. the concentration of Lead (Pb) ranged from 0.82 to 1.85 with a mean of 1.48. Nickel recorded values ranging from -1.57 to -0.44 with a mean value of -1.04. The Igeo values of Zn ranged from -0.64 to 0.15 with a mean value of -0.23. The Igeo values of Cd ranged from -6.26 to 3.55 with a mean of -1.88.

Table 4.9 Igeo of soil at spraying workshops

Site	Cu	Zn	Pb	Cd	Ni
S1	-0.10	-0.21	1.63	-6.26	-0.65
S2	-0.32	-0.43	1.70	3.55	-0.44
S3	-0.22	0.15	1.28	-5.85	-1.12
S4	0.22	-0.04	1.57	-3.27	-1.27
S5	-0.50	-0.64	0.82	1.85	-1.16
S6	-0.44	-0.30	1.85	-1.29	-1.57
CS	-6.37	-5.25	-6.55	-	-4.53

S1= Darkuman Junction, S2= Cable and Wireless, S3= Datus School, S4= Kokompe
S5= Alafia S6= Global church CS= Control site

4.8 Enrichment factor (EF)

The enrichment factor of soils at maintenance, welding and spraying workshops are presented in Tables 4.10, 4.11 and 4.12 respectively.

At maintenance workshops, enrichment factor of Cu, Zn, Pb, Cd and Ni were found to range from 0.18 to 0.28, 0.11 to 0.16, 3.87 to 7.91, 11.66 to 60.35 and 0.09 to 0.13 with means of 0.22, 0.13, 5.22, 42.36 and 0.11 respectively (Table 4.10).

Table 4. 10 Enrichment factor values for heavy metals at maintenance workshops

Site	Cu	Zn	Pb	Cd	Ni
S1	0.23	0.13	5.76	41.15	0.13
S2	0.21	0.14	4.72	11.66	0.11
S3	0.21	0.11	4.48	58.67	0.10
S4	0.28	0.16	7.91	60.35	0.13
S5	0.20	0.11	4.55	34.98	0.09
S6	0.18	0.11	3.87	47.32	0.11
CS	-	-	0.01	-	0.01

S1= Darkuman Junction, S2= Cable and Wireless, S3= Datus School, S4= Kokompe, S5= Alafia S6= Global church CS= Control site

The Enrichment Factor (EF) values recorded at the welding workshops are presented in Table 4.11. Enrichment Factor values for Cu ranged from 0.20 to 0.27 with a mean value of 0.23 while that of Zn and Pb were in the ranges of 0.16 to 0.32 and 1.85 to 3.85 with means of 0.23 and 2.9 respectively. The EF values for Cd ranged from 0 to 35.66 with a mean of 8.92. Analysis of variance (ANOVA) results showed significant sites differences ($p < 0.05$) in the enrichment factors for Cu, Pb and Ni.

Table 4.11 Enrichment factor values for heavy metals at welding workshops

Site	Cu	Zn	Pb	Cd	Ni
S1	0.25	0.25	3.12	4.12	0.08
S2	0.21	0.32	2.36	0	0.10
S3	0.22	0.30	3.85	13.72	0.07
S4	0.27	0.25	2.99	35.66	0.10
S5	0.21	0.16	1.85	-	0.05
S6	0.20	0.19	3.23	-	0.09
CS	-	0.01	0.01	-	0.01

S1= Darkuman Junction, S2= Cable and Wireless, S3= Datus School, S4= Kokompe, S5= Alafia S6= Global church CS= Control site

Table 4.12 presents the summary of EF values recorded at spraying workshops. Copper, Zinc, Lead, Cadmium and nickel were found to range from 0.16 to 0.26, 0.10 to 0.18, 1.74 to 3.21, 0 to 2.06 and 0.06 to 0.12 with mean values of 0.20, 0.14, 2.81, 0.95 and 0.08 respectively.

Table 4.12 Enrichment factor values for heavy metals at spraying workshops

Site	Cu	Zn	Pb	Cd	Ni
S1	0.21	0.15	3.05	1.03	0.10
S2	0.18	0.15	3.21	0	0.12
S3	0.19	0.18	2.40	0.21	0.08
S4	0.26	0.15	2.93	2.06	0.07
S5	0.16	0.12	1.74	0.82	0.07
S6	0.17	0.10	3.55	1.58	0.06
CS	0.00	0.01	0.01	-	0.01

S1= Darkuman Junction S2= Cable and Wireless S3= Datus School area S4= Kokompe S5= Alafia S6= Global Area, CS= Control sites

4.9 Contamination factor

The contamination factor of soils at maintenance workshops, welding workshops and spraying workshops are presented in Tables 4.13, 4.14 and 4.15 respectively.

The values for contamination factor (CF) of soils at the maintenance workshops are presented in Table 4.13. The CF value for Cu, Zn, Pb, Cd and Ni were found to range

from 1.20 – 1.86, 0.04 – 1.38, 5.88 – 12.02, 0.0 – 0.02 and 0.78 to 1.14 with total mean values of 1.46, 0.93, 7.92, 0.02 and 1.01 respectively

Table 4.13 Contamination factor at maintenance workshops

Site	Cu	Zn	Pb	Cd	Ni
S1	1.56	1.11	8.75	0.02	1.14
S2	1.40	1.18	7.16	0.00	1.03
S3	1.42	0.98	6.81	0.02	0.94
S4	1.86	1.38	12.02	0.02	1.17
S5	1.31	0.91	6.92	0.01	0.78
S6	1.20	0.04	5.88	0.02	0.99
CS	0.02	0.04	0.02	-	0.07

S1= Darkuman Junction S2= Cable and Wireless S3= Datus School area S4= Kokompe S5= Alafia S6= Global Area, CS= Control sites

The values for contamination factor (CF) of soils at the welding workshops are presented in Table 4.14. The CF value for Cu, Zn, Pb, Cd and Ni were found to range from 1.37 to 1.78, 1.35 to 2.68, 3.12 to 5.35, 0 – 0.87 and 0.45 to 0.95 with total mean values of 1.55, 2.09, 4.21, 0.22 and 0.75 respectively.

Table 4.14 Contamination factor at welding workshops

Site	Cu	Zn	Pb	Cd	Ni
S1	1.68	2.16	4.88	0.1	0.77
S2	1.43	2.68	4.18	0	0.89
S3	1.48	2.56	3.63	0.33	0.67
S4	1.78	2.16	5.35	0.87	0.95
S5	1.41	1.35	3.12	-	0.45
S6	1.37	1.64	4.08	-	0.79
CS	0.02	0.04	0.02	-	0.07

S1= Darkuman Junction S2= Cable and Wireless S3= Datus School area S4= Kokompe S5= Alafia S6= Global Area, CS= Control sites

The values for contamination factor (CF) of soils at the spraying workshops are presented in Table 4.15. The CF value for Cu, Zn, Pb, Cd and Ni were found to range from 1.06 to

1.75, 0.97 to 1.66, 2.64 to 5.39, 0 to 0.05 and 0.35 to 1.01 with total mean values of 1.30, 1.28, 4.27, 0.23 and 0.71 respectively

Table 4.15 Contamination factor at spraying workshops

Site	Cu	Zn	Pb	Cd	Ni
S1	1.40	1.29	4.63	0.03	1.01
S2	1.20	1.11	4.88	0.00	0.97
S3	1.29	1.66	3.65	0.01	0.67
S4	1.75	1.41	4.45	0.05	0.63
S5	1.06	0.97	2.64	0.02	0.62
S6	1.11	1.22	5.39	0.04	0.35
CS	0.02	0.04	0.02	-	0.07

S1= Darkuman Junction S2= Cable and Wireless S3= Datus School area S4= Kokompe S5= Alafia S6= Global Area, CS= Control sites

4.10 Pollution Index

The pollution index values for maintenance workshops, welding workshops and spraying workshops were found to vary from 0.40 to 1.65, 1.06 to 1.76 and 0.46 to 1.45 respectively as shown in Table 4.16.

Table 4.16 Pollution indexes at maintenance, welding and spraying workshops

Site	Maintenance workshops	Welding workshops	Spraying workshops
S1	0.81	1.06	0.76
S2	1.65	1.70	1.45
S3	0.71	1.25	0.55
S4	0.94	1.76	0.81
S5	0.57	1.22	0.50
S6	0.40	1.49	0.46

S1= Darkuman Junction S2= Cable and Wireless S3= Datus School area S4= Kokompe S5= Alafia S6= Global Area

4.11 Correlation between heavy metals and soil physicochemical parameters

The strength and direction of the physico-chemical parameters and heavy metals measured in the soil samples were determined using the Pearson's product moment correlation coefficient. At maintenance workshops, strong positive correlations were established between Cu and %OM (0.853), Zn and Cu (0.989), Pb and Cu (0.980), Pb and Zn (0.968), Ni and %OM (0.864), Ni and Cu (0.980), Ni and Zn (0.986), Ni and Pb (0.941) at $p < 0.01$ (Table 4.17). Strong positive correlations were also recorded for Cu and CEC (0.709), Cu and Ec (0.753), Zn and CEC (0.757), Zn and EC (0.742), Pb and %OM (0.773), Ni and CEC (0.771), Ni and EC (0.791) at $p < 0.05$.

At welding workshops, strong positive correlations were established between Cu and %OM (0.933), Cu and EC (0.877), Zn and CEC (0.894), Zn and %OM (0.883), Zn and EC (0.854), Zn and Cu (0.912), Pb and CEC (0.857), Pb and %OM (0.898), Pb and EC (0.869), Pb and Cu (0.913), Pb and Zn (0.902), Ni and %OM (0.929), Ni and Cu (0.940), Ni and Zn (0.929), Ni and Pb (0.892) at $p < 0.01$. Strong positive correlation at $p < 0.05$ (Table 4.19) were established Cu and CEC (0.782), Ni and CEC (0.822), Ni and EC (0.812), Cd and EC (0.792) (Table 4.18).

At spraying workshops, strong positive correlations at $p < 0.01$ (Table 4.19) were established between CEC and Pb (0.913), %OM and Cu (0.975), %OM and Zn (0.882), %OM and Pb (0.887), %OM and Ni (0.880), EC and Pb (0.947), Cu and Zn (0.946), Cu and Pb (0.891), Zn and Pb (0.883) and Pb and Ni (0.835). A positive strong correlation at $p < 0.05$ was also established for between CEC and Cu (0.796), CEC and Zn (0.806), CEC and Ni (0.761), EC and Cu (0.826), Cu and Ni (0.822) and Zn and Ni (0.794).

Table 4.17 Pearsons' correlation coefficient between soil physicochemical parameters and heavy metals content at maintenance workshops

Elements	pH	CEC	%OM	EC
Cu	0.450	0.709*	0.853**	0.753*
Zn	0.520	0.757*	0.829*	0.742*
Pb	0.396	0.624	0.773*	0.705
Ni	0.489	0.771*	0.864**	0.791*
Cd	-0.194	-0.086	0.153	-0.093

*Correlation significant at 0.05

**Correlation significant at 0.01

Table 4.18 Pearsons' correlation coefficient between soil physicochemical parameters and heavy metals content at welding workshops

	pH	CEC	%OM	EC
Cu	0.03	0.782*	0.993**	0.877**
Zn	0.32	0.894**	0.883**	0.854**
Pb	0.39	0.857**	0.898**	0.869**
Ni	0.16	0.822*	0.929**	0.812*
Cd	-0.03	0.52	0.58	0.792*

*Correlation significant at 0.05

**Correlation significant at 0.01

Table 4.19 Pearsons' correlation coefficient between soil physicochemical parameters and heavy metals content at spraying workshops

Elements	pH	CEC	%OM	EC
Cu	0.052	0.796*	0.975**	0.826*
Zn	0.147	0.806*	0.882**	0.787*
Pb	0.078	0.913**	0.887**	0.947**
Ni	-0.263	0.761*	0.880**	0.687
Cd	0.456	0.588	0.320	0.095

*Correlation significant at 0.05

**Correlation significant at 0.0

4.12 PAHs in soil samples

Results from the GC-MS showed that the levels of naphthalene, acenaphthalene, acenaphthene, fluorene, phenanthrene, anthracene, fluoranthene, pyrene, benzo (a) anthracene, chrysene, benzo (b) flouranthene, benzo (k) fluoranthene, benzo (a) pyrene, indeno (1,2,3-c,d) pyrene, dibenzo (a,h) anthracene, benzo (g,h,i) perylene in soil samples were found to be $<0.01 \mu\text{g/g}$ (below detection limit) of the instrument used (Varian CP – 3800 GC with a CP – 8400 Autosampler and saturn 2000).

4.13 Social survey

4.13.1 Demographic characteristics of respondents

The respondents for the survey were made up of 80 heads of households or household representatives, and 150 artisans (made up of welders, sprayers, mechanics and spare part dealers). The average number of persons living in a household was 8. About 71.3 % of household respondents had lived in Darkuman over 10 years. Majority (72.6 %) of artisans interviewed were below 40 years of age with 31 – 40 years being the modal age range. About 55.33% of artisans had formal education, which comprised basic education (37.3%), secondary education (16%) and tertiary education (2%). About 44.7% of artisans had no formal education. The demographic characteristics of households and that of the artisans are represented in Table 4.19 and Table 4.20 respectively.

Table 4.19 Socio-demographic characteristics of households' respondents (n= 80)

Variable	Description	Percentage (%)
Gender	Male	18.7
	Female	81.3
Age (years)	10 – 20	7.5
	21 - 30	11.2
	31 - 40	32.5
	41 – 50	28.8
	51 – 60	13.8
	Above 60	6.2
Highest educational level	Basic education	26.2
	Secondary education	38.8
	Tertiary education	23.8
	No formal education	11.2
Number of years lived in Darkuman	1 – 5	11.2
	6 -10	17.5
	11 – 15	20.0
	16 – 20	22.5
	Above 20	28.8
Household's membership	1 – 5	48.8
	6 – 10	41.2
	11 – 15	10.0

Source: Field survey, 2016

Table 4.20 Socio-demographic characteristics of artisans (n= 150)

Variable	Description	Percentage (%)
Gender	Male	74
	Female	26
Age (years)	20-30	26.7
	31-40	41.3
	41-50	26.7
	Above 50	5.4
Highest educational level	Basic education	37.3
	Secondary education	16.0
	Tertiary education	2.0
	No formal education	44.7
Work experience (years)	1 – 5	20.0
	6 – 10	26.0
	11 – 15	18.7
	16 – 20	19.33
	21 - 25	4.7
	26 – 30	2.0
	Above 30	7.3
Monthly income	Less than 100	12.0
	100 – 200	8.0
	200 – 300	15.3
	400 – 500	42.7
	Above 500	22.0
Residential Status	Resident	40.7
	Non-resident	59.3

Source: Field survey, 2016

4.14 Knowledge and perception of occupational health risks among artisans

More than fifty percent of respondents (77.3%) had some perceptions and knowledge of occupational health risks with about 77% of respondents being aware that coming into contact with chemicals can have adverse effect on their health. .

4.14.1 Factors influencing artisans' knowledge of occupational health risk

Table 4.21 presents the logit result on factors influencing artisans' knowledge of occupational health risk. It was revealed that gender of an artisan, years of experience, and membership of artisan based association and trainings (eg. workshop, seminars, etc.) significantly influenced artisans' knowledge of occupational health risk. Gender of an artisan and years of experience were significant at 1% while membership of artisan based association and training were significant at 5%.

Table 4.21 Logit results on factors influencing artisans' knowledge of occupational health risk

Variables	Coefficient	P-value	Marginal effect
Gender	1.743	0.001***	0.287
Age	-0.029	0.226	-0.004
Educational level	0.014	0.961	0.002
Experience	-0.113	0.000***	-0.014
Artisan based association	1.215	0.040**	0.164
Training	1.342	0.019**	0.164
Constant	1.778	0.105	-
Log likelihood	-60.644		
Pseudo R2	0.2446		
LR chi2(6)	39.28		
Prob >chi2	0.000		

***, ** represents 1% and 5% significance levels respectively

Source: Author's Computation

4.15 Use of protective clothing among artisans

Results from the survey showed that working hours of artisans varied according to their work load. Most of the workers (98%) worked more than six hours in a day with 81.3% usually having Sundays as their off days. About 63.3% of respondents answered in the

affirmative when they were asked if they used personal protective equipment (PPE) when working with almost half of these respondents (49.3%) not fully protecting themselves during work. Full protective clothing includes an overcoat (“working gear”), goggles, boots, gloves and nose mask. Partial protective clothing is any of these protective clothing and no protective clothing is when artisans use their own cloths without any of the items mentioned above The choice of PPE and reasons respondents gave for not fully protecting themselves are presented in Figures 4.7 and 4.8 respectively.

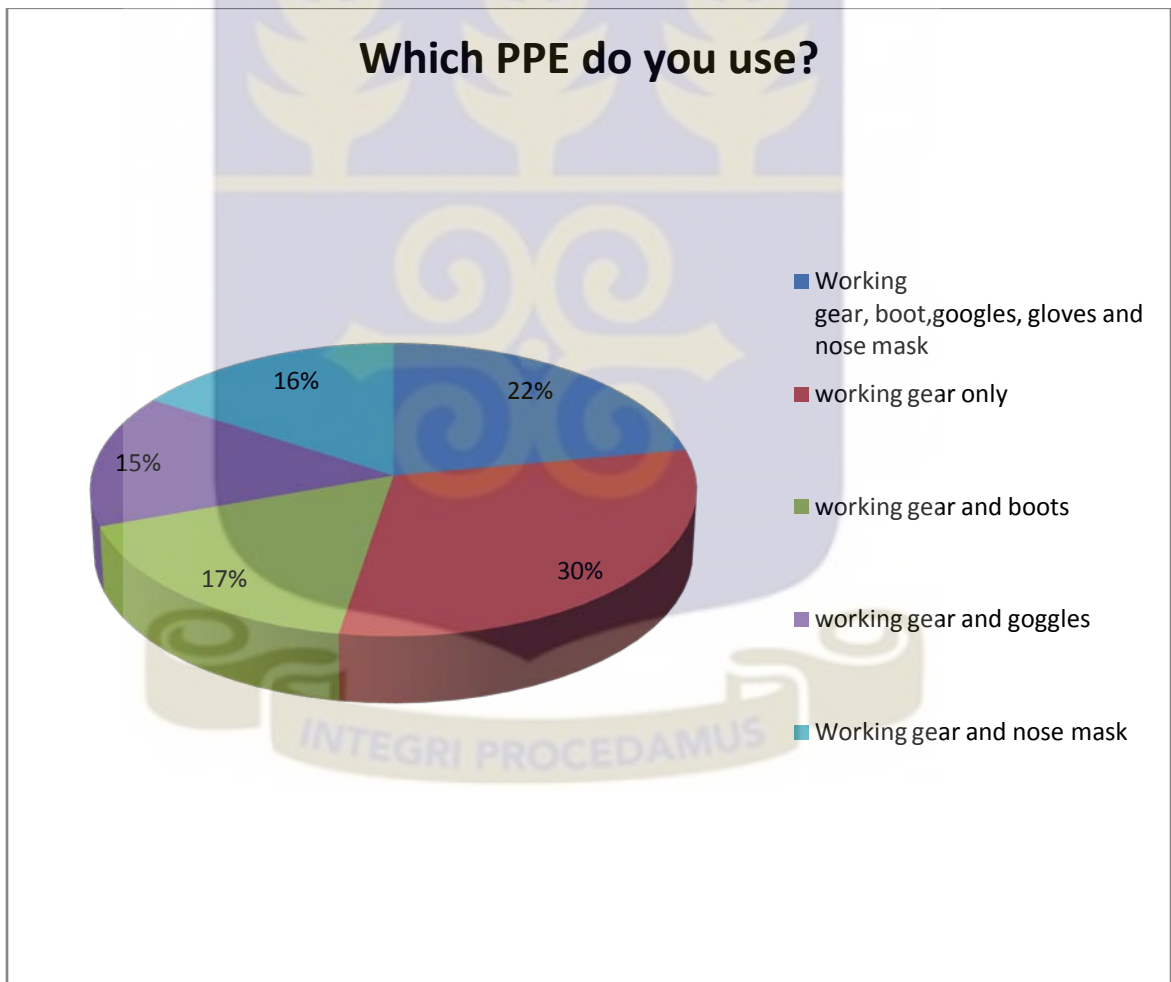


Figure 4.7 Choice of PPE among artisans

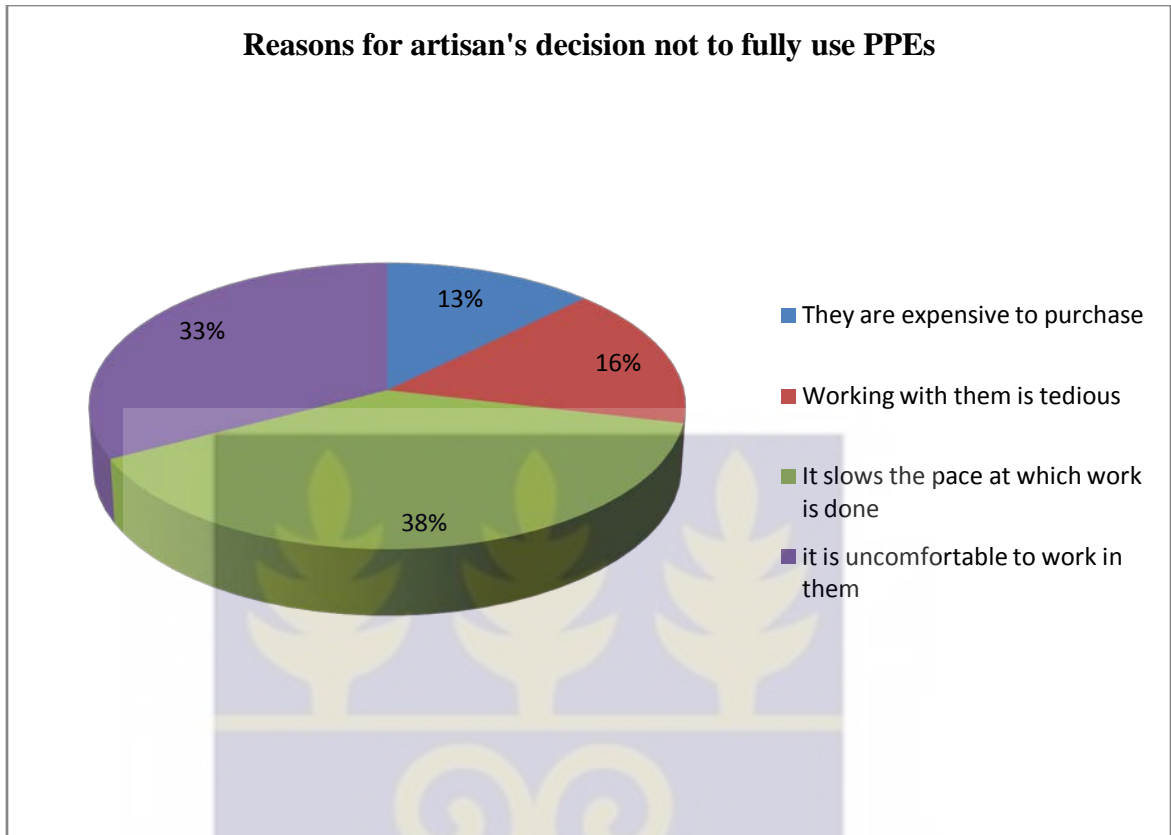


Figure 4.8 Reasons for artisans' decision not to fully use Personal Protective Equipment (PPE)

4.15.1 Factors influencing artisans' decision to wear protective clothing during work

Table 4.22 presents the logit result on factors influencing artisans' decision to wear protective clothing during work. The significant variables which influenced artisans' decision to wear protective clothing during work were educational level of an artisan, years of experience, knowledge of occupational health risk and income of an artisan. All the variables that significantly influenced artisans' decision to wear protective clothing during work were significant at 1%.

Table 4.22 Logit results on factors influencing artisans' decision to wear protective clothing during work

Variables	Coefficient	P-value	Marginal effect
Gender	-0.060	0.923	-0.012
Age	0.017	0.566	0.003
Educational level	1.015	0.003***	0.197
Experience	-0.225	0.000***	-0.044
Artisan based association	0.212	0.715	0.041
Training	-0.319	0.550	-0.062
knowledge of health risk	1.732	0.004***	0.382
knowledge of the safety and hygienic practices	0.578	0.380	0.118
Income of artisan	0.661	0.001***	0.128
Constant	-2.399	0.102	-
Log likelihood	-58.171		
Pseudo R2	0.4099		
LR chi2(9)	80.80		
Prob >chi2	0.000		

*** 1% significance level

Source: Author's Computation

4.15.2 Factors influencing artisans to partially or fully wear protective clothing during work

The multinomial logit was used to estimate the factors influencing an artisan to partially or fully wear protective clothing during work. Although artisans wear protective clothing, only a few fully wear protective clothing during work. Table 4.23 presents the multinomial logit result of the factors influencing an artisan to partially or fully wear protective clothing during work. The result shows that educational level of the artisan and income of an artisan had significant and positive correlation with partially and fully wearing of protective cloths during work while years of working experience had a

negative but significant effect on partially and fully wearing of protective cloths during work. Occupational health risk showed positive and significant relationship with partially wearing of protective cloths during work.

Table 4.23 Multinomial logit results on factors influencing artisans to partially or fully wear protective clothing during work

Variables	<u>Partial Protection</u>		<u>Full Protection</u>	
	Coefficient	P-value	Coefficient	P-value
Gender	-0.183	0.768	0.873	0.358
Age	0.040	0.254	-0.047	0.266
Educational level	1.019	0.004***	1.228	0.015**
Experience	-0.257	0.000***	-0.146	0.015**
Artisan based association	0.378	0.524	-0.780	0.339
Training	-0.379	0.487	0.080	0.913
knowledge of health risk	1.462	0.019**	16.401	0.988
knowledge of the safety and hygienic practices	0.825	0.241	-0.372	0.659
Income of artisan	0.644	0.002***	0.630	0.017**
Constant	-2.991	0.052	-17.424	0.987
Log likelihood	-96.754			
Pseudo R2	0.3496			
LR chi2(18)	104.00			
Prob >chi2	0.3496			
No protective clothing is the base outcome				

***, ** represents 1% and 5% significance levels respectively

Source: Author's Computation

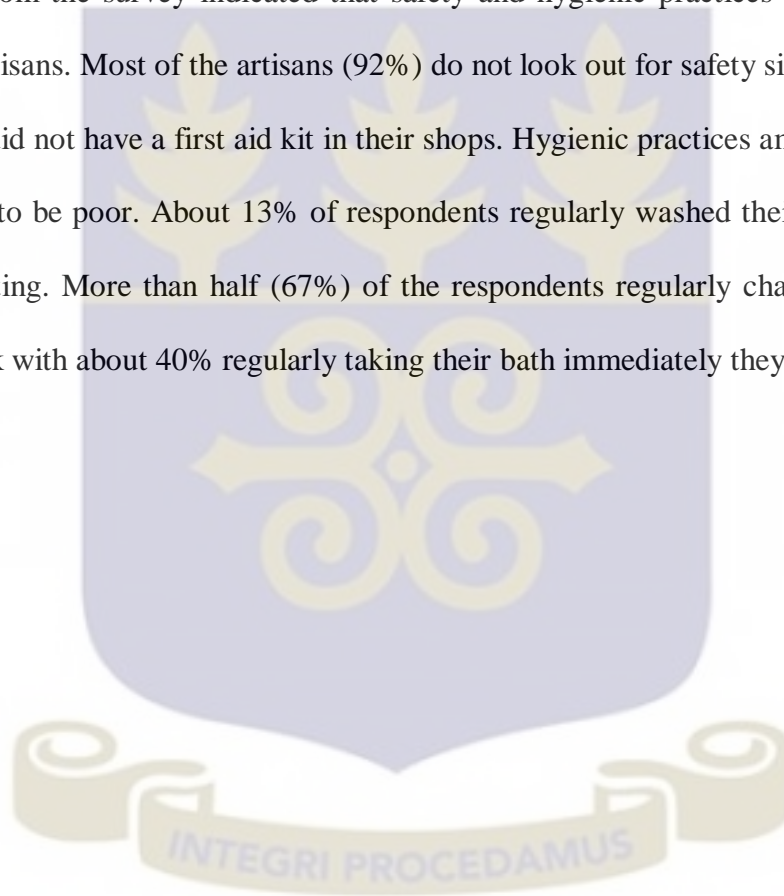
4.16 Health related issues reported by artisans associated with their work

All artisans interviewed were aware of the adverse effects of chemicals on their health with about 80% of respondents having experienced symptoms of ill health as a result of exposure to these chemicals. Major symptoms experienced by these artisans were dizziness (17%), body pains (38%), headaches (20%), coughing and skin irritations

(11%). These could be as a result of the direct exposure of artisans to hazardous chemicals due to their failure in using the right PPE during working hours. Some respondents also have suffered from malaria as a result of mosquitoes breeding on stagnant waters found in obscure places such as in lorry tyres.

4.16 .1 Safety and hygienic practices by artisans on the site

Results from the survey indicated that safety and hygienic practices are not prioritized among artisans. Most of the artisans (92%) do not look out for safety signs when working and also did not have a first aid kit in their shops. Hygienic practices among artisans were observed to be poor. About 13% of respondents regularly washed their hands with soap before eating. More than half (67%) of the respondents regularly changed their clothes after work with about 40% regularly taking their bath immediately they get home.



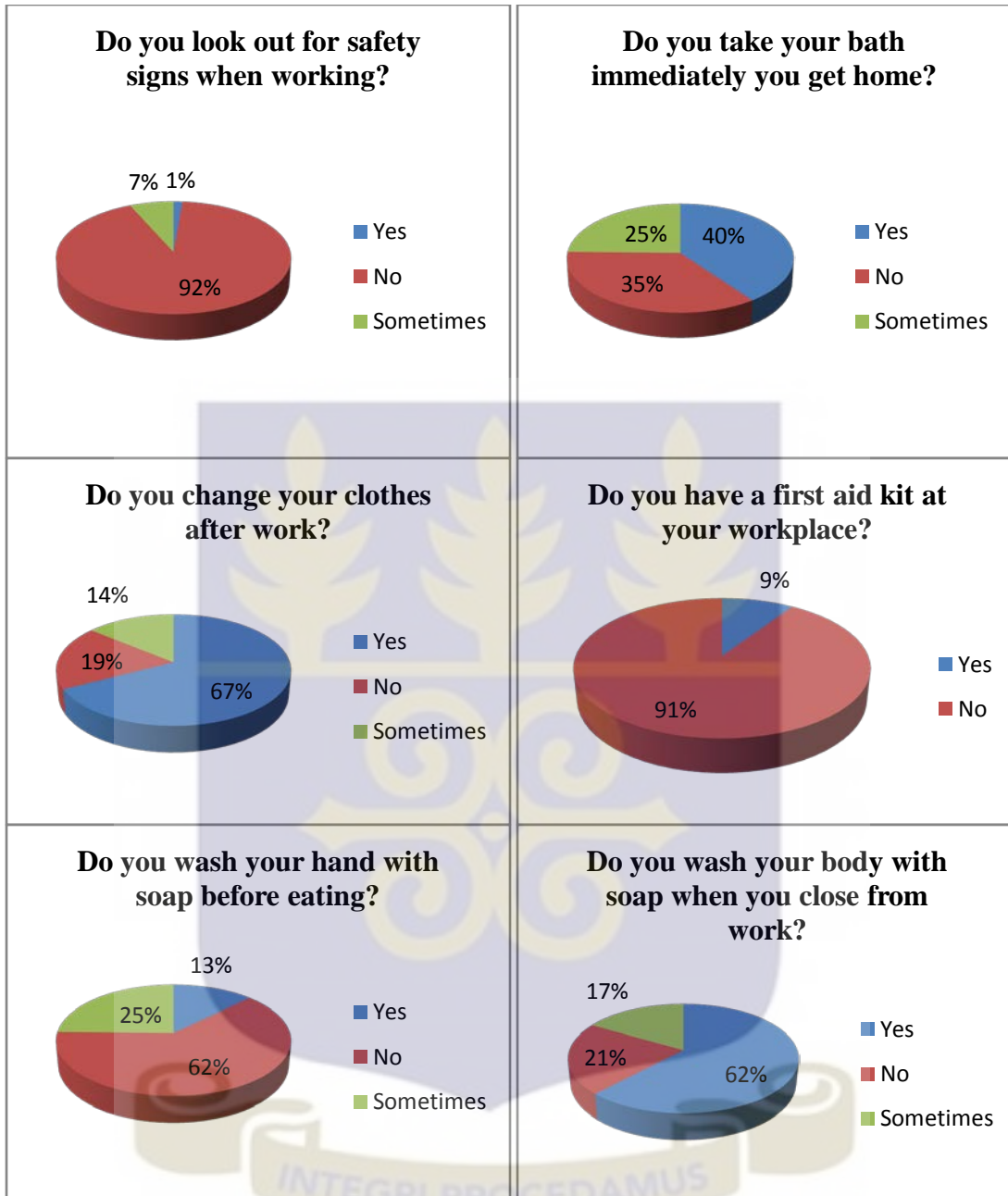


Figure 4.9 Response of artisans with regard to safety and hygienic practices on site

4.16.2 Factors influencing artisans’ knowledge of the safety and hygienic practices during work

Table 4.24 presents the logit result on factors influencing artisans’ knowledge of safety and hygienic practices during work. It was revealed that gender of an artisan, age of an

artisan, educational level of an artisan and years of experience significantly ($p < 0.01$) influenced knowledge of safety and hygienic practices during work.

Table 4.24 Logit results on factors influencing artisans' knowledge of the safety and hygienic practices during work

Variables	Coefficient	P-value	Marginal effect
Gender	-1.496	0.001***	-0.217
Age	0.097	0.000***	0.017
Educational level	-0.814	0.002***	-0.145
Experience	0.072	0.007***	0.013
Artisan based association	-0.719	0.122	-0.124
Training	0.192	0.677	0.034
Constant	-0.505	0.656	-
Log likelihood	-71.418		
Pseudo R2	0.2206		
LR chi2(6)	40.42		
Prob >chi2	0.000		

*** 1% significance level

Source: Author's Computation

4.17 Artisans' knowledge of impact of mechanic activities on water quality from hand dug wells

Hand dug wells popularly referred to as “bura” in the community are important source of water for the people in Darkuman especially when there is disruption in water supplies from the Ghana Water Company. Activities of mechanics and scrap dealers in the area generate wastes such as used engine oil which may pollute water sources through processes such as leaching and surface run-off. More than half of these respondents (64%) do not think the activities of artisans have any impact on water from the hand dug wells with 36% of the respondents answered in the affirmative.

4.17.1 Factors influencing artisans' knowledge of impact of mechanic activities on quality of water from hand dug wells

Table 4.25 presents the logit result on factors influencing artisans' knowledge of impact of mechanic activities on water from hand dug wells. The results revealed that age of the artisan, educational level, years of experience and training significantly influenced artisans' knowledge of impact of their activities on underground water (hand dug wells) quality. Age of an artisan and training were significant at 1%, years of artisan experience was significant at 5% while educational level of an artisan was significant at 10%. All the significant variables positively influenced artisans' perception of impact of mechanic activities on water from hand dug wells, except for age of an artisan which negatively influenced artisans' perception of impact of mechanic activities on water quality from hand dug wells.

Table 4.25 Logit results on factors influencing artisans' perception of impact of mechanic activities on water from hand dug wells

Variables	Coefficient	P-value	Marginal effect
Gender	-0.581	0.236	-0.128
Age	-0.111	0.000***	-0.023
Educational level	0.522	0.079*	0.110
Experience	0.064	0.024**	0.013
Artisan based association	0.695	0.143	0.143
Training	2.149	0.000***	0.444
Residential status	0.757	0.169	0.162
Use of hand dug well	0.643	0.215	0.136
Constant	-0.066	0.954	-
Log likelihood	-75.009		
Pseudo R2	0.2301		
LR chi2(6)	44.83		
Prob >chi2	0.000		

***, **, * represents 1%, 5% and 10% significance levels respectively

Source: Author's Computation

4.18 Perception of households on siting of auto-workshops in Darkuman

About 65% of household respondents had problems with the siting of auto-mechanic workshops in Darkuman. Majority (71%) of household respondents indicated that the activities of mechanics cause nuisance to them (Figure 4.10). These nuisances were mostly pollution of the air (37%) and noise pollution (47%). Assessment of the awareness of the impact of activities of mechanics among households indicated that 75% of respondents were aware of the likely impact on their health.

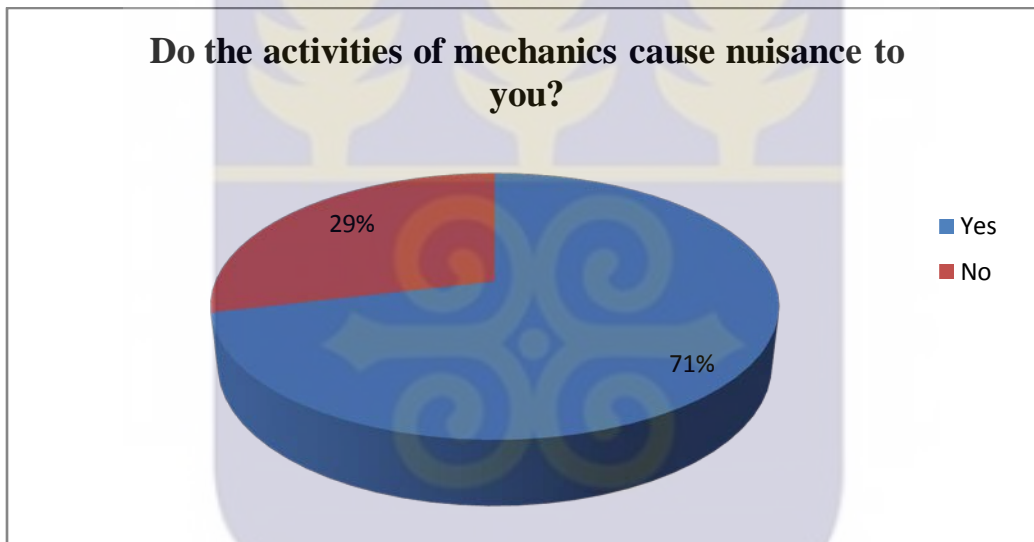


Figure 4.10 Households' response to nuisance caused by mechanic activities

4.18.1 Factors influencing households' perception and knowledge of impact of mechanic activities on quality of water from hand dug wells

Table 4.26 presents the logit result on factors influencing households' perception of impact of mechanic activities on quality of water from hand dug wells. From the analysis, gender, level of education, use of water from hand dug well and health related issues among households significantly influenced household perception and knowledge of

impact of mechanic activities on quality of water from hand dug wells. Gender and health related issues among households as a result of the use of water from hand dug wells was significant at 1%, educational level was significant at 5% while use of water from hand dug well was significant at 10%. Level of education and health related issues among households as a result of the use of water from hand dug wells, positively influenced households' perception of impact of mechanic activities on water from hand dug wells while gender and use of water from hand dug well negatively influenced households' perception of impact of mechanic activities on water from hand dug wells.

Table 4.26 Logit results on factors influencing households' perception of impact of mechanic activities on water from hand dug wells

Variables	Coefficient	P-value	Marginal effect
Gender	-3.518	0.000 ^{***}	-0.425
Age	0.359	0.272	0.075
Educational level	0.908	0.018 ^{**}	0.189
Years lived in the community	-0.205	0.477	-0.043
Closeness of hand dug well to mechanic shops	-0.412	0.360	-0.086
Use of hand dug well	-2.182	0.052 [*]	-0.478
Perceived health risk of mechanic activities	3.301	0.000 ^{***}	0.455
Constant	-2.936	0.306	-
Log likelihood	-35.840		
Pseudo R2	0.3159		
LR chi2(7)	33.09		
Prob >chi2	0.000		

***, **, * represents 1%, 5% and 10% significance levels respectively

Source: Author's Computation

4.19 Use of water from hand dug wells among households

About 61.8% of respondents use water from hand dug wells for various purposes including domestic (45%), religious (5%) and economic (11%). Majority (42.5%) of respondents indicated they occasionally used water from hand dug wells with 25% always using water from these sources (Figure 4.11).

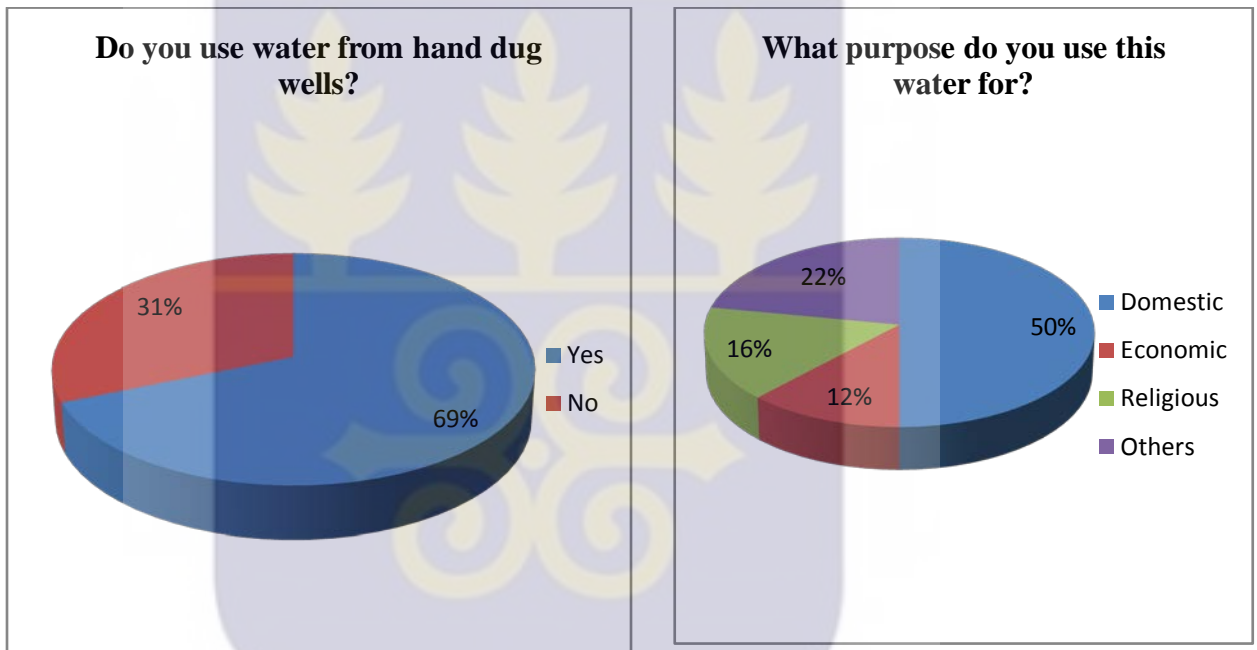


Figure 4.11 Use of water from hand dug wells among household respondents

CHAPTER FIVE

DISCUSSION

5.1 Physicochemical parameters of water

5.1.1 pH of water

The pH of water samples was found to be slightly acidic. With the exception of W2, water samples were all within the World Health Organization's (WHO) permissible pH levels for drinking water which is 6.5 – 8.5 (WHO, 2008). The pH value of W2 was below 6.5 which according to Nkansah *et al.*, (2010) can cause health issues such as acidosis and damage to the digestive systems. The high pH value recorded for W2 could be due to the heavy mechanic activities (which lead to the discharge of pollutants) that take place around this well. The pH of water samples from this study was found to be in line with those reported by Adewoyin *et al.*, (2013).

5.1.2 Electrical Conductivity

Conductivity is an indication of dissolved solids and contaminants especially electrolytes in a solution. A solution with a high conductivity value means there are lots of dissolved ions present in that solution. The mean conductivities of water samples recorded during the study period were all below the WHO maximum permissible limit for electrical conductivity in drinking water of 1000 $\mu\text{s}/\text{cm}$ (WHO, 2008). They were however found to be higher as compared to that found by Nkansah *et al.*, (2010). This dichotomy can be attributed to the difference in the geology of the soil and the activities that take place around the sampling sites.

5.1.3 Water Hardness

Water hardness is the measure of the ability of water to lather with soap. The hardness or softness of water varies from place to place and reflects the nature of the geological properties of the area, with which water have been in contact. From the results, the total hardness of all the samples was within the WHO maximum permissible limit of 500 mgCaCO₃ except that of W2 which recorded mean values of 532.3 ± 0.34 , 578.7 ± 0.56 and 610.2 ± 0.00 mgCaCO₃ in February, January and December respectively. This could be as a result of the high electrical conductivity of water from that site. Hardness of water may not have any adverse health implications but may affect the taste of water and influence its ability to lather with soap. The results from this study were observed to be lower than those of Adewoyin *et al.*, (2013) who recorded a value of 237 mg/L in groundwater in Ibadan metropolis.

5.1.4 Alkalinity

In natural water, alkalinity is caused by three major classes of minerals: hydroxides, carbonates and hydrogen carbonates. In all forms of effluents, alkalinity is due to the presence of salts of weak acid such as ethanoic, propanoic or the presence of ammonia hydroxides. Samples from this study recorded values below the WHO maximum permissible limit for drinking water (500 mgCaCO₃/L) (WHO, 2008).

5.1.5 Total Dissolved Solids (TDS)

As reported in the WHO guideline for drinking water (WHO, 2008), there is no health based limit for TDS in drinking water, as TDS occurs in drinking water at low concentrations to have any toxic effect. TDS value of less than 500 mg/L is generally considered to be good since drinking water becomes significantly and increasingly

unpalatable at TDS Levels greater than about 1000 mg/L. According to London *et al* (2005), drinking water with TDS greater than 1200 mg/L may be objectionable to consumers and could have impacts for those who need to limit their daily salt intake e.g. Severely hypertensive, diabetic, and renal dialysis patients. All of the water samples analyzed had TDS levels below 500 mg/L. The result for this study was however found to be higher than those recorded by Nkansah *et al.*, (2010) at some selected hand dug wells in Kumasi, Ghana.

5.1.6 Turbidity

Turbidity in water affects both the acceptability to consumers, and the selection and efficiency of treatment processes, particularly the efficiency of disinfection with chlorine since it exerts a chlorine demand and protects microorganisms and may also stimulate the growth of bacteria. The turbidity of the samples obtained was below the WHO maximum limit of 5 NTU (WHO, 2008).

5.2 PAHs in water samples

Levels of PAHs in the studied water samples were found to be below the detection limit of the instrument used for their identification and quantification. This could be as a result of the non-polar and hydrophobic nature of PAHs. Due to their hydrophobic nature, PAHs tend to have a high affinity for sediments and suspended water particles in the water column. As a result of this PAHs tend to settle out of water and accumulate in the bottom sedimentation. According to Owabor *et al.*, (2010), PAHs adsorb strongly to the organic fraction of soils so does not penetrate deeply into most soils, therefore limiting both leaching to groundwater. This could also account for PAHs not being detected in water samples.

The sensitivity of the instrument used could also be regarded to be low since PAHs have been detected at lower concentrations (ng/L) (ATSDR, 1994).

Another reason for this result could be due to the absence or less presence of microorganisms such as algae, bacteria and fungi which have been shown to degrade PAHs (Kafilzadeh, 2015).

The results found in this study were lower than those found by Karyab *et al.*, (2013) in water samples at Trehran, Iran.

5.2 Concentration of heavy metals in the water samples

The concentration of copper (Cu) in hand dug wells at all the sampling sites was below the WHO (2008) permissible limit of 2 mg/L. Concentrations of Cu recorded at W1 and W2 were however higher than those from the control sites which is an indication of contamination. This could be as a result of the fact that in water, copper (Cu) travels great distances either suspended on dust particles or as free ions (Adelekan and Abegunde, 2011). High levels of Cu in water according to Acharya *et al.*, (2008) may lead to chronic anemia. Results of Cu in this study was found to be the same as the concentrations recorded by Warmate *et al.*, (2011) who found the concentration of Cu in water receiving used engine oil at Port Harcourt, Nigeria to be 0.03 mg/L.

The results for the concentration of zinc in this study were observed to be within the WHO (2008) permissible limit of 3 mg/L. This suggests that water from the study sites are safe for consumption. The elevated levels of zinc recorded at W1 and W2 as compared to CW (control site) are however a cause for concern since excessive intake of zinc can have adverse health effect on the consumer. The results from this study were

found to be in line with the results recorded by Korankye (2015) in hand dug wells within the Kumasi Metropolis, Ghana.

Concentration of lead recorded was found to be within the WHO (2008) permissible limit of 0.4 mg/L. Significant concentrations were however recorded at W2. This could be attributed to this site being located within the Kokompe spare parts market where used engine oils are indiscriminately disposed off into the soil. Consistent use of water from this site can result in physiological, biological and behavioural dysfunction in consumers (Hsu and Guo, 2002). The results obtained were however found to be lower than that recorded by Amori et al., (2013) in their assessment of heavy metal concentration of groundwater deposits in Odeda region, Ogun state, Nigeria.

The concentration of cadmium at all the sites was found to be below the WHO (2008) permissible limit of 0.003 mg/L. The results from this study were found to be similar to the research carried out by Mebrahtu and Zerabruk (2011) who found the concentration of Cd in water samples to be below detection limits.

The concentrations of Ni were found to be below the WHO (2008) permissible limit for drinking water thus suitable for human consumption.

5.3 Physicochemical parameters of soil

Soil pH which is an indication of the acidity or alkalinity of the soil is a major factor which influences solute concentration and absorption in soil (Bohn, 2015). The results obtained from the study indicated that soil samples from the sites were slightly acidic to slightly alkaline. Due to the moderate alkalinity nature of most of the studied samples the mobility of heavy metals in the soil will be low therefore more of the heavy metals will

be adsorbed onto the soil and may persist in the environment for a longer time, which may have serious health implications on the artisans and the environment.

Cation exchange capacity (CEC) of soil is defined as the ability of the soil to hold and release elements and compounds. From the results obtained from the study the highest mean CEC value was recorded at a maintenance workshop. CEC is dependent on organic matter and also increases with increase in pH value. This means soils from maintenance workshops are likely to adsorb more of these pollutants onto its surface. This could be as a result of the higher pH of the soil and also high amount of organic matter contained in soils from these workshops.

The study recorded high levels of organic matter content in the studied soil samples as compared to those from the control sites. The highest mean value of organic matter content recorded was from the maintenance workshops. This could be due to indiscriminate disposal of used lubricants such as “dirty oil” on the soil at maintenance shops which may have contributed to increased organic carbon in addition to the carbon already present in the soil.

5.4 Heavy metals in soils

Heavy metals occur naturally in the environment at levels that do not cause threat to the people living in such communities (Jaishankar *et al.*, 2014). Elevated levels of heavy metals in the environment thus suggest anthropogenic pollution. All the studied samples were found to contain higher values of the analyzed metals as compared to those from the control sites.

The higher concentrations of copper at the welding and maintenance workshops as compared to the control sites could be as a result of the frequent use of cables and connecting wires at these workshops and also from the disposal of used engine oils. According to Vasquez Duhalt (1989) used engine oils contain significant amounts of copper hence it being found in higher concentrations in soil samples from maintenance workshops where used engine oils are indiscriminately disposed off into the soil. Although Ghana has no set limit for copper in soils, the values recorded for copper in the sampled soils were less than the maximum limit set by Japan (125 mg/kg) and USEPA (250 mg/kg) (Lacatusu, 2002),

The results from this study show that the soils from the study areas had elevated levels of copper as compared to the results from a research carried out at auto mechanic shops at Suame magazine by Korankye (2015). The levels were found to be lower than what was obtained in the research carried out by Ziblim (2015) at auto mechanic shops in the Lankwantamang Municipal Assembly in the Accra Metropolitan Assembly.

Lead (Pb) was also found in appreciable concentrations at the spraying sections of the workshops. This could be as a result of its high use in the making of chemical products such as paints and vanishes which are mainly used in larger amounts at these workshops. The values of lead recorded from the study sites were found to be higher than that of the control sample but lower than the 1162 mg/kg reported by Nwachukwu *et al.*, 2011 for auto mechanic workshop in the Owerri area, South-East Nigeria. The USEPA (2008) set the maximum allowable concentration of lead in soil to be 400 mg/kg beyond which it is deemed as hazardous in the environment. The values from the study sites revealed that these values are lower than the maximum allowable concentrations in the soil.

From the results it can be seen that the highest level of lead for each site was found at the maintenance workshop. These higher levels of lead can be attributed to the servicing of leaded batteries and the presence of used engine oils in the soils which are known to contain significant levels of lead (Vazquez-Duhalt, 1989).

Although these were less than the standard set by the USEPA (2008), there is still the need to regulate the amount of lead released into the environment since it has been reported that exposure to lead for longer periods can have adverse effect on the health of artisans and other people living in such environments especially children with pica-habits.

The results recorded for nickel in soil samples were higher than the 3.94 mg/kg recorded by Leke *et al.*, (2011), 52.00 recorded by Warmate *et al.*, (2011) and also above the maximum permissible limit of 30 and 50 mg/kg set by the USEPA (2008) and WHO (2002) respectively. The results from this research were however similar to values recorded by Ziblim (2015). The concentrations of nickel in this study were found to be higher in soils from maintenance workshops. This could be as a result of nickel being found in diesel which serves a variety of uses at these workshops.

The values of cadmium in this study were found to be less than the maximum permissible limit of 3 mg/kg for cadmium in soils set by the USEPA (2008), it was also found to be less than the values recorded by Korankye (2015) at Suame magazine but similar to the researches carried out by Ziblim (2015) at auto mechanic shops in the La- Nkwantamang Municipal Assembly and Abidemi (2011) at automobile workshops in Osun State, Nigeria.

Maintenance workshops recorded higher levels of zinc in this study. This could be attributed to used engine oils which are disposed off into the soil in larger amounts as compared to other sections. Waste engine oils are known to contain additives of zinc such as zinc dithiophosphate (ZnDTP) and zinc dialkyldithiophate (ZDDP) which are used to prevent corrosion within the engine parts therefore enabling it to run longer (Vasquez-Duhalt, 1989).

The highest total mean concentration of zinc in this study was recorded at welding workshops with S2 recording the highest mean concentration. At this workshop (S2), welders are specialized in the making of vehicle rims which employs the use of zinc in reinforcing tyre structure and steel structure. The higher levels of zinc at welding workshops could also be attributed to the several uses of zinc such as in electroplating and formation of brass by these artisans. The concentrations of zinc in this research were lower than the results of Ikhajiagbe *et al.*, (2014) and also below the maximum permissible limit of 300 mg/kg set by the WHO.

5.5 PAHs in soils

Levels of PAHs in the studied soil samples were found to be below the detection limit of the instrument used for their identification and quantification. This could be as a result of the loss of used engine oils which are known to contain PAHs through surface run-offs. Similar results were obtained by Obini *et al.*, (2013) who recorded the concentration of PAHs to be below detection limit at Abakaliki auto mobile village in Nigeria.

5.6 Geo-accumulation index of heavy metals in soils

The geo-accumulation index for heavy metals recorded at spraying workshops showed that the soil was not contaminated with Cu, Ni and Zn. This can be attributed to the low use of products containing these heavy metals in this section of workshops. Igeo values recorded for cadmium at spraying workshops showed that apart from S2 and S5 which were found to be strongly and moderately polluted respectively, all other sites remained unpolluted. This could be as a result of the intense spraying of vehicles which takes place at these sites as compared to the other sites. Spraying workshops were however found to be slightly polluted with Pb. This could be attributed to traces of used engine oils which were found at these sites as a result of surface runoffs.

Maintenance workshops were found to be unpolluted with Zn and Ni. They were however found to be highly polluted with Pb. This result could be due to the indiscriminate disposal of used oil at these workshops. The Igeo value recorded for Cd in all the sites was identified to be the highest. Soil samples at maintenance workshops were found to be extremely polluted with Cd. This could be as a result of the high mobility of Cd in soil mobile systems as compared to other heavy metals. Exposure to high levels of Cd may result in severe pains in the joints, bone diseases, kidney and lung problems and anaemia (Hardy *et al.*, 2008). According to Adelekan and Abegunde (2011), exposure to high levels of Cd may affect sperm, reduce birth weight and also a causal factor in cardiovascular diseases and hypertension.

Geo accumulation of heavy metals at welding sections of the workshops recorded appreciable levels of pollution as compared to other workshops. Sites S1 and S4 were found to be slightly polluted with Cu whereas the other sites were regarded as unpolluted.

The Igeo value for Zn for all sites showed a moderate pollution. This is because Zn is widely used at auto welding workshops for purposes such as galvanization and in the formation of brass. These activities are likely to release high levels of Zn into the environment. Welding workshops were generally found to be highly polluted with Pb. This could be attributed to the use of lead in soldering at these workshops. Samples from these workshops were however found not to be contaminated with Ni. However these soil samples were found to be extremely polluted with Cd with the exception of soil samples from S1, S3 and S4 which remained unpolluted.

5.7 Contamination factor

The mean contamination factor (CF) for the studied heavy metals at the maintenance workshops showed low contamination with Cu, Zn and Ni. There was however a considerable level of pollution in the soils with lead with that of S4 considered to be highly contaminated. Soil samples from all maintenance, welding and spraying workshops were found to be lowly contaminated with cadmium.

The CF values of Ni and Cd at welding workshops showed low contamination whereas the mean CF values of Cu and Zn showed moderate contamination. The CF value of Pb at welding workshops recorded showed considerable contamination levels with the highest being value being recorded at S4.

With the exception of the spraying workshop at S1 which recorded a moderate contamination with Ni, all other spraying workshops showed low contamination with Ni and Cd. The CF values of Cu and Zn at spraying workshops however showed moderate contamination. The CF values of Pb at spraying workshops generally showed considerable contamination with the exception of S6 which showed moderate contamination.

5.8 Enrichment factor

The mean enrichment factor values recorded at maintenance workshops shows that Cu, Zn and Ni fall within the minimal enrichment category ($EF < 2$). The mean enrichment factor values for Pb recorded at S6, S5, S3 and S2 were found to be of moderate enrichment ($EF = 2 - 5$). S4 and S1 were however found to be significantly enriched with lead. With the exception of S2, the mean enrichment factor recorded for Cd at all the other sites was found to be extremely high. S2 however recorded significant enrichment of cadmium.

The mean enrichment factor values recorded at welding workshops show that Cu, Zn and Ni fall within the minimal enrichment category ($EF < 2$). With the exception of S5, all the other sites recorded moderate enrichment factor values for Pb. The enrichment factor of lead at S5 was found to be minimal. The mean enrichment factor value for cadmium at S4, S3 and S1 was found to be in the categories high, moderate and minimal enrichment respectively.

The mean enrichment factor values recorded at spraying workshops shows that Cu, Zn, Cd and Ni fall within the minimal enrichment category ($EF < 2$) for all the studied sites. The mean enrichment factor values of Pb at all the sites with the exception of S5 were found to be of moderate enrichment. That of S4 was however found to be of minimal enrichment.

5.9 Survey

5.9.1 Factors influencing artisans' knowledge of occupational health risk

Gender had a positive significant effect on artisans' knowledge of occupational health risk. This means that male artisans are more likely to be aware of the occupational health risk. This could be due to the fact that artisans are mostly males and therefore, are much aware of the occupational health risk. The result is in line with the findings of Aluko *et al.*, (2016).

Years of experience had a negative significant effect on artisans' knowledge of occupational health risk. This means that as an artisan gains experience, the less likely he/she would be aware of the occupational health risk. This result was surprising because it was expected that years of experience would increase the likelihood of knowledge of occupational health risk among artisans, since it is noted that experience provides knowledge of health risk among artisans (Sabitu *et al.*, 2009).

There was a positive significant relationship between membership of artisan based association and knowledge of occupational health risk. This implies that being a member of an artisan based association increase the likelihood of an artisan being aware of occupational health risk. This could be due to the fact that artisan based associations are source of information to member artisans. Armendáriz de Aghion and Morduch, (2005), and Akudugu *et al.*, (2009) asserted that associations are reliable source of information to its members.

Training (eg. workshop, seminars, etc) also positively and significantly influenced artisans' knowledge of occupational health risk. This implies that training increases the

likelihood of an artisan being aware of occupational health risk. Training is a form of education which provides information and knowledge, hence, providing knowledge of occupational health risk. This result is in line with the findings of Bamidele *et al.*, (2015), and Aluko *et al.*, (2016) who concluded that knowledge is significantly and positively related to training.

5.9.2 Factors influencing artisans' decision to wear protective clothing during work

Educational level of an artisan was positive and had a significant effect on artisans' decision to wear protective clothing during work. This means that an increase in the level of education of an artisan, increases the likelihood of he/she wearing protective clothing during work. This could be explained by the fact that education provides knowledge, hence, an educated artisan is believed to have knowledge about the occupational health hazards which would motivate him/her to wear protective clothing during work. This result contradicts the findings of Eze *et al.*, (2015) who states that educational level has a negative significant effect on decision to wear protective clothing.

Years of working experience had a negative significant effect on artisans' decision to wear protective clothing during work. This means that as a person gains working experience, the less likely he/she would wear protective clothing during work. This result was surprising because it was expected that years of working experience would increase the likelihood of an artisan wearing protective clothing during work as reported by Kumar *et al.*, (2013). A plausible explanation for this could be that though they are experienced, they do not adhere to safety practices probably due to familiarity with working procedures.

Artisans' knowledge of occupational health risk had a positive significant effect on artisans' decision to wear protective clothing during work. This means that as an artisan becomes aware of the occupational health risk, he/she is more likely to wear protective clothing during work. This could be as a result of the fact that an artisan would probably take measures to reduce the occupational health risk and one of such measures is the wearing of protective clothing. Strong *et al.*, (2008) and Kumar *et al.*, (2013) revealed that awareness of risk is associated with utilization of safety measures such as wearing of protective clothing.

Income of an artisan was positive and had a significant effect on artisans' decision to wear protective clothing during work. This means that an increase in artisan's income, increases the likelihood of he/she wearing protective clothing during work. This could be due to the fact that an increase in income would enable artisans to afford protective clothing regardless of the cost.

5.9.3 Factors influencing artisans to partially or fully wear protective clothing during work

Educational level of an artisan had a positive and significant effect on an artisan partially wearing protective clothing. This means that artisans with higher level of education are more likely to partially protect themselves. This result is surprising because education provides information and increases an artisan's knowledge on the negative effect of not complying with safety regulations such as wearing of protective clothing during work. A plausible reason could be due to factors such as high cost of protective clothing and low income that could hinder an artisan from fully protecting him/herself. Also, educational level of an artisan had a positive and significant effect on an artisan fully wearing

protective clothing. This means that as the level of an artisan's education increases, the more likely he/she would fully protect him/herself. Enete and Igbokwe (2009), and Caleb and Ramatu, (2013) asserted that education increases the level of knowledge and ability of a person to critically analyze and make own decisions. Therefore, educated artisans would fully protect themselves since they would be aware of the dangers of not fully protecting themselves.

Income of artisan had a positive and significant effect on an artisan partially wearing protective clothing during work. This means that as artisan's income increases, the more likely an artisan would partially protect him/herself. This result is also surprising because, higher income is expected to enable artisans to afford protective clothing regardless of the cost. However, the result could be explained by the fact that some artisans claimed that wearing gloves makes it difficult for them to work with screws. Furthermore, income of artisan had a positive and significant effect on an artisan fully wearing protective clothing during work. This means that as income of artisan increases, the more likely an artisan would fully protect him/herself. It is expected that higher income would enable artisans to afford protective clothing regardless of the cost.

Years of working experience had a negative significant effect on an artisan partially wearing protective clothing during work. This means that as an artisan gains experience, the less likely he/she would partially wear protective clothing during work. This could be due to the fact that an artisan obtains requisite knowledge on the health implications of partially wearing protective clothing. Again, years of working experience had a negative significant effect on an artisan fully wearing protective clothing during work. This means that as artisan gains working experience, the less likely he/she would fully wear

protective clothing during work. It was expected that experience would positively influence an artisan to fully protect him/herself (Kumar *et al.*, 2013). Nevertheless, the result could be explained by the fact that artisans do not comply with safety practices or are not able to afford protective clothing.

Awareness of occupational health risk positively and significantly influenced an artisan partially wearing protective clothing during work. This means that as an artisan becomes aware of occupational health risk, he/she is more likely to partially put on protective clothing. It was expected that an artisan's awareness of occupational health risk would positively influence an artisan to fully wear protective clothing as revealed by Adewoye *et al.*, (2013). However, the result could be explained by the fact that factors such as high cost of protective clothing (as indicated by some of the artisans as the main reason for not wearing protective clothing) and it slowing the pace of work hinders an artisan from fully protecting him/herself.

5.9.4 Factors influencing artisans' knowledge of the safety and hygienic practices during work

Gender had a negative significant effect on artisans' knowledge of the safety and hygienic practices during work. This means that male artisans are less likely to be aware of the safety and hygienic practices during work. Thus, female artisans are more likely to be aware of the safety and hygienic practices during work. It is noted that women are more risk averse than men (Cohen & Einav, 2007; Dohem *et al.*, 2011; Donkers *et al.*, 2001), this would therefore influence female artisans to seek information on the safety and hygienic practices related to their kind of work in order not to endanger their lives as a result of their work.

Age was positive and significantly influenced artisans' knowledge of safety and hygienic practices during work. This implies that as an artisan grows in age, the likelihood of he/she being aware of the safety and hygienic practices during work increases. This could be due to the fact that older artisans are likely to have experienced or heard of some occupational hazards associated with their work, hence, may influence their knowledge about the safety and hygienic practices during work.

Educational level of an artisan had a negative and significant effect on artisans' knowledge of safety and hygienic practices during work. This means that as the level of education of an artisan increases, the likelihood of he/she being aware of the safety and hygienic practices during work decreases. This could be due to the fact that a person needs to be involved in the occupation in order to acquire requisite knowledge about the safety and hygienic practices during work. Bamidele *et al.*, (2015) reported similar findings on the relationship between education and knowledge of safety and hygienic practices. However, the result contradicts the findings of Tziaferi *et al.*, (2011).

Years of experience had a positive significant effect on artisans' knowledge of the safety and hygienic practices during work. This means that as a person gains working experience, the more likely he/she would be aware of the safety and hygienic practices during work. This could be due to the fact that experienced artisans are likely to have experienced or heard of some occupational hazards associated with their work, hence, may influence their knowledge about the safety and hygienic practices during work.

5.9.5 Factors influencing artisans' perception of impact of mechanic activities on water from hand dug wells

Age was negative and significantly influenced artisans' perception of impact of mechanic activities on water from hand dug wells. This implies that a year increase in the age of an artisan, decreases the likelihood of he/she perceiving an impact of mechanic activities on water from hand dug wells. The result on age could be explained by the fact that water from hand dug wells has remained clear over the years hence has been perceived to be clean and safe. Also older artisans may have had little or no adverse effect arising from the use of water from hand dug wells on their health.

Educational level of an artisan was positive and had a significant effect on artisans' perception of impact of mechanic activities on water from hand dug wells. This means that an increase in the level of education of an artisan increases the likelihood of him/her perceiving an impact of mechanic activities on water from hand dug wells. This could be explained by the fact that education provides awareness, hence, an educated artisan is believed to be much aware about the impact of mechanic activities on water from hand dug wells.

Years of working experience had a positive significant effect on artisans' perception of impact of mechanic activities on water from hand dug wells. This means that experienced artisans are more likely to be aware of the impact of mechanic activities on water from hand dug wells. This could be due to the fact that experienced artisans are much aware of the environmental hazards of their activities, since they have been involved in the particular work for a long time.

Training also positively and significantly influenced artisans' perception of impact of mechanic activities on water from hand dug wells. This implies that training increase the likelihood of an artisan being aware of the impact of mechanic activities on water from hand dug wells. This could be due to the fact that training provides information; hence, providing artisans awareness of the impact of mechanic activities on water from hand dug wells.

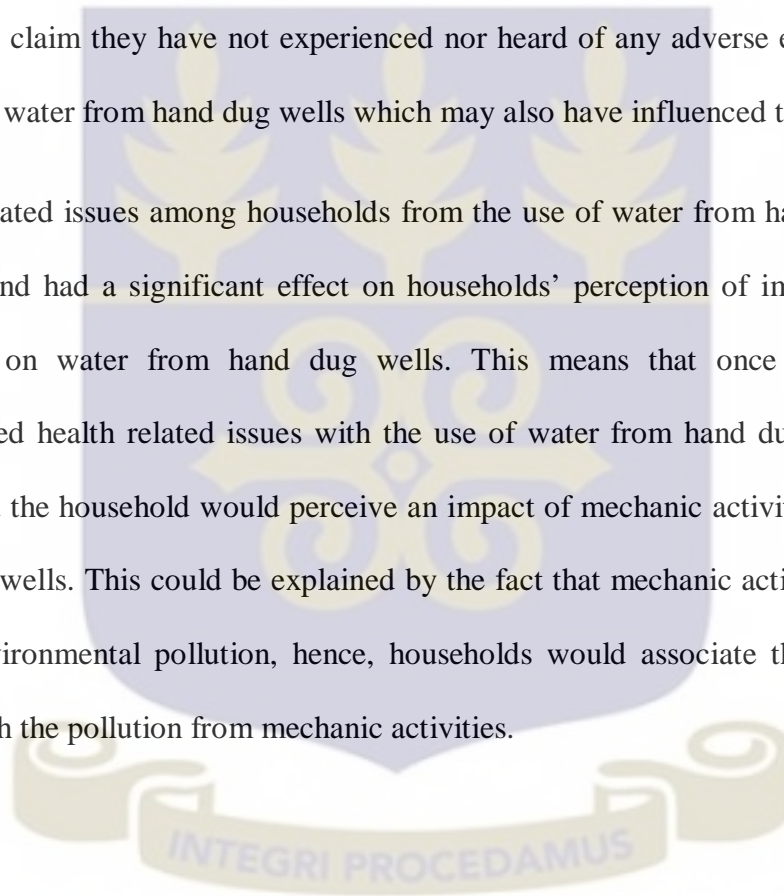
5.9.6 Factors influencing households' perception of impact of mechanic activities on water from hand dug wells

Gender was significant and negatively influenced households' perception of impact of mechanic activities on water from hand dug wells. This means that male-headed households are less likely to perceive an impact of mechanic activities on water from hand dug wells. This could be explained by the fact that women are more vulnerable when in contact with chemicals than men and therefore, once women are well informed that chemicals from mechanic activities could end up in ground and surface water, they would perceive an impact of mechanic activities on water from hand dug well.

Educational level of households was positive and had a significant effect on households' perception of impact of mechanic activities on water from hand dug wells. This means that an increase in the educational level of households increases the likelihood of households perceiving an impact of mechanic activities on water from hand dug wells. This could be explained by the fact that education provides awareness; hence, educated households are believed to be well informed about the impact of mechanic activities on water from hand dug wells.

Use of water from hand dug well among households was negative and had a significant effect on households' perception of impact of mechanic activities on water from hand dug wells. This means that use of water from hand dug well among households, decreases the likelihood of households perceiving an impact of mechanic activities on water from hand dug wells. This could be due to the fact that water from hand dug wells is usually clear hence it is perceived by users to be clean and safe. Users of water from hand dug wells also claim they have not experienced nor heard of any adverse effect arising from the use of water from hand dug wells which may also have influenced their perception.

Health related issues among households from the use of water from hand dug wells was positive and had a significant effect on households' perception of impact of mechanic activities on water from hand dug wells. This means that once a household has experienced health related issues with the use of water from hand dug wells, the more likelihood the household would perceive an impact of mechanic activities on water from hand dug wells. This could be explained by the fact that mechanic activities are likely to cause environmental pollution, hence, households would associate their health related issues with the pollution from mechanic activities.



CHAPTER SIX

CONCLUSION AND RECOMMENDATION

6.1 Conclusion

The primary objective of this research was to assess the level of Polycyclic Aromatic Hydrocarbons (PAHs) and heavy metals in soil from auto-mechanic shops in the Accra metropolis. Several statistical tools such as ANOVA, LSD, correlation analysis and Logit regression model were employed to analyze the appropriate data obtained from this study.

The results from the study showed that most of the soils were either moderately acidic or moderately alkaline and contained relatively higher amounts of organic carbon with those from maintenance workshops recording the highest. All of the soil samples were found to be saline ($EC > 150 \text{ uS/cm}$).

With the exception of cadmium (Cd), significant concentrations of the studied heavy metals were recorded for most soils at all the sites. These concentrations were used to calculate the enrichment factor (EF), the geo-accumulation index and pollution index (PI). These indices of pollution showed that the study area is contaminated with these metals in the order of $Pb > Cu > Zn > Ni > Cd$.

Results of water samples analyze showed that apart from W2, the physicochemical parameters and heavy metal contents were within the permissible limits of WHO (2008) standards for safe drinking water.

The concentrations of PAHs in the water and soil samples from the study area were however found to be below the detection limit of the instrument used.

Results from the survey indicated that although there was high awareness of the adverse effect of chemical and occupational hazards associated with the auto-mechanic industry, artisans do not give utmost priority to their safety and hygienic habits. The results also showed there was high awareness of the improper siting of auto-mechanic workshops and its associated impact due to the activities of artisans in the study area. This notwithstanding, households did little about this problem since they perceived that to be the responsibility of the central government.

6.2 Recommendation

- Further research should be carried out to determine the speciations of the metals found since the form in which the metal exist influences its mobility in soil and water.
- Regular training for these artisans by experts such as occupational health experts to educate artisans on the likely impact of their occupation on their health
- There should be a site allocated to these artisans which should not be so close to settlement areas since the waste generated by these artisans can be deleterious to inhabitants.
- There should be a ready market for investors who will need waste engine oils as their raw materials. This will encourage artisans not to dispose of this product indiscriminately into the soil but rather selling it out to these investors.
- There should be enforcement of the laws and regulations on the activities of these artisans and the siting of their workshops by relevant authorities.

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APPENDICE

Appendix A. Questionnaires for survey

University of Ghana

College of Basic and Applied Science

Institute for Environmental and Sanitation Studies

Environmental Science Program

The administration of this questionnaire is part of an academic research for the award of Master of Philosophy degree in Environmental Science. The purpose is to assess your knowledge and perception of chemical hazards associated with used engine oils. Information given will be treated confidentially.

(a) Socio- Demographic Information

1. Gender

Male Female

2. Age (years)

20 – 30 31 – 40 41 – 50 51 – 60 Above 60

3. Marital status

Single Married Divorced

4. Highest educational level

Basic education Secondary education Tertiary education No formal education

5. Religious affiliation

Christian Moslem Tradionalist Hindu Others, please specify,

6. Residential Status

Resident Non- resident

7. Occupation

Mechanic Spare parts dealer Food vendor Others, please specify

8. Work experience (years)

1 – 5 6 – 10 11 – 15 16 – 20 21 – 25 26 – 30 Above 30

9. Monthly Income (GH¢)

Less than 100 100 – 200 200 – 300 300 – 400 400 – 500 Above 500

10. How many hours in a day do you work?

Under 6hours 6 – 8hours Above 8hours

11. Is there any day(s) that you do not work?

Yes No

12. If yes, which day(s) of the week? (Tick as many as applicable)

Monday Tuesday Wednesday Thursday Friday Saturday Sunday

(b) Knowledge and Perception about chemical hazards

13. Do you look out for safety signs when working?

Yes No Sometimes

14. Do you understand these safety signs?

Yes No

15. Do you use protective clothing when working?

Yes No Sometimes

16. If yes, which of the following do you use? (Tick as many as you use)

Working gear Nose mask Gloves Boots Others, please specify.....

17. Which of the following reason(s) best describes your decision not to use protective clothings?

- They are expensive to purchase Working with them is tedious It slows the pace at which work is done You don't feel comfortable in them
 Others, please specify,.....

18. Do you know anything about chemical hazards?

- Yes No

19. If yes, please, specify
.....

20. In what way(s) can you be exposed to chemical hazards?.....

21. Do you know the chemical composition of the used engine oil?

- Yes No

22. If yes, please specify.....

23. Do you think coming into contact with used engine oils can expose you to chemical hazards?

- Yes No

24. If yes, please specify the type of chemical hazard
.....

25. Do you think chemical hazards associated with used engine oils can have an adverse effect on your health?

- Yes No

26. If yes, please specify
.....

27. Do you have a first aid kit at your workplace?

- Yes No

28. Do you belong to a registered workers' association?

- Yes No

29. If yes, do they organize education and training programs for you?

Yes No

30. If yes, how often?

.....

31. Do you deem these programs necessary?

Yes No

32. Does any organization conduct regular checks on your work?

Yes No

33. If yes, which of these organization(s)?

AMA EPA FDA Others

34. Do you know if there exists any laws and regulations with regards to the activities of mechanics and spare parts dealers?

Yes No

35. Do you think the activities of mechanics in the area have an impact on the quality of water from hand dug wells ('bura')?

Yes No

36. If yes, on which of the following does it impact on? (Tick as many as applicable)

Colour Salinity Taste Smell Others

(c) Health and hygiene

37. Have you experienced any health concern as a result of handling engine oil?

Yes No

38. What is the prevailing health problem associated with your business?

Headache Hypertension Fever Diarrhoea Others, please specify

39. Do you seek medical treatment when you face this health problem?

Yes No Sometimes

40. Do you have access to portable water?

Yes No

41. If yes, how often?

Always Not Always Occasionally Scarcely

42. Do you use water from hand dug wells (“buras”)?

Yes No

43. If yes, how often?

Always Not Always Occasionally Scarcely

44. What purpose(s) do you use this water for?

Domestic Economic Religious Agriculture Others

45. Do you treat the water before using it?

Yes No Sometimes

46. If yes, which of the process(es) below do you use?

Boiling Filtration Distillation Sedimentation Others

47. Are there mechanic shops close to your source of water?

Yes No

48. If yes, how close are these mechanic shops to your source of water?

10m – 50m radius 50m – 100m radius 100m – 200m radius Above 200m radius

49. Are you aware of any health concern arising from the use of water from hand dug (“bura”) wells?

Yes No

50. If yes, please specify

.....

51. Do you wash your hand with soap before eating?

Yes No Sometimes

52. Do you wash your body with soap after close of work?

Yes No Sometimes

53. Do you change your clothes after work?

Yes No Sometimes

54. Do you immediately take a bath when you get home?

Yes No Sometimes

55. Has any member of your family been diagnosed of a disease related to your work?

Yes No

56. If yes, which of the following

Eye irritations Throat irritations Difficulty in breathing Chest related diseases
 Vertigo (dizziness) Skin irritations

Questionnaires for household

(a) Socio- Demographic Information

1. Gender

Male Female

2. Age (years)

10 – 20 21 – 30 31 – 40 41 – 50 51 – 60 Above 60

3. Highest educational level

Basic education Secondary education Tertiary education No formal education

4. How many members are in your household?

5. How long have you been living in Darkuman?.....

6. How close are workshops of mechanics and spare parts dealers from where you live?

less than 50 m 50 – 100 m 100 – 200 m Above 200 m

(b) Awareness and concern

7. Do the activities of these artisans cause a nuisance to you?

Yes No

8. If yes, in what ways?

9. How serious will you consider this nuisance?

Very serious Somewhat serious Not serious

10. Do you have a hand dug well “bura” in your house?

Yes No

11. Do you use water from hand dug wells?

Yes No

12. If yes, how often?

Always Occasionally Scarcely

13. What do you use this water for?

Domestic Economic Religious Others.....

14. Do you think the activities of mechanics and spare parts dealers have an impact on water from hand dug wells “bura”?

Yes No

15. Have you experienced any adverse effect from the use of water from hand dug wells?

Yes No

16. If yes, please specify?
.....

17. Do you think the activities of mechanics and spare parts dealers have an impact on your health?

Yes No

18. Has any member of your household experienced any illness linked to the activities of mechanics and spare parts dealers in your area?

Yes No

19. If yes, in what ways?
.....

20. Do you have a problem with the siting of mechanic workshops in Darkuman?

Yes No

21. In your opinion, how serious is the problem of siting of mechanic workshops in Darkuman?

Very serious Somewhat serious Not serious

22. Could you please indicate what you think could be done by local government to tackle the improper siting of mechanic workshops in your area.

.....
.....

23. Could you please indicate what you think could be done by households to tackle the improper siting of mechanic workshops in your area.

.....
.....

