DETERMINATION OF LEAD AND CADMIUM LEVELS IN DECORATIVE PAINTS SOLD IN NAIROBI, KENYA

BY

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DECLARATION

I hereby declare that this thesis is my original work and has not been presented for the award of a degree in any other University.

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DEDICATION

This thesis is dedicated to my Almighty God and my parents.

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ABBREVIATIONS AND ACRONYMS

AAS	Atomic Absorption Spectrometry
ANOVA	Analysis of Variance
AR	Analytical Reagent
ATSDR	Agency for Toxic Substances and Disease Registry
BAL	British Anti-Lewis
BLL_S	Blood Lead Levels
CalEPA	California Environmental Protection Agency
CDC	Centers for Disease Control
HSDB	Hazardous Substances Data Bank
IQ	Intelligence Quotient
OSHA	Occupational Safety and Health Administration
PEL	Permissible Exposure Limit
RBC_S	Red Blood Cells
USEPA	United States Environmental Protection Agency
WHO	World Health Organization

ABSTRACT

Lead and cadmium which are heavy metals may be used as paint pigments as they speed drying, increase durability, retain a fresh appearance and resist moisture that causes corrosion. Both lead and cadmium metals are toxic, poisonous and are carcinogen, lower IQ, cause hyper activity among other effect. Their presence in decorative paints can produce toxic effect to both painters and those who live in painted houses or painted product especially children who use painted toys can be in danger of lead or cadmium poisoning if these heavy metals are present in toys. It is therefore necessary to determine the levels of these toxic heavy in paints used in Kenya. This study therefore was carried out to investigate the levels of lead and cadmium in decorative paint samples sold in Nairobi, Kenya. Sampling of fifty (n=50) decorative paint samples from five paint brands randomly selected was done, twenty four (n=24) oil based and twenty six (n=26) water based. The paint samples were digested using analytical grade nitric and perchloric acid and analyzed using atomic absorption spectrometer (AAS). Analysis of variance (ANOVA) using SPSS was used to analyze data. The results of the present study revealed that the oil based paints had high levels of lead amounts with a range of 275.86-37084.48 ppm for the paint brand with the highest lead levels. This exceeded the set limit of 90 ppm by far. The paint brand for water based paint samples with the highest lead levels had a range of 48.53-298.38 ppm. Cadmium levels in both water and oil based paint samples analyzed, met the set levels of 75 ppm. The results can be used by the Kenyan Government to regulate or eliminate lead in decorative paints.

CHAPTER ONE

INTRODUCTION

1.1 Background information

Paint is a mixture of liquid and powder; the powder is the pigment that gives colour to the paint and the liquid (binder) binds it and allows it to spread. In paints, the combination of the binder and solvent is referred to as the paint "vehicle" which is essentially composed of volatile organic compounds (VOCs). Pigments and additives are dispersed within the vehicle. The amount of each constituent varies with the particular paint. Typically solvents include toluene, xylene, methyl ethyl ketone (MEK) and methyl isobutyl ketone (MIBK). The solvent (thinner) is also used to make the paint easier to spread (Johnson *et al.,* 2009).

Paints are broadly classified into two types; decorative (domestic) and industrial paints. Industrial paints find their use in automobile coatings, steel structures, marine coatings and for other high performance purposes. Decorative paints which are either water based or oil based are primarily used for the interior or exterior decoration of buildings and homes. In Kenya there are numerous decorative paint brands notably; Crown berger, Sadolin, Dura coat, Smart, Apex, Solai, Glory, Ideal, Dulux, Ramco and Basco among others. Most white paint pigments are oxides, sulphates, carbonates and sulphides of titanium, calcium, zinc, lead, barium, antimony, silicon, aluminium and magnesium as appropriate. Inorganic coloured pigments are mainly compounds of cadmium, iron, chromium, nickel and molybdenum (Hassan, 1984).

White lead (basic lead carbonate) and lead (Π) chromate are the most common lead pigments. White lead is a superior paint pigment used in vehicle paints and has a tremendous hiding power. However, it has been widely replaced by titanium oxide and barium-zinc-sulphur combinations. For colour, lead pigments such as red lead (a lead oxide with four oxygen and bright orange in colour), and blue lead (lead sulphate with lead oxide, zinc oxide, and carbon) may be used industrially where corrosion protection and colour on metal is needed (OEDC, 1993).

Lead chromates are often used to produce yellow, orange, red and green paints. White house paint contained up to 50 % lead before 1955 (CDC, 2002), though the third international labour conference of the league of Nations had recommended banning of white lead for interior use (AJPH, 1923). Subsequently, the use of lead in paints has decreased significantly. There are proposed regulatory changes for both interior and exterior consumer paints to limit lead in paints to 0.06 percent by dry weight (600 ppm) U.S. Environment Protection Agency (EPA) Standards (USEPA, 2001) and 0.009 percent (90 ppm) by the consumer product safety improvement act (CPSIA, 2008). In paint pigments, cadmium forms various salts, with cadmium sulphide (CdS) being the most common. The sulphide is used as a yellow pigment. Cadmium selenide can be used as red pigment, commonly called cadmium red.

To painters that work with the pigment, cadmium yellow, orange, and red are the most potent colours to use. In fact, during production, these colours are significantly toned down before they are ground with oils and binders, or blended into watercolours, gouaches, acrylics, and other paint and pigment formulations. These pigments are toxic, and may cause skin irritation (Sitting, 1985; Lenga,1988). The new standards, 29 CFR 1910.1027 (General Industry) and 29 CFR 1926.63 (Construction), established a permissible exposure limit (PEL) of 5 $\mu g/m^3$ of cadmium of air with an action level of 2.5 $\mu g/m^3$ (OSHA, 1992). The solubility of cadmium in paints and surface coatings is 75 ppm (CPSIA, 2008).

Studies so far confirm that exposure to lead causes renal damage, encephalopathy, and impaired cognitive function in children and in adults (UNEP, 1984; Lin *et al*., 2003). Long-term inhalation of cadmium leads to damage of the olfactory function, decreased lung function and emphysema (Glaser *et al*., 1986; Davison *et al*., 1988; Cortona *et al*., 1992; Leduc *et al*., 1996). High levels of cadmium exposure by inhalation or oral can cause death in humans or animals (Seidal *et al*., 1993). Evidence is insufficient to determine an association between cadmium exposure and reproduction effects in humans. Some studies indicate no effect on male fertility (Genhart *et al*., 1992), male hormone levels (Mason, 1990) or semen quality (Saaramen *et al*., 1989). Others found a reduction in sperm number or viability (Xu *et al*., 1993a). Symptoms of acute toxicity are excessive salivation, abdominal pains, diarrhoea and loss of consciousness (Hutchinson and Meena, 1987). There is need therefore to determine levels of these toxic metals in various products to prevent the dangers associated with them.

1.2 Problem statement

Lead and cadmium which are toxic elements are used as pigments in decorative paints, and when applied to surfaces due to age, weather and chip. The accumulation of these toxic elements in indoor dust and outdoor soils makes them hazardous. Studies done by Owago (2000), Mogwasi (2009) and Were (2008) cited lead in paints as one of the many sources of lead poisoning, with people using glazed ceramics or living in painted houses having higher levels of lead in their blood and nails than those who did not. Painters who apply paints without protecting their hands and children are more vulnerable to lead poisoning. The chewing, licking and swallowing behaviour of children is a common source of lead and cadmium exposure (Kelley, 1993).

1.3 Justification

A lot of construction, renovation and re-modelling of old buildings are taking place in Kenya which end up being painted with a lot of decorative (domestic) paints. In Kenya a wide scope of paint brands are in existence, amongst them are Basco, Dura coat, Sadolin, Crown berger, Apex, Ideal, Solai, Dulux and Ramco. Each of these paint brands produces a wide range of different decorative paints both water and oil based paints. Lead levels in decorative paints have been reported in African countries like Nigeria (Adebamowo *et al.*, 2007) and Tanzania (Toxics Link, 2009), though in Kenya there is minimal information on their levels in decorative paints. There is hardly any information on cadmium in decorative paints although it is very toxic. The present study thus investigated levels of lead and cadmium in selected decorative paints sold in Nairobi, Kenya.

1.4 Hypotheses

i. Decorative paints used in Kenya do not contain high levels of lead and cadmium.

ii. Lead and cadmium levels in decorative paints are independent of the brands.

iii. No significance difference between the concentration of Pb and Cd in decorative paints.

1.5 Objectives

1.5 .1 General objective

To determine the levels of lead and cadmium in selected brands of decorative paints.

1.5.2 Specific objectives

i. To determine the concentrations of lead and cadmium in white, blue, red, black, green, cream and grey oil based paints from five selected paint brands.

ii. To determine the levels of lead and cadmium in water based paints in white, blue, green, cream, softwhite, butter and grey from five selected paint brands.

1.6 Significance of the study

The information on levels of lead and cadmium on various products is very important to the Government of Kenya in conjunction with the Kenya Bureau of Standards (KEBS) in establishing a legal framework, sale and use of lead paints and in particular decorative paints. The results of this study will be used to develop policies on levels of lead and cadmium in decorative paints. It will also be used to sensitize the public on their usage.

1.7 Scope

i. Only ten paint samples from each of the five paint brands were analyzed.

ii. Lead and cadmium elements were analyzed, although there many other toxic metals in the sampled decorative paints.

iii. Paints sampled for the same colour had different manufacturing date.

1.7.1 Assumption

i. The levels of lead and cadmium were assumed to depend on the type of paint colour.

ii. The levels of lead and cadmium were assumed to depend on the solvent of the paint therefore, both water and oil based paints were analyzed.

CHAPTER TWO

LITERATURE REVIEW

2.1 Paints

Paints are broadly classified into two types; decorative and industrial paints depending on the use and purpose. Paint is used to protect, preserve, decorate or add functionality to an object or surface by covering it with a pigmented coating. Paints are composed of four types of components: pigment, binder, solvent and additives. Pigments are granular solids incorporated into the paint to contribute colour, toughness, texture or simply to reduce the cost of the paint and are broadly classified as either natural or synthetic (Ashok, 1993).

Natural pigments include various clays, $CaCO_3$, mica ($K_2O.3Al_2O_3.6SiO_2$), silicas and talcs ($2MgO.4SiO_2.H_2O$). Synthetics include engineered molecules, calcined clays, blanc fix, precipitated $CaCO_3$ and synthetic silicas. Other subgroups are hiding pigments and filler pigments. Hiding pigments include titanium dioxide (TiO_2), phthalocyanine blue, red iron oxide and others, which make paint opaque and protect the substrate from effects of ultraviolet light. Titanium dioxide (white powder) is the most commonly used pigment due to its high index refraction and high hiding power (Farmand, 2012).

Fillers are special type of pigment that serve to thicken the film, support its structure and increase the volume of the paint. They comprise of cheap and inert materials like diatomaceous earth, talc, lime, clay among others. Heavy metals like; lead, cadmium, antimony, copper, zinc, chromium, cobalt, arsenic, antimony and others, which are the most polluting metals, may also be encountered in paints as pigments (Hassan, 1984).

Solvents are used to adjust the consistency of the material so that it can be applied readily to the surface. The solvent evaporates, contributing nothing further to the film. Solvents most commonly used are naphtha or mineral spirits; turpentine is sometimes used but is very expensive. In paint manufacture, lead is found in the waste solvent based paint sludges (Johnson *et al.*, 2009).

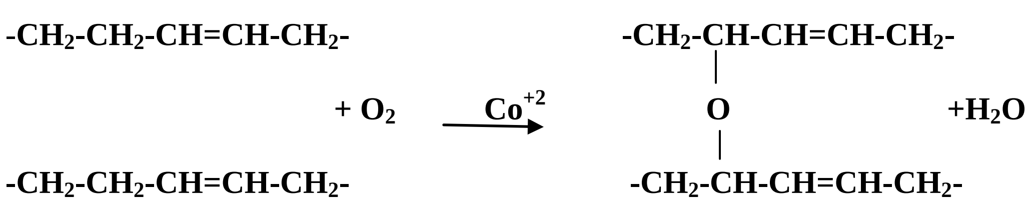
The binder is the actual film forming component of paint. It imparts adhesion, binds the pigments together and strongly influences properties as gloss potential, exterior durability, flexibility and toughness. Binders are composed of synthetic or natural resins like acrylics, polyurethanes, polyesters, melamine resins, epoxy or oils (Johnson *et al.*, 2009). The solvent or dilutant is the material which the pigment and binder are mixed with in order that the paint may be of the correct consistency to be applied to the surface carrier that allows one to get the paint from the can to the surface. On the other hand, additives are ingredients that give paint a specific benefit that it could not otherwise have. They comprise of: rheology modifiers, which provide opacity and leveling of coating; mildewiches, they keep mildew in check; dispersing agents, keep pigments evenly distributed and preservatives, which prevent spoilage (Koleske, 2013).

2.1.1 Industrial paints

Industrial paints are mainly used for high performance purposes like in automobile coatings, steel structures and marine coatings. It also functions as intumescent coatings for fire resistance. The common polymers used in its manufacture are polyurethane, epoxy, fluoropolymer and moisture-cure urethane. Industrial paints can be grouped into; inorganic zinc, phosphate, xylan and physical vapour deposition (PVD).

2.1.2 Decorative paints

Decorative paints are further classified on the basis of solvents used as water based (plastic or latex) or oil based (enamel) paints and are purposely for interior or exterior decorations of buildings. Linseed oil is the most commonly used binder in oil-based paints and consists of triesters of glycerol with unsaturated fatty acids. Pigments in powders are evenly dispersed in the binder to form a colloidal suspension. The pigments provide colour and hiding power, improve strength and adhesion of the paint film and can change gloss. The oil-base binders react with oxygen from air and harden as they dry. The drying process is accelerated by the action of driers like cobalt octanoate, $Co[O_2C(CH_2)_2CH_3]_2$ which catalyses both the uptake of oxygen and decomposition of peroxides as free radicals resulting in the hardened cross-link that bind the pigment to the substrate, as in Scheme 2.1.



Scheme 2.1: Cross-linking polymerization of the oil binder of paint

The binder for water based paints is high molecular weight polymers called resins. Acrylic resins are among the most popular because of their versatility. These are polymers and copolymers of the esters of methacrylic and acrylic acids as shown in Figures 2.1 and 2.2 respectively.

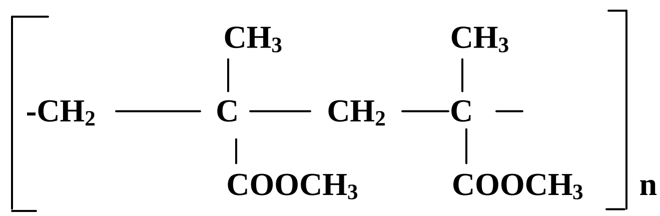


Figure 2.1: Poly (methyl methacrylate)

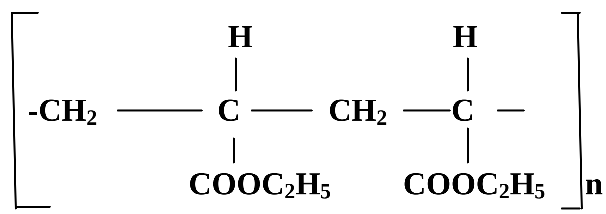


Figure 2.2: Poly (ethyl acrylate)

The acrylic binder is manufactured directly in emulsion form (latex). In the manufacture of acrylic water based paints pigments like TiO_2, supplied in powdry or slurry form are dispersed in water with dispersing agents like tetrasodium pyrophosphate, $Na_4P_2O_7$ and water-soluble thickeners such as hydroxyethyl cellulose, $HO\text{-}CH_2\text{-}CH_2\text{-}R$. This pigment dispersion is blended with latex to form paint. Additives like n-octyl alcohol, $CH_3(CH_2)_6CH_2OH$ decrease the surface tension of the water. Fungicides and bactericides are used to prevent degradation of the binder and thickeners (Koleske, 2013). Ammonia is added to maintain an alkaline condition preventing breakdown of emulsion. Propylene glycol, $CH_3CHOHCH_2OH$ acts as a wet-edge additive, which helps new paint to join the edge of existing paint film, and also functions as an anti-freeze. Tributyl phosphate, $(C_4H_9)_3PO_4$ is a coalescing agent that assists film formation by permitting fusion of latex particles upon drying. Coalescing agents and water evaporate as the acrylic binder hardens and dries (Vignola, 2003).

2.2 Theories of colour

Colour arises from the way in which colourants (pigments and dyes) interact with light. Coloured organic compounds contain groups of atoms whose bonds are unsaturated, such as C=C, C=O, N=O, NO_2, C=S, C=NH and N=N. These are part of an extended delocalized system of electrons called a chromophore (Ashok, 1993). A sequence of alternating double bonds through which the electrons are spread form a conjugated system. The presence of salt-forming groups of atoms such as –OH and NH_2 modify the colour. They are called auxochromes and contain lone pairs of electrons that become part of the delocalized electron system. Coloured inorganic compounds often contain transition metals in which the *d* subshell of electrons is split by attached groups, the ligands. The extent of this splitting is responsible for the colour. The oxidation state of metals also affects the *d* electrons and determines colour.

2.3 Lead and its poisoning

Lead (Pb) is a soft and malleable transition element which is also considered to be one of the heavy metals with a density of 11.3 g/cm^3 (ATSDR, 1997). Pb poisoning continues to be a significant public health problem in developing countries where there are considerable variations in the sources and pathways of exposure (Tong and McMichael, 1999). Pb is added to paint to speed drying, increase durability, retain a fresh appearance, and resist moisture that causes corrosion. It is used as pigment, with lead (II) chromate

($PbCrO_4$, "chrome yellow") and lead (II) carbonate ($PbCO_3$, "white lead") being most common (ILSG, 2004). Pb chromates are often used to produce yellow, orange, red, and green paints.

White lead (basic lead carbonate), it has a high affinity for paint ‘vehicles’ (binders) and a tremendous hiding power, widely replaced by titanium oxide and barium -zinc-sulphur combinations. For colour, lead pigments such as red lead (lead oxide with 4 oxygens and bright orange colour), and blue lead (lead sulphate with lead oxide, zinc oxide, and carbon) may be used industrially where corrosion protection and colour on metal is needed. Lead flake still finds use as an exterior primer, lead oleate and lead octoate may be encountered as driers in paints. Countries and different organizations have come up with lead based paint limits. U.S. Environment Protection Agency (EPA) Standards (USEPA, 2001) specifies that the maximum allowable total lead content is 0.06 % based on the total weight of the non-volatile portion of the paint (which is equivalent to 600 ppm).

The lead limit in paint and surface coatings applies to; paint and other similar surface coatings, toys and other articles intended for use by children, and certain furniture articles that are not exempted under these regulations. Substances controlled under Environment Protection and Management Act (EPMA) states also the lead content should not be more than 0.06 % (600 ppm) by weight of the paint (NEA, 2008). Global Alliance to Eliminate Lead Paint (GAELP) broad objective is to phase out the manufacture and sale of paints containing lead and eventually to eliminate the risks from such paint (GAELP, 2011).

According to the Kenya Bureau of Standards (KEBS); the only paint lead limit specified is for the universal undercoat which should have a maximum of 0.045 % m/m lead (KEBS, 2006) when tested in accordance with KS ISO 3856-1. Studies by Toxics Link (2009) indicate high levels of lead concentrations in oil based paints than in water based paints available to the public in Tanzania as shown in Table 2.1.

Table 2.1: Lead levels in ppm of different paint samples sold in Tanzania

Paint brand	Type of paint	Colour of the paints	Lead concentration (ppm)
Goldstar	Water based	Mist pink	19.3
Sadolin	Water based	Summer blue	17.1
Sadolin	Oil based	Black	2219
Sadolin	Water based	Mist pink	26
Coral	Water based	Summer blue	18
Sadolin	Oil based	Mist pink	2670.2
Coral	Water based	Candy pink	13
Goldstar	Water based	Summer blue	40.2
Goldstar	Oil based	Green	3651
Goldstar	Oil based	Alkot green	3612.2
Goldstar	Oil based	Yellow	2522
Sadolin	Oil based	Sunglow yellow	3914.2
Goldstar	Oil based	Black	11360
Goldstar	Oil based	White	3387
Coral	Oil based	Red	44068.5
Sadolin	Oil based	Green	31581
Sadolin	Oil based	Blue	4073.1
Sadolin	Oil based	Grey	9841
Sadolin	Oil based	White	1541.2
Goldstar	Oil based	Blue	4188
Coral	Oil based	White	7602
Goldstar	Oil based	Red	193.2
Coral	Oil based	Black	5484
Coral	Oil based	Blue	7722
Coral	Oil based	Yellow	120862.1
Coral	Oil based	Green	20248

Source: Toxics Link (2009)

Adebamowo *et al.* (2007) reported high levels of lead in paints than the recommended concentration of 600 ppm in Nigeria and some selected Asian countries as tabulated in Tables 2.2 .

Table 2.2: Lead level in ppm of different colours of paint sold in Nigeria, India and Malaysia

Countries									
Nigeria				India			Malaysia		
Colour	Median	n	Mean ± SD	Median	n	Mean ±SD	Median	n	Mean ±SD
Yellow	40515	4	4227±5393	114968	4	124892 ±46235	61852	14	57553± 5450
Red	24457	4	2374±1587 7	6804	3	36993± 55094	25992	8	30227± 3364
Green	12216	3	1597±9410	39155	3	31780± 1304	33372	4	38556± 3380
White	4110	5	3035±1864	1562	1	1562	124	1	124
Blue	3615	5	3457±1729	3366	1	3366	2033	3	2485± 2574

Source: Adebamowo *et al*. (2007)

Environmental pollution from Pb is a major health hazard throughout the world. The most common mechanisms of lead poisoning are industrial exposure (such as those working in lead battery manufacturing companies), drinking moonshine liquor, inhalation of lead fumes, gunshot wounds, variety of folk remedies, use of glazed ceramics, cosmetics and paints (ATSDR, 1997). Lead poisoning (saturnism or plumbism), is a medical condition caused by increased levels of the metal lead in the blood. In most of its chemical forms, lead can be toxic at the levels to which human beings are exposed in the work place and in the general environment, whether by inhalation or ingestion in water or food. The National Toxicology Program (CAS No. 7439-92-1) has classified it as a Group 2B, probable human carcinogen together with its compounds (USEPA, 1999). The International Agency for Research on Cancer (IARC) considers inorganic lead compounds as a potential carcinogen (IARC, 2004).

Lead and calcium are used interchangeably by bone. Lead has an affinity for bone and acts by replacing calcium (Clarkson, 1987). Nearly everyone has a measurable blood lead level (BLL). The centres for disease control and prevention (CDC) considers BLL of 10 μg/dl or above as a cause of concern (CDC, 2005). However, Lanphear *et al.* (2005) conducted a pooled analysis of 1,333 children and found that lead can impair development even at BLL_S below 10 μg/dl.

Lead affects every system of the body. Acute exposure to high levels of lead can result in death or significant damage to the brain or other organs. Lead can affect children at lower levels than those in adults. An article on Lead Encephalopathy on Emedicine (2007); states, “Lead also interferes with excitatory neurotransmission by glutamate, which is the transmitter at more than half the synapes in the brain and is critical for learning: The glutamate receptor thought to be associated with neuronal development and plasticity is the N-methyl-D-aspartate (NMDA) receptor, which is blocked selectively by lead; this disrupts long-term potentiation, which compromises the permanent retention of newly learned information’’(Christopher, 2007).

In adults, the peripheral nervous system is commonly affected (peripheral motor neuropathy). This can lead to irritability, behavioural disorders, low intelligence quotient (IQ), ataxia convulsions and coma in children. Adults fall victims of wrist drop, foot drop, or lead colic (Harrison and Laxen, 1981). Evidence indicates that children with levels less than 10 µg/dl may have compromised development and intellectual performance later in life (CDC, 2005). Most human exposure to lead occurs via ingestion, but in some cases, inhalation is the mode of entry into the body as per Table 2.3 and occasionally dermal contact.

Table 2.3: Main routes of lead exposure and critical effects identified with associated BLL for various population groups

Routes of intake	Population groups	Effects	Critical BLL (µg/L)
Placenta	Feotuses	Delays in neurological development	Threshold
Mother's milk Inhaled air	Neonates and young children	-Inhibition of d-aminolevulinic acid dehydratase (ALAD) -Physical development	30-300 <700
Inhaled air, Hand-mouth behaviour, Ingestion	Children	-Decrease nerve conduction velocity -Cognitive development and intellectual performance -Hearing loss -Jaundice -Anaemia	200-300 <100 <100 350 >200
Inhaled air, Food digestion	Adults	-Decreased ALAD activity -Blood pressure -Damage renal function -Sperm count	30-40 <20 20-100 400-500

Source: ATSDR (2005)

The absorption of lead and its fate in the body mainly depends on physiological characteristics of the exposed person, including nutritional status, health, and age. Once in the body, the kidneys and liver rapidly excrete lead and is removed from the body extremely slowly, mainly through urine at a rate of 16 μg/day (Harrison and Laxen, 1981). Absorbed lead that is not excreted gets distributed into blood, soft tissues and bones. In the blood, over 90 % is bound to red blood cells with a residence time of approximately one month (O'Neill, 1993).

Blood lead is important because the BLL is the most widely used measure of lead exposure. From the blood, lead accumulates in soft tissues and bones. The liver, kidney, lungs, and brain bear the most of the burden. Most of the retained lead in the human body is ultimately deposited in bones. In bones, lead is mainly distributed to those areas that are rapidly undergoing growth and calcification, which occurs predominantly in trabecular bone in childhood in the metaphyseal portion of the bone. Chronic lead poisoning can produce accumulation of lead in the gums, a condition referred to as “lead line” (James *et al*., 2005).

Lead intoxication has no pathognomonic symptoms. A meticulous environmental history is necessary in patients with suspected lead exposure. Lead poisoning should be considered whenever a patient presents peculiar symptoms that do not match any particular disease entity. For instance, the clinical presentation is variable in terms of symptoms and depends on the child’s age, degree of exposure, and duration of exposure (Christopher, 2007). Younger patients, children and pregnant women are widely held to be more susceptible to lead than older children and adults (Ratcliffe, 1981). This is because lead is absorbed more effectively from the gastrointestinal tract of children than from the gastrointestinal tract of adults. Despite elevated BLLs, most children have no symptoms. In general, children with the following signs and symptoms should be periodically screened. They include: irritable, temperamentally labile children, altered activity levels, hyperactive or excess lethargy, sleeplessness, delayed developmental milestones, language delay, poor appetite, headaches, vomiting, constipation, abdominal pain, ataxia, somnolence, seizures, stupor, and coma (Josef, 1982).

In adults, cognitive dysfunction is more prominent particularly with acute exposure, although symptoms similar to those in children may occur. Motor neuropathy (mainly foot and wrist drop), delirium and hallucinations are more common in adults (WHO, 1995). Though the only curative measure for lead poisoning is decreasing exposure to lead, there are some forms of chelation therapy that can reduce BLL_S namely; Dimercaptosuccinic acid (DMSA), Ethlenediaminetetraacetic acid (EDTA) and British anti-Lewis (BAL). Calcium supplementation may reduce BLL_S by decreasing intestinal absorption of lead or increasing the excretion of lead from circulation in the body, which decreases the risk of fetal and infant exposure (Ettinger, 2008).

2.4 Cadmium and its poisoning

Cadmium in its elemental form is either a blue-white metal or a greyish-white powder found in lead, copper and zinc sulphide ores. Cadmium compounds range in solubility in water from quite soluble to practically insoluble (ATSDR, 1997). Due to its low permissible exposure limit (PEL), over exposures may occur even in situations where only trace quantities of cadmium are found. It is a soft, ductile, bluish-white electropositive metal, which is very resistant to corrosion, with many chemical and physical similarities to zinc and occurs together with this metal in many natural forms (Friberg and Elinder, 1983; Sittig, 1985).

Cadmium dust includes various cadmium compounds such as cadmium chloride. Cadmium fumes consist of minute particles of cadmium or cadmium oxide formed during combustion. Cadmium loses its lustre in moist air and is rapidly corroded by moist ammonia and sulphur dioxide. The metal is soluble in acids but insoluble in water. Cadmium dust is reactive with strong oxidizing agents, elemental sulphur, selenium and tellurium. Most cadmium compounds are reactive with oxidizing agents, strong acids and bases, potassium and magnesium (Lenga, 1988).

The main use of cadmium is the electroplating of other metals mainly steel, iron and copper. Almost 50 % of all cadmium is used for this purpose. Cadmium may also be alloyed with copper, nickel, gold, silver, bismuth and aluminium to form easily fusible compounds which can be used as coatings for other materials, and in welding and in soldering processes (Friberg and Elinder, 1983; Sittig, 1985). In addition, cadmium compounds are used in the production of pigments, dyes (cadmium sulphide, cadmium sulphoselenide), as stabilizers in plastics (cadmium stearate), paints and in the electrodes of nickel-cadmium alkaline batteries. Cadmium is found in superphosphate fertilizers (Friberg and Elinder, 1983). The Occupational Safety and Health Administration (OSHA) established a PEL of 5 $\mu g/m^3$ of air with action level of 2.5 $\mu g/m^3$ (OSHA, 1992) and CPSIA (2008) limited its cadmium levels in paints and surface coatings at 75 ppm.

Cadmium poisoning is associated with industrial processes such as metal plating and the production of nickel-cadmium batteries, pigments, plastics, and other synthetics. The primary route of exposure in industrial settings is inhalation. Inhalation of cadmium-containing fumes can result initially in metal fume fever but may progress to chemical, pneumonitis, pulmonary oedema and death (Hayes, 2007). United States Environmental Protection Agency (USEPA) considers cadmium to be a probable human carcinogen (cancer-causing agent) and has classified it as a Group B1 carcinogen (USEPA, 1999).

Several occupational studies have reported an excess risk of lung cancer in humans from exposure to inhaled cadmium. The evidence is limited rather than conclusive due to confounding factors. Animal studies have reported cancer resulting from inhalation exposure to several forms of cadmium, while animal ingestion studies have not demonstrated cancer resulting from exposure to cadmium compounds (Calabrese and Kenyon, 1991; ATSDR, 1997; USEPA, 1997).

It has been estimated that worldwide anthropogenic emissions of cadmium exceed natural ones by a factor close to ten (Elinder, 1992). Mining operations in Japan contaminated the Jinzu River with cadmium and traces of other toxic metals. As a consequence, cadmium accumulated in the rice crops growing along the river banks downstream of the mines. The local agricultural communities consuming the contaminated rice developed Itai-itai disease and renal abnormalities, including proteinuria and glucosuria (Nriagu, 1988; Nogowa *et al*., 2004). Cadmium is one of the six substances banned by the European Union's Restriction on Hazardous substances (RoHS) (IARC, 1993). Cadmium and other cadmium-containing compounds are potential carcinogens and can induce many types of cancer (ATSDR, 1999).

Current research has found that cadmium toxicity may be carried into the body by zinc binding proteins; in particular, proteins that contain zinc finger protein structures. Zinc and cadmium are in the same group of the periodic table, contain the same common oxidation state (+2), and when ionized are almost the same size. Due to these similarities, cadmium can replace zinc in many biological systems, in particular, systems that contain softer ligands such as sulphur. Cadmium can bind up to ten times more strongly than zinc in certain biological systems, and is notoriously difficult to remove. Cadmium can also replace calcium and magnesium in certain biological systems. The absorption of cadmium from the lungs is much more effective than that from the gut, and as much as 50 % of the cadmium inhaled via cigarette smoke may be absorbed (Friberg, 1983).

No significant effect on blood cadmium concentrations has been detected in children exposed to environmental tobacco smoke (Jarup *et al*., 1998). Cadmium poisoning can be acute or chronic. Acute (short term) poisoning results in flu-like symptoms of weakness, fever, headache, chills, sweating and muscular pain. In severe intoxication, patients may develop acute pneumonities and lesional pulmonary oedema with respiratory failure which can progress to death in 3-7 days (Friberg and Elinder, 1983; Sittig, 1985).

If death from asphyxia does not occur, symptoms may resolve within a week. The most serious consequence of chronic cadmium poisoning is cancer (lung and prostate)

(Armstrong and Kazantis, 1985). The first observed chronic effect is generally kidney damage, manifested by excreation of excessive (low molecular weight) protein in the urine. Cadmium also is believed to cause pulmonary and bone disease (osteomalacia and osteoporosis). Cadmium exposure may cause emphysema, anaemia, teeth discolouration and loss of smell (anosmia) (OSHA, 1992; HSDB, 1993). The California Environmental Protection Agency (CalEPA) has established a chronic reference exposure level of 0.00001 mg/m^3 for cadmium based on kidney and respiratory effects in humans. The CalEPA reference exposure level is a concentration at or below which adverse health effects are not likely to occur (CalEPA, 1997).

Limited data on cadmium use in paints and its effect in animals are available, although some reproductive effects, such as decreased reproduction and testicular damage, have been noted following oral exposures (ATSDR, 1997). Animal studies provide evidence that cadmium has developmental effects, such as low fetal weight, skeletal malformations, interference with fetal metabolism, and impaired neurological development, via inhalation and oral exposure (Calabrese and Kenyon, 1991; HSDB, 1993).

2.5 Methods of analysis

The common methods for heavy metal analysis include; atomic absorption spectrometry (AAS) (Mireji *et al.,* 2007), electro- thermal vaporization inductively coupled plasma atomic emission spectroscopy (ETV-ICP-AES) (Wanjau *et al.*, 2004), Inductively coupled plasma mass spectroscopy (ICP-MS) (Horwitz, 2001), energy dispersive X- ray fluorescence (ED-XRF) (Oyugi, 2000), X- ray fluorescence (XRF) (Kalnicky and Singhvi, 2001) and differential pulse anodic stripping voltammetry (DPASV) (Skoog *et al*., 2004). The reference method for the determination of absolute amounts of lead is by isotope dilution mass spectrometry (IDMS) but due to equipment costs and required expertise, it is not widely used (Settle and Petterson, 1980; Grandjean and Olsen, 1984). In this study AAS technique was used.

Atomic absorption spectrophotometry is a physical process involving the absorption of light by free atoms of an element at a wavelength specific to that element. Absorption and emission of light are associated with the process of transition of atoms from one energy state to another. Atomization or generation of free atoms is the most critical process. To atomize a sample in flame, a solution is usually sprayed into a spray chamber by means of pneumatic nebulizer, which produces a fine aerosol, which is passed into flame. Radiation from an external source is passed through the flame where the free atoms absorb the appropriate wavelength of radiation before it is passed through a monochromator to the detector as shown in Figure 2.3.

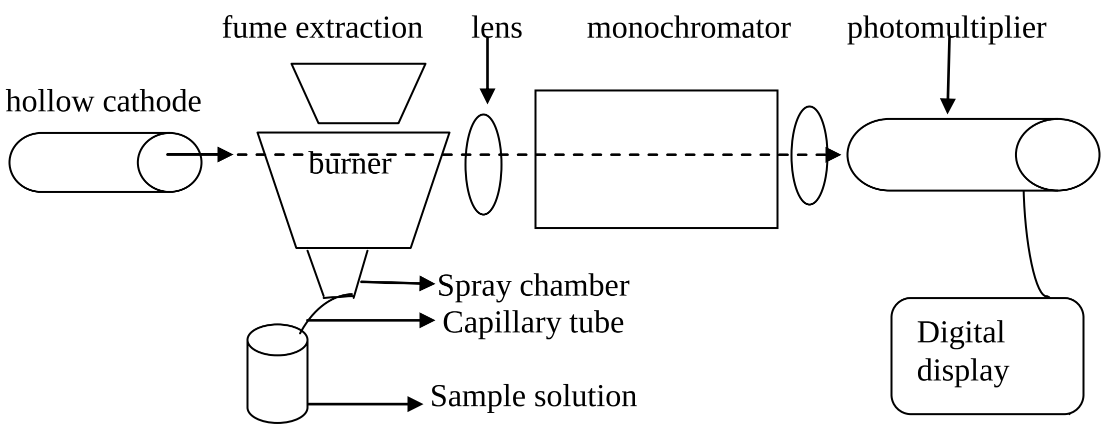


Figure 2.3: A Schematic diagram of an AAS

The amount of radiation absorbed depends on the number of atoms in the flame. This observes Beers law in which absorbance is directly proportional to concentration of the absorbing species. A calibration curve plotted using absorbance from known metal standards within the concentration range of the sample help to determine the sample concentration traced from its observed absorbance. For the case of a steady state O and J where $E_j > E_{o,}$ the O → J transition results in the absorption of light with frequency shown in Equation 2.1.

$$V_{oj} = \frac{E_j - E_O}{h} \qquad \text{Eq 2.1}$$

Where:
h- Planks constant and E is the energy
E_o- Energy at ground state
E_j- Energy at the excited state

The O → J absorption is always stimulated by external radiation. This phenomenon forms the integral part of atomic absorption spectroscopy. For non excited atom each electron is in the ground state. The proportion of excited to ground state atoms at a particular temperature are given by the Maxwell Boltzmann's Law in Equation 2.2.

$$\frac{N}{N_O} = \frac{g}{g_o} = \exp\frac{E_g - E_e}{KT} \qquad \text{Eq 2.2}$$

Where:
N and N_o- Number of atoms in the excited state ground sate respectively
E_g and E_e- Energy difference in joules between the ground state and the excited state respectively
g and g_o- Statistical weights of excited and ground state respectively
T- Absolute temperature
K- Boltzmann's constant

At most temperatures encountered in the flames and electro thermal atomizers all atoms with electrons higher than the first excited state are ignored. In fact, unless T is very large the exponential term is very small. The wavelength at which an atom absorbs radiation is called resonance wavelength. In calculating how much light is absorbed by a cloud of atoms, a parallel beam of light at the resonance wavelength for the atoms concerned striking a cell containing N atoms is considered. Let the cell be of unit cross section area and the light intensity be Io Watts per unit area as it enters the cell. The intensity transmitted after absorption is given by Equation 2.3.

$$\mathrm{T} = \frac{I}{I_o} \qquad \text{Eq 2.3}$$

Where:
T- Transmittance or transmitted radiation
Io- Original radiation intensity
I- Intensity of transmitted radiation

The intensity of transmitted radiation is related to the number absorbed through a term called absorbance, A, shown in Equation 2.4.

$$\mathrm{A} = log\frac{I_o}{I} = -log_{10}\mathrm{T} \qquad \text{Eq 2.4}$$

Beers–Lamberts law shows that absorbance is directly proportional to the path length and concentration as indicated in Equation 2.5.

$$A = abC = \frac{\log I_o}{I} = \frac{\log \mathrm{I}}{\mathrm{T}} \qquad \text{Eq 2.5}$$

Where:
A- Absorbance
a- Proportional constant
b- Path length
C- Concentration

The most important components of atomic absorption spectrometer are; spectral source, atom cell, monochromator, detector, amplifier and display system for recording of absorption values. The AAS has high sensitivity, selectivity, accuracy precision and speed, at which the analysis is done and hence adopted for the study.

CHAPTER THREE

MATERIALS AND METHODS

3.1 Sampling and sample size

In the study, purposive random sampling of paints ready to for sale in shops in Nairobi, Kenya was done. Five paint brands which were labelled A, B, C, D and E due to lack of permit to authorize use of their company names, were randomly selected amongst ten identified paint brands. From each sampled paint brand, ten paint samples of different colours were randomly selected (Appendices i and ii). The purchases were done in such a way that, the paint samples had different manufacturing date notably samples of the same colour. A sample size of fifty (n=50) paint samples for the five sampled brands was used. These included twenty six (n=26) water based paint samples (plastic paints) and twenty four (n=24) oil based paint samples (enamel paints) (Figure 3.1).

The water based paints were purchased in 500 and 1,000 ml containers as it was the only minimum volume while the oil based paints in volumes of 100, 200, 500 and 1,000 ml depending on availability. The paint samples were homogenized and put in labelled plastic bottles and kept at room temperature awaiting digestion and analysis (Appendix xiii).

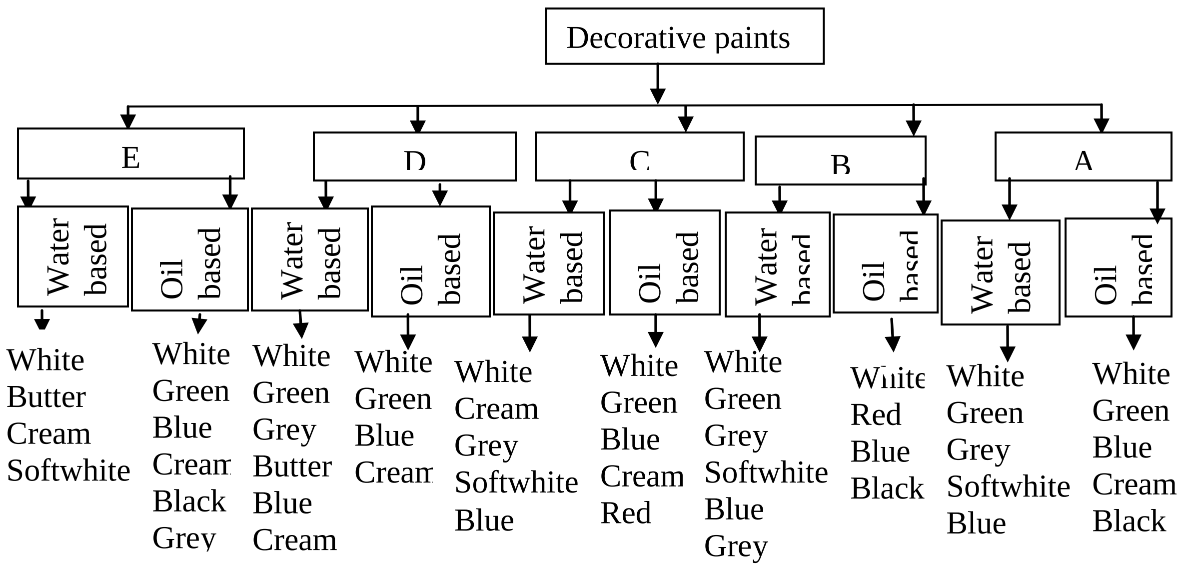


Figure 3.1: Decorative paints selected for analysis

3.2 Laboratory procedures

3.2.1 Glassware and plastic containers

The glassware, and plastic containers were cleaned with non ionic liquid soap and then rinsed with distilled water. All the glassware used in this study were decontaminated by soaking them overnight in 5 % nitric acid and rinsed thoroughly with distilled de-ionized water. They were then dried at 105 ^{o}C. The plastic containers were then soaked overnight in 1:1 nitric acid to water ratio and then rinsed thoroughly with distilled de-ionized water. After this they were dried on an open rack. Both the glassware and plastic containers were also stored in a clean drawer under lock and key to prevent contamination.

3.3 Preparation of standard solution for AAS

Double distilled de-ionised water stored in plastic containers was used to prepare the standard solutions and blank samples used in this study. The standard solutions of 1,000 ppm stock solutions of lead and cadmium were made from standard analar reagents from Alpha chemicals. The salts used to make the stock solutions were analar lead nitrate and cadmium nitrate to make one litre as shown in Table 3.1.

Table 3.1: Salts, solvents and masses used for lead and cadmium stock solution

Element	Analar reagent	Solvent	Mass (g)
Pb	$Pb(NO_3)_2$	H_2O	1.5980
Cd	$Cd(NO_3)_2$	H_2O	2.1032

3.3.1 Calibration curve and regression analysis

Lead and cadmium standard solutions were used to generate the calibration curves using AAS from their absorbance measurements taken (Appendix iii). The regression parameters for the lead and cadmium calibration curves are summarized in Table 3.2.

Table 3.2: Regression parameters for lead and cadmium and their concentration

Elements	Line of regression	R^2	Range of concentration used
Lead	Y=0.0113X–00.0015	0.9994	1–40 ppm
Cadmium	Y= 0.096X+0.0003	0.9999	0.02–1.0 ppm

From Table 3.2, the intercepts were very close to zero an indication that the lines pass near the origin and thus minimum matrix interference. The pearson correlation factors were close to 0.998 and the points were on the straight lines. The results indicate linearity with the concentrations used and the regression equations were hence used for quantification of the elements in the samples from the absorbancies.

3.3.2 Sample preparation

Samples were prepared according to standard operating procedures for lead in paints (USEPA, 2001). Wet paint samples were applied onto individual clean glass slides using different glass rods for each sample to avoid any cross contamination. Samples, were left to dry for a minimum of 72 hours in the sun and in the oven for 24 hours at 50 ^oC. After drying, samples were scraped off from glass slides using sharp, clean scalpel and accurately weighed to 1.000 g using analytical weighing machine (Shimadzu Model ATY224) and put into an acid washed 100 ml digestion tubes.

3.3.3 Acid digestion

The samples were subjected to wet acid digestion, using concentrated analytical grade nitric acid and perchloric acid to destroy the organic matter. A volume of 30 ml of concentrated nitric acid was added first and digested until the brown fumes were exhausted at temperatures of approximately 150 ºC. The samples were then allowed to cool and 10 ml of perchloric acid added for complete digestion, until the white vapours of perchloric acid were liberated. The digestates were then allowed to cool and diluted with 15 ml of double distilled de-ionized water, filtered into 50 ml volumetric flasks and quantitatively adjusted to the mark with double distilled de-ionized water, labelled and stored awaiting analysis (Chakrabarti, 1983).

3.3.4 The AAS analysis

All samples were analyzed for lead and cadmium using AAS techniques (Buck scientific Model 210 VGP). The concentration of lead and cadmium was assayed by use o AAS in triplicates with acetylene flame. Validation of the AAS was checked by triplication of the samples. A series of standards were prepared in distilled de-ionised water for instrumental calibration by serial dilution of the stock solution given in Table 3.1. The standards and blank samples were analyzed for every 10 samples analyzed. The validity of the method was ascertained by cross method checks, spiked recovery and replication analysis. The calibration curves obtained are given in Appendix iv. The main instrumental parameters such as band width, lamp current, heat of the flame and wavelength for AAS were optimized separately for each metal. The operating conditions of the AAS are given in Table 3.3.

Table 3.3: The AAS instrumental parameters

Operating parameter	Pb	Cd
Lamp curentr, (mA)	5	4
Measurement time (sec)	1	1
Wavelength (nm)	217	228.8
Slit width (nm)	1.0	0.5
Flame	Air-acetylene	Air-acetylene
Flow rate (litres/mm)	1.5	1.5
Sensitivity (µg/g)	0.1100	0.0110
Detection limit(µg/g)	0.0200	0.0006

Source: Rehman *et al*., 2012

3.4 Data analysis

The concentration of lead and cadmium from the paint samples in both water and oil based samples were tabulated as mean concentration profile together with their standard deviation. The mean concentrations for the brands were further analyzed for their standard error. The statistical significance of lead and cadmium in the paint samples was also determined by ANOVA. SNK (Studentized Newman-Keuls) test was used to compare the concentration of lead and cadmium in paints using statistical SPSS Program (17.0). The significant level was set at $p=0.05$ ($\alpha=0.05$). The ANOVA was useful in providing interdependence of variables and significant differences in the paint brands (Miller and Miller, 1990).

CHAPTER FOUR

RESULTS AND DISCUSSION

4.1 Lead and cadmium analysis

Fifty paint samples (n=50) were analyzed for lead and cadmium. Twenty four (n=24) and twenty six (n=26) were oil and water based respectively. The samples were analyzed in triplicates for cadmium and lead from the five randomly selected paint brands. The paint samples analyzed are given in Appendices i and ii. The detection limits of lead and cadmium are given in Table 3.2. The statistical results from analysis of lead and cadmium levels in the paint samples are presented in Tables 4.1-4.14 and Appendices iii-xii.

4.2 Levels of lead and cadmium in oil based paints

The results for the oil based paints analyzed (n=24), from the five brands are tabulated in the following sections.

4.2.1 Brand A

The mean levels of Pb and Cd in oil based paint for brand A are represented in Table 4.1.

Table 4.1: Lead and cadmium levels in oil based paints for brand A

Elements	Colour	n	Mean±SD (ppm)	Range (ppm)
Lead	White	3	1608.09 ± 1.31^{c}	1607.05-1609.56
	Blue	3	2647.87 ± 0.87^{d}	2647.25-2648.87
	Green	3	37802.57 ± 1.93^{e}	37800.63-37804.48
	Cream	3	276.53 ± 0.63^{a}	275.86-277.11
	Black	3	704.84 ± 0.15^{b}	704.72-705.01
Cadmium	White	3	1.30 ± 0.04^{d}	1.26-1.34
	Blue	3	0.46 ± 0.01^{a}	0.45-0.48
	Green	3	1.15 ± 0.04^{c}	1.11-1.18
	Cream	3	2.84 ± 0.03^{e}	2.82-2.88
	Black	3	0.98 ± 0.05^{b}	0.95-1.04
p-value			<0.001	

The results in Table 4.1 indicated lead levels in the green paint of brand A with concentration of 37802.57±1.93 ppm. The blue paint sample had lead level of 2647.87±0.87 ppm, white paint sample 1608.09±1.31 ppm and black paint sample 704.84±0.15 ppm. These lead levels were above the recommended limits of 600 ppm (CDC, 2002). Cream paint sample had the lowest lead concentration of 276.53±0.63 ppm, though higher than the 90 ppm lead limit (CPSIA, 2008). The lead levels for the five different colours of paint samples differed significantly from each other at 95 % confidence level ($P<0.05$) and their order of decreasing lead levels was as follows:

Green > Blue > White > Black > Cream

From Table 4.1, cadmium concentration was recorded highest in the cream paint sample with mean of 2.84±0.03 ppm followed by white and green with cadmium levels of 1.30±0.04 ppm and 1.15±0.04 ppm, respectively. The black paint sample (0.98±0.05 ppm) and blue paint (0.46±0.01 ppm) had the lowest cadmium levels. The five samples analyzed had cadmium concentration below the set limits of 75 ppm (CPSIA, 2008). The cadmium levels in the five colours of the paint samples were significantly different from each other at $p<0.05$ and 95 % confidence level. In order of decreasing cadmium levels in the paint samples can be arranged as follows:

Cream > White > Green > Black > Blue

4.2.2 Brand B

Four oil based paints of brand B were analyzed for lead and cadmium. The results are presented in Table 4.2.

Table 4.2: Lead and cadmium levels in oil based paints for brand B

Elements	Colour	n	Mean±SD (ppm)	Range (ppm)
Lead	White	3	25.69±0.36[a]	25.44-26.11
	Blue	3	100.84±0.04[c]	100.81-100.88
	Red	3	182.23±0.56[d]	181.64-182.74
	Black	3	97.49±0.15[b]	97.35-97.64
Cadmium	White	3	0.49±0.02[a]	0.47-0.51
	Blue	3	4.95±0.05[d]	4.90-5.01
	Red	3	1.30±0.01[b]	1.29-1.32
	Black	3	4.82±0.10[c]	4.73-4.93
p-value			<0.001	

Mean values within the same column for the same parameter followed by different small letters are significantly different at 95 % confidence level (SNK –test $p<0.05$)
Studentized Newman-Keuls test

From Table 4.2, red and blue paint samples had the highest lead levels of 182.23±0.56 ppm and 100.84±0.04 ppm respectively. The samples for brand B analyzed had lead levels below 600 ppm (CDC, 2002), but above 90 ppm (CPSIA, 2008) except the white paint sample which had lead concentration of 25.69±0.36 ppm. The four paint samples analyzed had lead levels which were significantly different from each other at 95 % confidence level and $p<0.05$ as indicated in Table 4.2. Their lead levels decreasing trend was as follows:

Red > Blue > Black > White

Cadmium concentrations from Table 4.2 in the four oil based paints met the required limits of 75 ppm (CPSIA, 2008). Blue paint sample had the highest cadmium level of 4.95±0.05 ppm followed by black paint sample with cadmium concentration of 4.82±0.10 ppm. Red (1.30±0.01 ppm) and white (0.49±0.02 ppm) paint samples indicated the lowest cadmium levels. The different colours for the paint samples had significantly different levels of cadmium ($p<0.05$, 95 % confidence level; Table 4.2**)** and their decreasing cadmium level was as below:

Blue > Black > Red > White

4.2.3 Brand C

Oil based paint samples analyzed for lead and cadmium from brand C were five in number and their results are as tabulated in Table 4.3.

Table 4.3: Lead and cadmium levels in oil based paints for brand C

Elements	Colour	n	Mean±SD (ppm)	Range (ppm)
Lead	White	3	9.24 ± 0.11^{a}	9.14-9.37
	Blue	3	13.79 ± 0.07^{b}	13.72-13.86
	Green	3	180.36 ± 0.41^{e}	180.09-180.83
	Cream	3	18.78 ± 0.11^{c}	18.66-18.88
	Red	3	27.97 ± 0.15^{d}	27.80-28.10
Cadmium	White	3	2.82 ± 0.02^{c}	2.80-2.83
	Blue	3	4.62 ± 0.03^{d}	4.59-4.64
	Green	3	0.82 ± 0.03^{b}	0.79-0.85
	Cream	3	0.85 ± 0.01^{b}	0.84-0.86
	Red	3	0.68 ± 0.01^{a}	0.67-0.69
p-value			<0.001	

From the Table 4.3 paint samples analyzed for lead metal had met the set standards of 600 ppm (CDC, 2002). Green paint sample with a lead level of 180.36±0.41 ppm measured the highest lead concentration above the latest set standards of 90 ppm (CPSIA, 2008), amongst blue (13.79±0.07 ppm), cream (18.78±0.11 ppm), red (27.97±0.15 ppm) and white (9.24±0.11 ppm) paint samples. The colours for the five oil based paint samples analyzed had significantly different lead levels from each other (95 %

confidence level, $p<0.05$; Table 4.3). The order of lead level starting with the highest to the lowest paint sample can be arranged as follows:

Green > Red > Cream > Blue > White

Table 4.3 shows that, cadmium levels for the paint samples analyzed from brand C were within the recommended limits of 75 ppm (CPSIA, 2008). The blue paint sample recorded the highest cadmium concentration of 4.62±0.03 ppm followed by white paint sample with 2.82±0.02 ppm (Table 4.3). The rest of the colours of the paint samples had cadmium levels less than 1.00 ppm and were all significantly different from each other at 95 % confidence level and $p<0.05$ (Table 4.3). Cadmium concentration in the paint samples analyzed in their decreasing index is:

Blue > White > Cream > Green > Red

4.2.4 Brand D

Results of brand D oil based samples analyzed for lead and cadmium are shown in Table 4.4 and comprised of four colours.

Table 4.4: Lead and cadmium levels in oil based paints for brand D

Elements	Colour	n	Mean±SD (ppm)	Range (ppm)
Lead	White	3	48.97 ± 0.32^{a}	48.60-49.19
	Blue	3	64.33 ± 0.15^{c}	64.16-64.45
	Green	3	141.03 ± 0.96^{d}	140.12-142.04
	Cream	3	58.85 ± 0.20^{b}	58.70-59.07
Cadmium	White	3	9.81 ± 0.01^{c}	9.81-9.82
	Blue	3	6.51 ± 0.02^{a}	6.50-6.54
	Green	3	23.55 ± 0.02^{d}	23.53-23.57
	Cream	3	7.12 ± 0.02^{b}	7.10-7.14
p-value			<0.001	

The sampled paint colours of brand D in Table 4.4 met the requirements of lead standards (USEPA, 2001). The green paint sample measured the highest level of 141.03±0.96 ppm which was above the latest lead limits of 90 ppm (CPSIA, 2008). The other paint samples recorded lead levels of less than 90 ppm. These samples had significantly different lead levels at 95 % confidence level and $p<0.05$ (Table 4.4). The order of lead level decrease can be arranged as follows:

Green > Blue > Cream > White

Cadmium level for green paint sample was recorded the highest, with a concentration of 23.55±0.02 ppm. The white, cream and blue paint sample had cadmium concentration of 9.81±0.01 ppm 7.12±0.02 ppm and 6.51±0.02 ppm respectively. These samples had statistically different cadmium levels ($p<0.05$, 95 % confidence interval; Table 4.4). The samples decreasing order of cadmium level can be arranged as below:

Green > White > Cream > Blue

4.2.5 Brand E

The oil based paint samples analyzed for lead and cadmium from brand E are tabulated in Table 4.5.

Table 4.5: Lead and cadmium levels in oil based paints for brand E

Elements	Colour	n	Mean±SD (ppm)	Range (ppm)
Lead	White	3	21.14±0.15[c]	21.02-21.31
	Blue	3	23.48±0.11[d]	23.38-23.60
	Green	3	423.70±0.72[f]	423.08-424.48
	Cream	3	7.77±0.26[a]	7.52-8.04
	Black	3	75.00±0.07[e]	74.93-75.07
	Grey	3	13.32±0.09[b]	13.27-13.42
Cadmium	White	3	4.84±0.07[c]	4.78-4.92
	Blue	3	4.57±0.04[b]	4.53-4.61
	Green	3	4.06±0.04[a]	4.02-4.09
	Cream	3	5.29±0.03[d]	5.27-5.32
	Black	3	5.87±0.04[e]	5.83-5.92
	Grey	3	5.28±0.03[d]	5.25-5.31
p-value			<0.001	

The oil based paint samples analyzed in Table 4.5 met the required lead standards of 600 ppm (USEPA, 2001), though the green oil based sample (423.70±0.72 ppm) did not meet the new lead standards of 90 ppm (CPSIA, 2008). The different colours of the paint samples had statistically different lead levels ($p<0.05$, 95 % confidence level; (Table 4.5). A decreasing trend in lead levels of the samples analyzed can be arranged as follows:

Green > Black > Blue > White > Grey > Cream

From Table 4.5, three samples; black (5.87±0.04 ppm), cream (5.29±0.03 ppm) and grey (5.28±0.03 ppm) recorded the highest cadmium concentration but below the recommended levels (CPSIA, 2008). Grey and cream paint samples being statistically not different ($p<0.05$, 95 % confidence level; Table 4.5). White (4.84±0.07 ppm), blue (4.57±0.04 ppm) and green (4.06±0.04 ppm) paint samples measured the minimum cadmium concentrations amongst all (Table 4.5). The order of cadmium levels in the samples from the highest to the lowest can be arranged as follows:

Black > Cream > Grey > White > Blue > Green

4.2.6 Cd and Pb mean levels in oil based paints for the paint colours

The cadmium and lead mean concentration for the five brands are indicated Table 4.6.

Table 4.6: Cadmium and lead mean levels for the paint colours

Colour	n	Cadmium (Mean±SE) ppm	Lead (Mean±SE) ppm
White	15	3.85±0.89	342.63±169.14[a]
Blue	15	4.22±0.54	570.06±277.78[a]
Green	12	7.39±2.84	9636.91±4903.12[b]
Cream	12	4.03±0.72	90.48±32.89[a]
Grey	3	5.28±0.02	13.32±0.05[a]
Black	9	3.89±0.74	292.45±103.15[ab]
Red	6	0.99±0.14	105.10±34.49[ab]
p-value		0.206	0.013

From the Table 4.6, paint colour and cadmium concentration, the p value ($p>0.05$) indicates that the difference in the levels was not significant at 95 % confidence level and were within the limits of 75 ppm (CPSIA, 2008). The green paint sample indicated the highest cadmium level of 7.39±2.84 ppm while red paint the lowest level of 0.99±0.14 ppm. The decreasing order of concentration of cadmium in terms of the colour of the paint can be arranged as follows (Table 4.6; Appendix xi):

Green > Grey > Blue > Cream > Black > White > Red

The levels of lead limits from Table 4.6 showed that the green oil based paint had the highest concentration of 9636.91±4903.12 ppm which was above the allowable limit of 600 ppm (USEPA, 2001). Blue oil based paint followed with concentration of 570.06±277.78 ppm. The green paint sample was statistically different from the rest of the paint colour samples; white, blue, cream and grey paint samples were not significantly different while black and red paint samples being statistically significant ($p>0.05$, 95 % confidence level; Table 4.6, Appendix ix). In order of decreasing lead concentration the paint colours can be arranged as follows (Table 4.6; Appendix ix):

Green > Blue > White > Black > Red > Cream > Grey

4.2.7 Pb and Cd mean levels in oil based paint samples for the 5 brands

Analysis for Pb and Cd levels in oil based samples of the 5 brands is tabulated in Table 4.7.

Table 4.7: Pb and Cd mean levels in oil based paint samples for the 5 brands

Element	Brands	n	Mean±SE (ppm)	Range (ppm)
Lead	A	15	8607.98±15133.11^{b}	275.86-37804.48
	B	12	101.56±57.87^{a}	25.44-182.74
	C	15	50.03±67.76^{a}	9.14-180.83
	D	12	78.29±38.27^{a}	48.60-142.04
	E	18	94.07±153.37^{a}	7.52-424.48
Cadmium	A	15	1.35±0.83^{a}	0.45-2.88
	B	12	2.89±2.11^{ab}	0.47-5.01
	C	15	1.96±1.60^{a}	0.67-4.64
	D	12	11.75±7.23^{c}	6.50-23.57
	E	18	4.99±0.60^{b}	4.02-5.92

From Table 4.7, brand A had lead levels ranging from 275.86-37804.48 ppm and recorded the highest lead concentration of 8607.98±15133.11 ppm which was significantly different at $p<0.05$ and 95 % confidence level from the rest of the other brands analyzed. Brands B, C, D and E had lead limits below the set standards of 600 ppm (USEPA, 2001) with C and D paint brands meeting the latest lead levels of 90 ppm (CPSIA, 2008). These paint brands with exception of paint brand A were not statistically different ($p>0.05$, 95 % confidence level). In order of lead level decreasing index the five brands can be arranged as follows (Table 4.7; Appendix v):

$$A > B > E > D > C$$

Results in Table 4.7, the oil based samples for paint brand D analyzed indicated the highest cadmium levels with a mean of 11.75±7.23 ppm which was statistically different from the rest ($\alpha=0.05$, 95 % confidence level), was above the recommended levels of cadmium. Paint brand E was second with a mean cadmium concentration of 4.99±0.60 ppm and a range of 4.02-5.92 ppm. Brand B with a mean level 2.89±2.11 ppm and a range of 0.47-5.01 ppm followed next. Brands C and A measured the minimum cadmium levels of 1.96±1.60 ppm and 1.35±0.83 ppm, respectively and were not significantly different at $\alpha=0.05$ and 95 % confidence level (Table 4.7). Generally all the paint brands had cadmium levels below the set limits of 75 ppm (CPSIA, 2008). The order of decreasing cadmium concentration in the five brands was as follows (Table 4.7; Appendix vii):

$$D > E > B > C > A$$

The results for paint brand A on lead levels for oil based samples were similar with the results done by Adebamowo *et al.* (2007) and Toxics Link (2009) (Tables 2.1, 2.2 and

4.1). The green oil based paint sample had lead concentration within the range measured in Malaysia. Tanzania and India, white oil based paint samples had lead levels in agreement with the white oil based sample analyzed for paint brand A in Kenya (Tables 2.1 and 4.1). Blue paint sample analyzed had lead limits close to those reported in Malaysia (Table 2.2 and 4.1). The rest of the oil based paint samples analyzed had mean lead levels within the set limits of 600 ppm (CDC, 2002). Brands C and D met the lead standards of 90 ppm (CPSIA, 2008).

4.3 Levels of lead and cadmium in water based paints

The water based paints analyzed were 26, from the five sampled brands namely A, B, C, D and E (Appendix i).

4.3.1 Brand A

Levels of lead and cadmium results in water based samples are presented in Table 4.8.

Table 4.8: Lead and cadmium levels in water based paints for brand A

Element	Colour	n	Mean±SD (ppm)	Range (ppm)
Lead	White	3	62.67 ± 1.30^{b}	61.52-64.09
	Blue	3	286.48 ± 0.75^{d}	285.62-286.95
	Green	3	73.12 ± 0.33^{c}	72.79-73.45
	Grey	3	299.53 ± 0.33^{e}	298.38-300.96
	Soft white	3	49.93 ± 1.28^{a}	48.53-51.03
Cadmium	White	3	5.47 ± 0.02^{d}	5.44-5.48
	Blue	3	4.19 ± 0.01^{a}	4.18-4.20
	Green	3	5.15 ± 0.16^{c}	4.96-5.27
	Softwhite	3	4.48 ± 0.01^{b}	4.47-4.49
	Grey	3	5.95 ± 0.03^{e}	5.92-5.97
p-value			<0.001	

The results from Table 4.8 showed lead levels were within the recommended limits of 600 ppm (CDC, 2002). Both the grey paint sample indicated the highest lead level of 299.53±0.33 ppm and blue paint sample 286.48±0.75 ppm measuring lead levels were above the allowed concentrations of 90 ppm (CPSIA, 2008). Lead levels in the five samples analyzed were statistically different (95 % confidence level, $p<0.05$). The order of lead concentration in the samples in decreasing index is:

Grey > Blue > Green > White > Softwhite

From Table 4.8, cadmium levels were indicated highest in three paint samples amongst the samples analyzed, (Table 4.8); grey paint sample (5.95±0.03 ppm), white paint sample (5.47±0.02 ppm) and green paint sample (5.15±0.16 ppm) which were all within the recommended cadmium levels of 75 ppm (CPSIA, 2008). Softwhite and blue paint samples had the lowest cadmium concentration of 4.48±0.01 ppm and 4.19±0.01 ppm respectively. All the samples analyzed had significantly different cadmium levels ($p<0.05$, 95 % confidence level; Table 4.8). The samples of cadmium levels in order of decreasing concentration can be arranged as follows:

Grey > White > Green > Softwhite > Blue

4.3.2 Brand B

Water based samples for brand B analyzed for lead and cadmium levels had their results presented in Table 4.9.

Table 4.9: Lead and cadmium levels in water based paints for brand B

Element	Colour	n	Mean±SD (ppm)	Range (ppm)
Lead	White	3	98.60±0.32[c]	98.23-98.82
	Blue	3	106.39±0.26[e]	106.12-106.64
	Green	3	100.22±0.07[d]	100.15-100.29
	Cream	3	121.51±0.43[f]	121.02-121.83
	Grey	3	84.49±0.67[b]	83.85-85.18
	Softwhite	3	83.19±0.20[a]	83.04-83.41
Cadmium	White	3	9.57±0.08[e]	9.48-9.62
	Blue	3	4.80±0.04[c]	4.76-4.83
	Green	3	4.39±0.06[b]	4.33-4.45
	Cream	3	4.84±0.03[c]	4.81-4.86
	Grey	3	4.29±0.01[a]	4.28-4.30
	Softwhite	3	8.25±0.07[d]	8.19-8.33
p-value			<0.001	

Results in Table 4.9 for water based samples for brand B indicated lead levels were within the recommended limits (CDC, 2002). Cream paint sample had the highest lead level of 121.51±0.43 ppm followed by blue paint sample with lead levels of 106.39±0.26 ppm, then the green paint sample with lead level of 100.22±0.07 ppm. However the grey and softwhite paint samples with lead concentrations of 84.49±0.67 ppm and 83.19±0.20 ppm, respectively met the latest lead limits of 90 ppm (CPSIA, 2008). These paint samples had statistically different lead levels (95 % confidence level, $p<0.05$; Table 4.9) with lead limits within 83.04-121.83 ppm. The decreasing order of lead level was as follows:

Cream > Blue > Green > Grey > Softwhite

Table 4.9 results indicated that, white and softwhite paint samples had the highest cadmium concentration of 9.57±0.08 ppm and 8.25±0.07 ppm respectively. Blue (4.80±0.04 ppm) and cream (4.84±0.03 ppm) paint samples were statistically not different at p>0.05 and 95 % confidence level. Green and grey paint samples measured the minimum cadmium levels of 4.39±0.06 ppm and 4.29±0.01 ppm in that order. The paint samples analyzed had cadmium levels below the recommended levels of 75 ppm (CPSIA, 2008). The cadmium concentration in the samples in the decreasing index is:

White > Softwhite > Cream > Blue > Green > Grey

4.3.3 Brand C

Results of lead levels analysis for water based samples for brand C are presented in Table 4.10.

Table 4.10: Lead and cadmium levels in water based paints for brand C

Element	Colour	n	Mean±SD (ppm)	Range (ppm)
Lead	White	3	65.49 ± 0.46^{d}	65.12-66.00
	Blue	3	72.82 ± 0.55^{e}	72.27-73.38
	Cream	3	63.94 ± 0.13^{c}	63.79-64.01
	Grey	3	53.74 ± 0.33^{a}	53.39-54.06
	Softwhite	3	54.87 ± 0.41^{b}	54.50-55.31
Cadmium	White	3	5.91 ± 0.01^{c}	5.90-5.93
	Blue	3	9.30 ± 0.04^{e}	9.26-9.34
	Cream	3	6.04 ± 0.05^{d}	5.99-6.09
	Grey	3	4.89 ± 0.02^{a}	4.87-4.90
	Softwhite	3	5.31 ± 0.03^{b}	5.28-5.34
p-value			<0.001	

The results from Table 4.10 showed that, the paint samples analyzed had lead levels below 90 ppm (Table 4.9) and met the set standards of 90 ppm (CPSIA, 2008). The samples had statistically different lead levels ($p<0.05$, 95 % confidence level) and had lead levels within 53.39-73.38 ppm. Lead concentrations in the samples analyzed in order of their decreasing index can be arranged as follows:

Blue > White > Cream > Grey > Softwhite

Results in Table 4.10 showed that cadmium levels were measured high in blue (9.30±0.04 ppm), cream (6.04±0.05 ppm), white (5.91±0.01 ppm) and softwhite (5.31±0.03 ppm) paint samples. Grey paint sample had the least cadmium concentration of 4.89±0.02 ppm. The samples had cadmium concentrations within the required limits of 75 ppm (CPSIA, 2008). These water based paint samples had statistically different cadmium levels at 95 % confidence level and $p<0.05$ (Table 4.9) and showed decreasing order in the cadmium levels as follows:

Blue > Cream > White > Softwhite > Grey

4.3.4 Brand D

The results of lead level analysis for water based samples for brand D are presented in Table 4.11.

Table 4.11: Lead and cadmium levels in water based paints for brand D

Element	Colour	n	Mean±SD (ppm)	Range (ppm)
Lead	White	3	21.17±0.20[b]	20.94-21.31
	Blue	3	94.00±0.59[d]	93.44-94.62
	Green	3	94.15±0.44[d]	93.73-94.62
	Cream	3	26.82±0.33[c]	26.47-27.14
	Grey	3	10.59±0.23[a]	10.40-10.84
	Butter	3	26.87±0.23[c]	26.62-27.06
Cadmium	White	3	6.06±0.04[c]	6.03-6.11
	Blue	3	4.81±0.02[b]	4.79-4.83
	Green	3	7.08±0.05[d]	7.03-7.12
	Cream	3	8.87±0.08[f]	8.78-8.95
	Grey	3	8.40±0.01[e]	8.39-8.41
	Butter	3	4.13±0.03[a]	4.10-4.15
p-value			<0.01	

Table 4.11 indicated that, water based samples for paint brand D had lead levels within the range of 10.40-94.62 ppm. The green paint sample had the highest lead concentration measuring 94.15±0.44 ppm followed by blue paint sample with 94.00±0.59 ppm (Table 4.11) and both were above the set limits of 90 ppm (CPSIA, 2008). The two samples were significant at 95 % confidence level and $p<0.05$. All the samples met the lead limits of 600 ppm (USEPA, 2001). The decreasing order of lead concentration for the samples can be arranged as follows:

Green > Blue > Butter > Cream > White > Grey

From Table 4.11, cadmium levels were noted to be high for the; cream (8.87±0.08 ppm), grey (8.40±0.01 ppm), green (7.08±0.05 ppm) and white 6.06±0.04 ppm paint samples but below the the recommended levels of 75 ppm (CPSIA, 2008). Blue paint sample recorded a cadmium level of 4.81±0.02 ppm which was the lowest in brand D. The water based samples analyzed were significantly different (P<0.05, 95 % confidence level). They showed a decreasing cadmium level trend to be:

Cream > Grey > Green > White > Blue > Butter

4.3.5 Brand E

Paint brand E, water based samples analyzed for lead and cadmium levels are presented in Table 4.12.

Table 4.12: Lead and cadmium levels in water based paints for brand E

Element	Colour	n	Mean±SD (ppm)	Range (ppm)
Lead	White	3	38.50±0.64[b]	38.05-39.23
	Cream	3	106.61±0.04[c]	106.56-106.64
	Softwhite	3	38.72±0.32[b]	38.50-39.09
	Butter	3	35.84±0.53[a]	35.40-36.43
Cadmium	White	3	6.09±0.03[b]	6.06-6.12
	Cream	3	9.84±0.13[d]	9.72-9.97
	Softwhite	3	6.69±0.02[c]	6.67-6.70
	Butter	3	5.05±0.03[a]	5.02-5.08
p-value			<0.001	

The paint samples for brand E in Table 4.12, measured lead levels below the set limits of 600 ppm (NEA, 2008). Cream paint sample with lead concentration of 106.61±0.04 ppm was the only sample with lead levels above the required limits of 90 ppm (CPSIA, 2008). White and softwhite paint samples had significant lead levels (p<0.05, 95 % confidence level; Table 4.12). The decreasing order of lead levels in the samples arranged as follows:

Cream > Softwhite > White > Butter

Cadmium concentration were within the recommended limits of 75 ppm (CPSIA, 2008) and statistically different at ($p<0.05$, 95 % confidence level; Table 4.12**)** for all the samples analyzed. Cream paint recorded the highest cadmium level of 9.84±0.13 ppm, followed by softwhite (6.69±0.02 ppm) and white (6.09±0.03 ppm). Butter paint sample had the minimum cadmium level of 5.05±0.03 ppm. The decreasing cadmium levels for the paint samples analyzed in the order below:

Cream > Softwhite > White > Butter

4.3.6 Cadmium and lead mean levels in water based paints for the colours

The cadmium and lead mean concentration in the water based paints for the colours in the five brands are shown in Table 4.13.

Table 4.13: Cadmium and lead mean levels for the paint colours

Colour	n	Cadmium (Mean±SE) ppm	Lead (Mean±SE) ppm
White	15	6.62 ± 0.40^{a}	57.28 ± 7.03^{ab}
Blue	12	5.78 ± 0.62^{ab}	139.92 ± 25.77^{c}
Green	9	5.54 ± 0.40^{ab}	89.16 ± 4.11^{abc}
Cream	12	7.40 ± 0.61^{b}	79.72 ± 11.20^{abc}
Grey	12	5.88 ± 0.47^{ab}	112.09 ± 33.58^{bc}
Softwhite	12	6.18 ± 0.43^{ab}	56.67 ± 4.94^{ab}
Butter	6	4.59 ± 0.21^{a}	31.35 ± 2.01^{a}
p-value		0.029	0.003

Cadmium levels in Table 4.13 were below set limits of 75 ppm (CPSIA, 2008) and statistically significant for white and butter paint samples. Blue, green; grey and softwhite paint samples being also not significant, while cream paint sample was statistically not different from blue, green, grey and softwhite ($\alpha=0.05$, 95 % confidence level; Table 4.13; Appendix xii). Lead concentration in the water based paint colours was highest in blue paint colour sample with a concentration of 139.92±25.77 ppm which was above the recommended limits of 90 ppm (CPSIA, 2008). Generally all these water based paint colours had their levels below the lead limit of 600 ppm (USEPA, 2001). The white, cream, green, softwhite and butter paint samples were significant. Blue, green, cream, grey, softwhite paint samples were also statistically significant at α=0.05, 95 % confidence level (Table 4.13; Appendix x).

4.3.7 Pb and Cd mean levels in water based paint samples for the five brands

Lead and cadmium concentrations in the water based samples for the five brands analyzed are shown in Table 4.14.

Table 4.14: Pb and Cd mean levels in water based paint samples for the five brands

Element	Brands	n	Mean±SE (ppm)	Range (ppm)
Lead	A	15	154.34±117.52[c]	48.53-300.96
	B	18	99.07±13.44[b]	83.04-121.83
	C	15	62.17±7.35[ab]	53.39-73.38
	D	18	45.60±35.71[a]	10.40-94.62
	E	12	54.92±31.20[ab]	35.40-106.64
Cadmium	A	15	5.05±0.67[a]	4.18-5.97
	B	18	6.02±2.15[ab]	4.28-9.62
	C	15	6.29±1.62[ab]	4.87-9.34
	D	18	6.56±1.79[ab]	4.10-8.95
	E	12	6.92±1.87[b]	5.02-9.97

Water based samples for paint brand A analyzed from Table 4.14, indicated the highest lead levels with a mean of 154.34±117.52 ppm and statistically different from the others (α=0.05, 95 % confidence level; Table 4.14). Paint brand B seconded with a mean lead concentration of 99.07±13.44 ppm. Brands C and E with lead levels of 62.17±7.35 ppm and 54.92±31.20 ppm respectively, were not significantly different at α=0.05 and 95 %

confidence level (Table 4.14). Paint brand D measured the lowest lead concentration with a mean of 45.60±35.17 ppm and a range of 10.40-94.62 ppm. Brands B, C, D and E were not statistically different at α=0.05 and 95 % confidence level (Table 4.14). All the water based paint samples for the five brands met the lead set limits of 600 ppm (CDC, 2002) with paint brands C, D and E meeting the 90 ppm lead standard (CPSIA, 2008). The decreasing lead level is as follows (Table 4.14; Appendix vi):

$$A > B > C > E > D$$

Results from Table 4.14, indicated that cadmium levels in the water based paints for the analyzed brands were below the set specifications of 75 ppm (CPSIA, 2008). Paint brands B, C and D were significantly indifferent ($p<0.05$, 95 % confidence level; Table 4.14). The order of decreasing cadmium concentration as per the five brands in water based paints (Table 4.14; Appendix viii):

$$E > D > C > B > A$$

The water based samples analyzed in the five brands A, B, C, D and E had a lead mean concentration range within the set specification of 90 ppm (CPSIA, 2008; Table 4.14; Appendix vi), this was in accordance with the research done by Toxics Link (2009). However no cadmium research on paints was noted for comparison purposes.

4.4 Discussion

A total of 50 paint samples from five brands of paints were analyzed for lead and cadmium metals. Twenty four (n=24) oil based paints were analyzed and eleven of the samples had lead concentration above 90 ppm. Four of these had lead levels above 1000 ppm. Out of the twenty six (n=26) water based samples analyzed, nine of them had lead levels above 90 ppm but none above 600 ppm. Paint brand A had the highest lead mean concentration in its oil based samples (Table 4.7; Appendix v) with range of 275.86-37804.48 ppm lead level. This was higher than the recommended concentration of 90 ppm. The other brands which included B, C, D and E had no significant difference in their oil based paints, mean lead concentrations ($p<0.05$, 95 % confidence level; Table 4.7; Appendix v). These paint brands had lead levels ranging above the set limits of 90 ppm (CPSIA, 2008).

Brand A water based paint samples also recorded the highest lead level with range of 48.53-300.96 ppm and significantly different from the rest at $p<0.05$ and 95 % confidence level (Table 4.14; Appendix vi). Paint brand C was the only brand with lead concentration range below the required levels of 90 ppm but statistically not different with paint brands B, D and E ($p<0.05$, 95 % confidence level; Table 4.14; Appendix vi).

Cadmium concentration in both oil and water based paint samples were below the set limits of 75 ppm (CPSIA, 2008). Paint brand D, cadmium level for oil based samples were statistically different from the others at $p<0.05$ and 95 % confidence level (Table 4.7; Appendix vii). The water based samples for all the brands were significant ($p<0.05$, 95 % confidence level; Table 4.14; Appendix viii).

CHAPTER FIVE

CONCLUSIONS AND RECOMMEDATIONS

5.1 Conclusions

Based on the results obtained from this study the following conclusion was reached:

i. Decorative paints used in Kenya contain high levels of lead above the recommended levels in almost all the oil based paints analyzed.
ii. The lead levels in oil based paints were more than in water based paints.
iii. Lead and cadmium levels in decorative paints are dependent of the paint brands analyzed.
iv. There was a significance differences in the concentration of Pb and Cd in the decorative paints analyzed in terms of the paint colour with green, blue and white oil based paint colours having higher levels of these heavy metals than the other colours.
v. Cadmium levels in both water and oil based decorative paints were below the set limits.

5.2 Recommendations

5.2.1 Recommendations from this study

i. Green, blue and white oil based samples should be avoided due to their high levels of lead concentrations and recommend the use of water based paints.
ii. The paint brands should indicate concentrations of heavy metals used as well as give guidelines and directions for use in homes.

iii. Legacy modalities need to be put in place in consultation with health care professionals to check lead exposure while removing old paints or repainting.

iv. Public awareness and campaigns need to be launched to educate and make people aware especially painters, architects and the paint industries on the dangers associated with lead.

v. Concerted efforts within the civil society organizations and other stakeholders in the developing countries should be put in place in order to ensure that lead and cadmium are eventually eliminated from decorative paints worldwide.

5.2.2 Recommendations for further research

There is need for further research to assess the levels of heavy metals. These should include:

i. Analysis to be done on other heavy metals in decorative paints.

ii. Furniture with paint coatings to be analyzed for lead, cadmium and other heavy metals.

iii. The cue stick powder which is a solid paint used in pool table game to be analyzed for lead, cadmium and other heavy metals.

iv. Colours used in lip-stick to be analyzed for lead, cadmium and other heavy metals.

v. Hair dyes to be analyzed for lead, cadmium and other heavy metals.

vi. Analysis to be done on heavy metals in industrial paints.

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APPENDICES

Appendix i

Water based paint samples

Brand	**Paint sample**	**Code No.**
A	White	SWH
	Green	SGH
	Grey	SGYH
	Softwhite	SSWH
	Blue	SBH
B	Blue	BBH
	Green	BGH
	Softwhite	BSWH
	Cream	BCH
	Grey	BGYH
	White	BWH
C	Blue	ABH
	Cream	ACH
	Grey	AGYH
	Softwhite	ASWH
	White	AWH
D	Butter	DBH
	Cream	DCH
	Grey	DGYH
	Blue	DDB
	Green	DBGG
	Softwhite	DSWH
E	Butter	CBH
	White	CWH
	Grey	CGYH
	Softwhite	CSWH
	Cream	CCH

Appendix ii

Oil based paint samples

Brand	Paint sample	Code No.
A	White	SWG
	Blue	SBG
	Green	SGG
	Cream	SCG
	Black	SBLG
B	Black	BBLG
	Blue	BBG
	Red	BRG
	White	BWG
C	Blue	ABG
	Green	AGG
	Cream	ACG
	Red	ARG
	White	AWG
D	Green	DGG
	Blue	DBG
	White	DWG
	Cream	DCG
E	Blue	CBG
	White	CBG
	Black	CBLG
	Green	CGG
	Cream	CCG

Appendix iii

Cadmium standard absorbancies

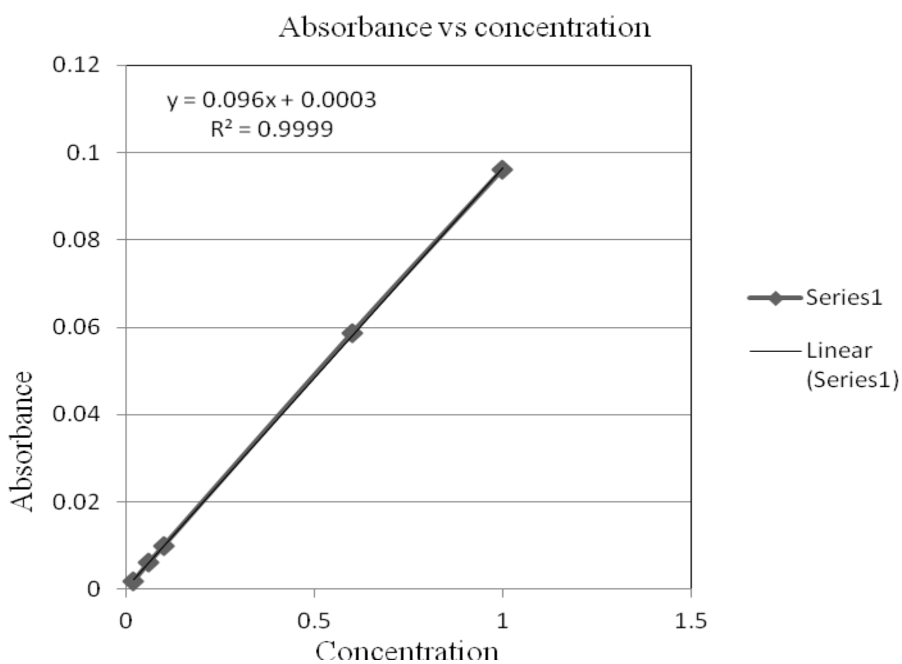
Standards	I	II	II	Average	X	Y
0.02 ppm	0.0028	0.0014	0.0016	0.0019	0.02	0.001933
0.06 ppm	0.005	0.0063	0.0061	0.0058	0.06	0.0058
0.1 ppm	0.0098	0.0099	0.01	0.0099	0.1	0.0099
0.6 ppm	0.0586	0.0586	0.0586	0.0586	0.6	0.0586
1.0 ppm	0.096	0.096	0.096	0.096	1	0.096

Lead standard absorbancies

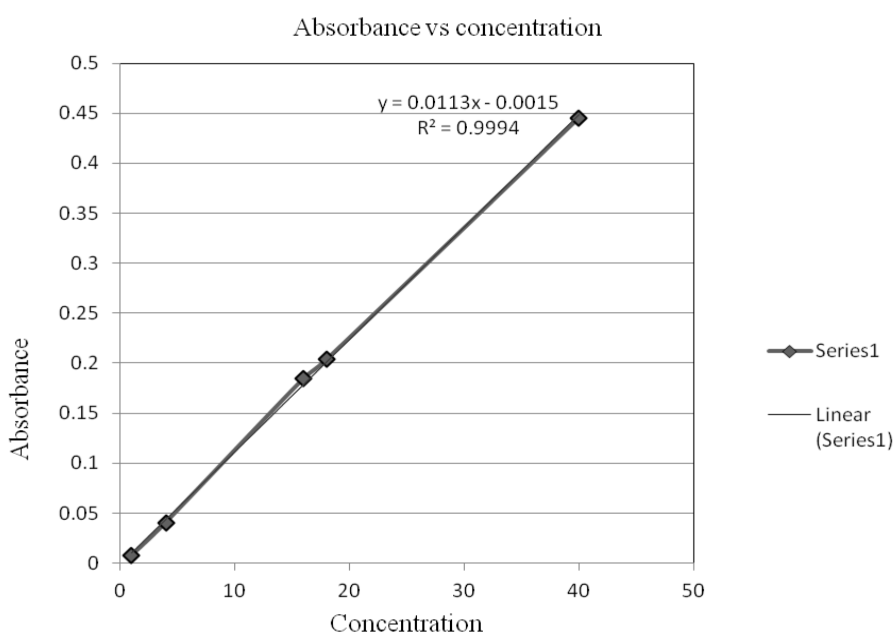
Standards	I	II	II	Average	X	Y
1	0.0082	0.0066	0.0072	0.007333	1	0.007333
4	0.0396	0.0414	0.0407	0.040567	4	0.040567
16	0.1846	0.1847	0.1847	0.184667	16	0.184667
18	0.2027	0.2026	0.2056	0.203633	18	0.203633
40	0.4456	0.4456	0.4456	0.4456	40	0.4456

Appendix iv

Calibration curve for cadmium

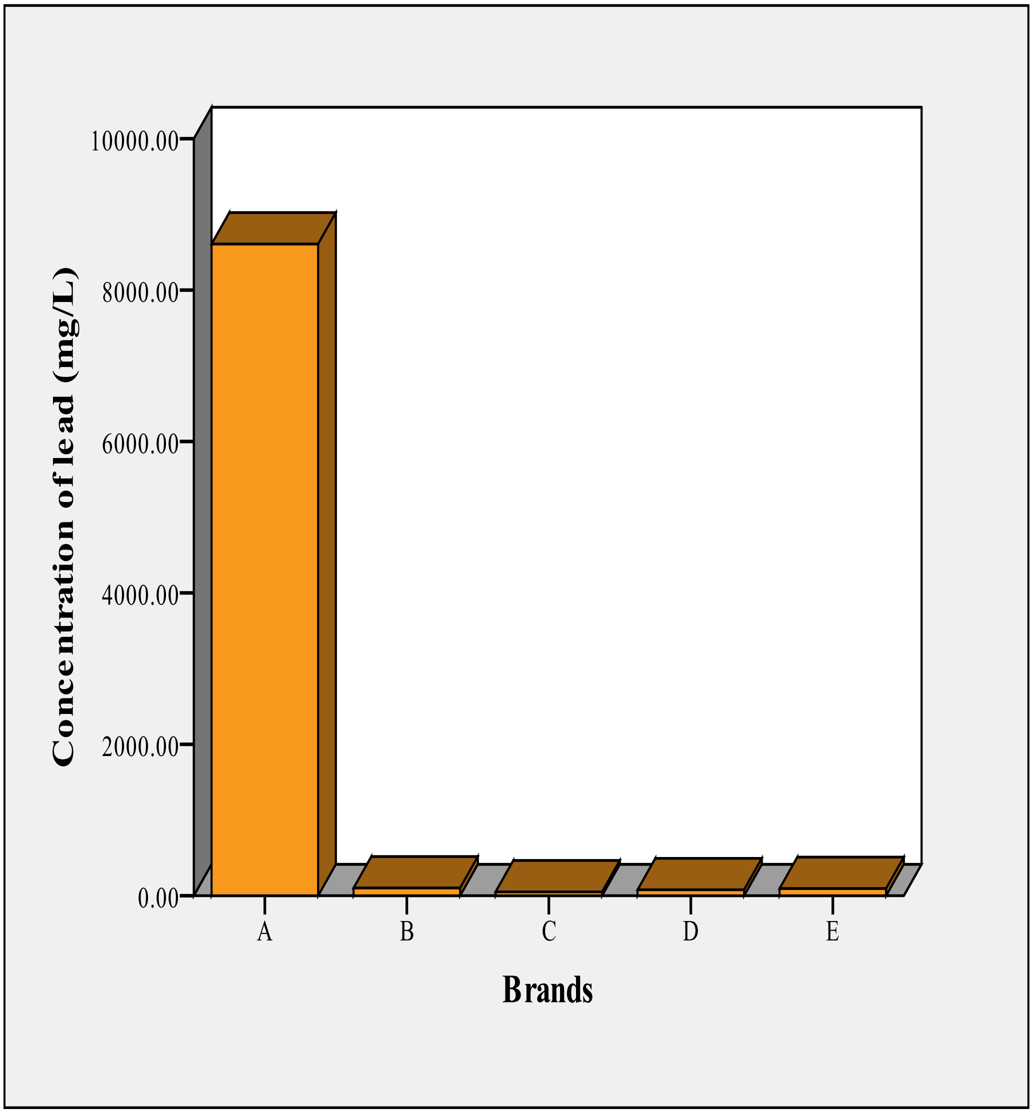


Calibration curve for lead



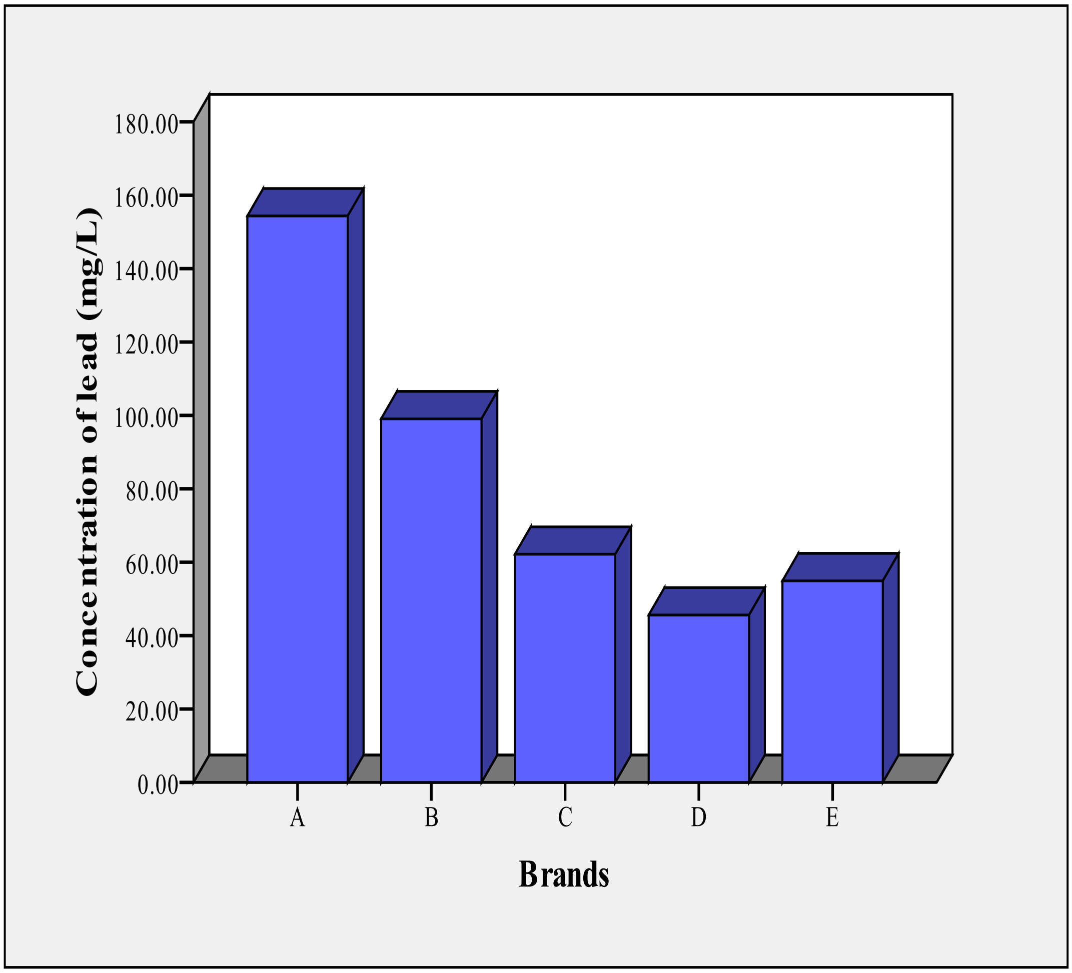
Appendix v

Lead levels in the oil based paint samples for the five brands



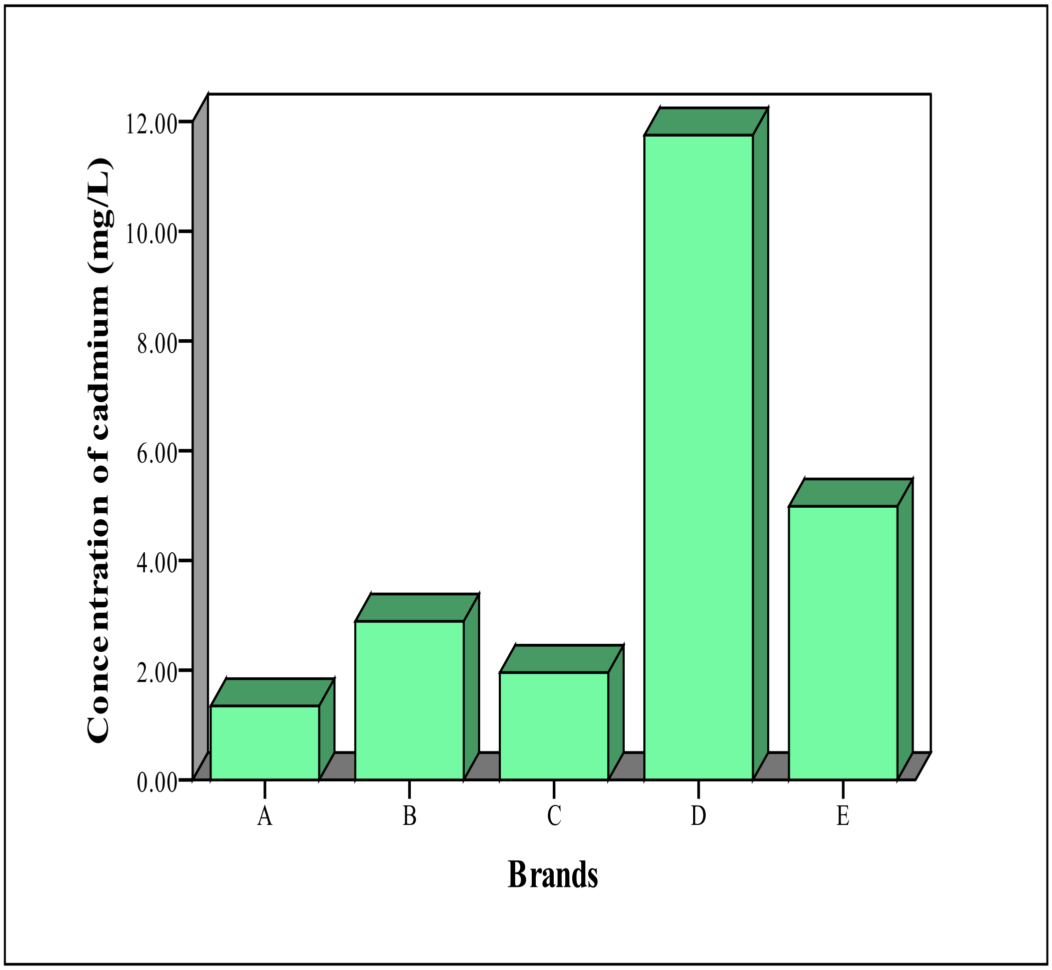
Appendix vi

Lead levels in the water based paint samples for the five brands



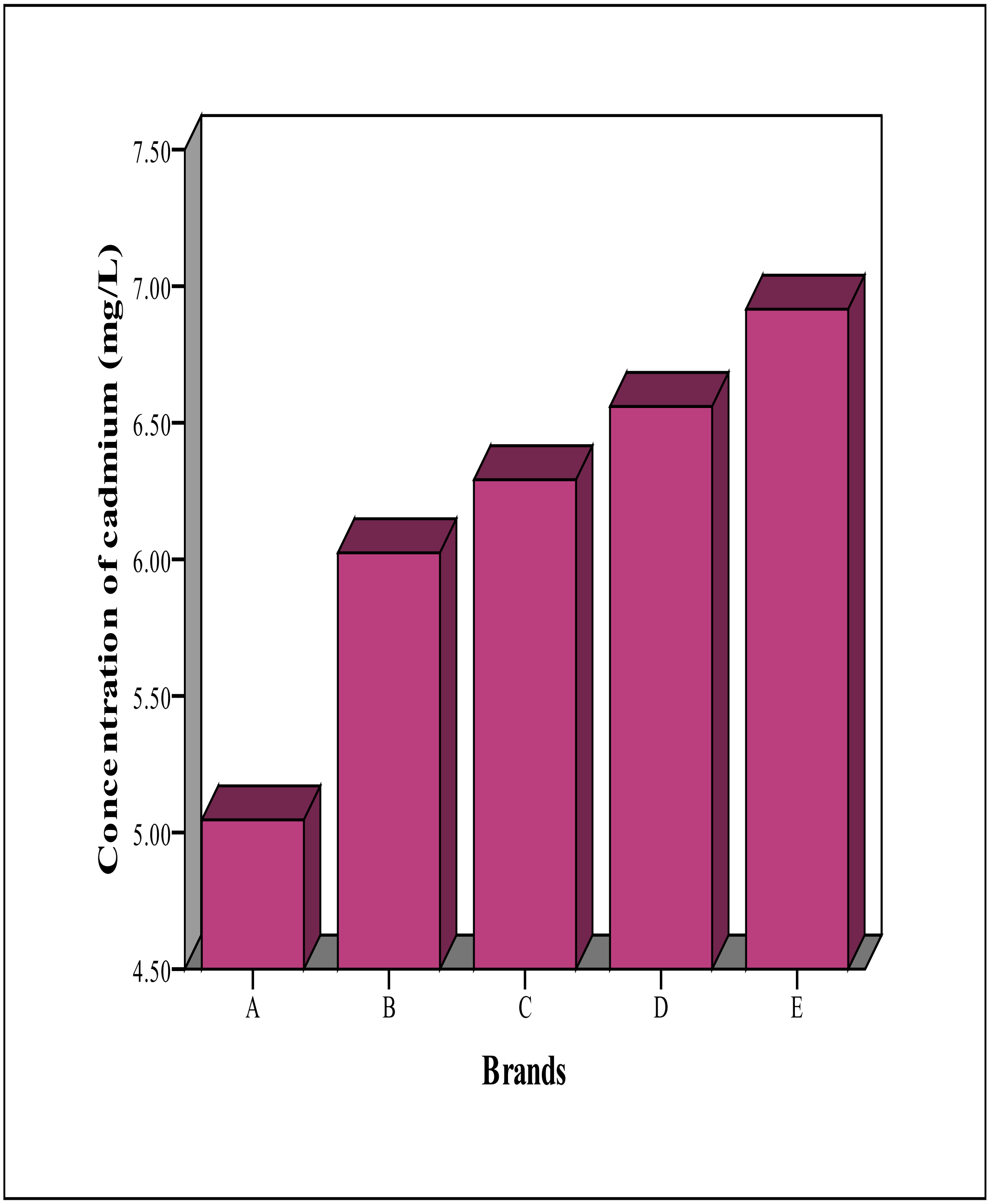
Appendix vii

Cadmium levels in the oil based paint samples for the five brands



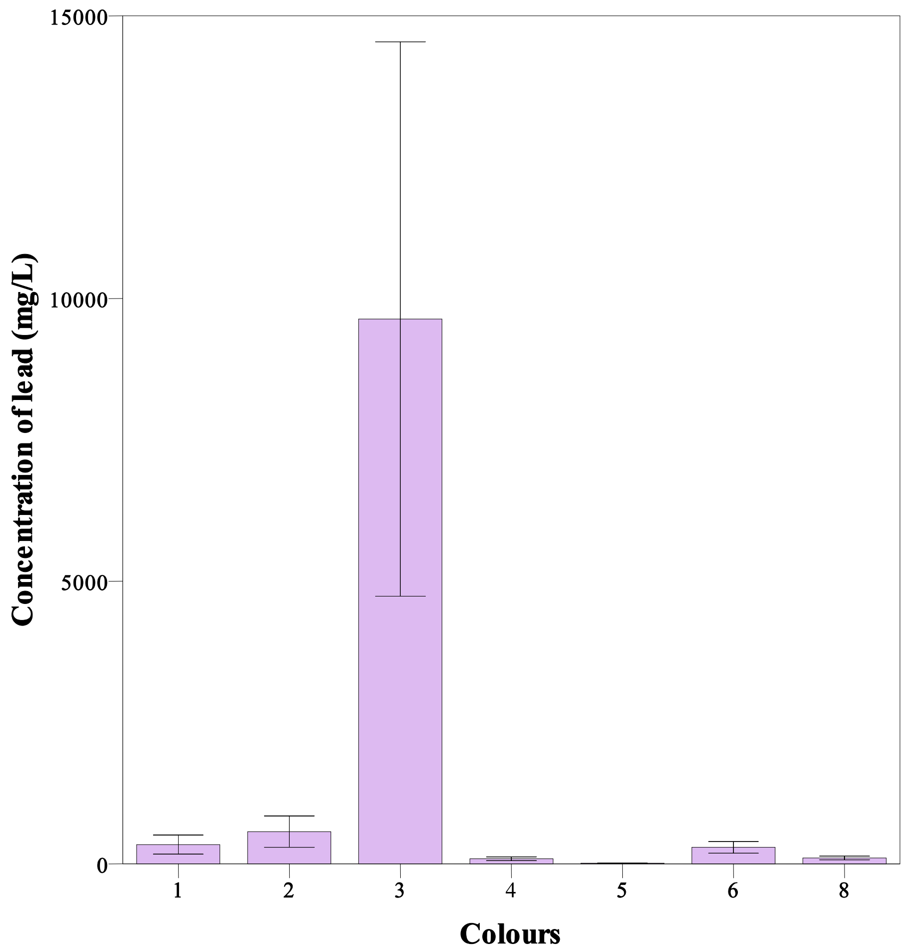
Appendix viii

Cadmium levels in the water based paint samples for the five brands



Appendix ix

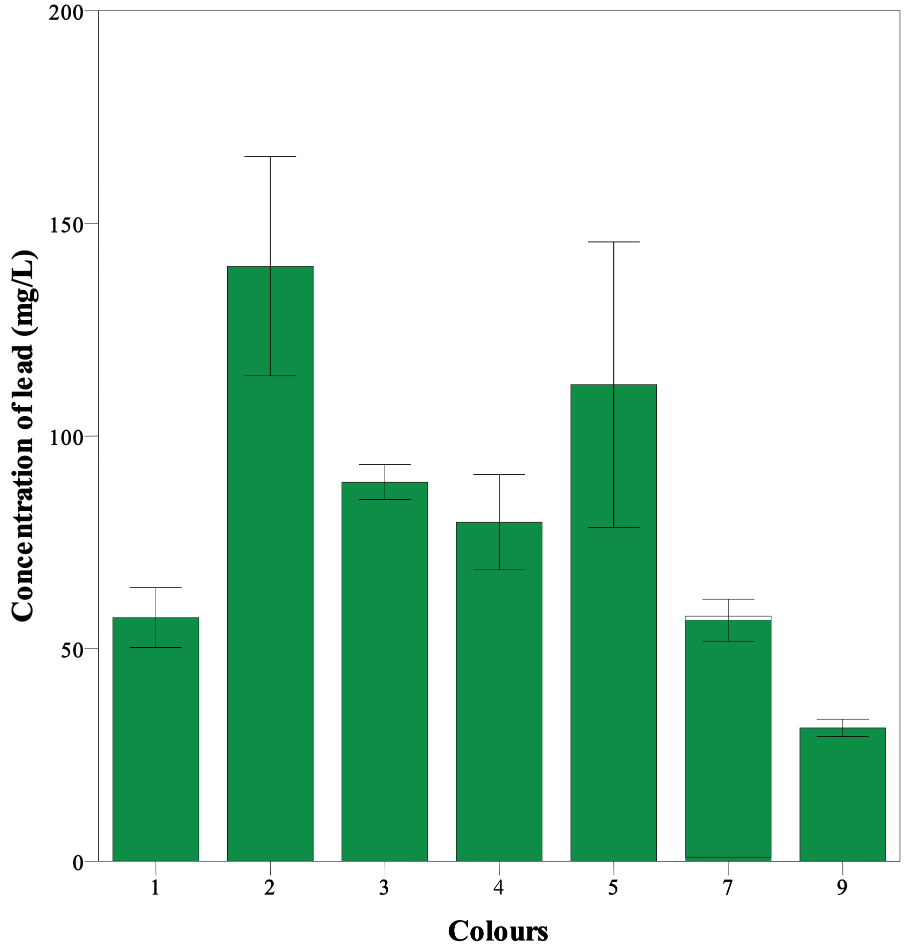
Lead concentration in the oil based paint samples for the five brands versus colours



1-White; 2-Blue; 3-Green; 4-Cream; 5-Grey; 6-Black; 8-Red

Appendix x

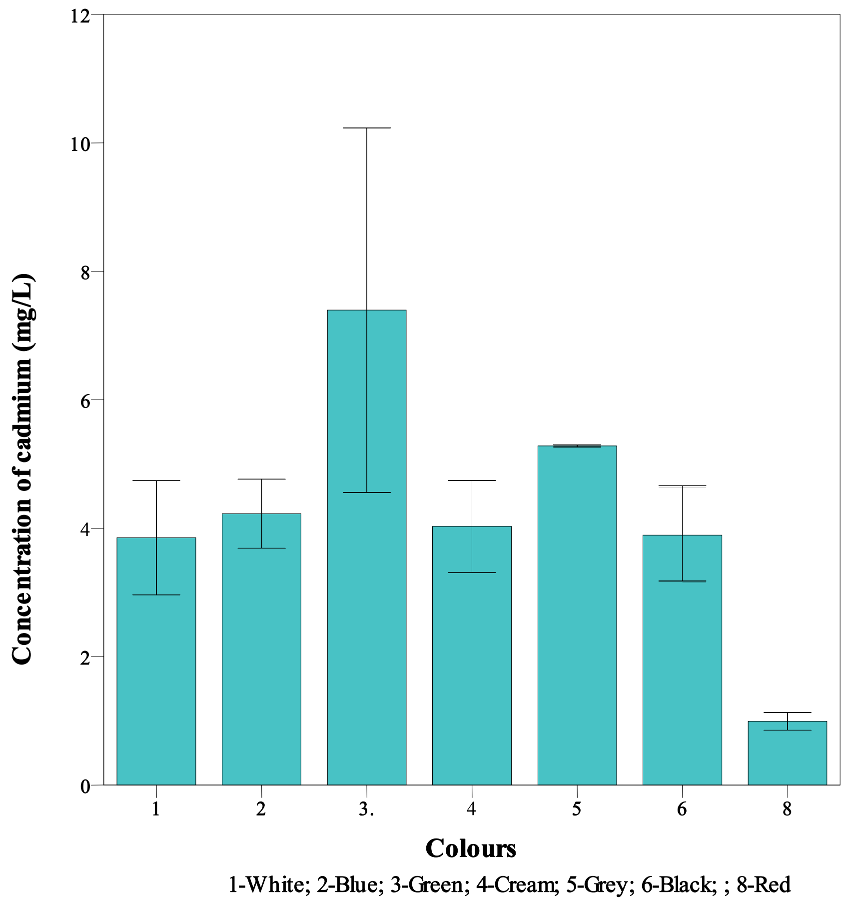
Lead concentration in the water based paint samples for the five brands versus colours



1-White; 2-Blue; 3-Green; 4-Cream; 5-Grey ; 7-Softwhite; 9-Butter

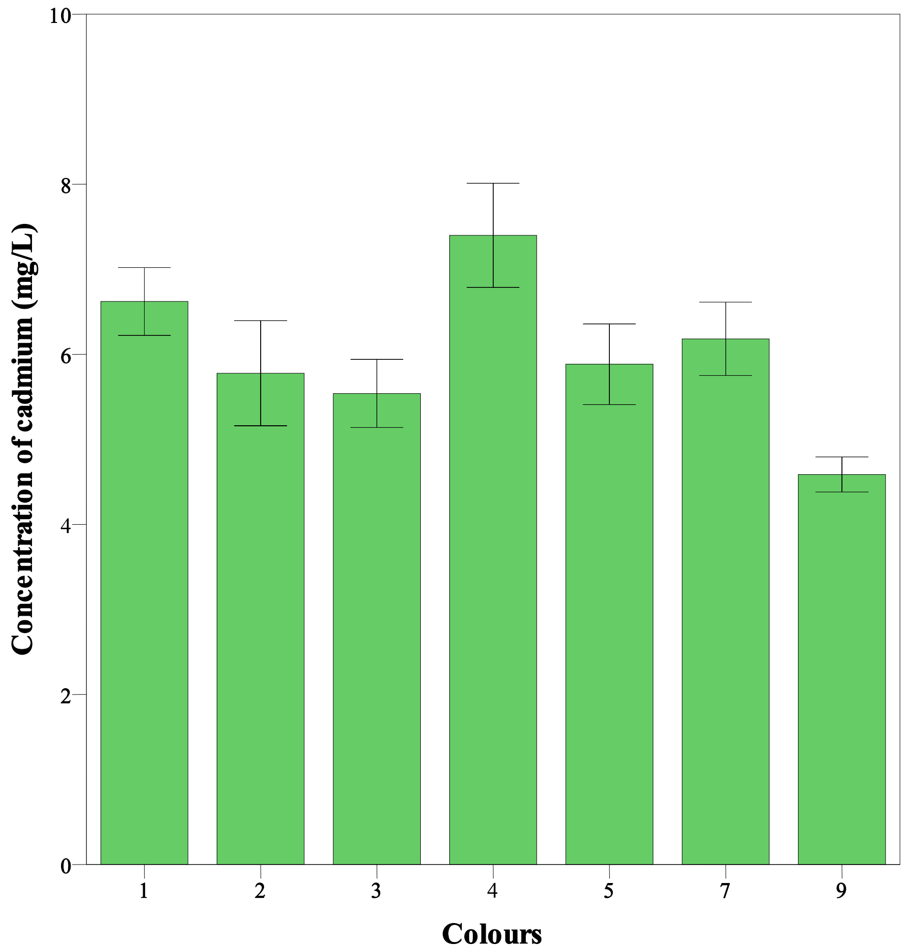
Appendix xi

Cadmium concentration in the oil based paint samples for the five brands versus colours



Appendix xii

Cadmium concentration in the water based paint samples for the five brands versus colours



1-White; 2-Blue; 3-Green; 4-Cream; 5-Grey ; 7-Softwhite; 9-Butter

Appendix xiii

Paint samples in stoppered containers