

**ASSESSMENT OF HEAVY METALS IN LIPSTICKS AND FACIAL
POWDERS IN NAIROBI CITY COUNTY, KENYA**

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DECLARATION

This thesis is my original work and has not been presented for any other award in any other institution.

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The work reported in this thesis was carried out by the candidate under our supervision.

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DEDICATION

This work is dedicated to my parents Benson Magui Likeya, Alice Kedogo Magui, my husband Victor Otieno, and our sons John and Emmanuel.

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MAY THE ALMIGHTY GOD REWARD YOU ALL ABUNDANTLY

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ABBREVIATIONS AND ACRONYMS

AAS	Atomic Absorption Spectroscopy
FAAS	Flame Atomic Absorption Spectrometry
FDA	Food and Drug Administration
IARC	International Agency for Research on Cancer
ICP-MS	Inductively Coupled Plasma - Mass Spectrometry
LIBS	Laser-Induced Breakdown Spectrometer
OES	Optical Emission Spectroscopy
PNPPRC	Pacific Northwest Pollution Prevention
PTWI	Provisional Tolerable Weekly Intake
WHO	World Health Organization

ABSTRACT

The desire to be more attractive by many people has increased demand for cosmetic products over the last few decades around the world. Today, the use of facial cosmetics has become routine body care for millions of women around the world and in Kenya as well. Facial cosmetics are common in all classes of society from the lower class through the middle class to the upper class. The demand for these products continues to rise even though issues about their safety are yet to be properly addressed. Some of these cosmetics products have higher levels of heavy metals than the allowed level tolerable by the body. These metals include lead, cadmium, nickel, chromium, and many others. Permissible levels of lead by WHO is 10 ppm while those of Cd, Ni, and Cr are 0.3 ppm, 200 ppm, and 50 ppm respectively. Permissible levels by KEBS for Pb, Cd, Ni, and Cr are 2.0 ppm, 0.1 ppm, 200 ppm, and 50 ppm respectively. High levels of lead cause skin problems, and cancer among others. Cadmium, nickel, and chromium also have negative health effects such as causing cancer, respiratory diseases, and damage to several human organs. It is based on this background that this study was conducted to find out the presence and concentration of some of the heavy metals in facial cosmetics particularly in lipsticks and face powders. Heavy metals that were studied are cadmium, lead, nickel, and chromium. Lipsticks and face powders were obtained from supermarkets and shops within Nairobi city in three batches A, B, and C. This study adopted an experimental research design where the atomic absorption spectroscopy technique (AAS) was employed in assessing levels of lead, cadmium, chromium, and nickel in sampled brands of lipsticks and face powders in Nairobi City, Kenya. Data obtained was analyzed by one-way ANOVA at a 95% confidence level using SPSS version 23 for Windows. Significant differences were taken at $p < 0.05$. Lead levels in lipsticks ranged between 0.0057 to 0.0082 ppm while those in face powders ranged between 0.0013 to 0.0066 ppm. The mean concentrations of lead in batches A, B, and C of lipsticks and face powder were all statistically significant. The concentration of cadmium in lipsticks was below the level of detection while in face powders the levels ranged from 0.0009 to 0.0048 ppm. The mean levels of cadmium in batches A, B, and C of face powders were not statistically significant. The concentration of chromium in lipsticks was below the level of detection. The level of chromium in face powders ranged from 0.0010 to 0.0029 ppm. These mean levels were not statistically significant. The levels of nickel in lipsticks ranged from 0.0006 to 0.0031 while in face powders, it ranged from 0.0041 to 0.0217 ppm. The mean levels of nickel in lipsticks were statistically significant. Levels of Pb, Cd, Cr, and Ni in brands A, B, and C of lipsticks were significantly different. Levels of Pb, Cd, Cr, and Ni in brands B and C of face powder were also significantly different while the levels in brand A of face powders were not statistically significant. The levels of lead, nickel, cadmium, and chromium in both lipsticks and face powders in the brands analyzed were lower than the maximum allowed level set by both WHO and KEBS, an indication that the lipsticks and face powders are potentially safe for use. However, the significant differences that were noted between some samples pose a risk of combined and continuous usage. There is therefore need to indicate levels of heavy metals on labels of lipsticks and face powders by manufacturers to enable users to make informed choices of these products.

CHAPTER ONE

INTRODUCTION

1.1 Background to the Study

Human beings especially women always have a desire to improve their physical appearance and therefore they end up trying out different products in the market for them to become attractive. This creates demand for cosmetics in the market hence manufacturers take advantage of the demand and come up with new cosmetic products. Cosmetics are substances applied to the body for different purposes which include beautifying, cleansing and even enhancing attractive body features. Examples of cosmetics in the market include nail polish, conditioners, shampoo, body lotion, styling gel, creams, lipsticks, powders, perfumes, face powders, eye make-ups such as mascara, artificial hair, hair colors, and hair sprays (Okereke *et al.*, 2015).

The idea of cosmetics being associated with beauty started a long time ago during the civilization of mankind. Human beings have used different beauty products to change how they look for at least 10,000 years and possibly much longer (Jones and Selinger, 2017). Women and girls in Egypt during ancient times used kohl, a substance that contains lead (galena in powder form) to make their eyelids dark (Jones and Selinger, 2017). It is reported that Cleopatra bathed in milk to make her skin softer (Jones and Selinger, 2017). People in China started staining their fingernails by 3000 B.C. according to their social class, while women in Greece used lead carbonate (PbCO_3) which is highly poisonous to achieve a pale complexion (Jones and Selinger, 2017). In traditional African societies, clay was made into pastes for use as cosmetic products (Jones and Selinger, 2017).

Over the last few decades, cosmetic products have been in high demand throughout the world because of the tremendous increase to enhance and make the face and even the entire body attractive (Ullah *et al.*, 2017). Marketing strategies in social media are another factor that has led to the tremendous increase in demand for cosmetics (Gondal *et al.*, 2010). Currently, millions of women throughout the world use cosmetics daily as a regular body care product for all kinds of people in society (Chauhan *et al.*, 2010). This high need for beauty substances has captured the attention of researchers, regulators, and even toxicologists because the safety of these products is a big issue worldwide and their biggest interest is to ensure the safety of these cosmetics (El-Aziz *et al.*, 2017). The main reason behind this is that the majority of beauty substances are applied to the skin directly and some of its contents go beyond the skin and harm vital organs (El-Aziz *et al.*, 2017).

The greatest health concern regarding cosmetics is the health risks due to the presence of different heavy metals for example lead and other chemicals that are toxic to the human body (Amponsah, 2010). Other heavy metals that are found contaminated with cosmetics include arsenic, nickel, and even mercury (Amponsah, 2010). Toxic metals concentrate in the body over time and this leads to cancer, hair loss, reproductive disorders, and skin diseases among others (Amponsah, 2010). These harmful chemicals enter the body through various ways such as inhalation of perfumes and nail polish, and absorption through body lotions and face powders (Amponsah, 2010).

The presence of toxic metals in cosmetics is amongst the greatest concerns that have attracted analysis of cosmetics to determine their presence and concentration due to their adverse side effects (Amponsah, 2010). The widely accepted definition is “these are elements with relatively higher density (Density of more than 5 g/cm³ is sometimes

quoted as a commonly used criterion) atomic weights, or atomic numbers” (Martins *et al.*, 2016). The IUPAC (International Union of Pure and Applied Chemistry) also defines heavy metals as dense alloys whose density is above 14.5 g/cm³ (Aldayel and Hefne 2018). According to Aldayel and Hefne (2018), 23 of the heavy metals are dangerous due to their ability to reside in the human body over a long duration. They are cobalt, chromium, mercury, tellurium, cerium, arsenic, cadmium, lead, vanadium, thallium, iron, copper, nickel, uranium, zinc, tin, silver, and uranium. Elteгани *et al.*, (2013) contend that some heavy metals in small quantities are very basic nutritionally, and are required for body building, hormonal production, fluid balance, and the building of protein structures.

Heavy metals are used in the manufacture of pigments and can be used in trace quantities in raw materials used in the manufacture of the various cosmetic products available to users (Aldayel and Hefne, 2018). Some of these metals are used in cosmetics for one reason or the other, for example, cadmium’s (a deep yellow to orange element) color properties enable it to be used in some lipsticks and facial cosmetics (El-Aziz *et al.*, 2017). Additionally, apart from the regulated intentional uses of these heavy metals in cosmetics, they can be found as impurities also in various cosmetic products (Aldayel and Hefne, 2018). It is the realization of the above facts that regulatory organizations such as Health Canada and WHO have investigated and recommended the highest allowed levels of heavy metals in beauty products (ASEAN, 2017). In Kenya, the Kenya Bureau of Standards (KEBS) is in charge of setting allowed maximum limits (El-Aziz *et al.*, 2017). Table 1.1 shows the allowed maximum limits of heavy metals that were analyzed in this study.

Table 1.1: Permissible Levels of Heavy Metals in Cosmetics According to WHO and KEBS

Heavy metal	WHO (ppm)	KEBS (ppm)
Lead	10	2
Cadmium	0.3	0.1
Chromium	50	50
Nickel	200	200

Source (WHO, 1995)

Some cosmetics industries have been able to comply with keeping heavy metal contamination below the permissible levels while others have not been able to keep the concentration of heavy metals lower than the permissible levels despite guidelines that have been provided; a good example of a cosmetic product found to contain a heavy metal (lead) at a higher concentration than a permissible level is lipstick (Aldayel and Hefne, 2018). Lipsticks are commonly used by most women of all classes to enhance their beauty and attractiveness (Aldayel and Hefne, 2018). A study by the campaign for safe cosmetics in the United States showed that 61% out of the 33 samples of lipsticks tested had lead levels as high as 0.65 ppm (Zakaria and Bin Ho (2015). Zakaria and Bin Ho (2015) have reported lead levels in lipstick between 0.09 to 3.06 ppm and 0.079 to 0.84 ppm, and a distinct case with 6.3 ppm. Sahu *et al.*, (2014) reported chromium levels in lipsticks ranging from 0.45 ppm to 17.83 ppm, and nickel levels ranging from 0.57 ppm to 9.18 ppm, while cadmium and lead were not detected.

Faruruwa and Bartholomew (2014) reported levels of lead in facial cosmetics ranging from 0.20–31.70 mg kg⁻¹ and also analyzed for cadmium, zinc, iron, chromium, and

nickel in the same study. Barghash *et al.*, (2017) in their study concluded that facial cosmetics commonly sold in Saudi Arabia had high levels of lead and cadmium.

El-Aziz *et al.*, (2017) analyzed levels of metals in facial cosmetics and reported that the levels of cadmium, nickel, lead, and chromium were more than the permissible level for skin safety. This is a clear indication that some lipsticks and face powders in the market have higher levels of heavy metals than the allowed levels. Moreover, the risk is enhanced by prolonged duration of contact, which occurs simply because regular and repeated use of these facial cosmetics for long exposure to heavy metal poses a great risk to users even in low concentrations.

According to Martins *et al.*, (2016), heavy metals build up in the body over some time and result in diseases like cancer. Toxic metals such as lead and cadmium can accumulate inside the body tissue at a faster rate than the body detoxifies them (Martins *et al.*, (2016) The human skin, despite being a protective barrier allows some components of beauty products like lead, cadmium, and arsenic to infiltrate into our systems (Health Canada, 2011). Sani *et al.*, (2016) report that the different ways of exposure to cosmetic substances occur through spraying, while dermally applied substances enhance the availability of these products to the human body through the skin membranes. Application of these products to the lips enables intake of these substances through the mouth. When these toxic impurities come into contact with the body, they get engrossed into the body and result in complexes of proteins that lead to abnormal functioning or even death of these cells, which eventually results in different types of diseases or even death (Ullah, *et al.*, 2017).

1.2 Statement of the Problem and Justification

Cosmetics have gained increased use by women in Kenya. The majority of women use cosmetics such as face powders and lipsticks to improve their physical appearance daily. Some of these cosmetics may contain higher concentrations than allowable levels of heavy metals that may lead to harmful health effects when used. The WHO and KEBS have set maximum allowed levels of various heavy metals (Ekere *et al.*, 2014). However, some manufacturers may not observe the limits while some distributors may adulterate the cosmetics resulting in higher levels of heavy metals. The presence of heavy metals in the body causes different diseases and sometimes death. For example, high accumulation of lead causes cancer and skin problems (Ullah, *et al.*, 2017). Other metals such as nickel, chromium, and cadmium cause respiratory diseases and damage to body organs (Ullah, *et al.*, 2017) hence the need to carry out this study and ascertain the safety of these facial cosmetics.

There are millions of women in Kenya who use cosmetics daily without knowing the safety of these cosmetic products. Some of these cosmetics may contain higher concentrations than allowable levels of heavy metals that may lead to harmful health effects. when used Some heavy metals poisoning such as lead have been recognized as dangerous to human health for over 2,000 years (Omenka and Adeyi, 2016). Omenka and Adeyi (2016) allude that lead can diffuse via the placenta of the pregnant mother and reach the unborn fetus causing damage to brain development. On the same note Omenka and Adeyi (2016) argue that children exposed to lead metal can suffer learning difficulties, memory loss, being extremely aggressive and hyperactive. High levels of lead are known to cause cancer and skin problems according to Omenka and Adeyi, 2016. Cancer is one of the leading causes of death in Kenya (Omenka and Adeyi, 2016).

Chromium ions have been found to have adverse health effects, for instance, hexavalent chromium (Cr^{+6}) corrodes and causes ulcerations on the skin and Cr^{+6} compounds are categorized as highly carcinogenic compounds (Ullah, *et al.*, 2017). Nickel (Ni^{+2}) has also been found to cause allergic reactions to the skin and if taken in high quantities by animals, it affects the kidneys and liver (Sahu *et al.*, 2014). The studies reviewed reveal that facial cosmetics may contain higher concentrations of toxic metals than the allowed amounts.

Very minimal research has been reported in Kenya to test the content of heavy metals in facial cosmetics especially when new products are coming to the market. This therefore calls for research to find out the amounts of heavy metals in facial cosmetics to reduce adverse health effects associated with heavy metal contaminations. The purpose of this study was to determine levels of lead, cadmium, chromium, and nickel in lipsticks and facial powders sold in Nairobi.

1.3 Research Hypothesis

The levels of lead, cadmium, chromium, and nickel in different brands of lipsticks and face powders differ significantly and are higher than the allowed levels set by WHO and KEBS.

1.4 Objectives

1.4.1 General Objective

The main purpose of this study was to determine the concentration of selected heavy metals in different brands of lipsticks and face powders sampled in Nairobi City County, Kenya.

1.4.2 Specific Objectives

- i. To determine the concentration of lead, cadmium, chromium, and nickel in lipsticks and face powders sampled in Nairobi City County, Kenya.
- ii. To assess whether levels of lead, cadmium, chromium, and nickel in different brands of lipsticks and face powders sampled in Nairobi City County, Kenya differ significantly.

1.5 Significance of the Study

Heavy metals may find their way into lipsticks and face powders in the final market as impurities or trace amounts of raw material in cosmetics. However, these products in the Kenyan market especially in Nairobi City neither show labels indicating the presence nor amounts of heavy metals in them. The finding of this study is useful to users of these products because they will be informed of the status of the amounts of heavy metals in facial cosmetics to be investigated. The information will enable them to make informed decisions when deciding which brand of facial makeup to purchase. The outcome of this research will also be helpful to KEBS. The findings will also be used to sensitize the public consumers on the health hazards of the heavy metals analyzed.

1.6 Limitations and Scope of the Study

There are many types and brands of facial cosmetics sold in Nairobi City County, Kenya. This study only considered red lipsticks and brown face powders. Many brands of lipsticks and face powders are available but this study considered twenty-four brands and 3 batches of lipsticks and facial powders. This study analyzed only lead, cadmium,

chromium, and nickel. The different possible metal ions of each specific heavy metal such as Cr^{3+} or Cr^{4+} were not analyzed. The study was conducted between January to June 2019 and the researcher ensured all brands used had not expired. However, the date of manufacture was not considered. There are several methods for determining the concentration of metals in cosmetics, but only Atomic Absorption Spectroscopy (AAS) was used because it was available, highly specific, and selective. Limited resources and time were the major limitations.

CHAPTER TWO

LITERATURE REVIEW

2.1 Cosmetics

Human beings naturally admire beauty. Cosmetics have been in use since ancient times where products like clay, mud, honey, milk, and lemon juice have been used to enhance beauty (Muda *et al.*, 2017). Asasutjarit (2017) observes that the use of cosmetics started a long time ago because body adornment was found in the rituals of hunting and mating in the ancient paintings of caves approximately 30,000 years ago. Early people in Egypt utilized henna leaves for painting their hair, kohl for painting their eyes, and castor oil for protecting the skin from the hot sun rays (Asasutjarit, 2017).

Cosmetics are defined as substances that are applied to the body for beautifying, changing the body's appearance, or increasing the attractiveness of the body without interfering with the structure or function of the body (Cosmetics info.org, 2016). Dermatologists have assorted beauty substances depending on different uses, such as; beauty products for the skin, beauty products for the face, beauty products for the hair and nail care cosmetics and after-shave lotions and perfumes, cosmetic products that slow down the aging process, and bleaching products (Abere, 2015).

Facial cosmetics also referred to as facial makeup are applied to the face to make the face appear more attractive (Eckert *et al.*, 2017). They improve physical appearance by adding or altering the color of the skin covering the face (Eckert *et al.*, 2017). The contents of face powders are in such a way that the powder is applied precisely on the skin and in a controlled manner (Cosmetics info.org, 2016). When applied facial makeup makes the color of the face even and the face smooth (Eckert *et al.*, 2017). This study considered lipsticks and face powders. Examples of lipstick and face powder

brands available in the Nairobi city market include Huddah, Golden Lips, Suzie Beauty, Pauline Cosmetics, Cover Girl, Rimmel, Maybelline, L. A girl, Renne, Revlon, Dior, black opal, Milani, Lupron, rose leaf, Nivea, and Yardley among others.

2.2 Heavy Metals

The presence of heavy metals in the body poses a great risk due to many health complications resulting from these metals (Flora *et al.*, (2012). Heavy metals alter the functioning of major organs in the body and interfere with the metabolic processes within the human body (Flora *et al.*, (2012). Heavy metals include but are not limited to arsenic, lead, chromium, and cadmium among others (Jaishankar *et al.*, 2014). The heavy metals that were analyzed in this study and their health effects are briefly discussed in the following subsections.

2.2.1 Lead and Its Health Effects

According to Flora *et al.*, (2012), lead poisoning in most cases occurs because of exposure to low levels but for a longer duration yet symptoms for slow lead, poisoning are majorly mental and emotional and hence go unnoticed. Some of the symptoms of lead poisoning over a long duration are reduced sperm count, headache, miscarriage, high blood pressure, memory loss, and production of abnormal sperm (Mayo Clinic Staff, 2016). There are also several adverse effects of contact with lead like the kidney and the central nervous system. To pregnant mothers, lead accumulates in bones and teeth and then later on circulates into the blood becoming a big threat to the young fetus (World Health Organization, 2018). Omenka and Adeyi (2016) allude that lead can easily cross the placenta of mothers and damage the brain of the fetus.

Kristina (2013) reported lead levels in cosmetics below the daily allowed levels. According to Canada Health (2014), the maximum permissible limit for lead in cosmetics is 20 parts per million as an impurity. Lead levels in facial cosmetics ranging from 0.20–31.70 mg kg⁻¹ have been reported by Faruruwa and Bartholomew (2014). Health Canada reported levels in lipsticks ranging from 0.079 to 0.8 ppm (Zakaria and Bin Ho, 2015). Lead levels of 0.20-31.70mg have been reported in lipsticks (Faruruwa and Bartholomew, 2014). Ahmed and Al Baker (2017) have also reported lead in face cosmetics. Additionally, levels of lead of 9.1 ppm have been reported in face powders (Elteгани *et al.*, 2013). El Aziz *et al.*, 2017 found concentrations of lead above the suggested safe limit for skin protection. Levels of lead above 10 ppm have been reported (Chauhan *et al.*, 2012). Additionally, lead levels of 87.8 ppm and 21.6 ppm have been reported in face cosmetics (Ojezele *et al.*, 2018). Saah *et al.*, 2022 reported lead levels of 11.34µg/g. Lead levels of 0.020-30.970 mg/kg have also been reported in lipsticks (Surendra *et al.*, 2021).

2.2.2 Cadmium and its health effects

Cadmium's deep yellow-to-orange pigmentation makes cadmium useful in beauty products (Swaddiwudhipong *et al.*, 2015). However, it has very harmful effects on body cells and it also causes nutritional deficiency in plants (Swaddiwudhipong *et al.*, 2015). Human beings can get exposed to these harmful metals through the mouth, through the products applied to the mouth, through inhaling erotic products, and through infiltration through the skin. When infiltrated into the body through the skin, it is transported to the liver through blood (Lenntech, 2018). It therefore bonds and forms complexes with proteins which are taken to the kidneys over time, cadmium builds up in the kidney and destroys excretion mechanisms (Lenntech, 2018). If cadmium builds up in the kidneys,

it stays in the kidney for a long duration before it can be excreted from the body (Lenntech, 2018).

According to Jaishankar *et al.*, (2014), Cadmium builds rapidly in the body when it combines with proteins that have cysteine-like metallothionein, and it also shares an oxidation state with zinc hence replacing zinc present in metallothionein preventing it from behaving as a free ion in the cell (Jaishankar *et al.*, (2014). Diabetes has been linked to cadmium accumulation in the body (Kobayashi *et al.*, 2012). Despite the negative effects of cadmium as mentioned, studies show that females are highly affected by cadmium exposure compared to men (Kobayashi *et al.*, 2012). It takes a long time before cadmium is excreted from the human body (Lenntech, 2018).

There are various cadmium guideline limits set by different bodies regarding tolerable intake that are not harmful. WHO recommends a limit of 0.3 ppm while KEBS recommends a limit of 0.1 ppm (Moraa, 2014) However, Bell (2013) warns that the level of cadmium in some of the lipsticks is higher than 20% of the allowed daily limit. Ahmed and Al Baker (2017) have reported cadmium in face cosmetics. El Aziz *et al.*, (2017) found concentrations of cadmium above the suggested safe limit for skin protection. 8 ppm of cadmium has been reported in face powders (Elteгани *et al.*, 2013). Bell (2013) warns that the amount of cadmium in some of the lipsticks can be greater than 20% of the acceptable daily limit. Cadmium levels of 0.10 to 1.875 ppm have been reported in face cosmetics (Sukenda *et al.*, 2012). Cadmium levels of 0.13 to 0.215 have been reported in face powders (Eticha *et al.*, 2018). Additionally, cadmium levels of 1.8 ppm have been reported in face powders (Ojezelle *et al.*, 2018).

2.2.3 Chromium and its health effects

Chromium exists in various oxidation states. Trivalent chromium is required in the human body though in small amounts for sugar and lipid metabolism (Stoll, 2017). However, some experts argue that it is not basic for mammals while others think it is a basic trace element for humans (Stoll, 2017). Chromium with an oxidation number of six is said to be highly toxic while chromium with an oxidation number of four is highly carcinogenic (Jaishankar *et al.*, (2014). While explaining the mechanism of chromium toxicity, Jaishankar *et al.*, (2014) allude that in the environment, trivalent chromium Cr (III) is generally harmless due to its weak membrane permeability. Hexavalent chromium Cr (VI), on the other hand, is more active in penetrating the cell membrane through passages for isoelectric and isostructural anions such as SO_4^{2-} and HPO_4^{2-} channels, and these chromates are taken up through phagocytosis. Because of the health issues associated with chromium, its usage has been prohibited in many parts of the world (Science Struck Staff, 2018). Chromium levels ranging from 0.45 ppm to 7.83 ppm have been reported in lipsticks (Sahu *et al.*, 2014). Chromium levels above the suggested safe limit for skin protection have been reported in face powders (El Aziz *et al.*, 2017). Chromium levels of $83.67\mu\text{g/g}$ have been reported in face powders (Saah *et al.*, 2022). Chromium levels of 2.5 ppm have also been reported in face powder (Ojezele *et al.*, 2018).

2.2.4 Nickel and its health effects

Females are more sensitive to nickel than men probably due to greater exposure like in jewelry (Zambelli *et al.*, 2016). Some human beings are not sensitive to nickel and such people are rarely affected by nickel unless they eat large amounts of nickel (Zambelli *et al.*, 2016). Dermatitis is a common skin reaction in people who have been exposed to nickel and may even occur at a different part of the skin away from the contact area

(Zambelli *et al.*, 2016). Severe health hazards occur when individuals are exposed to nickel for a long time (Zambelli *et al.*, 2016).

Chronic exposure to nickel causes cancer, bronchitis, and malfunction in the lungs (Zambelli *et al.*, 2016). Nickel levels of 0.57 ppm to 9.18 ppm have been reported in lipsticks (Sahu *et al.*, 2014). Concentrations of nickel above the suggested safe limit for skin protection have been reported (El Aziz *et al.*, 2017).

2.3 Methods of Analysis

Different methods can be used to detect and find out levels of lead, cadmium, chromium, and nickel that are present in lipsticks and face powders. Some of these methods include a laser-induced breakdown spectrometer (LIBS) (Verichek, 2016), Inductively Couple Plasma - Mass Spectrometry (ICP-MS) (Herwitz, 2001), Spark optical emission spectroscopy (Mee, 2018). Flame Atomic Absorption Spectrometry and Atomic absorption Spectrometry (AAS) (Moraa, 2014). The analysis of lead, cadmium, chromium, and nickel was done using the AAS due to its availability, selectivity, and its ability to be very specific.

2.4 Atomic Absorption Spectroscopy (AAS)

It is an analytical method that determines the levels of atoms in an analyte. This technique utilizes the wavelength of light that is only absorbed by an element. This wavelength of light corresponds to the energy that is needed to move an electron from a lower energy level to a higher energy level (Royal Society of Chemistry, 2018).

2.4.1 Working Principle

An atom of an element absorbs light of a specific wavelength. Light from a particular element is used to find out if a sample contains the same element. For instance, with

nickel, a lamp that has nickel gives out light from excited nickel atoms that produce specific wavelengths to be absorbed by any nickel atom present in the sample. In this technique, the sample is atomized in a vapor state, and electromagnetic radiation is produced by excited nickel atoms passed through the sample. Parts of this radiation are absorbed by nickel atoms in the sample. The quantity of light absorbed in the sample is directly proportional to the number of nickel atoms in the sample. The Calibration curve is plotted by running several samples of known nickel levels under similar conditions of the unknown. The amount of light absorbed by the standard is compared with the calibration curve and this enables the calculation of nickel concentration in the unknown sample.

2.4.2 Instrumentation

AAS (Atomic Absorption Spectroscopy) consists of 5 essential parts; a light source where a Hollow Cathode Lamp is mostly used, an atomizer which can be a flame, an electrothermal or a cold vapor generation system, a Monochromator for selecting the wavelength, a detector for measuring the amount of light absorbed and a recorder for recording the output from the detector.

Light source: The Hollow Cathode Lamp consists of a cathode which is made up of the element under investigation and an anode which is made from tungsten. The tube is filled with a noble gas like Argon or Neon. The large difference in charge between the positive and the negative electrode causes the flow of electrons. These electrons hit the cathode and metal atoms are produced from the cathode in a process called sputtering. These sputtered atoms are in excited states and therefore emit specific radiation as they fall back to the ground state (Ogunlowo, 2016).

Monochromator: It isolates a specific narrow region of the spectrum and excludes all wavelengths outside this region for transmission to the detector (Ogunlowo, 2016).

Detector: It converts light from the Monochromator into an amplified electrical signal which can be recorded and interpreted. The amount of light getting to the detector is directly proportional to the concentration of the element being analyzed. AAS uses a photomultiplier tube as the detector where electrons are emitted upon radiation exposure (Ogunlowo, 2016).

The Recorder: This is usually a computer system with installed suitable software that receives the analog signals from the detector and converts them to readable responses (Ogunlowo, 2016). Figure 2.1 shows the block diagram for AAS.

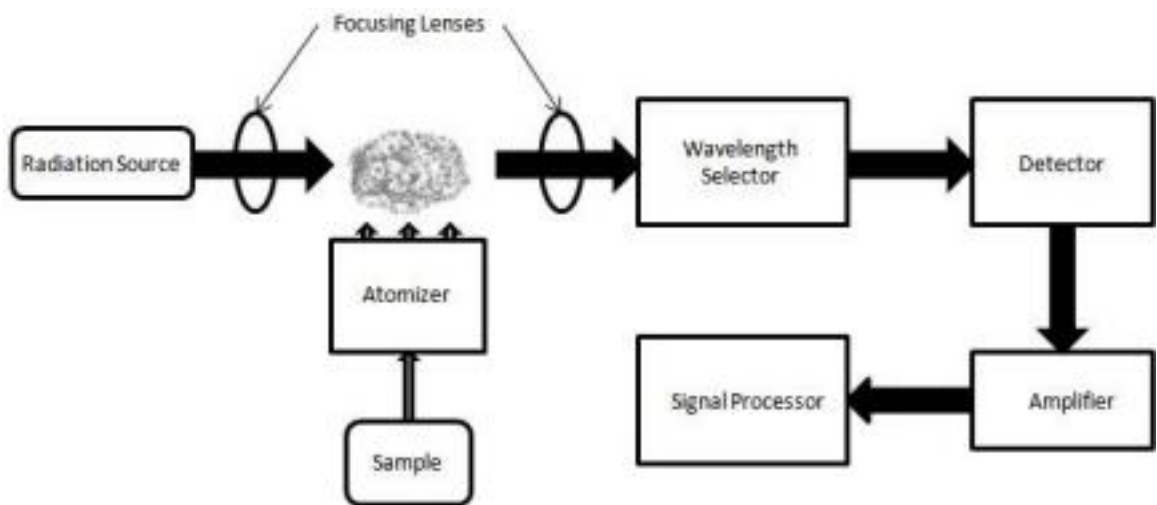


Figure 2.1: Atomic Absorption Spectrometer Block Diagram

CHAPTER THREE

MATERIALS AND METHODS

3.1 Research Design

This study was an experimental analysis where samples of different brands of facial powders and lipsticks in various beauty outlets in Nairobi City were analyzed for selected heavy metals. In this study, the atomic absorption spectrometry technique was used to determine levels of cadmium, lead, nickel, and chromium in selected brands of lipsticks and face powders in the Kenyan market.

3.2 Sample and Sampling Technique

Sampling involves selecting a subset or a sample of a population to be studied as a representative of the whole population. The samples taken represented the whole population to ensure findings from the study could be applied to the unsampled population. (Kothari, 2006). This study adopted a purposive sampling technique where 72 different lipsticks and 72 different face powders in Nairobi city were sampled in three different batches. Sampling was done three times at different times and in different parts of the city. The first sampling was done in January 2019, the second sampling was done in March 2019, and the final sampling was done in June 2019. Face powders and lipsticks which were sampled first were labeled as batch A, the ones sampled the second time were labeled as batch B while those sampled the third time were coded as batch C. Seventy-two different brands of facial powders and seventy-two different brands of lipsticks were bought in different market levels in Nairobi city. Brand names were blinded and codes:

LS1 -LS24 were given for lipsticks in every batch and FD1, -FD24 for face powder in every batch.

3.3 Chemicals, Reagents, and Solvents

Chemicals, reagents, and solvents used in this study were of analytical grade and above and were obtained from Fluka Chemie GmbH Chemical Company, inc. USA. These included stock solutions of lead, cadmium, chromium, and nickel. Others include sulphuric acid, concentrated nitric acid, hydrogen peroxide, potassium permanganate, and stannous chloride. Distilled and distilled deionized water water was used in the study.

3.4 Cleaning of Apparatus

Both glass and plastic apparatus were cleaned with soap using warm water and thereafter rinsed in hot water. Afterward, they were dipped in dilute nitric acid for 24 hours before rinsing with distilled water. The apparatus made of glass was dried in an oven at 105 °C for 24 hours. All were stored under lock and key until needed.

3.5 Preparation of Working and Standard Solutions

From the stock solutions, working standards for each element were obtained through dilution. The concentration of the acid was maintained at approximately 1% to keep the metal in a free ion state. For calibration purposes, 5 serial standards solutions were prepared for each element from their respective working solutions at the time of analysis. The standards made were then aspirated into the instruments and absorbance with corresponding concentrations was used to get calibration curves. The correlation coefficient was then calculated and later used to determine the levels of different elements in the sample.

3.6 Preparation of Samples

In this study, the method adopted is the one according to Mester, 2003 where 1.000 grams of a sample of lipstick was measured and placed into a conical flask. 15 mL of 100% nitric acid was then added to it and later 5 mL of 30% hydrogen peroxide and 5 mL of 100% hydrochloric acid. The reaction was allowed to take place by closing the flask and leaving it for 15 minutes. The contents of the flask were then heated at 150 °C until production of brown fumes stopped. The flask was then cooled and 20 mL of deionized water was added to it. The contents of the flask were then filtered using Whatman paper into a 50 mL volumetric flask diluted to 50 mL with deionized water and later aspirated to the AAS instrument. This was done three times in each case to enhance precision. The digestion of face powder was done using the same procedure.

3.7 Method Validation

This was done by calibration and spiking samples with standards whose amounts are known. Analysis was done three times in each case. The concentration of spiked samples, unspiked samples, and standard added were determined. The recoveries for the metals after digestion were calculated and later expressed as a percentage using Equation 1

$$\%R = \left(a - \frac{b}{c}\right) \times 100 \dots\dots\dots \text{Equation 1}$$

Where: R-recovery

- a- Amount of the sample after spiking
- b- Amount of the sample before spiking
- c- Amount of standard used for spiking

3.8 Instrumentation

Prepared analytes were aspirated into the instrument in triplicates with a regular check on the stability of the instrument by alternating aspiration of samples and standards at regular intervals. Air/Acetylene flame and oxidant flow of 4.5 l/min were used for Pb, Cd, Cr, and Ni. The slit width was maintained at 0.7 nm. A computerized atomic absorption spectrometer AAS (model AA-10) was used. The AAS operating conditions of each metal are described in Table 3.1.

Table 3.1: Working Conditions of AAS for Every Metal

Metal	Wavelength (nm)	Lamp current (mA)	Sensitivity (ppm)	Detection limit (ppm)
Pb	217.0	10.0	0.5	0.0001
Cd	228.8	2.0	0.025	0.0005
Cr	357.9	2.0	0.25	0.0005
Ni	215.9	2.0	0.05	0.0005

3.9 Data Analysis

The data obtained for the levels of heavy metals in the lipsticks and face powder was compared using One-Way ANOVA at 95 % confidence using SPSS 23 for Windows. Significant differences were taken at $p < 0.05$. Bonferroni post hoc test was used to determine the significance difference between specific means.

CHAPTER FOUR

RESULTS AND DISCUSSION

4.1 Introduction

The concentrations of lead, cadmium, chromium, and nickel in lipsticks and face powder sold in Nairobi city were analyzed using AAS. The results were as follows.

4.2 Method Validation

4.2.1 Instrument Calibration Curve

Calibration of the AAS was done by using a concentration of known standard to determine the absorbance at appropriate wavelengths. This was done to determine the linearity of concentration and absorbance, which is one of the methods of testing the instrument for accurate and reliable results. The calibration curve for lead is shown in Figure 4.1 below while for cadmium, chromium, and nickel are presented in the appendix. (Appendices i-iii).

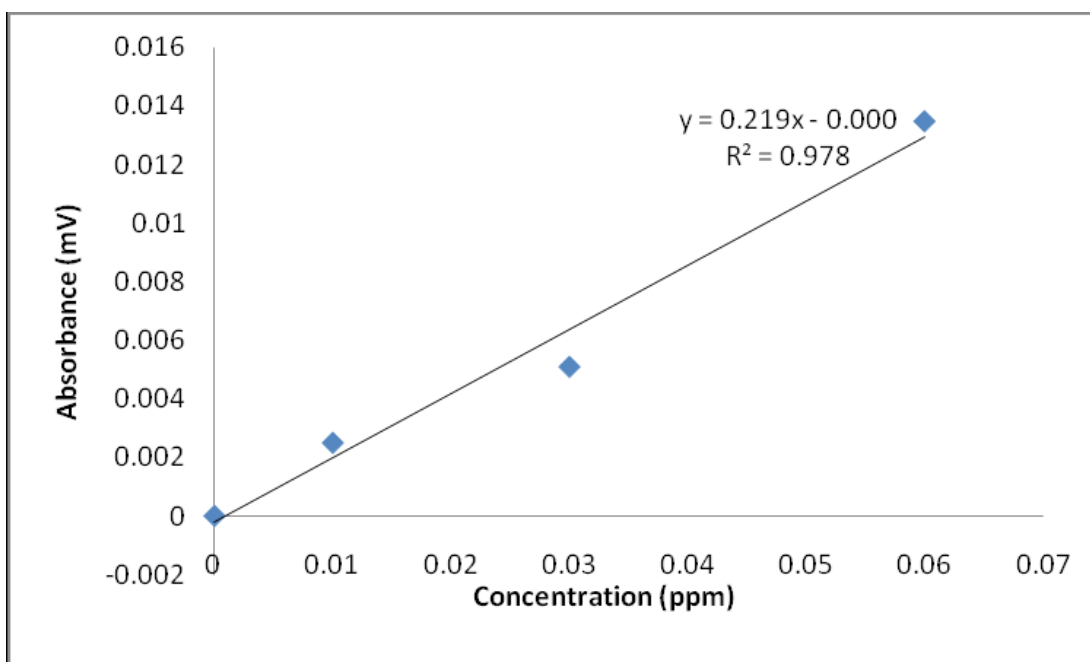


Figure 4.1: Calibration curve for lead standard

The standard linear calibration curve for lead, cadmium, chromium, and nickel obtained from the standard solution analysis shows that the relationship between the concentration and absorbance of the standard solution was linear since R^2 was above 0.9 in all calibrations. Therefore, the results for the concentration of lead, cadmium, chromium, and nickel are reliable. Table 4.1 shows the correlation coefficient and equations of lines of best fit for metals by the AAS instrument.

Table 4.1: Correlation coefficient and regression equations of calibration lines

Metal	Correlation coefficient r^2	Regression equation
Pb	0.978	$y=0.219x+0.000$
Cd	0.978	$y=0.001x+0.000$
Cr	0.985	$y=0.016x+0.003$
Ni	0.987	$y=0.031x+0.002$

All the correlation coefficient values for the analytes were above 0.978, thus implying linearity (Mendham *et al.*, 1999).

4.2.2 Accuracy of the AAS

The accuracy of the AAS was confirmed using the standard addition method (spike and recovery method) for assessing and validating the accuracy of the instrument used for analysis (Wachasunder & Nafade, 2017). Its function is to check whether the detection of the analyte can be affected by the difference between the diluent used and the sample matrix. Spiking is an additional method that involves the addition of the standard to the sample being analyzed. This is used to find out whether the sample matrix contributes to the signal being investigated (matrix effect) therefore it becomes impossible to compare the signal between the sample and the standard using the calibration curve. In this study, known amounts of standards were added to the samples.

The recovered amount was used to calculate the percentage recovery. The mean value of the recovered matrix was calculated at a 95 % confidence level (Rawar and Rohman, 2016). Recovery is a very important method used to test the reliability of the results hence ensuring validation. It is expressed as a percentage. Accepted and reliable values range from 95 % to 110 % (Ata *et al.*, 2016). Table 4.2 gives the concentration of spiked samples, the concentration of the standard added to each sample which is known, the concentration of the unspiked samples, and percentage recovery.

Table 4.2: Percentage recovery of AAS procedures

Analyte	Unspiked Sample(ppm) (Mean \pm SE) n=3	Standard added to the sample (g)	Spiked sample (Mean \pm SE) n=3	% recovery
Lead	0.440 \pm 0.01	1.000	1.430 \pm 0.02	97.73
Cadmium	0.150 \pm 0.01	0.200	0.348 \pm 0.01	98.66
Chromium	0.070 \pm 0.01	1.000	1.069 \pm 0.02	98.57
Nickel	0.100 \pm 0.01	0.500	0.599 \pm 0.01	98.00

The results presented in Table 4.2 show that the recovery is between 97.00-98.66 %.

This gives assurance that the method is fit, accurate, and reliable for analysis.

4.3 Concentrations of Metals in Lipsticks and Powders

4.3.1 Concentration of Metals in Batch A of Lipsticks

The levels of Pb, Cd, Cr, and Ni in batch A lipsticks were determined in the 24 samples of lipsticks, and the results are tabulated in Table 4.3 below.

Table 4.3: Concentration of Metals in Batch A of lipsticks

Mean levels (ppb) in different brands (Mean \pm SE n=3)														
Element	Samples												Mean	p-value
	LS14	LS15	LS16	LS17	LS18	LS19	LS20	LS21	LS22	LS23	LS24			
Pb	7.500 ^{aA} \pm 0.0005	6.400 ^{bB} \pm 0.0005	6.400 ^{aA} \pm 0.0005	7.400 ^{bB} \pm 0.0005	6.700 ^{aA} \pm 0.0005	6.700 ^{bB} \pm 0.0005	7.400 ^{aA} \pm 0.0005	6.400 ^{bB} \pm 0.0005	6.600 ^{aA} \pm 0.0005	7.500 ^{bB} \pm 0.0005	6.400 ^{aA} \pm 0.0005	7.108	0.001	
Cd	BLD	BLD	BLD	BLD	BLD	BLD	BLD	BLD	BLD	BLD	BLD			
Cr	BLD	BLD	BLD	BLD	BLD	BLD	BLD	BLD	BLD	BLD	BLD			
Ni	1.300 ^{bB} \pm 0.0003	1.800 ^{aA} \pm 0.0003	1.000 ^{bB} \pm 0.0003	1.900 ^{aA} \pm 0.0003	1.900 ^{bB} \pm 0.0003	1.800 ^{aA} \pm 0.0003	1.300 ^{bB} \pm 0.0003	1.800 ^{aA} \pm 0.0003	1.900 ^{bB} \pm 0.0003	1.300 ^{aA} \pm 0.0003	1.900 ^{bB} \pm 0.0003	1.654	0.001	
p-value	0.002	0.002	0.001	0.001	0.001	0.001	0.002	0.002	0.001	0.001	0.003			

Mean levels (ppb) in different brands (Mean \pm SE n=3)													
Element	Samples												
	LS1	LS2	LS3	LS4	LS5	LS6	LS7	LS8	LS9	LS10	LS11	LS12	LS13
Pb	6.700 ^{aA} \pm 0.0005	7.400 ^{bB} \pm	6.400 ^{bB} \pm	6.600 ^{aA} \pm	7.500 ^{bB} \pm	6.400 ^{aA} \pm	6.400 ^{bB} \pm	7.300 ^{aA} \pm	6.700 ^{bB} \pm	6.700 ^{aA} \pm	7.400 ^{bB} \pm	6.400 ^{aA} \pm	6.600 ^{bB} \pm
Cd	BLD	BLD	BLD	BLD	BLD	BLD	BLD	BLD	BLD	BLD	BLD	BLD	BLD
Cr	BLD	BLD	BLD	BLD	BLD	BLD	BLD	BLD	BLD	BLD	BLD	BLD	BLD
Ni	1.900 ^{bB} \pm 0.0003	1.800 ^{aA} \pm	1.300 ^{aA} \pm	1.800 ^{bB} \pm	1.900 ^{aA} \pm	1.300 ^{bB} \pm	1.800 ^{aA} \pm	1.900 ^{bB} \pm	1.800 ^{aA} \pm	1.800 ^{bB} \pm	1.900 ^{aA} \pm	1.300 ^{bB} \pm	1.300 ^{aA} \pm
p-value	0.001	0.001	0.001	0.002	0.001	0.001	0.002	0.001	0.002	0.002	0.002	0.001	0.001

Mean values with the same small letters within the same row are not significantly different ($\alpha=0.05$) (Bonferroni post hoc test)

Mean values with the same capital letters within the same column are not significantly different ($\alpha=0.05$) (Bonferroni post hoc test)

The levels of lead, cadmium, chromium, and nickel in batch A of lipsticks were determined in the 24 samples of lipsticks. The results in Table 4.3 show that the concentration of cadmium and chromium in batch A of lipsticks was below the detectable limit of the machine. Batch A of lipsticks had higher levels of lead (7.108 ppb) than nickel (1.654 ppb). This difference is statistically significant because the p-values are below 0.05 the maximum threshold for the values to be significant. The levels of lead in batch A of lipsticks are below the maximum permissible level, which is 10 ppm as set by WHO and 2 ppm as set by KEBS. The levels of nickel in brand A of lipsticks were also below the maximum permissible level, which is 200 ppm as set by WHO and 200 ppm as set by KEBS.

4.3.2 Concentration of Metals in Batch B of Lipsticks

The levels of Pb, Cd, Cr, and Ni in batch B lipsticks were determined in the 24 samples of lipsticks and the results are tabulated in Table 4.4 below.

Table 4.4: Concentration of Metals in Batch B of lipsticks

Mean levels (ppb) in different brands (Mean \pm SE n=3)													
Samples													
Element	LS1	LS2	LS3	LS4	LS5	LS6	LS7	LS8	LS9	LS10	LS11	LS12	LS13
Pb	6.600 ^{aA} \pm 0.0005	5.700 ^{bB} \pm 0.0005	5.800 ^{aA} \pm 0.0005	5.800 ^{bB} \pm 0.0005	6.500 ^{aA} \pm 0.0005	5.800 ^{bB} \pm 0.0005	5.800 ^{aA} \pm 0.0005	5.800 ^{bB} \pm 0.0005	6.500 ^{aA} \pm 0.0005	6.600 ^{bB} \pm 0.0005	5.700 ^{aA} \pm 0.0005	5.800 ^{bB} \pm 0.0005	6.500 ^{aA} \pm 0.0005
Cd	BLD	BLD	BLD	BLD	BLD	BLD	BLD	BLD	BLD	BLD	BLD	BLD	BLD
Cr	BLD	BLD	BLD	BLD	BLD	BLD	BLD	BLD	BLD	BLD	BLD	BLD	BLD
Ni	2.900 ^{bB} \pm 0.0004	3.600 ^{aA} \pm 0.0004	2.800 ^{bB} \pm 0.0004	2.800 ^{aA} \pm 0.0004	2.900 ^{bB} \pm 0.0004	3.600 ^{aA} \pm 0.0004	3.600 ^{bB} \pm 0.0004	2.800 ^{aA} \pm 0.0004	2.900 ^{bB} \pm 0.0004	2.800 ^{aA} \pm 0.0004	3.600 ^{bB} \pm 0.0004	2.900 ^{aA} \pm 0.0004	2.800 ^{bB} \pm 0.0004
p-value	0.002	0.002	0.001	0.002	0.001	0.001	0.001	0.002	0.002	0.001	0.001	0.001	0.002
Mean levels (ppb) in different brands (Mean \pm SE n=3)													
Element	LS14	LS15	LS16	LS17	LS18	LS19	LS20	LS21	LS22	LS23	LS24	Mean	p-value
Pb	6.600 ^{bB} \pm 0.0005	5.700 ^{aA} \pm 0.0005	5.800 ^{bB} \pm 0.0005	5.800 ^{aA} \pm 0.0005	6.600 ^{bB} \pm 0.0005	6.600 ^{aA} \pm 0.0005	5.700 ^{bB} \pm 0.0005	5.800 ^{aA} \pm 0.0005	5.800 ^{bB} \pm 0.0005	5.700 ^{aA} \pm 0.0005	5.700 ^{bB} \pm 0.0005	6.029	0.001
Cd	BLD	BLD	BLD	BLD	BLD	BLD	BLD	BLD	BLD	BLD	BLD		
Cr	BLD	BLD	BLD	BLD	BLD	BLD	BLD	BLD	BLD	BLD	BLD		
Ni	2.900 ^{aA} \pm 0.0004	3.600 ^{bB} \pm 0.0004	2.800 ^{aA} \pm 0.0004	2.900 ^{bB} \pm 0.0004	3.600 ^{aA} \pm 0.0004	2.900 ^{bB} \pm 0.0004	3.600 ^{aA} \pm 0.0004	2.800 ^{bB} \pm 0.0004	2.800 ^{aA} \pm 0.0004	2.900 ^{bB} \pm 0.0004	3.600 ^{aA} \pm 0.0004	3.371	0.003
p-value	0.002	0.003	0.003	0.001	0.002	0.002	0.001	0.001	0.001	0.003	0.002		

Mean values with the same small letters within the same row are not significantly different ($\alpha=0.05$) (Bonferroni post hoc test)

Mean values with the same capital letters within the same column are not significantly different ($\alpha=0.05$) (Bonferroni post hoc test)

The levels of lead, cadmium, chromium, and nickel in batch B of lipsticks were determined in the 24 samples of lipsticks. The results in Table 4.4 show that the concentration of cadmium and chromium in batch B of lipsticks was below the detectable limit of the machine. Batch B of lipsticks had higher levels of lead (6.029ppb) than nickel (3.371ppb). This difference is statistically significant because the p-values are below 0.05 the maximum threshold for the values to be significant. Levels of metals in all the samples tested are significantly different. The levels of lead in batch B of lipsticks are below the maximum permissible level, which is 10 ppm as set by WHO and 2 ppm as set by KEBS. The levels of nickel in batch B of lipsticks were also below the maximum permissible level, which is 200 ppm as set by WHO and 200 ppm as set by KEBS.

4.3.3 Concentration of Metals in Batch C of Lipsticks

The levels of Pb, Cd, Cr, and Ni in batch C lipsticks were determined in the 24 samples of lipsticks and the results tabulated in Table 4.5 below.

Table 4.5: Concentration of metals in Batch C of lipsticks

Mean levels (ppb) in different brands (Mean \pm SE, n=3)													
Samples													
Element	LS1	LS2	LS3	LS4	LS5	LS6	LS7	LS8	LS9	LS10	LS11	LS12	LS13
Pb	7.900 ^{aA} \pm 0.0004	8.200 ^{bB} \pm 0.0004	8.600 ^{aA} \pm 0.0004	7.800 ^{bB} \pm 0.0005	8.300 ^{aA} \pm 0.0004	8.600 ^{bB} \pm 0.0004	8.300 ^{aA} \pm 0.0004	7.800 ^{bB} \pm 0.0004	7.900 ^{aA} \pm 0.0004	7.900 ^{bB} \pm 0.0004	8.200 ^{aA} \pm 0.0004	8.600 ^{bB} \pm 0.0004	8.600 ^{aA} \pm 0.0004
Cd	BLD	BLD	BLD	BLD	BLD	BLD	BLD	BLD	BLD	BLD	BLD	BLD	BLD
Cr	BLD	BLD	BLD	BLD	BLD	BLD	BLD	BLD	BLD	BLD	BLD	BLD	BLD
Ni	0.600 ^{bB} \pm 0.0006	0.600 ^{aA} \pm 0.0006	0.700 ^{bB} \pm 0.0006	0.700 ^{aA} \pm 0.0006	0.700 ^{bB} \pm 0.0006	0.600 ^{aA} \pm 0.0006	0.600 ^{bB} \pm 0.0006	0.600 ^{aA} \pm 0.0006	0.600 ^{bB} \pm 0.0006	0.600 ^{aA} \pm 0.0006	0.600 ^{bB} \pm 0.0006	0.700 ^{aA} \pm 0.0006	0.600 ^{bB} \pm 0.0006
p-value	0.001	0.001	0.001	0.003	0.002	0.002	0.001	0.003	0.004	0.005	0.001	0.002	0.001

Mean levels (ppb) in different brands (Mean \pm SE, n=3)													
Element	LS14	LS15	LS16	LS17	LS18	LS19	LS20	LS21	LS22	LS23	LS24	Mean	p-value
Pb	8.200 ^{bB} \pm 0.0004	8.600 ^{aA} \pm 0.0004	7.800 ^{bB} \pm 0.0004	8.300 ^{aA} \pm 0.0004	8.300 ^{bB} \pm 0.0004	7.900 ^{aA} \pm 0.0004	8.200 ^{bB} \pm 0.0004	8.000 ^{aA} \pm 0.0004	8.000 ^{bB} \pm 0.0004	8.600 ^{aA} \pm 0.0004	8.000 ^{bB} \pm 0.0004	8.192	0.003
Cd	BLD	BLD	BLD	BLD	BLD	BLD	BLD	BLD	BLD	BLD	BLD		
Cr	BLD	BLD	BLD	BLD	BLD	BLD	BLD	BLD	BLD	BLD	BLD		
Ni	0.600 ^{aA} \pm 0.0006	0.600 ^{bB} \pm 0.0006	0.600 ^{aA} \pm 0.0006	0.700 ^{bB} \pm 0.0006	0.700 ^{aA} \pm 0.0004	0.600 ^{bB} \pm 0.0004	0.600 ^{aA} \pm 0.0004	0.600 ^{bB} \pm 0.0004	0.700 ^{aA} \pm 0.0004	0.600 ^{bB} \pm 0.0004	0.700 ^{aA} \pm 0.0004	0.633	0.004
p-value	0.003	0.004	0.004	0.003	0.003	0.005	0.004	0.004	0.004	0.005	0.001		

Mean values with the same small letters within the row are not significantly different ($\alpha=0.05$) (Bonferroni post hoc test)

Mean values with the same capital letters within the same column are not significantly different ($\alpha=0.05$) (Bonferroni post hoc test)

The levels of lead, cadmium, chromium, and nickel in batch C of lipsticks were determined in the 24 samples of lipsticks. The results in Table 4.5 show that the concentration of cadmium and chromium in batch C of lipsticks was below the detectable limit of the machine. Batch C of lipsticks had higher levels of lead (8.192 ppb) than nickel (0.633 ppb). This difference is statistically significant because the p-values are below 0.05 the maximum threshold for the values to be significant. The levels of heavy metals in all samples tested are significantly different. The levels of lead in brand C of lipsticks are below the maximum permissible level, which is 10 ppm as set by WHO and 2 ppm as set by KEBS. The levels of nickel in brand C of lipsticks were also below the maximum permissible level, which is 200 ppm as set by WHO and 200 ppm as set by KEBS.

4.3.4 Concentration of Metals in Batch A of Face Powders

The levels of Pb, Cd, Cr, and Ni in batch A face powders were determined in the 24 samples of face powders, and the results are tabulated in Table 4.6 below

Table 4.6: Concentration of metals in Batch A of face powders

Mean levels (ppb) in different brands (Mean \pm SE n=3)													
Samples													
Element	FD1	FD2	FD3	FD4	FD5	FD6	FD7	FD8	FD9	FD10	FD11	FD12	FD13
Pb	2.000 ^{aA} \pm 0.0007	3.100 ^{aA} \pm 0.0007	3.400 ^{aA} \pm 0.0007	2.000 ^{aA} \pm 0.0007	3.400 ^{aA} \pm 0.0007	3.400 ^{aA} \pm 0.0007	3.100 ^{aA} \pm 0.0007	2.000 ^{aA} \pm 0.0007	3.100 ^{aA} \pm 0.0007	2.000 ^{aA} \pm 0.0007	3.400 ^{aA} \pm 0.0007	3.100 ^{aA} \pm 0.0007	3.100 ^{aA} \pm 0.0007
Cd	2.900 ^{aA} \pm 0.0012	4.800 ^{aA} \pm 0.0012	4.900 ^{aA} \pm 0.0012	2.600 ^{aA} \pm 0.0012	4.800 ^{aA} \pm 0.0012	2.600 ^{aA} \pm 0.0012	2.900 ^{aA} \pm 0.0012	4.800 ^{aA} \pm 0.0012	2.600 ^{aA} \pm 0.0012	2.900 ^{aA} \pm 0.0012	4.800 ^{aA} \pm 0.0012	2.600 ^{aA} \pm 0.0012	2.600 ^{aA} \pm 0.0012
Cr	1.200 ^{aA} \pm 0.0010	2.600 ^{aA} \pm 0.0010	3.100 ^{aA} \pm 0.0010	2.600 ^{aA} \pm 0.0010	3.100 ^{aA} \pm 0.0010	1.200 ^{aA} \pm 0.0010	3.100 ^{aA} \pm 0.0010	1.200 ^{aA} \pm 0.0010	3.100 ^{aA} \pm 0.0010	1.200 ^{aA} \pm 0.0010	2.600 ^{aA} \pm 0.0010	3.100 ^{aA} \pm 0.0010	3.100 ^{aA} \pm 0.0010
Ni	4.600 ^{aA} \pm 0.0005	4.100 ^{aA} \pm 0.0005	5.000 ^{aA} \pm 0.0005	4.600 ^{aA} \pm 0.0005	5.000 ^{aA} \pm 0.0005	5.000 ^{aA} \pm 0.0005	4.600 ^{aA} \pm 0.0005	5.000 ^{aA} \pm 0.0005	4.600 ^{aA} \pm 0.0005	4.600 ^{aA} \pm 0.0005	4.100 ^{aA} \pm 0.0005	5.000 ^{aA} \pm 0.0005	4.100 ^{aA} \pm 0.0005
p-value	0.066	0.078	0.084	0.087	0.087	0.085	0.088	0.089	0.068	0.069	0.089	0.089	0.080
Mean levels (ppb) in different brands (Mean \pm SE n=3)													
Element	FD14	FD15	FD16	FD17	FD18	FD19	FD20	FD21	FD22	FD23	FD24	Mean	p-value
Pb	2.000 ^{aA} \pm 0.0007	3.400 ^{aA} \pm 0.0007	3.400 ^{aA} \pm 0.0007	2.000 ^{aA} \pm 0.0007	3.100 ^{aA} \pm 0.0007	2.000 ^{aA} \pm 0.0007	3.400 ^{aA} \pm 0.0007	3.100 ^{aA} \pm 0.0007	3.100 ^{aA} \pm 0.0007	3.400 ^{aA} \pm 0.0007	2.000 ^{aA} \pm 0.0007	2.833	0.085
Cd	2.600 ^{aA} \pm 0.0012	2.900 ^{aA} \pm 0.0012	4.800 ^{aA} \pm 0.0012	4.800 ^{aA} \pm 0.0012	2.600 ^{aA} \pm 0.0012	2.900 ^{aA} \pm 0.0012	4.800 ^{aA} \pm 0.0012	2.900 ^{aA} \pm 0.0012	2.600 ^{aA} \pm 0.0012	2.900 ^{aA} \pm 0.0012	2.900 ^{aA} \pm 0.0012	3.438	0.088
Cr	2.600 ^{aA} \pm 0.0010	1.200 ^{aA} \pm 0.0010	2.600 ^{aA} \pm 0.0010	1.200 ^{aA} \pm 0.0010	1.200 ^{aA} \pm 0.0010	1.200 ^{aA} \pm 0.0010	2.600 ^{aA} \pm 0.0010	3.100 ^{aA} \pm 0.0010	3.100 ^{aA} \pm 0.0010	2.600 ^{aA} \pm 0.0010	2.600 ^{aA} \pm 0.0010	2.300	0.079
Ni	4.100 ^{aA} \pm 0.0005	4.100 ^{aA} \pm 0.0005	5.000 ^{aA} \pm 0.0005	4.600 ^{aA} \pm 0.0005	5.000 ^{aA} \pm 0.0005	4.600 ^{aA} \pm 0.0005	4.100 ^{aA} \pm 0.0005	5.000 ^{aA} \pm 0.0005	4.100 ^{aA} \pm 0.0005	4.600 ^{aA} \pm 0.0005	4.100 ^{aA} \pm 0.0005	4.567	0.085
p-value	0.069	0.066	0.070	0.082	0.078	0.079	0.089	0.088	0.089	0.087	0.085		

Mean values with the same small letters within the same row are not significantly different ($\alpha=0.05$) (Bonferroni post hoc test)

Mean values with the same capital letters within the same column are not significantly different ($\alpha=0.05$) (Bonferroni post hoc test)

The levels of lead, cadmium, chromium, and nickel in brand A of face powder were determined in the 24 samples of face powder. The results in Table 4.6 show that the concentration of nickel in brand A of face powder was the highest (4.567 ppb) followed by cadmium (3.438 ppb), then lead (2.833 ppb) and chromium was the lowest (2.300 ppb). This difference is not statistically significant because the p-values are above 0.05 the maximum threshold for the values to be significant. The levels of metals in all samples tested were not significantly different. The levels of lead, cadmium, chromium, and nickel in brand A of face powder are below the maximum permissible level, which is 10 ppm as set by WHO and 2 ppm as set by KEBS for lead, 0.3 ppm as set by WHO and 0.1 as set by KEBS for cadmium, 50 ppm as set by both KEBS and WHO for chromium and 200 ppm as set by both KEBS and WHO for nickel.

4.3.5 Concentration of Metals in Batch B of Face Powders

The levels of Pb, Cd, Cr, and Ni in batch B face powders were determined in the 24 samples of face powders and the results are tabulated in Table 4.7 below.

Table 4.7: Concentration of metals in Batch B of face

Mean levels (ppb) in different brands (Mean \pm SE n=3)													
Element	Samples												
	FD1	FD2	FD3	FD4	FD5	FD6	FD7	FD8	FD9	FD10	FD11	FD12	FD13
Pb	1.200 ^{aA} \pm 0.0003	1.700 ^{bB} \pm 0.0003	1.100 ^{aA} \pm 0.0003	1.100 ^{bB} \pm 0.0003	1.200 ^{aA} \pm 0.0003	1.100 ^{bB} \pm 0.0003	1.700 ^{aA} \pm 0.0003	1.200 ^{bB} \pm 0.0003	1.200 ^{aA} \pm 0.0003	1.700 ^{bB} \pm 0.0003	1.100 ^{aA} \pm 0.0003	1.700 ^{bB} \pm 0.0003	1.700 ^{aA} \pm 0.0003
Cd	3.100 ^{bB} \pm 0.0012	4.800 ^{aA} \pm 0.0012	4.900 ^{bB} \pm 0.0012	2.600 ^{aA} \pm 0.0012	4.800 ^{bB} \pm 0.0012	2.600 ^{aA} \pm 0.0012	2.900 ^{bB} \pm 0.0012	4.800 ^{aA} \pm 0.0012	2.600 ^{bB} \pm 0.0012	2.900 ^{aA} \pm 0.0012	4.800 ^{bB} \pm 0.0012	2.600 ^{aA} \pm 0.0012	2.600 ^{bB} \pm 0.0012
Cr	1.900 ^{aA} \pm 0.0005	2.700 ^{bB} \pm 0.0005	2.900 ^{aA} \pm 0.0005	2.900 ^{bB} \pm 0.0005	1.900 ^{aA} \pm 0.0005	2.700 ^{bB} \pm 0.0005	2.900 ^{aA} \pm 0.0005	2.700 ^{bB} \pm 0.0005	1.900 ^{aA} \pm 0.0005	1.900 ^{bB} \pm 0.0005	2.700 ^{aA} \pm 0.0005	2.900 ^{bB} \pm 0.0005	2.900 ^{aA} \pm 0.0005
Ni	19.50 ^{bB} \pm 0.0045	18.70 ^{aA} \pm 0.0045	19.50 ^{bB} \pm 0.0045	18.70 ^{aA} \pm 0.0045	26.80 ^{bB} \pm 0.0045	19.50 ^{aA} \pm 0.0045	19.50 ^{bB} \pm 0.0045	18.70 ^{aA} \pm 0.0045	26.80 ^{bB} \pm 0.0045	26.80 ^{aA} \pm 0.0045	18.70 ^{bB} \pm 0.0045	19.50 ^{aA} \pm 0.0045	19.50 ^{bB} \pm 0.0045
p-value	0.004	0.005	0.001	0.005	0.004	0.004	0.001	0.003	0.004	0.004	0.005	0.004	0.004

Mean levels (ppb) in different brands (Mean \pm SE n=3)													
Element	FD14	FD15	FD16	FD17	FD18	FD19	FD20	FD21	FD22	FD23	FD24	Mean	p-value
Pb	1.200 ^b \pm 0.0003	1.700 ^a \pm 0.0003	1.100 ^b \pm 0.0003	1.200 ^a \pm 0.0003	1.100 ^b \pm 0.0003	1.100 ^a \pm 0.0003	1.700 ^b \pm 0.0003	1.700 ^a \pm 0.0003	1.100 ^b \pm 0.0003	1.200 ^a \pm 0.0003	1.200 ^b \pm 0.0003	1.333	0.001
Cd	1.100 ^a \pm 0.0013	1.100 ^b \pm 0.0013	3.400 ^a \pm 0.0013	1.100 ^b \pm 0.0013	1.100 ^a \pm 0.0013	3.400 ^b \pm 0.0013	3.100 ^a \pm 0.0013	3.100 ^b \pm 0.0013	1.100 ^a \pm 0.0013	3.400 ^b \pm 0.0013	3.100 ^a \pm 0.0013	2.958	0.004
Cr	2.900 ^b \pm 0.0005	2.700 ^a \pm 0.0005	2.900 ^b \pm 0.0005	1.900 ^a \pm 0.0005	1.900 ^b \pm 0.0005	1.900 ^a \pm 0.0005	2.700 ^b \pm 0.0005	2.900 ^a \pm 0.0005	2.700 ^b \pm 0.0005	1.900 ^a \pm 0.0005	2.700 ^b \pm 0.0005	2.500	0.001
Ni	19.50 ^a \pm 0.0045	26.80 ^b \pm 0.0045	18.70 ^a \pm 0.0045	26.80 ^b \pm 0.0045	26.80 ^a \pm 0.0045	26.80 ^b \pm 0.0045	18.70 ^a \pm 0.0045	19.50 ^b \pm 0.0045	18.70 ^a \pm 0.0045	18.70 ^b \pm 0.0045	26.80 ^a \pm 0.0045	21.67	0.003
p-value	0.001	0.003	0.003	0.004	0.005	0.005	0.004	0.005	0.001	0.001	0.004		

Mean values with the same small letters within the same row are not significantly different ($\alpha=0.05$) (Bonferroni post hoc test)

Mean values with the same capital letters within the same column are not significantly different ($\alpha=0.05$) (Bonferroni post hoc test)

The levels of lead, cadmium, chromium, and nickel in brand B of face powder were determined in the 24 samples of face powder. The results in Table 4.7 show that the concentration of nickel in brand B of face powder was the highest (21.67 ppb) followed by cadmium (2.958 ppb), then chromium (2.500 ppb) and lead was the lowest (1.333ppb). This difference is statistically significant because the p-values are 0.05 the maximum threshold for the values to be significant. The levels of metals in all samples tested are significantly different. The levels of lead, cadmium, chromium, and nickel in brand B of face powder are below the maximum permissible level, which is 10 ppm as set by WHO and 2 ppm as set by KEBS for lead, 0.3 ppm as set by WHO and 0.1 as set by KEBS for cadmium, 50 ppm as set by both KEBS and WHO for chromium and 200 ppm as set by both KEBS and WHO for nickel.

4.3.6 Concentration of Metals in Batch C of Face Powders

The levels of Pb, Cd, Cr, and Ni in batch C face powders were determined in the 24 samples of face powders and the results are tabulated in Table 4.8 below.

Table 4.8: Concentration of metals in Batch C of face powders

Mean levels (ppb) in different brands (Mean \pm SE n=3)													
Element	FD14	FD15	FD16	FD17	FD18	FD19	FD20	FD21	FD22	FD23	FD24	Mean	p-value
Pb	6.600 ^{bb} \pm 0.0013	4.000 ^{aa} \pm 0.0013	4.000 ^{bb} \pm 0.0013	5.300 ^{aa} \pm 0.0013	6.600 ^{bb} \pm 0.0013	4.000 ^{aa} \pm 0.0013	5.300 ^{bb} \pm 0.0013	6.600 ^{aa} \pm 0.0013	4.000 ^{bb} \pm 0.0013	6.600 ^{aa} \pm 0.0013	5.300 ^{bb} \pm 0.0013	5.300	0.004
Cd	2.200 ^{aa} \pm 0.0011	0.300 ^{bb} \pm 0.0011	0.200 ^{aa} \pm 0.0011	0.300 ^{bb} \pm 0.0011	0.200 ^{aa} \pm 0.0011	2.200 ^{bb} \pm 0.0011	0.200 ^{aa} \pm 0.0011	2.200 ^{bb} \pm 0.0011	0.300 ^{aa} \pm 0.0011	0.300 ^{bb} \pm 0.0011	0.200 ^{aa} \pm 0.0011	0.900	0.005
Cr	1.000 ^{bb} \pm 0.0001	1.000 ^{aa} \pm 0.0001	0.900 ^{bb} \pm 0.0005	0.900 ^{aa} \pm 0.0001	1.000 ^{bb} \pm 0.0001	0.900 ^{aa} \pm 0.0001	1.000 ^{bb} \pm 0.0001	1.000 ^{aa} \pm 0.0001	1.000 ^{bb} \pm 0.0001	0.900 ^{aa} \pm 0.0001	0.900 ^{bb} \pm 0.0001	0.967	0.004
Ni	BLD	BLD	BLD	BLD	BLD	BLD	BLD	BLD	BLD	BLD	BLD		
p-value	0.005	0.006	0.007	0.006	0.004	0.004	0.004	0.005	0.004	0.004	0.004		

Mean levels (ppb) in different brands (Mean \pm SE n=3)													
Samples													
Element	FD1	FD2	FD3	FD4	FD5	FD6	FD7	FD8	FD9	FD10	FD11	FD12	FD13
Pb	4.000 ^{aa} \pm 0.0013	5.300 ^{bb} \pm 0.0013	6.600 ^{aa} \pm 0.0013	4.000 ^{bb} \pm 0.0013	6.600 ^{aa} \pm 0.0013	5.300 ^{bb} \pm 0.0013	5.300 ^{aa} \pm 0.0013	4.000 ^{bb} \pm 0.0013	6.600 ^{aa} \pm 0.0013	4.000 ^{bb} \pm 0.0013	5.300 ^{aa} \pm 0.0013	6.600 ^{bb} \pm 0.0013	5.300 ^{aa} \pm 0.0013
Cd	2.200 ^{bb} \pm 0.0011	0.200 ^{aa} \pm 0.0011	0.200 ^{bb} \pm 0.0011	2.200 ^{aa} \pm 0.0011	0.200 ^{bb} \pm 0.0011	0.300 ^{aa} \pm 0.0011	0.300 ^{bb} \pm 0.0011	2.200 ^{aa} \pm 0.0011	0.200 ^{bb} \pm 0.0011	2.200 ^{aa} \pm 0.0011	0.300 ^{bb} \pm 0.0011	2.200 ^{aa} \pm 0.0011	0.300 ^{bb} \pm 0.0011
Cr	0.900 ^{aa} \pm 0.0001	1.000 ^{bb} \pm 0.0001	1.000 ^{aa} \pm 0.0001	1.000 ^{bb} \pm 0.0001	1.000 ^{aa} \pm 0.0001	1.000 ^{bb} \pm 0.0001	0.900 ^{aa} \pm 0.0001	1.000 ^{bb} \pm 0.0001	1.000 ^{aa} \pm 0.0001	0.900 ^{bb} \pm 0.0001	1.000 ^{aa} \pm 0.0001	1.000 ^{bb} \pm 0.0001	1.000 ^{aa} \pm 0.0001
Ni	BLD	BLD	BLD	BLD	BLD	BLD	BLD	BLD	BLD	BLD	BLD	BLD	BLD
p-value	0.003	0.003	0.005	0.004	0.004	0.005	0.004	0.003	0.001	0.004	0.004	0.005	0.004

Mean values with the same small letters within the same row are not significantly different ($\alpha=0.05$) (Bonferroni post hoc test)

Mean values with the same capital letters within the same column are not significantly different ($\alpha=0.05$) (Bonferroni post hoc test)

The levels of lead, cadmium, chromium, and nickel in brand C of face powder were determined in the 24 samples of face powder. The results in Table 4.8 show that the concentration of nickel in brand C was below the detectable limit of the machine. The concentration of lead in brand C of face powders was the highest (5.300 ppb) followed by chromium (0.967 ppb), then cadmium (0.900 ppb). This difference is statistically significant because the p-values are less than 0.05 the maximum threshold for the values to be significant. Levels of metals in all samples tested are statistically significant. The levels of lead, cadmium, chromium, and nickel in brand B of face powder are below the maximum permissible level, which is 10 ppm as set by WHO and 2 ppm as set by KEBS for lead, 0.3 ppm as set by WHO and 0.1 as set by KEBS for cadmium, 50 ppm as set by both KEBS and WHO for chromium and 200 ppm as set by both KEBS and WHO for nickel.

4.4 Concentration of Metals in Lipsticks and Powders in Different Brands

4.4.1 Concentration of Lead in Lipsticks

The levels of lead in lipsticks were determined in the 72 samples of lipsticks in batches A, B, and C and the results tabulated in Table 4.9 below.

Table 4.9: Concentration of lead in lipsticks

Mean levels (ppb) in different brands (Mean \pm SE n=3)													
Batch	Samples												
	LS1	LS2	LS3	LS4	LS5	LS6	LS7	LS8	LS9	LS10	LS11	LS12	LS13
A	6.700 ^{aA} \pm 0.0005	7.400 ^{bB} \pm 0.0005	6.400 ^{aA} \pm 0.0005	6.600 ^{bB} \pm 0.0005	7.500 ^{aA} \pm 0.0005	6.400 ^{bB} \pm 0.0005	6.400 ^{bB} \pm 0.0005	7.300 ^{aA} \pm 0.0005	6.700 ^{bB} \pm 0.0005	6.700 ^{aA} \pm 0.0005	7.400 ^{bB} \pm 0.0005	6.400 ^{aA} \pm 0.0005	6.600 ^{bB} \pm 0.0005
B	6.600 ^{bB} \pm 0.0005	5.700 ^{aA} \pm 0.0005	5.800 ^{bB} \pm 0.0005	5.800 ^{bB} \pm 0.0005	6.500 ^{bB} \pm 0.0005	5.800 ^{aA} \pm 0.0005	5.800 ^{bB} \pm 0.0005	5.800 ^{bB} \pm 0.0005	6.500 ^{aA} \pm 0.0005	6.600 ^{bB} \pm 0.0005	5.700 ^{aA} \pm 0.0005	5.800 ^{bB} \pm 0.0005	6.500 ^{aA} \pm 0.0005
C	7.900 ^{aA} \pm 0.0004	8.200 ^{bB} \pm 0.0004	8.600 ^{aC} \pm 0.0004	7.800 ^{aA} \pm 0.0004	8.300 ^{aA} \pm 0.0004	8.600 ^{bB} \pm 0.0004	8.300 ^{aA} \pm 0.0004	7.800 ^{bB} \pm 0.0004	7.900 ^{aA} \pm 0.0004	7.900 ^{aA} \pm 0.0004	8.200 ^{bB} \pm 0.0004	8.600 ^{aA} \pm 0.0004	8.600 ^{aA} \pm 0.0004
p-	0.001	0.003	0.003	0.001	0.003	0.001	0.001	0.003	0.001	0.002	0.002	0.003	0.003

Mean levels (ppb) in different brands (Mean \pm SE n=3)													
	LS14	LS15	LS16	LS17	LS18	LS19	LS20	LS21	LS22	LS23	LS24	Mean	p-
A	7.500 ^{aA} \pm 0.0005	6.400 ^{bB} \pm 0.0005	6.400 ^{bB} \pm 0.0005	7.400 ^{aA} \pm 0.0005	6.700 ^{bB} \pm 0.0005	6.700 ^{bB} \pm 0.0005	7.400 ^{aA} \pm 0.0005	6.400 ^{bB} \pm 0.0005	6.600 ^{aA} \pm 0.0005	7.500 ^{bB} \pm 0.0005	6.400 ^{aA} \pm 0.0005	6.800	0.003
B	6.600 ^{bB} \pm 0.0005	5.700 ^{aA} \pm 0.0005	5.800 ^{bB} \pm 0.0005	5.800 ^{bB} \pm 0.0005	6.600 ^{aA} \pm 0.0005	6.600 ^{aA} \pm 0.0005	5.700 ^{bB} \pm 0.0005	5.800 ^{aA} \pm 0.0005	5.800 ^{bB} \pm 0.0005	5.700 ^{aA} \pm 0.0005	5.700 ^{bB} \pm 0.0005	6.000	0.001
C	8.200 ^{aA} \pm 0.0004	8.600 ^{bB} \pm 0.0004	7.800 ^{aA} \pm 0.0004	8.300 ^{bB} \pm 0.0004	8.300 ^{bB} \pm 0.0004	7.900 ^{aA} \pm 0.0004	8.200 ^{bB} \pm 0.0004	8.000 ^{aA} \pm 0.0004	8.000 ^{aA} \pm 0.0004	8.600 ^{bB} \pm 0.0004	8.000 ^{aA} \pm 0.0004	8.200	0.001
P-	0.001	0.002	0.001	0.001	0.003	0.001	0.002	0.002	0.002	0.001	0.001	0.001	

Mean values with the same small letters within the same row are not significantly different ($\alpha=0.05$) (Bonferroni post hoc test)

Mean values with the same capital letters within the same column are not significantly different ($\alpha=0.05$) (Bonferroni post hoc test)

The levels of lead in the three batches of lipstick; A, B, and C presented in Table 4.9 are significantly different. The mean for the concentration of lead in batch C of lipsticks is highest (8.200 ppb), followed by batch A lipsticks (6.800 ppb) and finally batch B (6.000 ppb). Further analysis shows that the differences between the mean are statistically significant because the P values are less than 0.05 the minimum threshold for values to be significant. This means that the differences observed in the mean of the concentration of lead between batch A, B, and C lipsticks are not by chance. However, the concentration of lead in all three batches of lipstick was below the KEBS and WHO permissible levels of lead that are acceptable in cosmetics. The Maximum permissible level for lead by KEBS is 2.0 while for WHO is 10 parts per million (Moraa, 2014).

The result of this study correlates with a study done by Health Canada, which revealed that 81% of the samples of lipsticks that were analyzed contained lead levels between 0.079 and 0.84 ppm, and in one special case lipstick contained 6.3 ppm (Zakaria and Bin Ho, 2015). This is an indication that even though brands of lipstick tested are safe for use in terms of their concentration of lead, there is a possibility of finding a brand of lipstick that contains higher levels of lead than permissible levels when large sample size is used. This is because levels of lead ranging from 0.079 to 0.84 ppm have been reported in lipsticks (Zakaria and Bin Ho, 2015). Lead levels of 0.20-31.70mg have also been reported in lipsticks (Faruruwa and Bartholomew, 2014) and lead levels of 0.020-30.979 mg/kg have also been reported in lipsticks (Surendra *et al.*, 2021). There is thus a need to monitor different brands of lipsticks in the market because chronic low-dose exposure to lead can result in several health complications such as reduced sperm count, high blood pressure, loss of memory, joint and muscle pain, headache, abdominal pain, miscarriage, and premature birth (Mayo Clinic staff, 2016).

4.4.2 Concentration of Lead in Face Powder

The levels of lead in face powders were determined in the 72 samples of face powders and the results tabulated in Table 4.10 below.

Table 4.10: Concentration of Lead in Face Powders

Mean levels (ppb) in different brands (Mean \pm SE n=3)													
Samples													
Batch	FD1	FD2	FD3	FD4	FD5	FD6	FD7	FD8	FD9	FD10	FD11	FD12	FD13
A	2.000 ^{aA} \pm 0.0007	3.100 ^{bB} \pm 0.0007	3.400 ^{aA} \pm 0.0007	2.000 ^{bB} \pm 0.0007	3.400 ^{aA} \pm 0.0007	3.400 ^{aA} \pm 0.0007	3.100 ^{bB} \pm 0.0007	2.000 ^{aA} \pm 0.0007	3.100 ^{bB} \pm 0.0007	2.000 ^{aA} \pm 0.0007	3.400 ^{bB} \pm 0.0007	3.100 ^{aA} \pm 0.0007	3.100 ^{aA} \pm 0.0007
B	1.200 ^{bB} \pm 0.0003	1.700 ^{aA} \pm 0.0003	1.100 ^{bB} \pm 0.0003	1.100 ^{aA} \pm 0.0003	1.200 ^{bB} \pm 0.0003	1.100 ^{bB} \pm 0.0003	1.700 ^{aA} \pm 0.0003	1.200 ^{bB} \pm 0.0003	1.200 ^{aA} \pm 0.0003	1.700 ^{bB} \pm 0.0003	1.100 ^{aA} \pm 0.0003	1.700 ^{bB} \pm 0.0003	1.700 ^{aA} \pm 0.0003
C	4.000 ^{aA} \pm 0.0013	5.300 ^{bB} \pm 0.0013	6.600 ^{aA} \pm 0.0013	4.000 ^{bB} \pm 0.0013	6.600 ^{aA} \pm 0.0013	5.300 ^{bB} \pm 0.0013	5.300 ^{bB} \pm 0.0013	4.000 ^{aA} \pm 0.0013	6.600 ^{bB} \pm 0.0013	4.000 ^{aA} \pm 0.0013	5.300 ^{bB} \pm 0.0013	6.600 ^{aA} \pm 0.0013	5.300 ^{bB} \pm 0.0013
p-value	0.004	0.001	0.001	0.003	0.004	0.003	0.003	0.003	0.004	0.001	0.001	0.002	0.004

Mean levels (ppb) in different brands (Mean \pm SE n=3)													
Batch	FD14	FD15	FD16	FD17	FD18	FD19	FD20	FD21	FD22	FD23	FD24	Mean	p-value
A	2.000 ^{bB} \pm 0.0007	3.400 ^{aB} \pm 0.0007	3.400 ^{aA} \pm 0.0007	2.000 ^{bB} \pm 0.0007	3.100 ^{aA} \pm 0.0007	2.000 ^{bB} \pm 0.0007	3.400 ^{aA} \pm 0.0007	3.100 ^{bB} \pm 0.0007	3.100 ^{bB} \pm 0.0007	3.400 ^{aA} \pm 0.0007	2.000 ^{bB} \pm 0.0007	2.800	0.004
B	1.200 ^{bB} \pm 0.0003	1.700 ^{aA} \pm 0.0003	1.100 ^{bB} \pm 0.0003	1.200 ^{aA} \pm 0.0003	1.100 ^{bB} \pm 0.0003	1.100 ^{bB} \pm 0.0003	1.700 ^{aA} \pm 0.0003	1.700 ^{aA} \pm 0.0003	1.100 ^{aA} \pm 0.0003	1.200 ^{bB} \pm 0.0003	1.200 ^{aA} \pm 0.0003	1.300	0.003
C	6.600 ^{aA} \pm 0.0013	4.000 ^{bB} \pm 0.0013	4.000 ^{bB} \pm 0.0013	5.300 ^{aA} \pm 0.0013	6.600 ^{bB} \pm 0.0013	4.000 ^{aA} \pm 0.0013	5.300 ^{bB} \pm 0.0013	6.600 ^{aA} \pm 0.0013	4.000 ^{bB} \pm 0.0013	6.600 ^{aA} \pm 0.0013	5.300 ^{bB} \pm 0.0013	5.300	0.004
p-value	0.002	0.003	0.003	0.004	0.005	0.004	0.004	0.003	0.001	0.004	0.004	0.003	

Mean values with the same small letters within the same row are not significantly different ($\alpha=0.05$) (Bonferroni post hoc test)

Mean values with the same capital letters within the same column are not significantly different ($\alpha=0.05$) (Bonferroni post hoc test)

The concentration of lead in batch C of face powder had the highest levels of lead (5.3 ppb), then batch A of face powder (2.8 ppb), and the lowest was in batch B (1.3 ppb). ANOVA test shows that the difference in means is statistically significant since the p-values are less than 0.05 the lowest threshold for values to be significant. Similar research conducted by Chauhan et al. (2010) revealed that the concentration of lead in face powder was between 0.24 to 0.38 ppm. A concentration of 9.1 ppm levels of lead has also been reported in face makeups (Elteгани *et al.*, 2013). Ahmed and Al Baker (2017) have also reported lead in face makeups hence posing a great danger to the users. The values are still lower than the maximum acceptable concentration of lead in cosmetics as stipulated by both KEBS and WHO which is 2ppm and 10 ppm respectively (Ekere, *et al.*, 2014).

4.4.3 Concentration of Cadmium in Lipsticks

The results reveal that in all the 72 samples of lipsticks tested, the concentration of cadmium was below the minimum level that is detectable by the AAS. These findings agree with a study done by Moraa (2014) in Kenya where all the cosmetics tested had cadmium concentrations that were below the limit of detection. A similar result by a study conducted by Faruruwa and Bartholomew (2014) revealed that two brands of lipstick samples bought from a superstore had cadmium concentration that was below the detectable limit; however, still on the same study sample of lipsticks bought in the open market had cadmium level ranging from 0.4 to 0.9 ppm. This is an indication that even though the brands of lipsticks investigated had levels of cadmium below the detectable limit, more samples of different brands need to be tested. This is because Ahmed and Al Baker (2017) have reported cadmium in face cosmetics and 8ppm of cadmium has also been reported in face makeups (Elteгани *et al.*, 2013). Additionally, cadmium levels of 0.010 to 0.920 mg/kg have also been reported in lipsticks (Surendra

et al., 2021). Cadmium causes lung diseases, increased blood pressure, and renal dysfunction (Darube *et al.*, 2007).

4.4.4 Concentration of Cadmium in Face Powder

The levels of cadmium in face powders were determined in the 72 samples of face powders and the results tabulated in Table 4.11 below.

Table 4.11: Concentration of Cadmium in Face Powder

Mean levels (ppb) in different brands (Mean \pm SE n=3)													
Samples													
Batch	FD1	FD2	FD3	FD4	FD5	FD6	FD7	FD8	FD9	FD10	FD11	FD12	FD13
A	2.900 ^{aA} \pm 0.0012	4.800 ^{aA} \pm 0.0012	4.900 ^{aA} \pm 0.0012	2.600 ^{aA} \pm 0.0012	4.800 ^{aA} \pm 0.0012	2.600 ^{aA} \pm 0.0012	2.900 ^{aA} \pm 0.0012	4.800 ^{aA} \pm 0.0012	2.600 ^{aA} \pm 0.0012	2.900 ^{aA} \pm 0.0012	4.800 ^{aA} \pm 0.0012	2.600 ^{aA} \pm 0.0012	2.600 ^{aA} \pm 0.0012
B	3.100 ^{aA} \pm 0.0013	3.400 ^{aA} \pm 0.0013	3.100 ^{aA} \pm 0.0013	1.100 ^{aA} \pm 0.0013	3.100 ^{aA} \pm 0.0013	1.100 ^{aA} \pm 0.0013	3.400 ^{aA} \pm 0.0013	3.400 ^{aA} \pm 0.0013	3.400 ^{aA} \pm 0.0013	3.100 ^{aA} \pm 0.0013	3.400 ^{aA} \pm 0.0013	1.100 ^{aA} \pm 0.0013	3.100 ^{aA} \pm 0.0013
C	2.200 ^{aA} \pm 0.0011	0.200 ^{aA} \pm 0.0011	0.200 ^{aA} \pm 0.0011	2.200 ^{aA} \pm 0.0011	0.200 ^{aA} \pm 0.0011	0.300 ^{aA} \pm 0.0011	0.300 ^{aA} \pm 0.0011	2.200 ^{aA} \pm 0.0011	0.200 ^{aA} \pm 0.0011	2.200 ^{aA} \pm 0.0011	0.300 ^{aA} \pm 0.0011	2.200 ^{aA} \pm 0.0011	0.300 ^{aA} \pm 0.0011
p-value	0.099	0.098	0.099	0.099	0.098	0.098	0.098	0.099	0.099	0.099	0.098	0.097	0.097
Mean levels (ppb) in different brands (Mean \pm SE n=3)													
Batch	FD14	FD15	FD16	FD17	FD18	FD19	FD20	FD21	FD22	FD23	FD24	Mean	p-value
A	2.600 ^{aA} \pm 0.0012	2.900 ^{aA} \pm 0.0012	4.800 ^{aA} \pm 0.0012	4.800 ^{aA} \pm 0.0012	2.600 ^{aA} \pm 0.0012	2.900 ^{aA} \pm 0.0012	4.800 ^{aA} \pm 0.0012	2.900 ^{aA} \pm 0.0012	2.600 ^{aA} \pm 0.0012	2.900 ^{aA} \pm 0.0012	2.900 ^{aA} \pm 0.0012	3.400	0.099
B	1.100 ^{aA} \pm 0.0013	1.100 ^{aA} \pm 0.0013	3.400 ^{aA} \pm 0.0013	1.100 ^{aA} \pm 0.0013	1.100 ^{aA} \pm 0.0013	3.400 ^{aA} \pm 0.0013	3.100 ^{aA} \pm 0.0013	3.100 ^{aA} \pm 0.0013	1.100 ^{aA} \pm 0.0013	3.400 ^{aA} \pm 0.0013	3.100 ^{aA} \pm 0.0013	2.500	0.099
C	2.200 ^{aA} \pm 0.0011	0.300 ^{aA} \pm 0.0011	0.200 ^{aA} \pm 0.0011	0.300 ^{aA} \pm 0.0011	0.200 ^{aA} \pm 0.0011	2.200 ^{aA} \pm 0.0011	0.200 ^{aA} \pm 0.0011	2.200 ^{aA} \pm 0.0011	0.300 ^{aA} \pm 0.0011	0.300 ^{aA} \pm 0.0011	0.200 ^{aA} \pm 0.0011	0.900	0.097
p-	0.097	0.097	0.098	0.099	0.099	0.099	0.098	0.097	0.097	0.099	0.099		

Mean values with the same small letters within the same row are not significantly different ($\alpha=0.05$) (Bonferroni post hoc test)

Mean values with the same capital letters within the same column are not significantly different ($\alpha=0.05$) (Bonferroni post hoc test)

Concentration of cadmium for the 72 samples of face powder was done. From Table 4.11, the results show that batch A of face powder had the highest mean of cadmium at 3.400 ppb, followed by batch B at 2.5 ppb, and the lowest was in batch C of the face powder at 0.9 ppb (parts per billion). However, the analysis of variance shows that there was no significant difference between the three batches of face powder since the p-values are above 0.05 for the values to be statistically significant.

Cadmium is used in cosmetics because of its deep yellow-to-orange pigmentation. It is thus used in low amounts in several cosmetics. The maximum permissible level of cadmium by KEBS is 0.1 (KEBS, 2018), while the WHO is 0.3 (Ekere, Ayogu, & Ihedioha, 2014). The highest level of cadmium recorded in this study is below the maximum acceptable limit recommended by both KEBS (KEBS, 2013) and WHO (Ekere, Ayogu, & Ihedioha, 2014). This result of cadmium in face powder is in line with a study conducted by Ekere *et al.*, (2014) whose result revealed that white face powder had a concentration of 0.02 ppm.

Similarly, a study conducted by Foroghi *et al.*, (2013) found concentrations of Cadmium to be ranging between 0.02 to 0.05 ppm in face powder. Cadmium can be infiltrated into the body through the skin and builds up in body organs like the liver and the kidney (Ekere *et al.*, 2014). It is highly toxic even in small concentrations and in human beings can cause renal dysfunction after long-term exposure of long period. While in high exposure cadmium can result in obstructive lung disease, increased blood pressure, myocardic dysfunctions, bone defects, and cadmium pneumonitis (Foroghi *et al.*, 2013). A study done by Moraa (2014) found that there are brands of face powder whose level of cadmium is below the detectable limit, while according to a study done by Ekere *et al.*, (2014), the brown face powder had no cadmium. Cadmium levels of

0.130 to 0.215 ppm have been reported in face powders (Eticha *et al.*, 2018). Another study by Ojezele *et al.*, 2018 also reports cadmium levels of 1.8 ppm in face powders. These studies show that it is possible to have brands of face powders with cadmium. Such brands are not safe for use since even at low levels cadmium is toxic.

4.4.5 Concentration of Chromium in Lipsticks

The levels of chromium metal in all 72 samples of lipsticks were determined using AAS. The concentration in all the brands of lipsticks in this study had a concentration that was below the machine-detectable limit. However, two of the batch C lipsticks had a concentration of 0.1 ppb and 0.9 ppb. These results agree with a study conducted by Sani *et al.* (2016) investigating levels of chromium in 10 brands of lipstick. The result revealed that 9 out of 10 lipsticks analyzed had a concentration below the detectable limit, while one brand had a concentration of 0.0016 ppm. A similar study conducted by Sahu *et al.*, (2014) analyzing 30 brands of lipstick revealed that 15 out of the 30 had chromium ranging from 0.0051 to 17.83 ppm. Chromium levels of 0.45 ppm to 7.83 ppm have been reported in lipsticks (Sahu *et al.*, 2014). The maximum permissible level of chromium in cosmetics by KEBS is 50.0 ppm (Batsgech, 2014), and also for WHO it is 50.00 ppm (WHO, 2003). The levels of chromium are therefore below the maximum permissible levels.

4.4.6 Concentration of Chromium in Face Powders

The levels of cadmium in face powders were determined in the 72 samples of face powders and the results tabulated in Table 4.12 below.

Table 4.12: Concentration of Chromium in the Face Powder

Mean levels (ppb) in different brands (Mean \pm SE n=3)													
Samples													
Batch	FD1	FD2	FD3	FD4	FD5	FD6	FD7	FD8	FD9	FD10	FD11	FD12	FD13
A	1.200 ^{aA} \pm 0.0010	2.600 ^{aA} \pm 0.0010	3.100 ^{aA} \pm 0.0010	2.600 ^{aA} \pm 0.0010	3.100 ^{aA} \pm 0.0010	1.200 ^{aA} \pm 0.0010	3.100 ^{aA} \pm 0.0010	1.200 ^{aA} \pm 0.0010	3.100 ^{aA} \pm 0.0010	1.200 ^{aA} \pm 0.0010	2.600 ^{aA} \pm 0.0010	3.100 ^{aA} \pm 0.0010	3.100 ^{aA} \pm 0.0010
B	1.900 ^{aA} \pm 0.0005	2.700 ^{aA} \pm 0.0005	2.900 ^{aA} \pm 0.0005	2.900 ^{aA} \pm 0.0005	1.900 ^{aA} \pm 0.0005	2.700 ^{aA} \pm 0.0005	2.900 ^{aA} \pm 0.0005	2.700 ^{aA} \pm 0.0005	1.900 ^{aA} \pm 0.0005	1.900 ^{aA} \pm 0.0005	2.700 ^{aA} \pm 0.0005	2.900 ^{aA} \pm 0.0005	2.900 ^{aA} \pm 0.0005
C	0.900 ^{aA} \pm 0.0001	1.000 ^{aA} \pm 0.0001	1.000 ^{aA} \pm 0.0001	1.000 ^{aA} \pm 0.0001	1.000 ^{aA} \pm 0.0001	1.000 ^{aA} \pm 0.0001	0.900 ^{aA} \pm 0.0001	1.000 ^{aA} \pm 0.0001	1.000 ^{aA} \pm 0.0001	0.900 ^{aA} \pm 0.0001	1.000 ^{aA} \pm 0.0001	1.000 ^{aA} \pm 0.0001	1.000 ^{aA} \pm 0.0001
p-value	0.058	0.058	0.057	0.057	0.057	0.058	0.059	0.058	0.056	0.056	0.059	0.059	0.059
Mean levels (ppb) in different brands (Mean \pm SE n=3)													
Batch	FD14	FD15	FD16	FD17	FD18	FD19	FD20	FD21	FD22	FD23	FD24	Mean	p-value
A	2.600 ^{aA} \pm 0.0010	1.200 ^{aA} \pm 0.0010	2.600 ^{aA} \pm 0.0010	1.200 ^{aA} \pm 0.0010	1.200 ^{aA} \pm 0.0010	1.200 ^{aA} \pm 0.0010	2.600 ^{aA} \pm 0.0010	3.100 ^{aA} \pm 0.0010	3.100 ^{aA} \pm 0.0010	2.600 ^{aA} \pm 0.0010	2.600 ^{aA} \pm 0.0010	2.300	0.058
B	2.900 ^{aA} \pm 0.0005	2.700 ^{aA} \pm 0.0005	2.900 ^{aA} \pm 0.0005	1.900 ^{aA} \pm 0.0005	1.900 ^{aA} \pm 0.0005	1.900 ^{aA} \pm 0.0005	2.700 ^{aA} \pm 0.0005	2.900 ^{aA} \pm 0.0005	2.700 ^{aA} \pm 0.0005	1.900 ^{aA} \pm 0.0005	2.700 ^{aA} \pm 0.0005	2.500	0.058
C	1.000 ^{aA} \pm 0.0001	1.000 ^{aA} \pm 0.0001	0.900 ^{aA} \pm 0.0001	0.900 ^{aA} \pm 0.0001	1.000 ^{aA} \pm 0.0001	0.900 ^{aA} \pm 0.0001	1.000 ^{aA} \pm 0.0001	1.000 ^{aA} \pm 0.0001	1.000 ^{aA} \pm 0.0001	0.900 ^{aA} \pm 0.0001	0.900 ^{aA} \pm 0.0001	1.000	0.057
p-value	0.059	0.059	0.057	0.057	0.057	0.057	0.057	0.059	0.058	0.058	0.059		

Mean values with the same small letters within the same row are not significantly different ($\alpha=0.05$) (Bonferroni post hoc test)

Mean values with the same capital letters within the same column are not significantly different ($\alpha=0.05$) (Bonferroni post hoc test)

The level of chromium in face powder was analyzed and the results are presented in table 4.12 above. The p-values are above 0.05 hence no significant difference between the means. The low level of chromium detected in face powder is comparable to levels recorded by Sani *et al.*, (2016), whose results investigating 20 different brands of face powder revealed concentrations ranging from 0.000 to 0.0120 ppm. Chromium levels of 83.67 $\mu\text{g/g}$ have been reported in face powders (Saah *et al.*, 2022). This poses a great risk to the users. Additionally, chromium levels of 2.5 ppm have been reported in face powders Ojezele *et al.*, 2018). There is therefore, a need to monitor the concentration of chromium because long-term exposure to chromium increases the risk of lung cancer and also damages the small capillaries in the intestines and kidneys (Sahu *et al.*, 2014).

4.4.7 Concentration of Nickel in Lipsticks

The levels of Nickel in lipsticks were determined in the 72 samples of lipsticks and the results tabulated in Table 4.13 below

Table 4.13: Concentration of Nickel in Lipsticks

Mean levels (ppb) in different brands (Mean \pm SE n=3)													
Samples													
Batch	LS1	LS2	LS3	LS4	LS5	LS6	LS7	LS8	LS9	LS10	LS11	LS12	LS13
A	1.900 ^{aA} \pm 0.0003	1.800 ^{bB} \pm 0.0003	1.300 ^{aA} \pm 0.0003	1.800 ^{bB} \pm 0.0003	1.900 ^{aA} \pm 0.0003	1.300 ^{bB} \pm 0.0003	1.800 ^{aA} \pm 0.0003	1.900 ^{bB} \pm 0.0003	1.800 ^{aA} \pm 0.0003	1.800 ^{aA} \pm 0.0003	1.900 ^{bB} \pm 0.0003	1.300 ^{aA} \pm 0.0003	1.300 ^{aA} \pm 0.0003
B	2.900 ^{bB} \pm 0.0004	3.600 ^{aA} \pm 0.0004	2.800 ^{bB} \pm 0.0004	2.800 ^{bB} \pm 0.0004	2.900 ^{aA} \pm 0.0004	3.600 ^{bB} \pm 0.0004	3.600 ^{bB} \pm 0.0004	2.800 ^{aA} \pm 0.0004	2.900 ^{bB} \pm 0.0004	2.800 ^{bB} \pm 0.0004	3.600 ^{bB} \pm 0.0004	2.900 ^{bB} \pm 0.0004	2.800 ^{bB} \pm 0.0004
C	0.600 ^{aA} \pm 0.0006	0.600 ^{bB} \pm 0.0006	0.700 ^{aA} \pm 0.0006	0.700 ^{aA} \pm 0.0006	0.700 ^{bB} \pm 0.0006	0.600 ^{aA} \pm 0.0006	0.600 ^{bB} \pm 0.0006	0.600 ^{aA} \pm 0.0006	0.600 ^{bA} \pm 0.0006	0.600 ^{aA} \pm 0.0006	0.600 ^{aA} \pm 0.0006	0.700 ^{aA} \pm 0.0006	0.600 ^{bB} \pm 0.0006
p-value	0.001	0.002	0.001	0.001	0.002	0.001	0.001	0.003	0.003	0.002	0.002	0.001	0.001

Mean levels (ppb) in different brands (Mean \pm SE n=3)													
Batch	LS14	LS15	LS16	LS17	LS18	LS19	LS20	LS21	LS22	LS23	LS24	Mean	p-value
A	1.300 ^{bB} \pm 0.0003	1.800 ^{aA} \pm 0.0003	1.000 ^{bB} \pm 0.0003	1.900 ^{aA} \pm 0.0003	1.900 ^{aA} \pm 0.0003	1.800 ^{bB} \pm 0.0003	1.300 ^{aA} \pm 0.0003	1.800 ^{bB} \pm 0.0003	1.900 ^{aA} \pm 0.0003	1.300 ^{bB} \pm 0.0003	1.900 ^{aA} \pm 0.0003	1.700	0.001
B	2.900 ^{aA} \pm 0.0004	3.600 ^{bB} \pm 0.0004	2.800 ^{aA} \pm 0.0004	2.900 ^{bB} \pm 0.0004	3.600 ^{aA} \pm 0.0004	2.900 ^{bB} \pm 0.0004	3.600 ^{aA} \pm 0.0004	2.800 ^{bB} \pm 0.0004	2.800 ^{bB} \pm 0.0004	2.900 ^{aA} \pm 0.0004	3.600 ^{bB} \pm 0.0004	3.100	0.001
C	0.600 ^{bB} \pm 0.0006	0.600 ^{aA} \pm 0.0006	0.600 ^{bB} \pm 0.0006	0.700 ^{aA} \pm 0.0006	0.700 ^{bB} \pm 0.0006	0.600 ^{aA} \pm 0.0006	0.600 ^{bB} \pm 0.0006	0.600 ^{aA} \pm 0.0006	0.700 ^{bB} \pm 0.0006	0.600 ^{aA} \pm 0.0006	0.700 ^{bB} \pm 0.0006	0.600	0.002
p-value	0.003	0.001	0.002	0.002	0.002	0.001	0.002	0.001	0.001	0.002	0.002		

Mean values with the same small letters within the same row are not significantly different ($\alpha=0.05$) (Bonferroni post hoc test)

Mean values with the same capital letters within the same column are not significantly different ($\alpha=0.05$) (Bonferroni post hoc test)

The levels of nickel in 72 samples of the lipstick brands were determined using AAS. The result in Table 4.13 shows that batch B had the highest concentration of nickel (3.100 ppb), followed by batch A (1.700 ppb) and the lowest was in batch C (0.600 ppb). This mean difference is statistically significant because the values are less than 0.05 the minimum threshold for values to be significant. The low level of nickel in lipstick recorded in the current study agrees with a study done by Gonzalez (2014), which revealed that the concentration of nickel in lipstick was 0.0020 ppm. However other studies have found higher concentrations. A good example is a study conducted by Sahu *et al.*, (2014), which recorded that 13 out of 30 different brands of lipsticks analyzed had nickel in them. Nickel levels of 0.57 ppm to 9.18 ppm have been reported in lipsticks (Sahu *et al.* (2014). These levels in this study were lower than the highest permissible levels in lipsticks as set by KEBS and WHO. The maximum permissible level of nickel set by KEBS and WHO is 200 ppm.

4.4.8 Concentration of Nickel in Face Powders

The levels of Nickel in face powders were determined in the 72 samples of face powders and the results tabulated in Table 4.14 below.

Table 4.14: Concentration of Nickel in Face Powder

Mean levels (ppb) in different brands (Mean \pm SE n=3)													
Samples													
Batch	FD1	FD2	FD3	FD4	FD5	FD6	FD7	FD8	FD9	FD10	FD11	FD12	FD13
A	4.600 ^{aA} \pm 0.0005	4.100 ^{bB} \pm 0.0005	5.000 ^{aA} \pm 0.0005	4.600 ^{bB} \pm 0.0005	5.000 ^{aA} \pm 0.0005	5.000 ^{aA} \pm 0.0005	4.600 ^{bB} \pm 0.0005	5.000 ^{aA} \pm 0.0005	4.600 ^{bB} \pm 0.0005	4.600 ^{aA} \pm 0.0005	4.100 ^{bB} \pm 0.0005	5.000 ^{aA} \pm 0.0005	4.100 ^{bB} \pm 0.0005
B	19.50 ^{bB} \pm 0.0045	18.70 ^{aA} \pm 0.0045	19.50 ^{bB} \pm 0.0045	18.70 ^{aA} \pm 0.0045	26.80 ^{bB} \pm 0.0045	19.50 ^{bB} \pm 0.0045	19.50 ^{aA} \pm 0.0045	18.70 ^{bB} \pm 0.0045	26.80 ^{aA} \pm 0.0045	26.80 ^{bB} \pm 0.0045	18.70 ^{aA} \pm 0.0045	19.50 ^{bB} \pm 0.0045	19.50 ^{aA} \pm 0.0045
C	BLD	BLD	BLD	BLD	BLD	BLD	BLD	BLD	BLD	BLD	BLD	BLD	BLD
p-value	0.003	0.003	0.002	0.003	0.003	0.001	0.002	0.002	0.002	0.003	0.003	0.002	0.003

Mean levels (ppb) in different brands (Mean \pm SE n=3)													
Batch	FD14	FD15	FD16	FD17	FD18	FD19	FD20	FD21	FD22	FD23	FD24	Mean	p-value
A	4.100 ^{bB} \pm 0.0005	4.100 ^{aA} \pm 0.0005	5.000 ^{bB} \pm 0.0005	4.600 ^{aA} \pm 0.0005	5.000 ^{bB} \pm 0.0005	4.600 ^{aA} \pm 0.0005	4.100 ^{bB} \pm 0.0005	5.000 ^{aA} \pm 0.0005	4.100 ^{bB} \pm 0.0005	4.600 ^{aA} \pm 0.0005	4.100 ^{bB} \pm 0.0005	4.600	0.003
B	19.50 ^{aA} \pm 0.0045	26.80 ^{bB} \pm 0.0045	18.70 ^{aA} \pm 0.0045	26.80 ^{bB} \pm 0.0045	26.80 ^{aA} \pm 0.0045	26.80 ^{bB} \pm 0.0045	18.70 ^{aA} \pm 0.0045	19.50 ^{bB} \pm 0.0045	18.70 ^{aA} \pm 0.0045	18.70 ^{bB} \pm 0.0045	26.80 ^{aA} \pm 0.0045	21.700	0.003
C	BLD	BLD	BLD	BLD	BLD	BLD	BLD	BLD	BLD	BLD	BLD		
p-value	0.003	0.002	0.003	0.003	0.003	0.003	0.002	0.002	0.001	0.002	0.003		

Mean values with the same small letters within the same row are not significantly different ($\alpha=0.05$) (Bonferroni post hoc test) Mean values with the same capital letters within the same column are not significantly different ($\alpha=0.05$) (Bonferroni post hoc test)

The level of nickel in face powder was determined in the 72 samples of face powder. The results in Table 4.14 show that the concentration of nickel in batch C of the face powder was below the detectable limit of the machine. Batch B had the highest level of nickel (21.700 ppb) and batch A with lowest (4.600 ppb). This difference is statistically significant because the p-values are less than 0.05 the maximum threshold for the values to be significant. The levels of nickel in face powder are below the maximum permissible level, which is 200 ppm as set by WHO and KEBS. The low record of concentration of nickel is similar to the findings of Faruruwa and Bartholomew (2014), which found levels of Ni to range from 0.0141 ppm to 0.0398 ppm in face powder.

CHAPTER FIVE

CONCLUSIONS AND RECOMMENDATIONS

5.1 Conclusions

The finding of the study indicates that lead, cadmium, chromium, and nickel were detectable in some brands of lipsticks and face powder. All the levels of lead, cadmium, chromium, and nickel in the study were lower than the maximum permissible limits set by KEBS and WHO (Ekere et al., 2014). However, this does not guarantee safety because continuous use leads to accumulation which is dangerous to human health.

From the findings of this study, levels of lead and nickel in lipsticks and face powders were statistically significant. Chromium and cadmium levels in face powders were not significantly different. Levels of metals in Batch B and C for both lipsticks and face powders were significantly different. Levels of heavy metals in batch A were significantly different for lipsticks and not face powders. Levels of cadmium and chromium in face powder were not significantly different while levels of nickel in lipsticks and face powders were statistically significant.

5.2 Recommendations

5.2.1 Recommendations from this study

It is recommended that users of face powders and lipsticks should take precautions because these products contain heavy metals, especially lipsticks. After all, levels of metals in all the batches tested A, B, and C were significantly different. Continuous use may lead to accumulation in the body higher than the limits recommended by KEBS and WHO.

5.2.2 Recommendations for further study

- i. Other face cosmetics like eye shadows, lip glow, eye shadows, eye pencils, and mascara should be studied to determine the levels of heavy metals in them.
- ii. Other heavy metals like mercury, manganese, arsenic, manganese, and iron should be analyzed for all cosmetics products.

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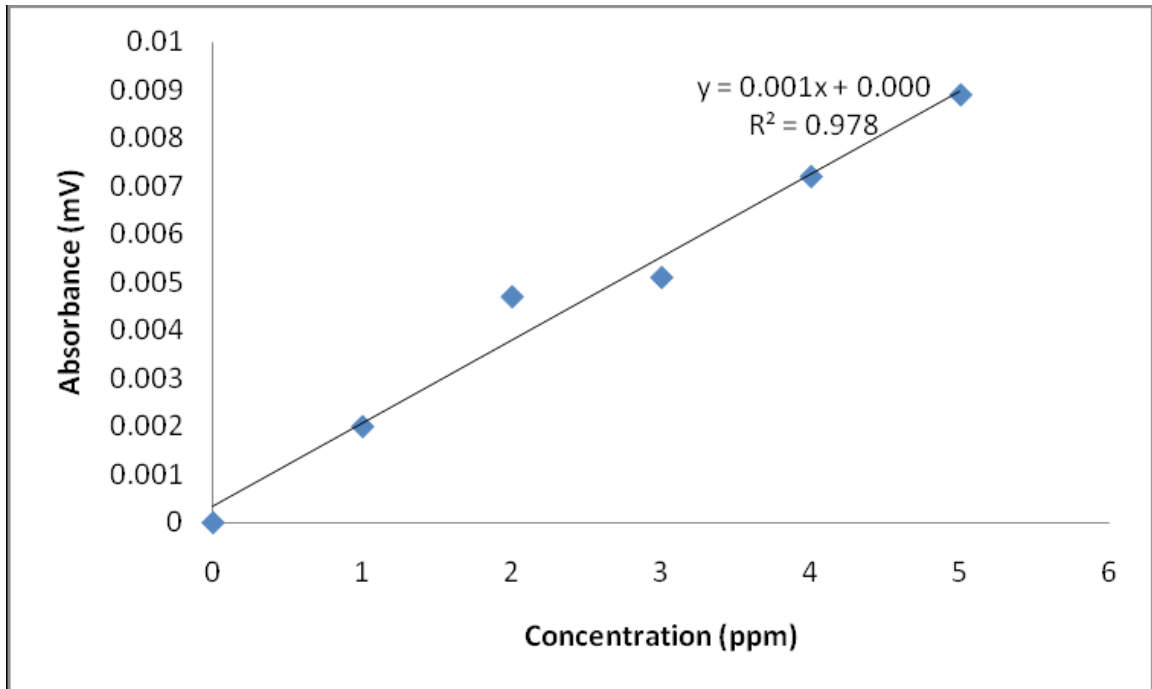
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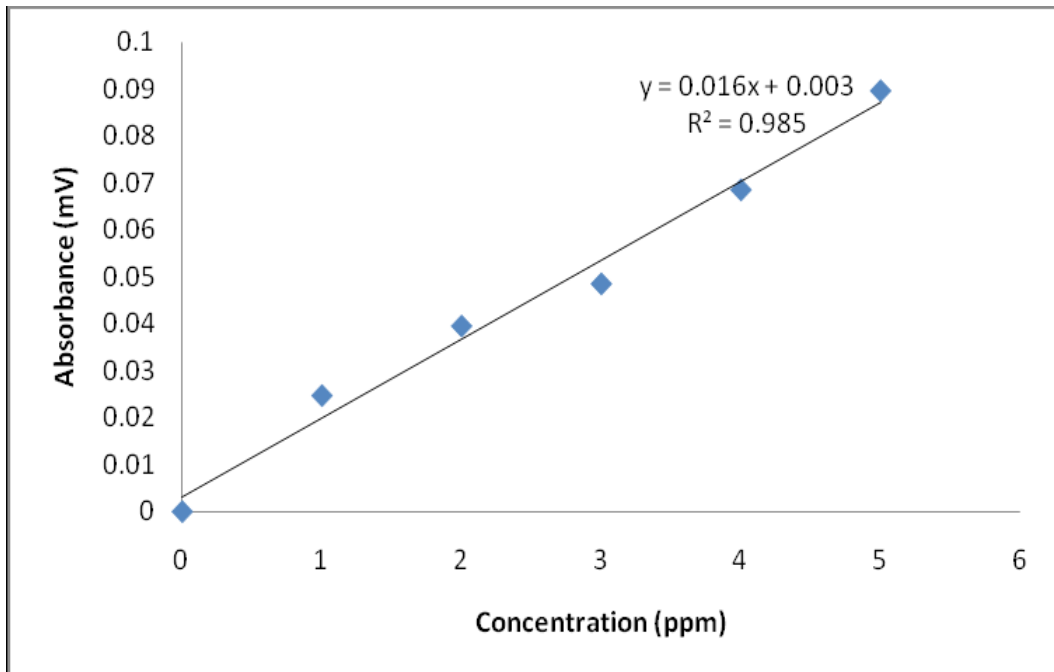
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APPENDICES

Appendix I: Calibration curve for cadmium standard



Appendix II: Calibration curve for chromium standard

Appendix III: Calibration curve for Nickel standard