NEAR EAST UNIVERSITY

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DEPARTMENT OF PHARMACY

DETERMINING TOXIC HEAVY METAL (LEAD) IN EYELINERS (SURMA) MARKETED IN TURKEY

M.Sc. THESIS

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Nicosia

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Approval

We certify that we have read the thesis submitted by Fadwa Elkawlak titled **"Determining Toxic Heavy Metal (Lead) in Eyeliners (Surma) Marketed in Turkey**" and that in our combined opinion it is fully adequate, in scope and in quality, as a thesis for the degree of Master of Educational Sciences.

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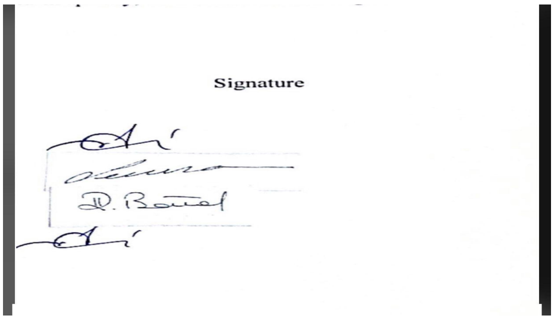

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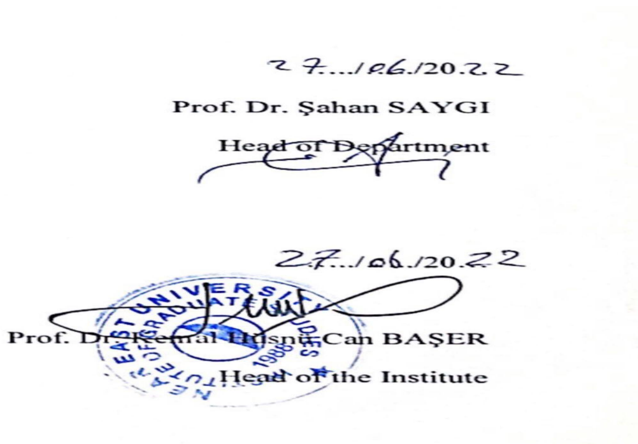

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DECLARATION

I hereby declare that all information, documents, analysis, and results in this thesis have been collected and presented according to the academic rules and ethical guidelines of the Institute of Graduate Studies, Near East University. As required by these rules and conduct, I have fully cited and referenced information and data that are not original to this study

Fadwa Ghassan Kamal Hamd Elkawlak

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DEDICATION

To my parents ……

Fadwa Ghassan Kamal Hamd Elkawlak

Abstract

Determining Toxic Heavy Metal (Lead) in Eyeliners (Surma) Marketed in Turkey.
Fadwa Elkawlak

MA, Department of Pharmacy

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Objective: The major objective of this thesis was to investigate the safety of commercial eyeliner brands in Turkey based on the determined levels of lead (Pb). Furthermore, the thesis aimed to determine the level of toxic heavy metal (lead) in eyeliners marketed in Turkey as well as determine if the selected samples of eyeliners had acceptable international standards in comparison.

Method: 50 samples of eyeliners products marketed and sold in Turkey, were selected at random. 84% of the samples were Turkish brands, 8% were from France, 4% of the brands were from the United Kingdom, and finally, 4% were from United States. These samples were sent to AZOLAB in Istanbul, Turkey for the analysis of lead (Pb) concentration by using the Inductively Coupled Plasma Mass Spectrometry (ICP-MS) technique after suitable digestion process and recovery. The concentration of the Pb in the 50 samples were compared with the three international Pb permissible standard i.e. WHO/ USFDA (10*mm/Kg*), Canada (10*mm/Kg)* and Federal Office of Consumer Protection and Food Safety (BVL) (*2mm/Kg*).

Result: From the results, two of the Turkish brand had a lead concentration level of 12.41mg/kg and 4.81mg/kg, which exceeded the threshold for the German BVL. Furthermore, only two samples were compromised which accounts for 4.8% of the 42 Turkish samples, that violated the German BVL, the remaining 40 samples passed the BVL set limit of 2mg/kg. In comparison, to other brands from France, United Kingdom and the United States, all Pb level were below the detectable limits.

Conclusion: Although, there were only two samples that exceeded the German BVL limit, the safety of eyeliner brands marketed in Turkey still need to be investigated thoroughly to identify the presence and amounts of hazardous contents such as Lead. Furthermore, assessment of estimated background exposures and comparison to health-based international standards need to be carried out.

Key words: Kohl, Surma, Eyeliner, Lead (Pb), ICP-MS

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1. INTRODUCTION

Over the years, the beauty make-up segment and in particular, cosmetic products significantly affected millions of people's lives all in almost every part of theword (Nouioui et al., 2016). According to Sahu et al. (2014), a cosmetic can be defined as any sort of article that is meant to be sprinkled, rubbed, poured, sprayed or applied to a selected part of an individual body or whole body, in order to promote attractiveness, improve beauty, cleanse, or alter the appearance of the individual. Usually, cosmetic products are a mixture of variety of compounds such as surfactants, oils, pigments etc., and so, most consumers purchasing these cosmetic products expect these products to be stable, long lasting, effective and most importantly, safe for use. From the various variety of cosmetic products out there in the markets, cosmetic products can be distinguished by their functionality and usage. These includes powder and rouge (utilised for colouring the face, improve flaws and lighten, to give the impression of youth and health), lipstick and lip gloss (utilised for colouring the lips), mascara (utilised for enhancing the eye lashes of the individuals), nail polish (utilised for toenails and finger nails) and finally, the eye liners and eye shadows (used for colouring the eyelids) (Sani, 2016).

Although cosmetics have been greatly celebrated as a key component for enhancing attractiveness and self-care since ancient times, the chemicals that have been utilised for making such natural cosmetic in the past are still being used by cosmetic brands to manufacture their products. As a result, many cosmetics products can potentially contain heavy metals such as cadmium, lead, chromium, mercury, arsenic, cobalt, zinc and nickel (Abdul et al., 2017). Such amounts of traces of heavy metals are also amongst the contents used for making some cosmetic or as impurities from the raw materials that are used in the manufacturing process. The key ingredients that is prevalent in most of the cosmetic brands includes emulsifiers, waters, preservatives (parabens), moisturizers as an emollient (Lecithin, agar), thickeners (glycol stearate, cellulose), fragrances, colours and PH stabilizers (Sodium hydroxide) (Fletcher et al., 2008). Most times, these cosmetics are loaded with these chemicals to extend their shelf life, improve their quality, provide selected and diverse colours, and any other desired feature. Nonetheless, the use of heavy metals as an ingredient in cosmetics (i.e. mercury) are illegal and prohibited in many advanced nations; however, even with the best manufacturing processes there could be some such impurities that contaminates the cosmetic product (Al-Saleh and Al-Enai, 2011). One reason for this occurrence is that some of these metallic impurities exist naturally within the environment, and so, are difficult to avoid. Therefore, exposure to high concentrations of these heavy metals can have adverse negative impact on the human body such as allergy, hypersensitivity, and even carcinogenic effects in some cases.

For over 2000 years, lead (Pb) poisoning has been recognised as a serious health hazard that can compromise the human body. The characteristic feature of lead toxicity includes neuropathy, anemia, sterility, nephropathy, and colic. Even exposure to minute amounts of lead can be linked to learning impairments, impaired cognitive functionality, decreased hearing, and behavioural abnormalities (Saxena et al., 2006). Exposure to lead has also been linked to reduced infertility in women and men, miscarriages, hormonal changes, puberty delays in girls, and menstrual irregularities (Yusuf et al., 2010). A number of reports have surfaced over the years on the presence of leads in branded cosmetic products (Al-Saleh et al., 2011). Usually, lead can potentially finds its way into cosmetic products as compounds such as Pb sulphide, Pb chromate, Pb acetate, and Pb carbonate, because they are usually utilised as colour pigments (Al-Saleh et al., 2011).

Eye liners, usually utilised by women and children have been reported to contain toxic metal lead. These are cosmetic products that are used to define the eyes, and is applied around the contours of the eyes in order to create an aesthetic effect on the individuals' eyes. These types of cosmetics can be in the form of a pencil, gel, cream, sticks or pressed powder, and are highly pigmented makeup products. For instance, a traditional cosmetic, known as "Surma", is made from antimony trisulphide (Sb_2S_3), and was used as an eye liner and medicinal eye drop in ancient Egypt (Gunn, 2014). It is also known by many other names, by other nations such as Kohl, Kajal and Tiro. In contrast, most modern eyeliners are composed of three major ingredients i.e. film formers, thickening agents, and pigments. Film formers are usually designed to lay down a thin layer on the skin in order to ease up the application process. Following this is the thickening agent, which constitutes the higher percentage of eyeliner ingredients both by volume and weight. This includes gums, clays and waxes, of which most of these ingredients are naturally derived. One of the more used waxes is the Japanese wax, which is extracted from the succedanea plant. Finally, the pigment which makes up the colour of the eyeliner. The most widely used pigments for eyeliners include iron oxides for brown or black shades, chromium oxide for green, titanium dioxide for lighter colours (including white) and ultramarine for blue (Zee, 2019). This is regarded as a safer eyeliner in comparison with surma, however, some brands still utilised traditional surma ingredients for thier eyeliner production (Tiffany-Castiglioni, Barhoumi, and Mouneimne, 2012)

In the last 10 years, the most common composition of Surma has been changed to galena stone, which is based on a lead compound known as Pb_2SO_4 and has gained widespread popularity in East Africa, North, Middle East, and in Asia (Such Nepal, Iran, Bangladesh, and Pakistan). There are some studies that have shown the beneficial properties of Kohl as a stimulator of non-specific immunological defences (due to nitric oxide production) as well as an antimicrobial drug (Tapsoba et al., 2010). However, other studies have highlighted potential health risk due to the Kohl due to heavy metals high concentration like (Bassal, Mahmoud, and Fayez-Hassan, 2013). Therefore, lead is major cause of Surma toxicity due to the high concentration of this element in consistent and regular users of this cosmetic (Gouitaa et al., 2016). Moreover, other studies have shown that the lead levels are very high in this cosmetic and can be linked to the development of plumbism (Lekouch, Sedki, Nejmeddine, and Gamon, 2001). Additionally, the composition and method in which Surma based product is applied are factors that can lead to harmful influence on the user. As a matter of fact, this cosmetic is usually mixed with saliva before it is used on the eyebrows or skin of women and children (Serra-Delgado et al., 2021). Therefore, Surma can enter into the body through the skin or orally.

In all, it is clear that there needs to be more research done on cosmetics as these are products that are applied directly to the human skin and are kept on for a prolonged period of time. Furthermore, assessing the levels of heavy metals as a toxic substance is of utmost importance in the manufacturing of cosmetic products. Naturally, cosmetic products need to undergo several safety test and standardization test in order for it to be placed on the market, unfortunately there could be potential traces of these heavy metals (toxins) in some cosmetic brands if proper cautionary measures aren't followed adequately. Eyeliners are directly applied around the eye region and so, are potentially riskier if direct contact comes in contact with the eyes.

In this study, we will focus on a specific type of cosmetic product, which is eyeliners. To further streamline this research, lead (Pb) as a heavy metal toxic substance will be investigated in eyeliner cosmetic products manufactured and marketed in Turkey by using ICP-MS technique.

2. EYELINER, SURMA AND LEAD TOXICITY

2.1. Overview and Background of Cosmetics

The application of various oils and materials on oneself is a practice that dates back to 10,000BC. Moreover, one civilization that is well documented for utilizing the various types of herbs and poultices, were the Egyptians, who laid the foundation to today's mainstream cosmetics. Furthermore, people have been known to use metarials that are toxic like burnt almonds as well as copper to create colours that can be used to sort of beautify the face such as *Kohl* eyeliner. The *Kohl* eyeliner, was believed for several years to be an essential product for medicine which included reducing the sun's intensity to increase the eyesight. Also, oil and ointments have been known to provide much needed relief to the harsh desert landscape, and so, were essentially very important and heavily priced commodities (Lucas, 1930; Tatomir, 2016).

The word cosmetics was derived the Latin word, "Cosmetae". This is a word originally used by Romans which essential means the women and men committed to overwhelm Romans with fashion and beauty. Furthermore, cosmetic usage nowadays consists of history that is rich and broad. At one time in the 20th century, cosmetic was labelled as inappropriate and unclassical to fit into the context of a respectable woman. Therefore, women who didn't want to be labelled by the public as inappropriate and unclassed, were limited to the use of simple powders. Also, burned match sticks were used to darken the areas around the eyes. Over time, this negative ideology began to dwindle, as cosmetics began to gain widespread acceptance and adoption, it was made spread widely in Paris by a Russian ballet who happened to have a great impact on the culture due to its widespread popularity amongst tourist being a major source of attraction. Also, cosmetics coming into the big screen, Hollywood, increased its popularity as actors utilized cosmetics for preparing for scenes in a movie or play. Take for instance, in daily papers, the faces of ballerians with make up as well as cosmetic adoption to the silver screen, and so, this changed the negative narrative of cosmetic, making it more appealing to the public. There were many advancements in technology, that made cosmetics design and concoctions more popular over time, and so, overtime it was accepted as the norm of how girls were to be groomed. Nonetheless, the popularity of cosmetics grew amongst the general public but there were great concerns on the toxic nature of some of the ingredients that was used for making these cosmetics. There was research carried out by the British Medical Journal in 1960 titled “Safe Cosmetics” and following the publication of this article, one year later, the British Medical Journal printed another article named, “Hazards from Cosmetics and Toilet Preparations” (Alsherari, 2019; Alberman, 1958). Both of these articles gave great insight in to the toxicity of the ingredients used in the available cosmetics, as well as the detrimental impact that it had on the human body. It was even more recently, in the 21st century, that the nature of the toxic ingredients in cosmetics began to cause great concern as there was more growing awareness by consumers on the toxicity of such ingredients used in making cosmetics. And so, cosmetic laws and regulations needed to be put in place, however, this differed from nations to nations, like those of the European union standing strong on subject matter than the United States, embracing a laxer approach. For the case of the United States, the concerns raised by the consumers on the issue of toxicity amongst cosmetics that the Food and Drug Administration (FDA) did not fully follow up on. Also, the FDA couldn’t mention products that were proved to be harmful to customers (Liang and Hartman, 1998). Nonetheless, the FDA was instrumental in carrying out surveys on heavy metals like mercury, chromium, nickel, cadmium and also lead. These elements posed high probability of chronic toxicity when exposed to these elements on a long term. Interestingly, in cosmetics very low concentration to the metals is allowed even though it was disapproved and prohibited even as additional elements. Studies by the FDA actually showed that several cosmetic products have consist of more than the allowed amounts of these heavy metals (FDA, 2019). The methodology that is employed by the FDA is the method of total dissolution whereby hydrofluoric acid is utilized for to tell the concentration of heavy metals within the substance being tested, however, there are limits to this approach (FDA, 2019). However, in the European Union things are done differently as regulations are being executed, where companies are supposed to give a report any instance of harm that the consumer might have experience while using your products. Also, the cosmetic industries have to proof the efficacy and how safe some contents are after deploying the products to the market (Bowman et al., 2010). Therefore, due to the lax regulations being employed by the FDA and the judicial accountability of cosmetic companies, it is absolutely vital that external parties carry out independent studies on the potential risk associated with heavy metals like lead. Moreover, research into eyeliners have been limited and so, researches like that will be an addition to the discussion being taken by so many nations in support of more regulatory actions to be taken.

2.2. Trace Metals (TMs) as an Unavoidable Ingredients in the Cosmetics Formulation

Throughout the years, chemical compounds like dye, natural mineral mica, shine, and other pigments used for coloring have been included in the production of cosmetic products, like lip cosmetics to enhance their brightness, therefore producing a quality that is healthier and increased effectiveness. Consequently, the inclusion such chemicals led to involvement of TMs within the production of cosmetics, that includes arsenic (As), antimony (Sb), cobalt (Co), cadmium (Cd), lead (Pb), chromium (Cr), copper (Cu), manganese (Mn) and nickel (Ni) (Nourmoradi et al., 2013). Various harmful results of using cosmetics of the TMs mentioned above as key ingredients in cosmetics production are shown in Fig. 2.1. Among these TMs cadmium, chromium, and nickel are identified as the leading cancer-causing elements by the IARC, (IARC, 2011). A number of reviews claimed that being exposed to these elements or metals for a long period of time had a relationship with higher risk of several infectious diseases like cardiovascular and neurologic disorders (Hepp et al., 2014). The arsenic included in the scream for skin and powder for make-up production causes circulatory, peripheral neuropathy, problems related to the skin, and a greater chance of having urinary as well as gastrointestinal tract cancers. A low concentration of the arsenic was observed in shampoo, eye pencils, hair conditioner, eye shadows and several showering products (Sneyers et al., 2009). Breathing in antimony, mainly found in face powder, skin creams, eye pencils, and eye shadows and lipsticks, could be the cause of respiratory disorders and harmful gastrointestinal symptoms such as abdominal pains, diarrhoea and vomiting.

From research carried out by colleagues and Sneyers (2009), the researcher's detected low amounts of antimony 0.0134–0.265, 0.157–0.76 and 0.179–0.46 µg/g for skin cream, eye shadow and makeup powder respectively. In respect to its colouring property, cadmium is used in the production of several cosmetic products like skin, hair creams and lipsticks (Godt et al., 2006). Being exposed to cadmium for a long period of time can cause may lead to kidney damage and tumours on the skin. Bone brittleness is another result of exposure to cadmium and thus, it increases

bone fractures chances (Pereira and Pereira, 2018). Several researches are analyzing chromium; that includes eyeliner, eye shadow, makeup powders and lipstick (Gondal et al., 2010; Lim et al., 2018). Researches have been carried out to investigate the lip cosmetic samples containing chromium levels that ranged from LOD–9.72 µg/g (Liu et al., 2013). Chromium can be found in two states of valence, and also states of oxidation, Cr6+ and Cr3+ which might cause contact allergies related to dermatitis (Thyssen et al., 2007). A recent research, Lim et al., (2018) separated Cr6+ and Cr, and it was found that Cr6+ concentration in most coloured cosmetics varrying from zero to 39.2 µg/g. It is worth noting that Cr6+ is more harmful than Cr3+, however, cosmetics containing Cr6+ are not banned by regulation officials. Consequently, it is very important to monitorcosmetics that contain Cr because it's very harmful to human health. Mercury is also found in several cosmetic products like hair conditioners, nail polishes, lipsticks and shampoos. (Adepoju-Bello et al., 2012). From a research, Murphy et al. (2009) discovered a range of mercury levels varying from 0.01 to 12,590 µg/g, while analyzing nineteen creams within Cambodia. McKelvey et al. (2010). They found great levels of mercury reaching up to 4000 µg/g in germicidal ointments, cream and soaps. It is important to note that the risks of mercury contents must be put to consideration during cosmetics production, because it is harmful to human health and can cause disorders that are gastrointestinal and neurol
ogical (Chan, 2011).

Nickel and cobalt are mostly found in eye shadow, hair cream, face paint that related to lipsticks and contact dermatitis. Cobalt and cobalt-based salts are normally utilised in colouring hair light brown colour and makeup (Fischer, 2003). A copper level varying between 1.05–2.42 and 0.055 to 0.105 µg/g was found in eye shadow as well as lipsticks (Sneyers et al., 2009).

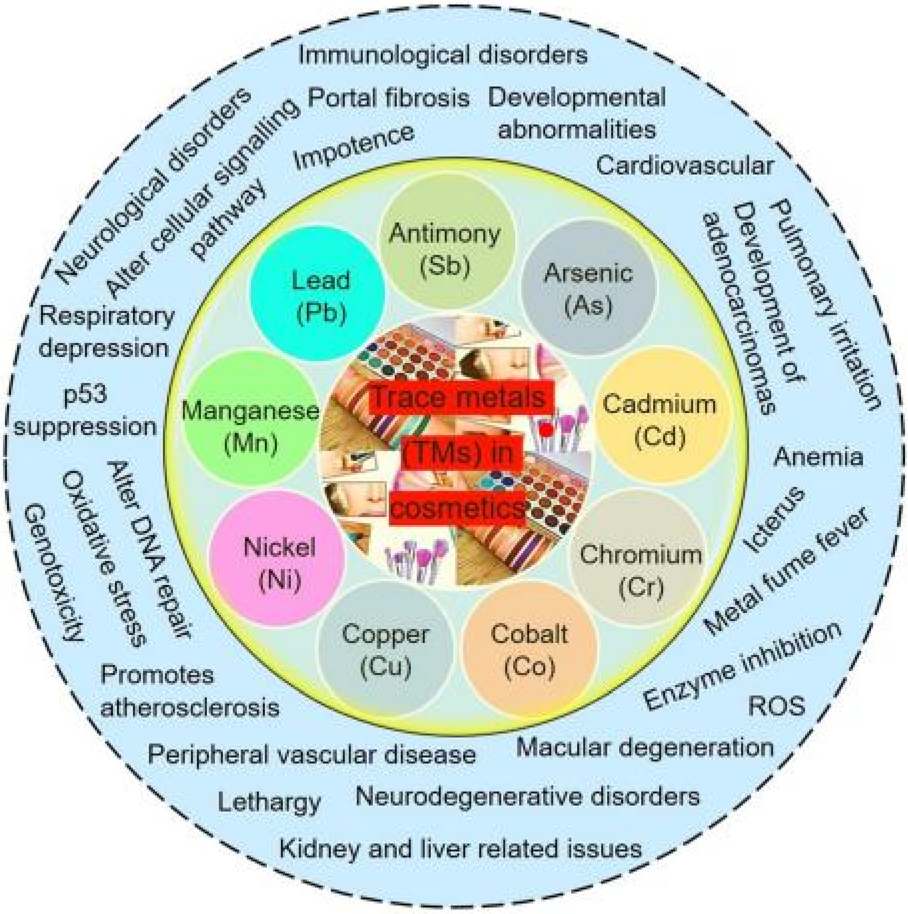

Figure 2.1: Harmful impact of trace metals in cosmetic products (Bakr et al., 2019)

Lastly, Inorganic lead is an element also included in the manufature of several cosmetics like hair dyes eye liners, eye pencil, eye shadow and lipsticks. Lead levels are between 0.25 and 81.50 µg/g was found inside eye shadows in Chinese, USA and Italian products (Volpe et al., 2012). Including four hundred lipsticks products examined, thirteen lipsticks and the one with the highest lead concentration was 7.19 µg/g as reported by the FDA (Hepp, 2012). In shampoos and soaps were the highest levels found (Chauhan et al., 2010). The main ways that lead enters into the human body are ingestion and inhalation (Devóz et al., 2017). Even though the human skin rarely let a little amount pass through, considerable awareness is necessary for regulating lead from being absorbed by the skin. Getting large quantities of it into the stomach may disturb the synthesis of calcium channels, that are vital in the transmission of nerves (Bocca et al., 2014; Pereira and Pereira, 2018). Additionally, accounts suggested that that being exposed to lead can interfere with the pregnancy and the nervous system in infants' bodies (Bellinger, 2008). Briefly, being exposed to these metals for a long period can have a harmful to the public, especially those that are employed in some of cosmetic manufacturing companies. The lead can slowly accumulate over a long period of time/

2.3. Standards, Challenges and Regulations of Lead (Pb) in Cosmetics

In Turkey, even though the economy has declined a little, the beauty care industry has grown by 10.9% between 2013 and 2018 and reached eight billion Turkish Lira, according Deloitte's analysis (Deloitte, 2020). In the same way, in the United States, personal care products have an industry of $71 billion and are greatly unregulated (Engel et al., 2016). The Federal Food Drug and Cosmetic Act (FD & C), section 201 (1) defines cosmetics in accordance to how they are meant to be used, "articles intended to be rubbed, poured, sprinkled, or sprayed on, introduced into, or otherwise applied to the human body…for cleansing, beautifying, promoting attractiveness, or altering the appearance" (FDA, 2016a). If the product is meant to be used for therapeutic purposes, it is considered a drug per FD & C Act, 201 (g) (FDA, 2016a). Thus, it is important that cosmetic manufacturers should make sure that the cosmetic they sell is harmless in accordance to the directions and warnings described on the product's label (FDA, 2016b).

EC Cosmetics Regulation 1223/2009 under Guidelines for Reporting Serious Adverse Effects was issued in 2012 and these guidelines have been established in Turkey by TITCK (Türkiye İlaç ve Tıbbi Cihaz Kurumu) ever since. The cosmetovigilance system was used by healthcare professionals who found the harmful reactions through their manufacturer, company, clinic or institution consisting Cosmetic Product Undesirable Effect / Serious Undesirable Effect Notification Forms. TITCK also determines the responsibilities of cosmetic manufacturers and examine them in line with the cosmetovigilance system to regulate and analyze all suspected harmful effects of products produced by the manufacturer. The manufacturer has the responsibility to record, evaluate and collect data regarding the reliability and risks of the products. It makes sure that up-to-date records are store in the product data files of cosmetics, and also resolves serious harmful effect reports are made to TITCK (Al-Saleh and Al-Enazi, 2011). The reports, pieces of information, and notifications are received and analyzed by the TITCK, if need be, opinions are submitted to the Scientific Commission. From the results of the evaluations made, the additions or alterations suggested to be made in the product data file or on the product's packing are communicated to the manufacturer by TITCK. Even though cosmetic product manufacturers are responsible of reporting the results of the analysis and manage their contents in accordance to legal restriction, at times, production conditions that do not meet up to the restrictions may occur. In those cases, the production process is analyzed to see whether or not the effects are caused by the product. The product that is causing harmful effects is examined by TITCK and can be withdrawn from the market if it is not found safe for use. Since sending feedback can avoid such situations from happening, it is very necessary for the health of the public.

Although there is an established cosmetovigilance system in Turkey, it might need some new implementations and regulations to increase its effectiveness. For example, the final product is normally not analyzed by the laboratories because the manufactures only need to show that they are making use of appropriate ingredients once to prove that they are following restrictions in accordance to the law. This negligence might allow the harmful effect of the cosmetic products affect people even though they have gotten a license. According to research carried out in Turkey, which was the only analysis in this sector, it has been suggested that the marketing after tests are carries out like using in vitro tests for ingredients must be done regularly and be managed by the authorities (Hepp, Mindak, and Cheng, 2009). The current data of the cosmetovigilance concept makes it challenging to follow up the harmful effect from products. Some researchers claim that this problem is considered to be insignificant by health professionals concerning harmful effects related to cosmetics (Parry and Eaton, 1991). Sadly, feedbacks on harmful effects concerning cosmetic products are quite restricted. This is because the consumer stops making use of the cosmetic product and treats the effects having not consulted a healthcare professional when they obverse most of these seemingly mild side effects (Alberman, 1958). As these side effects are mostly not extreme, healthcare professionals might not have the time to carefully analyze even if they found out any case.

In the United States, U.S. Code does not need safety information to be given by any cosmetic company for any product they sell in the U.S. The FDA is responsible of examining whether a product or an ingredient is indeed detrimental when used in accordance to the instructions on the product's label (FDA, 2015). The FDA acts in accordance to its own guidelines which include: making the resources available to carry out the analysis and protecting the public health (FDA, 2016a). But they agree that they lack authority and resources to make sure products are labelled correctly for all cosmetics before marketing in the U.S. (FDA, 2014). This makes the consumer vulnerable to the manufacturers who priorities selling their products above all else. The FDA needs "reliable scientific information" to ensure that a cosmetic do comply with safety guidelines before imposing any action (FDA, 2016b). Only then can it check cosmetics companies to see whether they produce products with respect to substantiated side effects and safety concerns. Nevertheless, neither is it not a testing laboratory, nor does it have any private laboratories to analyze products (FDA, 2016b). However, companies are advised to register cosmetic establishments or formulas data with the FDA so that they gain the access to import products into the U.S (FDA, 2016b).

The FDA has an issuing that is available for International Cooperation on Cosmetic Regulations to help international companies in making bringing it up to U.S. standards (International Cooperation, 2014). Furthermore, it has specific standards for drug and cosmetic labels such as size, warnings, ingredients, intended use, content, country which they were produced and contact information. The FDA agrees that natural products are already contaminated by lead even before being processed and that it cannot be completely removed from cosmetics (FDA, 2016c). The regulations for colour additives used in drugs, cosmetics and food are controlled by the Code of Federal Regulations. Various cosmetic colour additives are prohibited in food and drugs, but are not prohibited for cosmetic products such as lipsticks (Listing of Colour, 1977). Most of food colour additives contain a maximum lead level of 10 ppm, which is the same level for lip products. Most of drug colour additives contain a maximum lead level of 20 ppm, but there are some with higher level of lead allowed for colour additive used in cosmetics. Titanium Oxides must stay below 1% in the total weight of food. When mixed with each other Reds 6 and 7 have limits (Listing of colour, 1977). In all, traditional color additives like *Kohl, Surma* etc., are illegal by the Federal Food, Drugs and Cosmetic Act, Section 201 (1) due to its high heavy metal content, most predominant lead (FDA, 2016a). However, the FDA approved *mica* as a cosmetic colour additive. *Mica* has been found in the natural environment because it is sparkly and shimmer but it is normally found coexisting together with lead and other heavy metals (Blum, 2016; Colour Additives Permitted, 2014). Hence, it is vital that higher regulations need to be very strict towards cosmetic products, and also higher consumer caution and vigilance as far as some cosmetics are concerned, as a way to minimize lead in these cosmetics products.

2.4. Adverse Effect of Lead (Pb) Toxicity on the Human Body

Lead can have toxic effects on any organ of the human body system. Lead can result in a varriety of physiological, genetic and biochemical disorders. That also refers to the capability of lead to behave like Ca2+ ion and also disrupt some proteins like those in carboxyl, phosphate, sulfhydryl and amine groups. Bimolecular consequences that are lead-induced in the human body are outlined in the following discussions.

2.4.1. Effect on Nervous System

The nervous system is one of the systems that are very prone to the effects of lead exposure. Normally, it leads to neurotoxicity and reduces paediatric cognitive activities considerably. The surplus formation of free radical ions are also related to neurotoxicity because it causes disturbs in the activities in the brain. As lead successfully passes the blood brain barrier (BBB) and replaces Ca2+, it disrupts the intracellular processes of calcium by hindering its activities in brain cells (Lekouch et al., 2001). In infants, exposure to lead over a long period of time may cause altered mental status comas and seizures. Many researches have been carried out regarding association of the exposure to lead and how it affects neurological functions as well as development. A report of their accounts negatively correlates the level of lead in the blood to the neurological functions and development. The infants suffering from lead poisoning were found to have abnormal behaviours like destruction, social withdrawal, aggression, atypical body movement and depression (Farrag et al., 2015). Mainly, the ionic mechanism plays a role in neurological variations, since lead ions substitutes Ca2+ and have the potential to pass the BBB at a significant rate. Just after crossing the BBB, astroglia cells carrying lead bind proteins. The lead toxicity is more evident in the development nervous system which as a result lacks developed astroglia cells. Developed astroglia cells do not have lead binding proteins. Lead can destroy the immature astroglia cells and disrupts the formation of myelin sheath. With the endothelial cells composed of 12-transmembrane domain protein divalent metal transporter's movements (DMT1). The DMT-1's function is to transport necessary metals; however, toxic metals get transported as well because they are similar to other important minerals. The sub nanomolar concentration of lead can result in protein kinase C (PKC), an enzyme which play a key role in several cellular actions like cell development and proliferation of the central nervous system of the body. This is the one of the common mechanisms of neurotoxicity that is lead-induced. The capability of lead to go through the blood-brain barrier is because of its capability to replace Ca2+ chemically. In the brain, destruction that is induced by lead in the hippocampus, cerebellum and prefrontal cerebral cortex might result in several of neurological disorders like mental retardation, behavioural problems, brain damage, and sometimes leading to the start of Parkinson's disease, schizophrenia and Alzheimer's illness. Lead also disturbs the actions of Ca2+ in cell regulations and interrupts several intracellular processes (AI-Saleh and Coate, 1995).

2.4.2 Effects on Haematological Indices

Lead diminishes the ability of the body to manufacture haemoglobin by disrupting procedures of the hematopoietic system. Toxicity take place when lead inhibits several enzymes that are essential for synthesis like co-uroporphyrinogen, ferrocholinate and δ-aminolaevulinic acid (ALAD) (Scinicariello et al., 2007). ALAD is considerably prone to Pb and also reduces the life span of circulating red blood cells by weakened cell membranes. Destruction of red blood cells occurs and results in anaemia are some of the results of lead toxicity. Basing on the duration and dose of lead, it is recognised as a haemolytic anaemia related to high levels of lead exposure, whereas long-term exposure to lead results frank anaemia (Finger and Schiller, 2012). There was made a statement that subjection to lead over a long period of time played the key role in decreasing the erythrocytes' membrane permeability, which results in the reduction protein transportation in the membrane. RBCs' basophilic stippling is one of the first discoveries related to haematological outcomes of lead poisoning, as well as a capable biomarker for Pb poisoning (Alsherari, 2019). Many of the signs of lead poisoning are quite like other disorders that are common, and is often misdiagnosed. An accurate diagnosis of lead intoxication is extremely crucial, beginning with a precise analysis regarding regular of clinical symptoms, medical history and exposure carried out by medicinal specialists with toxicologists. The blood lead level (BLL) is the main examination carried out in lead poisoning detection. The other haematological variable analyzed is the basophilic stippling of red blood cells, which results from ribonucleic acid degradation. High levels of erythrocyte protoporphyrin and zinc protoporphyrin are recognized in lead intoxication as well which indicates haematological degradation by Pb poisoning (Zhang, Zhang, and Sun, 2018).

2.4.3. The Effects on the Reproductive Systems

The displayed data shows negative effects of Pb on human the reproductive system, sperm count, pregnancy and the fertility outcomes. Various researches have shown that lead poisoning plays role in the reproductive faults at greater levels of Pb. Known results of lead poisoning found in men are abnormal prostatic function, differentiation in serum testosterone, infertility, abnormal spermatogenesis, chromosomal damage, and decreased libido, such as reduced sperm count. There was a statement that the men employed in battery companies have hypospermia, testicular atrophy, as well as decreased levels of testosterone (Thuppil and Annir, 2013). In men, protamine protects sperm DNA. Zinc (Zn) is needed for chromatin stability of sperm and for the binding of protamine. Since Pb can substitute Zn, it decreases the HP2-DNA activities resulting in the changes in sperm chromatin production thus decreasing fertility significantly. Animal researches show that lead concentration ranging from 30 to 40 μg/dl can cause loss in spermatogenesis as well as decreased androgens concentration. Lead-acetate when exposed to rats considerably decreased sperm count, motility as well as changed the sperm structure and also negative changes in Leydig cells and seminiferous tubules. In addition, administration of Lead-acetate also considerably decreases the serum, testicular E2, serum testosterone and sky rocket the testicular testosterone levels (Abt et al., 2018). In contrast, women are even more prone to Pb intoxication that can lead to pre-eclampsia, premature membrane rupture, premature delivery as well as miscarriage (Tooma et al., 2015). Furthermore, it was recorded that during the pregnancy, fetuses were more prone to lead at the developmental stages. Some other symptoms of lead toxicity are decreased gestational period, offspring having abnormalities and irregularity in estrus cycle. In some situations, spontaneous abortion was also recorded. Being exposed to Pb at the development stage of postnatal hypothalamic alters the reproductive system’s activies and development.

2.4.4 Effects on Vision

Even though Pb intoxication in has been recorded since the old days, Pb has ever since been widely in use in industrial products, which is one of the key reasons why it widely distributed. Lead has been a used in the production of several consumer products like plumbing materials, gasoline, craft supplies including paint. Several researches have shown that being exposed to Pb can cause lead to alterations of proteins in the eye lens and that might decrease the transparency of the eye (Mulak et al., 2008). One well known root of blindness in this regard is cataracts. They also claimed that men with great levels of tibial Pb have two and half times higher risk of developing cataracts when compared to other men with lower tibial Pb levels. Regarding exposure to Pb, no greater chance of developing cataract has been discovered.

2.4.5. Hormonal Imbalance

Infants who have been highly exposed to lead have been found to show a relationship between levels of vitamin D and blood lead levels (BLLs). It has been recorded that a most of the disorders emerge because the lead that would have accumulated over a period of time. Some researchers concluded that the endocrine glands exposure to Pb was largely related to occupation and experimental models in animals. Lead has significant impact on the hypothalamic-pituitary axis which results in weakened the follicle-stimulating hormone (FSH), growth hormone (GH) and thyroid-stimulating hormone (TSH) which further increases growth hormone releasing hormone (GHRH), gonadotropin-releasing hormone (GnRH) and thyrotropin-releasing hormone (TRH). Growth hormone release is suppressed which may be a result of limited production of GHRH. The intoxication of lead was claimed to raise the levels of serum prolactin. The intoxication of Pb in people is related to great FSH and LH levels mostly associated with the testosterone levels, while in chronic poisoning, Pb is related to limited levels of testosterone that do not result high levels of LH and FSH. These researches suggested that Pb causes chronic damages and subclinical testicular harm. In the histological, cytological and parenchyma of adrenals variations are regarded to lead in alterations in levels of corticosterone. Lead is regarded to be the cause of reduction in the cytosolic receptor binding and nuclear glucocorticoids also. The alterations in hormone activities can be a result from the binding of the lead. Lead also disturbs the hormone homeostasis which is highly linked to many skeletal disorders (Singh et al., 2018).

2.4.6. Carcinogenesis

Some evidence from vivo in rodent framework reinforces how lead is carcinogenic in nature. The analysis from several epidemiological researches have introduced the chances of the risk of having cancer in the same circumstances. Nonetheless, similarly to other carcinogenic metals, the device of lead-induced cancer is still often misunderstood. Studies carried out earlier have concluded that Pb-induced cancer is mainly caused by cells that are injured. However, recent studies have openly expounded that low levels of lead, which cannot result in target organs cell injury. Prolonged exposure to lead at work or at home makes us understand the place of lead long-term and in short risks to many people, especially its role in many chronic diseases (Singh et al., 2018).

2.5. Traditional Eyeliners and Lead (Pb) Toxicity

The exposure to lead can have incredibly harmful implications to the human health as can be seen by the aforementioned facts presented in the previous section. Traditional eyeliners, which has been immensely popular amongst many parts of the world have provoked serious health concerns amongst the populace as these eyeliners have been linked to large amounts of lead (Pb) as well as other heavy metals (Singh et al., 2018).

Figure 2.2: Natural surma stone
(https://www.desertcart.com.cy/products/153438655-pmw-natural-surma-stone-kohl-stibnite-100-grams-for-pooja-cooling-of-eyes-loose-packed, 12/05/2022).

Surma, is an ore that is usually mined and crushed into powdery form. This type of cosmetic has been used for over a 100years by locals to ward off evil. The manufacturing process of *Surma* is most often not regulated and the lead content within a specific product can range from a value of 16% to 70% (AI-Saleh and Coate, 1995). Women are known to make use of *Surma* as a type of eye cosmetic for improving their facial appearance. Also, many women have been known to apply *Surma* to the faces of their infants, with little to no clue of the potential risk of lead exposure. The *Surma* is used as an eye liner and is a popular practise and it is believed by people to be a safe product. The word *Surma* is gotten from the Urdu word for antimony, where the main compound is antimony sulphide. However, due to the scarcity of antimony sulphide, lead sulphide was used instead (AI-Saleh and Coate, 1995). Usually, *Surma* is applied traditionally to the conjunctival surfaces rather than the exterior of the eyelids. This is done with the use of a metal applicator, where a streak eye powder is applied across the eyeballs. It functions as both a cosmetic and for medicinal purposes. It is usually used for circumcision for hygienic purposes as well as for stopping bleeding. When *Surma* is being used, it can get into the hands and user might ingest it unknowingly. Also, it can also get in contact with the eyes during the application process. Interestingly, *Surma* is usually washed off during a bath and so, it can pass down through the nasolacrimal duct, which is a small opening between the nose and the eyes. This very tiny opening and duct is narrow. When *Surma* gets into the channel, it can block it causing total or partial occlusion. Therefore, there is also a high probability that lead poisoning can occur.

At times, the marketed *Surma* brand being used may not contain information on its content and so, the consumers can't tell the difference between the dangerous ones and the safer ones. As a matter of fact, *Surma* which contain a dangerously high amount of lead might not have lead enlisted as part of its ingredients. Furthermore, it is still a widely used cosmetic and is marketed under different names.

Figure 2.3. Women Wearing Traditional Eye Liner Surma (https://pipanews.com/kajal-which-enhances-the-beauty-of-the-eyes-was-first-used-in-egypt-india-has-many-names-other-than-surma-know-its-full-story-kajal-origin-making-and-trendsetter-story-know-how-to-apply-kajal-in/ 15/05/2022).

Another traditional eyeliner similar and often interchangeably called *Surma* is *Kohl*. *Kohl* is a traditional eyeliner that is used in the Middle East, Africa and Far East regions. *Kohl* is an Arabic word which denotes a fine powder that has a texture that is similar to mascara. Usually, it is worn on the eyelids or the conjunctival sac by native. It is used for different reasons, such as religious, medicinal and cosmetics. Amongst the Arabs, it is most popular for the protection of sun rays in the Arab peninsula amongst the Arab Bedouins (Mahmood et al., 2009; Al-Hazzaa and Krahn, 1995). It is usually applied on the lid margins for the purpose of beauty and can also be applied in the conjunctiva for the treatment of diseases related to red eyes, trachoma and blephritis (Mahmood et al., 2009). Therefore, prolonged exposure to

Kohl can lead to excessive storage of lead in the body, which compromises the brain as well as the formation of marrow in the bones. It may also lead to convulsions and anaemia (AI-Saleh and Coate, 1995). The FDA has identified *Surma*, *Kohl*, as well as similar materials such as *Kajal*, as an illegal color additives as defined by the Federal Food, Drugs and Cosmetic Act, Section 201 (1) (FDA, 2019). Based on this law, the color additives needs to be approved by the FDA and enlisted as a color additive before it is allowed in cosmetics or any other related products. Therefore, none of the aforementioned traditional eyeliners have been approved by the FDA and these eyeliners are not enlisted as a color additive. Meaning their usage is against the law under the FDA. There are import alerts being instituted by the FDA to flag eye area cosmetics that declare *kajal, Surma,* or *Kohl* on its label. This isn't just because of the high lead concentrations but also other labelling violations also. Some of these eye cosmetics have been falsely labelled as FDA approved and so, are subject to refusal and detention at the U.S. port of entry. Also, other types of traditional eyeliners similar to *Kohl* and S*urma*, such as *Tozali*, *Kwalli* and *Tiro* are traditional products that have come from the West African region, most predominately, Nigeria (CDC, 2011). Despite being illegal, it can be smuggled and sold via mail orders and on some websites. In all, these traditional eyeliners can be marketed under several brands and some modern eyeliner cosmetic may still be utilizing these colour additive in producing their products, although in minute amount. Therefore, there might be traces of lead in these eye liners that are detrimental to the health of the individual.

2.6. Previous Research on the Toxicity of Lead (Pb) in Cosmetics

The level of lead in cosmetics is of high concern. Pb is harmful to people in low levels and can be fatal in higher quantities. There should be no amount of lead allowed as an ingredient in cosmetic products. A considerable effort is being carried out on the topic, with most accounts mainly focusing on the consistent proof for the presence of Pb in most beauty products, the discussion focuses also on the dangers that customers might face even when Pb is present in small quantities. Exposure to even small amounts of lead over a long period of time, might have great impact on the body. To address media reports of concern claiming the existence of Pb in cosmetics, sold out to customers at any price, from cheap to the more expensive ones (Clarke and Bundon, 2009). Al-Saleh and her associates carried out a study that was issued in article named is "Assessment of lead in cosmetic products". The research majored on products that was imported from Saudi Arabia. A study was carried out using an atomic absorption spectrometer. There was a discovered even though most products examined had some concentrations of lead beneath the extremes set by the FDA, various companies came in through them. The studies were mainly focused on the risk presented to pregnant women and people that were attending to babes, since the products with lead would come in contact with babies and affect their growth over a long period of time. Al-Saleh with the assistance of her co-worker's studies suggested that regular examination programs be enforced by the government, and also higher monitoring to minimize the risk associated with being exposed to lead over a long period of time to everyone (Al-Saleh, Al-Enazi, and Shinwari, 2009).

A different study aiming on the levels of Pb in *Kohl*, often used cosmetic products in Africa, the Middle East and Asia. In a study carried out by Parry and Eaton (1991), on the toxicity of Kohl eyeliners, the researchers bought samples from various kinds of manufacturers based in different countries like Pakistan and Saudi Arabia. From the results from the analysis conducted, the researchers discovered a wide range of lead concentration in the cosmetic products, a few having only small quantities of Pb while others had over 50% concentration of Pb by mass. Regarding that more than 33% of the products were found to have lead levels more than 50% of lead, researchers recommended health workers and physicians to watch out for signs of Pb intoxication, and also the use of *Kohl* over a long period of time, since researchers might not have been aware of the issues prior to their warning.

In another research, the researchers emphasized on concentrations of Pb and other metals present in the eye shadow products imported from Italy, China and the United States discovered a similar observation in Pb concentrations in cosmetic products from several nations (Volpe et al., 2012). Generally, the study found out that variance in monitorisation led to the biggest contrasts in the amounts of Pb in the products. It was pointed out that Chinese cosmetics companies followed their own standards different from those in most nations including the US. For that reason, the concentration of Pb in cosmetics products made in China happened to be greater. It was suggested that stringent alterations in monitorisation concerning products that were exported to nations with less strict standards for manufacturing.

Nigerian research emphasized on the same regions also discovered several products that had higher concentration of lead than what was allowed by law. Research was carried out by Usman et al. (2021) to examine the presence of heavy metals within a selected sample pool of 50 cosmetics products in Nigeria. There were 5 pieces each of eyeliners, bio clear, primer, lip gloss, eye shadow, face powder, mascara, foundation, lipsticks and lip gloss, were chosen randomly from various shops in Nigeria, and their level of toxicity was examined from the various shops within Nigeria. The toxicity of lead, cobalt, nickel, chromium and copper were assessed. The analytical instrument that was used was the flame atomic absorption spectrophotometer. From the results, it was seen that all the samples of the cosmetics contain varying amount or concentration of such heavy metals. From the results, the overall average concentration for Pb, Co, Cu, Cr, and Ni, were 19.46 (± 0.32), 0.81 (± 0.09), 11.92 (± 0.86), 5.98 (± 0.46) and 1.42 (± 0.05) mg kg−1, respectively. Therefore, the margin of safety (MoS) for these heavy metals in the cosmetics is greater than 100. And so, even if the concentration of these toxic heavy metals in the cosmetic products is in trace amounts, the gradual introduction of these metals into the human body can have disastrous impact on the biological system. According to these findings, researchers recommend that agencies be initiated for taking products like that from the market. A study of similar fashion effort carried in South Africa discovered that only a quarter of samples of a group of cosmetics randomly purchased from several stores had safe amounts of lead according to the United States FDA (Brandao et al., 2012). This presents a great health problem for South African customers, especially considering the fact that a customer might use a product with lead several times in a day. The researchers made no particular policy suggestions, nonetheless warned that such cosmetic products are very likely to negatively impact most of women in South Africa over a long period of time.

In another resent study carried out by Filella, Martignier, and Turner (2020), traditional *Kohl* as an eye cosmetic was evaluated for the presence of heavy metals such as lead. The researchers bought twenty-three products of *Kohl* from stores of 5 European countries as well as through the internet and was analyzed with the use of the Scanning Electron Microscopy (SEM) with Energy Dispersive X-Ray Analysis (EDX). From the results, a total of 17 products didn't conform to the European legislations based on the presence of lead (Pb) from 8mg kg^{-1} to over 400,000 mg

kg^{-1}. It can be seen that the poor control of manufacture in *Kohl* attributes to occurrence of toxicity and unwanted elements within the product. Therefore, there is need for strict regulations but it is difficult to regulate products sold over the internet.

Another research was carried out by Pawlaczyk et al. (2021) to determine the metallic impurities of eye shadows using the Inductively Coupled Plasma Mass Spectrometry (ICP-MS) technique. In the research, a total of 94 eye shadow samples were selected randomly from the polish market and the concentration of Ag, Pb, Bi, Sr, Tl, and Cd were studied. From the results, Cd, Ag and Tl, were below the established limits of quantification. However, the presence of bismuth, barium and lead were confirmed in all samples. Based on the results, just a minute number exceeded the limit; where one sample of eye shadow, had Pb detected by the analysis, exceeding 10 mg kg^{-1} and two samples having Cd detected exceeding 0.5 mg kg^{-1}. The researchers found the highest amount of Cd detected was 4 mg kg^{-1}, while lead was 16 mg kg^{-1}. The samples with the highest health risk emanated from Italy and Poland.

So, the traces of Pb in products has given rise to a broad range of media focus and discussions and also studies on the subject. This is mainly because lead is very toxic to the human body, even in low quantities, and the public is very much aware of its toxicity. Researches around the globe have examined levels of lead in products such as makeup, like lipstick, eye liners and eye shadow, and also commonly used deodorants and creams. Researches have even gone as far traditional beauty products and practices like *Kohl* and henna. Different levels of Pb exposure were tested in the product, including its country of origin and the restrictions of that country regarding heavy metals in such products. Research Africa, the Middle East and Asia appeared to have recorded higher levels of Pb concentrations compared to other parts of the world. In contrast to the researches that were carried out in the United States and Europe, or testing cosmetics manufactured in these countries, seemed to have found lower levels of Pb. This depended on how the manufacturing processes are carried out and the level at which companies are monitored.

2.7. Analytical Instrumentations for Toxic Heavy Metals

There are several analytical instrumentations that are employed by laboratories for detecting traces of heavy metals and other elements. However, for this study, just four will be discussed and implemented in the research. This includes Microwave Plasma Atomic Emission Spectroscopy (MP-AES), Measuring Element Concentration, X-Ray Florescence (XRF) Spectroscopy, and finally, Inductively Coupled Plasma Mass Spectrometry (ICP-MS).

2.8. Microwave Plasma Atomic Emission Spectroscopy (MP-AES)

Microwave Plasma Atomic Emission Spectroscopy (MPAES) is a basic test technic that was designed to improve the performance and productivity within a chemical test at the same time reducing operating costs and removing completely the expensive gas costly machines like hollow cathode lamps, that are made us by several conventional basic examinations' ways such as flame atomic absorption spectroscopy and also inductively-coupled plasma atomic emission spectroscopy. An MPAES instrument consists of a microwave-induced plasma that has an atomic emission spectrophotometer. MPAES is used for identifying of the levels of several tests of major and minor elements. Inside a MPAES device, microwave waves are used to form a plasma discharge in nitrogen ions that will be extracted from a gas cylinder. The gas is nebulized before they are exposed to the plasma. The gas particles are charged into ions by the plasma and electrons, and are let go when they are in an excited state. To return to a stable state atom release the energy inform of a light spectrum. The light that is emitted is classified into a spectrum by a spectrometer and the detector determines the strength of each spectrum. The MPAES method gives limits of spectrum, analyses the speed and compares the conventional flame atomic absorption spectroscopy and superior linear dynamic range. Additionally, this method gives simplified spectrum displays compared ICP-OES. The test measured, is the first data that was recorded of this study analytical approach to analyse the cosmetics products contamination with harmful metals (Zamanian and Kashanaki, 2018). The economic detection monitorisation and inexpensive processing makes MPAES very appropriate for this examination.

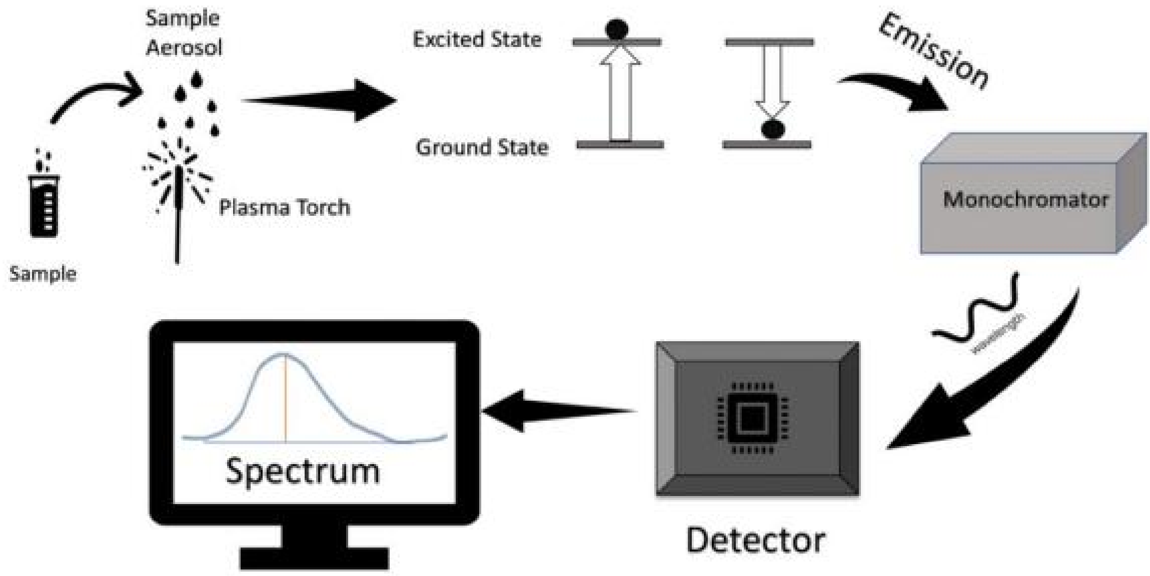

Figure 2.4: Schematic Diagram of a Microwave Plasma Atomic Emission Spectroscopy (MP-AES) (Balaram, 2020)

This method is specifically beneficial in deciding the amounts of several elements and metals and set out to be one of the best when it comes to measuring lead concentration in cosmetic products. Its sensitivity gives room for a high level of trust in the results. This technic has proved to be very useful to investigators striving to fully accurately determine the concentration of toxic metals in various of products. In one analysis, plasma emission spectrometry was used to determine the levels of titanium inside common cosmetic products like face masks. The investigators found the technic very effective at accurately measuring trace amounts of several metal elements very precisely and rapidly. The authors further suggested that it should be used in more routine study (Bulska, 2017).

2.9. X-Ray Florescence (XRF) Spectroscopy

X-ray fluorescence is a widely used method for to investigative elements that can quickly find the existence of any element that have greater mass than sodium for example. Each element has characteristics when exposed to X-ray fluorescence rays that is independent the way the element is bonded within a compound. For instance, the characteristics of Pb in X-ray fluorescence spectrum is the same to lead chromate as it is for lead fluoride. The chemical disintegration of a sample is on the bases of results of the secondary X-rays that are released from the atom within a sample that are excited from the first X-ray ray. The main X-ray source gives out electrons from sublevel of lower energy levels within an element's atom. The next, electrons in the shells with higher energy move to stay in the free shells simultaneously releasing an X-ray photon that is that compensates for the energy difference. As the energy of the X-ray that is emitted varies from element to element. Most metals on the periodic table can be easy be detected this way. An X-ray florescence spectrometer has 2 components, a primary X-ray emitter as well as the detector. A typical detector is a semiconductor device that has the ability to find and quantify the X-ray spectrum of every element available. XRF spectroscopy is more difficult compared to MPAES when it comes to quantitative analysis due to its narrowly restricted linear range because some of the rays are absorbed by element in the compound that are not involved. However, XRF spectroscopy is the best device for qualitative screening and analysis of a sample. The point of this test was to figure if XRF spectroscopy was an appropriate device in classifying cosmetic product samples for Pb levels regulations without the need to dissolute the sample (Shackley, 2011). Additionally, the efficiency of XRF spectroscopy and MPAES were compared in regard to measurement of rubidium and lead in cosmetics.

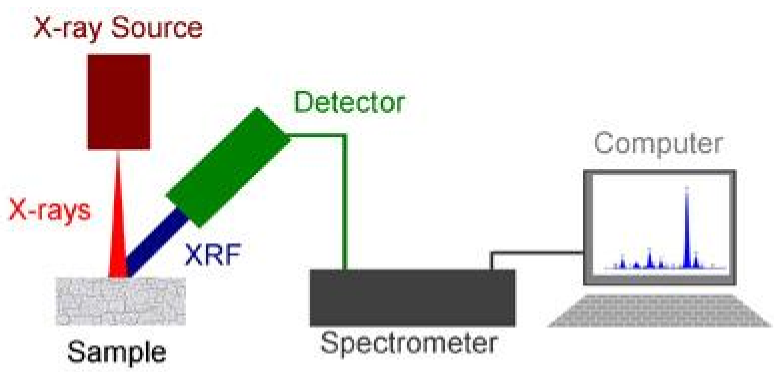

Figure 2.5: Diagrammatic Schematic of an X-Ray Florescence (XRF) Spectroscopy (https://physicsopenlab.org/2016/02/24/diy-xrf-spectrometry/ 16/05/2022.)

2.10. Inductively Coupled Plasma Mass Spectrometry (ICP-MS)

A kind of mass spectrometry that makes use of a coupled plasma to ionize and excite the sample is known as Inductively Coupled Plasma Mass Spectrometry (ICP-MS). It atomizes the sample and creates atomic and ions, which can be detected. It is used to identify metals and some non-metals in liquid samples even in low concentrations. It can identify isotopes of the same element, which makes it an efficient device as far as isotopic labelling is concerned. In comparison to atomic absorption spectroscopy, ICP-MS is way faster, more precise and sensitive. Nonetheless, in comparison with other mass spectrometry technics, like glow discharge mass spectrometry (GD-MS) and thermal ionization mass spectrometry (TIMS), ICP-MS gives several species, contamination from glassware and component gases of air that leak through the cones.

There are six basic compartments of a quadrupole ICP-MS: the introduction of the sample into the system, inductively coupled plasma (ICP), ion optics, mass analyzer and lastly the detector that detects atoms. Figure 2.4 shows a simple diagram of the device. Liquid samples are first converted into fine spray on the introduction of the sample into system, and then is afterwards taken to the argon plasma. The sample is ionized in the high-temperature plasma, the ions are then transferred directly into electrostatic lenses or ion optics through the interface region. The ions are focused into a beam and then guided into the mass analyzer. The quadrupole mass analyzer groups ions in accordance to their mass-charge ratio, and then the detector measures these ions (Nardi et al., 2009).

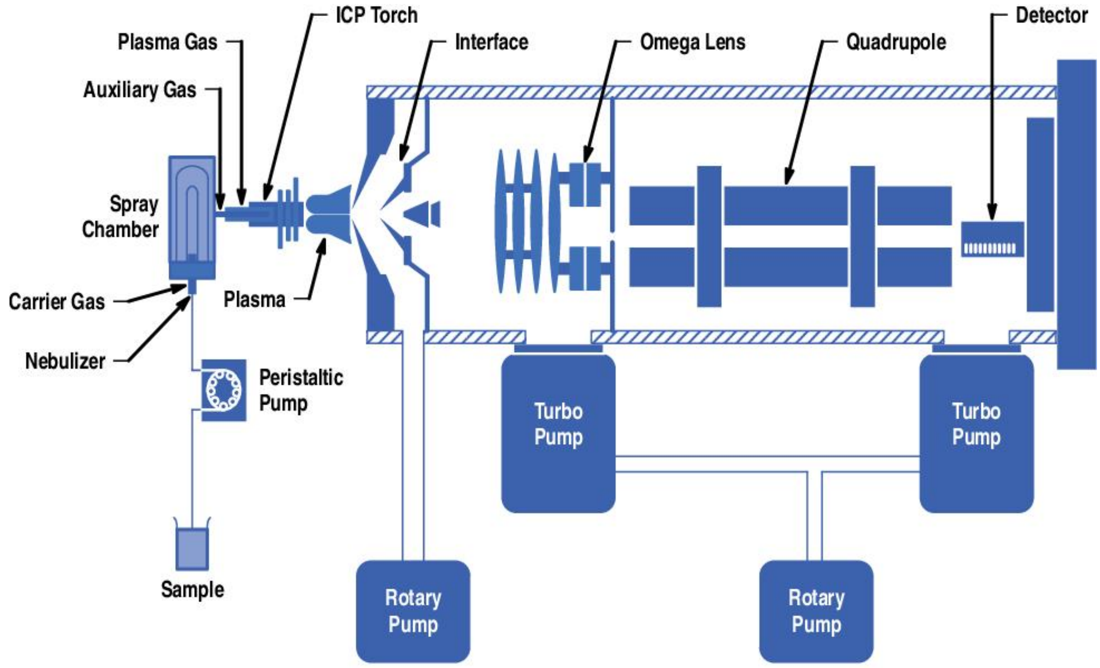

Figure 2.6: Diagrammatic Schematic of a Cross section schematic of an ICP-MS (https://www.semanticscholar.org/paper/A-Benchtop-Inductively-Coupled-Plasma-Mass-Kishi/a44181f5e765b9ab405774c9b3d26494fecb9222/figure/0 22/05/2020)

3. MATERIALS AND METHODS

3.1. Reagents

All reagents were of analytical purity, having deionized water used in the analysis. Moreover, the element concentration in the water was used in the determination of the witness, the preparation of the reagent and for providing standard solutions. The reagents and chemicals utilized in the experiments were:

- Lead (Pb),
- Nitric Acid, Concentrated (65% w/w)
- Hydrogen Peroxide (30% w/w)
- Hydrochloric Acid (37% w/w)

3.2. Instrumentation

An instrumentation Ion Chromatography System Model was utilized for the analysis of the anion and the cations in water. Also, a microwave with model Milestone (Italy) was employed for carrying out the digestion process of the samples collected. Before the analysis of the samples was initiated, the ICP-MS spectrometer underwent calibration by utilizing multi-elemental mixture of metal standards. Following this, the samples were analyzed by using the Thermo scientific ICAP RQ, Inductively Coupled Plasma Mass Spectrometry (ICP-MS) instrument. This consists of an ICP source that is coupled with a plasma metal shielded touch, a quadrupole mass analyzer, radio frequency mode, and an octapole reaction system which is operated by a radio frequency mode. The parameters of the instruments and the operation conditions, which was employed during the analytical processes are as follows: nebulizer type, argon auxiliary gas (flow rate, 0.14L/min), purity of argon gas (99.99%), ICP Radio-frequency power (1500W), nebulizer gas (flow rate, 0.9L/min), reaction gas (helium-flow rate, 0.14L/ min), plasma gas (flow rate, 15L/min), temperature of a spray chamber (2°C) and finally, the integration time (flow rate 0.6 seconds). The general lab supplies are presented below:

- Precision balance, 0.0001g precision
- Automatic pipette, 1000 μL, 100 μL

- 0.45 um PTFE filter
- Microwave (Milestone)
- ICP-MS (Thermo ICAP RQ)

Figure 3.1: ICP-MS (Thermo ICAP RQ)

Table 3.1: ICAP RQ ICP-MS Configuration and Performance Specification

Nebulizer	Borosilicate glass
Spray chamber	Quartz , Cyclonic
Torch	Quartz, Demountable, no shield
Injector	Quartz, 2.5 mm ID Option: 1.0 and 2.0 mm ID
Cones/Interface	Ni, high matrix interface Option: Ni, robust interface (supplied) and high sensitivity
Digitally C. Plasma Gas Flows	Three
Additional Mass Flow Controllers Option (Two)	Option (Two)

3.3. Samples

There were 50 samples of eyeliners representing 50 different brands which were randomly collected from Turkey during the period of January 21, 2022 March 21, 2022. These samples were either locally manufactured or marketed in Turkey, and were kept in room temperature before the examination. Most of the product samples being tested were made in Turkey with a percentage of 84%, 8% were from France, 4% of the brands were from the United Kingdom, and finally, 4% were from United States. They were all marketed in Turkey. Some of the packages, didn't have their ingredient information on their product, while some brands had information on their labels that was insufficient. A deionized water of high purity (18 MΩcm) which is gotten from Barnstead E-Pure System was utilized for the dilution of the samples and for the standardization.

3.4. Experimentation

3.4.1. Preparations of Calibration Solutions

In this experiment, 10 ppm mix solution is prepared from heavy metal stock standards. With this mix solution, calibration is prepared at 10 – 20 – 50 – 100 – 200 – 500 ppb levels. Readings are made with the working standard solutions at the prepared concentration, each with at least 3 repetitions, and a calibration curve is drawn with the obtained standard solution reading results. It is acceptable if the calibration accuracy value (r) is at least 0.995. If not, the standards are prepared again and read again. It should be noted that while reading the calibration standards, they were read in the calibration blank.

3.4.2. Preparation and measurements of Samples

The eyeliner samples were grounded and homogenized in a mortar. It was left in an oven of 80°C for 12 hours to dry. In carrying out the experiment, approximately 0.2 – 2 grams of sample was weighed into the combustion tubes. Following this, care was taken in extracting the sample homogeneously. Following this, 10 ml of concentrated nitric acid and 1 ml of hydrogen peroxide was introduced into the combustion tube. Next, 1-2 ml of hydrochloric acid or 1-2 ml of perchloric acid was added. The tube was closed and then placed in the microwave, with the oven door also shut closed. The oven program was set and the program was initiated. After this process, the combustion tubes are taken out of the microwave oven and allowed to cool before opening their mouths. The blind sample was equally subjected to the same procedure. After the tubes were opened, the cap and the walls of the container were shaken as well. Furthermore, the solution was transferred to a 25 ml or 50 ml flask and poured distilled water up to the mark. The operating conditions of the ICP-MS were adjusted according to the device specification in the manual. The concentrations of the elements in the sample solutions were gotten from the curves of the absorbance vs. the concentration of the standard solutions. Moreover, the blank solutions were also analyzed in the same manner. The sample results were read in the ICP-MS device and then, an observation was made to check if it is out of the calibration range, the sample result was then read by applying the dilution process again.

3.4.3. Validation

In order to validate the wet digestion procedures, recovery test was carried out by utilizing spiked samples with predetermined concentration. Analysis of sample blanks were carried out of which no lead was contained within it. Following this, a lead spike on the sample with a known lead concentration was done. Then it was analysed on the device, and the amount of concentration that was gotten was recorded. As seen in Table 4.1, the results of the percentage recoveries for Pb heavy metal was at a value of 99.95% with an expanded uncertainty value of 0.013 i.e. 1.3%. The results show that good recoveries were obtained for the Pb metals. And so, this range was with the acceptable range for most metals i.e. between 80 – 120% as defined by Mico et al. (2006), while confirming how valid of the wet digestion approach is for the products.

Therefore, the agreement of the instrumental detection limit (IDL), which is 0.1mg/kg and the acceptability of the recovery test for the lead metal, demonstrate the appropriateness of this methodology, instrument and procedures which was employed in the study.

3.5. Data Analysis

The analysis of the data was carried out by utilizing a statistical software (Microsoft Excel). Descriptive statistical parameters were used, which includes the mean for describing the Pb concentration in the various eyeliner samples. Moreover, graphical illustrations of the samples are given and the formulae for calculating the heavy metal concentration as done by the ICP-MS machine is given below:

W = C x V x F / (M x 10000)

Where,

W = Heavy metal result (mg/kg)

C = Heavy metal concentration (µg/ml)

V = Sample final volume (ml)

F = Dilution factor (if applicable)

M = Initial weight of sample (g)

Note, that for this experiment, the initial mass of the sample was taken as either 0.2g to 2g. While the final volume was between 25ml to 50ml. No extra dilution was required in the samples and so, the value was taken 1. For the Heavy metal concentration, Lead (Pb), it is 1000µg/ml.

3.6. Quality Assurance

The appropriate quality assurance precautions and procedures were carried out in order to ensure the results were reliable. Samples were very carefully handled in order to avoid contamination of the samples. Furthermore, the reagents blank determination was utilized for correcting the instruments readings. In order to validate the analytical procedures, the standard addition method which is considered as a validation method was utilized (Ullah et al., 2017). Therefore, a recovery study was carried out by spiking and homogenizing several of the analyzed samples with varying amounts of the standard solutions of the heavy metals. Furthermore, the spiked samples were processed for the analysis by employing the same procedure and reanalyzed as the analysis of the samples studied. In the table below, the permissible limit of lead (Pb) is provided with respect to international standard. This value will then be compared with the results of the experiment.

Table 3.2: International Lead Limit standards

	Body	**Pb mg/kg**
1.	WHO/ USFDA (WHO, 1997; FDA,	10

	2007)	
2.	Canada (Canada, 2011)	10
3.	Federal Office of Consumer Protection and Food Safety (BVL) (Germany) (Bund, 2017).	2

4. RESULTS AND DISCUSSION

All the features (mass, type , colour , country of manufacture and manufacture and expiry date) of the collected 50 samples from Turkey were given in Table 4.1.

Table 4.1: List of Eyeliner Sample and their features.

No.	Sample Code	Mass (grams)	Type	Colour	Country of Manufacture	Manufacture & Expiry Date
1.	A-1	5	Solid	Black	United Kingdom	2022
2.	A-2	10	Solid	Black	United Kingdom	2022
3.	A-3	0.8	Solid	Black	United States	2022
4.	A-4	5	Solid	Black	United States	2022
5.	A-5	0.5	Solid	Black	Turkey	2022
6.	A-6	10	Solid	Black	Turkey	2022
7.	A-7	10	Solid	Black	Turkey	2022
8.	A-8	10	Solid	Black	Turkey	2022
9.	A-9	10	Solid	Black	Turkey	2022
10.	A-10	10	Solid	Black	Turkey	2022
11.	A-11	10	Solid	Black	Turkey	2022
12.	A-12	10	Solid	Black	Turkey	2022
13.	A-13	2.5	Solid	Black	Turkey	2022
14.	A-14	10	Solid	Black	Turkey	2022
15.	A-15	2.5	Solid	Black	Turkey	2022
16.	A-16	10	Solid	Black	Turkey	2022
17.	A-17	10	Solid	Black	Turkey	2022
18.	A-18	10	Solid	Black	Turkey	2022
19.	A-19	10	Solid	Black	Turkey	2022
20.	A-20	10	Solid	Black	Turkey	2022
21.	A-21	2.5	Solid	Blue	Turkey	2022
22.	A-22	2.5	Solid	Blue	Turkey	2022
23.	A-23	2.5	Solid	Blue	Turkey	2022
24.	A-24	2.5	Solid	Brown	Turkey	2022
25.	A-25	10	Solid	Brown	Turkey	2022
26.	A-26	10	Solid	Brown	Turkey	2022
27.	A-27	10	Solid	Brown	Turkey	2022
28.	A-28	30	Solid	Brown	Turkey	2022
29.	A-29	33	Solid	Black	Turkey	2022
30.	A-30	10	Solid	Black	Turkey	2022
31.	A-31	10	Solid	Black	Turkey	2022
32.	A-32	10	Solid	Black	Turkey	2022

33.	A-33	10	Solid	Black	Turkey	2022
34.	A-34	10	Solid	Black	Turkey	2022
35.	A-35	10	Solid	Black	Turkey	2022
36.	A-36	10	Solid	Black	Turkey	2022
37.	A-37	10	Solid	Black	Turkey	2022
38.	A-38	10	Solid	Black	Turkey	2022
39.	A-39	10	Solid	Black	Turkey	2022
40.	A-40	10	Solid	Black	Turkey	2022
41.	A-41	10	Solid	Black	Turkey	2022
42.	A-42	10	Solid	Black	Turkey	2022
43.	A-43	10	Solid	Black	Turkey	2022
44.	A-44	2.5	Solid	Black	Turkey	2022
45.	A-45	2.5	Solid	Black	Turkey	2022
46.	A-46	2.5	Solid	Black	Turkey	2022
47.	A-47	2.5	Solid	Black	France	2022
48.	A-48	2.5	Solid	Black	France	2022
49.	A-49	2.5	Solid	Black	France	2022
50.	A-50	10	Solid	Black	France	2022

After the validation has been done, and the calculations of (Concentration of spike – the concentration of un-spike / added concentration) it was equal to the recovery results which was (0.995) (99.5%) were given in Table 4.2.

Table 4.2.: Recovery Test for the Eyeliner Sample

Metal	Concentration of spike (mg/kg)	Concentration of added (mg/kg)	Concentration of un-spike (mg/kg)	Recovery
Pb	10.2	6	4.23	0.995 (99.5%)

50 samples of eyeliner (Surma) that were collected from Turkey ,were tested by ICP-MS to measure the amount of heavy metal (lead) that could be present in the ingredients of the eyeliners , were given in Table 4.3. The highest two results were A-6 (12.41 mg/kg) that was above the accepted international standers , and A-19 (4.81mg/kg) that was above the Federal Office of Consumer Protection and Food Safety (BVL) (Germany) standerds.

Table 4.3: Lead (Pb) Concentration in Eyeliner Samples

Sample	Pb(mg/kg)	Sample	Pb(mg/kg)
A-1	<0.1	A-26	<0.1
A-2	<0.1	A-27	<0.1
A-3	<0.1	A-28	<0.1
A-4	<0.1	A-29	<0.1
A-5	<0.1	A-30	<0.1
A-6	12.41	A-31	<0.1
A-7	<0.1	A-32	<0.1
A-8	<0.1	A-33	<0.1
A-9	<0.1	A-34	<0.1
A-10	<0.1	A-35	<0.1
A-11	<0.1	A-36	<0.1
A-12	<0.1	A-37	<0.1
A-13	<0.1	A-38	<0.1
A-14	<0.1	A-39	<0.1
A-15	<0.1	A-40	<0.1
A-16	<0.1	A-41	<0.1
A-17	<0.1	A-42	<0.1
A-18	<0.1	A-43	<0.1
A-19	4.81	A-44	<0.1
A-20	<0.1	A-45	<0.1
A-21	<0.1	A-46	<0.1
A-22	<0.1	A-47	<0.1
A-23	<0.1	A-48	<0.1
A-24	<0.1	A-49	<0.1
A-25	<0.1	A-50	<0.1

Overall, the results from the descriptive statistics from the 50 eyeliner samples in Table 4.4. Show that the mean of the Pb level was 0.44 with a standard error of 0.261. Moreover, the standard deviation was 1.85 with a maximum and minimum value of 12.41mg/kg to 0.1mg/kg, respectively.

Table 4.4: Summary Descriptive Statistics Over All Sample Measurements:

Properties	**Value for Pb**
Mean	0.4404
Standard Error	0.261
Standard Deviation	1.851

Minimum	0.1
Maximum	12.41

Under the United States Food and Drug Administrative (USFDA), and the WHO, the acceptable limits for heavy metal such as lead (Pb) in cosmetics was set at 10mg/kg. Also, Health Canada also put a limit on Pb at 10mg/kg (Canada, 2011, FDA, 2016). However, the Federal Office of Consumer Protection and Food Safety (BVL) in Germany established stricter policy on Pb lead permissible limit in Cosmetics, in order to reassure the public on their stance on safety and health. In 2017, BVL suggested that the amount of Pb that should be permissible in cosmetics should be lower than 2mg/kg (Bund, 2017). Therefore, in this study, the maximum permissible limit for Pb will align with the policy put forward by the BVL, which is less than 0.2mg/kg. In table 4.2, the Pb concentration in the 50 eyeliner samples are shown. To the best of the authors knowledge, this is the only thesis that considers the use of the BVL stringent standards for the evaluation of the level of Pb toxicity in 50 eyeliners samples purchased in Turkey. From the results, it can be seen that the Pb concentration for 48 of the samples were significantly lower than the detectable limit of the machine of 0.1mg/kg and so, this did not exceed the acceptable limits of the as defined by the BVL. However, from one of the sample A-6, a Turkish brand, it was seen that the value was 12.41mg/kg, which is a very high amount of lead concentration and at a significantly dangerous level. Furthermore, it can be seen that the sample A-19, another Turkish brand had a significantly high Pb concentration of 4.81mg/kg, which also exceeds the BVL permissible level of 2mg/kg. In all, the overall outcomes indicate that the amount of Pb in the eyeliners were lower than the BVL standards (<0.2 mg/kg).

In the last 10 years, there have been many countries that have pieced together laws for the regulation of cosmetics, where special care and attention has been given to heavy metals as well as other toxic elements. The German BVL, the European Parliament Regulation no. 1223/2009, WHO, United States Food and Drugs Administrative (USFDA) and The Canadian Cosmetic Regulations (CRC), have indicated varying levels of permissible lead (Pb) concentration in cosmetics (Union, 2009; FDA, 2006; Saadatzadeh et al., 2019; Canada H, 2011; Bund, 2017). The presence of these Pb is unauthorized in cosmetics, however, Pb presence as a trace element derived from its manufacture is permissible. In most cases, the primary source of Pb impurities in cosmetics arises as a result of the use of natural ingredients in the production process. However, some of the eyeliners are made from Kohl ingredients which has high level of lead toxicity due to its mineral pigments, resulting in the contamination of the eyeliner with Pb (Chen and Thyssen, 2018). Nonetheless, Trace amounts need to be very minute so as to present no issues whatsoever during the manufacturing process and it also has to be safe for human health. However, due to varying differences with the legislations in the permissible limits that is allowed and the lack of the specific limits for the trace elements of Pb that a cosmetic can contain, there has been challenges in regulating and fact checking the cosmetic products conformity to the guidelines (Navarro-Tapia et al., 2021).

From previous literature, the presence of Pb concentration in cosmetic products have been reported by several researchers to be above the recommended limits (Iwegbue et al., 2016; Balarastaghi et al., 2018; Saadatzadeh et al., 2019; Zafarzadeh et al., 2018). One reason for the presence of Pb within the cosmetic is the use of chemical substances as an additive in order to keep it in good condition (Saadatzadeh et al., 2018). And so, Pb mainly can enter into cosmetics through compounds such as Pb carbonate, Pb chromate, Pb sulffide, and Pb acetate, due to its use in color pigmentation (Balarastaghi et al, 2018).

In the study carried out by Zafarzadeh et al. (2018), the observed levels of Pb concentration for the Turkish brand and the Chinese brand was 6.64mg/kg (Standard error (SE): 0.57) and 10.08 (SE:1.08), respectively. Similarly, in this study two of the Turkish brand had a lead concentration level of 12.41mg/kg and 4.81mg/kg, which exceed the threshold for the German BVL. However, what was different is that the only two samples accounting for 4.8% of the 42 Turkish samples, violated the German BVL, the remaining 40 samples passed the BVL set limit of 2mg/kg. Interestingly, in the study by Balarastaghi et al. (2018), the researchers found that that the Pb concentration values were between 0.013-0.355mg/kg (sunscreen) and 0.021-0.366 mg/kg (foundation cream), which is significantly lower than the BVL threshold limit. The bulk of the samples from this thesis showed values lower than 0.1mg/kg and so, similar findings was found in that context.

Furthermore, in a study carried out by Mustafa and Mohamed (2016), the objective was to study the levels of heavy metals in facial cosmetics by using ICP-MS. The results showed that the concentration for lead in their eye shadow samples ranged from a value of 17.22mg/kg to 52.02mg/kg, which was extremely higher than the values gotten in this thesis which ranged from less than 0.1 to 12.41mg/kg. Interestingly, from the study from Zafarzadeh et al. (2018), 27 to 13% of the Turkish brand cosmetics had Pb concentration that was higher than set threshold limit 10mg/kg. Also, higher concentration was found in Chinese brand of up to 63.42mg/kg. On the other hand, brands from France and Iran, had significantly lower levels of Pb in their cosmetics. This could suggest the quality of production affecting the amount of lead detected, however, based on this thesis findings, the sample size to make a credible and accurate comparison isn't enough and so, it is still a grey area that can be explored in further studies. Nonetheless, cheaper brands have been found to have higher traces of lead in cosmetics in comparison to more expensive brands (Al-Saleh et al., 2009).

In all, lead concentration exceeding the recommended threshold of 10mg/kg in eyeliners, can lead to severe health risk compromising the central nervous systems, damaging the kidney, lungs, eyes, liver, and other more important organs in the body. Due to the nature of how eyeliners are applied and the need for continuous usage, it can lead to degenerative diseases on the long run such as Parkinson's disease, Alzheimer's disease and multiple sclerosis (Singh et al., 2018).

5. CONCLUSION AND RECOMMENDATION

5.1 Conclusion

In all, although lead (Pb) is a very toxic and dangerous heavy metal, it is quite unfortunate that some eyeliners still in use today are made from Kohl ingredients which have high levels of Pb toxicity due to its mineral pigments. The objective of this thesis was to investigate the safety of commercial eyeliner brands in Turkey based on the determined levels of Pb in the selected samples of 50 cosmetic eyeliners marketed in Turkey. To address this objectives, the samples were evaluated by using ICP-MS technique. From the results, it was seen that only two of the Turkish brand had a lead concentration level of 12.41mg/kg and 4.81mg/kg, which exceeded the threshold for the German BVL. However, as previously aforementioned, only two samples were compromised which accounts for 4.8% of the 42 Turkish samples, that violated the German BVL, the remaining 40 samples passed the BVL set limit of 2mg/kg. In comparison, to other brands from France, United Kingdom and the United States, all Pb level was below the detectable limits and so, this suggest higher quality production of the eyeliners. However, the sample size isn't large enough to arrive at a conclusive finding. The eyeliners that was analysed in this study are usually applied in the eyelids and therefore the long-term use of these eyeliners can compound and lead to harmful health problems. Nonetheless, leads toxicity gives rise DNA damages, livers, oxidative stress, carcinogenicity and kidney damage, and neurological disorder which is known as magnesium which leads to tremors and anxiety disorders. Therefore, appropriate measures need to be taken to control and reduce the levels of lead toxicity in eyeliner brands in Turkey.

5.2 Recommendation

This thesis recommends the need to look deeply into the health, safety and security measures employed by Turkish cosmetic brands. Using eyeliners that have high level of lead concentration can be very deadly overtime to the consumers. And so, not only will the consumers be affected but also the manufacturers. One of key strategic movement that needs to be done in the cosmetic manufacturing plant, is within the risk management and control schemes being undertaken by management. There needs to be proper storage, maintenance, transportation, surveillance, and disposal systems, to identify and extract contaminants from the manufacturing process employed by these cosmetic industries. Finally, the regulatory bodies in charge of quality assessments need to grade these eyeliners based on their independent research and verify the ingredients being used and ensure, it meets the threshold level of Pb as an active ingredient.

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APPENDICES

Plagiarism Report

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