COLLEGE OF HEALTH SCIENCES

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Assessment of Occupational Chromium Exposure and Associated Factors Among Tannery Workers in Addis Ababa, Ethiopia: A Comparative Cross-Sectional Study.

By

Belaynesh Demissie

Advisor's

1. **Samson Wakuma (Ph.D.)**
2. **Teferi Abegaz (Ph.D.)**

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Acronyms and Abbreviations

AAS	Atomic Absorption Spectrophotometry
AAU	Addis Ababa University
Cr (III)	Trivalent Chromium
Cr (VI)	Hexavalent Chromium
EFDA	Ethiopian Food and Drug Administration
EPA	Environmental Protection Agency
EPHI	Ethiopian Public Health Institute
MP-AES	Microwave Plasma Atomic Emission Spectrometer
OSH	Occupational Safety and Health
PPE	Personal Protective Equipment
SPSS	Statistical Package for Social Science

Abstract

Background: Chromium is not only released into the environment from natural sources but also from industries. The pollutants generated in the tannery industry contain a high concentration of chromium which directly affects human health. Long-term exposure and high concentrations of chromium can cause respiratory challenges, cancer, skin damage, and birth defects. Despite this fact, there is no study done that shows chromium exposure levels in the tannery in Ethiopia.

Objective: The objective of this study is to determine the level of chromium in hair samples and associated factors among tannery workers in Addis Ababa Ethiopia.

Methods: A comparative cross-sectional study design was conducted to assess the hair chromium level of the tannery workers compared to the bottled water factory workers from November 2023 – June 2024 in Addis Ababa. A simple random sampling method was used to identify a total of 112 study participants with tannery (n=56) and water (n=56) factory workers. The hair samples' chromium levels were analyzed using a microwave plasma emission spectrometer (MP-AES), and structured questionnaires were used to assess the associated factors of hair chromium exposure levels. SPSS Version 26, independent t-test, chi-square, and linear regression were used for analysis.

Results: The findings showed that the average hair chromium level of (11.2±10.0**)** mg/kg among tannery workers was significantly ($p<0.001$) higher than the average hair chromium level of **(**4.6±2.7) mg/kg among water factory workers. The linear regression analysis result also observed that working duration in the year, working hours per day, and working sections were statistically significant ($p<0.05$) relationships to hair chromium levels among tannery workers.

Conclusion: This study concluded that the tannery workers had higher significant hair chromium levels as compared to the water factory workers. Consequently, overall, tannery workers had two times higher mean chromium levels as compared to water factory workers. Hence the exposure of chromium in tannery workers should draw much more attention shortly by conducting more research and developing occupational exposure limit guidelines.

Keywords: chromium level, associated factors, tannery workers, Addis Ababa, Ethiopia

1. Introduction

1.1 Background

Globally, leather has been in existence during which technologists were concerned with creating stability on raw skins and hides; however, leathermaking involves the use of many chemicals including chromium and acid solvents (1). In many African countries, including Ethiopia, leather industries have been rapidly growing in recent decades and leather products exports have also significantly increased (2).The leather industries have significant economic importance because it is a source of foreign currency income and creates job opportunities for many people; however, recently it received a lot of criticism because of the toxic waste emissions (3)

Chromium is one of the most widely used heavy metals on an industrial scale and it is not only released into the environment from natural sources but also from industries. The pollutants generated in the tannery contain a high concentration and long-term exposure to chromium which directly affects human health and can cause respiratory problems, cancer, skin allergic, headaches, high blood pressure, and birth defects (4).

Tanning of leather includes various steps ranging from pretreatment to dying which involves the worker's direct contact with chemicals and which is responsible for causing serious health problems. The four major sections (stage) in which the tanning process takes place and the majority of employees are working and exposed to chemicals including chromium metal. The pre-tanning section is called beam house soaking, liming, de-fleshing, de-liming and bating takes place using sodium chloride, chromium salt, sodium metabisulphite, and acid solvent chemicals. After pre-tanning; the tanning section gets started which is the chemical process of converting skin into tanned leather by stabilizing the collagen structure, protecting the leather from microbial enzymatic and microbial degradation to enhancing the strength and increasing its resistance to heat hydrolysis, in this process trivalent chromium sulfate widely used as tanning agent to form cross-linking collagen. After tanning retaining section process gets started which is conducted to enhance the attributes of the leather and the rehydration properties of the hides, which are essential for streamlining and enhancing the effectiveness of the following dyeing procedure. finishing is the last section the application of protective and decorative coating, dyeing, and also using several dyes, pigments, and chemicals again (1, 5).

Thus, the main objective of this study is to assess the toxic chromium exposure level and its associated factors among tannery workers in Addis Ababa Ethiopia.

1.2. Statement of the problem

Tanneries encompass various procedures, among them is the process of tanning, which involves the utilization of numerous chemicals, some of which possess potential carcinogenic properties and are capable of inducing various detrimental health impacts. Chromium metal (Cr) stands out as a typical example of such chemicals, recognized for its status as a toxic heavy metal with direct implications for human health (6, 7). Some include allergic asthma, dermatological hypersensitivity reactions, gastrointestinal disturbances, hypertension, cephalgia, respiratory complications, and reproductive as well as developmental disorders (8, 9).The study conducted in 2020 and 2023 in Bangladeshi shows that the mean concentration of chromium in scalp hair samples of tannery workers was 5.85 mg/l and 6.254mg/l respectively the findings indicate that the presence of chromium is in very large amounts in Bangladesh tannery workers hair that compares 1.18mg/l of the occupational chromium exposure limit according to the International Occupational Safety and Health Information Center (IOHS, 1999) (6, 10).The study held in Gajju-Matah tannery also shows that the mean level of chromium in hair samples of tannery workers is 19.68 ± 12.78mg/l which is the highest chromium exposure level observed (11).

Most chromium exposure for tannery workers occurs by skin absorption and mainly through inhalation reaches the respiratory tract in the form of vapors, mists, fumes, or dust, while internal absorption is also possible in cases where chromium is present in two oxidation states: trivalent (III) and hexavalent (VI) (7, 12). As an excretory system, human hair can accumulate chromium metal as a metabolic product, incorporating metal into its structure during the growth process. So, the concentration of chromium metal in the hair can reflect the average level of toxicity in the human body compared to other bio-indicators such as blood, nails, urine, and saliva, human hair has aesthetic advantages to show long-time exposure to chromium metal and higher metal concentrations than in other bio-indicators. Hair is a metabolic end product capable of reflecting the body's chromium burden (13). Measuring the amount of trace elements in hair has long been used to assess occupational exposure to heavy metals as well as metabolic status. So far, several recent studies have reported that hair analysis has been used to obtain information about the level of chromium metal. Hence, Human hair is considered to be an excellent screening tool for the extensive assessment of chromium metal (14, 15).

In the Ethiopian context some studies have been conducted, to assess chromium metal contamination levels in water, soil, vegetable, and workplace. Most of these previous studies show the external exposure level of chromium metal. No studies were conducted on the exposure of chromium in Ethiopian tanneries. Due to this reason, the internal toxic elements like chromium exposure levels and health risks to tannery workers largely remain un-investigated. The focus of this study was to evaluate the level of chromium exposure and its contributing factors in tannery workers by measuring the concentration level of chromium in hair samples.

1.3. Rational of the study

Some studies have been done in Ethiopia showing the exposure and pollution levels of chromium and other heavy metals in the environment. Chromium is a heavy metal that plays an important role as an excellent tanning agent widely used in the tannery production process of the tannery industry, but in this production process, tannery workers are highly exposed to chromium metals and its compounds even though it makes workers vulnerable to various occupational diseases. despite this fact, no studies have been conducted in our country on the level of chromium exposure and associated factors in tannery workers. This research will be mainly focused on investigating the level of chromium exposure and its associated factors among tannery workers.

1.4. Significant of the study

This study will help us to know the level of chromium exposure among tannery workers which can be an important input to take prevention actions, improve the safety and well-being of workers in the tannery, and also serve as scientific evidence to employers and employees. In addition, the findings may help to formulate prevention strategies in the tannery. This study also served as baseline information for further studies,and may be used as a reference for academic purposes.

2. Literature review

2.1. Leather Industry

Leather manufacturing processes involve many operations, including the use of various chemicals that are detrimental to the health of workers and nearby communities. In developed countries, the production of leather has been tremendously reduced due to the closure of tanneries brought about by stringent environmental laws. Developed nations have increasingly come to depend on leather supply from developing countries (7). Leather making is a very long process and consists of many different chemical and mechanical process steps. The most important step of all tanning processes is the tanning step, which is typically done with vegetable or mineral hides. Over 85-90% of tanning is done by chrome tanning, which is the most common type of mineral tanning today (5).

2.2. Description of tanning process

Tanning is a chemical treatment operation in which the soft and perishable proteins of animal skins are converted into durable and flexible leather. Tanning involves a process that permanently changes the protein structure of the skin, making it more durable and less susceptible to decay, as well as coloring (5).

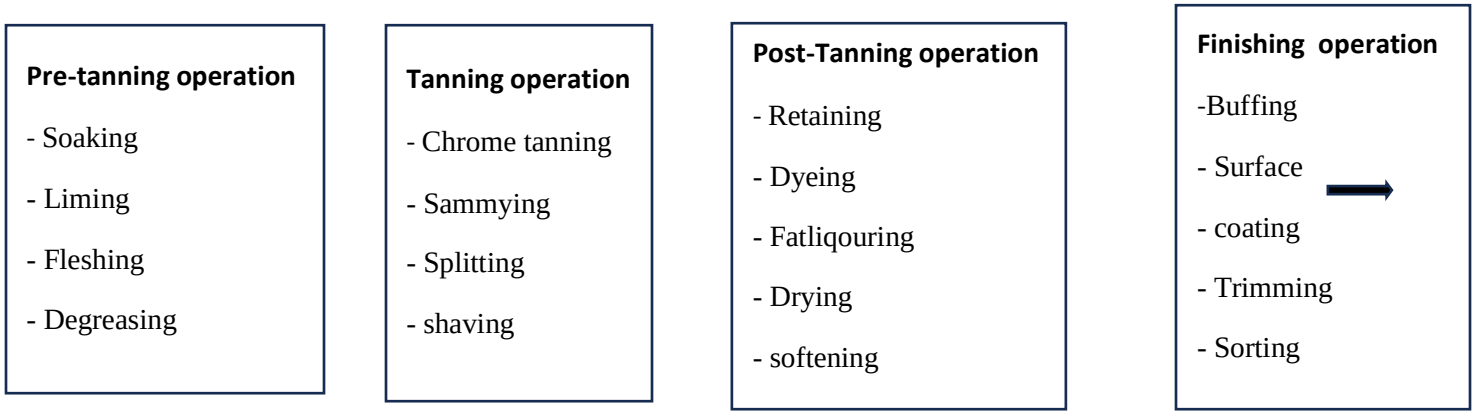


Fig 1: Diagram of the leather tanning process

2.2.1. Pre-tanning (Beam house) operation

Beam house operation includes: soaking, liming, bating, and degreasing. The first step in developing wet leather is that preserved rawhides or salted skins are treated with water, which makes the leather free and soft. The main purpose of exfoliation is to remove salt, rejuvenate dry

skin, and remove unwanted materials such as blood, dirt, and feces. Liming is the second operation which includes the elimination of hair and unnecessary materials that are not transferred to leather. de-liming and bating the unhaired, fleshed, and alkaline hide are neutralized with acid ammonium salts and serve with enzymes, parallel to those found in the digestive system, to remove hair remains and to degrade proteins. Degreasing is an operation important to avoid additional fat and oils which allows the tannin to enter easily through the skin (1).

2.2.2. Tanning opration

In this step, tannins are permitted to interrelate with the prepared skin which acts on collagen and makes it stable. Tanning agents can be categorized into three main groups namely mineral, vegetable, and chrome tanning agents. Chrome tanning is the most frequently used tanning operation. Chromium (III) sulfate is employed in the process, being recognized as the most optimal and productive tanning agent. Through a mechanism known as olation, it generates polychromium compounds that function as vital components in the tanning process, facilitating the crosslinking of collagen subunits. The chromium-infused leather typically contains around 4-5% chromium content, with its effectiveness gauged through heightened hydrothermal durability and heightened resistance to deformation under high temperatures (1).

2.2.3. Post-tanning opration

The post-tanning process requires neutralizing and bleaching, followed by re-tanning, dyeing, and fat-liquoring. These operations are mostly concentrated in a single processing vessel and after re-tanning and drying submitted to several finishing operations. Finishing procedures improve the aesthetic qualities of the leather and deliver the anticipated performance attributes in the finalized leather regarding aspects such as color, texture, flexibility, and bonding, along with additional properties like elasticity, tear strength, resistance to light and perspiration, permeability to water vapor, and resilience to water (2).

2.3. Distribution of chromium in human scalp hair

Hairs have higher metal concentration potential and show past exposure of up to one year due to the slower growth rate (10 mm per month) and the potential of the metal cations to bind with the keratin proteins present in the hair matrix (16). Accordingly, exposure to chromium metal contaminants is preferred by researchers for biological monitoring of human exposure. For

several years, hair analysis has been rationalized to play a significant role in the control of chromium metal and is considered one of the most important biomarkers suggested to the Environmental Protection Agency (EPA) (15). A study in Vellore showed that the presence of chromium content in different colored hair which is the chromium level in black and mixed (black and white) colored hair samples were higher than white and mixed colored hair contains high chromium level as compared to black hair however, white colored hair has a relatively low concentration of chromium (14).

The other study ensured that the length (distance) of the hair from the scalp increases the concentration of chromium also increases while the concentration of chromium is not dependent on the time of hair has been exposed to the external environment. Therefore, the external factors do not normally affect the hair chromium levels rather than the nutritional status of the individual (17). As an excretory system, human hair can accumulate chromium metal and, it can integrate metals into its structure during its growth process. Hence, concentrations of chromium metals in hair can show the average level in the human body, documenting the population's exposure to chromium metals. In addition, compared to the other bio-indicators including blood, nails, urine, and saliva, human hair has presented chronic exposure to chromium metal and higher chromium concentration than in other bio-indicators (18). So, Human hair is considered an excellent screening tool for assessing chromium levels. Until now, several recent studies have shown that the importance of hair analysis is necessary to obtain information on the level of chromium. In contrast, the physiological concentration of Cr in hair is up to 1000 times higher than in serum and urine, thus facilitating analysis (15, 19).

2.4. Chromium exposure and adverse human health effects

Chromium represents a category of persistent environmental contaminants capable of infiltrating the human organism via various pathways, including inhalation, ingestion, dermal contact, respiratory tract, and food intake (the predominant channel for chromium metal exposure), subsequently resulting in bodily accumulation(6, 15). Chromium metal is an essential micronutrient, but it becomes toxic at concentrations higher than the amount normally required and a serious health risk to human and ecosystem health (20). chromium is also one of the widely used heavy metals in many industries and acts as a root cause of many health-related problems in humans as well as animals. Recently, chromium released from chrome plating and

tanner highly contaminates the environment than the release from natural resources and causes serious health problems including cancer, increased levels of oxidative stress, chromosome breaks, cellular damage, and chromium allergy, which affects around 1% of the general population and the workers who are involving in various tanning process from pretreatment to dying were health-wise severely affected by chromium pollution (13, 21, 22). Exposure to chromium metals in the tannery industries has been implicated as the causative agent for many health hazards as documented by many authors in the past. A cross-sectional survey held in India shows the higher prevalence of medical complaints in the form of hand dermatitis, asthma, and low back trouble in workers. *Rastogi et al*. reported that chronic exposure to the tannery industries caused pulmonary disorders, such as asthma, chronic bronchitis, and pulmonary tuberculosis (3).

The primary health impacts of chromium are damage to the gastrointestinal, respiratory, and immunological systems, as well as reproductive and developmental problems (23)**.** The study done in Bangladesh shows that **t**he pollutants generated in tanneries contain high concentrations of chromium which directly affects human health (6). Chromium, a major metal exploited in tannery, exits in two stable oxidation states: trivalent (III) chromium and hexavalent chromium (VI). Cr (VI) is more toxic than Cr (III) owing to its oxidizing ability and high solubility (24). Chrome tanning is the most common technique in leather processing; 90% of tanning industries use basic Cr (III) sulfate instead of other tanning agents to obtain better‐quality leather (1, 25). Tannery workers are mainly exposed to Cr in the inorganic or protein‐bound form (leather dust), Occupational exposure to Cr is generally through inhalation and dermal absorption, although ingestion is also possible where there is poor personal hygiene the common exposure pathway of chromium includes ingestion, inhalation, and dermal contact (23, 25).

Chromium exposure is a persistent health problem for leather industrial workers in developing countries including Pakistan (26). As a matter of general practice, a large number of the workers do not observe proper safety measures during the leather tanning process and hence are directly exposed to chromium (27). The majority of the epidemiologic researchers and several studies have found a relationship between chromium inhalation during the tanning process and they reported that exposure to chromium causes other health problems such as dermatitis, respiratory illnesses, increased lung and nasal cancers, carcinoma of the larynx and lung parenchyma,

paranasal sinuses, upper respiratory irritation, lungs obstructions and damage the lower respiratory system (11, 28).

2.5. Biological monitoring of chromium in human hair

Human biomonitoring including invasive biological samples, such as axillary hair and saliva alternative to classical fluids (blood and urine) has become an important tool to evaluate the internal dose of individuals occupationally exposed to chromium metal and to establish environmental limits of exposure and has contributed to reduce exposure and to prevent adverse health effects(16). A study held in Bangladesh showed Biological monitoring is the best option to get the actual degree of chromium and other heavy metals exposure levels and adverse health effects as compared the other indicators like soil, water, and air in different occupational settings (6). A study conducted in 2018 at the Rani pet industrial area, Vellore District stated that the biological monitoring of chromium that accumulated in the body of tannery workers indicated by analyzing the concentration level of chromium in hair, blood, urine, air, and fingernail samples and also the biological monitoring of chromium level has been documented in tanneries through analysis of hair, blood, and urine. Hair and nails are used as biomarkers which indicates the presence of toxic chromium exposure that affects the biological mechanism of humans and it can also be used to measure its internal dose (9). The level of chromium in the blood (CrB) has been checked as a biomarker for occupational level of chromium exposure. The study conducted in China shows that evaluating the concentration level of chromium in the blood (CrB) is important for biological monitoring in occupational chromium exposure workers and in addition to this, it investigates the reference value of chromium in the blood (CrB) for biological monitoring by studying of the correlations between the concentration chromium in the air (CrA) and chromium in the blood (CrB) which was 20 µg/L among occupational chromium exposed workers. The measurement of chromium concentration levels either urine or blood is more available in biological matrices and used for assessment of exposure in occupational biological monitoring (9, 18, 27).

2.6. Associated factor and chromium exposure level among tannery workers

2.6.1. Socio-demography factors

According to the study conducted in China shows that the concentration of chromium level in hair is associated with age and gender, the average concentration of chromium in male workers'

hair samples is lower than in female hair samples. In addition to these highest concentrations of chromium (Cr) were in the 36–50, 51–75, 7–12, 7–12, and 35–50 age groups for males and in the 36–50, 19–35, 36–50, 7–12, and 13–18 age groups for females, respectively (29). These prevalence differences in chromium metal concentrations between the age groups were mostly due to the metabolic process, occupational exposure, and physiological effects of gender (15). The study done in Gajju-Matah with a cross-sectional study design showed that the chromium level in various age profiles of workers of chromium concentration was very high in old age male workers as compared to the level of chromium in middle-aged males, similarly, chromium concentration levels in young male workers were higher compared to middle-age (11). The study held in 2011 showed that females had higher levels of Cr concentration than males because the concentration of chromium level increased, and the distance of the hair increased from the scalp due to this female tannery workers were more exposed to chromium (16, 17). The study conducted in Bangladesh shows that (40.2%) illustrated tannery workers were more exposed to chromium as compared to 43.5% of the workers who have primary education and 16.3% who had secondary education education is the key determinant of lifestyle and provides workers with skill and knowledge that can protect from the hazard chemicals (8).

2.6.2. Behavioral factors and chromium exposure level

The individual characteristics of knowledge, personal hygiene, working practice, and the use of PPE including (gloves, masks, and boots) are important to protect workers from occupational exposure to chromium. The study done on tanneries in Kenya shows that poor personal hygiene causes the entrance of chromium into the body and improper implementation of personal protective equipment (PPE) was significantly associated with chromium exposure level and prevalence of occupational diseases among tannery workers (7). The study in Bangladesh shows that in the case of the use of PPE, 26.1% of workers were found using gloves, 16.3% of using safety boots, and 26% were using masks during their working period and no workers were found to use respirators. This study shows poor use of personal protective equipment (PPE) among tannery workers (8).

Behavioral factors of individual workers including smoking cigarettes, drinking alcohol, and chewing chat have contributed to increasing the concentration of chromium levels and in the development of associated occupational diseases. A study conducted in 2015 in India among

tannery workers showed that the smoker and alcohol drinker workers had significantly higher concentrations of chromium as compared to the control group. The smoking habit, alcohol drinker workers, and control mean concentration of chromium was 10.6 ± 0.9 µg/l, 9.8 ± 1.3 µg/l, and 4.0 ± 0.7 µg/l respectively (30). The other studies also reported that smoking practice and alcohol consumption were observed to significantly higher concentrations of chromium along with a decreased number of leukocytes in tannery workers a big concern problem for the tannery workers (11, 16).The study conducted in Pakistan shows, that chromium exposure is high among tannery workers because of the lack of knowledge, careless attitude, and non-adoption of safety practices during work practice and knowledge was determined based on the workers' understanding of the chromium exposure risk effect (27, 31).

2.6.3 Occupational factors and chromium exposure level

So far several studies have been carried out on chromium exposure and related occupational factors in tanneries. Most of them agreed that the following factors were significantly associated with chromium exposure levels. Working duration in (years) working department (sections), working hours per day, provision of required personal protective equipment (PPE), training, and regular supervision.

The study held in 2020 in Bangladesh shows strong correlations and significant associated were found between the duration of tannery work and Cr levels in hair ($r=0.62$, $p<0.01$) and high levels of chromium cause higher levels of skin pigmentation of the face tannery workers. The study conducted in Bangladesh also showed the relationship between the chromium concentration in workers' hair and their working experience in year. This study found that the highest concentration level of chromium is present in the Samina tannery (8.72mg/kg), which has been associated with the tanning process for 40 years. The second highest range is found in RK tanner (7.64 mg/kg), which has been associated with the tanning process for 35 years. This study was conducted only by male tannery workers and excluded female workers (6, 8, 32). The other study revealed that the tannery workers enter into their works without prior training 73.7% of workers agreed that they require training before entering into the job. In addition to this study, 64.1% of the workers did not know the chromium exposure and its health effects and 90.5% of the workers know that personal protective equipment (PPE) can decrease the chromium exposure level (33).

The working environment focuses on the availability of ventilation, light, space, and hygiene (washroom, latrine) in the workplace that directly influences chromium exposure levels. The environmental status of the workplace in the tannery industry is very useful for continuing the good health of the tannery workers and controlling chemical exposure. Poor ventilated light and space in the workplace increase the exposure of chemicals including chromium, associated occupational and work-related diseases in tannery workers (2, 4).

Conceptual framework

A conceptual framework illustrates the expected relationship between independent and dependent variables and develops based on different literature that highlights the variables that affect one another and each other (Figur1). The independent variables include socio-demographic factors, behavioral factors, and occupational factors that contribute to the occupational chromium exposure level directly and/or indirectly. For instance, sociodemographic factors were to influence behavioral factors, and also behavioral factors influenced occupational factors directly and indirectly thereby resulting in a great deal of chromium exposure levels. Behavioral and occupational factors affected each other indirectly. Socio-demography, behavioral, and occupational factors affected occupational chromium exposure levels directly.

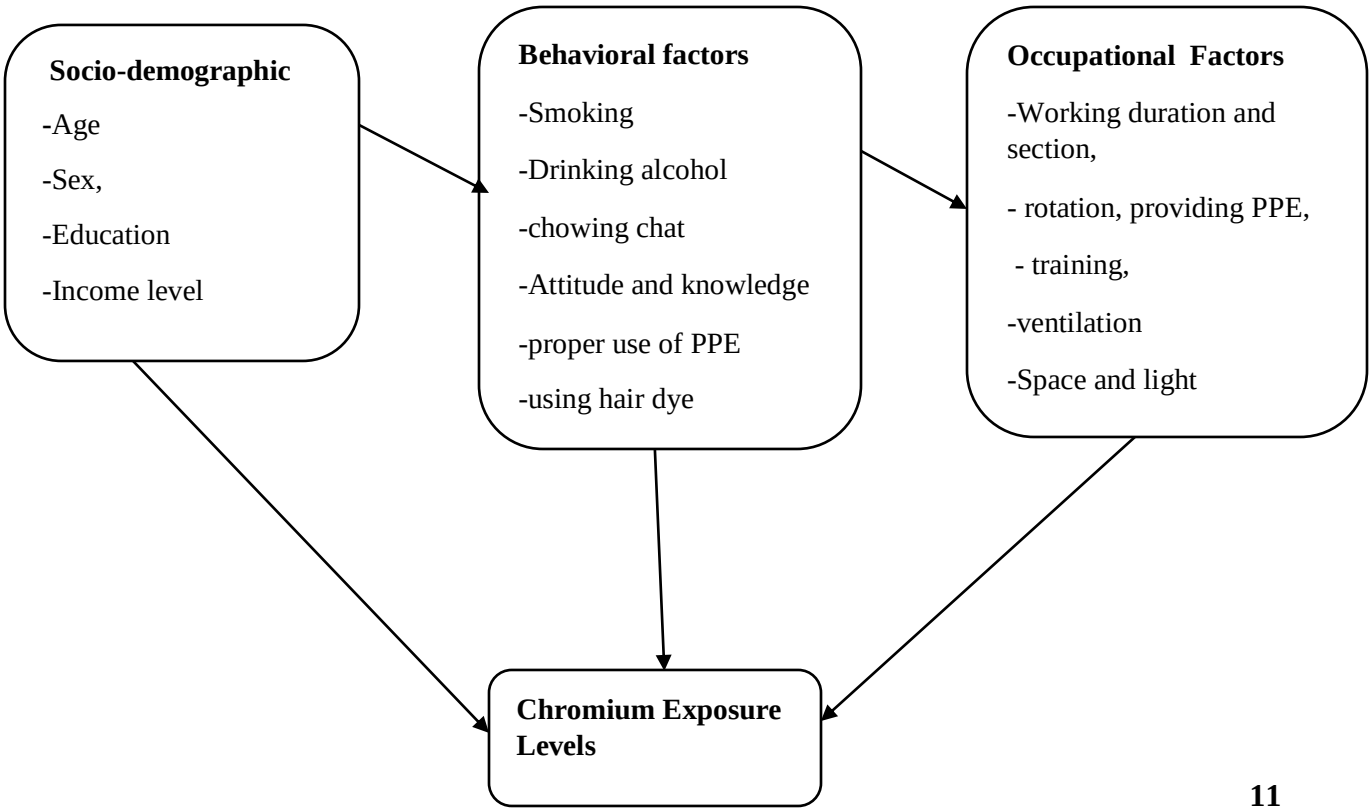


Figure 2: A conceptual framework for the study of chromium exposure levels

3. Objective

3.1. General Objective

Assessment of occupational chromium exposure level and associated factor among tannery workers in Addis Ababa Ethiopia.

3.2. Specific Objective

1. To assess occupational chromium exposure levels among tannery workers in Addis Ababa Ethiopia**.**

2. To determine the factors associated with occupational chromium exposure levels among tannery workers in Addis Ababa Ethiopia.

4. Method and materials

4.1. Study Design and Period

A comparative cross-sectional study design was used among tannery workers and comparison groups (non-tannery workers who are working in a bottled water factory) from November 2023-June 2024 to evaluate occupational chromium exposure level and its associated factors among tannery workers.

4.2. Study area

The study was conducted in the tannery industries found in Addis Ababa**.** There are twenty-six tanneries in Ethiopia, twenty-two of which are private and four of them are government-owned which have 153,650 sheep and goat skin soaking capacity and 9,725 cowhides soaking capacity per day, and together they employ 4577 people. Out of the twenty-six tanneries, six tanneries found in Addis Ababa, four of them were found in Akaki Klity, and two of them were found in Kolfe-Keranio sub-cities (34).

4.3. Source and Study Population

All workers in the tanneries and a comparison group working in a bottled water factory found in Addis Ababa were a source of population. The comparison group who worked in the bottled water factory had a comparative characteristic of sociodemographic parameters as tannery workers and the study population were the selected participants from the selected tannery factories and a comparison group who worked in a selected bottled water factory found in Addis Ababa.

4.4. Inclusion and Exclusion Criteria

Inclusion criteria

1. Employees who are working in the production process department directly involved in the four working sections (beam house (pre-tanning), tanning, re-tanning (post-tanning), and finishing of the tanning process were included in the study. Because the workers who work in those sections are actively and directly in contact with chromium through high exposure to

chromium and other chemicals every day and at time. In addition to this, the majority of the employees work in those production process working sections.

2. The participants who have at least one year of working experience at a tannery were included in the study. Because chromium exposure level in hair shows chronic exposure rather than acute so below one year's experience may not show chronic exposure levels.

3. The participant who uses hair dye was included in the study.

Exclusion Criteria

Employees who were full of bald hair were excluded from the study. i.e., the workers who had no scalp hair at all.

4.5. Sample size determination

for the first specific objective:

To determine the sample size for the first specific objective a double mean-standard deviation comparison formula with a 1:1 ratio for exposed and non-exposed groups was used. The standard deviations and the means of chromium exposure level for exposed and non-exposed groups 17.4 ± 3.6 µg/g and 14.5 ± 2.9 µg/g (micro gram chromium per gram hair weight) were obtained from a previous study that determined the concentration of chromium among tannery workers respectively (35, 36).

Sample Size (n) $=\frac{(\sigma_1^2+\sigma_2^2)(Z_{1-\beta}+Z_{1-\alpha/2})2}{(d)2}$=34 for each group

Where: n=the desired sample size per group

Z1-α/2= the confidence level at 95% CI is 1.96.

Z1-β=the desired power at 95 % (1.64)

σ1 = SD of exposed groups (Tannery workers)

σ2 = SD of unexposed groups (non-tannery workers)

d = 2.9 difference in means of two groups (effect size)

Hence by adding 15% of the non-response rate, the final sample size was 40 for each group and the total sample size was **80.**

for the second specific objectives

The sample size for the second specific objective was also calculated by using a double mean standard deviation comparison formula with a 1:1 ratio for chromium exposed group between male and female tannery workers. Hence; σ ± SD of =3.07±7.02 µg/L and 10.90±18.24µg/L were obtained from the previous study respectively (16).

Sample Size (n) $=\frac{(\sigma_1^2+\sigma_2^2)(Z_{1-\beta}+Z_{1-\alpha/2})2}{(d)2}$=49

Where: n = number of sample size

σ1= 3.07 mean of male tannery workers.

SD1=7.07 standard deviation of male tannery workers

σ2= 10.9 mean of female tannery workers

SD2= 18.24 standard deviation for female tannery workers.

Hence by considering the 15% non-response rate the final sample size for both male and female tannery workers was 56 which was the highest sample size to meet both specific objectives. Hence the final sample size used for the study was 112 (n=56 exposed group who working at tannery and n=56 non-exposed group who working at bottled water factory). To make sure the sample size calculation for both specific objectives; I have used Open Epi Version3 software **(http://www.openepi.com/SampleSize/SSMean.htm).**

4.6. Sampling Method

Out of six tannery industries found in Addis Ababa, three of them were included in the study. Because three of the tannery industries are not functional currently. The precise figures representing the employees within the designated tannery industries and the four major tannery factory operational sections of the selected tannery factory were identified. After getting the list of employees, from the human resource department; the calculated sample size was

proportionally allocated to each total number of tannery workers and the four production process sections (departments) workers (fig 2). Finally, a stratified random sampling method was applied to each selected section (department) to pick individual participants.

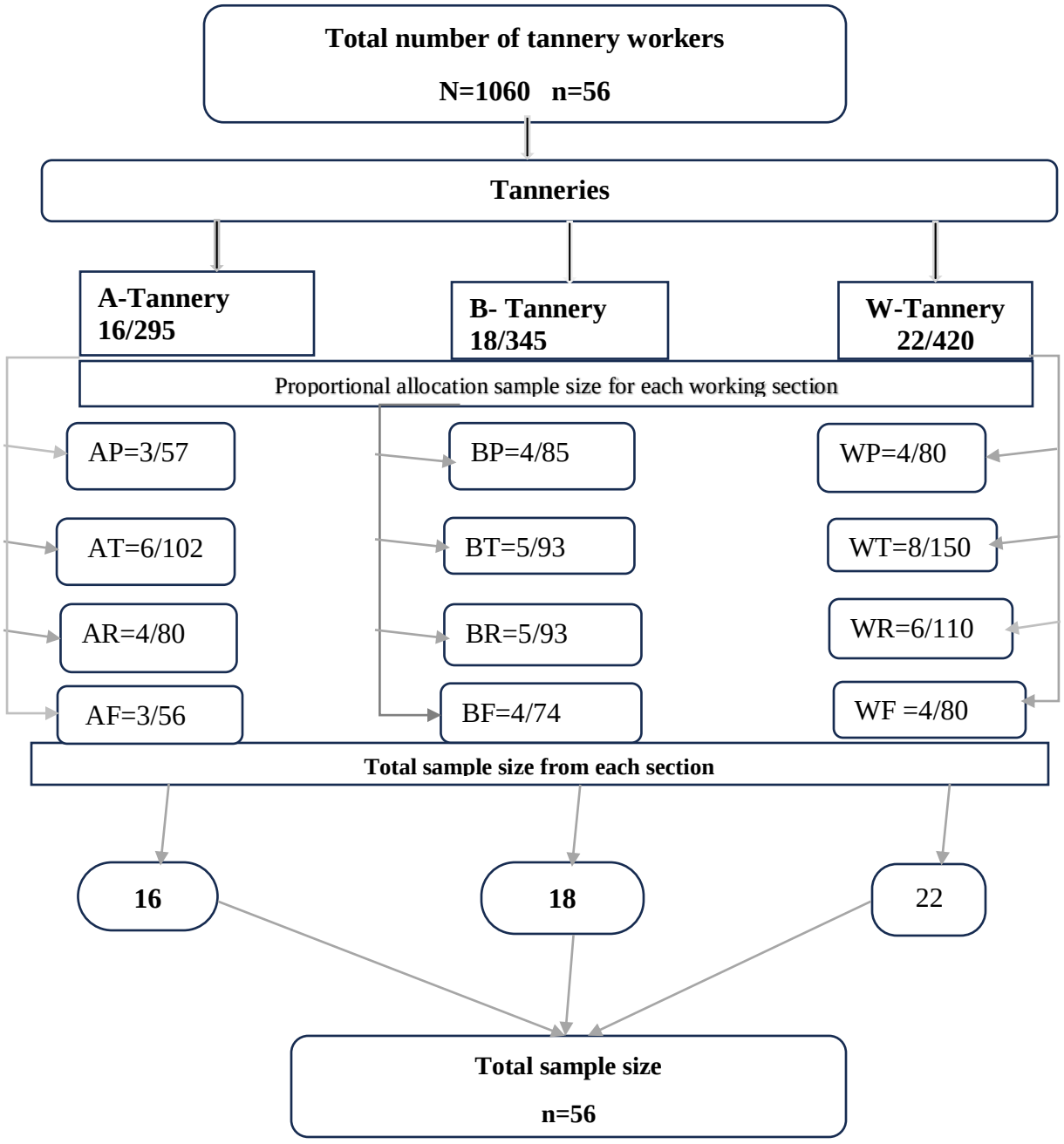


Figure 3: Sampling procedure and proportional sample size distribution diagram

Where: n=total number of workers in selected tanneries,

n=sample size

P=Pre-tanning section, T=Tanning section, R=Retanning, and F=Finishing working sections of each tannery. Letters: A, B, and W symbols represent selected tanneries.

4.7. Study variables

Dependent Variable

The outcome or dependent variable in this study is occupational chromium exposure level.

Independent Variables

The independent variables of this study will be included:

Sociodemography factors (Sex, age, marital status, monthly income, and education)

Occupational factors (Working duration and section, rotation, PPE, training, ventilation, and workplace light and space)

Behavioral Factors (personal habits (smoking, drinking alcohol chewing chat), attitude and knowledge, proper use of PPE, using hair dye).

4.8. Data Collection Procedure

In addition to hair chromium level analysis, structured questionnaires were prepared based on different published literature to collect information on the associated factors related to chromium exposure levels (8, 30, 37). To maintain consistency, the questionnaires were first prepared in English, then translated into Amharic by a linguistic professional, and then back-translated into English. It was pretested on 5% of the total sample size to modify contextually, quantitatively, and terminologically effectiveness on participants before the actual data collection was started. one day of training was given to the data collector on how the data is collected and observed.

Hair sample collection, transportation, and handling

The investigator, chemist-trained data collectors, and supervisor were involved in collecting the hair samples of approximately 1.5 g by freshly cutting from the scalp of selected tannery workers and the comparison group who working a selected bottled water factory using a pair of sterilized stainless-steel scissors and the hair samples were put in sealed plastic bags and kept at room temperature and before the hair sample collection, the questionnaire that prepared from different publish literature was distributed to the participant (6, 10). The collected hair was transported to

the Ethiopian Food and Drug Administration (EFDA) laboratory found in the Ethiopian Public Health Institute (EPHI) and finally preserved in the refrigerator at −18 °C until the time of analysis. The hair samples' chromium level was measured by the investigator with (EFDA) laboratory personnel via microwave plasma atomic emission spectroscopy (MP-AE) with model 4210 at a wavelength of 425.433 nm. (38).

Hair sample preparation and analyses

The hair samples were prepared and analyzed with the procedure that was validated in different published literature. The collected hair samples were washed with deionized water then with acetone and finally washed with deionized water to avoid dirty molecules in the outer portion of the sample that interfered with the analysis procedure and dried in an oven at 110 for one hour. 1g dried hair sample was put in a 50ml conical flask and digested in 20ml concentrated nitric acid and perchloric acid with 6:1 ratio solution prepared then put at room temperature for overnight. Then after boiled on a hot plate between 160 and 180^{o}c until the solution was cleared and cooled at room temperature and then transferred to 25ml volumetric flask and diluted with deionized water (6, 10, 15).The chromium concentration was determined by preparing with calibration curve with a series standard solution by known reference commercially available 1000mg/l stock solution of chromium using a microwave plasma emission spectrometer (MP-AES).

4.9. Data Management

To assess the comprehensiveness and coherence of the collected data, the data collectors delivered the hair samples in plastic bags along with completed questionnaires to the supervisor and principal investigator. The principal investigator checked the appropriate code and completeness for each hair sample plastic bag and filled questionnaires during and after data collection and inappropriate or missed hair sampled and filled questionnaires were sent back to the data collector for correction. The missed hair sample was corrected by re-consenting the participant to give his/her hair sample by discussing the cause of the missed his/her hair sample. Anything unclear and ambiguous was the rectification was done on the subsequent day following the data gathering process. After the conclusion of data collection, both hair specimens and completed questionnaires underwent a meticulous review to ensure their thoroughness and to address any instances of missing information. was excluded from the entry. The raw data was

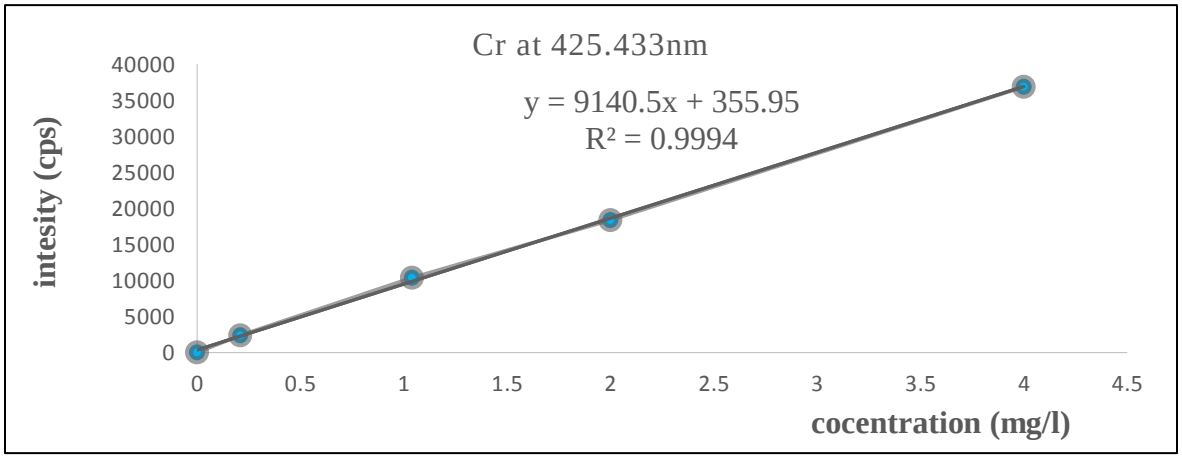
edited and entered into a computer using SPSS version 26, for data analysis. the data was backed up by saving it in different folders of the computer and using removable disks including USB drives, CD/DVD-ROM/RWs, and external hard drives.

4.10. Data Processing and Analysis

The statistical data analysis was done using SPSS (version 26) software. Descriptive statistics were used to display the demographic, behavioral, and occupational characteristics. The results were presented in the form of a frequency table, mean, percentages, cross-tabulation, and graph. The mean values of chromium levels in hair were analyzed using an independent t-test to compare the mean hair chromium levels of exposed (tannery factory workers) and unexposed groups (water factory workers). The chi-square test was used to observe the association between the two groups sociodemographic independent variables and also simple linear regression analysis was used to test the association between a dependent variable (hair chromium level) and independent (sociodemography, occupational, and behavioral factors) variables by checking the model assumptions.

4.11. Data quality Assurance and Control

All equipment used for laboratory work was cleaned and leveled to minimize contamination of samples. and the reagent blank samples were digested in the same way as for hair samples and were used to correct the instrument readings. The samples were analyzed in duplicate and the readings were made average for each sample. The analysis was performed in an accredited Food and Drug Administration laboratory using microwave plasma atomic emission spectroscopy (Agilent model 4210) at a wavelength of 425.433 nm. The lower limit of detection(LOD) for chromium was 0.003 mg/kg. sires calibration curves were prepared by plotting the intensity and respective readings against the concentrations (0.2,1, 2, and 4 mg/kg of certified reference stan



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m (fig 3).

Fig 4: Standard calibration curve of chromium analysis in hair

A recovery test was also done using randomly selected hair samples with the sample procedures as sample preparation for the spiked sample and un-spiked sample with a known chromium concentration contained sample solution. Then, the percentage recoveries were calculated as shown in the following formula:

$$\% \text{ Recovery} = \frac{\text{Spiked Value} - \text{Unspiked Value}}{\text{Standard of Spiked added}} * 100$$

From the randomly selected hair sample, the calculated percentage recovery result was 93.6%, it was in a conventionally acceptable precision and accuracy with the percentage recovery range (85% - 110%) of the samples. One day of training was given to the data collector and supervisor regarding the objective of the study, data collection method, the importance of data quality, data collection tools, inclusion and exclusion criteria, Ethical issues, and record keeping. The questionnaire was prepared first in English and then translated into Amharic and finally, it was retranslated back to English by an independent translator to check for consistency. The investigator and supervisor coordinated the interview process, conducted supportive supervision, discussed with data collectors, and checked the completeness and consistency of collected data.

4.12. Operational definition

Chromium (Cr): is an excellent tanning agent widely used in the tannery factories

Routes of chromium exposure: the way of chromium exposure that can enter the body through inhalation (mist, gas, or dust) form of chromium exposure can be absorbed through the lungs of workers, ingestion, and skin contact.

Chromium exposure level: the concentration of chromium found in tannery factory workers' hair samples.

Working sections: the main production unit that performs by using chromium as a tanning agent and the majority of workers involved in this unit have direct contact with chromium in the tannery factory

Tanning: is the main production process in tannery factories mainly uses trivalent chromium to treat the skin and hides of animals to produce leather.

4.13. Ethical consideration

The ethical approval of the study was obtained from the Ethical Review Board of Addis Ababa University (Ref. No.: SPH/296/2024). An official support letter was written to the tannery management to obtain permissions. All respondents were informed about the purpose of the study and why it was being conducted on tannery workers. The participants have the right to give a tip of hair sample from all parts of their head or refuse it at any time voluntarily, according to their informed consent. The study participants were requested for their interest to participate in the study and they were involved in the study only after getting their informed verbal consent. Participation in the study was voluntary and they can withdraw at any time during the sampling and interview process. The response of the participant was kept confidential using tough strict coding measurements.

4.14. Dissemination of the Findings

The findings will be disseminated to Addis Ababa University, the School of Public Health Department of Preventive Medicine, and the Occupational and Environmental Health track staff, at the thesis defense date. After the finalization of the study, it will be disseminated to the tannery industry manager and all concerned bodies. Publication in national and international journals will be considered.

5. Results

5.1. Socio-demography information of the study population

A total of 112 participants were included in the study. Among those participants, 56 (38 males and 18 females) were working in the tannery factory, and the others 56 (51 males and 5 females) working in the water factory. The mean age of the tannery workers was (36.77±8.93) with a range of 21-58 years, whereas the water factory workers' mean age was **(**26.63±4.74**)** with a range of 20-43 years. More than two-thirds of tannery and water factory workers were married and single respectively. Regarding educational status, more than half 58.9% of the tannery workers were in secondary school. The result also showed that 37.5% of water factory workers participants had a degree, and a better educational level as compared to tannery workers participants. Two-thrid 64.3% of tannery and 67.9% of water factory workers participants were paid a monthly income between 3,000-6,000 Ethiopian Birr respectively. Regarding the employment status of the participants, 98.2% of the tannery and 82.1% of the water factory participants were permanent workers (**Table 1**).

Table 1: Socio-demography Characteristics of Respondent

Variable		n= 56 Exposed group n (%)	n= 56 Unexposed group n (%)	X^2	p-value
Sex	Male	38 (67.9)	51 (91.1)		
	Female	18 (32.1)	5 (8.9)	0.16	0.69

Age	18-30	18 (32.1)	47 (83.9)		
	31-45	26 (46.4)	9 (16.1)		
	>45	12 (21.4)			
	(Mean ±SD) year	**(36.77±8.93)**	**(26.63±4.74)**	0.98	0.61
Marital status	Single	16 (28.6)	35 (62.5)		
	Married	39 (69.6)	21 (37.5)	0.37	0.54
Educational Level	primary school	12 (21.4)	5 (8.9)		
	secondary school	33 (58.9)	24 (42.9)		
	diploma	10 (17.9)	6 (10.7)		
	degree	1 (1.8)	21 (37.5)	9.7	0.38
Monthly Income	<3000	3 (5.4)	6 (10.7)		
	3000-6000	36 (64.3)	38 (67.9)	3.69	0.72
	7000-12000	17 (30.4)	8 (14.3)		
	>12000		4 (7.1)		
Employment Pattern	Permanent	55 (98.2)	6 (82.1)		
	Contract	1 (1.8)	10 (17.9)	0.22	0.64

5.2 Occupational working factors

Out of the four main production sections in a tannery, more than half 60.7% of the respondents worked in the tanning and retaining sections. Fifteen (26.8%) of the total respondents in the tannery worked more than eight hours a day, while thirty (53.6%) of the respondents in the water factory worked more than eight hours a day on average. Regarding working duration in the tannery 27 (48.2%) of respondents had above 10 years of working experience and the mean years experience of tannery workers was (12.7±8.1) with the range of 3-38 years. On the other hand, water factory 50 (89.3%) respondents worked between 1-5 years, and the mean year's experience was (2.7±1.9) with a range of 1-8 years.

More than half 62.5%) and 89.3% of the tannery and water factory respondents reported that personal protective equipment (PPE) was provided regularly respectively. However, there is a limitation of masks, gloves, hallmates, and eye goggles in both groups. On the other hand, 52 (92.9%) of the respondents said that there was no regular working rotation in both exposed and non-exposed groups respondents. In addition to this 54 (96.4%) and 56 (100%) of almost all respondents said that there was enough light and space in the workplace in both exposed and nonexposed groups respectively (**Table 2**).

Table 2: Occupational working factors of both selected tannery and water factories

Variable		n= 56 Exposed group n (%)	n= 56 Unexposed group n (%)	P-value
Working Section	Pre-tanning	11(19.6)		
	Tanning	19 (33.9)		
	Re-tanning	15 (26.8)		<0.001
	Finishing	11(19.6)		
Working hours per day	<8hrs	11 (19.6)	5 (8.9)	
	For 8hrs	34 (60.7	21 (37.5	0.03
	>8hrs	11 (19.6)	30 (53.6)	
Working duration in year	1-5	3 (5.4)	50 (89.3)	
	6-10	25 (44.6)	6 (10.7)	0.03
	>10	28 (50.0)		
	(Mean ±SD)	**(12.32±73)**	**(2.7±1.89)**	
Regular Provide PPE	Yes	35 (62.5)	50 (89.3)	
	No	21 (37.5)	6 (10.7)	0.34
Training and supervision	Yes	33 (58.9)	39 (69.6)	
	No	23 (41.1)	17 (30.4)	0.7
Regular Working Rotation	Yes	4 (7.1)	4 (7.1)	
	no	52 (92.9)	2 (92.9)	0.39

Availability of Ventilation	Yes	17 (30.4)	32 (57.1)	
	No	39 (69.6)	24 (42.9	0.11
Working space and light	Yes	54 (96.4)	56 (100)	0.59
	No	2 (3.6)		

5.3. Behavioral factors for both exposed and Unexposed group

This section presents personal factors, awareness about chromium exposure, and the importance of PPE, and measures the occupational exposure training of the respondents. In all tannery workers, 56 (100%) of the respondents used available personal protective equipment (PPE) properly and almost all 96.4% of water factory workers respondents also used available PPE properly. Out of the total, only 27 (48.2%) and 21 (37.5%) of exposed and non-exposed group respondents were taken occupational exposure training respectively. Regarding the hair color, most of the participants did not use hair color, out of the total only 10 (17.9%) and 7 (12.5%a) of exposed and unexposed groups respondents used hair color (dye).

The majority of the respondents in both exposed and unexposed groups had no addiction habits of smoking cigarettes drinking alcohol, and chewing chat. However, 30 (53.6%) and 6(10.7) of exposed and unexposed group respondents were drinking on average two glasses of alcohol occasionally. In addition to this 6 (10.7%) and 8 (14.3%0 of exposed group respondents were smoking cigarettes and chewing chat the last two years respectively. Out of the total 23 (41.1%) of the exposed and all unexposed groups respondents were not aware of chromium exposure and its health effects. The majority, 96.4% of the exposed group participants were aware of the importance of personal protective equipment (PPE) for their job. However, in unexposed groups, more than half 62.5% of respondents were not aware of the usage of personal protective equipment (PPE) **(Table 3**).

Table 3: Behavioral factors for both exposed and Unexposed groups

Variable		n= 56 Exposed group n (%)		n= 56 Unexposed group n (%)	P- value
Proper use of available PPE	Yes	56 (100)		54 (96.4)	0.70
	No			2 (3.6)	
Occupational exposure training	Yes	27 (48.2)		21 (37.5)	0.8
	No	29 (51.8)		35 (62.5)	
Used hair color	Yes	10 (17.9)		7 (12.5)	
	No	46 (82.1)		49 (87.5)	0.55
Cigarette smoking status	Yes	6 (10.7)		3 (5.4)	
	No	50 (89.3)	53 (94.6)		0.54
Alcohol drinking status	Yes	30 (53.6)		6 (10.7)	
	No	26 (46.4)		50 (89.3)	0.41
Chat chowing status	Yes	8 (14.3)		4 (7.1)	
	No	48 (8.7)		52 (92.9)	0.68
Chromium exposure Awareness	Yes	33 (58.)			
	No	23 (41.1)		56 (100)	0.31
PPE usage awareness	Yes	54 (96.4)		18 (32.1)	
	No	2 (3.6)		38 (67.9)	0.37

5.4. Comparison of hair chromium levels among tannery and water factory workers

This section presents the evaluation of hair chromium exposure levels between tannery and control groups of water factory workers using independent t-test analysis. The t-test revealed a significant difference between the two groups ($t(110) = 4.7$, $P< 0.001$), with the mean score of hair chromium levels for exposed groups (M=11.2, SD=10), and unexposed groups(M=4.6, SD=2.7). The magnitude of the two groups' mean difference (Mean difference =6.6, at 95% CI: 3.8 to 9.4) was statistically significant.

The descriptive analysis finding also showed that there was a higher hair chromium concentration in females as compared to males in both groups. However, in the exposed group, the mean score (14.2±9.2) mg/kg of the highest female hair chromium concentration was recorded to compare the exposed male workers' mean (9.8±10) mg/kg and unexposed groups male (4.5±2.7) mg/kg and female(5.3±3) mg/kg of hair chromium concentration respectively.

Thus, The finding of the investigation observed that the tannery workers (exposed groups) had very high levels of chromium in their hair samples to compared unexposed groups. The magnitude of exposed groups of female and male hair chromium levels means difference (4.4) mg/kg was statistically significant. (**Table 4**).

Table 4: Comparison of hair chromium levels between exposed and unexposed groups

	n	(Mean ±SD)mg/kg^{-1}	Median	Range	Mean difference	95% CI
Exposed Group	56	11.2±10.0	9.2	0.13-56.13	6.6	3.8-9.4
Unexposed group	56	4.6±2.7	4.1	BLD-13.75		
Exposed groups						
Female	18	14.2±9.7	12.3	0.38-39.38	4.4	
Male	38	9.8±10	7.3	0.13-56.13		
Unexposed groups						
Female	5	5.3±3	4.13	2.63-10.25	0.8	
Male	51	4.5±2.7	4.13	BDL-13.75		

BLD= below the detection limit (0.003) ppm of the instrument

5. 5 . Associated factors and hair chromium exposure levels among tannery workers

These sections present the relationship between the hair chromium concentration (level) and associated factors including socio-demography, occupational, and behavioral factors among tannery workers.

Hair chromium concentration and Sociodemography factors

The correlation finding revealed that hair chromium level and sex of the respondents were found to be a low positive correlation and statistically significant (r = 0.28, p =0.04). The result also showed that there was a higher hair chromium concentration in females as compared to males among tannery workers. The other sociodemographic factors including age of the respondent, income, marital status, and level of education were not significantly associated with the hair chromium concentration (level) p >0.005 at 95% CL. Nevertheless, the study findings indicated a notable prevalence of high chromium levels in hair samples from individuals aged between 31 and 45, with an average hair chromium concentration of 13.67 mg/kg among tannery workers study participants **(fig 4**).

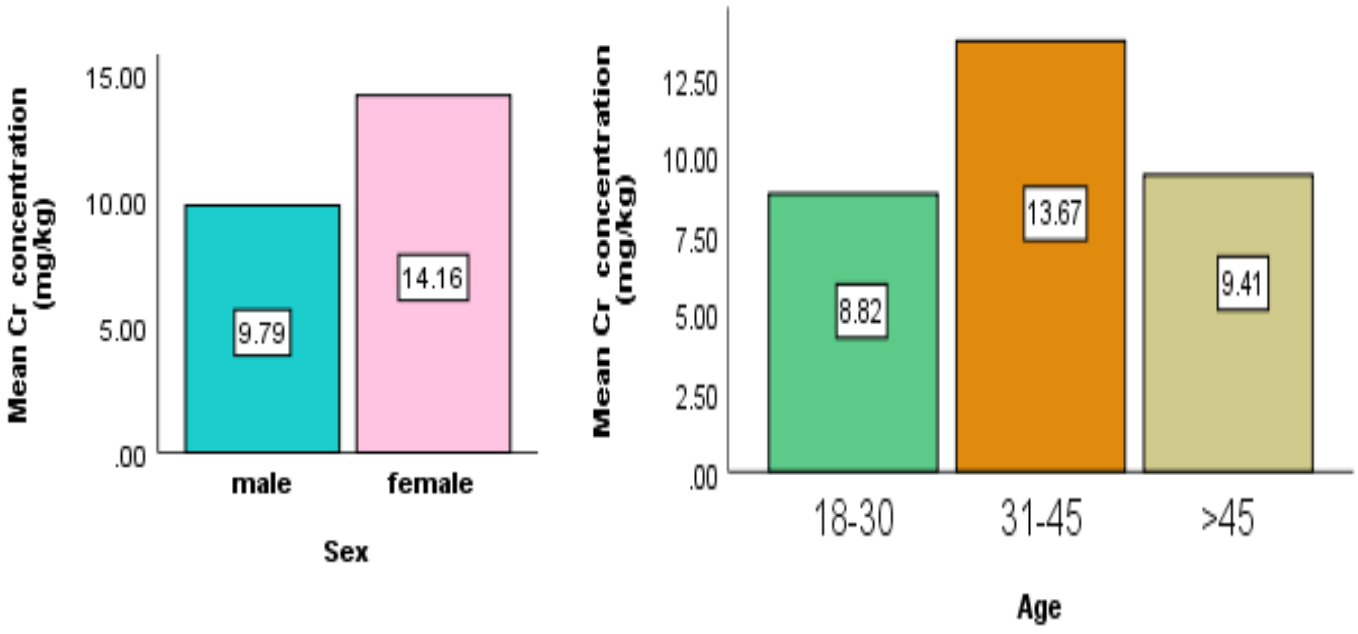

Fig 5: The relationship between hair chromium concentration of sex and age (n=56)

Hair chromium concentration and occupational working factors

The linear regression analysis result revealed that the working duration was significantly associated with the hair chromium concentration among tannery workers (B=4.5, t=2.1, p= 0.03). The hair chromium level was compared with the working duration of workers found that the mean hair chromium concentration level in workers who worked for 6-10 and above ten (>10) years was (mean±SD) (8.51±6.6) and (13.99±12.18) mg/kg among tannery workers respectively. the finding showed that there was a significantly higher hair chromium concentration found in the workers who worked above ten years **(fig 5).**

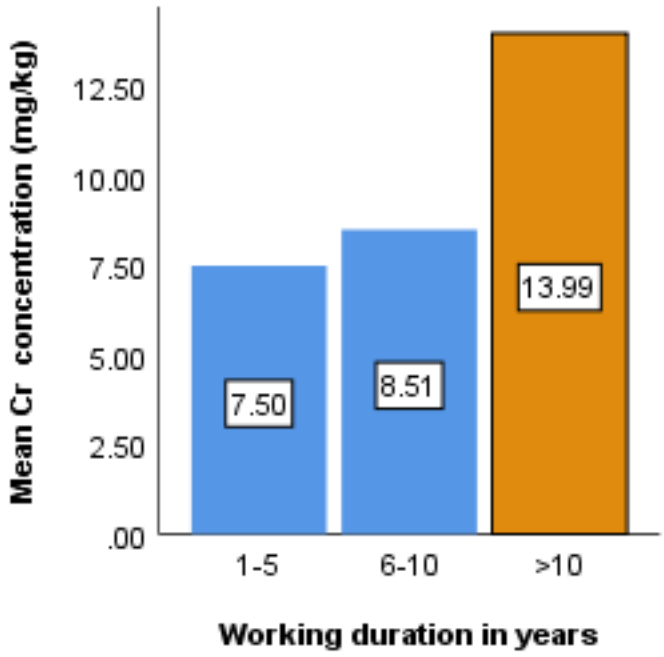

Fig 6: Chromium (Cr) concentration-response relationship with service years (n=56)

Hair chromium concentration level and working hours days

The investigation unveiled that the duration of work per day exhibited a significant correlation with the levels of chromium concentration in the hair of employees at tanneries (B=4.4, t=2.13, p= 0.03). A comparison was made between the chromium concentration levels in the hair of workers and their daily working hours. In individuals working less than eight hours daily, the mean hair chromium concentration was (6.83±4.06) mg/kg. For those working eight hours a day, the average chromium concentration in their hair was (11.17 ±11.35)mg/kg, ranging from 0.13 to 56.13 mg/kg. Furthermore, it was noted that the highest mean chromium concentration level in workers' hair was (15.66±8.24) mg/kg, with a range of (1.65 to 27.5) mg/kg, among those working more than eight hours (**fig 6).**

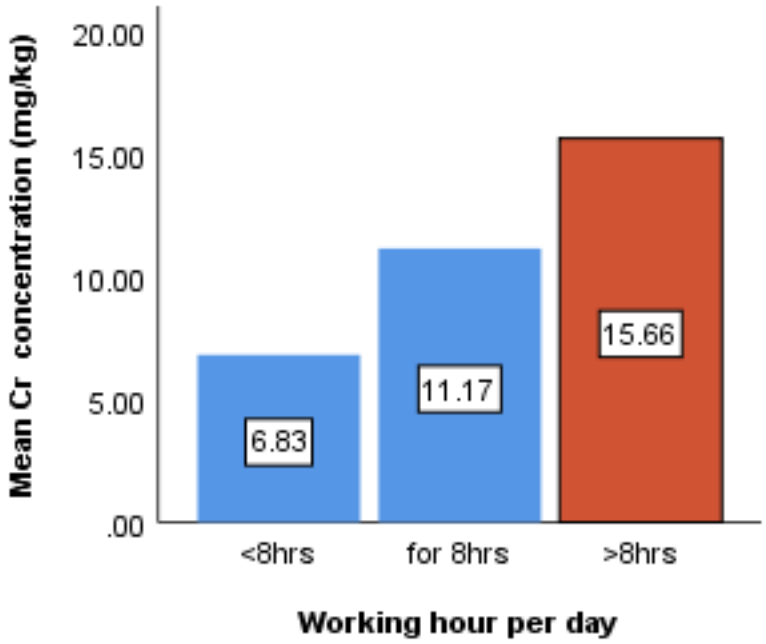

Fig 7: The relationship between Cr concentration with working hours per day (n=56)

Hair chromium concentration levels and working section

The four primary operational sections within the examined tannery are outlined in Table 6. An inspection conducted on a specific production unit, fulfilling the dual role of storage and weighing revealed the daily usage of an average of 34 bags of chrome, with each bag weighing 25 kg, throughout the tanning operations. Nevertheless, the quantities of Cr applied varied in alignment with Clint's stipulations. The result showed that the production operational working sections were significantly ($p<0.001$) associated with the worker's hair chromium concentration levels who worked those sections. The investigation revealed that the tanning working production sections had higher mean chromium concentration levels (12.37±13.64) mg/kg with a range of 1.65 to 56.13 compared to those in the pre-tanning, retaining, and finishing production working sections with the mean concentration levels of 12±8.91 mg/kg, 9.01±6.56 mg/kg and 11.36±8.12 mg/kg respectively. The result also observed that hair chromium concentration level in pre-tanning working section workers was higher next to the tanning working sections.

Table 5: The hair chromium concentration levels in the working production section

Production process Working section	**N (56)**	**Cr conc (mg/kg) (Mean±SD) mg/kg**	**Range**
Pre-tanning	11	12±8.91	0.75-27.5
Tanning	19	12.37±13.64	1.65-56.13
Re-tanning	15	9.01±6.56	0.38-24.25
Finishing	11	11.36±8.12	0.13-23.38
p-value	<0.001		

Hair chromium concentration levels and Behavioral factors

The study also evaluated the association between the hair chromium concentration levels of tannery workers and their attitudes towards chromium exposure, awareness of personal

protective equipment (PPE) significance, knowledge, occupational training, as well as detrimental habits such as smoking, drinking, chewing, and hair dye usage. The participants lacking training in occupational chromium exposure exhibit elevated mean hair chromium concentration levels (11.56) mg/kg compared to trained participants (10.49) mg/kg. Consequently, the linear regression analysis displayed that training on occupational chromium exposure, detrimental habits such as alcohol consumption, smoking, and chat chewing and hair dye users were not significantly associated ($p>0.05$) with hair chromium exposure levels among individuals working in tanneries. This study also evaluates the hair chromium exposure levels in participants' natural hair color types of black, and mixed (black and white) among tannery workers. The black hair type had higher mean chromium concentration levels (11.36±10.91) mg/kg with a range of 0.13 to 56.13 mg /kg compared with mixed hair mean chromium concentration levels of (10.93±8.56)mg/kg with a range of 0.38 to 39.38 mg/kg. no participants who have only white natural hair color type in the study (**Table 7**).

Table 6: Hair chromium concentration of occupational training, hair dye, and hair type.

Variables		Mean Cr concentration (mean±SD) mg/kg	Range	p-value
Occupational training	Yes	10.49±11.73	0.13-56.13	0.80
	No	11.56±8.52	0.63-39.38	
Using hair dye	Yes	12.65±13.9	0.38-56.13	0.55
	No	10.55±8.48	0.13-39.38	
Hair type	Black hair	11.36±10.91	0.13-56.13	0.88
	Mixed (black and white) hair	10.93±8.56	0.38-39.38	

6. Discussion

This finding demonstrated a notable disparity in the average hair chromium levels, with the exposed groups exhibiting a significantly higher mean of 11.2 mg/kg compared to the unexposed groups' mean of 4.6 mg/kg chromium levels. Furthermore, this study also noted that surpassing the typical 8-hour workday, prolonged working experience within the tannery, and the specific operational production units in the factory were identified as the key influential factors linked to elevated levels of chromium exposure in the hair of tannery workers.

The findings reveal that 38 individuals (67.9%) were male within the exposed group, whereas in the unexposed group, the majority consisted of 51 male individuals (91.1%). This may be because of the physically demanding nature of factory work that requires a certain level of energy and fitness to perform the tasks effectively. Several previous studies conducted in other countries had not explored the levels of chromium in hair among female workers in the tannery factory (6, 11, 25). The mean age of exposed groups was 36.77±8.9 years, ranging from 21 to 58 years. This indicated the range of age in this study was greater than that of the study conducted in Bangladesh where the range of age was 20 to 50 years among tannery workers (6).

This study found that the tannery workers' mean hair chromium concentration is 2.44 times greater than the control group's hair chromium concentration. This finding was Similar to studies conducted in Canada Ontario and Turkey tannery workers which showed significantly ($p<0.001$) higher means of 0.55 and 17.4 mg/kg hair chromium concentration compared to the control group means of 0.12 and 14.5 mg/kg hair chromium concentration levels respectively (19, 35).

The present study revealed a lower mean of 11.2 mg/kg tannery worker hair chromium levels compared to the study done in Pakistan and Turkey, a mean of 19.68 mg/kg and 17.4 mg/kg of hair chromium concentration respectively (11, 35). The difference might be due to variations in sample size and technological advancement between this study and previous studies. On the other hand, the mean chromium concentration level in this study was much higher than the

study conducted in India, and two studies conducted in Bangladesh among tannery workers with a mean of (7.3± 0.41) mg/kg and (5.8± 0.84) mg/kg, (6.254± 6.18) mg/kg respectively (6, 10, 13). The disparity observed in this scenario may stem from variations in sample size, working hours, duration of workload, and the superior utilization of technology in the other country to mitigate exposure and these countries also have significant emphasis on occupational health and safety concerns, contrasting with our country's.

The International Occupational Safety and Health Information Center (IOHS, 1999) recommended that the maximum hair chromium levels should be 1.18mg/kg. However, this study found that 51 (91.1%) of the tannery individual study participants' hair chromium levels exceeded the maximum recommended limits of IOHS,1999 (10). This may cause different health problems. This argument was supported by the study conducted in Pakistan and Bangladesh that indicated tannery workers were suffering from different health problems including skin infections, respiratory problems, and cutaneous allergic reactions due to prolonged contact with elevated levels of chromium exceeding the recommended limit (10, 11).

In the current study, there was a statistically significant correlation between sex and mean hair chromium levels among tannery workers participants. The result indicated a higher level of chromium concentration in the hair among female tannery workers compared to their male counterparts. This finding was consistent with a study conducted in India and Spain that showed a higher concentration of chromium among females compared to males with the mean (0.361±0.47 and 10.90±18.24) mg/kg of hair chromium levels to compare male mean (0.25±0.28 and 3.07±7.02) mg/kg of hair chromium levels respectively (16, 39). This may be due to the fact that females exhibited a greater length of hair in comparison to males and men also tend to wash and rinse their hair frequently. Studies have indicated that the chromium concentration was significantly correlated to the hair length and repeatedly washing hair with detergent and subsequently rinsing it extensively with deionized water results in a reduction in hair chromium concentration (17, 40).

This study also revealed that the regression analysis did not show a significant association between age and hair chromium levels. The finding is consistent with the study conducted in China and Bangladesh showed that there was no significant association between hair chromium concentration and age (15, 32). On the other hand, the study held in Pakistan and Bangladesh

observed that there was a notable correlation between the levels of chromium found in the hair samples of the workers and their respective ages, indicating a trend of increasing chromium concentration with age (10, 11). The possible reason for this disparity between these studies could be attributed to the fact that the majority of the participants were very young making it difficult to see the difference compared to the studies in Pakistan and Bangladesh.

Our study also observed that there was a statistically significant association between the working experience and hair chromium levels of tannery workers with the mean (13.99) mg/kg hair chromium levels of the participants working above ten years being much higher than the mean 8.51 and 7.5 mg/kg hair chromium levels working duration of 6-10 and 1-5 years respectively. The finding is consistent with the study conducted in Bangladesh which also demonstrated a notable correlation between the duration of working in the year and the level of chromium in the tannery workers' hair with the highest chromium level recorded at 8.72mg/kg and 7.64 mg/kg associated with individuals who have worked for 40 years and 35 years respectively (6).

The present study also showed that there was a significant relationship between working hours per day and the hair chromium concentration of tannery workers. A similar study in Bangladesh finding revealed that there was a correlation between the amount of chromium in tannery workers' hair and the amount of time they worked (10).

This study found a significant association between the working section and hair chromium levels of tannery workers. This finding was consistent with the studies conducted in Kenya and Bangladesh held that there was a significant association between the working section and chromium level among tannery workers (7, 10). The highest mean of hair chromium levels was observed in the tanning working unit followed by pre-tanning sections. The high concentration of chromium in the hair of tanning section workers was attributed to their direct contact with powdered chromium due to their involvement in mixing, weighing, and loading chromium. The next highest hair chromium level was recorded in the pre-tanning section because the tanning and pre-tanning working sections were performed in one class for the studied tanneries, due to this the workers working in those sections were easily exposed to chromium directly as dust forms. The lowest hair chromium level was found in the re-tanning working section. The possible reason for this the retaining section performed its work far away from the tanning and pre-tanning section and was not directly in contact with the chromium.

Furthermore, the study observed there was a higher average hair chromium concentration among participants who utilize hair dye (color), in contrast to the participants who do not use hair dye (color) among tannery workers. The study conducted in Libya assessed the chromium level in different brands of hair dyed and showed that chromium metal was found in all hair dye samples tested, and another study also showed various chromium content in different hair dyes (39, 41). The possible explanation for this disparity, the hair dye (colors) used by the participant may contain chromium metal.

Strengths and limitations of the study

The strength of the study was the hair chromium level was measured in an accredited laboratory using the latest MP-AES instrument and it was also conducted between the two comparison groups of expos tannery workers and control water factory workers to verify the hair chromium levels and give baseline information for further study.

This study's limitation is that no similar study was conducted in Ethiopia, and it is difficult to evaluate and compare this finding in our country's context. The research was conducted under challenging circumstances, as there were obstacles in obtaining hair samples from volunteer participants. These challenges arose from a small sample size, which could potentially lead to information biases, causing participants to inaccurately report events This study did not assess the health effect of chromium exposure among tannery workers.

7 . Conclusion and Recommendation of the Study

Conclusion

The findings revealed that the tannery workers had higher significant hair chromium levels as compared to the water factory workers even though the study also observed that higher mean hair chromium levels were found in female hairs in tannery workers to compare both male and female hair chromium levels of water factory workers. The study observed that significant numbers of 51 (91.1%) of individual tannery workers' hair chromium levels exceeded the maximum recommended limit (1.18) mg/kg of the International Occupational Safety and Health (IOHS). Extra working hours (more than 8 hours per day), long duration of service years, and production working units in factories were found to be the main significant predictors for the presence of elevated hair chromium exposure levels among tannery workers. Thus, Workers who work in tannery factories require more attention to occupational health and safety training, awareness creation of chromium exposure and its health effects, and preventive mechanisms to reduce occupational exposures to chromium and improve the hygiene practices of workers in each working department.

Recommendation

The employers

- The tannery management/administration should give more attention to workers' health and safety by providing adequate and relevant personal protective equipment (PPE) of face and mouth masks gloves and halmate.
- Should minimize more than eight working hours tasks to reduce the chromium exposure levels of workers
- Should set regular working rotation from one working section to another to minimize the exposure

The employees

- The workers also take self-responsibility to apply exposure prevention methods and try to exercise hygiene practices to reduce the presence of chromium exposure.
- Should report immediately to the nearest supervisor if any defects occur at the work

The MOLSA and other concerned body

- Should develop and implement the occupational exposure limit guideline for chromium and other heavy metals to reduce workers' exposure and prevent their health.
- Should establish health education and promote awareness of occupational chromium exposure and its adverse health effects through different media

For further research studies:

- Further longitudinal studies should be done by using additional bioindicators including nails, urine, and blood to show the full image of chromium exposure levels and its health effects to for taking early prevention actions and to ensure workers' health in the tannery.

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9. Annexes

Annex I: Study information sheet (English version)

Hello dear brother or Sister

Introduction: My name is Belaynesh Demissie. I am a Master of Public Health (MPH) student in the environmental and occupational health specialty program at Addis Ababa University, College of Health Sciences, School of Public Health. Currently, I am conducting my research in partial fulfillment of the Master's degree. I have permission to do this research from the Addis Ababa University School of Public Health Research Ethics Committee, management of tannery industries, and other concerned bodies. Hence, you are invited to participate and give your hair sample voluntarily in this study.

Research Title: Assessment of Chromium Exposure Level and Associated Factors among Tannery Workers in Addis Ababa, Ethiopia: A Comparative Cross-Sectional Study.

The objective of the Study: Assessment of occupational chromium exposure level and associated factors among tannery workers in Addis Ababa Ethiopia.

Benefit and risk of the study: There will be no financial benefits for you in participating in this study. However, the information you provide will be very helpful for the prevention of chromium exposure and related health effects in the future. In addition, the result from this study will be used to help policymakers and other responsible bodies to improve occupational safety and health services in this organization. Your participation in the study will not have any risk or discomfort feeling on you other than your time spent.

Rights of Participants: All participants will take part in this study voluntarily, meaning that no one has the right to be forced to give hair samples. If the respondent is not voluntarily participating, he or she will have stopped the participation, asked questions, and skipped questions at any time during the study period. If you are a volunteer to participate in this study, I have to take 1.5 grams of your hair sample by cutting the tip of your hair from all parts of your head.

Confidentiality and privacy protection: The information you provide will be kept confidential and your name will not be revealed in the study. The data will be secured not used for other purposes other than the study and stored only by the investigator.

Dissemination of the study report: The final findings of this study will be presented at Addis Ababa University School of Public Health. The study results may be presented in seminars and conferences and published in national and international journals that will be accessible to all scientific societies and the public.

Contact Address: If you have any questions or suggestions for further clarification, you can contact the investigator directly or indirectly through phone number, email, or face-to-face.

Email Address: dbelaynesh87@gmail.com

Mobile: +251-12-41-51-08

Annex II. Information Sheet (Amharic version)

ሰላም ወድ ወንድሜ/እህቴ

ስሜበላይነሽ ደምሴ እባላለሁ። በአዲስ አበባ ዩኒቨርሲቲ ውስጥ በሚኘውየጠፍ ሳይንስ ኮሌጅ በህብረተሰብ ጠፍ ትምህርት ክፍል የአካባቢ እና የሥራ ጠፍ ስፔሻሊቲ ፕሮግራምየሚስተርስ ዲግሪ ተማሪ ነኝ። በአሁኑ ሰዓት በቆዳ ፋብሪካ ሰራተኞች መካከል ስላለውየከሮሚየም ተጋላጫት እና ተያያዥምክንያቶችን ለሜተሸ እና ለማወቅ ምርምሬን እያካሄድኩእገኛለሁ፡ ፡ይህንን ጥናት ለሚድረግ ከአዲስ አበባ ዩኒቨርሲቲ የህብረተሰብ ጠፍ ጥናትና ምርምር ስነ ምግባር ኮሜቴ፣ ከቆዳ ፋብሪካ ሜጅመንቶች እና ከሚመለከታቸው አካላት ፈቃድ አግኝቻለሁ።ስለዚህ እርስዎ በዚህ ጥናት ወስጥ እንዲሳተፉ እና የፀጉር ናመፃዎንም በፈቃደኝነት እንዲሰጡ ተጋብዘዋል።

የጥናቱ ርዕስ፡ በአዲስ አበባ፣ ኢትዮጵያ ወስጥ በሚኘዉየቆዳ ፋብርካ ሰራተኞች ላይ ያለወን የከሮሚም ተጋሃጫት ደረጃ እና ተያያዝ ምክንያቶችን ማጥናት እና መጠምነው፡ ፡

የጥናቱ ዓላማ የዚህ ጥናት ዋና አላማ በአዲስ አበባ ኢትዮጵያ ወስጥ በሚኙ በቆዳ ፋብርካ ሰራተኞች መካከል ያለወን የከሮሚም ኬሚካል ተጋላጫትን እና ተያያዥምክንያቶችን የፀጉር ናመፃ በመወሰድ ማጥናትና መጠምነው።

ጥናቱ ጥቅምእና ጉዳት፡ በዚህ ጥናት ወስጥ በመሳተፍ ምንምአይነት የገንዘብ ድጋፍ አይኖርም። ነገር ግን፣ ያቀረቡት መረጃ ለወደፊት ክሮማቶ ም ተጋላጫነትን ለመከላከል እና ተዛማጅ የጠፍ ችግሮችን ለመከላከል በጣም ጠቃሚይሆናል። በተጨማሪም, የዚህ ጥናት ወጤት ፖሊሲ አወጪዎች እና ሌሎች ኃላፊነት የሚሰማቸውአካላት በዚህ ድርጅት ወስጥ ያለውን የሥራ ደህንነት እና ጠፍ አገልግሎት ለማሻሻል ለመረዳት ጥቅም ላይ ይውላል። በጥናቱ ወስጥ ያለዎት ተሳትፎ ጊዜዎን ከማጥፋት በስተቀር በእርስዎ ላይ ምንምአይነት ስጋት ሆነ ጉዳት አይኖረውም።

የተሣታፊዎች መበቶች፡ ሁሉም ተሳታፊዎች በዚህ ጥናት ወስጥ በፈቃደኝነት ይሳተፋሉ, ይህም ማንምሰውየፀጉር ናሙናዎችን እንዲሰጥ የመረደድ መበት የለውም። ምላሽ ሰጪውበፈቃደኝነት ካልተሳተፈ, እሱ ወይምእሷ በጥናት ጊዜ ወስጥ በማንኛውምጊዜ ተሳትፎውን ማቆም, ጥያቄዎችን እና ማስይቆችን መመላት ማቋረጥ የችላሉ።

ሚስጥራዊነት እና ግላዊነት ጥበቃ፡ ያቀረቡት መረጃ በሚስጥር ይጠበቃል እና ስምዎ በጥናቱ ወስጥ አይገለጽም። መረጃዉከጥናቱ ውጭለሌላ ዓላማዎች ጥቅምላይ አይውልምእና በሚሚሪውብቻ ይከማቻል.

የጥናት ዘገባውን ማሰራጨት፡ - የዚህ ጥናት የሜጨረሻ ወጤት በአዲስ አበባ ዩኒቨርሲቲ የህብረተሰብ ጠፍ ትምህርት ክፍል ይቀርባል። የጥናት ወጠጮቹ በሴሜፎሮች እና ኮንፈረንሶች ሊቀርቡ እና ለሁሉም ሳይንሳዊ ማህበረሰቦች እና ህዝቦች ተደራሽ በሚሆኑ ብሄራዊ እና አለምአቀፍ መጽሔቶች ላይ ሊታተምይችላል።

አድራሻ፡ ለበለጠ ማብራሪያ ማንኛቸውም ጥያቄዎች ወይም ጥቆማዎች ካሉ ሚሚሪውን በቀጥታም ሆነ በተዘዋዋሪ በስልክ ቁጥር፣ በኢሜል ወይምፊት ለፊት ማነጋገር ይችላሉ።

በላይነሽ ደማኬ

ኢ-ሜል : dbelaynesh87@gmail.com

ሞባይል: +251-12-41-51-08

Annex III. Informed consent (English Version)

I fully understand that they are going to take my hair sample and ask me about socio-demographic, behavioral, work-related, working environment, and personal factors. I have read this information based on all of the above-written words and meaning-filled sentences to know my occupational chromium exposure level, I am interested in providing my hair sample and fill the questionnaires for this study without any outside pressure**.** Hence, I would like to declare voluntarily by putting my signature on two copies of this informed consent form, returning one copy to the investigator, and keeping the other with me as a document.

Investigator Name: _____ Participants Name_____

_

Sign: _____ Sign:

_____

Great thank you for voluntarily participation on this study!!!

Annex IV. Informed Consent (Amharic version)

የፀጉሬን ናሙና እንደሚወስዱ እና ስለ ማህበራዊ-ስነ -ህዝብ ባህሪ፣ ከስራ ጋር የተያያዘ፣ የስራ አካባቢ እና የግል ሁኔታዎች እንደሚጠይቁኝ መሉ በመሉ ተረድቻለሁ። የመያ የክሮምየም ምተጋላጫነት ደረጃዬን ለማወቅ ከላይ በተጻፉት ሁሉም ቃላቶች እና ትርጉም የተሞሉ ዓረፍተ ነገሮች ላይ ተመርኩዞ ይህንን ሚጃ አንብቤያለሁ፣ የፀጉሬን ናሙና ለማቅረብ ፍላጎት አለኝ እናም የዚህ ጥናት ማጠይቆችን ያለ ምንም ጫፍ መሙላት እንደምችል ተረድቻለሁ። ስለሆነ ም ፊርሜን በዚህ በሚጃ የተደገፈ የስምማት ቅጽ በሁለት ቅጂዎች ላይ በማስቀመጥ አንዱን ቅጂ ወደ መርማሪው በመመለስ ሌላወን እንደ ሰነድ ከእኔ ጋር በመያዝ ፍቃደኝነቴን አረጋግጣለሁ።

የተመራማሪው ስም: _____ ፊርማ_____ቀን _____

የተሳታፊ ስም: .....ፊርማ .....ቀን: .....

በዚህ ጥናት ላይ በፈቃደኝነት ስለተሳተፉ በጣምእናመሰግናለን

Annex V: Structural Questionnaire (English Version)

This questionnaire helps the investigator to assess the risk factors of occupational chromium exposure. Hence, respondents please carefully read and filling out the questionnaire correctly

PARTICIPANTS ID No.----------

Tannery code _____Tannery Site Location: _____

Residence area of the participant

1. Sub-city: ----------
2. Woreda: ----------
3. Phone No.----------

Section A: Socio-Demographic Characteristics

No.	Variables	Responses	Codes
1	Sex	Male	(1)
		Female	(2)
2	Age	18-30	(1)
		31-45	(2)
		>45	(3)
3	Marital Status	Single	(1)
		Married	(2)
		Divorced	(3)
4	Level of Education	Primary School	(1)
		Secondary School	(2)
		Diploma	(3)
		Degree	(4)
		Above degree	(5)
5	What is your average monthly salary from this industry?	<3000	(1)
		3000-6000	(2)
		7000-12000	(3)
		>12000	(4)
6	Employment condition	Permanent	(1)
		Contract	(2)

7	Do you have another working experience before join in tannery?	Yes No	(1) (2)
8	If **yes** to question 7, what type of industry/institution have you worked	Steel industry Tannery factory Shoe factory Color factory Others----------	(1) (2) (3) (4) (5)
9	How long have you been worked in that industry/institute (in years)	1-5 6-10 >10	(1) (2) (3)
10	What was your role in that industry/institute?	quality manager Machine Operator Labor worker Welder Others----------	(1) (2) (3) (4) (5)
Section B: Occupational factors			
11	In which department are you working now?	Beamhouse Tanning Re-tanning Finishing	(1) (2) (3) (4)
12	How long have you been working in tannery industry (in years)	1-5. 6-10 >10	(1) (2) (3)
13	How many hours do you work per day in your assigned tasks?	<8hrs for 8hrs >8hrs	(1) (2) (3)
14	does the industry regularly provide personal protective equipment (PPE)?	Yes No	(1) (2)
15	Does the industry give training and regular supervision about your job?	Yes No	(1) (2)

16	Is there any rotation from one section to another section	Yes No	(1) (2)
17	If your answer to question number 16 is **yes**, for how often rotation is done	Daily Weekly Monthly	(1) (2) (3)
18	Is there ventilation in your workplace	Yes No	(1) (2)
19	If your answer to question number 18 is **yes,** What type of ventilation is there?	Natural ventilation Exhaust ventilation Other specify_____	(1) (2) (3)
20	Is there enough space and light in your working section	Yes No	(1) (2)
Section C: Behavioral Factors			
21	Do you use the available PPE properly	Yes No	(1) (2)
22	If **yes** to question number 21, mostly what kind of personal protective devices do you use?	Mouth mask Hand glove Safety shoes Gown Eye goggles	(1) (2) (3) (4) (5)
23	If your answer to question number 21 is **no**, why?	Size not suitable Not comfortable to do work Others(list)_____	(1) (2) (3)
24	Have you taken occupational exposure training in the workplace?	Yes No	(1) (2)
25	Are you working in other tannery industry during your free time	Yes No	(1) (2)
26	Does your hair have color?	Yes No	(1) (2)

27	What type of your hair color	Black White Black and white	(1) (2) (3)
28	Have you ever smoked cigarettes?	Yes No	(1) (2)
29	If your answer to question number 28 is **yes**, do you smoke currently?	Yes No	(1) (2)
30	If **yes** to question 29, how often?	Every day Occasionally 1-3 days/week	(1) (2) (3)
31	If you don't smoke now, when did you stop?	Six months ago One years ago Two years ago Other specify _____	(1) (2) (3) (4)
32	When you smoke, how many cigarettes are used per day?	One cigarette Two cigarettes Three cigarettes Half pack cigarettes Othe specify_____	(1) (2) (3) (4) (5)
33	Have you ever drunk alcohol?	Yes No	(1) (2)
34	If your answer to question number 33 is **yes**, do you drink currently?	Yes No	(1) (2)
35	If **yes** to question 34, how often?	Every day Occasionally 1-3 days/week	(1) (2) (3)
36	If you don't drink now, when did you stop?	One month ago Six months ago One year ago Two years ago	(1) (2) (3) (4)

		Other specify _____	(5)
37	When you drink, how many glasses are used per day?	One glass Two glasses Three glasses More than three glass	(1) (2) (3) (4)
38	Have you ever chewed chat?	Yes No	(1) (2)
39	If **yes** to question 38, do you chew currently?	Yes No	(1) (2)
40	If **yes** to question 39, how often?	Every day Occasionally 1-3 days/week	(1) (2) (3)
41	If you don't chew now, when did you stop?	Six months ago One year ago Two years ago Other specify _____	(1) (2) (3) (4)
42	Are you aware of chromium exposure and health problems?	Yes No	(1) (2)
43	Do you know the importance of PPE for your job?	Yes No	(1) (2)
44	Do you believe PPE is important for controlling chromium exposure and maintaining your health?	Yes No	(1) (2)

Questionnaire status:

1.Complet 2. Refuse

3. Not available to respond 4. Partial Complete

Checked by supervisor: name_____ sing_____ date _____

Annex VI: Structural Questionnaires (Amharic Version)

ቆዳ ፋብሪካዎች ላይ ተቀጥረው በሚሰሩ ሰራተኞች ላይ ከስራቸው ጋር በተያያዘ የሚደርስባቸውን የክሮሚም ተጋላጭነት እና ተያያዥ ችግሮችን ለማጥናት የተዘጋጀ መጠይቅ፤

የተሳታፊ መለያ ቁጥር----------			
የፋክቶሪዉመለያ ኮድ:_____ፋክቶሪዉየሚገኝበት ክፍለ ከተማ:_____ የተሳታየመሪያ አካባቢ: 1. ክፍለ ከተማ ---------- 2. ወረዳ: ---------- 3. ስልክ ቁጥር: ----------			
ክፍል ሀ፡ ማህበራዊና ስነ -ሕዝባዊ ገጽታዎችን በተመለከተ			
ተ.ቁ	**ጥያቄዎች**	**መልስ**	**መለያ**
1	ጸታ	ወንድ ሴት	(1) (2)
2	ዕድሜ	18-30 31-45 >45	(1) (2) (3)
3	የጋብቻ ሁኔታ	ያላገባ/ች ባለትዳር የፈታ/ች	(1) (2) (3)
4	የትምህርት ደረጃ	የመጀመሪያ ደረጃ ትምህርት ሁለተኛ ደረጃ ትምህርት ዲፕሎማ ዲግሪ ከዲግሪ በላይ	(1) (2) (3) (4) (5)

5	አማካይ ወርሃዊ ደሞዝዎ ስንት ነው?	<3000 3000-6000 6000-12000 >12000	(1) (2) (3) (4)
6	የቅጥር ሁኔታ	ቋሚ ኮንትራት	(1) (2)
7	በቆዳ ፋብሪካ ስራ ከመጀመርዎ በፊት ሌላ የስራ ልምድ አለዎት?	አዎ የለም	(1) (2)
8	ለጥያቄ ቁጥር 7 መልስዎ **አዎ** ከሆነ በምን አይነት ኢንድስትሪ ወስጥ ስርተዋል?	የብረታ ብረት ኢንዱስትሪ የሜዳድን ኢንዱስትሪ የሲሚንቶ ኢንዱስትሪ የማኒታወት ሥራ ኢንዱስትሪ ሌላ ካለ ይግለጹ_____	(1) (2) (3) (4) (5)
9	በዚያ ኢንዱስትሪ/ኢንስቲትዩት ወስጥ ለምን ያህል ጊዜ ሰርተዋል (በአመታት ወስጥ)?	1-5 6-10 >10	(1) (2) (3)
10	በዚያ ኢንዱስትሪ/ኢንስቲትዩት ወስጥ የእርስዎ ሚና ምን ነበር?	ምርት አስተዳዳሪ የደኅንነት ሀላፊ ጥራት ተቆጣጣሪ ሌሎች ይጠቅሳሉ_____	(1) (2) (3) (4)
ክፍል ለ፡ ድርጅታዊ እና የሥራ አካባቢ ሁኔታዎችን በተመለከተ			
11	አሁን እየሰሩ ያሉት በየትኛዉየስራ ክፍል ወስጥ ነዉ?	ቤምሀወስ ታኒንግ ሪታኒግ ፍኒሽንግ	(1) (2) (3) (4)
12	በቆዳ ፋክቶሪ ወስጥ ለስንት አመታት ያህል ሰርተዋል?	1-5 6-10 >10	(1) (2) (3)

13	በተመደበበት ምድብ ስራ ወስጥ በቀን ለስንት ሰዓት ያህል ይሰራሉ?	<8ሰዓት ለ 8ሰዓት >8 ሰዓት	(1) (2) (3)
14	ኢንዱስትሪው በመደበኛነት የግል መከላከያ መሳሪያዎችን (PPE) ያቀርባል?	አዎ የለም	(1) (2)
15	ኢንዱስትሪውስለ ሥራዎ ስልጠና እና መደበኛ ቁጥጥር ይሰጣል?	አዎ የለም	(1) (2)
16	ከአንድ የሥራ ክፍል ወደ ሌላ የሥራ ክፍል ዝወወር አለ?	አዎ የለም	(1) (2)
17	ለጥያቄ ቁጥር 16 መልስዎ አዎ ከሆነ ፣ በየስንት ጊዜ ዝወወር ይከናዎናል	በየቀኑ በየሳምንቱ በየወሩ	(1) (2) (3)
18	በስራ ቦታዎ ወስጥ አየር ማሽፈሻ አለ?	አዎ የለም	(1) (2)
19	ጥያቄ ቁጥር 18 መልስዎ አዎ ከሆነ ፣ ምን ዓይነት አየር ማሽፈሻ አለ?	ተፈጥሯዊ አየር ማሽፈሻ የጫነ ማውጫአየር ማሽፈሻ ሌላ ይግለጹ ----------	(1) (2) (3)
20	በስራ ክፍልዎ ወስጥ በቂ ቦታ እና ብርሃን አለ?	አዎ የለም	(1) (2)
ክፍል መ፡ የሰራተኛውስነ -ባህሪን በተመለከተ			
21	ያለወጓ PPE በትክክል ይጠቀማሉ	**አዎ** **የለም**	(1) (2)
22	ለጥያቄ ቁጥር 21 አዎ ከሆነ ፣ በአብዛኛው የሚጠቀሙት ምን አይነት የግል መከላከያ መሳሪያዎችን ነው?	አፍ ጫብል የእጅ ጓንት የፊት ጫብል የደህንነት ጫማዎች	(1) (2) (3) (4) (5)

		ጋወን	(6)
		የዓይን መነፅር	(7)
		አፕሮን	(8)
23	ለጥያቄ ቁጥር 21 መልስዎ የለምከሆነ ለምን	መጠን ተስማሚአይደለም ስራ ለማከራት ምቹ አይደለም ሌሎች (ይዘርዝሩ)----------	(1) (2) (3)
24	በስራ ቦታላይ የሞያ ተጋላጭነት ስልጠና ወስደዋል?	አዎ የለም	(1) (2)
25	በትርፍ ጊዜዎ በሌላ የቆዳ ፋብሪካ ወስጥ እየሰሩ ነው።	አዎ የለም	(1) (2)
26	ጸጉርዎ ቀለምአለው?	አዎ የለም	(1) (2)
27	የፀጉርዎ ቀለምምን አይነት ነው	ጥቁር ነጭ ጥቁርና ነጭ	(1) (2) (3)
28	ሲጋራ አጨህ ታውቃለህ?	**አዎ** **የለም**	(1) (2)
29	ለጥያቄ ቁጥር 28 መልስዎ አዎ ከሆነ ፣ በአሁኑ ጊዜ ያጨሉ?	**አዎ** **የለም**	(1) (2)
30	ለጥያቄ 29 አዎ ከሆነ ፣ በየስንት ጊዜው?	**በየቀኑ** **አልፎ አልፎ** 1-3 ቀናት / ሳምንት	(1) (2) (3)
31	የሚያጨሱ ከሆነ ፣ መቼ አቆሙ?	**ከስድስት ወራት በፊት** **ከአንድ አመት በፊት** **ከሁለት አመት በፊት** **ሌላ ይግለጹ**_____	(1) (2) (3) (4)

32	ሲያጨሱ፣ በቀን ስንት ሲጋራዎች ይጠቀማሉ?	አንድ ሲጋራ ሁለት ሲጋራዎች ሶስት ሲጋራዎች ግማሽ ጥቅል ሲጋራ አንድ ጥቅል ሲጋራ ሌላ ይግለጹ_____	(1) (2) (3) (4) (5) (6)
33	አላኮል ጠጥተዉታውቃሉ?	**አዎ** **የለም**	(1) (2)
34	ለጥያቄ ቁጥር 33 መልስዎ አዎ ከሆነ ፣ በአሁኑ ጊዜ ይጠጣሉ?	**አዎ** **የለም**	(1) (2)
35	ለጥያቄ 34 አዎ ከሆነ ፣ በየስንት ጊዜው?	**በየቀኑ** **አልፎ አልፎ** 1-3 ቀናት / ሳምንት	(1) (2) (3)
36	የ ማትጠጡከሆነ ፣ መቼ አቆመ?	**ከስድስት ወራት በፊት** **ከአንድ አመት በፊት** **ከሁለት አመት በፊት** **ሌላ ይግለጹ**_____	(1) (2) (3) (4)
37	ሲጠጡ፣ በቀን ስንት ብርጫቆ ይጠቀማሉ?	አንድ ብርጫቆ ሁለት ብርጨቆ ሶስት ብርጫቆ ከሶስት ብርጫቆ በላይ	(1) (2) (3) (4)
38	ጫት አኝከዉያወቃሉ?	**አዎ** **የለም**	(1) (2)
39	ለጥያቄ 38 አዎ ከሆነ ፣ በአሁኑ ጊዜ ያኝካሉ?	**አዎ** **የለም**	(1) (2)
40	ለጥያቄ 39 አዎ ከሆነ ፣ በየስንት ጊዜው?	**በየቀኑ** **አልፎ አልፎ** 1-3 ቀናት / ሳምንት	(1) (2) (3)

41	ለጥያቄ 39 የለምከሆነ ፣ መቼ አቆመ?	ከስድስት ወራት በፊት ከአንድ አመት በፊት ከሁለት አመት በፊት ሌላ ይግለጹ_____	(1) (2) (3) (4) (5)
42	የ ከሮሚየ ም ተጋላጭ ት ን እና የሚየ ስከ ትለ ዉን የ ጠፍ ችግር ያ ውቃሉ?	አ ዎ የ ለ ም	(1) (2)
43	ለ ስ ራ ዎ የ PPE ን ጠ ቃ ሚ ት ያ ውቃሉ?	አ ዎ የ ለ ም	(1) (2)
44	PPE ከ ሮሚየ ም ተ ጋ ላ ጭ ት ን ለ መ ቆ ጣ ጠር እ ና ጠ ፍ ዎ ን ለ ማ ጠ ቅ አ ስ ፈ ላ ጊ ነ ው ብ ለ ው ያ ምና ሉ?	አ ዎ የ ለ ም	(1) (2)

የ ማጠይቅ ግ ምገ ማ ው

1.ተሟ ልቷ ል 2. ተ ቃ ወ መ ዋ ል

3.ተጠ የ ቂ ዉ አ ል ተ ገ ኙ ም 4. በ ከ ፊ

ያ ረ ጋ ገ ጠ ዉ ሱ ፐ ፐ ረ ቫ ዘ ር ስ ም_____ ፊ ር ማ_____ ቀ ን _____

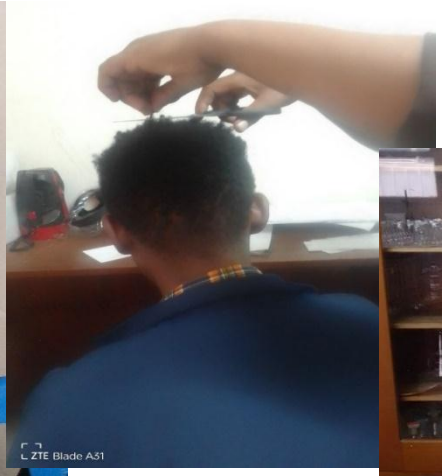
Annex VIII: Laboratory Results of hair chromium levels for each group

Table: The quantity of chromium in both tannery and water factory workers hair (mg kg^{-1})

Tannery workers (Exposed group) Cr concentration (mg kg^{-1})				Water factory workers (non-exposed group) Cr concentration (mg kg^{-1})			
Sample code	Cr	Sample Code	Cr	Sample cod	Cr	Sample code	Cr
BP1	0.75	AR2	5.63	C1	0.10	C34	6.13
BP2	0.75	AR3	9.25	C2	5.13	C35	6.50
BP3	13.63	AR4	3.38	C3	13.75	C36	2.63
BP4	3.13	AF1	11.13	C4	2.00	C37	7.00
BT1	7.63	AF2	23.38	C5	3.25	C38	5.50
BT2	2.00	AF3	6.13	C6	7.38	C39	BLOD
BT3	39.38	WP1	19.38	C7	10.25	C41	8.75
BT4	6.88	WP2	13.13	C8	7.88	C42	4.38
BT5	9.00	WP3	27.50	C9	2.88	C43	3.75
BR1	4.50	WP4	23.13	C10	9.63	C44	4.38
BR2	12.00	WT1	18.63	C11	5.00	C45	3.75
BR3	0.38	WT2	11.50	C13	4.13	C46	6.75
BR4	2.13	WT3	15.63	C14	5.50	C47	0.38
BR6	0.63	WT4	2.40	C15	3.75	C48	4.13
BF1	0.13	WT5	1.30	C16	5.75	C50	3.13
BF2	8.38	WT6	5.63	C17	4.25	C51	2.75
BF3	4.13	WT7	9.13	C18	9.00	C52	3.13
BF4	6.50	WT8	56.13	C19	3.25	C56	2.88
AP2	5.75	WR1	12.75	C20	2.38	C57	2.00
AP3	13.00	WR2	24.25	C21	0.25	C58	3.88
AP4	11.88	WR3	16.13	C22	1.13	C59	8.75
AT1	10.38	WR4	12.13	C23	4.13	C62	3.38
AT2	1.75	WR5	14.50	C24	2.63	C63	BLOD
AT3	7.50	WR6	9.25	C26	4.63	C64	2.75
AT4	15.63	WF1	12.50	C28	6.13	C65	2.75
AT5	9.25	WF2	23.38	C31	7.50	C66	3.38
AT6	3.50	WF3	6.88	C32	5.88	C67	5.63
AR1	8.25	WF4	22.38	C33	6.00	C68	4.00

BLOD = Blow Limit of Detection

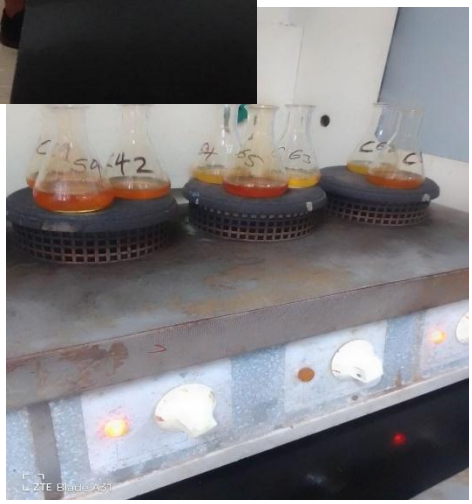
Annex IX: photographic image for hair chromium analysis



Hair sample collection

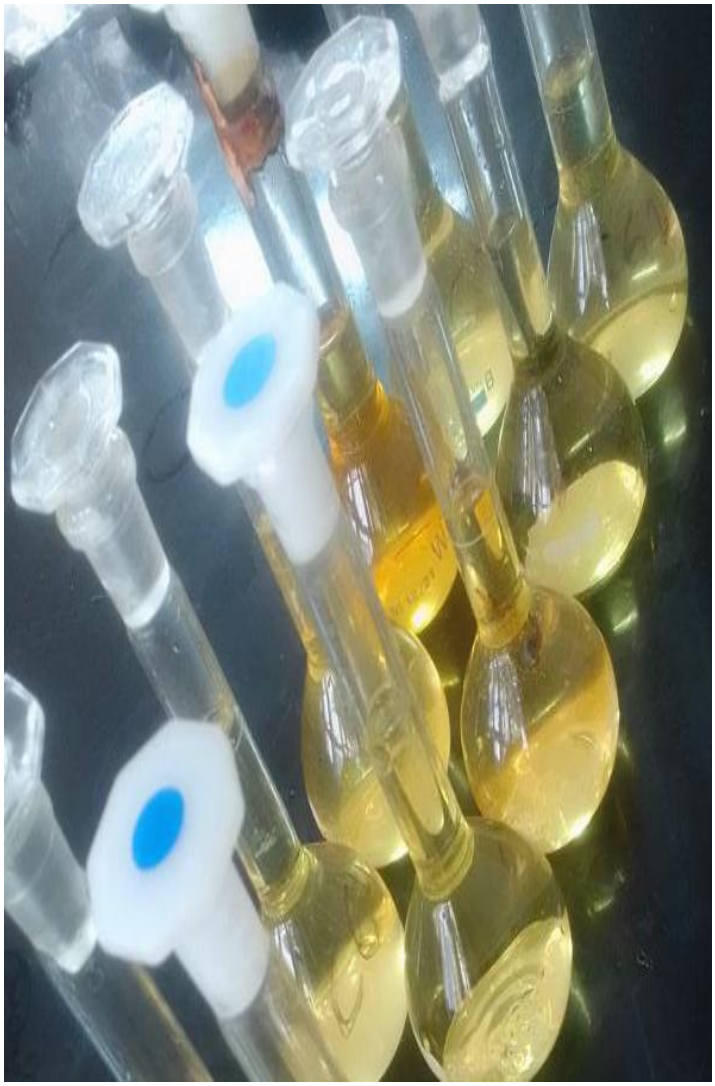
Collected hair samples in a plastic bag

Hair sample washing



Hair sample dagetion on hote plate

Digested hair sample filtration



makeup digested hair sample ready for analysis

MP-AES instrument of the EFDA Laboratory

Tanning section at Tannery factory

Declaration of investigators

The undersigned hereby asserts that the present thesis represents an authentic contribution towards the fulfillment of the criteria for the attainment of a Master's degree in Public Health with a specialization in Environmental and Occupational Health. Furthermore, it is affirmed that the material contained herein has not previously been disseminated in this institution or any other academic establishment and that proper recognition has been given to all sources and references utilized in the compilation of this thesis.

Name of the student: Belaynesh Demissie

Signature: ---------- Date: 6/7/2024

Name of the Institute to be summited the thesis: Addis Ababa University, School of Public Health for Environmental and Occupational Health Track

Name of principal advisor: Samon Wakuma (Ph.D)

Signature: ---------- Date: 6/7/2024

Name of Co-advisor: Tefere Abegaz (Ph.D.)

Signature: ----------Date: 6/7/2024