FORMALDEHYDE EXPOSURE AND IT'S POTENTIAL HEALTH RISK IN SOME BEAUTY SALONS IN KUMASI METROPOLIS

BY

JAMES KUSI APPIAH (BSc. Hons)

A Thesis submitted to the Department of Chemistry,

College of Science, Kwame Nkrumah University of Science and Technology, Kumasi

in partial fulfilment of the requirements for the degree of

MASTER OF PHILOSOPHY

(ANALYTICAL CHEMISTRY)

April, 2018

DECLARATION

I hereby declare that this submission is my own work and that, to the best of my knowledge and belief, it contains no material previously published or written by another person nor material which to a substantial extent has been accepted for the award of any other degree or diploma at Kwame Nkrumah University of Science and Technology, Kumasi or any other educational institution, except where due acknowledgment is made in the thesis.

James Kusi Appiah ……………………….. ………………
(PG 4622515) Signature Date
Student name & ID

Certified by:
Prof. A. A. Adimado ……………………….. ………………
(Supervisor) Signature Date

Certified by:
Prof. R. B. Voegborlo ……………………….. ………………
(Supervisor) Signature Date

Certified by:
Dr. Osei Akoto ……………………….. ………………
(Head of Department) Signature Date

ABSTRACT

Formaldehyde and compounds that release formaldehyde are used in cosmetic products to prevent spoilage and health hazards likely to be caused by microbial contamination. Exposure to high levels of formaldehyde may pose health risks to humans since it is classified in group (1) of human possible carcinogens by International Agency for Research on Cancer (IARC). Cosmetologists may be potentially exposed to high levels of formaldehyde than the general public as a result of their exposure to formaldehyde released from the various cosmetic products used in the beauty salons. In order to assess the exposure of cosmetologists to formaldehyde, the indoor air in sixty beauty salons across the ten sub-metros in Kumasi were sampled to determine the formaldehyde levels and the associated non-carcinogenic human health risks. Sampling was done using System Service Innovation Incorporation air sampler model 1000i and the MBTH spectrophotometric method was used for analysis. The formaldehyde concentrations ranged from 21 to 434 $\mu g/m^3$. Out of the sixty salons sampled, 36 salons representing 60% had formaldehyde levels above the WHO permissible limit of 100 $\mu g/m^3$ for eight hours working period and also exceeded the $55 \mu g/m^3$ and $9 \mu g/m^3$ chronic and acute reference exposure limit set by Office of Environmental Health Hazard Assessment. Twenty-four (24) salons representing 40% had formaldehyde levels below the WHO permissible limit of $100 \mu g/m^3$ for eight hours working period. The results of this study revealed that the number of customers that visit the salon in a week, number of salon services offered and age of salon had positive significant correlation with the level of formaldehyde determined in each salon. The health risk study also revealed that about 50% of the salons had Hazard Quotient (HQ) above the safety limit (HQ=1) and may therefore pose health risks to cosmetologists in these salons. Results from the analysis of the questionnaire revealed that hairdressers in salons that provide the entire salon services captured in the study are at higher risk to the effects of formaldehyde.

TABLE OF CONTENTS

LIST OF TABLES

LIST OF FIGURES

LIST OF ABBREVIATIONS/ACRONYMS

ACCC	Australian Competition & Consumer Commission
ACGIH	American Conference of Governmental Industrial Hygienists
ATSDR	Agency for Toxic Substances and Disease Registry
ADH	Alcohol dehydrogenase
AL	Allowed Limit
BP	Bronopol
C	Ceiling
CAREX	CARcinogen Exposure
COMEAP	Committee on the Medical Effects of Air Pollutants
CH_2O	Formaldehyde
DU	Diazolidinyl urea
DMDM	Dimethyloldimethlhydantoin
DNA	Deoxynucleic acid
DAOS	Differential Optical Absorption Spectroscopy
EPA	Environmental Protection Agency
ETS	Environmental tobacco smoke
EU	European Union
FA	Free formaldehyde
FTIR	Fourier Transform Infrared Absoption
GSS	Ghana Statistical Service
HCHO	Formaldehyde
HDFB	High Density Fiber Board
IARC	International Agency for Research on Cancer
IPCS	International Program on Chemical Safety

IU	Imidazolidinyl urea
LIFS	Laser-Induced Fluorescence Spectroscopy
LOAEL	Lowest Observable Adverse Effect Levels
MBTH	3-Methyl-2-Benzothiazolinone hydrazone hydrochloride
MDF	Medium Density Fiber Board
MHW	Ministry of Health and Welfare
MUPF	Melanine-urea-phenol formaldehyde
NICNAS	National Industrial Chemicals Notification and Assessment Scheme
NIOSH	National institute of Occupational Safety and Health
NOAEL	No Observed Adverse Effect Levels
OEHHA	Office of Environmental Health Hazard Assessment
OELs	Occupational Exposure limits
O.P.I	Odontorium Products Inc.
OSB	Oriented Strand Board
OSHA	Occupational Safety and Hazard Administration
PEL	Permissible exposure limit
PF	Phenol formaldehyde
QU	Quaternium-15
REL	Reference Exposure Limit
RNA	Ribonucleic acid
SCHER	Scientific Committee on Health and Environmental Risks
SCOEL	Scientific Committee on Occupational Exposure Limits
SPSS	Statistical Package for the Social Sciences
STEL	Short term exposure limit
TDLAS	Tunable Diode Laser Absorption Spectroscopy
TLV	Threshold limit value

TRI	Toxic Release Inventory
TWA	Time Weighted Average
UF	Urea formaldehyde
U.K	United Kingdom
USA	United State of America
UV	Ultra violet
VOCs	Volatile Organic Compounds
WHO	World Health Organisation

ACKNOWLEDGEMENT

I would like to first of all thank the Almighty God for his love, grace, kindness and mercies for seeing me through this study and for my life all these years till now. I sincerely want to thank my father and mother; Mr. Kwabena Wiafe and Mrs. Margret Wiafe for their affection and support throughout my entire life up till now.

I wish to acknowledge the timeless assistance and guidance given to me by my supervisors; Professor Anthony A. Adimado and Professor Ray B. Voegborlo for their directives and positive criticisms among many other inputs which made this work a reality. I am very appreciative for everything. Sincerely I would also want to say a big thank you to the owners of the various salons used in this study for their permission and assistance.

The successful completion of this work would not have been possible without the assistance of my colleagues and friends; Desmond Boakye-Agyemang, Jerry Mensah and Evans Boakye. I say God richly bless you guys for all your efforts to make this work a success.

Finally, I am indebted to all the staff of the department of chemistry and anyone who in any diverse way contributed to the success of this work.

DEDICATION

I dedicate this work to my uncle, Mr. Samuel Kofi Nsiah. I say may the good Lord richly bless you for your love, guidance and financial support.

CHAPTER ONE

INTRODUCTION

I.1 BACKGROUND

Formaldehyde is prevalent everywhere in the environment and it is a volatile organic compound (Tibbens, 2015).

Sources of formaldehyde include both natural and anthropogenic sources. The natural sources are mainly from combustion of biomass and the human or anthropogenic sources include exhaust gases from vehicle motors, on-site industrial emissions and many consumer and care products such as cosmetics (Tibbens, 2015).

Formaldehyde is also known as methanal, methylene oxide, oxymethylene, methylaldehyde, and oxomethane. At room temperature, formaldehyde is a colourless, flammable gas with a sharp pungent, distinct odour and may cause a burning sensation to the eyes, nose, and lungs at high concentrations (ATSDR, 2008)

Formaldehyde is used in many industries. It is used in the production of cosmetics, fertilizer, plywood, paper and urea-formaldehyde resins. It is also used in well-drilling fluids, as a preservative for grains and seed dressings in agriculture, production of latex in the rubber industry, leather tanning, wood preservation, and in photographic film production. Moreover it is combined with methanol and buffers to make embalming fluid and is also used in many hospitals and laboratories to preserve tissue specimens (ATSDR, 2008).

At low levels formaldehyde is safely and legally used in cosmetics as it is released in small amounts over time to help protect cosmetic products against contamination by bacteria during storage and during continued usage. Compounds that release formaldehyde (formaldehyde donors) are also often used in cosmetics as preservatives to prevent spoilage and health hazards as a result of microbiological contamination (ACCC, 2010).

Cosmetics are substances that are used to enhance the appearance of the body and the United State Food Drug and Cosmetic Act also defines it as "articles intended to be rubbed, poured, sprinkled, or sprayed on, introduced into, or otherwise applied to the human body or any part thereof for cleansing, beautifying, promoting attractiveness, or altering the appearance" (ACCC, 2010).

Cosmetics can contain up to 9000 different ingredients and several hundreds of them can be used in beauty salons of which formaldehyde is a common constituent (Labreche et al., 2003). A beauty salon is an establishment that deals with cosmetic treatments for women and men and offer services such as facials, pedicure, manicure, eyelash/eyebrow tinting and hair washing and styling among many others. In Ghana beauty salons represent one of the significant and growing occupations in the country with the workers being mostly women.

In beauty salons the two main categories of chemical products used that contain high amounts of formaldehyde are hair straightening/smoothening treatments and nail hardeners. Free formaldehyde is permitted as a preservative ingredient in cosmetic hair products at concentrations of up to 0.05% and where a product is labelled with the warning statement "contain formaldehyde" it may contain formaldehyde of up to 0.2% (ACCC, 2010)

The majority of formaldehyde exposures occur through inhalation, the skin and eye contact and in the beauty salons the level of exposure depends upon the product used, stylist technique and ventilation in the salon.

Most people can detect the odor of formaldehyde at concentrations between 0.5 and 1 parts per million. People who become sensitized to formaldehyde may experience headaches and minor eye and airway irritation even at relatively low levels (Labreche et al., 2003).

The irritant effects of formaldehyde are well documented, with reports of eye, nose and throat irritation, loss of sense of smell, increased upper respiratory disease, dry and sore throats, respiratory tract irritation, cough, chest pain, shortness of breath and wheezing. Salon workers complaints such as nose bleeds, eye irritation and difficulty in breathing after using Brazillian blowout hair smoothing or straightening product have been reported (Pierce et al., 2011).

Cosmetologists and beauticians and to some extent customers are exposed to high concentrations of several compounds that are included in the various chemical products used in their work or treatments. In beauty salons a wide diversity of chemical products are used in the different therapies such as facial cleansing, skin, nails and body hydrotherapy and care, anti-wrinkle, pigmentation and acne treatment, make up, depilation, body and face massage, reflexology, aromatherapy, face and body hair removal among many others. Each of the products has a large number of components including several Volatile Organic Compounds (VOCs), including formaldehyde. The variations of chemical exposures have been described in a few studies mainly focused on hairdressing and nail salons (Tsigonia et al., 2010).

Coppola, global keratin, la brasiliana and brazillian blowout are all hair straitening products that have been found to contain formaldehyde with global keratin and brazillian blowout containing levels that exceed OSHA limit of 0.5 ppm which calls for “potential cancer” to be included on the product label (Pierce et al., 2011).

O.P.I original nail envy, essie millionails and poshe nails strengthening treatments are nail products used that have received formaldehyde exposure complains as well as eyelash products such as Lash me and Locks lash eyelash glues (ACCC, 2010).

Working as a hairdresser or a beautician has been associated with adverse reproductive health effects such as spontaneous abortion, congenital malformations, childhood cancer, and developmental problem (Labreche et al., 2003).

Indoor air pollution simply refers to the toxic substances we encounter in our homes and workplaces. Formaldehyde is one of the most studied pollutants since it is classified in Group one of human carcinogens by the International Agency for Research on Cancer (IARC, 2004). Indoor and Outdoor air quality studies have shown that there exist significant formaldehyde emissions indoor than outdoor and is usually 2-10 times higher in concentration. The probable reasons are that there exist high formaldehyde emitters in the indoor environment with low level of air exchange rates (ventilation) in the indoors than outdoors (Dafni et al., 2010). Even though a rank profiling of chemicals and exposures that cause concern is difficult and unknown, the Scientific Committee on Health and Environmental Risks (SCHER) states that formaldehyde like carbon monoxide, nitrogen dioxide, benzene, naphthalene, environmental tobacco smoke (ETS), radon, lead, and organophosphate pesticides is a compound of concern in the indoor environment (Salthammer et al., 2010).

1.2 STATEMENT OF THE PROBLEM

Formaldehyde is a common constituent of several cosmetic products that are used by beauticians in their line of work. Hairdressers and allied professionals represent a large and fast growing occupation in Ghana. The implication of this is that more cosmetic products for the various services offered are now being used and this may increase the chances of levels of formaldehyde being released. Hairdressers and allied professionals may therefore be exposed to high levels of formaldehyde than the general public and this is why there is need to assess the levels of formaldehyde exposure in beauty salons, since is a carcinogen.

1.3 OBJECTIVES

The main aim of this study is to assess the formaldehyde exposure and it potential health risk in some beauty salons in Kumasi metropolis.

1.3.1 SPECIFIC OBJECTIVES

- To determine the exposure levels of formaldehyde in the beauty salons
- To evaluate the health risks of beauty salon workers associated with the formaldehyde exposure
- To examine formaldehyde exposure patterns in these salons or facilities using selfstructured questionnaire

1.4 JUSTIFICATION OF STUDY

Acute exposure to formaldehyde concentration of greater than 0.1 mg/m^3(0.08 ppm) can lead to irritation or contact allergy on various parts of the body while certain types of cancers, asthma, reproductive and developmental toxicity may result from sustainable exposure (Lv et al, 2015). Consequently, several safety and occupational health authorities worldwide have established permissible exposure levels of formaldehyde by inhalation. Such occupational threshold limit values (TLV) are often categorized as time-weighted average (TWA), shortterm exposure limit (STEL), and ceiling (C) values, with the last defining the exposure limit, which should not be exceeded at any time (Salthammer et al., 2010).

The Occupational Safety and Health Administration (OSHA) have set the STEL for formaldehyde at 2 ppm in 15 min and the permissible exposure limit time-weighted average (PEL-TWA) at 0.75 ppm. The TLV-C proposed by the American Conference of Governmental Industrial Hygienists (ACGIH) is 0.3 ppm. The National Institute for Occupational Safety and Health (NIOSH) has set a more stringent STEL of 0.1 ppm and a recommended exposure limit for occupational exposure of 0.016 ppm. In countries such as the U.K. the Committee on the Medical Effects of Air Pollutants (COMEAP) recommended a limit value of 100 $\mu g\ m^{-3}$ (0.5 h) for indoor formaldehyde in 2004, in Korea, the indoor formaldehyde was set at 0.1 ppm (8h) according to the Air Quality Standard in Office and Indoor Air Quality

Management Act in 2004 and the Ministry of Health and Welfare (MHW) in Japan established an indoor air guideline value of 0.08 ppm (0.5 h) in June 1997 (Salthammer et al., 2010). However in Ghana no such guideline value has been established and this necessitates the need to monitor formaldehyde levels indoor as one step research towards that. This study sought to determine indoor formaldehyde levels in beauty salons.

CHAPTER TWO

LITERATURE REVIEW

2.1 PHYSICAL AND CHEMICAL PROPERTIES OF FORMALDEHYDE

Formaldehyde is produced on a large scale by the oxidation of methane or methanol in the presence of a catalyst. At room temperature, it is a colorless gas that is flammable and highly reactive. Formaldehyde is soluble in water, ethanol, diethyl ether, and acetone. In aqueous solution, methylene glycol [$CH_2(OH)_2$] and polymethylene glycols[$H(CH_2O)_nOH$] are formed (Salthammer et al., 2010). Formaldehyde is commonly purchased as a 37% solution in water, with 10% methanol as stabilizer to reduce polymerization.

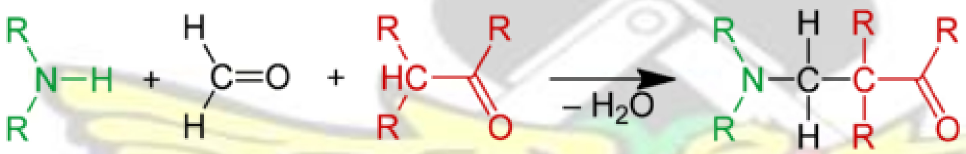
Formaldehyde (CH_2O) with a molecular weight of 30.03g/mol has a pungent, suffocating odour and an irritant action on the eyes and skin.

Formaldehyde liquefies at -19.2 ^oC and solidifies at -118 ^oC to give a white paste. The liquid and gas polymerize readily at low and ordinary temperatures up to 80 ^oC.

At a low temperature, liquid formaldehyde is miscible in all proportions with nonpolar solvents such as toluene, ether, chloroform, or ethyl acetate. However, solubility decreases with increasing temperature and at room temperature polymerization and volatilization occur, leaving only a small amount of dissolved gas. Solutions of liquid formaldehyde in acetaldehyde behave as ideal solutions (Magregor et al., 2006). Polar solvents, such as alcohols, amines or acids, either catalyze the polymerization of formaldehyde to form methylol compounds or methylene derivatives.

Formaldehyde is one of the most reactive organic compounds known and as such differs greatly from its higher homologues and aliphatic ketones. Formaldehyde undergoes a wide variety of chemical reactions and some of the most important ones among them are decomposition, polymerization, condensation, addition, oxidation and reduction reactions.

The decomposition reaction of formaldehyde occurs at a temperature of 150°C where it heterogeneously decomposes to give methanol (CH_3OH) and carbon dioxide (CO_2). Polymerization reaction of formaldehyde occurs when gaseous formaldehyde polymerizes slowly at temperatures below 100°C and this makes it impossible for anhydrous monomeric formaldehyde to be handled commercially with this reaction being accelerated by traces of polar impurities such water, acids and alkalis. Important condensation reactions are the reaction of formaldehyde with amino groups to give Schiff's bases, as well as the Mannich reaction which is an organic reaction consisting of an amino alkylation of an acidic proton placed next to a carbonyl functional group by formaldehyde and a primary or secondary amine or ammonia to form β-amino-carbonyl compound also known as a Mannich base.



Amine Formaldehyde Carbonyl group Mannich base

Figure 2.1: Mannich reaction of formaldehyde

Formaldehyde also condenses with itself in an aldol-type reaction to yield lower hydroxy aldehydes, hydroxy ketones, and other hydroxy compounds; the reaction is autocatalytic and is favored by alkaline conditions. Condensation with various compounds gives methylol (CH_2OH) and methylene ($=CH_2$) derivatives. The formation of sparingly water-soluble sodium formaldehyde bisulfite is an important addition reaction of formaldehyde. Other addition reaction of formaldehyde includes the reaction of formaldehyde with hydrocyanic acid to give glycolonitrile(methanal glycolonitrile) and formaldehyde reaction with acidcatalyzed prins which forms a-hydroxymethylated adducts with olefins (Eckert et al., 2006).

Figure 2.2: Reaction of formaldehyde with hydrogen cyanide

Formaldehyde is readily reduced to methanol by hydrogen over many metal and metal oxide catalysts. It is oxidized to formic acid or carbon dioxide and water. In the presence of strong alkalis or when heated in the presence of acids, formaldehyde undergoes a Cannizzaro reaction with formation of methanol and formic acid. This reaction is shown below;

$2HCHO + NaOH \rightarrow CH_3OH + HCOONa$.............................equation (1)

Similarly, a vapor-phase Tischenko reaction is catalyzed by copper and boric acid to produce methyl formate (Gerberich and Seaman, 1994). At ordinary temperatures, formaldehyde gas is readily soluble in water, alcohols, and other polar solvents. Its heat of solution in water and lower aliphatic alcohols is approximately 63 kJ/mol (15kcal/mol). The reaction of unhydrated formaldehyde with water is very fast with a first-order rate constant at 22^{O}C of 9.8 per seconds (Gerbrich and Seaman, 1994).

2.2 SOURCES OF FORMALDEHYDE

Primarily formaldehyde is formed by the combustion of organic materials and by a variety of natural and anthropogenic activities. Moreover secondary formation of formaldehyde occurs in the atmosphere through the oxidation of natural and anthropogenic volatile organic compounds (VOCs) in the air. Naturally formaldehyde occurs in the environment and is also a product of many natural processes. During biomass combustion such as forest and bush fires formaldehyde is released and in water it is also formed by the irradiation of humic substances by sunlight (Reinhardt, 1991; Kieber et al., 1990). As a result of various metabolic processes occurring in living organisms including human's formaldehyde is naturally present in very low but measurable concentrations as metabolic intermediate and is essential for the biosynthesis of purines, thymidine, and some amino acids (IARC, 1995).

Anthropogenic sources of formaldehyde include direct sources such as fuel combustion, industrial onsite uses, and off-gassing from building materials and consumer and personal products such as cosmetics among many others.

2.3 PRODUCTION OF FORMALDEHYDE

The catalytic oxidation of methanol has been used for the commercial production of formaldehyde since the year 1889 and currently, the two predominant production processes are the silver catalyst process and the metal oxide catalyst process (Bolt et al., 2015).

On the industrial scale where the largest production of formaldehyde takes place it is produced from methanol by the following three processes;

I. Partial oxidation and dehydrogenation with air in the presence of silver crystals, steam, and excess methanol at 680-720 ^{0}C

II. Partial oxidation and dehydrogenation with air in the presence of crystalline silver or silver gauze, steam, and excess methanol at 600 – 650 ^{0}C .The conversion is completed by distilling the product and recycling the unreacted methanol.

III. Oxidation only with excess air in the presence of a modified iron – molybdenum – vanadium oxide catalyst at 250 – 400 ^{0}C (Reuss et al., 2013).

Processes for converting propane, butane, ethylene, propylene, butylene and ethers into formaldehyde are not of major industrial significance for economic reasons. Processes that employ partial hydrogenation of carbon monoxide (CO) and oxidation of methane (CH_4) do not compete with methanol conversion processes because of the lower yields of the former processes (Eckert et al., 2006).

The annual production of 37% formaldehyde is about 20 million tons worldwide. In a recent review article, Tang et al. 2009 estimated a global formaldehyde output of 32 million tons in 2006, with the highest producers being China (34%), the United States (14%), and Germany (8%) (Salthammer et al., 2010).

2.4 USES OF FORMALDEHYDE

Formaldehyde is one of the most commercially important aldehydes. The majority of formaldehyde produced worldwide is used extensively in the production of resins being mainly urea, phenol, melamine and polyacetal resins (Kim et al., 2011).

According to IHS in 2012, urea-, phenol- and melamine-formaldehyde resins accounted for about 63% of world demand in 2011 with other large applications being 1,4-butanediol, hexamethylenetetramine, , pentaerythritol and methylene-bis(4-phenyl isocyanate) (MDI) and polyacetal resins (Bolt et al., 2015).

The main industrial use of formaldehyde and paraformaldehyde is for the manufacture of formaldehyde-based resins, which are widely used in a variety of industries, predominantly the wood industry. Urea-formaldehyde (UF) adhesives are the most widely used products in the manufacturing of wood-based materials and furniture due to their rapid curing, their compatibility with additives, and their low price. Phenol-formaldehyde (PF) resin was one of the earliest marketed synthetic polymers with the tradename Bakelite. The most important application of PF resins is production of composite boards such as plastic laminate. Melamine-urea-phenol-formaldehyde (MUPF) adhesives are used for the production of moisture-proofed woodbased products and for construction materials.

Formaldehyde is also used in wood-based products such as particle board, oriented-strand board (OSB), high-density fiber board (HDF), medium density fiber board (MDF) and plywood, Cork products including flooring materials, Insulation materials made of UF foam, mineral wool, or glass wool, Paper product, Coating materials, paints, and lacquers, Textiles, Cleaning and caring products, Disinfectants and preservatives Photoprocessing chemicals, consumer and personal care products such as cosmetics (Salthammer et al., 2010).

In the agriculture industry, formaldehyde has been used as a fumigant, germicide and fungicide for plants and vegetables and as well as an insecticide for destroying flies and other insects and in the manufacture of slow- release fertilizers. It has also been used as a preventative for mildew and spelt in wheat, and for rot in oats. In Canada, under the Pest Control Products Act; formaldehyde is registered as a pesticide and about131 tonnes are being applied annually for pest control (IPCS, 2002).

In addition to paraformaldehyde being used in some selected pesticide applications, it has also been used in making thermosets, varnish resins and foundry resins, the synthesis of chemical and pharmaceutical products, the preparation of disinfectants and deodorants, and the production of textile products. In the plastics industry, formaldehyde is use for the preparations of urea, melamine and phenol resins and where the presence of water could interfere with the production process, in place of aqueous formaldehyde solutions paraformaldehyde may be used. Moreover, in the petroleum industry, formaldehyde has been used as a biocide in oil well-drilling fluids and as an auxiliary agent in refining. It has also been used as an anticorrosive agent for metals (IARC, 1995).

In the food industry, formaldehyde is used as an antibacterial agent in processing of foodstuffs and has been use as a bacteriostatic agent in some foods, such as cheese. As an antimicrobial agent, formaldehyde displays very few side effects, but has a broad spectrum of action. All alternative agents have unpleasant or to some extent dangerous side effects and moreover, their toxicity has not been investigated as thoroughly as that of formaldehyde, and their spectrum of action is limited. Formaldehyde does not accumulate in the environment since it is completely oxidized to carbon dioxide within a relatively short time and this is another advantage over other antimicrobial agents. In the cosmetics industry, formaldehyde is employed as a preservative in hundreds of products, for example, hair and body lotions, mascara and eye makeup, soaps, deodorants, shampoos, cuticle softeners nail products (hardeners and polishes), hair smoothening and straightening creams (Eckert et al., 2006).

2.5 FORMALDEHYDE USE IN COSMETICS

Cosmetics are widely used on daily basis to improve the appearance and odour of the human body. Anti-bacterial preservatives are generally added into cosmetics to prevent decomposition and spoilage by microbial growth. Free formaldehyde (FA) is one of the good choices for the preservation of cosmetics due to its bactericidal and fungicidal properties. Aside from free FA, cosmetics are also preserved by several formaldehyde donors known as formaldehyde releasing preservatives, which slowly release formaldehyde through degradation or decomposition under usage conditions (Lv et al., 2015).

Formaldehyde donors such as quaternium-15 (QU), imidazolidinyl urea (IU), diazolidinyl urea (DU), dimethyloldimethylhydantoin (DMDM) and 2-bromo-2-nitropropane-1,3-diol (bronopol, BP) are the most commonly used to prevent the growth of micro-organisms in cosmetic products. The anti-microbial activity of these preservatives probably results from formaldehyde released by hydrolysis in the presence of water. Moreover, the amount of formaldehyde released by these formaldehyde donors may be dependent on various variations such as the nature and concentration of the releaser, pH, temperature and storage time (Reuss et al., 2013).

In the beauty salon formaldehyde can be found in cosmetic product used such as nail polishes, nail hardeners, hair dyes, hair relaxer, hair smoothing/straightening creams, eyelash/eyebrow glues, hair gels and makeup products among many others. But in the beauty salon the two cosmetic products used that contain the most formaldehyde are hair straightening/smoothing treatments and nail hardeners. In nail hardeners, formaldehyde is not just used as a preservative as in most cosmetic product but is also used as an active ingredient to coat and strengthen the surface of brittle or cracked nails. A professional hair straightener is a salon product designed to straighten curly or fizzy hair for up to a period of three months after it has been applied by the stylist with the use of flat iron (ACCC, 2010).

2.6. RELEASE OF FORMALDEHYDE FROM COSMETICS IN BEAUTY SALONS

Formaldehyde is released in small amounts over time to help protect cosmetic products against contamination by bacteria during storage and during continued usage. In cosmetics formaldehyde releasing preservatives are ingredients of concern as they slowly and continuously release small amounts of formaldehyde. These formaldehyde releasing preservatives are diverse group of chemicals that can be recognized by a small, easily detachable formaldehyde moiety. Formaldehyde releasing preservatives are some of the most effective preservatives on the market and are especially effective in preventing growth of gram negative bacterial (Marks et al., 2002). The five most commonly used formaldehyde releasing preservatives are quaternium-15, dimethyl-dimethyl (DMDM) hydantoin, imidazolidinyl urea, diazolidinyl urea and 2-bromo-2-nitropropane-1,3-diol (bronopol BP). The amount of formaldehyde released into a product that is preserved with formaldehyde releasing preservative can vary. The level of free formaldehyde can be affected by factors such as specific type of formaldehyde releasing preservative, concentration of formaldehyde releasing preservative and amount of water in the product. Moreover, the amount of formaldehyde released by these formaldehyde donors may also be dependent on various parameters such as pH, temperature and storage time (De Groot et al., 2010).

2.7 RELEASE OF FORMALDEHYDE INTO THE ENVIRONMENT

Formaldehyde is ubiquitous in the environment as a result of a number of natural and anthropogenic processes. Notable natural sources of formaldehyde include the decomposition of organic material, forest and bush fires, and volcanic emissions. Moreover photochemical oxidation of volatile organic compounds is also a secondary source of formaldehyde in the atmosphere (Bolt et al., 2015).

A monitoring studies by Gaffney et al., (1997) in Albuquerque (New Mexico), which looked at the average formaldehyde concentrations and formaldehyde to acetaldehyde ratios revealed that if formaldehyde and acetaldehyde were being formed solely from the atmospheric oxidation of naturally occurring alkenes, the ratio of the two chemicals would be expected to be about ten. In this study, the formaldehyde to acetaldehyde ratio was lowest during the winter months and highest in the summer months and concluded that atmospheric formaldehyde in urban areas resulted from both anthropogenic emissions and natural sources in the summer and primarily from anthropogenic sources during the winter. Combustion processes also account directly or indirectly for most of the formaldehyde entering the atmosphere and one of the important sources of formaldehyde is automotive exhaust from engines that are not equipped with catalytic converters (WHO, 2002).

In the troposphere formaldehyde is formed in large quantities by the oxidation of hydrocarbons and this leads to elevated formaldehyde levels shortly after periods of high vehicular traffic (Grosjean et al. 1996).

According to the Toxics Release Inventory (TRI), in 1996, 21 million pounds of formaldehyde were released to the environment from 674 domestic manufacturing and processing facilities and this number represents the sum of all releases of formaldehyde to air, water, soil, and underground injection wells (ATSDR, 1999).

Formaldehyde does not accumulate in the environment due to its short half-life which is around one hour as such when is released into the environment majority of it degrades while a smaller portion moves into water where it broken down (IPCS, 2002).

However, formaldehyde is continuously released or formed, leading to a long-term exposure for populations living near emission sources or production activities. Furthermore, formaldehyde can also be formed in a reaction of ozone with unsaturated volatile organic compounds in the atmosphere (Raviora et al., 2016).

Moreover the general public may be exposed to exogenous formaldehyde from contact with consumer products which contain it or from a range of indoor air sources such as cosmetics used in beauty salons that contain formaldehyde with indoor air having been estimated to contribute to 98% of total inhalation exposure to formaldehyde. Levels of formaldehyde in ambient air are generally below 0.01 mg/m^3 but may reach 0.02 mg/m^3 in urban or industrial areas (Bolt et al., 2015).

2.8 ENVIRONMENTAL LEVELS OF FORMALDEHYDE

2.8.1 LEVELS OF FORMALDEHYDE IN AIR

Kelly et al. (1994) measured a median formaldehyde concentration of 2.5 ppb for a total of 1,358 samples collected at 58 different locations in a survey of ambient measurements of hazardous air pollutants.

De Serves C (1994) reported atmospheric measurements of formaldehyde made in 1992 at an extremely remote site of Alert, Nunavut during the dark winter and sunlit spring and it ranged from 0.033 to 0.70 ppb (0.04 to 0.84 µg/m3) on a 5-min basis with a mean of 0.40 ppb (0.48 $µg/m^3$).

Formaldehyde was detected in 99% of 48 ambient air samples obtained in Ohio urban centers from June-July 1989 with a mean and maximum formaldehyde concentration of 3.0 and 15.5

ppb, respectively. The daily changes in concentration were found to be consistent with initial direct emissions from vehicles followed by secondary photochemical production and atmospheric removal ultimately. These data provided an indication that formaldehyde concentrations in urban atmospheres are expected to be highest during or shortly after rush hour, or other periods of high vehicular traffic (Spicer et al., 1996).

In the indoor environment formaldehyde concentrations has been measured in several monitoring studies in the United States. In general, indoor residential formaldehyde concentrations were significantly higher than outdoor concentrations and this ranged from 0.002 to 0.006 ppm in remote, unpopulated regions from 0.01 to 0.02 ppm in highly populated areas and industrial urban air. The range of formaldehyde concentrations measured in complaint homes, mobile homes, and homes containing large quantities of particle board were 0.02–0.8 ppm, with levels as high as 4 ppm adequate to cause irritating symptoms noticed in some instances (Gold et al., 1993).

2.8.2 LEVELS OF FORMALDEHYDE IN WATER

In water formaldehyde is not stable but it has been detected in industrial and municipal aqueous effluents. In general, concentrations of formaldehyde in drinking-water are expected to be below 100 µg/l (IARC, 1995).

Quarterly analyses of five monitoring wells on the property of a Canadian plant that produces urea formaldehyde resins were carried out during 1996–1997 and concentrations measured ranged from below the detection limit (50 µg/l) to 8200 µg/l, with an overall median of 100 µg/l. Concentrations for different wells indicated little dispersion from wells close to the source of contamination. Concentrations of formaldehyde in rain ranged from 0.44 µg/litre (near Mexico City) to 3003 µg/litre (during the vegetation burning season in Venezuela; anthropogenic sources). Mean concentrations ranged from 77 µg/l (in Germany) to 321 µg/l (during the non-burning season in Venezuela). In snow, concentrations of formaldehyde ranged from 18 to 901 µg/l in California, USA. A mean snow concentration of 4.9 µg/l is reported for Germany. In fog water, concentrations of 480–17027 µg/l have been measured in the Po valley, Italy, with a mean of 3904 µg/l (IPCS, 2002).

2.8.3 LEVELS OF FORMALDEHYDE IN SOIL

The concentrations of formaldehyde in soil were measured at manufacturing plants that use phenol/formaldehyde resins, a plywood plant and six soil samples collected in 1991 and formaldehyde concentrations of 73–80 mg/kg, with a mean of 76 mg/kg (detection limit not specified) were measured. At a fibreglass insulation plant, formaldehyde was not detected (detection limit 0.1 mg/kg) in soil samples collected from six depths at four industrial areas on-site. Formaldehyde was also not detected in samples taken from a non-industrial site at 120 km away from the plant (Chenier, 2003).

2.8.4 LEVELS OF FORMALDEHYDE IN FOOD

Although formaldehyde is a natural component of a variety of foodstuffs there have been no systematic investigations of levels of formaldehyde in a range of foodstuffs as a basis for estimation of population exposure and monitoring has generally been sporadic and source directed (IARC, 1995).

Higher concentrations of formaldehyde of up to 800 mg/kg have been reported in fruit and vegetable juices in Bulgaria but it is however not clear if these elevated levels arise during processing (Tashkov, 1996).

In processed foods, the highest concentrations of formaldehyde of up to 267 mg/kg have been reported in the outer layer of smoked ham and in some varieties of Italian cheese, where formaldehyde is permitted for use under regulation as a bacteriostatic agent.

In a variety of alcoholic beverages formaldehyde concentrations which ranged from 0.04 to 1.7 mg/l in Japan and from 0.02 to 3.8 mg/l in Brazil have been reported. Formaldehyde concentrations of 3.4 and 4.5 mg/kg in brewed coffee and 10 and 16 mg/kg in instant coffee have also been reported in the USA (IPCS, 2002).

2.9 INDOOR GUIDELINE VALUES FOR FORMALDEHYDE

According to the World Health Organization (WHO) guidelines on assessing human health risk of chemicals, the setting of an indoor air quality guideline value for a particular pollutant is based on the careful review and interpretation of globally accumulated scientific evidence linking exposure to the particular pollutant in air with the health outcomes of that exposure and on the evaluation of epidemiological evidence for environmental health risk assessment. With the inhalation of formaldehyde in the indoor environment as the major route of personal exposures and higher concentrations of formaldehyde in the indoor environment than outdoors which may be high enough to cause adverse health effects the setting of indoor guideline for formaldehyde is therefore appropriate (WHO, 2010).

Worldwide several safety and occupational health authorities have laid down exposure levels of formaldehyde that are permissible by inhalation. Most of these levels set are based on results of toxicological and epidemiological test outcomes gotten from both human and animal data within a certain exposure time or on health hazard assessments in the relevant toxicological literature. Limit values are basically divided into two main categories which are workplace environments in which occupational exposure occurs and non-occupational environments. Such occupational threshold limit values (TLV) are often categorized as shortterm exposure limit (STEL), ceiling (C) and time-weighted average(TWA) values, with the ceiling (C) value defining the exposure limit which should not be exceeded at any time. The Occupational Safety and Health Administration(OSHA) has set an STEL value for formaldehyde at 2 ppm in 15 min and a permissible exposure limit time-weighted average value (PEL-TWA) at 0.75 ppm. The

American Conference of Governmental Industrial Hygienists (ACGIH) has proposed a formaldehyde concentration of 0.3 ppm as TLV-C. A more stringent STEL value of 0.1 ppm has been set by the National Institute for Occupational Safety and Health (NIOSH) and has also set 0.016 ppm as a recommended exposure limit for occupational exposure (Salthammer et al., 2010).

Moreover indoor guideline value for formaldehyde has also been set in different countries by different organizations. In Austrialia the the National Industrial Chemicals Notification and Assessment Scheme (NICNAS) recommends a formaldehyde indoor air guideline value of 0.08 ppm for a short duration, the Committee on the Medical Effects of Air Pollutants (COMEAP) in Uninted Kingdom recommended a limit value of 100 μg m^{-3} (0.5 h) for indoor formaldehyde in 2004, the Air Quality Standard Office and Indoor Air Quality Management Act of Korea in the year 2004 setthe indoor formaldehyde concentration at 0.1 ppm (8h) and the Ministry of Health and Welfare (MHW) in Japan laid down an indoor air guideline value of 0.08 ppm (0.5 h) in June 1997 (Salthammer et al., 2010).

2.10 TOXICOLOGY OF FORMALDEHYDE

Formaldehyde has a high solubility in water and this causes rapid absorption of it in the respiratory and gastrointestinal tract where it can be oxidized to form formate and exhaled as carbon dioxide or incorporated in biological matrices. It has extremely short half of about 1 minute (Magregor et al., 2006).

Formaldehyde is electrophilic and can react with biogenic compounds in the body which are nucleophilic. In small amounts formaldehyde itself is produced from methanol via the enzyme alcohol dehydrogenase (ADH), this is a human metabolite and can be measured in urine (Salthammer et al., 2010).

Endogenously formaldehyde produced in humans is an essential intermediate in the production of purines, thymidine and some amino acids and this is produced in all metabolically active cells with levels in blood ranging from 2-3 mg/L. Formaldehyde reacts rapidly with primary and secondary amines, thiols, hydroxyls and amides, forming methylol derivatives at the site of contact. It may also react with DNA, RNA and protein to form adducts or cross-links (WHO, 2010).

Mainly the effects of formaldehyde occur at the site of contact which is a severe irritation to the eyes, nose, skin, mouth, and upper respiratory tract. According to a report by "Health Canada" based on human clinical studies and on animal experiments, the primary effects of acute exposure to formaldehyde are the irritation of the mucosa of the upper respiratory tract and the eyes. The no observable adverse effects level (NOAEL) and lowest observable adverse effects levels (LOAEL) are 615 and 1,230 $\mu g/m^3$ respectively.

2.11 OCCUPATIONAL EXPOSURE TO FORMALDEHYDE

Formaldehyde occurs mainly as a gas in the occupational environment. Occupational exposure to formaldehyde can occur during its production and during its use in a wide variety of occupations industries including furniture, textiles, paper, synthetic vitreous fiber, plastics, medical, pharmaceutical and cosmetics industries among many others. The routes of exposure to formaldehyde can either be inhalation, ingestion or absorption through the skin with inhalation being considered to be the main route of exposure to exogenous formaldehyde (Checkoway et al. 2012).

IARC (2012) refers to CAREX (CARcinogen Exposure) which is an international information system on occupational exposure to known and suspected carcinogens based on data collected in the European Union (EU) from 1990 to 1993 measured the highest continuous exposures to formaldehyde to be (2–5 ppm; 2.5–6.1 mg/m^3) in the past during varnishing of furniture and wooden floors, in the finishing of textiles, in the garment industry, in the treatment of fur, and in certain jobs within manufactured board mills and foundries. Short-term exposures to high levels (3 ppm and higher; ≥3.7 mg/m^3) were reported earlier for embalmers, pathologists, and paper workers.

Moreover, an exposure simulation study conducted by Pierce et al., (2011) to characterize the potential formaldehyde exposures of salon workers and clients during keratin hair smoothing treatments of four different hair treatment brands (Brazilian Blowout, Coppola, Global Keratin, and La Brasiliana) showed a mean airborne concentrations of formaldehyde ranging from 0.08–3.47 ppm during blow-dry and 0.08–1.05 ppm during flat-iron and the mean airborne concentrations during each treatment ranged from 0.02–1.19 ppm throughout different zones of the salon.

2.12 HEALTH EFFECTS OF FORMALDEHYDE

In both humans and experimental animals, formaldehyde is absorbed easily by all exposure routes, thus inhalation, dermal and oral routes. Once formaldehyde is inhaled, it quickly reacts at the site of contact and is readily metabolised in the respiratory tissue. As a result of formaldehyde reactivity in target tissues direct contact with it causes local irritation, acute and chronic toxicity and has genotoxic and cytotoxic properties (Bolt et al., 2015).

After acute exposure to formaldehyde through oral, dermal and inhalation routes formaldehyde causes immediate local irritation in mucous membranes, including eyes, nose, and upper respiratory tract whiles ingestion of formalin causes severe injury to the gastrointestinal tract in humans at levels in air of 0.5 ppm formaldehyde and above.

Evidence clearly indicates that formaldehyde solution is a skin irritant and a strong skin sensitizer and available human and animal data shows gaseous formaldehyde is unlikely to induce respiratory sensitisation. Lung function tests suggest that asthmatics are no more sensitive to formaldehyde than healthy subjects. Limited evidence indicates that formaldehyde may elicit a respiratory response in some very sensitive individuals with bronchial hyperactivity, probably through irritation of the airways. No systemic toxicity has been observed following repeated exposure to formaldehyde in animals and humans. A no-observed adverse-effect level (NOAEL) of 1 ppm (1.2 mg/m^3) by inhalation and a NOAEL of 15 mg/kg bw/day by oral administration has been identified for histopathological changes to the nasal tract and the fore- and glandular stomach in rat (NICNAS, 2006).

The major concerns of repeated and chronic exposure to formaldehyde are sensitization and cancer. In sensitized persons, formaldehyde can cause asthma and contact dermatitis. In persons who are not sensitized, prolonged inhalation of formaldehyde at low levels is unlikely to result in chronic pulmonary injury. Adverse effects on the central nervous system such as increased prevalence of headache, depression, mood changes, insomnia, irritability, attention deficit, and impairment of dexterity, memory, and equilibrium have been reported to result from long-term exposure (ATSDR, 2014).

Based on available nasopharyngeal cancer data, formaldehyde is regarded as a possible human carcinogen following inhalation exposure and as such is classified in group one of human possible carcinogen by the International Agency for Research on Cancer (IARC).

2.13 ANALYTICAL METHODS USED FOR THE DETERMINATION OF FORMALDEHYDE

In- situ spectroscopic methods, derivatization methods and the use of sensors are analytical methods that have been used for the determination of formaldehyde in air.

Spectroscopic methods involving in-situ determination of formaldehyde provides real time measurementS but are of limited scope because of restrictions imposed by method sensitivity and the requirement for elaborate and expensive instrumentation. Four different in-situ spectroscopic techniques have been used and these are Differential Optical Absorption Spectroscopy (DAOS), Fourier Transform Infrared Absorption (FTIR), Laser-Induced Fluorescence Spectroscopy (LIFS) and Tunable Diode Laser Absorption Spectroscopy (TDLAS). These methods are specific, non-destructive and quantitative but their requirement for large, complex and expensive instrumentation makes them unsuitable for routine applications (Vairavamuthy et al., 1992).

With derivatization method formaldehyde is trapped in an absorber or on impregnated filters and cartridges. The compound is then derivatized and the resulting chromophore can be analyzed by either spectroscopy or chromatograhy. The most difficulty associated with this method is the non-specificity for formaldehyde if no chromatographic separation is applied and more so reagents also react with other carbonyl compounds, and these could result in interference of the byproduct with the target analyte (Salthammer et al., 2010).

The need for fast and simple methods for monitoring of formaldehyde levels has led to increased research activities in the field of sensor technology methods. As a result, sensing instrumentation capable of accessing information at a real-time level is now available and it is found that the sensing mechanism of the majority of these sensors can be classified in as receptor-based or transducer-based formaldehyde sensors (Chung et al., 2013).

Lv et al., 2011 developed a microgas sensor based on a microhot plate and this could detect an indoor formaldehyde concentration of up to 0.06 ppm.

2.14 DERIVATIZATION REACTION OF FORMALDEHYDE WITH MBTH

The first step in this chemical reaction process is the reaction of the MBTH with formaldehyde to form azine (A). The second stage involves the oxidation of excess MBTH to form a cationic oxidized complex (B) which in turn reacts with azine formed in the first step to form a blue cationic dye (C) as the final product in the final step of the reaction process. This dye formed is ultra violet active at a wavelength of 628nm on a spectrophotometer. The reaction process is shown in the figure below.

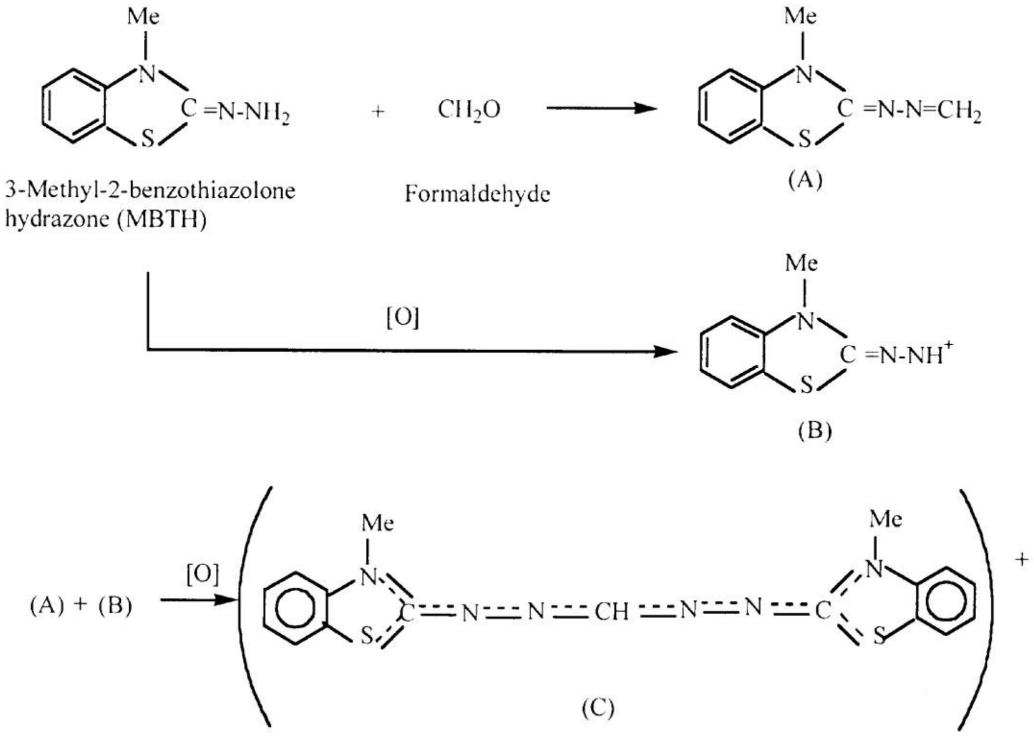


Figure 2.3: Reaction of MBTH with Formaldehyde

2.15 THEORY OF THE UV/VISIBLE ABSORBTION TECHNIQUE

A spectrophotometer is an instrument that resolves or separates polychromatic light into different wavelengths. A UV/ visible spectrophotometer consist of five components. These are

1. A source of light that provides continuous radiation over the wavelength of interest. The visible region consists of tungsten filament incandescent lamp and wavelength range from 32 5nm to 3 μm and the ultraviolet region can consists of hydrogen discharge tube lamp or deuterium discharge tube lamp. Both can be used from 185 nm to 375 nm.

2. A filter or monochromator for selecting wavelength or narrow band of wavelengths from the source spectrum
3. Sample compartment for holding the sample
4. A detector or transducer for converting radiant energy into electrical energy
5. Readout to show response of the detector.

The light source provides all wavelengths of the visible light while also providing wavelengths in the ultraviolet and near infrared range. The filter or monochromator separate the light into its component wavelengths so that a relatively small range or band of wavelengths can be directed through the sample. The sample compartment permits the entry of no stray light while at the same time not blocking out any light from the source. The photo-detector converts the amount of light which it has received into a current which is then sent to a processor which is the brain of this machine. The signal processor converts the simple current it receives into absorbance, transmittance and concentration values which are then sent to the display.

2.15.1 MODE OF OPERATION OF SHIMADZU 1240 MINI UV/VISIBLE SPECTROPHOTOMETER

For measurement of Absorbance /Transmittance:

After initialisation of UV/Visible spectrophotometer, the basic mode menu will be displayed on the monitor. Press 1 to go in the photometric mode, then press GOTO WL and give the required wavelength. Afterwards, press enter to get that wavelength. Press F1 key to select Absorbance or Transmittance mode. Fill the cuvettes with blank solution and place it in the cell holder and press. Auto Zero the current wavelength will automatically be set to zero absorbance (100% Transmittance). Then remove the cuvette, discard the blank solution. Rinse the cuvette with sample solution. Then fill the cuvette with sample solution and replace in the cell holder. The monitor will display the absorbance of the sample solution at the wavelength displayed.

CHAPTER THREE

MATERIALS AND METHODS

3.1 STUDY AREA AND SAMPLING SITES

The republic of Ghana is a country located along the Gulf of Guinea and Atlantic Ocean in the sub-region of West Africa with an estimated population of 27,043,093 (GSS 2014). Ghana is subdivided into two major sectors namely the southern and northern sector which host the ten regions of the country and the Ashanti region is one of them and located in the northern sector. The Ashanti region of Ghana has a projected total population of 5,406,209 (GSS, 2016). Kumasi is the capital city of Ashanti region and is the second-largest city in the country after the country's capital city Accra and has an area of 254 km^2. Kumasi is approximately 300 miles (480 km) north of the Equator and 100 miles (160 km) north of the Gulf of Guinea. It is popularly known as "The Gar-den City" or "Heart Beat" of Ghana because of its many beautiful species of flowers and plants (Kuffuor et al., 2012).

Air samples were obtained from various types of beauty salons located in the ten sub-metros that make up the Kumasi metropolis. The ten sub-metros are Suame, Bantama, Manhyia, Tafo, Asawase, Asokwa, Subin, Asokwa, Kwadaso and Nhyiaeso. Within each sub-metro samples were obtained from the salons scattered throughout the sub-metro. The various services offered by salons where air samples were taken for the study includes hair washing, retouching, styling, braiding, dying/colouring, smoothening/straightening, pedicure, manicure and makeup. Majority of the salons where sampling was done were located in container shops sited along roadsides. Samples were taken from the centre area of the salon. Six salons were sampled from each sub-metro. Figure 3.1 shows is the map of the study area.

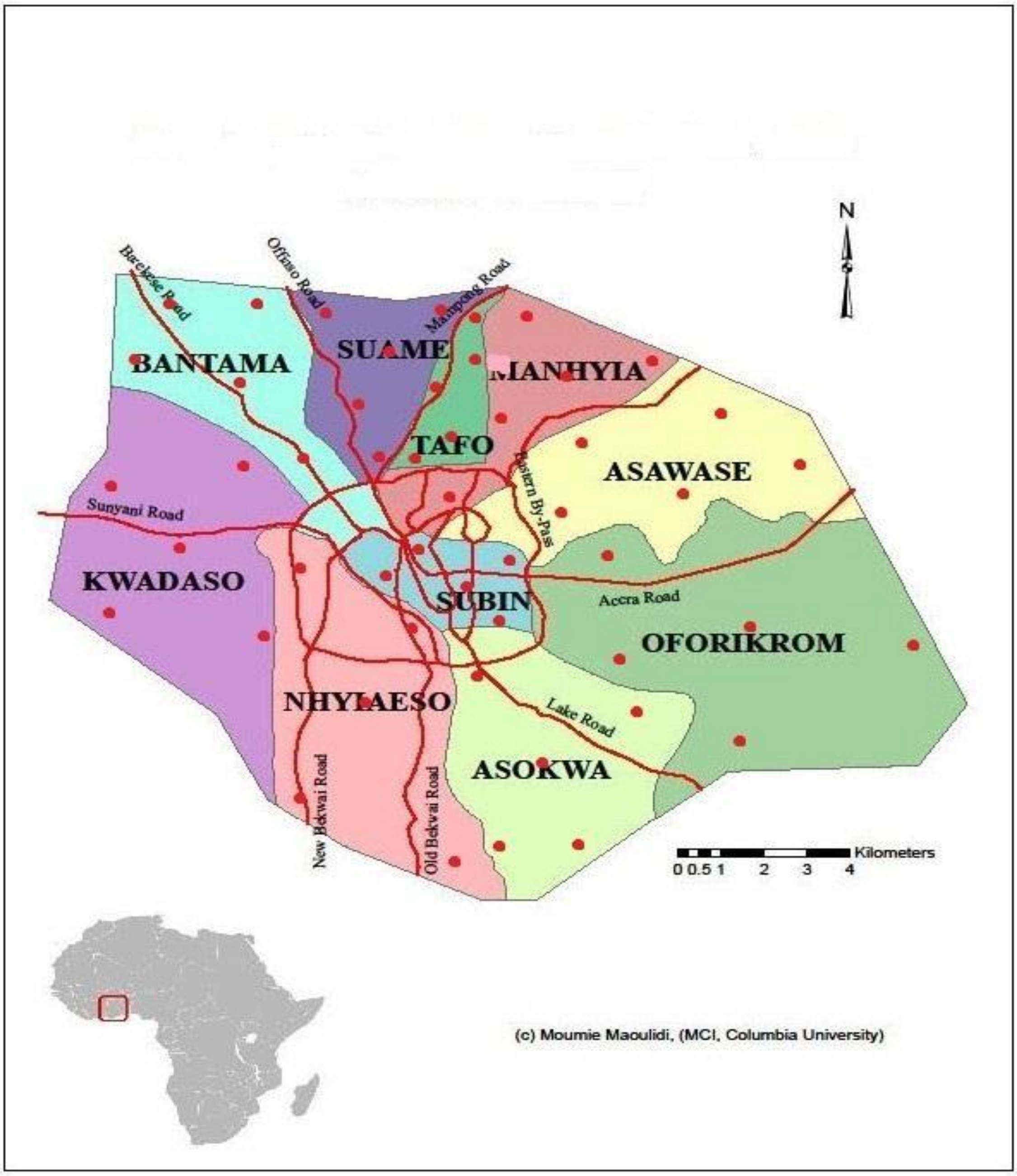


Figure 3.1: Map of Kumasi Metropolis showing sampling points within the sub-metros

3.2 MATERIALS AND METHODS

3.2.1 EQUIPMENT

1. Analytical balance
2. Shimadzu mini UV/Visible Spectrophotometer model 1240

3. System Service Innovation Incorporation air sampler model 1000i
4. 433 MHz Electronic Weather station

3.2.2 GLASSWARE USED

1. Beakers (50 mL, 250 mL)
2. Graduated pipettes (10 mL)
3. Volumetric flasks (25 mL, 50 mL, 100 mL, 500 mL, 1000 mL)
4. Sample tubes
5. Measuring cylinder (10 ml)

3.2.3 REAGENTS AND CHEMICALS

1. 3-methyl-2-benzothiazolinone hydrazone hydrochloride (MBTH)
2. Formaldehyde solution 38% w/w
3. Sulfamic acid
4. Ferric Chloride

3.2.4 CLEANING OF GLASSWARE AND SAMPLE BOTTLES

Glass wares that were used for preparation of solutions and sampling bottles were all initially cleaned by rinsing with 10% trioxonitrate (v) acid. They were then soaked in detergent overnight and then followed with peroxide sulphate cleaning solutions. Afterwards double distilled water was used to rinse them. Double distilled water produced by the chemistry department of KNUST was used in the preparation of blanks, reagents and standards.

3.2.5 PREPARATION OF ABSORBING SOLUTION

0.05% 3-methyl-2-benzothiazolinone hydrazine hydrochloride (MBTH) absorbing solution was prepared by dissolving 0.5 g of MBTH in small volume of double distilled water and diluted to the mark in a 1L volumetric flask.

3.2.6 SAMPLING

System service Innovation Incorporation air sampler model 1000i was used for sampling. Thirty-five millilitres (35 ml) of MBTH solution was placed in an impinger of the sampler. The air inlet of the air sampler was placed at a height of 1.5 meters above the ground level and approximately in the centre of each salon. Air was drawn through the MBTH solution at a rate of 0.5L/min for 30mins. After 30 minutes of sampling, the absorbing MBTH solution was transferred into an air-tight sample container which was then taken to the laboratory for analysis. During the 30 minutes sampling period, a 433 MHz electronic weather station was used to record the temperature and humidity of the sampling facility. Before sampling, fans were switched off and doors and windows were also closed.

Figure 3.2: Picture of System Service Innovation Incorporation air sampler model 1000i and 433 MHz Electronic Weather station

3.2.7 PREPARATION OF OXIDIZING SOLUTION

A 1.6 g of sulfamic acid and 1.0 g of ferric chloride were weighed and dissolved in a 100 ml volumetric flask with distilled water and topped to the 100 ml mark.

3.2.8 PREPARATION OF FORMALDEHYDE STOCK STANDARD SOLUTION

A 2.7 ml of 38% (w/w) formalin solution was diluted to 1L with double distilled water. This solution is stable for at least three months.

Table 3.1 Instrumental Parameters used in the UV/Visible Spectrophotometric technique for determination of Formaldehyde

PARAMETER	FORMALDEHYDE
Lamp	Tungsten halide
Wavelength (nm)	628
Wavelength reproducibility (nm)	0.1
Lamp current (A)	5
Voltage range (V)	220-240
Cuvet path length (cm)	1.0
Bandwidth (nm)	2.0

3.3 PREPARATION OF CALIBRATION SOLUTION AND CURVE

A formaldehyde stock standard solution of concentration 402402 mg/L was used to prepare intermediate or working formaldehyde standard solution of concentration 4000 mg/L. Formaldehyde standard solutions of concentrations 0.5, 1.0, 1.5, 2.0 and 2.5 mg/L were prepared from the intermediate or working formaldehyde standard solution. To a clean tube, 5 ml of 0.05% MBTH, 5 ml of standard formaldehyde solutions and 2 ml of oxidizing solutions were added. This mixture was allowed to stand for a minimum of twelve minutes for the formation of a blue coloured solution. The absorbance of the coloured solution was measured using a Shimadzu mini UV/Visible Spectrophotometer model 1240 at a wavelength of 628 nm in a 1 cm cell against a reagent blank. The calibration curve was plotted as absorbance against concentration in mg/L.

3.4 PREPARATION OF REAGENT BLANK

A 5 ml H_2O and 5 ml of 0.05% MBTH solution were pipetted into a 50 ml volumetric flask. 2 ml of oxidizing solution which was prepared from Sulfamic acid and ferric chloride was added and mixed well.

3.5 QUALITY CONTROL AND ASSURANCE

A series of quality assurance and control processes were followed both in the laboratory analysis of samples and on the field during sampling to ensure that results obtained from the study were accurate and precise. All samples were quantified with multipoint calibration curves from pure chemicals of analytical grade. Analytical blanks were included in all analysis. Background correction of the spectrophotometer was also performed before any analysis was done.

3.6 ADMINISTRATION OF QUESTIONNAIRE

Questionnaire was administered at each sampling facility visited to gather information about the workers, working practices and the facility. Information such as age of the salon, services offered, various cosmetic products used in the salon, number of years of working experience, knowledge about the products used and health conditions experienced during the period of work among others were gathered.

CHAPTER FOUR

RESULTS AND DISCUSSION

4.1 CALIBRATION PLOT

The calibration plot for formaldehyde was done using prepared known concentrations of formaldehyde solutions and was plotted as concentration against absorbance. The regression equation obtained was used to obtain the formaldehyde concentration which in turn was used to calculate the formaldehyde concentration in the air samples. The results for the plot of the curve are shown in Table 4.1 and Figure 4.1.

Table 4.1: Calibration Curve for Formaldehyde

CONCENTRATION(mg/L)	MEAN ABSORBANCE
0.0	0.00
0.5	0.112

1.0	0.226
1.5	0.309
2.0	0.405

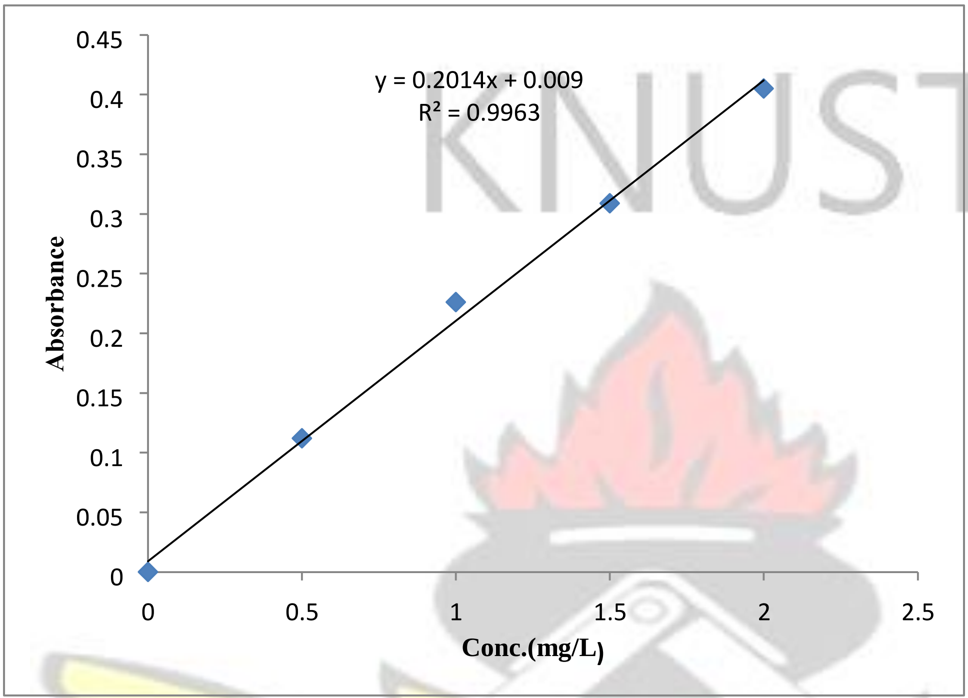


Figure 4.1: Calibration Curve

4.2 RESULTS OF THE STUDY AT BANTAMA

Six beauty salons were sampled at Bantama. Below is the table showing the results of the salons sampled during the study of the submetro.

Table 4.2: Results of study at Bantama Sub-metro

Bantama	Concentration of HCHO (µg/m^3)
Sandy Hair Care	434
Salina Hair Do	257
Blessing Beauty Salon	152
Nyarko Beauty Salon	48
Grace Beauty Salon	100
Kate Beauty Salon	33
Range(H)	33-434

The concentrations of formaldehyde determined from the salons at Bantama ranged from 33 to 434 μg/m^3. Sandy Hair Care recorded the highest formaldehyde concentration while Nyarko Beauty Salon recorded the lowest formaldehyde concentration as seen in Figure 4.2.

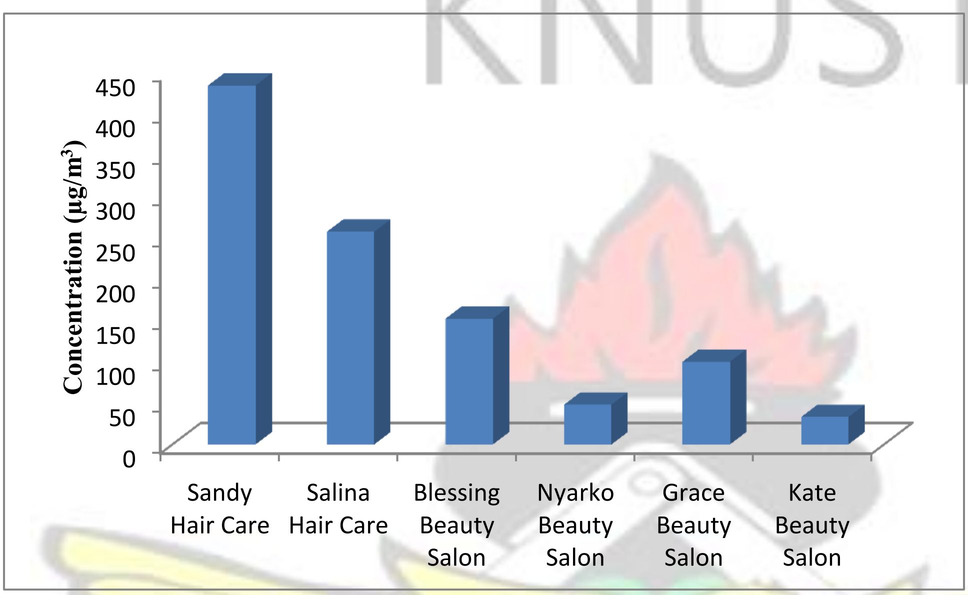


Figure 4.2: Salons and their levels of HCHO (μg/m^3) at Bantama

Sandy Hair Care which offered the most services, had the highest number of customers visiting the salon in a week and was also the oldest in terms of age of the salons sampled in this area. What this means is that more cosmetics are being used in this salon than the rest which could result in a high overall release of formaldehyde from these cosmetics used. From literature, a study by Labreche et al in the year 2003 characterizing chemical exposures in hairdressing salons revealed that increase in number of chemical services offered in a day results in higher level of chemical exposure. In the salon the number of services offered in a day is directly linked to the number of customer's visiting. Nyarko Beauty Salon on the other hand which offered only one service which was hair, was only 2 years old which was the newest out of the salons in this area and moreover had the lowest number of customers visiting in a week. These could account for the results observed.

4.3 RESULTS OF THE STUDY AT TAFO

Six salons were sampled during the study at Tafo and table 4.3 indicates the results obtained from the study.

Table 4.3: Results of study at Tafo Sub-metro

TAFO	CONCENTRATION OF HCHO($\mu g/m^3$)
Gisela Beauty Salon	152
Vernadu Beauty Salon	195
Portapp Beauty Salon	105
Amet Beauty Salon	200
Annette Beauty Salon	107
Classic Hair Beauty Salon	179
Range(H)	105-200

The level of formaldehyde concentration determined at the salons at Tafo ranged from 105 to 200 $\mu g/m^3$. Amet Beauty Salon recorded the highest level of formaldehyde concentration of 200 $\mu g/m^3$ and was closely followed by Vernadu Beauty Salon with 195 $\mu g/m^3$ with the least being Portapp Beauty Salon recording a formaldehyde concentration of 105 $\mu g/m^3$ as shown in Figure 4.3.

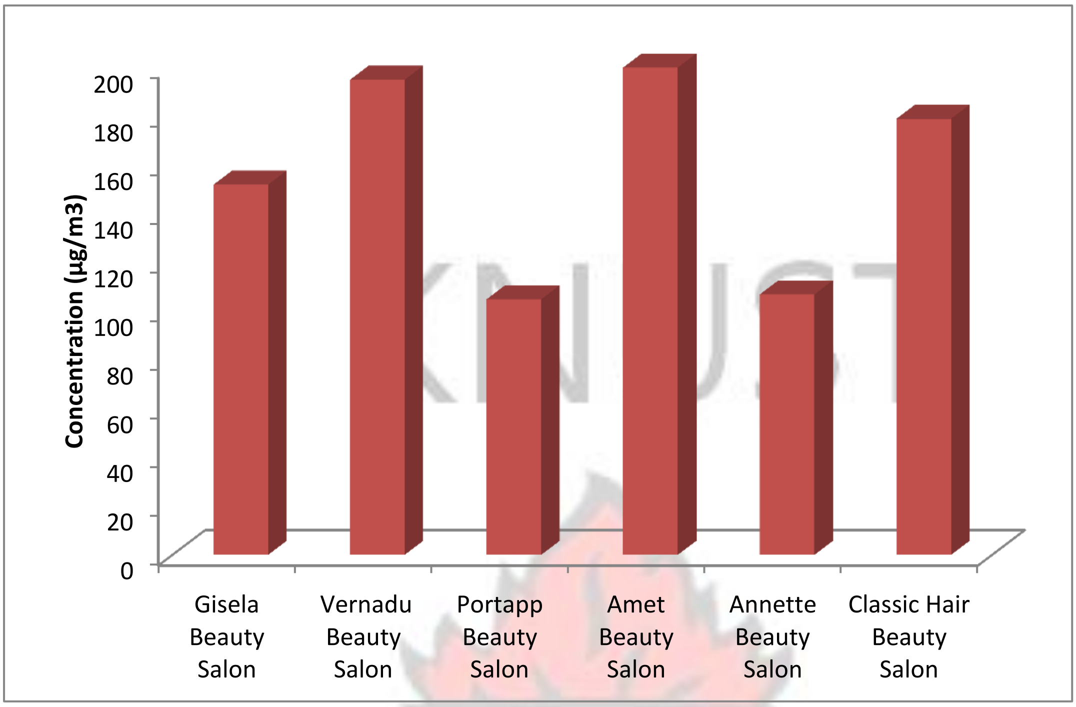


Figure 4.3: Salons and their levels of HCHO (µg/m^3) at Tafo

All the salons sampled in this area offered the same services. The difference in the formaldehyde levels determined could therefore be attributed to the number of customers that visit each salon, age of facility (salon) and the level of expertise of the salon workers indicated by years of working experience. Although ventilation systems in place in each of the salons could be a key factor in the level of formaldehyde determined that is not the case as all the salons sampled use the same ventilation system (windows and ceiling fan) as observed during sampling.

4.4 RESULTS OF THE STUDY AT KWADASO

At Kwadaso sub-metro six salons were sampled for the study. Table 4.4 shows the results obtained from the study.

Table 4.4: Results of study at Kwadaso Sub-metro

KWADASO	CONCENTRATION OF HCHO (µg/m^3)
Psalm 91 Beauty Salon	101
Thy Grace Beauty Salon	197

Greatfulness Beauty Salon	24
Joyce Beauty Parlour	349
3y3 Adom Beauty Salon	134
Vision Parlour Beauty Salon	116
Range(H)	24-349

The determined levels of formaldehyde concentration from the salons sampled at Kwadao ranged from 24 to 349 µg/m^3. Joyce Beauty Salon had the highest formaldehyde concentration level of 349 µg/m^3 and the lowest was obtained at Greatfulness Beauty Salon with a formaldehyde concentration level of 24 µg/m^3 as shown in Figure 4.4.

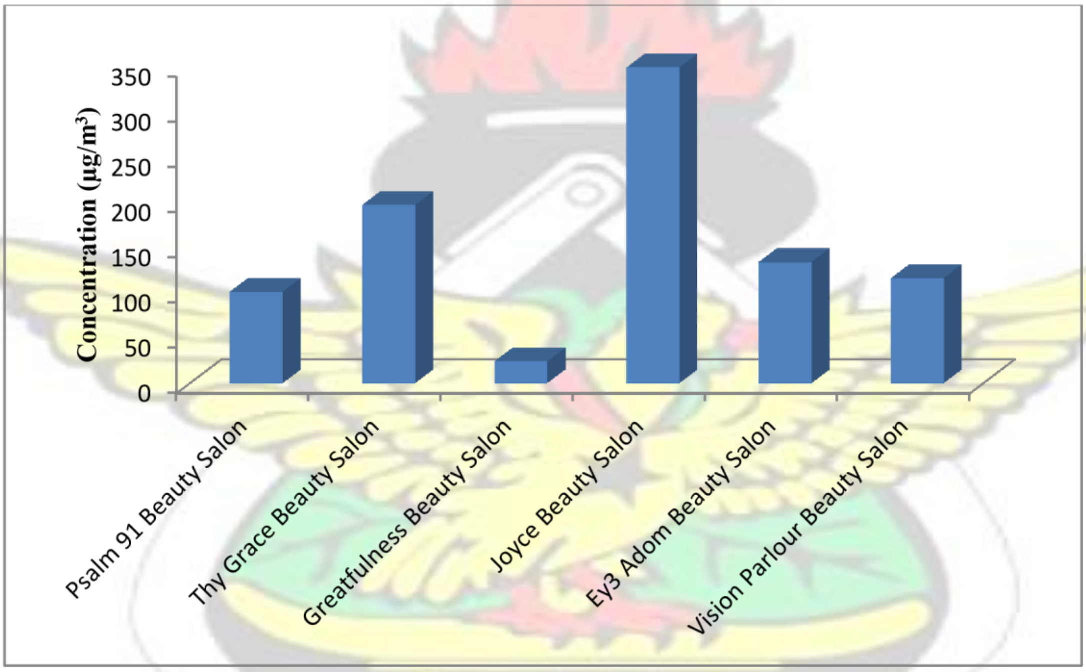


Figure 4.4: Salons and their levels of HCHO (µg/m^3) at Kwadaso

Joyce Beauty Salon offered more services as compared to the other salons sampled in this area and also had more customers visiting in a week which could account for it having the highest formaldehyde level recorded. Greatfulness Beauty Salon offered only one service which was hair and was established only year ago and moreover was one of the least visited by customers in a week. These might have accounted for the low formaldehyde level determined.

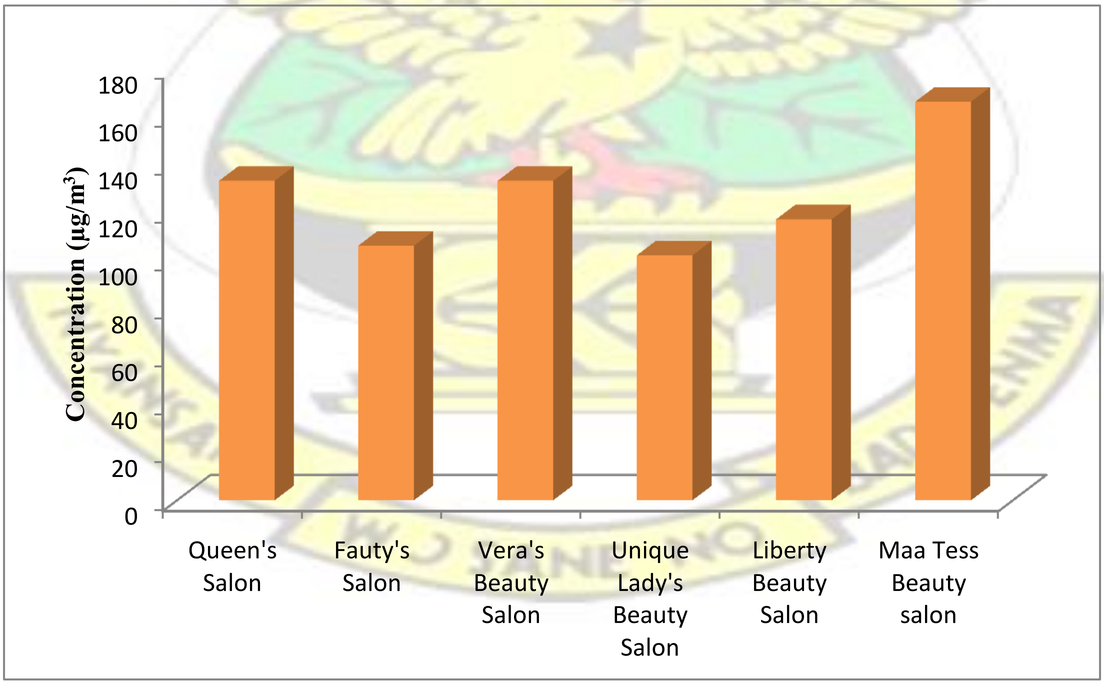
4.5 RESULTS OF THE STUDY AT MANHYIA

A total of six salons were sampled for the study at Manhyia sub-metro. Table 4.5 shows the results obtained from the study.

Table 4:5 Results of study at Manhyia Sub-metro

MANHYIA	CONCENTRATION OF HCHO ($\mu g/m^3$)
Qeen's Salon	133
Fausty's Salon	106
Vera's Beauty Salon	133
Unique Lady's Salon	102
Liberty Beauty Salon	117
Maa Thess Beauty Salon	166
Range(H)	102-166

The levels of formaldehyde concentration determined from the salons sampled at Manhyia ranged from 102 to 166 $\mu g/m^3$. Maa Tess Beauty Salon had the highest formaldehyde concentration level of 166 $\mu g/m^3$ out of the six salons sampled in this area as shown in the figure 4.5



3

Figure 4.5: Salons and their levels of HCHO (μg/m) at Manhyia

Fausty's Salon had formaldehyde concentration level of 106 μg/m^3 and was the lowest in this area. Maa Tess Beauty Salon offered variety of services with the rest of the salons offering at least two services. All the salons in this area also had close but different numbers of customers visiting in a week and these could contribute to the different levels of formaldehyde determined in each salon.

4.6 RESULTS OF THE STUDY AT SUAME

Samples were collected and analysed from six salons at Suame in the study. The results are presented in table 4.6.

Table 4.6: Results of study at Suame Sub-metro

SUAME	CONCENTRATION OF HCHO (μg/m^3)
Doris Beauty Salon	74
God's Time is the Best Beauty Salon	98
Sie Sie me Beauty Salon	21
Obaa Yaa Palace	166
Stella Salon	56
Adonai Salon	117
Range (H)	21-166

At Suame the levels of formaldehyde concentration determined from the salons sampled ranged from 21 to 166 μg/m^3. Obaa Yaa Palace recorded the highest formaldehyde concentration level of 166 μg/m^3 while the lowest recorded formaldehyde concentration of 21 μg/m^3 was for Sie Sie Me Beauty Salon as seen in figure 4.6.

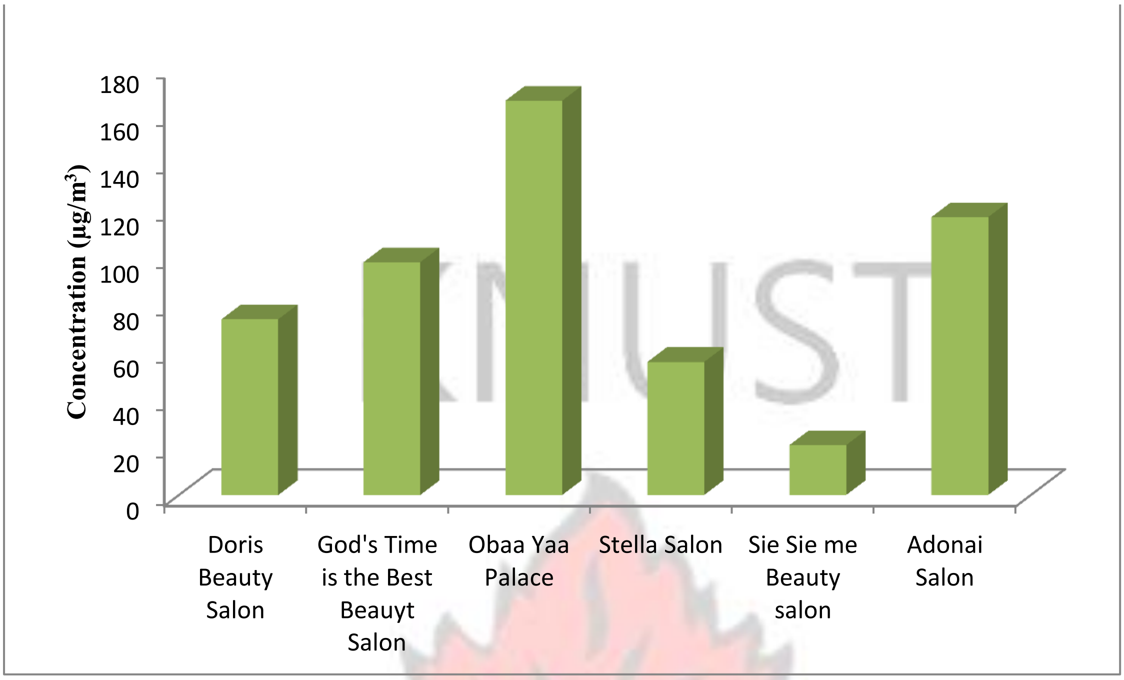


Figure 4.6: Salons and their levels of HCHO (µg/m^3) at Suame

Obaa Yaa Palace offered the more services in this area and was also the most visited by customers in a week and this could have accounted for it having the highest formaldehyde concentration level. On the other hand, Sie Sie Me Beauty Salon offered only hair service and was the least visited by customers in the area and this could account for the results observed. The remaining salons offered two or more services with difference in numbers of customers visiting in a week and also with varying ages of salon establishment.

4.7 RESULTS OF THE STUDY AT OFORIKROM

Six salons were selected at this study area and the results obtained from the analysis of air samples from the salons are presented in Table 4.7.

Table 4.7: Results of study at Oforikrom Sub-metro

OFORIKROM	CONCENTRATION OF HCHO (µg/m^3)
Eyelashes Beauty Salon	97

Victoria’s Beauty Salon	81
Classic Lady’s Beauty Salon	92
All Shall Pass Beauty Salon	327
Lasty Vee Beauty Salon	86
Exodus 14:14 Beauty Salon	119
Range	81-327

The levels of formaldehyde concentration determined from the salons sampled at Oforikrom ranged from 81 to 327 µg/m^3. Eyelashes, Classic Ladies and Lasty Vee’s beauty salons offered hair and nail services only whereas the rest offered hair services only with Exodus 14:14 beauty salon offering additional Eyelash/Eyebrow service. All Shall Pass Beauty salon had the highest formaldehyde concentration level of 327 µg/m^3 while Victoria’s Beauty Salon had 81 µg/m^3 as the lowest formaldehyde concentration level as shown in Figure 4.7.

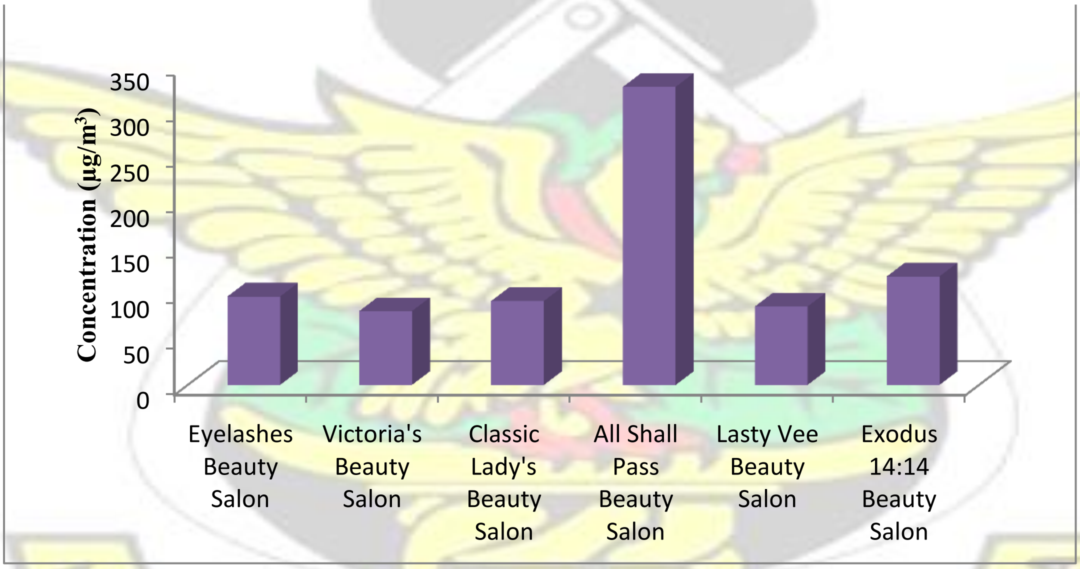


Figure 4.7: Salons and their levels of HCHO (µg/m^3) at Oforikrom

The salon that recorded the highest formaldehyde concentration level was among the salons that offered only hair service but had the highest customer visits in a week and was also the second most aged facility (salon) in the area. The least visited salon in the area was Victoria’s Beauty Salon which offered only hair services. The differences in the formaldehyde levels recorded among the salons that offered only hair and nail services could be due to the average number of customer visits in a week and age of facility. During sampling it was observed that all the salons in this area had similar ventilation systems in place which was a window and a ceiling fan.

4.8 RESULTS OF THE STUDY AT ASAWASE

The results obtained from the six salons selected for the study at this study area are presented in table 4.8.

Table 4.8: Results of study at Asawase Sub-metro

ASAWASE	CONCENTRATION OF HCHO (μg/m^3)
Mercy's Beauty Salon	85
Mary's Beauty Salon	90
Unique Beauty Salon	268
Aisha Hair Do	175
Maria Beauty Salon	21
Mavis Beauty Salon	47
Range(H)	21-268

The levels of formaldehyde concentration determined from the salons sampled at Asawase ranged from 21 to 268 μg/m^3. Unique Beauty Salon had the most formaldehyde concentration level while Maria Beauty Salon recorded the least as seen in figure 4.8.

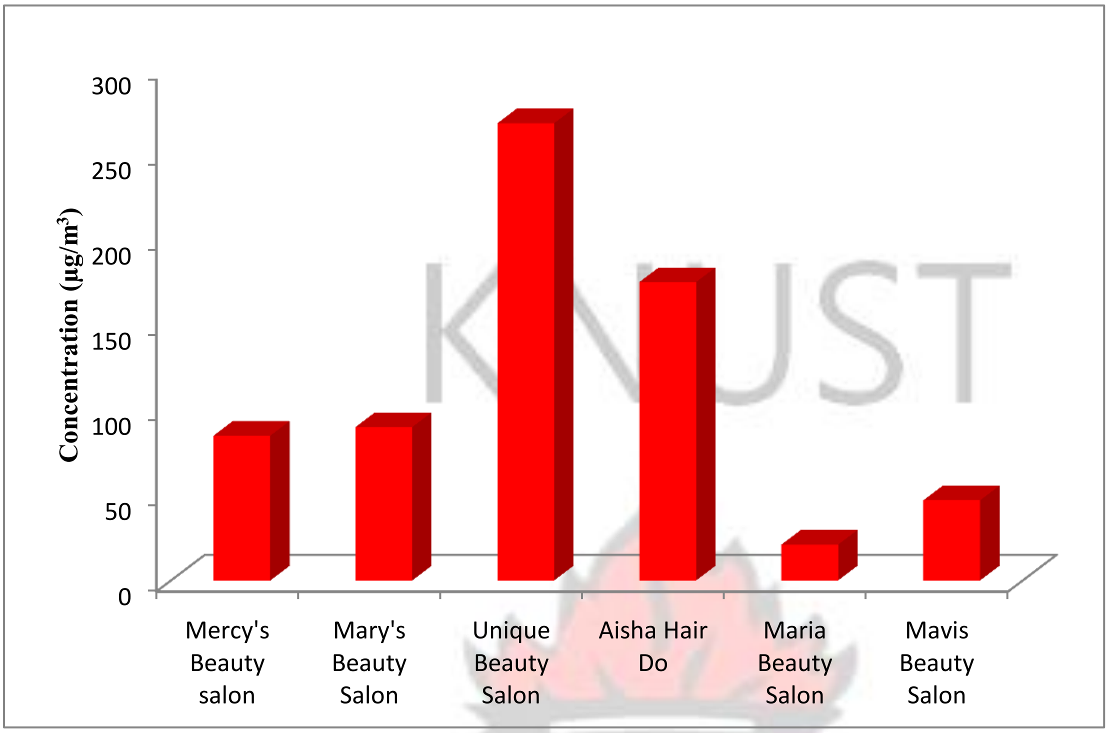


Figure 4.8: Salons and their levels of HCHO ($\mu g/m^3$) at Asawase

Unique Beauty Salon offered the most salon services, the most customer visits in a week and was also the second most aged facility (salon) in this area which all might have contributed to the results obtained. Maria Beauty Salon was only established a year ago, offered only one service which was hair and had the least customer visits in a week. The rest of the salons offered hair and nail services with the exception being Aisha Hair Do which offered only hair services as Maria's Beauty salon but had been established six years ago and also had more customer visit in week than the latter.

4.9 RESULTS OF STUDY AT SUBIN

Table 4.9 shows the results of the study obtained from the six salons sampled for the study at Subin sub-metro in Kumasi.

Table 4.9: Results of study at Subin Sub-metro

SUBIN	CONCENTRATION OF HCHO ($\mu g/m^3$)

Nhyira Beauty Salon	193
Aseda Nka Boafo Beauty Salon	72
Gina Hair and Nail Salon	265
Papaye Beauty Salon	24
Ange's Beauty Salon	97
Thy Faithfulness Beauty Salon	169
Range(H)	24-265

At Subin sub-metro area the levels of formaldehyde concentration determined from the salons ranged from 24 to 265 µg/m^3. From figure 4.9, it can be seen that Gina Hair and Nail Salon recorded the highest formaldehyde concentration level while Papaye Beauty Salon had the lowest.

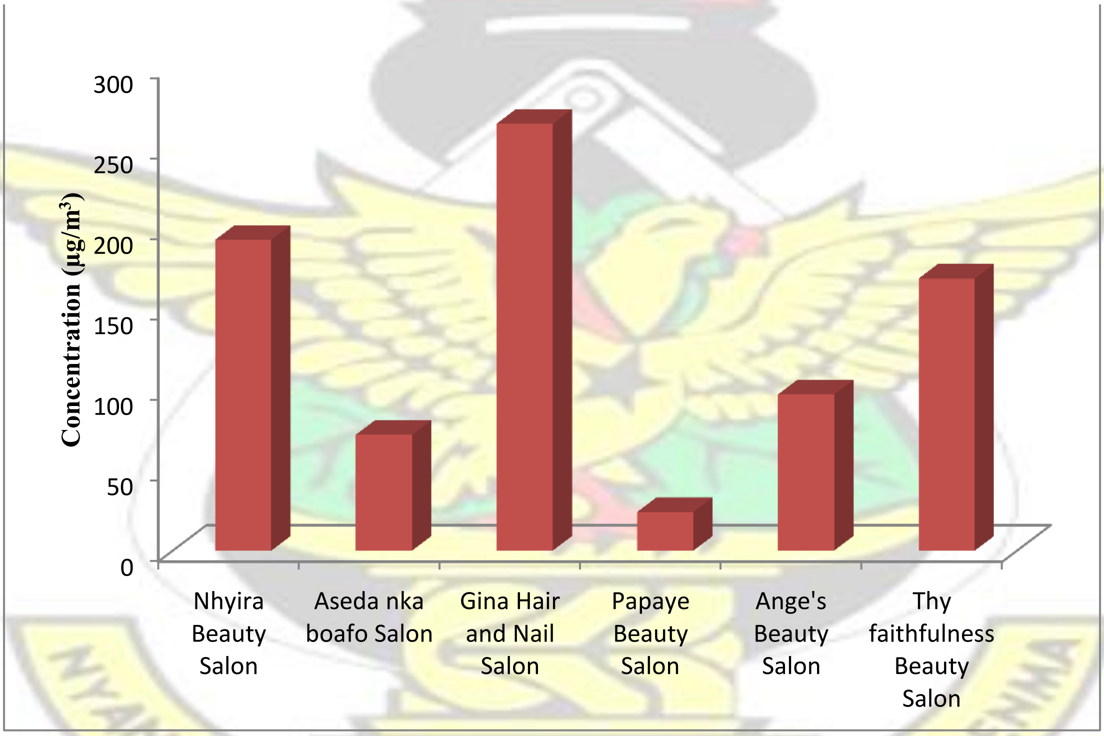


Figure 4.9: Salons and their levels of HCHO (µg/m^3) at Subin

Gina Hair and Nail Salon offered the highest number of salon services and had the most average customer visits in a week as well. Most customer visits in week implies more cosmetic products are being used which could results in overall increase in the level of formaldehyde released and hence the level determined in the salon. Papaye Beauty Salon offered only hair service and also had the lowest customer visits in a week. The rest of salons sampled in this area offered either hair and nail or only hair services.

4.10 RESULTS OF THE STUDY AT ASOKWA

A total of six salons were selected and sampled for the study at Asokwa and the results from the study are presented in table 4.10.

Table 4.10: Results of study at Asokwa Sub-metro

ASOKWA	CONCENTRATION OF HCHO (µg/m^3)
Euniel's Salon	104
Care Care Beauty Salon	97
Lizzy Beauty Salon	132
The Beauty Studio	157
3ny3 Maho)den Salon	109
Blessing Beauty Salon	152
Range(H)	97-157

The levels of formaldehyde concentration determined from the salons sampled at Asokwa ranged from 97 to 157 µg/m^3. The Beauty Studio Salon recorded the highest formaldehyde concentration level of 157 µg/m^3 and was closely followed by Blessing Beauty Salon with a formaldehyde concentration level of 152 µg/m^3. The least formaldehyde concentration level was 97 µg/m^3 and was recorded by Care Care Beauty Salon as shown in figure 4.10.

Figure 4.10: Salons and their levels of HCHO (µg/m^3) at Asokwa

All the salons sampled in this area offered two or more services. The Beauty Studio Salon was the most visited by customers and was also the most aged salon in the area.

4.11 RESULTS OF THE STUDY AT NHYIASO

The last sub-metro visited during the course of the study was Nhyiaso and the results obtained from the six salons sampled for the study are presented in table 4.11.

Table 4.11: Results of study at Nhyiaso Sub-metro

NHYIASO	CONCENTRATION OF HCHO (µg/m^3)
Jane Beauty Salon	35
Aseda Beauty Salon	78
Gina’s Salon	67
Matilda’s Beauty Salon	187
Adom Beauty Salon	58
Lady Nash Beauty Salon	176
Range(H)	35-187

The levels of formaldehyde concentration determined from the salons sampled at Nhyiaso ranged from 35 to 187 µg/m^3. Matilda’s Beauty Salon had the highest formaldehyde concentration of 187 µg/m^3 while Jane Beauty Salon had the lowest formaldehyde concentration level of 35 µg/m^3 as shown in figure 4.11.

Figure 4.11: Salons and their levels of HCHO (µg/m^3) at Nhyiaso

All the salons sampled in this area for the study offered two or more services with the exception of Jane Beauty Salon which offered only one service (hair). The services offered by the salons were hair, nail and Makeups. Matilda's Beauty Salon offered hair and nails services and had the highest customer visits in week and was followed by Lady Nash Beauty Salon.

4.12 HISTOGRAMS OF FORMALDEHYDE CONCENTRATIONS (µg/m^3) DETERMINED AND TEMPERATURE (^{0}C) RECORDED

The figures below shows a histogram plot of the formaldehyde concentrations determined across the sixty salons sampled in the ten sub-metros in Kumasi for the study and the temperatures recorded during sampling at the salons.

Table 4.12: Frequency table for plot of formaldehyde concentration histogram

CH_2O Conc. ($\mu g/m^3$)	*Frequency*
0-99	23
100-199	30
200-299	4
300-399	2
400-499	1

Table 4.12.1: Frequency table for plot of histogram for temperature recorded in salons

Temperature (^oC)	*Frequency*
20-25	0
26-30	7
31-36	51
37-42	2

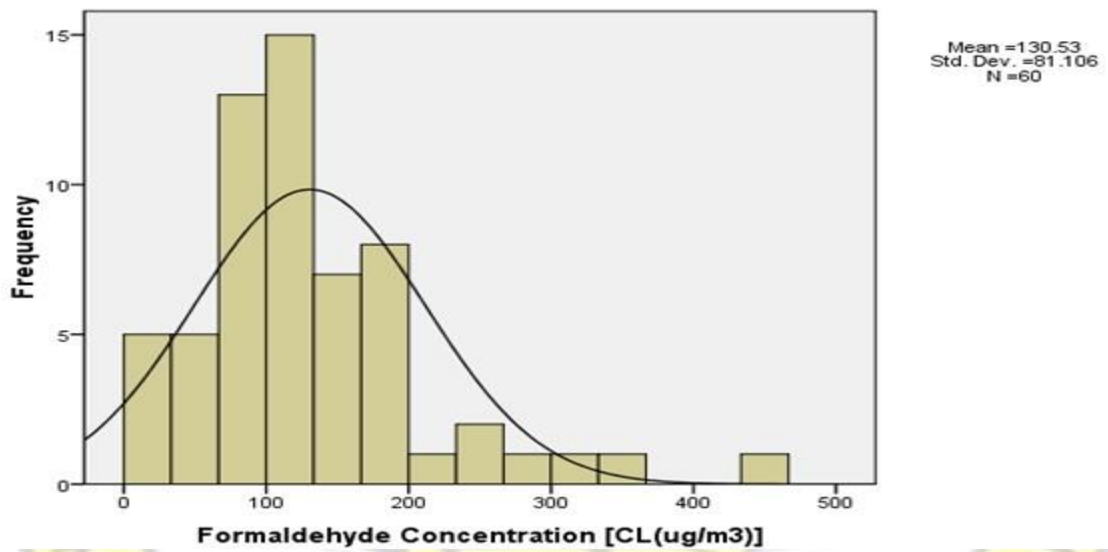


Figure 4.12.1: Histogram of Formaldehyde Concentrations in the sixty salons sampled.

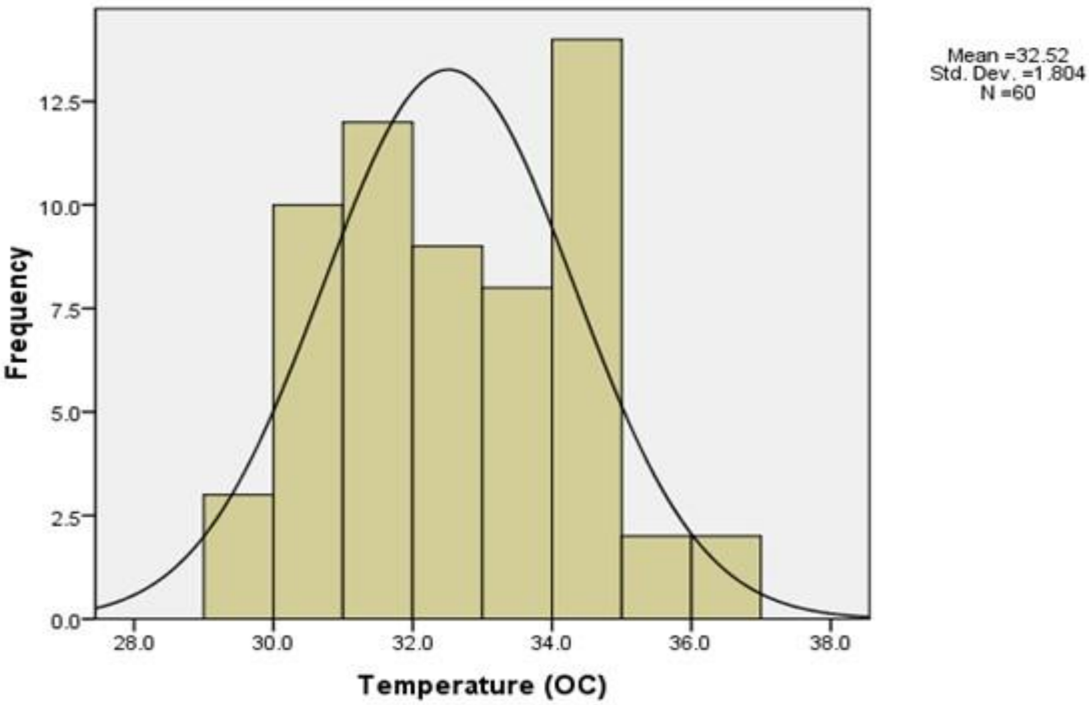


Figure 4.12.2: Histogram showing Temperature (⁰C) recorded at the salons.

We can see from the figures 4.12.1 and 4.12.2 that the data for Formaldehyde Concentration

(3 ^{0}C) all follow a normal distribution with mean of 130.53 and (µg/m) and Temperature

32.52 respectively. The standard deviation value of 81.106 for the formaldehyde concentrations determined means that the data is spread around the mean with a resulting wider normal distribution as shown in the figure 4.12.1. For the temperature values recorded, the smaller standard deviation value of 1.804 means that the data is tightly clustered around the mean with a resulting taller normal distribution as seen in figure 4.12.2.

4.13 TYPE OF SERVICES RENDERED BY RESPONDENTS (SALON OWNERS)

The response provided by questionnaire administered revealed the type of services offered by salons. The table below shows the types of services offered by the salons.

Table 4.13: Type of Services offered by Respondents (Salon Owners)

TYPE OF SERVICE	FREQUENCY

Hair	60
Nail	46
Skin	1
Eyelash/Eyebrow	7
Makeups	15

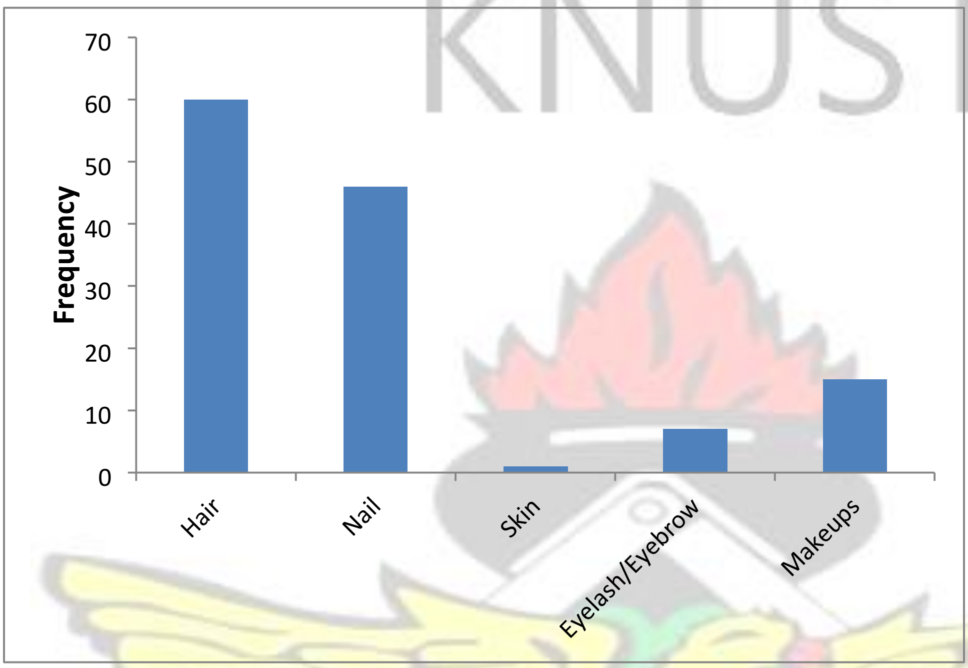


Figure 4.13: Type of Services offered by salons.

The figure 4.13 depicts that all the salons offer Hair services and this represent 47% of the total number of services offered by the salons. Nail services represent 35.7% of the total services offered and is the second most offered service followed by Makeups (11.6%), Eyelash/Eyebrow (5.4%) and Skin (1%) which is offered by only one salon.

4.14 NUMBER OF SERVICE(S) PERFORMED BY SALONS

The table below indicates the total number of services that is offered by each salon.

Table 4.14: Number of Service(s) offered by Salons

		Frequency	Percent	Valid Percent	Cumulative Percent
Valid	One Service	13	21.7	21.7	21.7
	Two Services	32	53.3	53.3	75.0
	Three Services	8	13.3	13.3	88.3
	Four Services	6	10.0	10.0	98.3
	Five Services	1	1.7	1.7	100.0
	Total	60	100.0	100.0	

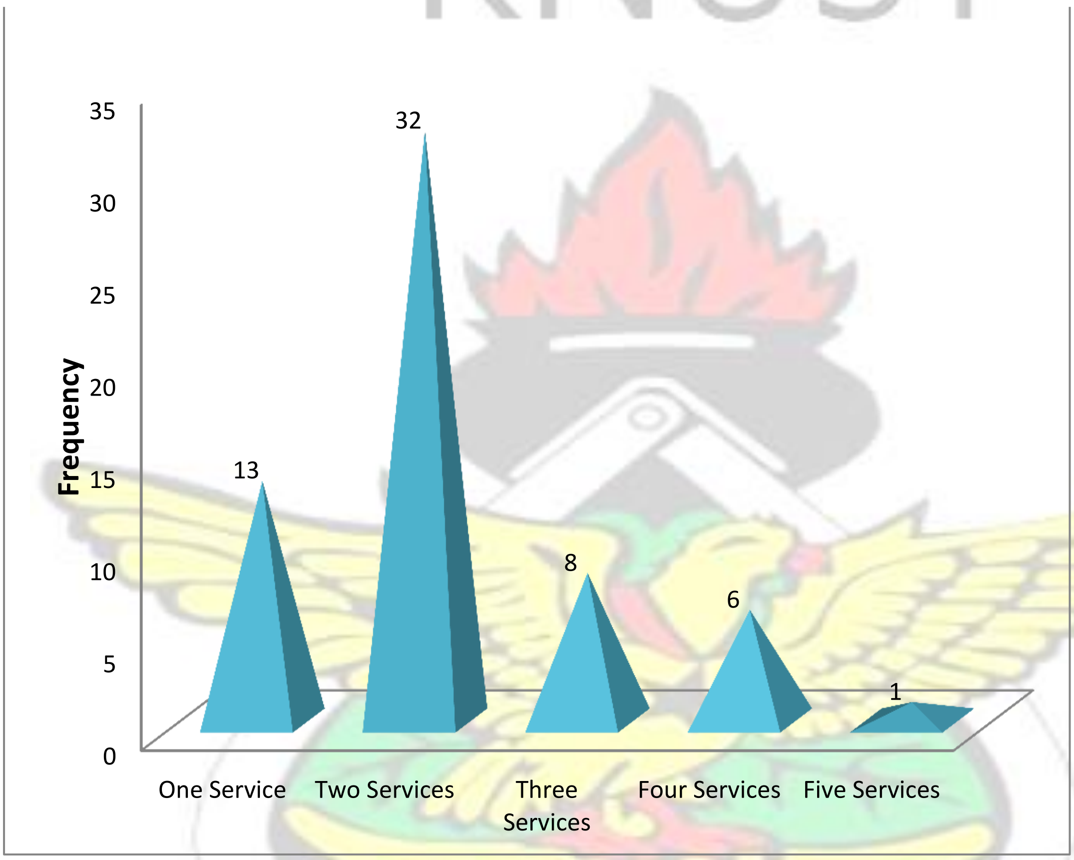


Figure 4.14: Number of Services offered by salons

The figure 4.14 shows that majority of the salons offer two services which is 53.3% of the total salons sampled for the study. The two most offered services are Hair and Nail services. Only one salon performs all the five services offered by salons in the study.

4.14 AVERAGE NUMBER OF CUSTOMERS IN A WEEK

Table 4.15 shows the average number of people (customers) that come to the salon in a week as revealed by the questionnaire administered.

Table 4.15: Average Number of Customers in a Week

		Frequency	Percent	Valid Percent	Cumulative Percent
Valid	Less than 20	1	1.7	1.7	1.7
	20-29	28	46.7	46.7	48.3
	30-39	24	40.0	40.0	88.3
	40-49	6	10.0	10.0	98.3
	50 and above	1	1.7	1.7	100.0
	Total	60	100.0	100.0	

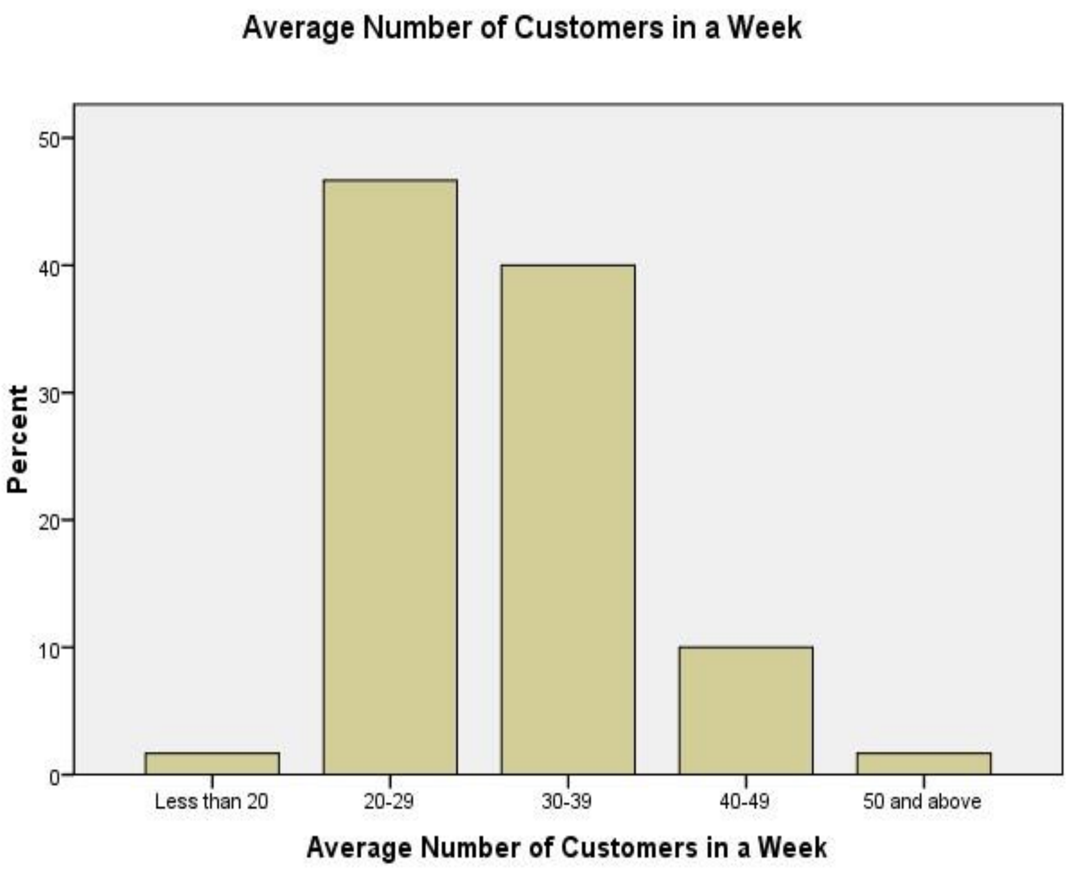


Figure 4.15: Average Number of customers in a week.

Figure 4.15 depicts that, on average majority (46%) of the respondents (salon owners/workers) revealed that 20 to 29 of customers visit their salons in a week with only one (1.7%) of the respondents asserting that 50 and more customers visit her salon in a week. Salon owners/workers further asserted that most visits by the customers to their salon is on weekends which start from Friday evening to Sunday evening during which most events such as weddings, funerals and parties among many others are held.

4.16 AGE OF FACILITY (BEAUTY SALON) AND YEARS OF WORKING EXPERIENCE

The questionnaire administered also provided information on the age of the various salons sampled for the study and this is presented in Table 4.16. The years of working experience among workers of the salons sampled were also obtained and this is also depicted in Figure 4.16.2.

Table 4.16: Age of Facility

		Frequency	Percent	Valid Percent	Cumulative Percent
Valid	Less than or equal to 5 Years	47	78.3	78.3	78.3
	More than 5 years	13	21.7	21.7	100.0
	Total	60	100.0	100.0	

Table 4.16 shows that majority of the beauty salons (exactly 47) to be precise representing 78.3 % are below 5 years with the remaining 13 salons with a percentage of 21.7% being more than 5 years. This data is also represented in Figure 4.16.1.

Table 4.16.1: Years of Working Experience

		Frequency	Percent	Valid Percent	Cumulative Percent
Valid	0-5 Years	29	48.3	48.3	48.3
	6-10 Years	26	43.3	43.3	91.7
	11-15 Years	4	6.7	6.7	98.3
	16 Years and Above	1	1.7	1.7	100.0
	Total	60	100.0	100.0	

Figure 4.16.2 shows that majority of the Respondents had worked between 0 and5 years with only one (1) working for 16 years and above.

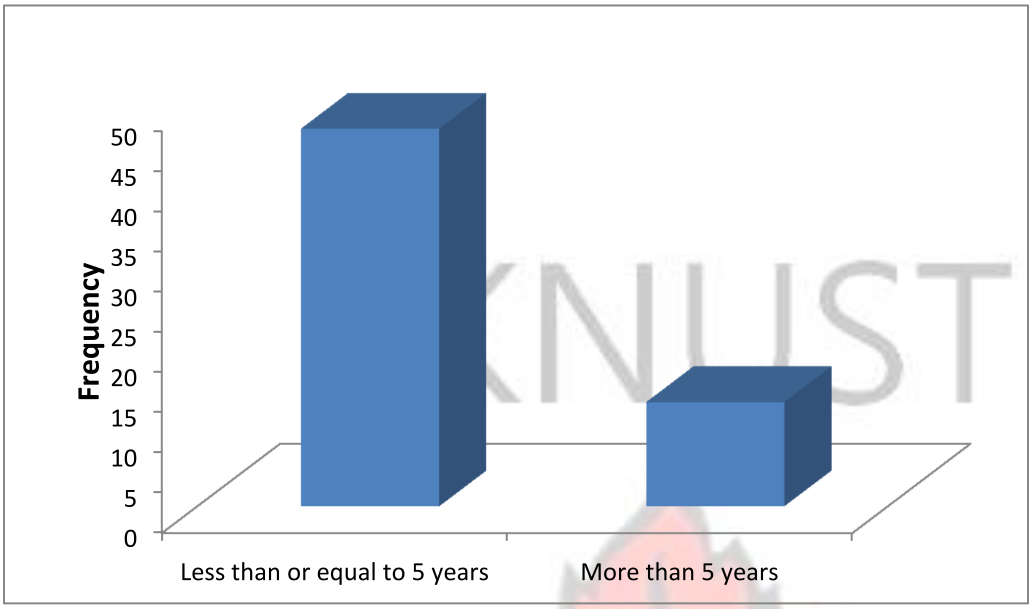


Figure 4.16.1: Age of Beauty Salons.

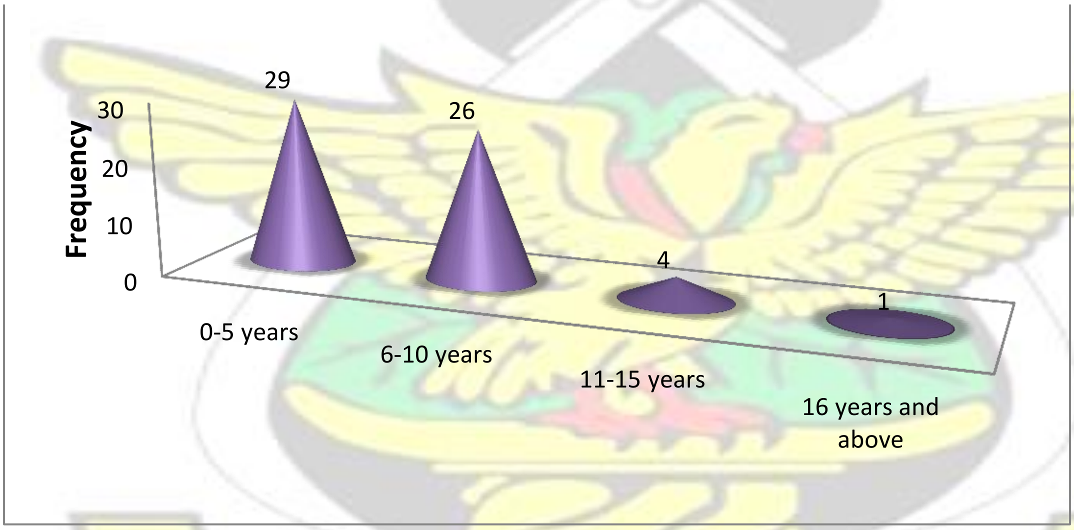


Figure 4.16.2: Years of Working Experience.

4.17 ACADEMIC QUALIFICATION OF SALON OWNERS/WORKERS

The educational background of the hairdressers was ascertained with the help of the questionnaire administered and the data is presented in Table 4.17 and Figure 4.17. **Table 4.17: Academic Qualification of salon owners/workers**

		Frequency	Percent	Valid Percent	Cumulative Percent
Valid	JHS	50	83.3	83.3	83.3
	SHS	3	5.0	5.0	88.3
	NVTI	6	10.0	10.0	98.3
	NONE	1	1.7	1.7	100.0
	Total	60	100.0	100.0	

Frequency based on Academic Qualification suggests that majority of salon workers (83.3%) completed JHS, SHS (5%), and NVTI (10%) while none (1.7%) of them completed Diploma and Masters level.

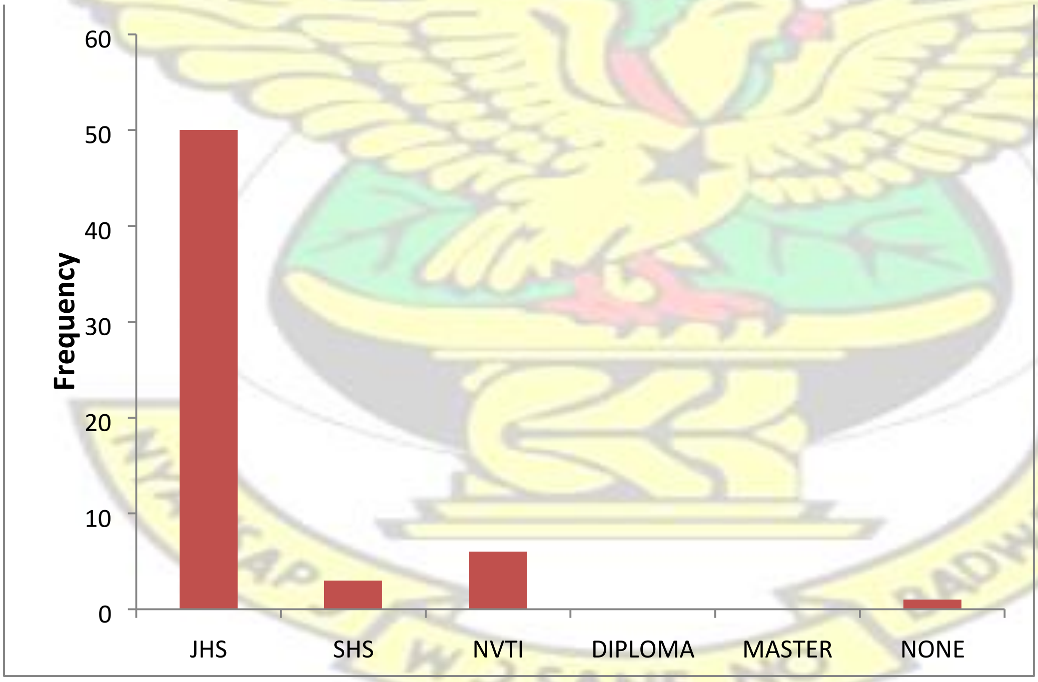


Figure 4.17: Academic Qualification of facility Owners/Workers.

4.18 KNOWLEDGE ABOUT CHEMICAL COMPOSITION OF PRODUCTS USED

The knowledge of the salon workers which were mostly hairdressers about the chemical composition of the cosmetic products used for the various services was obtained with the help of the questionnaire administered. Out of the sixty salons sampled, it was revealed that only one hairdresser had knowledge about some of the ingredients of some cosmetic products used with the remaining majority having no knowledge at all about the chemical composition of the products used. The lack of knowledge about the products used can be attributed to low level of education among the hairdressers. This data is presented in table 4.18 and Figure 4.18.

Table 4.18: Knowledge about chemical composition of products used

Knowledge about Chemical Composition of Cosmetics Used	Frequency
Yes	1
No	59

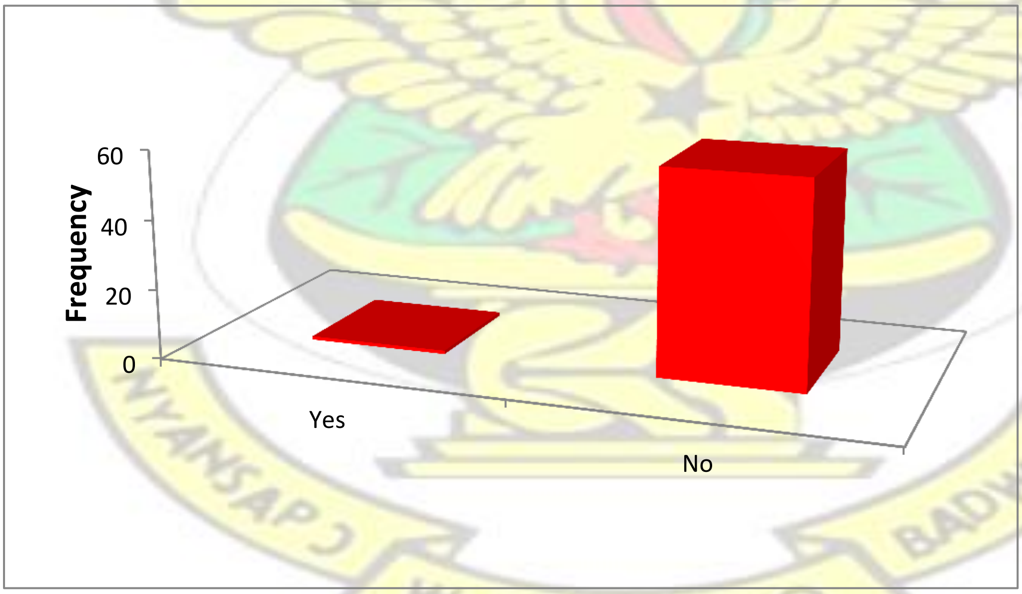


Figure 4.18: Knowledge about chemical composition of the products used

The figure 4.18 shows that 98% of the hairdressers in the salons sampled do not have knowledge about the chemical composition of the products used with only one representing 2% having knowledge about the chemical composition of the products used.

4.19 HEALTH EFFECTS EXPERIENCED BY WORKERS

The various health effects experienced by the salon workers during their line of work were ascertained with the help of the questionnaire administered. This is presented in table 4.19.

Table 4.19 Health Effects Experienced by Workers

HEALTH EFFECT	FREQUENCY
Respiratory Irritation	37
Eye Irritation	27
Nose Irritation	20
Skin Irritation	16
Nausea	-
Vomiting	-
Asthma	-
Headache	4

It was revealed that the most experienced health effects in order of magnitude are Respiratory, Eye, Nose and Skin irritations with Headache being the least. Nausea, Vomiting and Asthma were reportedly not experienced by any of the workers as shown in the table. Most of the health effects experienced in the salons are associated with the inhalation route of exposure to formaldehyde. The skin irritations experienced could be as a result of skin contact with shampoos, lotions, sprays and creams as well used in the salons. The experienced health effects are also depicted in Figure 4.19.

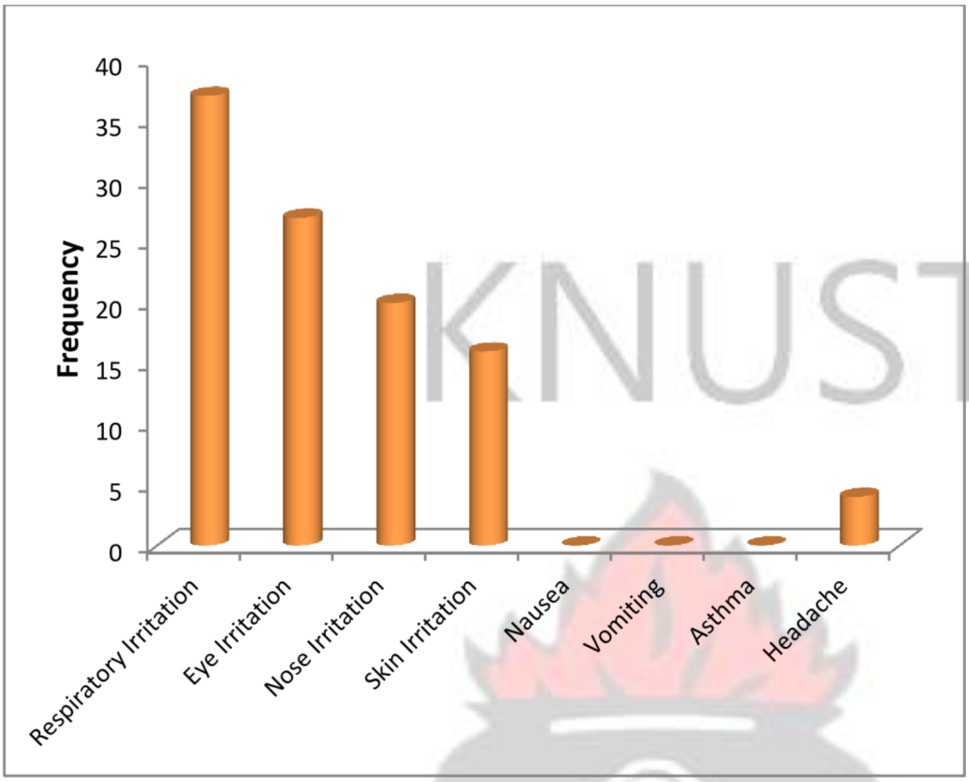


Figure 4.19: Health Effects and Frequency of occurrence among Workers

4.20 DESCRIPTIVE STATISTICS OF RESULTS

The descriptive statistics of the levels of formaldehyde determined from the salons together with other variables such as temperature was carried out and the results are presented the table 4.21.

Table 4.20: Descriptive Statistics of Results

	TEMPERATURE_OC	CL_UG_M3	ACADEMIC_QU...	WORK_EXP...	AGE_OF_FA...	NO_OF_SE...	AVERAGE_...
Mean	32.51500	130.5333	1.333333	1.616667	0.216667	2.166667	2.633333
Median	32.15000	108.0000	1.000000	2.000000	0.000000	2.000000	3.000000
Maximum	36.40000	434.0000	6.000000	4.000000	1.000000	5.000000	5.000000
Minimum	29.70000	21.00000	1.000000	1.000000	0.000000	1.000000	1.000000
Std. Dev.	1.804028	81.10580	0.876562	0.691147	0.415450	0.941810	0.758381
Skewness	0.218222	1.426076	3.259601	0.972807	1.375493	0.891152	0.716502
Kurtosis	1.975762	5.672701	15.23356	3.902931	2.891980	3.509473	3.353611
Jarque-Bera	3.098863	38.19526	480.4002	11.50175	18.94897	8.590418	5.446359
Probability	0.212369	0.000000	0.000000	0.003180	0.000077	0.013634	0.065666
Sum	1950.900	7832.000	80.00000	97.00000	13.00000	130.0000	158.0000
Sum Sq. Dev.	192.0165	388110.9	45.33333	28.18333	10.18333	52.33333	33.93333
Observations	60	60	60	60	60	60	60

From table 4.20, it is observed that the formaldehyde levels determined in µg/m^3 from the sixty salons ranged from 21.00 to 434.00 with a median of 108.00 and an average value (mean) of 130.53 with a corresponding average temperature of 32.5.

Similarly, the standard deviation which is an expression that reflects the degree to which the different (Observed) values of the variable vary from the average, the standard deviation value of 81.10 determined for the formaldehyde concentration levels measured implies that the data set are spread apart. Table 4.22 below shows the current occupational exposure limits that have been set for formaldehyde by various agencies with their corresponding averaging time over which exposure is allowed.

Table 4.21: Current Occupational Exposure Limits (OELs) for Formaldehyde

AGENCY	**OEL**	**AVERAGING TIME**	**CONCENTRATION (ppm)**
OSHA	PEL AL STEL	8 hr 8 hr 15 min	0.75 0.5 2
NIOSH	REL REL-C	8 hr 15 min	0.016 0.1
ACGIH	TLV-C	Ceiling	0.3

Table 4.22: Percentiles

		Formaldehyde Concentration [CL(ug/m3)]	Temperature (OC)	Academic Qualification	Years of Working Experience	Age of Facility (Beauty Salon)	Number of Service(s)	Average Number of Customers in a Week
N	Valid	60	60	60	60	60	60	60
	Missing	0	0	0	0	0	0	0
Percentiles	25	82.00	31.000	1.00	1.00	.00	2.00	2.00
	50	108.00	32.150	1.00	2.00	.00	2.00	3.00
	75	168.25	34.100	1.00	2.00	.00	2.75	3.00

It can be observed from table 4.22 that 25 (1/4) and 75(3/4) percentile of Formaldehyde concentration is 82.00 µg/m^3 and 188.25 µg/m^3 respectively with the median (1/2) being

3. This means 25% of the formaldehyde concentration levels determined from 108.00 µg/m the study can be observed below this percentile while 75% falls below this percentile.

4.21 CORRELATION BETWEEN VARIABLES

The correlation between formaldehyde levels and variables of the study was carried out with SPSS version 17 and the results are presented in Table 4.23.

Table 4.23: Correlation between Variables

		Formaldehyde Concentration [CL(ug/m3)]	Temperature (OC)	Academic Qualification	Years of Working Experience	Age of Facility (Beauty Salon)	Number of Service(s)	Average Number of Customers in a Week
Formaldehyde Concentration [CL (ug/m3)]	Pearson Correlation	1	.307**	.087	.314**	.418**	.315**	.545**
	Sig. (1-tailed)		.009	.255	.007	.000	.007	.000
	N	60	60	60	60	60	60	60
Temperature (OC)	Pearson Correlation	.307**	1	.156	.229*	.082	.180	.231*
	Sig. (1-tailed)	.009		.116	.039	.268	.084	.038
	N	60	60	60	60	60	60	60
Academic Qualification	Pearson Correlation	.087	.156	1	.075	-.062	.383**	.289*
	Sig. (1-tailed)	.255	.116		.286	.319	.001	.013
	N	60	60	60	60	60	60	60
Years of Working Experience	Pearson Correlation	.314**	.229*	.075	1	.353**	-.004	.439**
	Sig. (1-tailed)	.007	.039	.286		.003	.487	.000
	N	60	60	60	60	60	60	60
Age of Facility (Beauty Salon)	Pearson Correlation	.418**	.082	-.062	.353**	1	.036	.203
	Sig. (1-tailed)	.000	.268	.319	.003		.392	.060
	N	60	60	60	60	60	60	60
Number of Service(s)	Pearson Correlation	.315**	.180	.383**	-.004	.036	1	.206
	Sig. (1-tailed)	.007	.084	.001	.487	.392		.057
	N	60	60	60	60	60	60	60
Average Number of Customers in a Week	Pearson Correlation	.545**	.231*	.289*	.439**	.203	.206	1
	Sig. (1-tailed)	.000	.038	.013	.000	.060	.057	
	N	60	60	60	60	60	60	60

**. Correlation is significant at the 0.01 level (1-tailed).

*. Correlation is significant at the 0.05 level (1-tailed).

It can be observed from table 4.23 that there is a positive correlation between level of Formaldehyde (CH_2O) concentration and all the independent variables. Since all the Pearson Correlation coefficients are positive, it implies that as the dependent variable increases in value, Formaldehyde concentration also increases in value. Similarly, as the dependent variables decreases in value, the level Formaldehyde concentration also decreases in value. For instance the Average number of customers in a week showed a significant positive correlation of 0.000 ($p< 0.05$) with the level of Formaldehyde concentration.

Moreover, the Pearson correlation coefficient for CH_2O and Average number of customers in a week is 0.545 which is close to 1; therefore, there is a strong level of significance for the positive correlation between Formaldehyde concentration and Average number of customers in a week.

Academic qualification showed a positive correlation of 0.255 with the level of Formaldehyde concentration which is not significant ($p< 0.05$). The Pearson correlation coefficient for CH_2O and Academic Qualification is 0.087 which is close to 0; therefore, there is a weak level of significance for the positive correlation between level of Formaldehyde concentration and Academic Qualification.

The positive statistically significant correlation between CH_2O levels and the average number of customers in a week could be due to the fact that, the more customers you have in a particular salon the more cosmetic products that are going to be used which could in turn result in an increase level of formaldehyde released. Moreover, more customers in a particular salon could also mean that different brands of cosmetic products are being used since each customer has his/her preferred suitable brand of cosmetic product and each might have a different level of formaldehyde as preservative. Therefore, the usage of different brands of cosmetics could also result in an increase in the level of formaldehyde released.

4.22: DATA ANALYSIS AND MODELING

4.22.1 STATISTICAL IDENTIFICATION OF THE MODEL.

In this section, a non-parametric model called Multiple Linear Regression Model which is widely used in research in order to determine what independent variables have an influence on dependent variables.

The formula of the Multiple Linear Regression Model is given as:

$$y = \beta_0 + \beta_1 x_1 + \beta_2 x_2 + \dots + \beta_k x_k + \varepsilon$$

In this study the Multiple Linear regression Model selects among the covariates, those that have a higher influence on level of Formaldehyde Concentration in Beauty salons.

Using the model:

Analysis of the covariates, X, to determine their significance in determining the level of formaldehyde concentration (CH_2O) which is our dependent variable.

$$CH_2O = \beta_0 + \beta_1 X_1 + \beta_2 X_2 + \beta_3 X_3 + \beta_4 X_4 + \beta_5 X_5 + \beta_6 X_6 + \varepsilon$$

X_1 *is* Temperature (C)^o

X_2 *is* Academic Qualification

X_3 *is* Years of work Experience

X_4 *is* Age of Facility

X_5 *is* No. of Service

X_6 *is* Average No. of Customers in a week.

ε *is* error term

β is regression coefficient β_o is the

predicted value of CH_2O

4.22.2 PARAMETER ESTIMATION AND MODEL SELECTION

These was done using computer software package SPSS Version 17.

Table 4.24: Variables Entered/Removed

Model	Variables Entered	Variables Removed	Method
1	Average Number of Customers in a Week, Age of Facility (Beauty Salon), Number of Service(s), Temperature (OC), Academic Qualification, Years of Working Experience[a]	.	Enter
2	.	Years of Working Experience	Backward (criterion: Probability of F-to-remove >= .100).
3	.	Academic Qualification	Backward (criterion: Probability of F-to-remove >= .100).
4	.	Temperature (OC)	Backward (criterion: Probability of F-to-remove >= .100).

a. All requested variables entered.

b. Dependent Variable: Formaldehyde Concentration [CL(ug/m3)]

The first table in the results output tells about the variables in the analysis. It turns out that only Average number of customers in a week, Age of Facility (Beauty salon) and Number of service (s) are useful to predict the Level of Formaldehyde concentration in beauty salons.

Backward criteria method was used in the selection process. Variable whose probability value was greater than an alpha value of 10% (0.10) was excluded and those whose probability values are less than an alpha value of 5% (0.05) were included in the multiple linear regression model.

Table 4.25: Model Summary

Model	R	R Square	Adjusted R Square	Std. Error of the Estimate
1	.690[a]	.476	.417	61.916
2	.690[b]	.476	.428	61.348
3	.679[c]	.461	.422	61.650
4	.663[d]	.440	.410	62.306

a. Predictors: (Constant), Average Number of Customers in a Week, Age of Facility (Beauty Salon), Number of Service(s), Temperature (OC), Academic Qualification, Years of Working Experience

b. Predictors: (Constant), Average Number of Customers in a Week, Age of Facility (Beauty Salon), Number of Service(s), Temperature (OC), Academic Qualification

c. Predictors: (Constant), Average Number of Customers in a Week, Age of Facility (Beauty Salon), Number of Service(s), Temperature (OC)

d. Predictors: (Constant), Average Number of Customers in a Week, Age of Facility (Beauty Salon), Number of Service(s)

e. Dependent Variable: Formaldehyde Concentration [CL(ug/m3)]

Table 4.25 shows the multiple linear regression model summary and overall fit statistics. It was found out that the adjusted R of the model 1 is .690 with the $R^2 = .417$. This means that the linear regression explains 41.7% of the variance in the data.

Table 4.26: Anova

Model		Sum of Squares	df	Mean Square	F	Sig.
1	Regression	184931.762	6	30821.960	8.040	.000[a]
	Residual	203179.171	53	3833.569		
	Total	388110.933	59			
2	Regression	184880.906	5	36976.181	9.825	.000[b]
	Residual	203230.027	54	3763.519		
	Total	388110.933	59			
3	Regression	179069.936	4	44767.484	11.779	.000[c]
	Residual	209040.998	55	3800.745		
	Total	388110.933	59			
4	Regression	170715.448	3	56905.149	14.658	.000[d]
	Residual	217395.486	56	3882.062		
	Total	388110.933	59			

a. Predictors: (Constant), Average Number of Customers in a Week, Age of Facility (Beauty Salon), Number of Service(s), Temperature (OC), Academic Qualification, Years of Working Experience

b. Predictors: (Constant), Average Number of Customers in a Week, Age of Facility (Beauty Salon), Number of Service(s), Temperature (OC), Academic Qualification

c. Predictors: (Constant), Average Number of Customers in a Week, Age of Facility (Beauty Salon), Number of Service(s), Temperature (OC)

d. Predictors: (Constant), Average Number of Customers in a Week, Age of Facility (Beauty Salon), Number of Service(s)

e. Dependent Variable: Formaldehyde Concentration [CL(ug/m3)]

Table 4.26 is the F-test. The linear regression's F-test has the null hypothesis that the model explains zero variance in the dependent variable (in other words $R^2 = 0$). The F-test is highly significant, thus we can assume that the model explains a significant amount of the variance in Level of Formaldehyde Concentration with the independent variables.

Table 4.27: Coefficients

Model		Unstandardized Coefficients		Standardized Coefficients	t	Sig.
		B	Std. Error	Beta		
1	(Constant)	-268.119	146.782		-1.827	.073
	Temperature (OC)	7.267	4.708	.162	1.543	.129
	Academic Qualification	-12.732	10.348	-.138	-1.230	.224
	Years of Working Experience	-1.597	13.870	-.014	-.115	.909
	Age of Facility (Beauty Salon)	59.091	20.969	.303	2.818	.007
	Number of Service(s)	20.397	9.465	.237	2.155	.036
	Average Number of Customers in a Week	47.445	12.556	.444	3.779	.000
2	(Constant)	-266.598	144.844		-1.841	.071
	Temperature (OC)	7.180	4.606	.160	1.559	.125
	Academic Qualification	-12.741	10.253	-.138	-1.243	.219
	Age of Facility (Beauty Salon)	58.372	19.833	.299	2.943	.005
	Number of Service(s)	20.537	9.301	.238	2.208	.032
	Average Number of Customers in a Week	46.901	11.526	.439	4.069	.000
3	(Constant)	-256.037	145.308		-1.762	.084
	Temperature (OC)	6.851	4.621	.152	1.483	.144
	Age of Facility (Beauty Salon)	61.753	19.743	.316	3.128	.003
	Number of Service(s)	16.624	8.794	.193	1.890	.064
	Average Number of Customers in a Week	43.451	11.242	.406	3.865	.000
4	(Constant)	-45.825	32.140		-1.426	.159
	Age of Facility (Beauty Salon)	62.855	19.939	.322	3.152	.003
	Number of Service(s)	18.443	8.801	.214	2.096	.041
	Average Number of Customers in a Week	46.625	11.154	.436	4.180	.000

a. Dependent Variable: Formaldehyde Concentration [CL(ug/m3)]

Table 4.27 shows the multiple linear regression estimates including the intercept and the significance levels.

In the multiple linear regression analysis, a non-significant intercept was observed but highly significant age of Facility coefficient, which we can interpret as: for every 1-unit increase in age of a beauty Salon, we will observe 62.855 additional level of Formaldehyde Concentration.

Comparison of all variables in the multiple linear regression shows that only Age of Facility, Number of Service(s) and Average number of Customers in a week are significant predictors.

It was also observed that Average number of customers in a week has a higher impact than Age of Facility and Number of Service(s) by comparing the coefficients (beta = 0.436 versus beta = 0.322 and 0.214).

Table 4.28 shows the number of variables that were removed from the model based on their significant level. It was observed that the significant value for Years of working Experience, Academic qualification and Temperature (^{0}C) are all greater than the alpha value of 5% (0.05) indicating they are not significant.

Table 4.28: Excluded Variables

Model		Beta In	t	Sig.	Partial Correlation	Collinearity Statistics
						Tolerance
2	Years of Working Experience	-.014[a]	-.115	.909	-.016	.707
3	Years of Working Experience	-.015[b]	-.124	.902	-.017	.707
	Academic Qualification	-.138[b]	-1.243	.219	-.167	.790
4	Years of Working Experience	.013[c]	.112	.912	.015	.726
	Academic Qualification	-.128[c]	-1.140	.259	-.152	.792
	Temperature (OC)	.152[c]	1.483	.144	.196	.927

a. Predictors in the Model: (Constant), Average Number of Customers in a Week, Age of Facility (Beauty Salon), Number of Service(s), Temperature (OC), Academic Qualification

b. Predictors in the Model: (Constant), Average Number of Customers in a Week, Age of Facility (Beauty Salon), Number of Service(s), Temperature (OC)

c. Predictors in the Model: (Constant), Average Number of Customers in a Week, Age of Facility (Beauty Salon), Number of Service(s)

d. Dependent Variable: Formaldehyde Concentration [CL(ug/m3)]

Also comparison of the significant values of all the three independent variables shows that Years of working Experience has the highest significant value of 0.912 as compared to 0.259 and 0.144. It was therefore removed first followed by Academic qualification and Temperature (^{0}C). The information in the table 4.28 also allows us to check for multicollinearity in our multiple linear regression model. Tolerance should be > 0.1 for all variables.

4.23 NON-CARCINOGENIC HUMAN HEATH RISK STUDY

The formaldehyde concentrations were used to assess human health risk through inhalation. The characterization of non-carcinogenic health risks for humans consisted of calculations of Hazard Quotient (HQ), which is defined as the relation between the predicted exposure concentration and the inhalation reference dose (RfDinh). The RfDinh value of 9.83 $\mu g/m^3$ used to calculate HQ was taken from the US EPA (Rovira et al., 2016). Table 4.30 shows the HQ values calculated for the formaldehyde concentrations determined for each salon in the study.

Table 4.29: Hazard Quotient

Name of Salon	HCHO Conc.($\mu g/m^3$)	Hazard Quotient(HQ)
Sandy Hair Care	434	4.2
Salina Hair Care	257	2.5
Blessing Beauty Salon	152	1.5
Nyarko Beauty Salon	48	0.5
Grace Beauty Salon	100	1.0
Kate Beauty salon	33	0.3
Gisela Beauty Salon	152	1.5
Vernadu Beauty Salon	195	1.9
Portapp Beauty Salon	105	1.0
Amet Beauty Salon	200	1.9
Annette Beauty Salon	107	1.0
Classic Hair Beauty Salon	179	1.7
Psalm 91 Beauty Salon	101	1.0
Thy Grace Beauty Salon	197	1.9
Greatfulness Beauty Salon	24	0.2
Joyce Beauty Salon	349	3.4
Ey3 Adom Beauty Salon	134	1.3
Vision Parlour Beauty Salon	116	1.1
Queen's Salon	133	1.3
Fausty's Salon	106	1.0
Vera's Beauty Salon	133	1.3
Unique Lady's Beauty Salon	102	1.0
Liberty Beauty Salon	117	1.1
Maa Tess Beauty Salon	166	1.6
Doris Beauty Salon	74	0.7
God's Time is the Best Salon	98	0.9
Obaa Yaa Palace	166	1.6
Stella Salon	56	0.5
Sie Sie me Beauty Salon	21	0.2

Adonai Salon	117	1.1
Eyelashes Beauty Salon	97	0.9
Victoria's Salon	81	0.8
Classic Lady;s Beauty Salon	92	0.9
All Shall Pass Beauty Salon	327	3.2
Lasty Vee Beauty Salon	86	0.8
Exodus 14;14 Beauty Salon	119	1.2
Mercy's Beauty salon	85	0.8
Mary's Beauty Salon	90	0.9
Unique Beauty Salon	268	2.6
Aisha Hair Do	175	1.7
Maria Beauty Salon	21	0.2
Mavis Beauty Salon	47	0.5
Nhyira Beauty Salon	193	1.9
Aseda nka Boafo Salon	72	0.7
Gina Hair and Nail Salon	265	2.6
Papaye Beauty Salon	24	0.2
Ange's Beauty Salon	97	0.9
Thy faithfulness Beauty Salon	169	1.6
Euniel's Salon	104	1.0
Care Care Beauty Salon	97	0.9
Lizzy's Beauty Salon	132	1.3
The Beauty Studio	157	1.5
Eny3 Mahoden Salon	109	1.1
Blessing Beauty Salon	152	1.5
Jane Beauty Salon	35	0.3
Aseda Beauty Salon	78	0.8
Gina's Salon	67	0.7
Matilda's Beauty Salon	187	1.8
Adom Beauty Salon	58	0.6
Lady Nash Beauty Salon	176	1.7

The HQ values calculated ranged from 0.2 to 4.2 with a mean value of 1.3. About 50% of the calculated HQ values were above the safety limit (HQ=1). This means that the formaldehyde levels determined in half of the salons sampled in this study may pose health risk to workers.

CHAPTER FIVE

CONCLUSIONS AND RECOMMENDATIONS

5.1 CONCLUSIONS

This study reports the formaldehyde levels determined in sixty salons across the ten submetro areas in Kumasi. The formaldehyde concentration determined ranged from 21 to 434 μg/m^3.

Out of the sixty salons sampled, 36 salons representing 60% had formaldehyde levels above the WHO permissible limit of 100μg/m^3 for eight hours working period and also exceeded the 55μg/m^3 and 9μg/m^3 chronic and acute reference exposure limit set by Office of Environmental Health Hazard Assessment (OEHHA) for prevention of health risk to humans and 24 salons representing 40% had formaldehyde levels below the WHO permissible limit of 100μg/m^3 for eight hours working period.

The number of customers that visits the salon in a week, number of salon services offered and age of salon had positive significant correlation with the formaldehyde levels determined. They were shown to have direct influence on the level of formaldehyde determined in each salon.

The health risk study conducted using HQ revealed that the formaldehyde levels pose health risk to workers in about 50% of the salons sampled. The HQ values calculated ranged from 0.2 to 4.2.

Results from analysis of the questionnaires revealed that the effects of exposure to formaldehyde were experienced by almost all workers. All the workers in the salons complained of respiratory, eye and skin irritations during the study.

The results of the study also revealed that hairdressers in salons that provide the entire salon services captured in the study are at higher risk of being exposed to the effects of formaldehyde.

5.2 RECOMMENDATIONS

The recommendations based on the results of this study are as follows:

- Appropriate governmental agency should take necessary measures to check and regulate the formaldehyde content in cosmetic products that are imported and manufactured in the country.
- Salon workers should be sensitized about formaldehyde and its health effects in cosmetics so as to inform them about choice of products for the various offered services.
- Improving ventilation of the salons, closing the packages of the beauty products when not in use and selecting safer beauty products without strong odor could be key steps towards reducing the levels of formaldehyde released from the cosmetics used in the salon.
- A further study investigating the formaldehyde levels released during usage of common cosmetic products on the Ghanain market used in salons should be conducted to ascertain the actual formaldehyde levels released from each product during their usage.
- Routine studies monitoring the levels of formaldehyde in salons should be established.
- Formaldehyde levels should be determined in the blood of the salon workers.

REFERENCES

Australian Competition and Consumer Commission, (2010). ACCC research survey of formaldehyde in cosmetics, final report.

Bolt, H. M., Johanson, G., Nielsen, G. D., Papameletiou, D. and Klein, C. L., (2015) SCOEL/REC/125 Formaldehyde. *Recommendations from the Scientific Commission on Occupational exposure Limits.* pp.1-76

Checkoway, H., Boffetta, P., Mundt, D. J. and Mundt, K. A., (2012). Critical review and synthesis of the epidemiologic evidence on formaldehyde exposure and risk of leukemia and other lymphohematopoietic malignancies. *Cancer Causes & Control*, *23*(11), 747-1766.

Chénier, R., (2003). An ecological risk assessment of formaldehyde. *Human and Ecological Risk Assessment*, *9*(2), 483-509.

Chung, P. R., Tzeng, C. T., Ke, M. T. and Lee, C. Y., (2013). Formaldehyde gas sensors: a review. *Sensors*, *13*(4), 4468-4484.

De Groot, A. C., White, I. R., Flyvholm, M. A., Lensen, G. and Coenraads, P. J., (2010). Formaldehyde‐releasers in cosmetics: relationship to formaldehyde contact allergy. *Contact dermatitis*, *62*(1), 2-17.

Eckert, M., Fleischmann, G., Jira, R., Bolt, H. M. and Golka, K., (2006). Acetaldehyde. Ullmann's Encyclopedia of Industrial Chemistry.

Formaldehyde, I.P.C.S. and World Health Organization, (2002). International Program on Chemical Safety (Concise International Chemical Assessment Document No. 40). *WHO, Geneva, Switzerland*, 1-75.

Gaffney, J. S., Marley, N. A., Martin, R. S., Dixon, R. W., Reyes, L. G. and Popp, C. J., (1997). Potential air quality effects of using ethanol− gasoline fuel blends: A field study in Albuquerque, New Mexico. *Environmental science & technology*, *31*(11), 3053-3061.

Gerberich, H. R. and Seaman, G .C., (1994). Formaldehyde. *Kirk-Othmer encyclopedia of chemical technology*.

Ghana Statistical Service (GSS), (2014). Projected population census of Ghana. Available at http://www.statsghana.gov.gh/pop stats html (Accessed 18 July 2016)

Ghana Statistical Service (GSS), (2016). Projected population census of Ashanti region. http://www.statsghana.gov.gh/pop stats html (Accessed 18 July 2016)

Gold, K. W., Naugle, D. F. and Berry, M. A., (1993). Indoor concentrations of environmental carcinogens. *IARC scientific publications*, (109), p.41.

Grosjean, E. and Grosjean, D., (1996). Carbonyl products of the gas-phase reaction of ozone with 1-alkenes. *Atmospheric Environment*, *30*(24), 4107-4113.

Health Canada, (2006). Residential indoor air quality guideline: formaldehyde, Ottawa (ON).

IARC Working Group on the Evaluation of Carcinogenic Risks to Humans and International Agency for Research on Cancer, (1995). *Wood dust and formaldehyde* (Vol. 62). World Health Organization.

International Agency for Research on Cancer, (2004). IARC classifies formaldehyde as carcinogenic to humans. *Press release*, (153), p.15.

International Agency for Research on Cancer, (2012). IARC monographs on the evaluation of carcinogenic risks to humans: A Review of Human Carcinogens: Chemical Agents and Related Occupations, Vol. 100F. *Lyon: International Agency for Research on Cancer*.

Kelly, T. J., Mukund, R., Gordon, S. M. and Hays, M. J., (1994). *Ambient measurement methods and properties of the 189 Clean Air Act hazardous air pollutants. Final report* (No. PB-95-123923/XAB). Battelle, Columbus, OH (United States).

Kieber, R. J., Zhou, X. and Mopper, K., (1990). Formation of carbonyl compounds from UV - induced photodegradation of humic substances in natural waters: Fate of riverine carbon in the sea. *Limnology and Oceanography*, *35*(7), 1503-1515.

Kim, K. H., Jahan, S. A. and Lee, J. T., (2011). Exposure to formaldehyde and its potential human health hazards. *Journal of Environmental Science and Health, Part C*, *29*(4), 277-299.

Kuffour, G. A., Anto, B. A., Afari, C., Kyei, S. and Gyanfosu, L., (2012). Occular discomforts following eyelash extension. *Journal of Medical and Biomedical Sciences*, *1*(3), 55-61.

Labrèche, F., Forest, J., Trottier, M., Lalonde, M. and Simard, R., (2003). Characterization of chemical exposures in hairdressing salons. *Applied occupational and environmental hygiene*, *18*(12), 1014-1021.

Lv, C., Hou, J., Xie, W. and Cheng, H., (2015). Investigation on formaldehyde release from preservatives in cosmetics. *International journal of cosmetic science*, *37*(5), 474-478.

McGregor, D., Bolt, H., Cogliano, V. and Richter-Reichhelm, H. B., (2006). Formaldehyde and glutaraldehyde and nasal cytotoxicity: case study within the context of the 2006 IPCS Human Framework for the Analysis of a cancer mode of action for humans. *Critical reviews in toxicology*, *36*(10), 821-835.

National Industrial Notifications and Assessment Scheme (NICNAS). (2006). Formaldehyde. Priority Existing Chemical Assessment Report No. 28. Pp.41,42,54.

Pierce, J. S., Abelmann, A., Spicer, L. J., Adams, R. E., Glynn, M. E., Neier, K., Finley, B. L. and Gaffney, S. H., (2011). Characterization of formaldehyde exposure resulting from the use of four professional hair straightening products. *Journal of occupational and environmental hygiene*, *8*(11), 686-699.

Reinhardt, T. E., (1991). Monitoring firefighter exposure to air toxins at prescribed burns of forest and range biomass.

Reuss, G., Disteldorf, W., Gamer, A. O. and Hilt, A., (2013). Formaldehyde. Ullmann's Encyclopedia of Industrial Chemistry.

Rovira, J., Roig, N., Nadal, M., Schuhmacher, M. and Domingo, J.L., (2016). Human health risks of formaldehyde indoor levels: an issue of concern. *Journal of Environmental Science and Health, Part A*, *51*(4), 357-363.

Salthammer, T., Mentese, S. and Marutzky, R., (2010). Formaldehyde in the indoor environment. *Chemical reviews*, *110*(4), 2536-2572.

Serves, C., (1994). Gas phase formaldehyde and peroxide measurements in the Arctic atmosphere. *Journal of Geophysical Research: Atmospheres*, *99*(D12), 25391-25398.

Spicer, C. W., Buxton, B. E., Holdren, M. W., Smith, D. L., Kelly, T. J., Rust, S. W., Pate, A. D., Sverdrup, G. M. and Chuang, J. C., (1996). Variability of hazardous air pollutants in an urban area. *Atmospheric Environment*, *30*(20), 3443-3456.

Tang, X., Bai, Y., Duong, A., Smith, M. T., Li, L. and Zhang, L., (2009). Formaldehyde in China: Production, consumption, exposure levels, and health effects. *Environment international*, *35*(8), 1210-1224.

Tashkov, W., (1996). Determination of formaldehyde in foods, biological media and technological materials by headspace gas chromatography. *Chromatographia*, *43*(11), 625-627.

Tibbens, L., (2015). *Formaldehyde exposure and the indoor environment* (Doctoral dissertation, University of Pittsburgh).

Tsigonia, A., Lagoudi, A., Chandrinou, S., Linos, A., Evlogias, N. and Alexopoulos, E. C., (2010). Indoor air in beauty salons and occupational health exposure of cosmetologists to chemical substances. *International journal of environmental research and public health*, *7*(1), 314-324.

U.S. Department of Health and Human Services, (2008). *Public Health Statement for formaldehyde.*

US Department of Health and Human Services, (1999). *Toxicological profile for formaldehyde*.

US Department of Health and Human Services, (2014). *Toxicological profile for formaldehyde*.

Vairavamurthy, A., Roberts, J. M. and Newman, L., (1992). Methods for determination of low molecular weight carbonyl compounds in the atmosphere: a review. *Atmospheric Environment. Part A. General Topics*, *26*(11), 1965-1993.

World Health Organization (WHO), (2002). Formaldehyde, concise international chemical assessment, Document 40. *World Health Organization, Geneva*.

World Health Organization (WHO), (2010). Formaldehyde, concise international chemical assessment, Document 40. *World Health Organization, Geneva*.

APPENDICES

APPENDIX I: QUESTIONNAIRE

Throughout this questionnaire your responses will be used for academic purposes only

1. Name of facility………………………………………….
2. Gender Male ☐ Female ☐
3. Age……………………………………..
4. Academic qualification

J.H.S ☐ S.H.S ☐ NVTI ☐ DIPLOMA ☐ MASTERS ☐ NONE ☐

5. Location of workplace……………………………………..
6. Years of work experience……………………………….
7. Age of facility…………………………………………..
8. What type of services do you offer?

Hair ☐ Nails ☐ Skin ☐ Eyelash/Eyebrow ☐ Makeups ☐ Other ☐

9. Have you experienced any of these health effects during these years of work? Tick where appropriate

☐ Respiratory Eye ☐ irritations Skin irritations ☐ Nausea ☐

Nose ☐ irritations Vomiting ☐ — Diarrhoea ☐ Headache ☐ ☐
Asthma

10. What are the names of some of the beauty products you use? …………………………..

11. Do you have any knowledge about the chemical composition of the products you use?

Yes ☐ No ☐

12. If yes, indicate the type of chemicals you know

………………………………………………………………………………………

13. On the average, how many customers come to your salon in a week? ………………

Temperature…………… Relative Humidity…………………..

APPENDIX II: CALCULATIONS FOR PREPARATION OF FORMALDEHYDE STANDARD SOLUTIONS

- % Purity of formaldehyde = 37%
- Molecular weight of formaldehyde = 30.03g/mol
- Density (ρ) = 1.09g/mol

$$Concentration\ of\ stock\ formaldehyde\ solution = \frac{\%\ Purity \times Density \times 1000}{100 \times 30.03}$$

$$= \frac{37 \times 1.09 \times 1000}{100 \times 30.03} = 13.4 mol/dm^3$$

$$Therefore\ in\ milligram\ per\ litre = 13.4 \times 30.03 \times 1000 = 402402 mg/L$$

Hence a series of dilutions was made from the stock solution to prepare the desired formaldehyde concentration using: $C_1V_1=C_2V_2$

For 4000mg/L;

C_1= 402402mg/L, C_2= 4000mg/L, V_2= 250mL

Hence, $V^1 = \frac{C2V2}{C1} = 2.5mL$

Therefore to prepare a formaldehyde concentration solution of 4000mg/L in 250mL volumetric flask, 2.5mL of the stock formaldehyde solution is pipetted and transferred into the flask and topped to the 250mL mark with distilled water. Subsequent desired known concentrations of formaldehyde standard solutions were prepared using the same approach.

APPENDIX III: CALCULATION OF FORMALDEHYDE CONCENTRATION IN VOLUME OF AIR SAMPLED AT SALON

Conversion of volume of air sampled to the volume of air at standard conditions as follows:

$$Vs = \frac{P \times V \times 298}{101(T+273)}$$ ………………………………………..equation (1)

Where:

Vs = volume of air at standard conditions (101 kPa and 298 K), L,

V = volume of air sampled, L, *P* =

barometric pressure, kPa, and

T = temperature of sample air, °C.

Calculation of total micrograms of formaldehyde collected in each impinger sample as follows:

$$Ct = Ca \times Fa$$ ……………………………………………………equation (2)

Where:

Ct = total formaldehyde in the sample, µg,

Ca = total quantity of formaldehyde in the sample aliquots taken from the impinger as determined from the calibration curve as follows

$$Ca = \frac{Absorbance - 0.009}{0.2014}$$ µg ………………....equation (2) and

$$Fa\ is\ aliquot\ factor = \frac{Sampling\ Solution\ Volume, mL}{aliquot\ used, mL}$$

……………………….equation (4)

Calculation of the formaldehyde concentration in the volume of air sampled at the salon as follows:

$$C_L = \frac{Ct \times 24.47}{Vs \times 30.03}$$ ……………………………….equation (5)

Where:

C_L = parts of formaldehyde per million parts air, ppm,

30.03 = molecular weight of formaldehyde, and

24.47 = µL of formaldehyde gas in 1 µmol at 101 kPa and 298 K.

C_L is converted to mg/m^3 by way multiplying by 1.23 and mg/m^3 is converted to µg/m^3 by dividing by 1000

APPENDIX IV: CALCULATION OF HAZARD QUOTIENT

The Hazard Quotient was calculated as follows:

$$\textit{Exposure concentration (EC)} = \frac{Ca \times IR \times ET \times EF \times ED}{BW \times AT}$$

Where;

Ca= Chemical concentration in air (mg/m^3) at sampling site

IR= Inhalation rate (m^3/hr) = 20 m^3/hr

ET= Exposure time (hours/days) = 8 hours

EF= Exposure frequency (days/yrs) = 365days/year

ED= Exposure duration (years) = 70 years

BW= Body weight (kg) = 70 kg

AT= Averaging time (period over which exposure is averaged-days)

$$HQ = \frac{EC}{RfDinh}$$

Where, RfDinh is the reference inhalation dose for formaldehyde.

APPENDIX FIVE: SOME OF THE COMMON COSMETIC PRODUCTS USED IN

THE SALONS

Name of product	Image
1.Universl Basic (UB) hair relaxer	
2. Malizia hair spray	
3. ORS nourishing sheen hair spray	
4. Chapter 2000 hair cream	
5.Dark and Lovely hair cream and relaxer	
6.DAX hair food	

7.Optimal Professional hair relaxer	
8. Shea butter hair conditioner	
9. Revlon Professional lip gross & nail polishes	
10. American Beauty Care (ABC) hair food	
11. Beauty Over-16 (BO-16) hair relaxer and shampoo	
12 .Acrylic nail products