INFLUENCE OF OCCUPATIONAL EXPOSURE TO WHITE BOARD MARKER INK ON SYMPTOMS OF ALLERGIC CONJUNCTIVITIS AMONG SECONDARY SCHOOL TEACHERS IN NAKURU COUNTY, KENYA

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A Thesis Submitted to the Graduate School in Partial Fulfillment of the Requirements for the Award of the Degree of Doctor of Philosophy in Environmental and Occupational Health of Egerton University

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DECLARATION AND RECOMMENDATION

DECLARATION

This thesis is my original work and has not been presented for a degree in any other university or any other award.

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Signature Date

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ND15/51533/14

RECOMMENDATION

This thesis has been submitted for publication with our recommendation and approval as University Supervisors.

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DEDICATION

This work is dedicated to my husband Thomas and my daughters Purity, Neema, Abigail and Melissa. It is also dedicated to my granddaughter Jade. My success is their success.

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ABSTRACT

Allergic conjunctivitis is a common problem affecting about 20% of the world's population. In Kenya, it constitutes one fifth of all the total diagnoses made in eye clinics with school teachers in Nakuru North Sub-County in Nakuru County having a prevalence of 51.2%. Untreated allergic conjunctivitis can cause injury to the conjunctiva and the eye lids while some of the drugs used to treat can cause life threatening diseases. Irritants such as the volatile organic compounds which constitute the ink solvents of whiteboard marker pens increase the likelihood of developing the allergy. This study therefore sought to establish the influence of the VOCs from the whiteboard marker ink on the development of symptoms of allergic conjunctivitis among the teachers in Nakuru County. The research design was Cross Sectional using repeated measures with a sample of 224 secondary school teachers. Only schools which use whiteboards were considered for the study. Questionnaires were used to collect information on the reported symptoms of allergic conjunctivitis among teachers while air samples were collected using transparent polythene bags. Classroom temperature and CO_2 were measured using carbon dioxide sensor AZ-0004. Data was collected in July-Aug (2016), Sep-Oct (2016) and Jan-Feb (2017) months of the year. Air samples were analyzed using gas chromatography. Data was analyzed using both descriptive and inferential statistics. The results showed that the marker pen inks used contained methanol, acetone, hexane and ethanol. The ink VOCs were more likely to be found at the upper parts and front of the classrooms. Teachers were not knowledgeable on ink safety but had a positive attitude towards the use of the marker pens. They also did not show safe practices when using the marker pens in classrooms. The concentration of ink VOCs in the air increased with increase in concentration of CO_2 and temperature. The highest incidences of symptoms of allergic conjunctivitis were in the cold seasons while the lowest incidence was in the hottest and dry months of the year. Increase in symptoms of allergic conjunctivitis increased with increase in concentration (r^2=0.8414) and duration of exposure (r^2=0.5807) to ink VOCs while there was a significant association (χ^2 =6.933; p=0.031) between ink brand and eye irritation. This study concludes that occupational exposure to whiteboard marker pen ink causes symptoms of allergic conjunctivitis and recommends that teachers be trained on occupational safety procedures on handling whiteboard marker pens in classrooms.

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LIST OF ABBREVIATIONS AND ACRONYMS

ACGIH-	American Conference of Governmental Industrial Hygienist
AKC-	Atopic KeratoConjunctivitis
ATSDR-	Agency for Toxic Substances and Disease Registry
CDC-	Centre for Disease Control and Prevention
CDC-	Contact DermatoConjunctivitis
dCO2-	Difference between the indoor and outdoor concentrations of carbon dioxide
EPA -	United states Environmental Protection Agency
EHS-	Environmental Health and Safety
GOK-	Government of Kenya
GPC-	Giant Papillary Conjunctivitis
KAP-	Knowledge, Practice and Attitude
KEBs-	Kenya Bureau of Standards
KNBS-	Kenya National Bureau of Statistics
MoE-	Ministry of Education
MoL-	Ministry of Labour
MSDS-	Material Safety Data Sheet
NACOSTI-	National Commission for Science, Technology and Innovation
NIOSH-	National Institute for Occupational Safety and Health
NPCS-	Niir Project Consultancy Services
OELs-	Occupational Exposure Limit Values
OSHA-	Occupational Safety and Health Administration
PAC-	Perennial Allergic Conjunctivitis
PEL-	Permissible Exposure Limits
ppm-	Parts Per Million
REL-	Recommended Exposure Limits
SAC-	Seasonal Allergic Conjunctivitis
SDGs-	Sustainable Development Goals
STEL-	Short Term Exposure Limit
TLV-	Threshold Limit Value
t_R -	Retention time
TSC-	Teachers Service Commission
TVOCs-	Total Volatile Organic Compounds
TWA-	Time Weighted Average

USAID-	U.S. Agency for International Development
VKC-	Vernal Keratoconjunctivitis
VOCs-	Volatile Organic Compounds

CHAPTER ONE

INTRODUCTION

1.1 Background information

Allergic conjunctivitis is an irritation and inflammation of conjunctiva (Vally and Irhuma, 2017). It results when allergens get into the eyes of a person who has a genetic predisposition to it (Andrews and Hirano, 2012; Tindall *et al.*, 2014). It affects about 20 % of the world's population (Vally and Irhuma, 2017). Different parts in Africa have different prevalence with no distribution pattern (Ait-khaled *et al*., 2007; Foliaki *et al*., 2007). In Kenya, it constitutes one fifth of all the total diagnoses made in eye clinics with school teachers in Nakuru North Sub County in Nakuru County having a prevalence of 51.2%. It affects the active age group with 39.7% of the affected teachers being in the age group of 35-44 years. The symptoms of allergic conjunctivitis as well as the effects of the drugs used to treat it affect the quality of life of the teachers. Allergic conjunctivitis is also associated with depression and anxiety affecting the effectiveness of the affected teacher (Muchemi, 2011). Irritants such as the ink solvents, fuming chemicals and those with strong odours increase the likelihood of developing the allergy (Dick, 2006; Adkinson *et al*., 2014).

Teaching, as an occupation, involves imparting knowledge by the teacher to the learners. To enhance this, methods of visually presenting information to a full room of students all at once are used. Traditionally, school teachers used chalkboards written on using chalk. The chalk produces a lot of dust which accumulates on surfaces and the computer machines making many schools to substitute the chalkboards with whiteboards. The whiteboards or dry-erase boards came into use during the late 1980s (Muttappallymyalil *et al*., 2016). Whiteboards are written on using marker pens with dry erase inks (Heppner, 2007; Jobrack, 2012). Isopropyl alcohol and xylene are common solvents used in marker pen inks. Xylene affects the brain. High levels can cause headaches, lack of muscle coordination, dizziness, irritation of the eyes, nose and the throat. It can cause unconsciousness and even death at very high levels (ATSDR, 2007). It may also damage the liver, kidney and the reproductive system (ATSDR**,** 2015**).** Acute exposure to Isopropyl alcohol can irritate the external skin and also the mucous membranes of the eyes, nose and throat (Kandyala *et al*., 2010). Bradycardia, a slowing of the heartbeat, has been observed after oral ingestion of isopropyl alcohol solutions of 25 ml to 100 ml of water. When absorbed through the skin, isopropyl alcohol can lead to extreme difficulties in breathing and eventual coma or death (Dikshith, 2011). Alcohols are generally anaesthetics and irritants of the eyes and upper respiratory tract. In general they are strong narcotics (Dick, 2006).

Under the Occupational Safety and Health Act of the laws of Kenya, the employer has a duty to ensure as far as is reasonably practical the health of the employees at work. This Act requires that risk assessments be carried out at the places of work (OSHA, 2010). A risk assessment is a process for describing and quantifying the risks associated with a hazardous substance (Rout and Sikdar, 2017). It therefore includes the identification of hazards as well as the severity of their consequences. Although risk assessment should be a continuous process at a work place, it is especially important when a change that introduces a new chemical or work process takes place (Tadesse and Admassu, 2006). In Nakuru County, Kenya, the use of whiteboards in classrooms is a new phenomenon which is currently being implemented in schools thereby introducing the marker pen ink chemicals in those classrooms. It is against this background that this study sought to assess the influence of occupational exposure to the whiteboard marker ink on the development of symptoms of allergic conjunctivitis among the school teachers.

1.2 Statement of the problem

The prevalence of allergic conjunctivitis among the school teachers in Nakuru County is higher than the National average (20%) with Nakuru North Sub County having a prevalence of 51.2%. If allergic conjunctivitis is not treated, it can cause injury to the eyelids and the conjunctiva affecting the quality of life of the teacher. The allergens may also drain into the nose and cause allergic signs and symptoms. Drugs used to alleviate the symptoms of allergic conjunctivitis may cause drowsiness, react with other medications to cause life threatening cardiac arrhythmias while others can be sight threatening or may cause acceleration of allergic conjunctivitis. Whiteboard marker inks used in schools contain volatile organic compounds (VOCs) as solvents which can irritate the eyes and also cause other health problems. Also, most of these VOCs are chronically toxic, with symptoms that may not become fully manifest for years necessitating the need to monitor their actual concentrations at the workplaces. There is no documentation on studies done to establish the actual concentrations of the whiteboard marker ink VOCs in the Kenyan school classrooms and whether these levels contribute to significant eye irritations among the school teachers. This study therefore sought to assess the influence of the occupational exposure to the whiteboard marker ink on the development of symptoms of allergic conjunctivitis among the school teachers in Nakuru County.

1.3 Broad objective

To assess the influence of occupational exposure to the whiteboard marker ink on the development of symptoms of allergic conjunctivitis among the school teachers.

1.3.1 Specific objectives

i. To establish the composition of the VOCs produced by the whiteboard marker ink
ii. To analyze the distribution of the VOCs from the whiteboard marker ink in a school classroom
iii. To assess the knowledge, attitude and practice (KAP) of teachers related to use of white board markers
iv. To assess the influence of classroom factors on the occupational exposure levels of teachers to VOCs from the whiteboard marker ink.
v. To establish the seasonal variations of symptoms of allergic conjunctivitis among the teachers
vi. To assess the influence of exposure to the whiteboard marker ink on the development of symptoms of allergic conjunctivitis among the teachers

1.3.2 Research questions

i. What is the composition of the VOCs released from a whiteboard marker ink?
ii. How are the VOCs from the white board marker ink distributed in a school classroom?
iii. What is the knowledge, attitude and practice (KAP) of teachers on the use of whiteboard markers?
iv. What is the influence of classroom factors on occupational exposure level of the teacher to the VOCs from the whiteboard marker ink?
v. How do the symptoms of allergic conjunctivitis vary with seasons among the school teachers?
vi. What is the influence of exposure to the whiteboard marker ink on the development of symptoms of allergic conjunctivitis among the teachers

1.4 Justification of the Study

The global strategy on occupational safety and health, adopted by the International Labour Conference at its 91st session in 2003 includes knowledge development as a prerequisite for identifying key priorities, developing coherent and relevant strategies and implementing national OSH programmes (ILO, 2004). This study has demonstrated that some of the whiteboard markers in use today contain components that may adversely affect the health of the teachers. Further, the current knowledge level and occupational practices and attitudes among teachers may partially contribute to the existence of symptoms of allergic conjunctivitis. Thus the recommendations emanating from this study can guide the relevant agencies and stakeholders in addressing the occupational exposure to whiteboard marker inks and thus safeguard the safety and health of teachers as stipulated in the ILO (2004. The study findings if utilized accordingly will make a contribution to the realization of sustainable development goal number three of ensuring good health and wellbeing for people (in this case teachers). The study is also in line with sustainable development goal number eight of promotion of productive employment and decent work for workers (Beisheim, 2015).

The data can then aid in the setting of the occupational exposure limits for those whose work involves the use of the whiteboard marker pen ink. The information from this study can also aid in the formulation of health policy statement as required by law (OSHA, 2010), which should indicate how the management intends to ensure safety of the workers at the schools (Armstrong, 2009; Gaceri, 2015). Improving the health and safety at school will bring to realization the commitment of the ministry of education to ensure that the schools are safe for workers and students as envisaged in the safety standards manual for schools in Kenya (2008). Improving the safety in schools also enhance corporate image of the education sector (Gaceri, 2015).

This study is also in line with article 42 of the Constitution of Kenya (2010) that states that each person has a right to a clean and healthy environment. Providing a safe and clean environment for teachers is a basic right and thus the study findings will form a basis for enacting and revising occupational safety and health policies relating to the use of whiteboard markers in learning institutions in Kenya. The findings of this study further support the spirit and aspirations of the social economic pillar of Kenya's Vision 2030 with regard to ensuring a healthy population and safe space for the workers for improved economic productivity and human and environmental health wellbeing.

1.5 Scope of the study

The study was limited to school teachers in Nakuru County because research had shown that teachers in this county had a very high prevalence of allergic conjunctivitis (Muchemi, 2011). The schools that had implemented the use of whiteboards in their classrooms were considered because whiteboard marker pen ink was a new phenomenon and therefore there was need to assess the risk associated with it. Also, earlier studies had already indicated that chalk dust was associated with allergic conjunctivitis but had not studied the effects of whiteboard marker pen ink (Muchemi, 2011). It was also limited to the VOCs from the whiteboard marker pen ink because the rest of the components of the ink were likely to remain on the surface of the whiteboard after writing and may not reach the eyes of the teachers (Halverson, 2011). The air samples were collected at the 1.5 m height because it is the breathing level of a standing person (Olumayede and Okuo, 2013). Air samples were collected from six schools only because they were close to Egerton University allowing quick transportation of the samples to the laboratory for analysis before they could convert. Symptoms of allergic conjunctivitis were considered because other effects of the VOCs may be chronic taking a long time to manifest (ATSDR, 2007). Also allergic reactions take short time (30 min) to develop on exposure and are also short lived and clear when the trigger factors are removed (Bielory and Friedlaender, 2008) making it easy to confirm the association between exposure and development of the symptoms. The study used the concentration of carbon dioxide as a measure of ventilation because carbon dioxide is mainly produced indoors as a product of exhaled air and is removed or diluted by outdoor air. It's concentration in the classroom is therefore influenced by ventilation (Godwin and Batterman, 2007; Lu *et al*., 2015).

1.6 Limitations

Not many schools had implemented the use of whiteboards and this limited the size of the study population. However, Mwangi (2000) cites several authors to argue that a sample of 30 respondents is the lowest acceptable if some form of statistical analysis is to be carried out in the data obtained indicating that the results from this study are still acceptable.

Also the first chromatography column during laboratory analysis got exhausted and another one was put in place. However, the results were consistent in terms of the concentrations of the standards indicating that the effects of the change of the column would not affect the results of the research study significantly.

Samples were injected into the injector manually and this resulted in inconsistencies in terms of retention time. However, all the values were within the acceptable range of coefficient of variation (CV) of 15% as is required by the criteria of the International Conference on Harmonization (ICH) (Portari *et al*., 2008).

Frequent power outages in the laboratory disrupted analysis of some air samples and more samples had to be taken from the same school.

The samples were converting if they were allowed to stay for long before getting analyzed. To prevent this, the classrooms where air was sampled from were selected purposefully based on the proximity to Egerton University. The farthest classroom was only one hour drive from Egerton University by which time no chemical changes had taken place within the air samples.

The ink VOCs in the study eluted as a single peak during chromatography and therefore it was impossible to calculate the concentration of the components based on the individual standards. However, Kimball *et al*. (2005) and Kushwah *et al*. (2011) say that use of one compound as a standard to calculate the concentration of other VOC compounds in a mixture is acceptable.

1.7 Assumptions

This study assumed that the teachers were honest as they gave information concerning their work and health status and that they were be able to isolate and identify the symptoms of allergic conjunctivitis. It also assumed that all the teachers in a given school used a common type of marker pen ink and the measured concentrations of VOCs represent the exposure levels to the teacher. The study assumed that the air sample that had similar retention time as that of ink vapour was composed of ink VOCs since both the air samples and the ink headspace were analyzed under similar conditions of temperature. The research used repeated measures design where the same teachers were observed on several occasions. This study therefore assumed that the personal factors which influence the development of allergic conjunctivitis would not affect the results because they remained constant at the different times of observations of the same individuals. The study also assumed that the percentage composition of the components of pure ink vapours remained constant because they were based on the amount of each component in the ink as well as their physical properties which remained constant.

1.8 Definitions of terms

Exposure level- This refers to the concentration of a hazardous substance to which an organism is exposed during a specified period

Occupational exposure limit (OEL) - This is an upper limit on the acceptable concentration of a hazardous substance in work place air for a particular material or class of materials.

Permissible exposure limits (PEL) –This is a level which is allowed in a workplace by the enforcing authority

Recommended exposure limits (REL)-This is a limit value which is believed not to cause any health effects to an exposed worker. It is a level which is believed to be safe for the exposed worker

Short term exposure limits (STEL) – This is the limit level to which a hazardous chemical is allowed to overshoot the threshold limit value time weighted average (TLV-TWA). However the exposure duration should not exceed 15 minutes. Some chemicals have their STEL set as 10 minutes. It is usually set for those substances which are not lethal.

Threshold Limit Value (TLV)- These are set out amounts or concentrations of substances that should not be exceeded at a work place if the worker is to be safe

Allergic conjunctivitis- This is an inflammation and irritation of the eye. The identifying symptom is the itchiness of the eye along with the other symptoms.

Threshold limit values time weighted average (TLV-TWA)-These are average limits which are usually averaged over eight or ten hours. This limit represents an average value which should not be exceeded. But since it is an average, it is acceptable to exceed the value as long as the overall average over the shift time is within the acceptable average value.

Volatile organic compounds (VOCs)- These are compounds which are liquids at room temperature and pressure but have low boiling points and easily vaporizes forming vapors.

Second hand smoke- The smoke emitted from the burning end of a cigarette or from other tobacco products usually in combination with the smoke exhaled by the smoker.

Coefficient of Variation- This is a measure of dispersion from the mean. It is calculated as a ratio of the standard deviation to the mean. In this study it refers to the dispersion from the mean retention time of the pure ink VOCs.

Retention time-This is the time taken by a compound to go through the column and elute at the end. It is a unique characteristic of a compound for a given chromatography column and temperature conditions.

Seasonal variations – This was the variation in incidences of symptoms of allergic conjunctivitis in the cold and hot seasons of the year. The cold months were the July and early part of the August months, September and October months were neither very cold nor very hot while the January and February months were very hot.

Classroom factors- These are factors that may influence the exposure of the teacher to the ink VOCs. The study considered the concentration of carbon dioxide as a surrogate measure of ventilation efficiency. Temperature was measured because it influences management of operable ventilations

Attitude –Individual’s evaluation of an object. In this study it is the individual’s evaluation of whiteboard marker pen ink.

Ventilation- The process by which pollutants are removed from the occupied zone and results in clearing or dilution of the pollutants.

Duration of exposure- This is the time that a person remains in contact with the whiteboard marker pen ink VOCs. It was measured using the number of lessons that a teacher has because teaching takes place in the classrooms where whiteboard marker pens are used.

CHAPTER TWO
LITERATURE REVIEW

2.1 History of the use of marker pens in schools

In the eighteenth and nineteenth centuries, students used slate boards which were written on using small pieces of slate and later chalk. In the late 1700s a Scottish teacher hung a set of slates on the wall and the blackboard was invented. This allowed the teacher to present his ideas and concepts to the whole class in a visual way. By 1960s green steel chalkboards were introduced because the green was easier on eyes. By 1980s, businesses began using whiteboards with markers that eliminated the harmful chalk dust and schools began replacing their chalkboards with whiteboards (Jobrack, 2012). Whiteboards are flat boards made of plastic, melamine, porcelain or aluminium (Griffith and Kocsis, 2011; Atwopetu and Bello, 2017). They can have different shapes and sizes that work with special markers called dry erase markers. They can be freestanding or hung on a wall (Griffith and Kocsis, 2011).

Global upgrading of the chalkboard to whiteboards is influenced by urbanization and is therefore more rapid in developed economies (Nagi, 2017). In Africa, many of the schools are yet to upgrade with South Africa still upgrading by resurfacing old chalkboards (Kennedy, 2011). In Kenya the process of substituting the chalkboards has been a gradual and slow one (Wambugu, 2010; Oyier, 2017) with only sixteen schools in Nakuru County having fully substituted the use of chalkboards with whiteboards. Many of the other schools have installed the whiteboards in some classrooms whereas chalkboards are used in the remaining classrooms (Irungu, 2015).

2.2 Chemical composition of the marker pen ink

Dry erase ink for whiteboard marker pen is composed of volatile solvent vehicle, binder resin, fluorinated surfactant, non-fluorinated surfactant or surfactants, including the preferred cationic amide oxide, release agent and poly(oxyalkylene) substituted colorant. The specific composition by mass as well as the solvent used differs from manufacturer to manufacturer. (Carroll and Valenti, 2006). A solvent can be defined as a liquid that has the ability to dissolve, suspend or extract other materials, without chemical change to the material or solvent (Dick, 2006). The solvent easily vaporizes allowing the mark to dry on the surface of the whiteboard (Uhara *et al*., 2009). In the process, these volatile organic compounds (VOCs) are released into the air and can easily get into contact with the eyes and the skin of the teachers. They can also be inhaled or be ingested by both the teachers and the students. The solvents used include butanol, diacetone alcohol, ethanol, Isopropyl alcohol, Methyl isobutyl ketone and 2-butoxy-ethanol (Halverson, 2011). Toluene and xylene are also used as solvents (Conner, 2009). Marker pen inks with alcohol as a solvent are characterized with low odour unlike the toluene and xylene solvents which have strong odours (ATSDR, 2007). The manufacturers of the alcohol based marker pen inks label their products as non-toxic. However, even alcohols are irritants (ATSDR, 2015).

Since there are several solvents which can be used for the whiteboard marker pen ink, the actual composition and concentration of the components of an ink brand depend on the manufacturer. A material safety data sheet contains the detailed information on the components of the ink as well as the health effects of the components and the safety measures that should be taken in case of poisoning (Eastlake *et al*., 2012). However most of the manufacturers are less conscientious when it comes to informing users on health risks and therefore do not provide the material safety data sheets (Suleiman and Svendsen, 2014). It is therefore impossible to know the actual components and their concentrations in a given ink brand in the absence of a material safety data sheet from the manufacturer.

2.2.1 Use of chromatography to determine the type and amount of solvents in ink

Several researches have used gas chromatography to determine the type and concentration of VOCs in different mixtures (Sannik, 2013; Mochalski et al., 2016). A gas chromatography uses a mobile phase (gas) and a stationery phase (solid or liquid) packed in a column. When an analyte is injected, the high temperature at the injection port volatilizes it forming vapour which enters the column. The components of the analyte partition between the mobile and stationery phases differently. The rate and degree of partitioning depends upon the chemical affinity of the analyte for the stationery phase and the analyte vapor pressure which is governed by the column temperature. A component with a lower affinity for the stationery phase is moved through the column more quickly than the others making the components to separate out and elute (come out of the column) at different times known as retention time (tR). As the analyte elute it passes into a detector which generates an electronic signal which when sent to the integrated data system produces a peak known as chromatogram. These peaks are approximately Gaussian shaped and the area under the curve is related to the quantitative aspect of the analyte. The retention time is a unique characteristic of a specific compound and is therefore used to establish the identity of an unknown substance (Al-Bukhaiti et al., 2017).

The identity of the compound in the analyte is established by comparing the retention time with that of a known standard. The analyte and the standard must be analyzed under similar conditions of temperature using the same column because the column material as well as the temperature conditions can affect the retention time of a compound (Al-Bukhaiti *et al*., 2017). The concentration of a known compound in the analyte is established by relating the area under the curve with the area under the curve of a known amount of the standard under similar conditions. The concentration of a mixture of many volatile organic compounds in an analyte can be determined by adding the areas under the curves and comparing them with the area of a known standard such as toluene and n-hexane (Srivastava and Mazumdar, 2011).

There are several approaches used to determine the concentration of a given compound or a mixture of compounds using an external standard. These include use of response factor of the known standard. In this method, a known amount of the standard is first injected into the column and the area under the curve determined. The response factor is then calculated by dividing the area under the curve with the amount of the standard injected. The amount of the unknown analyte is calculated by dividing the area under the curve with the response factor of the known standard. Another method involves drawing of a calibration curve of the known standard. This is a curve of the area under the curve against the concentration. The values are obtained by running several runs of the standard with different concentrations and the resulting values are used to plot a curve. The concentration of a compound in the analyte can then be determined using the curve (Brevard et al., 2011).

Since the VOCs in the environment exist as a mixture of the known and unknown compounds, several research studies recommend the comparison of the total area under the curves with the area of toluene or n-hexane or one of the components in the mixture. Such concentrations are reported as concentrations of the Total Volatile Organic Compounds (TVOCs) instead of reporting the concentration of each individual compound in the mixture (Mølhave *et al*., 1997; Srivastava and Mazumdar, 2011).

2.2.2 Exposure levels of the solvents

Exposure level refers to the concentration of a hazardous substance to which an organism is exposed during a specified period (Silbergeld, 2012). An occupational exposure limit is an upper limit on the acceptable concentration of a hazardous substance in workplace air for a particular material or class of materials. It is typically set by competent national authorities and enforced by legislation to protect occupational safety and health (Borak and Brosseau, 2015). Occupational exposure limit values (OELs) are set to prevent occupational diseases or other adverse effects in workers exposed to hazardous chemicals in the workplace. OELs assume that exposed persons are healthy adult workers, although in some cases the OELs should also protect vulnerable groups such as pregnant women or other more susceptible people. They are tools to help employers protect the health of workers who may be exposed to chemicals in the working environment. OELs are usually set for single substances, but sometimes they are also produced for common mixtures in the workplace, for example solvent mixes, oil mists, fumes from welding or diesel exhaust fume (McKee *et al*., 2017).

The occupational exposure limits are set as threshold limit values time weighted average (TLV-TWA) which is usually averaged over eight or ten hour shift, recommended exposure limits (REL), permissible exposure limits (PEL) and short term exposure limit (STEL) which is the limit level to which a hazardous chemical is allowed to overshoot the time weighted average (TWA). However the exposure duration should not exceed 15minutes. Some chemicals have their STEL set for 10minutes.The most basic use of an OEL as a risk reduction measure is to compare it to actual exposures at the work-place. This implies that workplace exposures have to be actually measured (Schenk, 2008). The recommended TWA for the solvent vapours are as shown in the Table 2.1.

Table 2.1: Recommended time weighted averages of VOCs

Solvent vapour in the air	TWA in ppm
Butanol	20
Diace- tone alcohol	50
Isopropyl alcohol	200
Methyl isobutyl ketone	20
2-butoxy-ethanol	20
Toluene	20
Xylene	100
Acetone	250
Hexane	50
Methanol	200
Ethanol	1000

Source: CDC, 2016

The STEL for ethanol is 1000ppm while that of isopropyl alcohol is 400ppm (CDC, 2016).

Since many different VOCs exist together each at a low indoor concentration but higher than outdoors, the concept of total VOCs (TVOCs) has been introduced in existing literature (Chatzidiakou, 2012). In some countries, thresholds for TVOCs in indoor nonindustrial environments have been developed, and most of them are in the magnitude of 200 to 600 µg/m^3 (Salthammer, 2011) to prevent discomfort and acute distinct health issues. In the UK, the recent version of Building Regulations Part F (HM Government, 2010) based on the European Collaborative Action (ECA, 1992) recommends concentrations below 300 µg/m^3 for domestic buildings.

2.3 Distribution of ink VOCs in the classroom

The concentration of VOCs is influenced by the amount of emiting material (Panagopoulos *et al*., 2011; Huang *et al*., 2016), the rate of emission from the material (Huang *et al*., 2016), the rate of dilution by the outdoor air (Liang *et al*., 2014; Chin *et al*., 2015) as well as the speed of clearing of these vapours from a room by the air current (Du *et al*., 2015; Soto-Garcia *et al*., 2015; Holøs *et al*., 2018). The rate of emission from the writings depends on the classroom conditions of temperature and humidity. High temperature and humidity increases the rate of emission while low temperature slows down the emission from the writings resulting in a low concentration that persists for a longer time with the continued emission (Lin *et al*., 2009; Kang *et al*., 2010; Parthasarathy, 2011; Xiong *et al*., 2013). The age of the writings on the whiteboard also influences the concentration of the VOCs. The emission is higher soon after the writings but it decreases with time (Ishidao *et al*., 2005; Holøs *et al*., 2018).

The concentration of the ink VOCs also depend on the presence of other VOCs and air components which may react with the ink VOCs reducing their concentrations in the classroom (Wei *et al*., 2017). These VOCs can result from emissions of the building materials as well as the furniture and chemicals in a classroom such as cleaning agents and science chemicals (Schlink *et al*., 2010; Panagopoulos *et al*., 2011; Dunagan *et al*., 2011; Chin *et al*., 2015). Some can also enter into the classroom with the outdoor air from an outdoor source such as a pollutant or from the motor vehicle exhaust (Batterman *et al*., 2007; Chin *et al*., 2015). The rate of emission from the building materials depend on the age of the building as well as the type and age of renovations (Jia *et al*., 2008; Jo and Sohn, 2009; Breen *et al*., 2010; Langer and Bekö, 2013; Chin *et al*., 2015; Vilceková *et al*., 2017). The speed of conversion of the ink VOCs into other VOC mixtures by reacting with other components depend on the temperature as well as humidity of the classroom. High temperature and humidity favour the conversion (Hinks *et al*., 2016). The time of natural decay of the VOCs also influence their concentration at the different parts of the classroom. Some VOCs take longer than others to decay and they may linger in the room longer. However, it is expected that the VOCs will naturally undergo decay with time even if they are not cleared out of the room (Panagopoulos *et al*., 2011; Holøs *et al*., 2018).

The concentration of VOC is highest close to the point of production and therefore the position of the whiteboard where writing takes place can influence the spread of the VOCs in a room (Du *et al.*, 2015; Noguchi *et al*., 2016). The spread to the rest of the room is affected by both the ventilation type and pattern (Atkinson *et al*., 2009; Panagopoulos *et al*., 2011). In a naturally ventilated classroom, the pattern of ventilation is not only influenced by the design (Yang and Chen, 2001; Kembel *et al*., 2012) but is also influenced by the management of these ventilations (Moghaddan *et al.*, 2011; Marr *et al.*, 2011). Opening the windows on one side of the classroom may create a unidirectional flow of outdoor air while opening the windows from both sides (where they exist) may allow the cross through type of ventilation pattern (Moghaddan *et al*., 2011).

Indoor materials can act as buffers for VOCs reducing peak concentrations but prolonging the presence of compounds in the air (Kim, 2008). Some materials allow the sorption of the VOCs while others allow the VOCs to diffuse through them. Those that allow sorption reduce the concentration of the VOCs but increase the duration of their life in the room (Kim, 2008; Ho *et al*., 2011). All this influence the concentration and spread of VOCs at the different parts of the room. However, the relative density of a VOC mixture does not influence its spread in the air (Xu *et al*., 2012). It is therefore expected that all the VOC would diffuse and mix effectively with the room air.

2.4 Knowledge, attitude and practices of teachers on marker ink safety

Chemical safety is the prevention of the short and long term adverse effects to humans and the environment from the production, storage, transportation, use and disposal of chemicals (WHO, 2011). Schools can be insecure for teachers and students because of the presence of toxic chemicals (Malik *et al*., 2016). These chemicals include the chemicals used to teach science in secondary schools as well as the chemicals in the whiteboard marker pen inks (EPA, 2006). Organic solvents in the whiteboard marker pen ink can cause many health hazards including the central nervous toxicity, respiratory effects and eye irritation (ATSDR, 2015). The use of chemicals therefore require an understanding of what makes the chemicals dangerous as well as its both acute and chronic hazards (Fivizzani, 2007). Weekes (2017) says that to be safe, one must have core learning around safety and have a grasp of specific safety knowledge that one can apply at work. Knowledge improves safety at the workplace (Vinodkumar and Bhasi, 2010). However, the safety guidelines at secondary schools are limited to science laboratory chemicals (Muange *et al*., 2015).

Use of technology in education has come a long way since the earliest times of human civilization. This ranges from slates, blackboards, green and brown boards, the white boards and finally interactive boards. The whiteboards or dry-erase boards came into use during the late 1980s. They have a glossy-white surface for writing. Instead of chalk pencils, whiteboard pens were used to write on whiteboards. Considering the health reasons and cost-effectiveness, by 1990s most of the classrooms were replaced with whiteboards instead of blackboards (Muttappallymyalil, 2016).

Fishbien and Ajzen (1975) defined “attitude” as the individual’s evaluation of an object. There are several models that try to explain the attitude of workers towards a new technology.

These include the theory of diffusion of innovations (DIT) (Rogers, 1995), the theory of task-technology fit (TTF) (Goodhue and Thompson, 1995), the theory of reasonable action (TRA) (Fishbein and Ajzen, 1975), theory of planned behavior (TPB) (Ajzen, 1991), decomposed theory of planned behaviour, (Taylor and Todd, 1995), the technology acceptance model (TAM) (Davis *et al*., 1989), technology acceptance model 2 (TAM2) (Venkatesh and Davis, 2000), unified theory of acceptance and use of technology (UTAUT), (Venkatesh *et al*., 2003) and technology acceptance model 3 (TAM3) (Venkatesh and Bala, 2008).

Attitudes and values have a tendency to influence practice. They have more influence on teacher practice than teacher knowledge (Ottenbreit-Leftwich *et al*., 2010). Teachers' attitudes as regards to technology are based on whether or not they think technology can help them achieve the instructional goals they perceive to be most important (Watson, 2006). Davis *et al*. (1989) purported that a causal linkage exists between beliefs around perceived usefulness and perceived ease of use, user attitudes, intentions, and subsequent technology adoption and that these beliefs are mediated by external variables. Teachers' attitudes toward technology, perceived ease of use and perceived usefulness (beliefs that the technology will enhance job performance) influence teachers' intention to use technology (Courduff *et al*., 2016).

Personal factors also influence the attitude of persons towards technology. These factors include age, gender, type of fuel used at home and marital status. According to the impressionable years hypothesis, people are likely to hold on that which was introduced to them when they were young (Krosnick and Alwin, 1989). This is also supported by the increasing persistence hypothesis which says that the young people are flexible to changes while old people are rigid because flexibility decreases with age (Glen, 1974). Gergen and Black (1966) explain that aging entails social disengagement and decrease in interest in events distant from ones immediate life. Young people are therefore more receptive to changing technology than the old.

Early studies of elementary and high school students identified an apparent dominance of males with regard to new technology (Ray et al., 1999). Raub (1982) attributed the gender difference to culturally learned roles. Males have been socialized by a society that encourages them to be proficient in all technological issues (Ray et al., 1999). According to Williams et al. (1993) the gender difference tends to be consistent across all age groups.

The fuels used in a home can be used as an indicator of susceptibility to changing attitude. Those that use the traditional solid fuel are the rigid type of persons who are not able to change and embrace the new clean types of fuels. Such persons are also likely to remain rigid to the changing technology and prefer to use the conservative methods (Shen et al., 2014). Marital status of a teacher is also believed to influence the aspect of the teaching of the individual teacher. The teacher's effectiveness is significantly influenced by the marital status of the teacher (Islahi and Nasreen, 2013) with the single teachers being better classroom managers Tyagi (2013).

Several researchers have studied the behaviour and practices of teachers and students in the classrooms. Many of them found that the teachers do not open windows often and when they do they only respond to temperature changes and not indoor air quality (Wargocki and Wyon, 2006; Wyon and Wargocki, 2008). This can allow the ink VOCs to accumulate in the classrooms (Willem, 2013; Singer *et al*., 2014).

2.5 Classroom factors that influence the exposure to the VOCs from ink

The major exposure factor is the concentration of the ink VOCs in the classroom because the dose of the allergen determines the response of a person to the allergen (Kirk and Deaton, 2007). The classroom factors that influence the concentration of the ink VOCs include the ventilation, temperature and workload or duration of exposure.

2.5.1: Ventilation

Ventilation allows for dilution of the pollutants as well as allows them to be pushed out and cleared out of the room (Seppänen and Kurnitski, 2009). In a poorly ventilated room, the vapours of the VOCs can tend to accumulate to unacceptable levels (Wyon and Wargocki,. 2008; Matysik *et al*., 2010; Willem, 2013; Noguchi *et al*., 2016). The effectiveness of the ventilations can be determined by studying the concentration of the carbon dioxide in the classroom (Godwin and Batterman, 2007; Lu *et al*., 2015). Humans produce and exhale carbon dioxide (CO_2) making concentrations of CO_2 in occupied indoor spaces to be higher than concentrations outdoors (Lazović *et al*., 2015; Chiu *et al*., 2015). As the ventilation rate decreases, the magnitude of the indoor–outdoor difference in CO_2 concentration increases.

Consequently, peak indoor CO_2 concentrations, or the peak elevations of the indoor concentrations above those in outdoor air is an indicator for poor ventilation rate (Godwin and Batterman, 2007; Lu *et al*., 2015).

2.5.2: Temperature

The indoor classroom temperature is a combination of radiations received through the roof and walls of the building (Ponni and Baskar, 2015). It is influenced by the external temperatures which depend on the number of buildings, the type of manmade materials in the surrounding and presence or absence of vegetation in the surrounding (Kleerekoper *et al*., 2012; Scott *et al*., 2017). It is also as a result of heat generated by the classroom occupants as a result of physiological body activities (Cowan *et al*., 2010). These temperatures are usually regulated by the classroom occupants by managing the operable ventilations based on their comfort (Lazović *et al*., 2015). Low temperature makes the room occupants to close the operable ventilation resulting in indoor accumulation of the VOCs. It also reduces photochemical reaction rates of the VOCs and in the process increase their atmospheric lifetime (Hellen *et al*., 2012; Hinks *et al*., 2016). Increase in temperature increases the rate of emission of VOCs from the writings (Lin *et al*., 2009; Xiong *et al*., 2013). Increase in temperature also increases the diffusion of the ink VOCs in the classroom making the spread effective (Bauerle, 2011; Bag *et al*., 2014). Chiu *et al*. (2015) found that the temperature between 20 ^{o}C and 25 ^{o}C decreases the dispersion of VOCs and in the process increase the concentration of the VOCs in a classroom. High temperature combined with high concentration favour the sorption of the VOCs by the interior surfaces reducing the peak concentrations (Salthammer, 2008).

2.5.3: Duration of exposure

The workload of a teacher is determined in terms of the number of lessons that a teacher has to attend per day. Workload of a teacher determines the duration of exposure of that teacher to the ink VOCs. The more the number of lessons, the longer the teacher remains in the classroom and therefore the longer the duration of exposure to ink VOCs. Prolonged exposure to a pollutant exacerbates the reaction to that pollutant (Świebocka *et al*., 2014; Ackerman *et al*., 2016) because increased duration increases the dose of the pollutant on the target organ (Kirk and Deaton, 2007).

2.6 Seasonal variation of allergic conjunctivitis

Allergic conjunctivitis tends to be high during the peak season of pollen production (Imonikhe *et al.,* 2011). Singh *et al*. (2010) found that the ocular allergy was highest during the months of June and July in the United States of America. Allergic conjunctivitis is induced by the outdoor allergens which differ not only in their location distribution but also in their seasonal distributions. In some parts of the world, tree pollens have seasonal peaks in spring, grass pollens in summer and weed pollens in fall (Chung *et al*., 2012). Nakuru , Kenya, produces maize (Ariga and Jayne, 2009) and maize pollen has been associated with development of allergic conjunctivitis (Oldenburg *et al*., 2011). It is therefore expected that the incidences of allergic conjunctivitis would increase during the pollen production of the maize.

Ocular allergy is also triggered by indoor allergens such as pet dander, dust mites, molds and irritants (D'Amato, *et al*., 2015). These tend to accumulate during winter when the ventilation is abated because the room occupants tend to close the windows to conserve heat and prevent entry of cold outdoor air (Kay *et al.,* 2009). The heating of the rooms also results in products which increase the allergies during cold seasons (D'Amato, *et al*., 2015). In Kenya, the coldest season is in the months of June and July while the hottest season is in the months of January and February (KNBS, 2015). Some forms of eye allergy are triggered by environmental factors such as dust, wind and sunlight (La Rosa *et al*., 2013) which are more likely to exist during the dry hot season.

2.7 Health impacts of the marker ink solvents

Butanol causes irritation to the eyes, skin and the throat. It also causes headache, drowsiness blurred vision, photophobia (abnormal visual intolerance to light), dermatitis, auditory nerve damage, hearing loss and central nervous system depression. Diacetone alcohol causes corneal damage and also irritates the eyes, skin, nose and the throat. Ethanol causes lassitude (weakness, exhaustion), drowsiness, headache, and is also an irritant to the eyes, skin and the nose. Isopropyl alcohol (rubbing alcohol) may cause dizziness, headache and drowsiness as well as irritate the nose, eyes and the throat. Methyl isobutyl ketone irritates the eyes, mucous membrane and the skin when it comes into contact with it. It may also cause headache, narcosis, dermatitis and coma if the exposure is high. Monobutyl ether (2-butoxy-ethanol) causes eyes, skin, nose and throat irritation, destruction of red blood cells, central nervous system depression, headache and vomiting. It may also result in blood in the urine (Halverson**,** 2011).

Health effects of xylene are determined by the dose, the duration and the route of exposure (ATSDR, 2007). Short-term exposure of people to high levels of xylene can cause irritation of the skin, eyes, nose, and throat, difficulty in breathing, impaired function of the lungs, delayed response to a visual stimulus, impaired memory, stomach discomfort and possible changes in the liver and kidneys. Both short- and long-term exposure to high concentrations of xylene can also cause a number of effects on the nervous system, such as headaches, lack of muscle coordination, dizziness, confusion, and changes in one's sense of balance. It can also cause death (Kandyala *et al*., 2010).

Low to moderate levels of toluene can cause tiredness, confusion, weakness, drunken- type actions, memory loss, nausea, and loss of appetite. Long-term exposure to toluene in the workplace may cause some hearing and color vision loss while repeatedly breathing in toluene may permanently damage the brain (ATSDR, 2015).

Toluene and xylene based inks have strong odours while the alcohol based ones have low odours and are also claimed to be less toxic (ATSDR, 2015). This can make the teachers more comfortable with the alcohol based inks and may end up exposing themselves to high concentrations and for a long duration because the low odour does not provide adequate warning of hazardous concentrations (ATSDR, 2015; Sengupta and Sarkar, 2015). Methanol can cause severe metabolic disturbances, blindness, permanent neurologic dysfunction and death. It also leads to severe hypotension (Jahan *et al*., 2015) and is an irritant (Clary, 2013).

Maurer *et al*. (2001) studied the effects of acetone on eyes and found that contact resulted in mild irritation. Acetone also act on the central nervous system and acts as a depressant (Greenberg *et al*., 2003). Hexane is carcinogenic, upper respiratory irritant and central nervous system depressant. Chronic exposure causes periphery neuropathy (Hathaway and Proctor, 2004; ATSDR, 2015)

2.7.1 Allergic Conjunctivitis

Conjunctivitis refers to inflammation of the conjunctiva of the eyes. The causes of conjunctivitis are bacterial or viral infections and an allergic reaction. In newborns, conjunctivitis can result from an incompletely opened tear duct. Conjunctivitis caused by bacterial infection is characterized with a thick mucous discharge which is yellow- green in colour. If the cause is viral, the mucous produced is watery (Sanders, 2012).

Allergic conjunctivitis is an inflammation of the conjunctiva as a result of a reaction of the body's immune system to an allergen (Bielory and Friedlaender, 2008). The symptoms of allergic conjunctivitis include itching, irritation or hurting, stinging or burning sensation, watery eyes, discomfort, swelling of the eyelids, red eyes and a feeling of presence of foreign particles in the eyes or 'fullness' in the eye. Itching is the hallmark of allergic conjunctivitis and without it a person may not be suffering from allergic conjunctivitis even if all the other symptoms are present. Itching may be mild or severe (Ono and Abelson, 2005; Leonardi, 2013; Miraldi and Kaufman, 2014).

Allergic conjunctivitis is an inclusive term that encompasses seasonal allergic conjunctivitis (SAC), perennial allergic conjunctivitis (PAC) vernal keratoconjunctivitis (VKC), atopic keratoconjunctivitis (AKC) and giant papillary conjunctivitis (GPC) (Leonardi *et al*., 2012; La Rosa *et al*., 2013). SAC and PAC represent the majority of all ocular allergy diagnosis. SAC is triggered by pollen while PAC is due to an allergy to house dust mite. GPC is as a result of immunological reaction to debris which causes mechanical irritation to the conjunctiva and use of extended wear soft contact lens. Mechanical irritation of the conjunctivitis by exposed sutures after a surgery can also result in GPC. It is characterized by the presence of giant papillae (Chowdhury, 2013). VKC and AKC are chronic and severe forms of ocular allergies (Leonardi *et al*., 2012).

Allergic conjunctivitis is a type I hypersensitivity reaction occurring within 15 to 30 minutes after exposure. Allergic conjunctivitis involves an inflammatory cascade. It starts when an allergen comes into contact with the ocular surface of a person who is genetically predisposed. The allergen is then phagocytosed and processed into simpler peptides by antigen-presenting cells and is presented on major histocompatibility complexes on the surface of the antigen-presenting cells. This induces T lymphocytes to start generating T helper (Th2) cells and the production of inflammatory mediators. The Th2 cells activate the B cells to produce IgE molecules which bind to mast cells and basophils in the conjunctiva resulting in degranulation and the release of inflammatory mediators. These include Histamines, leukotrienes, prostaglandins, and platelet activating factor. These cause blood vessel dilatation (hyperemia), increased vascular permeability/fluid exudation (edema), and mucosal swelling (Friedlaender, 2011; La Rosa *et al*., 2013; Chigbu and Minhas, 2018).

The chronic phase occurs after approximately 4 to 6 hours. It is secondary to the release of pro inflammatory (interleukin [IL]-6, macrophage inflammatory protein, and tumor necrosis factor alpha) and type 2 (IL-4, IL-5, and IL-13) cytokines. The production of these mediators results in the recruitment and activation of inflammatory cells, such as monocytes, T cells, eosinophils, and basophils. Chronic inflammation plays a major role in the pathophysiology of the most severe forms of ocular allergic disorders and can be secondary to persistent allergies swelling (Chigbu and Minhas, 2018).

Allergic conjunctivitis influences many quality of life parameters. The itchiness and irritation result in discomfort of the eyes. Pain is also one of the symptoms of allergic conjunctivitis. Scratching and inflammation may result in ocular damage which can give rise to secondary infection of the eye. The vision is affected resulting in reading difficulties. The symptoms such as running eyes can interfere with the patient's confidence in social places and limit the choice of outdoor activities. It can also affect one's ability to wear eye make ups making the patient to feel unattractive. Scratching of the eyes can result in periorbital excoriations and bruising making the eyes to appear even worse. This affects the patient emotionally. The allergens in the eyes can also drain into the nasal cavity and cause nose allergies increasing the discomfort (Pitt *et al*., 2004; Bielory and Friedlaender, 2008; Sánchez *et al*., 2011).

The drugs used to treat allergic conjunctivitis are harmful. These include the oral antihistamines which causes drowsiness to the patient. They may also react with other medications causing life threatening cardiac arrythmias or may dry the eye reducing its ability to flash away bacteria resulting in secondary infections. Steroids used to treat allergic conjunctivitis may interfere with the body immunity as they block, reduce or inhibit the production of inflammatory mediators. The patients may experience burning and stinging sensation during the formulation of the topical drugs. This can be worsened by high frequency of application for those drugs which do not have a prolonged duration of action. Allergic conjunctivitis is associated with depression and anxiety in some patients (Bielory and Friedlaender, 2008; Kari and Saari, 2010; Sánchez *et al*., 2011; Leonardi, 2013).

Economy of the household is affected due to expenditures on prescriptions, productivity losses related to absenteeism and decreased job effectiveness due to discomfort from the symptoms of the ocular allergy. The patients have to reschedule their activities to create time to consult an ophthalmologist for the eye problems especially in undeveloped countries where the waiting time at the health facilities is long due to few facilities as well as few specialists that have to serve many persons over a long distance. Allergic conjunctivitis is also common among the population in the productive age group who are dependent upon by the rest of the household members (Sánchez *et al*., 2011; Muchemi, 2011; Santacreu, 2016).

Allergic conjunctivitis cannot be cured but it can be prevented by avoiding the triggers. It is therefore necessary for the patients to identify those factors that influence the development of allergic conjunctivitis so that they can avoid them (Bielory and Friedlaender, 2008; Chigbu and Minhas, 2018). The avoidance at the workplace can be facilitated by the policy makers eliminating the source, substituting the source or placing the worker at areas where the specific allergens are not produced based on the genetic predisposition of the workers. New allergens at the work places should also be recognized and control measures put in place to ensure that the worker is safe as required by the occupational Safety and Health Act of 2007. Researchers can aid in revealing the causal relationship between patterns of allergic conjunctivitis and their occupational exposure. Non pharmacological approaches can also be used to manage the allergic conjunctivitis when it occurs. These include use of cold compresses to constrict the capillaries and use of artificial tears to wash the eyes and flash out the allergens (Chowdhury, 2013; La Rosa *et al*., 2013).

2.8 Legal framework of occupational safety and health in Kenya

Occupational safety and health in Kenya is regulated by laws and standards that originate from different sources. The International Covenant on Economic, Social and Cultural Rights (1966) provides for the right to safe and healthy working conditions. It provides that all State parties to the Covenant will recognize the right of everyone to the enjoyment of just and favorable conditions of work which will ensure safe and healthy working conditions. The Universal Declaration of Human Rights (1948) provides that everyone is entitled to the right to work, to free choice of employment and to just and favorable conditions of work. The International Labour Organization stipulates that a worker should be protected from all unsafe conditions at the workplace (ILO, 2006). The Constitution of Kenya (2010) stipulates that the general rules of international law shall form part of the law of Kenya. This article ensures that these conventions and other sources of international law form part of the Kenyan law. The constitution also provides that every person has a right to the highest attainable standard of health. This being the case it is tenable to argue that the right of workers to a safe and clean working environment is a fundamental right in Kenya. Article 42 of Kenya's constitution guarantees every Kenyan the right to a clean and healthy environment. By analogy then, it means that the working environment also needs to be clean and healthy to the workers (Muigua, 2012). The safety requirement for the worker at the workplace is further emphasized in the Occupational Safety and Health Act (2007). This Act stipulates that the employer has a duty to ensure that the workplace is safe for the worker and that the worker has a responsibility to work safely. Health for all is also one of the many sustainable development goals (SDG number 3) (Beisheim, 2015).

The labour laws in Kenya regulate the relationship between the employer and the employees in the process contributing to the health and safety of the worker. The labour laws in place in Kenya include the Employment Act, The Labour Relations Act, Work Injury Benefit Act, Labour Institutions Act, National Social Security Act, National Hospital Insurance Fund Act, Industrial Training Act and the Retirement Benefits Act (ILO, 2016). Other legislations that touch on occupational safety and health are Public Health Act (GoK, 2017), Environmental Management and Coordination Act (GoK, 2012), Radiation Protection Act (GoK, 2012), and The Pest Control Products Act (GoK, 2012).

2.9 Research gaps

Although several research studies have been carried out on the indoor concentrations of VOCS (Shendell *et al*., 2005; Chatzidiakou, 2012) and their effects on the health of the students and teachers (Madureira *et al*., 2009; Madureira *et al*., 2015), there is limited information on the effects of occupational exposure to whiteboard marker ink VOCs and development of allergic conjunctivitis among the Kenyan school teachers. Use of whiteboard marker pen in secondary schools is also a new phenomenon with some of the schools yet to implement the same. As such, the set threshold values for occupational exposure to the VOCs from whiteboard marker inks have not been monitored in the school set up in Kenya. Knowledge, attitude and practices among teachers with respect to use and handling of whiteboard markers is limited and thus forms the basis upon which this study was carried out. There is paucity in data on the influence of various physico-chemical parameters and classroom structural characteristics on the concentrations of the ink VOCs from whiteboard marker pens. Finally, the influence of seasonality on the development of allergic conjunctivitis especially within the tropics is least understood. It was therefore necessary that a study of this nature be undertaken to address the aforementioned research gaps, and provide recommendations to the relevant agencies to address occupational safety and health issues among teachers with respect to use whiteboard markers.

2.10 Theoretical framework

Since allergic conjunctivitis has a lot of effect on quality of life (Belgü, 2014), there is need to control and prevent it. For this to be possible, it is important to focus on the attitudes and beliefs of individuals on allergic conjunctivitis as outlined by the Health Belief Model (Glanz *et al*., 1997). The Health Belief Model (HBM) is a psychological model that attempts to explain and predict health behaviours. The HBM is based on the understanding that a person will follow a recommended action if he feels that a disease or other health conditions can be prevented and that he is capable of adhering successfully to the prescribed actions of prevention.

The health belief model is spelled out in terms of six constructs representing the perceived threats and net benefits. These are perceived susceptibility, perceived severity, perceived benefits, perceived barriers, cues to action and self- efficacy. Perceived susceptibility construct refers to one’s opinion of chances of getting a condition. This involves defining the population(s) at risk and heightening perceived susceptibility if found to be too low. Teachers who write on whiteboards are exposed to chemicals in the ink. This study will determine the effects of these substances on the eyes of the teachers as well as reveal whether they are aware of their susceptibility.

Perceived severity construct refers to one’s opinion of how serious a condition is and its consequences. It involves specification of consequences of the risk and the condition. Based on this construct, this study spells out the consequences of allergic conjunctivitis as a disease that can be sight threatening and with many effects on the quality of life. Perceived benefits construct refers to one’s belief in the efficacy of the advised action to reduce risk or seriousness of impact. As such, this study believes that when the teachers are made aware of the effects of ink on their eyes they will participate actively in reducing their exposure to the ink.

Perceived barriers, as a construct, involve identification and reduction of barriers towards putting in place the recommended action. The researcher therefore hopes that the policy makers would be willing to put in place measures which would ensure that the teachers are safe based on the findings of the study. The research would create awareness about allergic conjunctivitis among the teachers and highlight some of the causes of allergic conjunctivitis in line with Cues to action construct. Knowledge would help them to prevent the condition in line with the sixth construct (self-efficacy).

2.11 Conceptual framework

The conceptual framework shows the interactions between dependent and independent variables (Figure 2.1). Exposure to ink used to write on whiteboards formed the independent variables while the dependent variables comprised of the symptoms of allergic conjunctivitis. The dependent variables were the symptoms of allergic conjunctivitis such as redness of the eye, swelling, watery eyes, itchiness, hurting/irritation, discomfort and feeling like there is a foreign body in the eye. The intervening factors were those believed to influence the development of allergic conjunctivitis. Mugenda and Mugenda (1999) define the intervening factors as those factors which influence the relationship between the independent and dependent factors

Exposure to the ink was studied in terms of actual use of the ink with its constituent VOCs, the concentration of the VOCs, the duration of exposure to these VOCs and the knowledge, attitude and practice (KAP) of teachers on the use of the whiteboard marker ink. The concentration of the VOCs is likely to be influenced by the ventilation which allows for dilution of the contaminated air and the temperature which affects the vaporization of the volatile compounds in the ink after writing on the board. Duration of exposure to the VOCs in the classroom was studied using the workload of a teacher which in turn dictates the amount of time the teacher spends in the classroom and the time taken for the VOCs to clear from the classroom air.

Knowledge on safety of science chemicals used in teaching in the secondary schools was studied because it was assumed that teachers who have had training on science chemicals and laboratory safety rules are likely to be knowledgeable on other chemicals such as the chemicals in the whiteboard marker pen ink. Influence of personal factors on the attitude of the teachers on the use of the whiteboard marker pen ink was also studied because demographic characteristics of a person influence the attitudes. Practices of a teacher also determine the extent of exposure to the whiteboard marker ink. If the teacher does not replace the lid every time he stops writing, the VOCs continue to vaporize from the exposed nib. Opening and closing of the windows by the teachers would influence the ventilation which has a great influence on the accumulation and spread of ink VOCs in the classrooms.

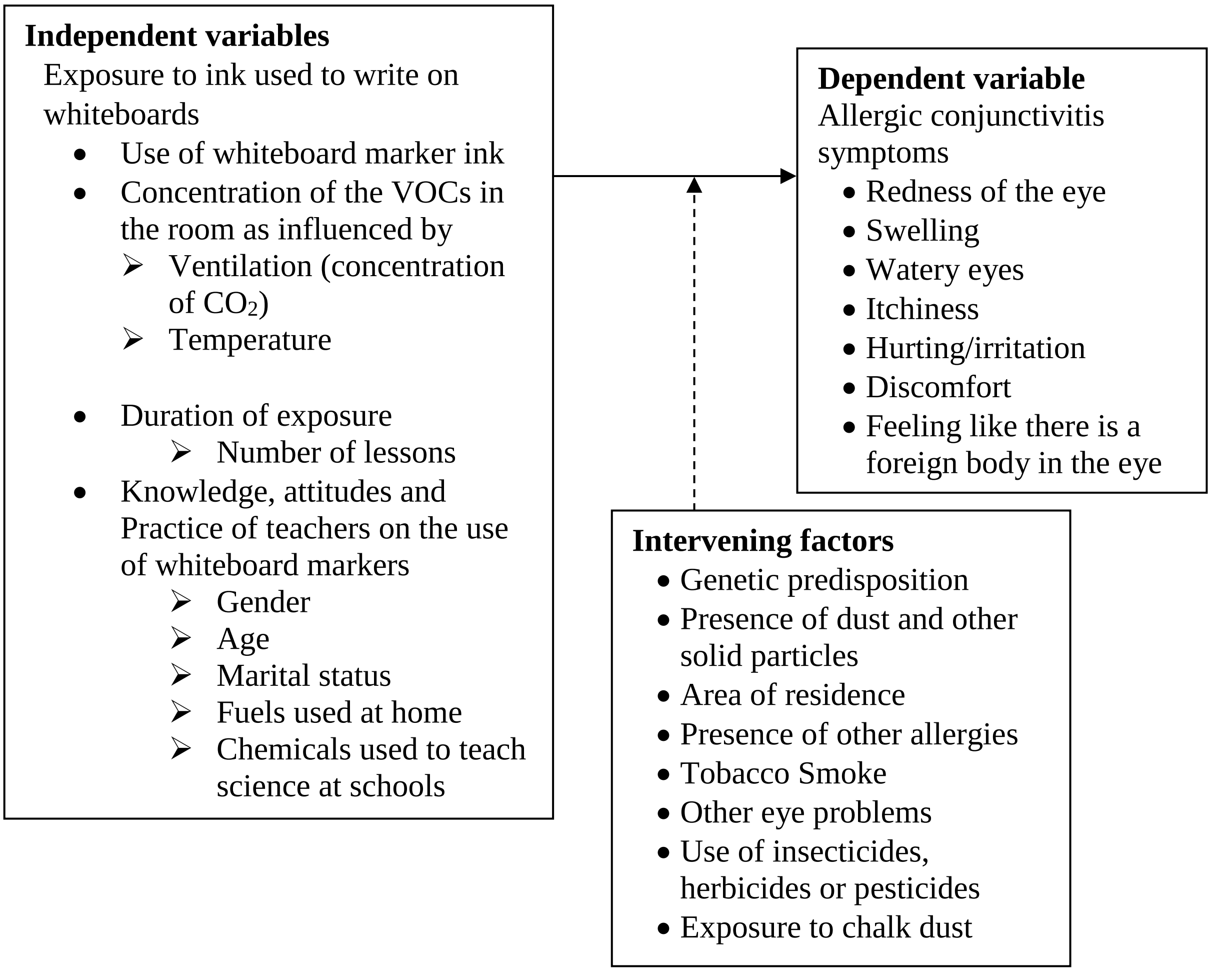


Figure 2.1: Conceptual framework of the relationship between the variables

CHAPTER THREE
METHODOLOGY

3.1 Study area

3.1.1 Location of the Study

Nakuru County is Located in the former Rift Valley Province of Kenya, about 90 km from Nairobi. It is bounded between latitude 0^{o} 13'N and 1^{o} 16' S and longitude 35^{o} 36' E and 35 ^{o} 28'W. It is an agriculturally-rich County and covers an area of 7495.10 square kilometres. The name Nakuru means a dusty place in the Maasai language, in reference to frequent whirlwinds that engulf the area with clouds of dust. It borders eight Counties. These are Laikipia to the north east, Kericho and Bomet to the west, Narok to the south west, Kajiado to the south, Baringo to the north, Nyandarua to the east and Kiambu to the south (KNBS, 2015). Figure 3.1 shows the map of the study area.

3.1.2 Climate

Nakuru County has predictable weather patterns with temperatures ranging between 10°C during the cold months (July and August) and 20°C during the hot months (January to March). The county receives between 700 mm and 1200 mm of rainfall annually, with average annual rainfall being an approximated 800 mm. It has two rainy seasons; April, May and August (long rains) and October and December (short rains). The average altitude of the county is approximately 1850 metres above the sea level. The predominant soil type is loam formed from the volcanic activities (KNBS, 2015).

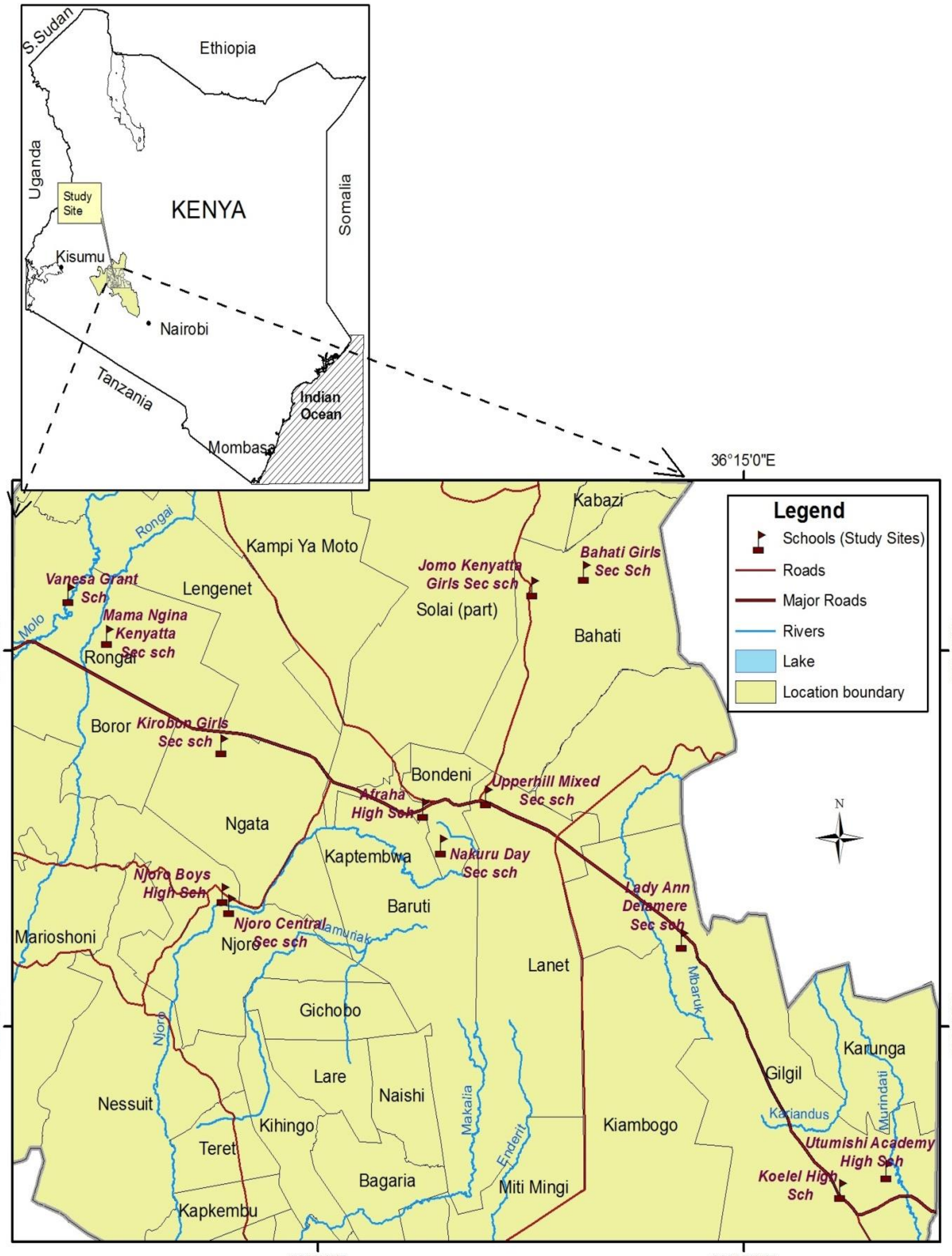


Figure 3.1: Map showing the study sites
Source: Survey of Kenya (2019)

3.1.3 Demographics and Socio-Economic activities

Nakuru County has a population of 1,603,325 people (50.2% males and 49.8% females) (KNBS, 2013). Small-scale agriculture, manufacturing and tourism are the backbone of the economy of Nakuru County. The area surrounding the Nakuru town is known for its vast agricultural potential with numerous small farms and also vast agricultural enterprises. The main crops grown around Nakuru and marketed in the town include coffee, wheat, barley, maize, and beans. These crops are stored in massive silos at the outskirts of the Nakuru town by the National Cereals and Produce Board and Lesiolo Grain Handlers Limited. The crops provide the primary raw material for the manufacturing industries found in Nakuru and Nairobi towns. These industries include flour milling and grain ginneries. Dairy farming is a key economic activity and provides the inputs for various milk processing plants around the town. Nakuru town is Africa's fastest growing town and the fourth in the world (Mubea and Menz, 2012). It is also a centre for various retail businesses that provide goods and services to the manufacturing and agricultural sectors. A large public market lies to the west of the town (USAID, 2015)

3.1.4 Distribution of Schools in Nakuru County

There were 900 primary schools (614 public and 286 private) and 334 secondary schools with 7317 primary school teachers and 7919 secondary school teachers (TSC, 2010; Wanjohi, 2013; Mbugua *et al*., 2015). Only sixteen secondary schools had fully implemented the use of whiteboards in the classrooms (Irungu, 2015). The teachers in the county were well distributed in all the schools (Ojwan'g, 2016) and therefore the teachers in the selected schools were representative of the teachers in the county. Implementation of the whiteboards in the secondary schools in the Nakuru County was ongoing with only sixteen schools having fully substituted the use of chalkboards with whiteboards. Some of the other schools had installed the whiteboards in some classrooms and were yet to complete installation in the remaining classrooms. Many had not started the installation of the whiteboards in their classrooms (Irungu, 2015).

3.1.5 The County's eye health burden

The Nakuru County eye health burden among the health seeking persons in the health facilities is 14,715 among the under-fives and 29,286 persons among the five and above years of age. This constitutes about 1.9% of all health conditions among the health seeking persons at all the health facilities in the Nakuru County. Naivasha Sub County has the highest burden with 16.3% and 21.2% of the entire County's eye health burden among the under-fives and five years and above age groups respectively (KNBS, 2015).

3.2 Research Design

The research design was Cross Sectional design using repeated measures. Exposure and non-exposure to whiteboard ink were used as the two treatments at the times of observations. Only schools which use whiteboards were considered for the study. The incidences of symptoms of allergic conjunctivitis among the teachers were determined at the end of the school term (term two of the school calendar) when the schools were doing their exams and not using the whiteboard marker inks. This was considered to be time one observation. The schools were then assigned into two groups based on how they scheduled their continuous assessment exams during the term. Those that suspended teaching during the midterm exams were placed in one group (Group A). The rest of the schools which did their exams during prep time and so did not suspend teaching during the midterm exams were placed in the second group (group B).

The second observation was made during the half term exam in the months of September-October (term three of the school calendar). At that time, one group (Group B) was exposed while the other (Group A) was not exposed. The third observation was made during the months of January- February (term one of the school calendar). During this third observation time, the two groups were observed during the teaching season when the two groups were both exposed to the whiteboard marker pen ink. The three observations could therefore be represented as in Figure 3.2. The teachers were divided into two groups to make it possible to have a group being observed in two different seasons without changing its exposure status. This would ensure that there is no interaction of seasonal factors with ink exposure when determining the seasonal variation of the incidences of symptoms of allergic conjunctivitis. Use of the same group allows each group to be its control so that the extraneous factors are held constant (Lawson, 2010).

The first observation was done when all the teachers were non-exposed while the third was done when all the teachers were exposed to allow the single group (all the teachers) to be its control during the two different exposure status (Lawson, 2010). The information from the two observation times (first and third) was to be used to establish the influence of exposure to ink on the development of symptoms of allergic conjunctivitis.

Use of repeated measures design allowed the group of teachers to control itself when testing for seasonal variations of the occurrence of symptoms of allergic conjunctivitis as well as the influence of the white board marker pen ink on the development of symptoms of allergic conjunctivitis. This ensured that the intervening factors were controlled for because they remained constant throughout the different observations (Gravetter, 2008).

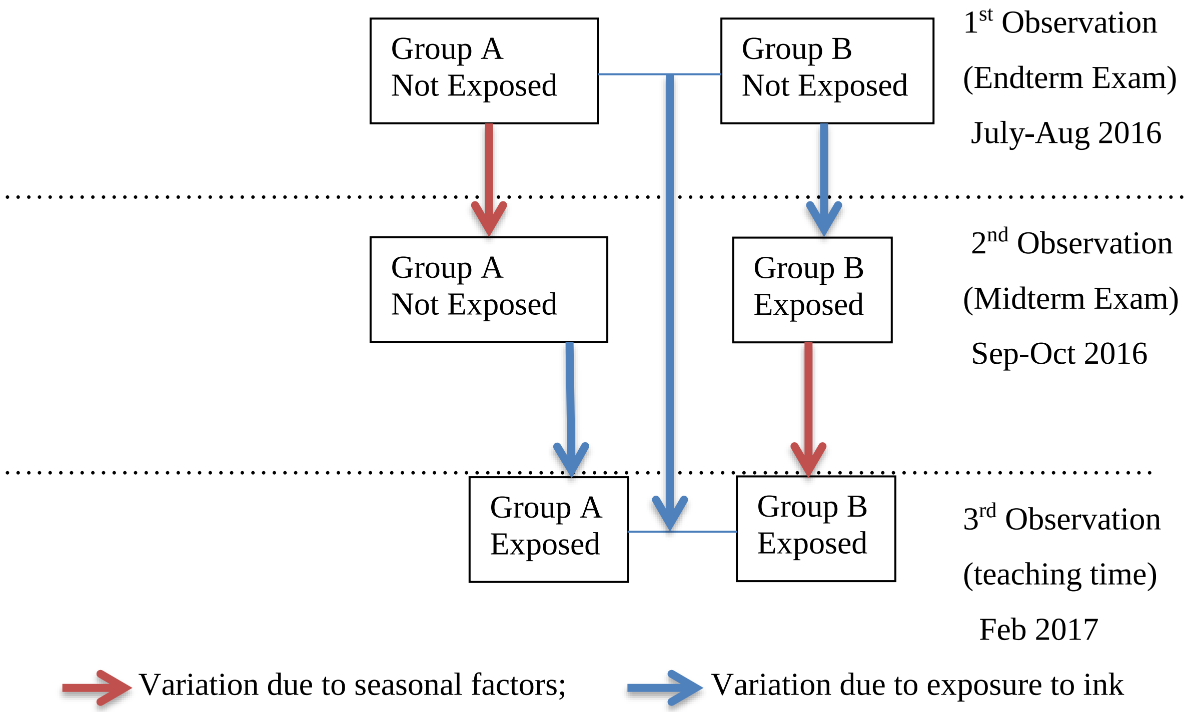


Figure 3.2: Flow chart of observations throughout the year

3.3 Study Population

The study population was composed of the teachers in the thirteen schools where whiteboard marker pens were used and not chalk. These schools had a population of 543 teachers (teachers' registers in the schools (TSC, 2010).

3.4 Sample Size

The general rule of thumb is to use as large sample as possible in order to enhance representativeness to the population (Kerlinger, 1983, Gall *et al*., 1996). The Fisher *et al.* (1999) formula was adopted for this study.

$$n = \frac{Z^2 pq}{d^2}$$

Where

n = the desired sample size

z=1.96 at 95% confidence level (C.L)

p=0.5 (since the prevalence of allergic conjunctivitis among teachers in the whole Nakuru County is not known)

q=1-p

d=significance level

$n = \frac{1.96^2 \times 0.5 \times 0.5}{0.05^2} \cong 384$Subjects

But since the study population is less than 10,000, the sample size was adjusted as follows

Adjusted $n' = \frac{n}{1+{n}/{N}}$ (Mugenda and Mugenda, 1999)

Where n'= Adjusted number of respondents

$n' = \frac{384}{1+{384}/{543}}$= 224 Subjects

The sample sizes of the different strata were determined using the proportionate stratification formula (Berman, 2016).

$$nh = (Nh/N)n$$

Where nh = sample size for the group which suspend teaching to do midterm exams (stratum h)

Nh= Population size for stratum h

N= Total population size

n= Total sample size

$$nh = \left(\frac{251}{543}\right) 224 = 103$$

$$224 - 103 = 121$$

≈ 103 teachers in the group that suspend teaching during monthly exams and 121 subjects in the group which does not suspend teaching to do monthly exams.

3.5 Sampling Design

The sampling design was stratified random sampling. The schools were already stratified into two groups based on how they schedule their midterm exams. The first category (Group A) was composed of those schools which schedule their midterm exams during the teaching time and therefore suspend teaching completely for five days. The other category (Group B) was composed of those schools which did their midterm exams outside the teaching hours and therefore did not suspend the teaching during midterm exams. Teachers in the selected schools were randomly and proportionately sampled to participate in the study (Table 3.2).

Two classrooms from each of the six schools close to Egerton University were sampled randomly and air samples collected for the determination of the concentration of the ink VOCs. Each of the six selected schools used only one of the three brands of ink with each ink brand being in use in two schools. These ink brands of ink were ink 1, ink 2 and ink 3. The air samples were collected at 1.5 m height above the floor which is the breathing level (Olumayede and Okuo, 2013), and also at 0.5 m height above the floor to establish the vertical distribution of VOCs in the classroom. These samples were collected at a distance of 30 cm from the centre of the whiteboard where the teacher is likely to spend most of his/her time during the lesson. More air samples were also collected at 8 m towards the back of the classroom because this is the average length of a Kenyan classroom (GoK, 2006). Sampling was done at the same heights of 1.5 m and 0.5 m above the floor to establish the horizontal spread of the ink VOCs in the classroom. The air samples were collected at 8a am before the lessons started, at 12.40 pm just before lunch break and at 2 pm before the afternoon lessons started.

Table 3.1: Sampling of teachers

Name of the school	**Established no. of teachers**	**Group**	**No.of sampled teachers**
Utumishi Boys Academy	56	A	23
Koelel Secondary School	87	B	36
Lady Ann Delamere Secondary School	19	A	8
Upper Hill Secondary School	28	B	11
Afraha Secondary School	58	A	24
Nakuru Day Secondary School	35	A	15
Njoro Central Day Secondary School	24	B	10
Kirobon Girls Secondary School	36	A	15
Mama Ngina Kenyatta Secondary School	65	B	27
Vanesa Grant Girls Secondary School	28	B	11
Jomo Kenyatta Girls Secondary School	17	A	7
Bahati Girls Secondary School	30	A	12
Njoro Boys Secondary School	60	B	25
Total	**543**		**224**

3.6 Research instruments

Only closed ended questionnaires for the school teachers were used to ensure that the respondents gave only the required information for the study. Some items had yes/no items followed by some open ended questions to give the respondents opportunity to provide their own answers (Peil, 1995). A Likert scale was also included to establish the attitudes and level of knowledge of teachers on the use of whiteboard marker ink. The questionnaires were as shown in appendix I. An observation checklist was used to collect information on the practices of the teachers related to the use of whiteboard marker pens as well as other subjective information such as the cleanliness of the classrooms (Appendix II).

A carbon dioxide sensor AZ-0004 was used to measure the concentration of carbon dioxide as well as the temperature in the classrooms. The composition of ink vapours was determined using an Agilent technologies 7820A gas chromatography machine using a DB 624 column with a length of 30 m, an internal diameter (ID) of 320 µm and a film thickness (DF) of 1.8 µm. The identity and concentration of the vapours in the classrooms were determined by use of gas chromatography (Dewulf *et al*., 2002) using a Varian 3400CX gas chromatography machine with non-polar columns. These were RTX-5MS with a length of 30 m, an internal diameter (ID) of 0.25 mm and a film thickness (DF) of 0.25µm and a chiral fused silica with a length of 25 m, an internal diameter of 0.25 mm and a film thickness of 0.12 µm. A flame ionization detector (FID) was used because it is very stable and it detects a very large number of VOCs (Sannik, 2013). The gas in the oven was hydrogen gas while the carrier gas was nitrogen gas. The samples were injected into the injector using 1 µl syringes. The air samples were collected using transparent polythene bags and the bags sealed at the site of sampling. The bags had an advantage that they were easy to use and they do not adsorb organometallic species like the metal canisters (Maillefer *et al*., 2003; Watson *et al*., 2012).

The non-polar columns were selected because they did not separate the VOCs mixtures in the ink but gave them in form of one peak. Only the mixture with the exact composition like that of the ink vapour gave the same retention time as the ink vapour. This made it possible to know those mixtures that contained only the components of the ink in the exact composition reducing the likelihood of including the ink vapours that had already mixed with other VOCs in the room exaggerating the reported concentrations. If the column separated the components, it would have been impossible to tell which of those components originated from the ink and which ones came from the other VOCs mixtures in the room. Also the study was based on the VOC mixture from the marker pen ink and not the separate specific components because the teachers were exposed to all of them together and not to individual compounds in the ink. Rösch *et al*. (2014) supports the study of mixtures of VOCs contrary to the study of individual VOC. Gas chromatography using a flame ionization detector (GC-FID) was used because it detects organic compounds with high sensitivity, a linear response and a low background noise (Sethi *et al*., 2013).

3.7 Reliability and Validity of research instruments

Pilot study was carried out at Solai boys and Patel day secondary schools which used whiteboards in the County. These schools were in the same County and therefore had similar environmental conditions with the study schools. The two schools were selected purposefully based on the availability and use of whiteboards. Ten teachers from the two schools were randomly selected to participate in the pilot study. The teachers were first explained to the importance of the study, confidentiality was assured and their consent was sought before participating in the pilot study. The questionnaires were then administered among the selected teachers and their responses assessed to establish whether they were consistent showing that the respondents had understood them. The items that showed lack of consistency were reconstructed accordingly and retested until they were consistent and had a Cronbach's alpha coefficient of 0.6 and above since it is considered as acceptable by many authors (Husain, 2014; Felizardo *et al*., 2016). Blooma *et al*. (2013) and Meghouar, (2016) say that Cronbach's alpha value of 0.5 and above is acceptable. Cronbach's alpha coefficient was calculated to establish validity and reliability of the questionnaires (Table 3.2). Samples were also collected from the pilot schools and taken to Egerton University Chemistry laboratory for analysis. This was to test the effectiveness of the column in analyzing of the air samples. The carbon dioxide sensor was also tested and found to be in good working condition indicating that factory calibration had been effectively done.

Table 3.2: Cronbach's Alpha values for items in the questionnaires

No. of items in the questionnaires	**Aspect being measured**	**Cronbach's alpha coefficient**
7	Symptoms of allergic conjunctivitis	0.8
11	Attitude of teachers on use of marker pens	0.7
7	Knowledge of teachers on ink safety	0.6

3.8 Data Collection

The questionnaires for teachers were delivered personally by the researcher to ensure that they reached the respondents. All through the filling of the questionnaires, the researcher was present to ensure that each teacher filled independently. The questionnaires collected information on social-demographic variables, occupational variables and self-reported information on the presence or absence of symptoms of allergic conjunctivitis. An observation checklist (Appendix II) was filled by the researcher while observing the practices of the teacher in class. The observation checklist also collected other subjective information from the school environment.

The air samples in the classrooms were collected using transparent polythene bags. The transparent polythene bag was opened at the point of sampling and flapped allowing the air to enter actively. The paper bag was then sealed, labeled, packed and transferred to chemistry laboratory at Egerton University for analysis. The air samples were collected at 8 am before the lesson started and then at 12.40 pm in all the selected classrooms. They were transferred quickly to the laboratory to prevent conversion before analysis (Environmental Health and Safety, 2015).

The conditions of the gas chromatography machine were such that the inlet temperature was 150 °C while the column temperature program started at 50.0 °C for 1.00 minute and was then ramped at 14.0 °C per minute until 120 °C was obtained. The column was kept at a constant flow of 1.6 ml/min and the detector temperature was set at 180 °C. The flow rate for hydrogen was 30.0 ml/min, for air was 400.0 ml/min, and the makeup flow of nitrogen was 25.0 ml/min (Forensic Scientist Manager, 2015).

First, a sample of the ink was placed in an evacuated tube using a syringe. The ink was warmed in water bath at 60 ^{o}C for 20 minutes to allow the headspace to reach equilibrium (Portari *et al*., 2008). The headspace vapours were then sucked using a syringe and dissolved in acetone, hexane and ethanol solvents. Chromatography was then carried out on these solutions. The temperatures at the injection, detector and column were 250 ^{o}C, 200 ^{o}C and 60 ^{o}C -150 ^{o}C respectively. The airflow rates of oxygen, hydrogen and nitrogen were 400ml/min, 40ml/min and 45ml/min respectively**.** The split ratio used was 100:1**.** The column temperature program started at 60.0 °C for 2.00 minute and was then ramped at 6.0 °C per minute until 150 °C was obtained. The area under the curve on the chromatogram of each of the components was used to determine the percentage composition of the components in the ink vapour. These percentages were used to estimate the concentration of each of these ink components in the classroom air samples.

More headspace vapour was collected using a 1µm syringe. The ink vapour was then injected into a chromatography machine with a non-polar column. The ink vapour eluted as one peak. The retention time of the peak was determined and considered to be the retention time of the ink mixture. This retention time was used to act as a standard to identify the ink mixtures in the different air samples from the classrooms. Those that had different components from that of the ink gave a different retention time from that of the ink vapour while those similar to the ink (originating from ink in the classroom) gave the same retention time as that of the ink vapour. The air samples from the polythene bags were sucked using a 1µm syringe by piercing through the polythene bag. The air sample was then injected directly into the chromatography machine as found in Cristescu *et al*. (2013) and Portari *et al*. (2008). Standard procedures such as use of blanks and standards were followed throughout the laboratory analysis of all samples.

The concentration of the vapours in the air samples (TVOCs) was determined by comparing the area under the peak with that of the ethanol with a density of 0.790g/cm^3 and a purity of 99.9%. Ethanol was chosen because it was found to be part of the mixture in the ink (Mølhave *et al*., 1997; Srivastava and Mazumdar, 2011) and because it showed a lot of consistency in its calculated response factor at different times of testing. The concentration of the ethanol used (amount) was 790,000mg/l.

$$\text{Response factor of the ethanol} = \frac{area\ under\ the\ curve}{amount}$$

$$\text{Amount of the VOCs} = \frac{area\ under\ the\ curve}{response\ factor\ of\ ethanol} \qquad \text{(Brevard et al., 2011)}$$

The carbon dioxide sensor AZ-0004 gave direct readings of the temperature in ^{o}C, carbon dioxide concentrations in ppm and the relative humidity in percentages. These readings were useful as an indication of the effectiveness of the classroom ventilations (HSE, 2000). This gadget was plugged into the power source and allowed to stabilize for at least 10 seconds (as recommended in the operational manual of the AZ-0004 before taking the readings.

3.9 Data Analysis

SPSS package was used to manage the data. Descriptive and inferential statistics were used to analyze data. Data was presented using tables, graphs and charts. The specific statistics used are summarized in Table 3.3.

Table 3.3: Data analysis summary table

	Objective	Variables	Statistics
1.	To establish the composition of the VOCs produced by the whiteboard marker ink	-Components in the ink vapour -% composition of the components in the ink	Percentages of the components of ink VOCs
		-Concentration of the ink VOCs in different classrooms	One way ANOVA
2.	To establish the vertical and horizontal distribution of the VOCs from the whiteboard marker ink in a school classroom	-Where the ink vapours are found in classroom	Means
3.	To determine knowledge, attitude and practice of teachers on the use of whiteboard markers	-Knowledge on ink safety	Percentages
		-Relationship between knowledge of science chemical safety and levels of good knowledge on ink safety	Chi-Square test
		-Attitude on the use of marker Pen	Percentages
		- Influence of Personal factors on the attitude on the use of marker pen	Chi-Square test
		-Practice of teachers on issues related to use of marker pens	Percentages
4.	To assess the influence of classroom factors on the occupational exposure levels of teachers to VOCs from the whiteboard marker ink.	Diurnal changes of Temperature and CO_2	One way ANOVA
		Influence of no. of students on concentration of CO_2	Pearson Correlation
		Influence of gender of students on concentration of CO_2	t-test for independent samples
		Relationship between CO_2 and concentration of VOCs	Pearson Correlation

		Relationship between temperature and concentration of VOCs	Pearson Correlation
5.	To assess the seasonal variations of symptoms of allergic conjunctivitis among the teachers	Trends in incidences of symptoms of allergic conjunctivitis through different seasons of the year	One way ANOVA of repeated measures -Percentages
6.	To assess the influence of the whiteboard marker ink on the development of symptoms of allergic conjunctivitis	Relationship between symptoms and	
		• Use of ink	- One way ANOVA for repeated measures
		• Ink brand	-Percentages -Chi-Square, Odds ratio and
		• Concentration of ink VOCs	-Regression analysis
		• Workload of teachers	-Regression analysis

3.10 Ethical Considerations

Permission was sought from all relevant bodies before embarking on the research. These bodies included the Egerton University School of post graduate, Bio-Ethics committee in Egerton University Research Extension Division, National Commission for Science, Technology and Innovation (NACOSTI), the Nakuru county commissioner and the Nakuru county director of Education (teacher management). Permission was also sought from the principals of the specific schools during the time of visit before approaching the teachers. Informed consent was requested of the respondents. For those who declined to participate, their decision was respected. The students in the visited classrooms were also explained to about the study before the air samples were collected in the classrooms. Confidentiality of the information from the respondents was ensured. This was ensured by having each teacher assign himself/herself a unique number which was not known to the researcher. This number was used to track the cases throughout the three times of observations but the information could not be traced to a specific teacher. Also, numbers were randomly assigned to the schools and classrooms studied so that the research results cannot be used to identify the schools and classrooms. The three brands of ink were randomly assigned numbers so that the detailed information obtained from their analysis cannot be traced to a specific brand of ink.

CHAPTER FOUR
RESULTS AND DISCUSSION

4.1 Socio-demographic characteristics of the respondents

There were 103 respondents in group A that suspended teaching during the monthly examination and 121 respondents in the group B that did not suspend teaching during the monthly time of examination. The table 4.1 is a summary of the socio-demographic characteristics of these respondents

Table 4.1: Socio-demographic characteristics of the respondents

Characteristic of teachers		**Group A**		**Group B**	
		n	**%**	**n**	**%**
Gender	Male	55	53.4	75	62.0
	Female	48	46.6	46	38.0
Age in years	18-24	15	14.7	19	16.0
	25-34	44	43.1	49	41.2
	35-44	15	14.7	29	24.4
	45-54	26	25.5	16	13.4
	55-60	2	2.0	6	5.0
Level of education	Degree	89	89.9	102	85.0
	Diploma	10	10.1	18	15.0
Marital status	Married	68	68.7	68	57.1
	Single	29	29.3	51	42.9
	Widowed	2	2.0	0	0.0

There were more male than female respondents. There were very few teachers in the age group 18-24 years. This can be explained by the prevailing employment practice in Kenya where there is no direct employment by the government for many young college graduates; they have to wait until a position falls vacant through retirement or natural attrition. There were very few respondents in the age bracket of 55 to 60 years. This may be explained by Kenya's policy on retirement whereby a public service employee is allowed to proceed on early retirement upon attainment of 50 years and above. (GoK, 2012). All the teachers in the sample had a diploma or above level of education. Further, there were more degrees than diploma holders in the study population. This could be attributed to the current TSC practice of engaging teachers that have received adequate training (diploma and above) and have been registered by the TSC to teach in Kenyan secondary schools (GoK, 2012). Most of the respondents (68.7% and 57.1%) were married. According to Kenya demographic survey of 2014, women are likely to marry at a mean age of 20.2 years while men are likely to get married at a mean age of 25.2 years (KNBS, 2014). Majority of teachers (85.3% and 84.0%) were above these ages. Age, gender and marital status are likely to influence the attitudes of the teachers on the use of whiteboard maker pen ink and in the process influence their practices which can contribute to their exposure to the ink VOCs.

4.2 Characteristics of the schools as a work place for the teachers

The selected classrooms were visited and their physical characteristics identified. The factors of the classroom considered included material used in constructing the classroom walls, the material used for roofing, the presence and absence of a ceiling, the size of the classroom, the type of ventilation, the size and direction of the windows, height of the windows relative to the desk level, density of the students in each of the classroom, the frequency of washing of the classrooms, the accessibility of water to the teachers who taught in those classrooms and the availability of a sink for the teacher to wash the hands. It was observed that the classrooms differed in many aspects indicating that there is no enforcement of the requirements of a standard classroom in Kenya. The failure in enforcement is attributed to lack of financial resources to upgrade the old classrooms to the current requirements (World Bank, 2008).

4.2.1 Buildings of the classrooms in the schools

The results showed that most of the classrooms walls (92%) were built using stones while only one of the studied classrooms had a wooden wall. Ten of the classrooms had a roof of iron sheet with only 2 having a roof made from asbestos sheets. Approximately 58% of the classrooms surveyed had a ceiling (Table 4.2).

Table 4.2: Buildings of the classrooms in the schools

Characteristic		**n**	**%**
Material that makes the Classroom walls	Wooden	1	8.3
	Stones	11	91.7
Roofing	Iron sheet	10	83.3
	Asbestos	2	16.7
Ceiling	Present	5	41.7
	Absent	7	58.3

The stone brick buildings were more popular than the wooden structures. Local resources, culture, climate and building traditions have significant effects on building design and construction (Seppänen and Kurnitski, 2009). However, all the classrooms had a lot of furniture made from wood. Wood is associated with increased levels of some type of VOCs because of the rotting wood and the use of wood preservatives (Annika, 2012). These VOCs can react with the ink VOCs resulting in new mixtures of compounds. Some classrooms (16.7%) had asbestos roofing in spite of the Kenyan government banning the use of the asbestos as a roofing material in 2006. This is an indication that the classroom was built before 2006 (Okoth, 2013). Asbestos is associated with cancer and the National Environmental Management Authority (NEMA) requires the government to replace all the asbestos on all the institutional rooftops (Okoth, 2013). However limited resources may hinder the process. Ngara and Magwa (2015) recommend the use of a ceiling where there is asbestos roofing to protect the teacher and the students from the asbestos fibers as a way to mitigate the effects of the asbestos roofing. The specific classrooms with the asbestos roofing were among the 58.3% classrooms that did not have a ceiling.

4.2.2 Windows of the classrooms

Among the studied classrooms, one classroom had permanently open type of ventilations on one side of the wall while the other 11 classrooms had operable ventilations in form of windows. The study found that 52.94% of the classrooms had the windows facing east and west while 47.06% had the windows facing south and north directions. The effective window area ranged from 1.122m^2 to 9.246 m^2 with classrooms in the same school having different effective window areas. These findings are summarized in Table 4.3.

Table 4.3: Windows of the classrooms

Classroom	Area of the classroom (RA) in m^2	Effective area of the window (WA) in m^2	% Window area relative to floor area ($\frac{WA}{RA} \times 100$)
1	79.56	4.323	5.4
2	77.19	4.365	5.7
3	75.20	1.122	1.5
4	74.70	4.365	5.8
5	66.83	1.683	2.5
6	64.50	4.294	6.7
7	64.50	2.872	4.5
8	63.99	7.222	11.3
9	63.57	6.992	11.0
10	54.90	6.019	11.0
11	54.11	4.780	8.8
12	52.32	9.246	17.7

Ventilations were all natural with windows acting as the main type of ventilations. The windows in the different classrooms differed in many aspects. Some faced south and north while others faced east and west. Those with windows facing east and west are likely to experience morning and evening glare of light especially for those that have low windows. Many of these windows were painted at the lower parts reducing the amount of natural light that penetrate into the classroom yet the regulation require that the classrooms should be properly lit (MoE, 2008). During the morning and evening light glares the windows are also likely to be closed to reduce the direct light interference reducing the ventilations (Yacan, 2014).

The windows facing south and north are not likely to allow direct light glare into the room and therefore the management of these ventilations may not be light dependent. Whether to paint or not to paint these windows depend on what is immediately outside such classrooms. Those that open to Walkways are likely to be painted to prevent the attraction of the students to the activities in the Walkways interfering with their concentration in the learning processes (Yacan, 2014). Those that open to a slanting field with plants and limited distance of view are likely to remain unpainted allowing sufficient light into the classroom (Yacan, 2014). In all the schools visited, the lower part of the windows at the desk level was painted. This is an indication that outside interference was common in those schools. Teachers are therefore likely to ask the students not to open these windows. This study found that 90% of windows facing a busy area that was likely to result in interference were not open during the visit.

The height of the windows was considered relative to the desk level. Five classrooms had low windows (at the level of the desk) on both sides of the classroom while 4 had low windows on one side and high windows (above the level of the door) on the other side. Only 3 had low windows on one side and a mixture of both low and high windows on the other side. The high windows were small and beyond the comfortable reach of the students. The students therefore tended to open and close the low windows to manage the temperature of the classrooms. The researcher found all of the high windows closed during all the visits.

Although the current building code in Kenya is silent on the size of the classroom windows (GoK, 2009), the Local Government (Building) By laws of 1968 required that the effective window area of a classroom should have an area not less than one fifth of the area of the classroom floor (GoK, 1968). This is further advocated for by the child friendly school manual which recommends that a minimum of 20% of the classroom floor area should be window area (UNICEF, 2009). All the classrooms visited had less effective area than the recommended 20%. It was not possible to compare the effectiveness of the ventilation based on the effective size because the researcher did not manipulate the opening and closing of the windows in the classrooms.

4.2.3 Size and density of the classrooms in the schools

The classrooms differed in the actual sizes even when found in the same school compound. There was only one school with a set of classrooms that had exactly the same size. These were found in a school which had relatively new buildings. However the size difference was not very big among the classrooms in the same school. All the classrooms had a size larger than the recommended one (43.875m^2or 45.0 m^2) (MoE, 2008). The number of students per classroom was different resulting in different densities in the classrooms. However, 80% of the classrooms had densities which were within the recommended range of 0.684 and 0.889 students per m^2 (MoE, 2008). Table 4.4 summarizes these findings.

Table 4.4: Size and density of the classrooms in the schools

Classroom	Area of the classroom (RA) in m^2	No. of students (NS)	Density ($\frac{NS}{RA}$)
1	79.56	40	0.5030
2	77.19	51	0.6607
3	75.20	62	0.8244
4	74.70	50	0.6690
5	66.83	64	0.9577
6	64.50	47	0.7290
7	64.50	54	0.8370
8	63.99	55	0.8590
9	63.57	25	0.3930
10	54.90	54	0.9836
11	54.11	56	1.0340
12	52.32	41	0.7830

The sizes of the classrooms ranged from 49.46m^2 to 79.56 m^2 indicating that all of the classrooms had attained the minimum required sizes of 43.875m^2 (7.5m x 5.85m) or 45.0 m^2 (7.5m x 6.0m) as provided for in the regulation (MoE, 2008). Different classrooms in the same school had different enrolment. This could be due to dropping out of students in the course of the studies. It could also be due to differences in the preferences of students in certain subjects which are considered as optional in the upper classes in the secondary schools. This coupled with the differences in the sizes of classrooms resulted in different densities in the different classrooms. The recommended density is 0.684 or 0.889 students per

m^2 (MoE, 2008). The densities ranged from 0.5030 to 1.0340 students per m^2. Only three classrooms (0.9577, 0.9836 and 1.0340) had densities above the recommended ones.

The numbers of students as well as the density in a classroom influence the arrangement as well as the amount of furniture in the classroom. This may influence the pattern of distribution of VOCs as well as their concentration and lifetime at specific parts of the classroom. This is because some of this material in the classroom may allow sorption of the VOCs and in the process act as a sink for these VOCs reducing the concentration but later re-emitting the same back to the room when VOC production reduces (Meininghaus *et al*., 2000; Kim, 2008; Ho *et al*., 2011).

4.2.4 Cleanliness in the schools

Only 16.7% of the classrooms observed were washed daily although all the classrooms studied were in schools where water was accessible. Fifty percent of the classrooms were in schools that had sinks for washing hands. The Table 4.5 summarizes these results.

Table 4.5: Cleanliness in the schools

Characteristic		**n**	**%**
Frequency of washing of classrooms	Daily	2	16.7
	Twice a week	2	16.7
	Weekly	8	66.6
Accessibility of water in schools	Yes	12	100
	No	0	0
Presence of a sink	Yes	6	50.0
	No	6	50.0

Although water was available in all the schools, 66.6% of the schools washed the classrooms only once a week. This is an indication that the frequency of washing of the classrooms depended on the tradition and policy of the schools but not on the availability of water. Washing the classrooms daily reduces the accumulated dust in the classrooms since the dust is very common in Nakuru County (KNBS, 2015). The accumulated dust may also get into the air increasing the particulate matter in the air which can be inhaled or get into the eyes of the occupants (WHO, 2013; Lazović *et al*., 2015). Washing also reduces the concentration of some VOCs in a classroom (Zhong *et al*., 2017) because some may dissolve in the water (Görgényi *et al*., 2005). The cleaning agents can also be a source of other VOCs (Rösch *et* *al*., 2014). If cleaning is followed up with good ventilation, the concentration of VOCs emitted by the cleaning agents may reduce through dilution as well as escaping to the outside from the classrooms (Morawska *et al*., 2009; Salthammer and Bahadir, 2009).

Availing of the water in the schools was in line with the requirements of the Employment Act of 2007 which requires that the employer provide wholesome water to the employees at the work place. The population of schools with water had also increased from 27.8% (Muchemi, 2011) to 100%. This could be as a result of the national development towards achieving sustainable development goal number six on availability and sustainable management of water and sanitation for all (Republic of Kenya, 2007). Sinks encourage the washing of hands especially if they are clean and placed in strategic positions (Chittleborough *et al*., 2013). Cleaning hands may reduce the likelihood of transferring the marker pen ink into the eyes of the teachers who rub the whiteboard with bear hands. However, 90% of the teachers in schools where sinks are found did not wash the hands every time they left the classrooms. This could be due to the fact that a majority of the teachers (76.1%) believed that the use of marker pen did not make them dirty.

4.3 Composition of the VOCs produced by marker pen inks used at schools

Three different brands of marker pen ink were found to be in use in the schools studied. These were ink 1, ink 2 and ink 3. The three brands were sold in small bottles and each bottle was placed in a small box. All of the three brands did not have the material safety data sheets in the boxes. This agrees with Suleiman and Svendsen (2014) who found that many suppliers of commodities are less conscientious when it comes to informing users on health risks. The composition of the VOCs from the marker pen inks were studied in terms of the actual components in the ink vapour as well as their concentrations in the air samples.

4.3.1 Actual components of the ink VOCs

The components of the VOCs of the marker pen inks were determined using gas chromatography using a polar column that was able to separate the components of the ink vapours. Figures 4.1 to 4.13 show the chromatograms obtained.

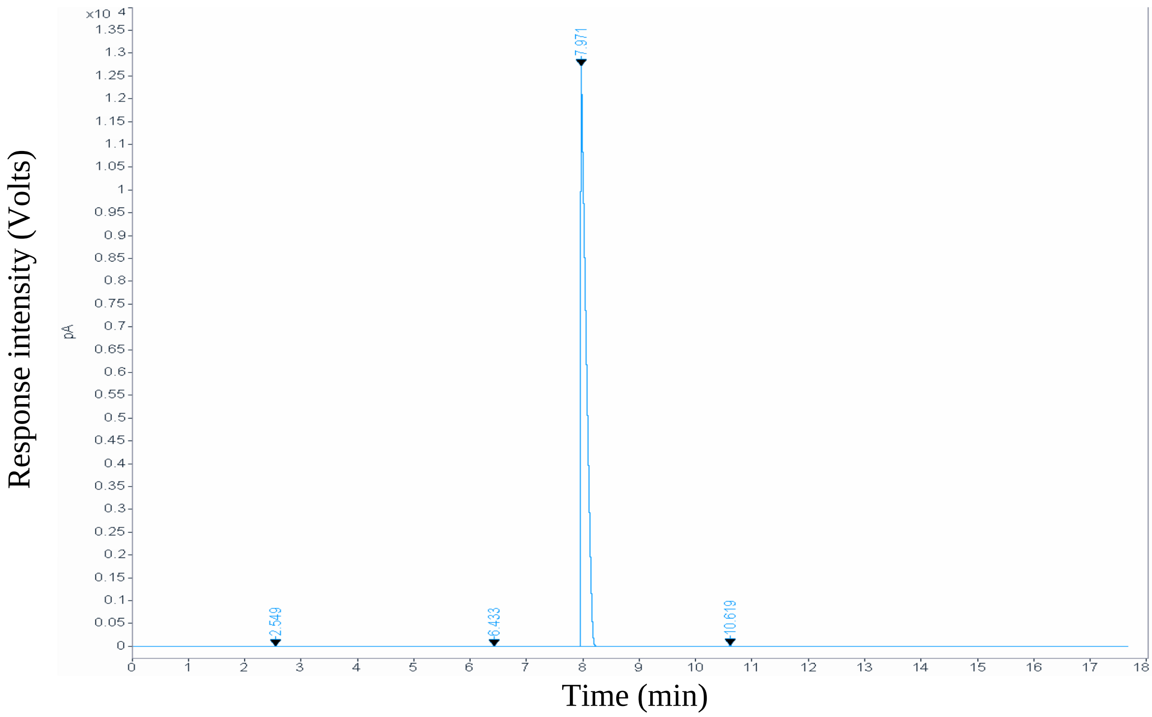


Figure 4.1: Ink 1 vapour in acetone

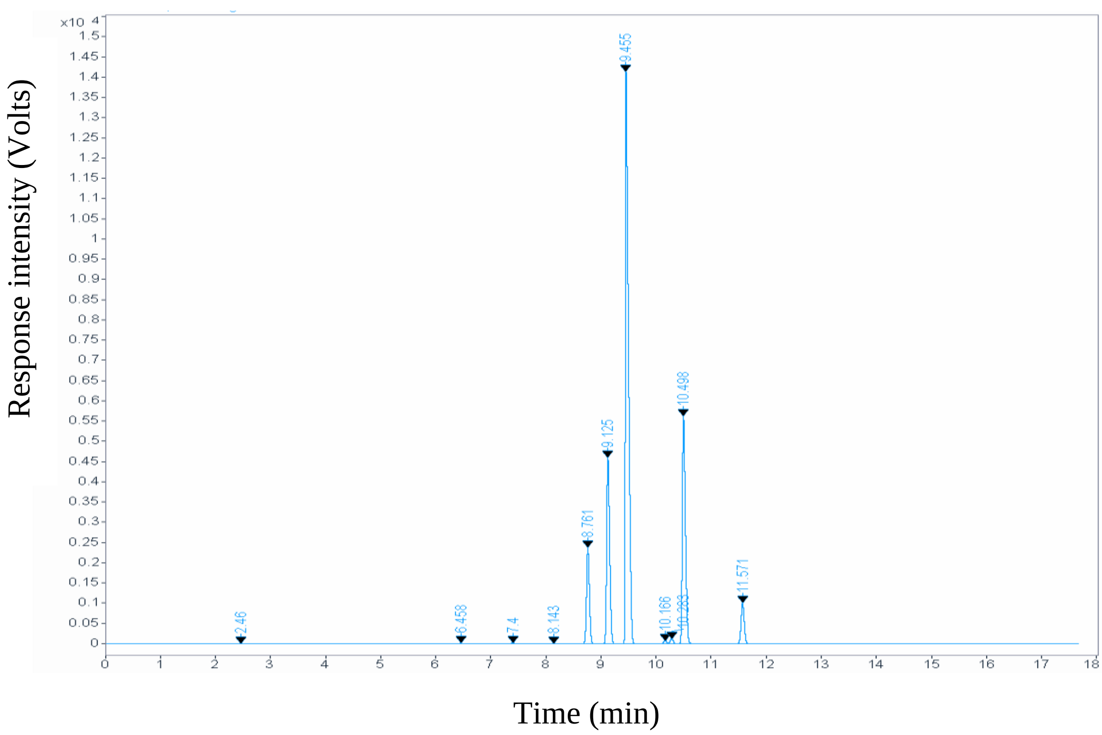


Figure 4.2: Ink 1 vapour in hexane

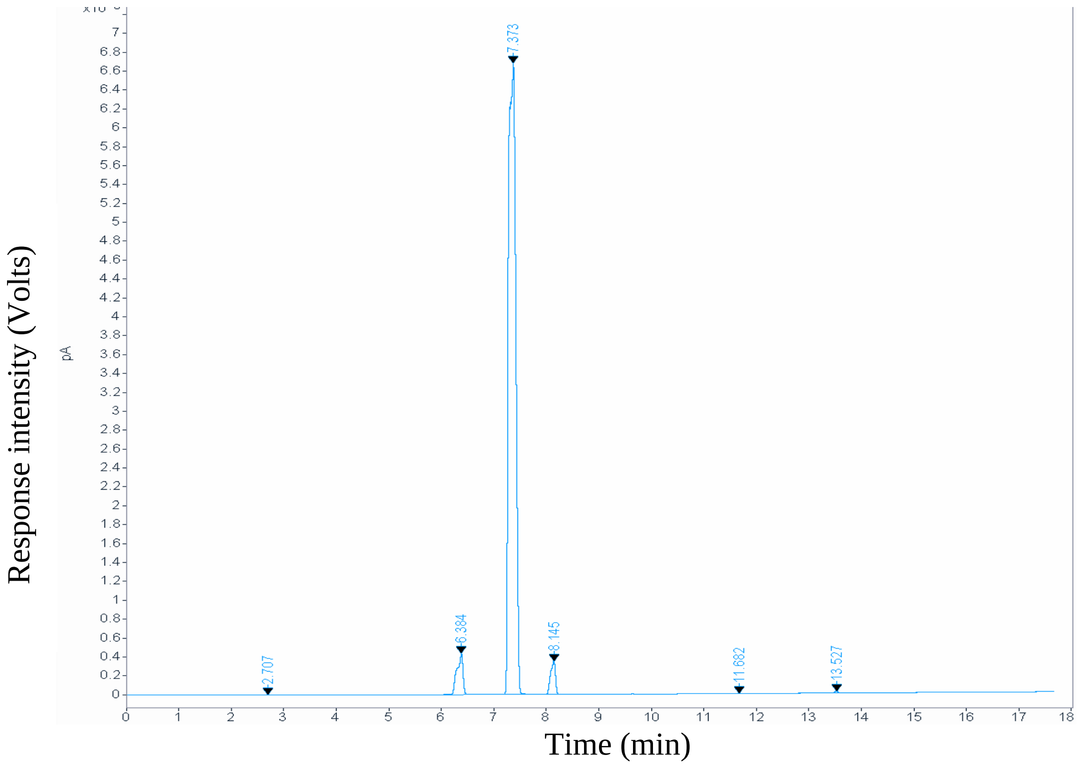


Figure 4.3: Ink 1 vapour in ethanol

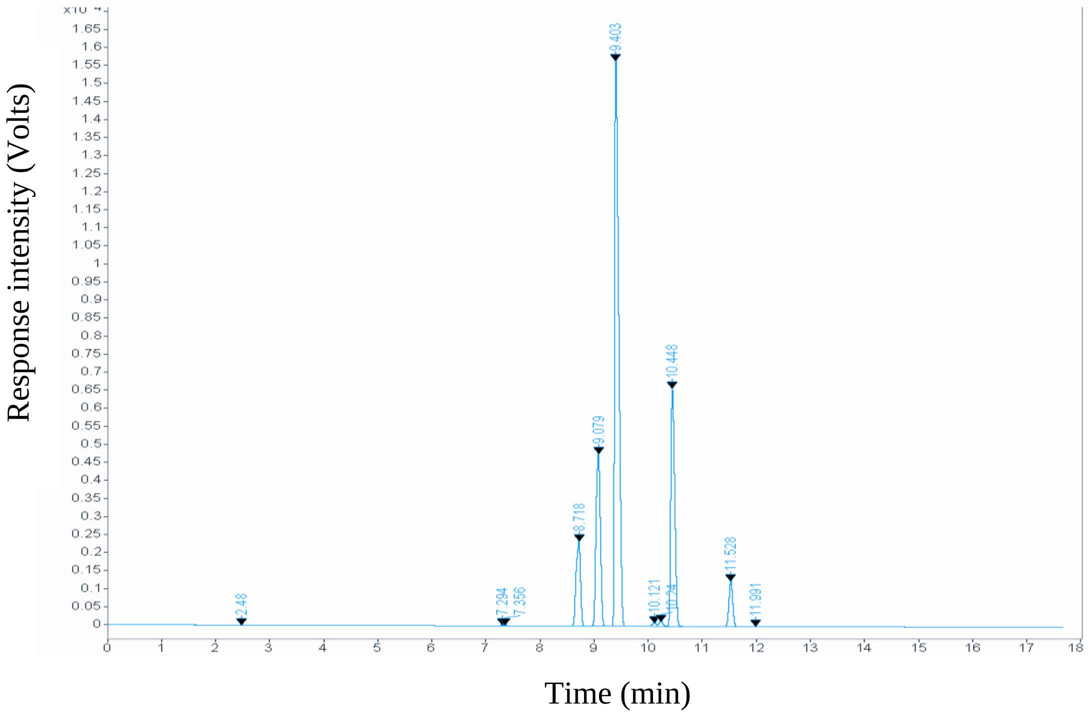


Figure 4.4: Hexane

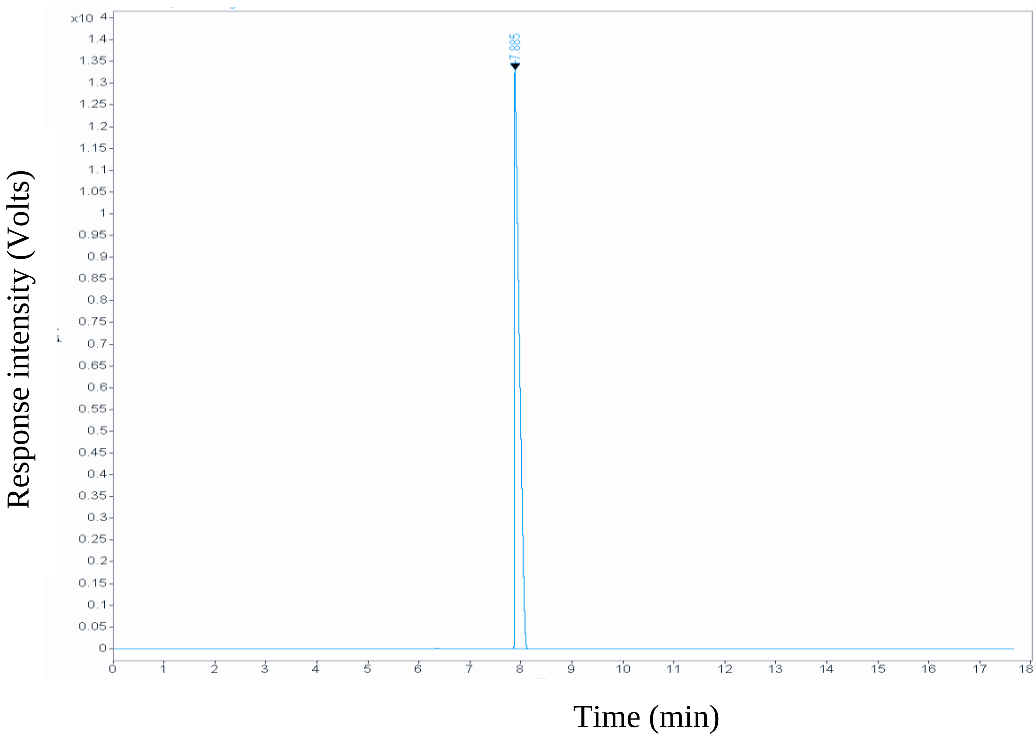


Figure 4.5: Acetone

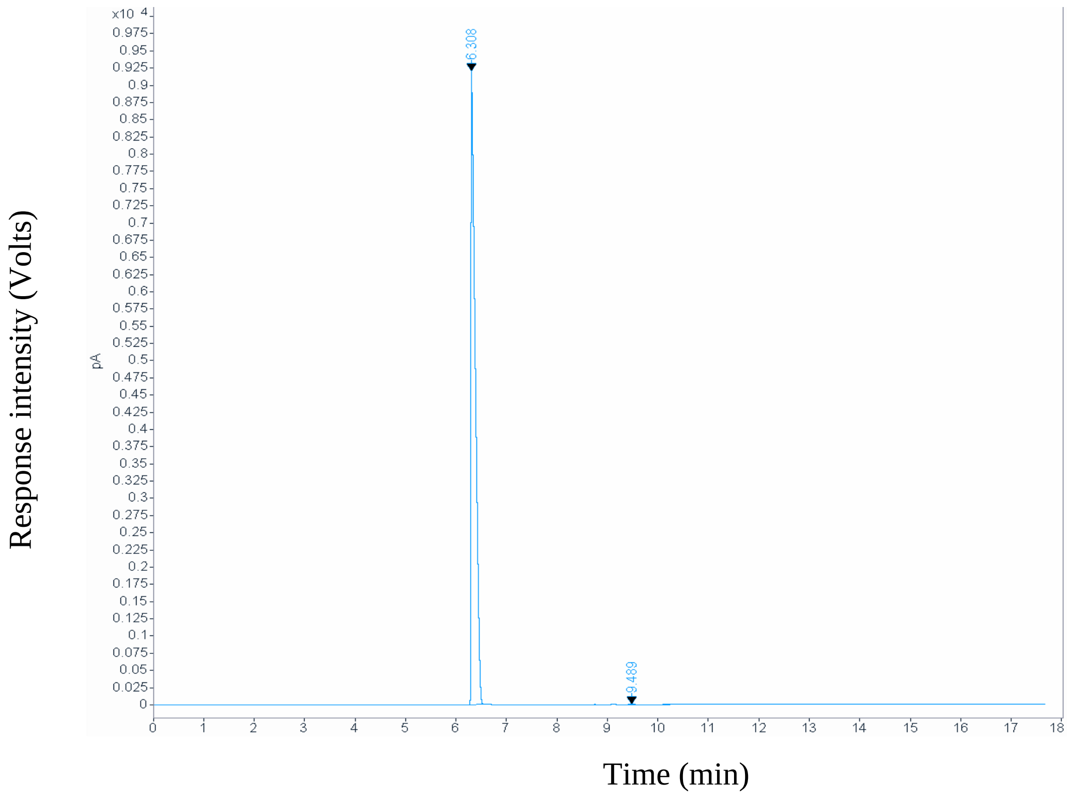


Figure 4.6: Methanol

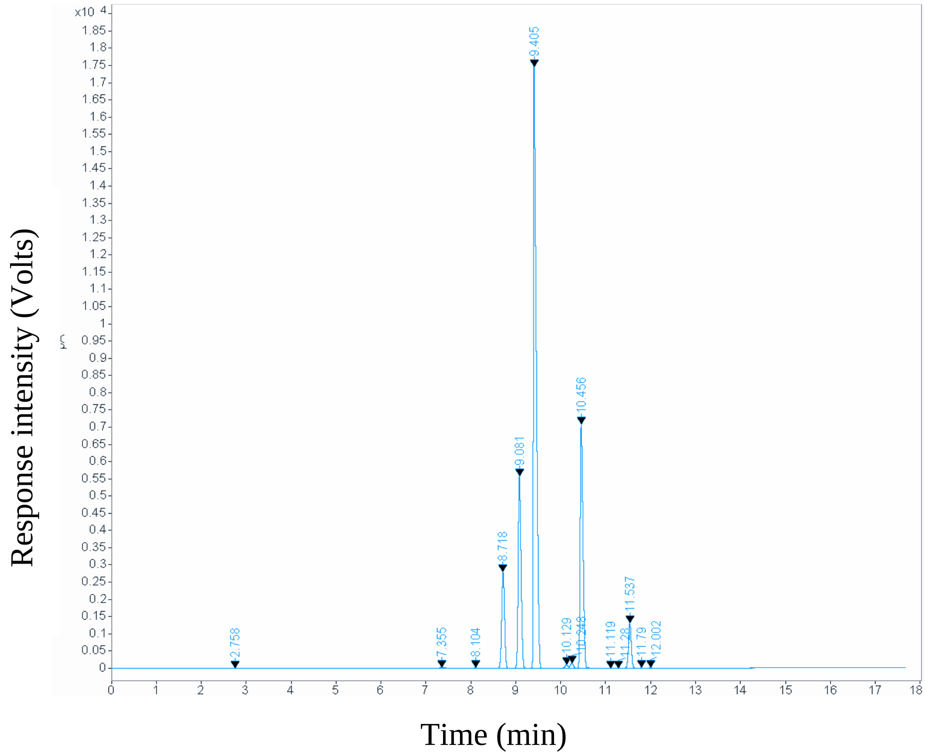


Figure 4.7: Ink 2 vapour in hexane

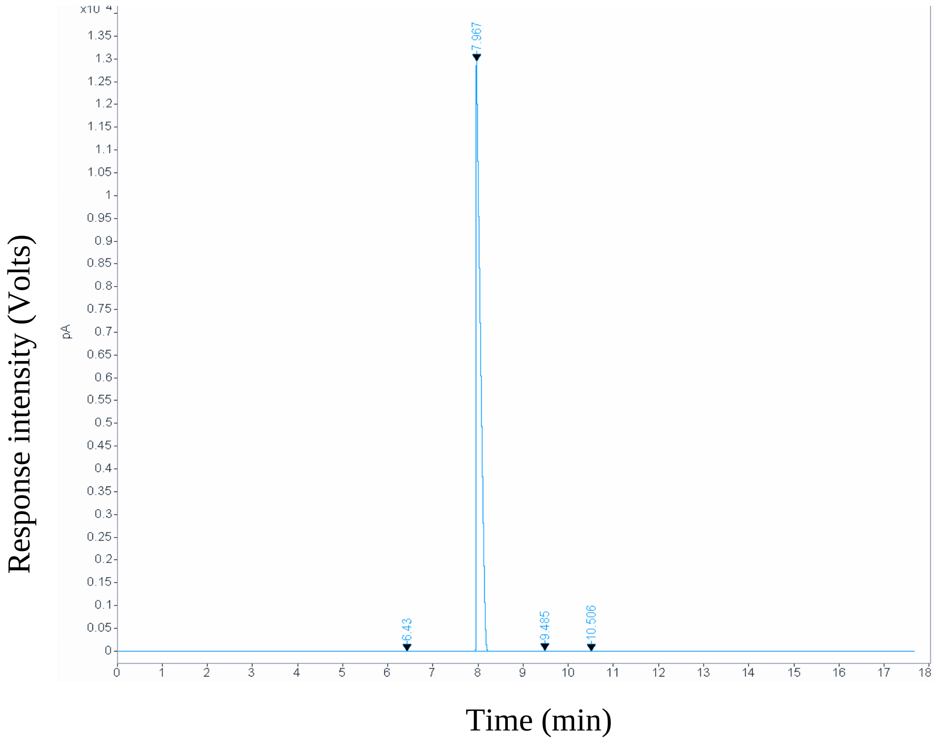


Figure 4.8: Ink 2 vapour in acetone

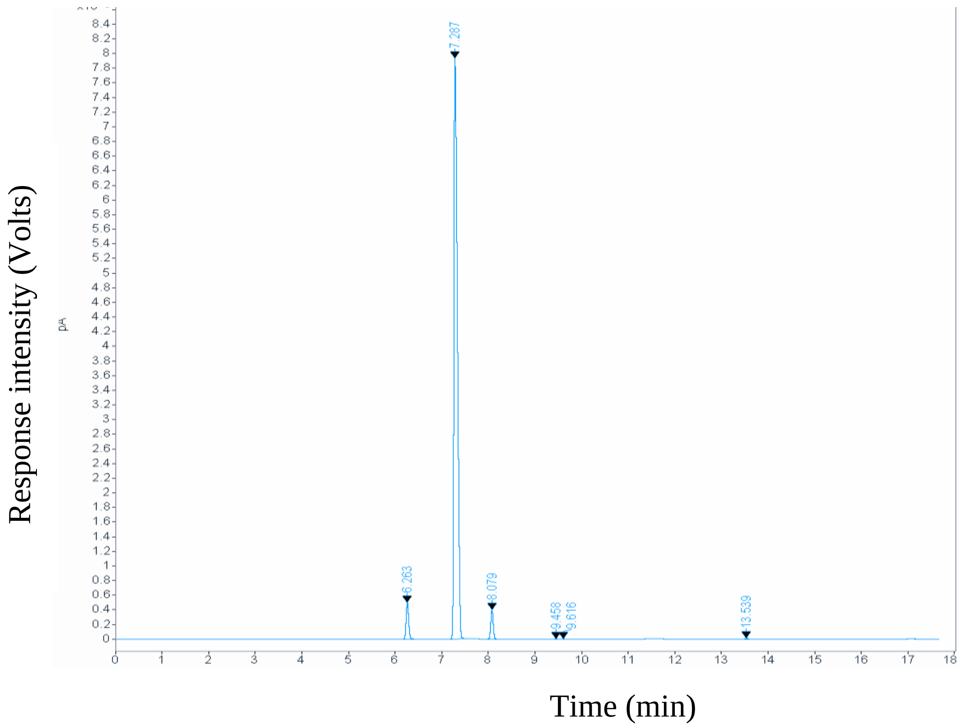


Figure 4.9: Ink 2 vapour in ethanol

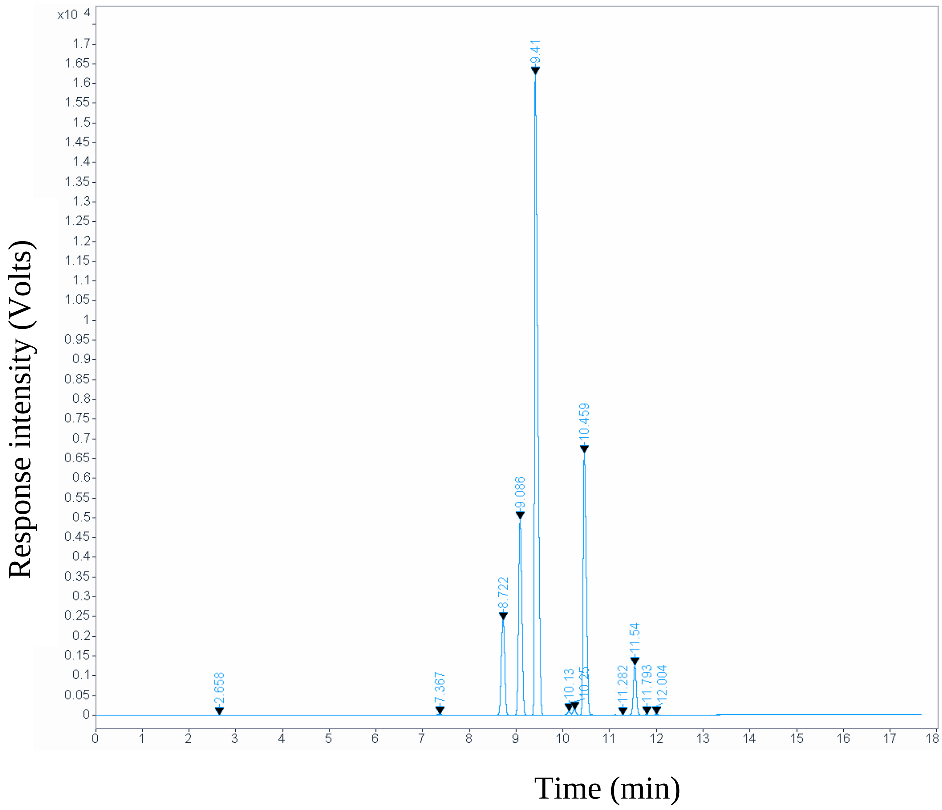


Figure 4.10: Ink 3 vapour in hexane

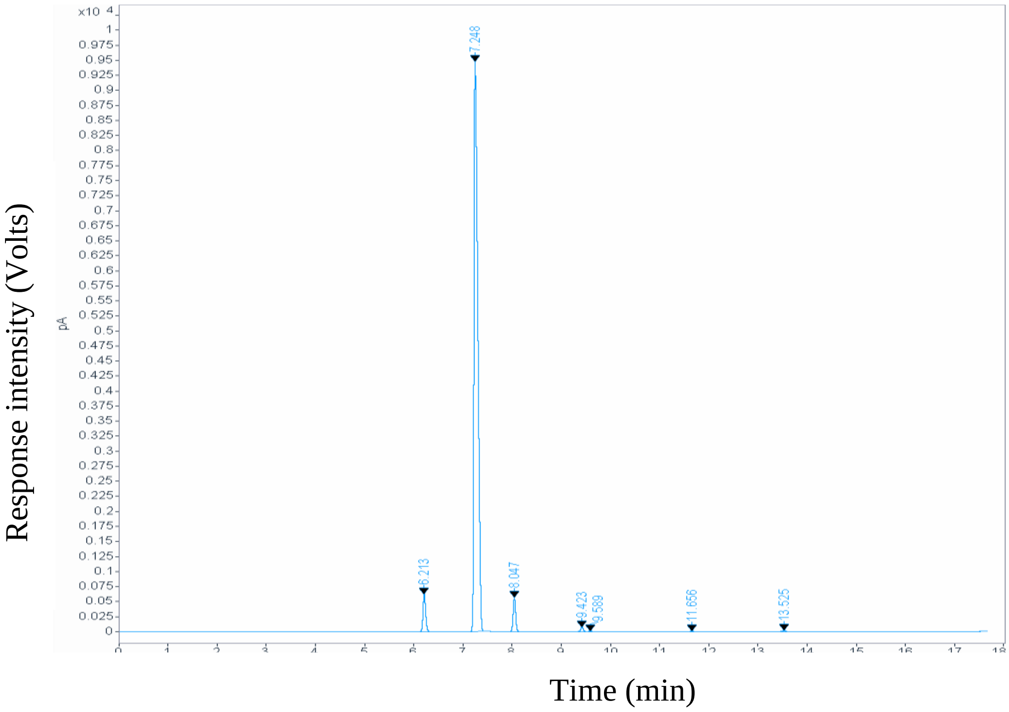


Figure 4.11: Ink 3 vapour in ethanol

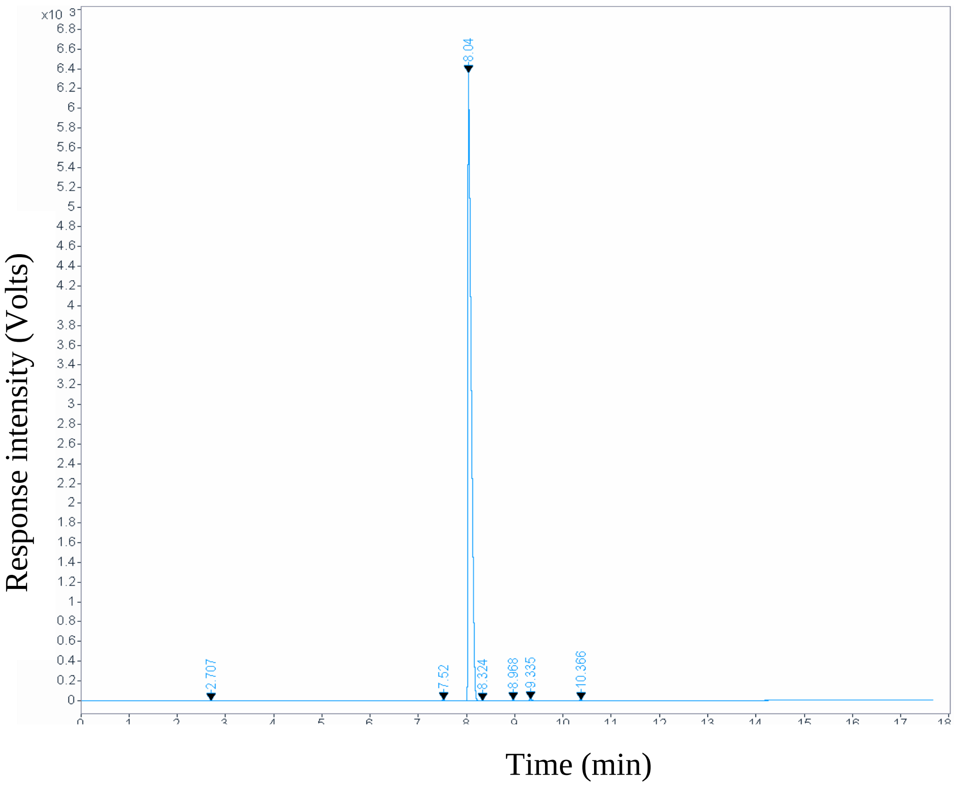


Figure 4.12: Ink 3 vapour in acetone

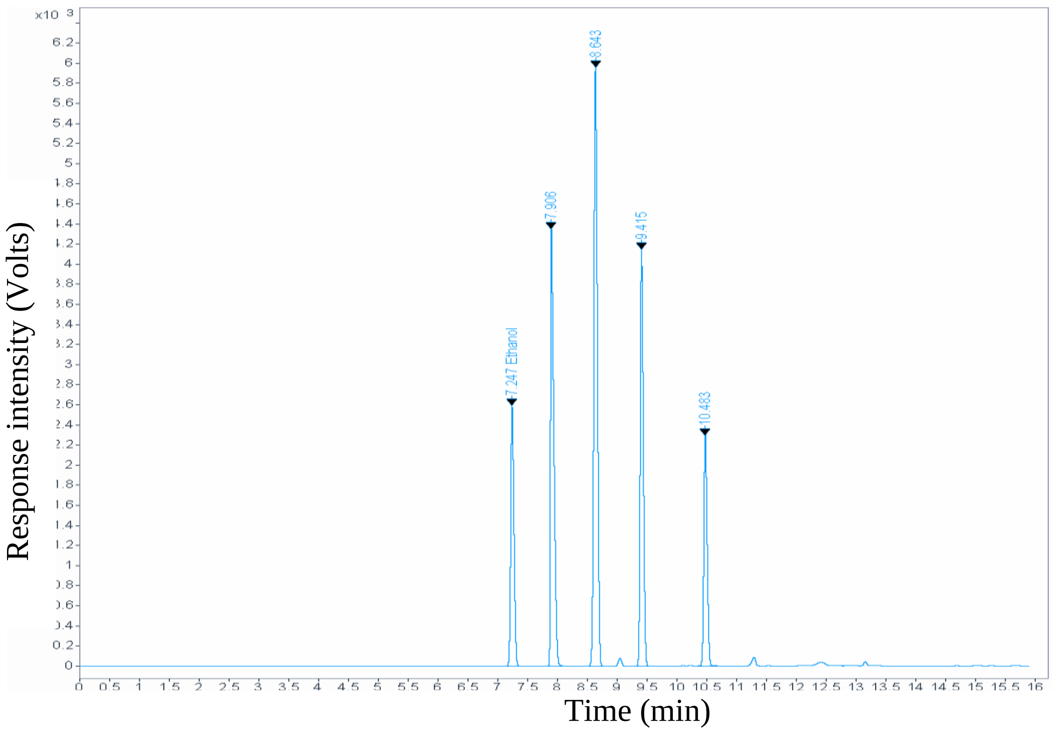


Figure 4.13: Ethanol and other solvents

The results indicate that the vapour from the first ink had methanol and acetone. The vapour of the second ink had acetone and hexane while the vapour of the third ink had ethanol and hexane. These components had easily evaporated from the ink when it was placed in a water bath at 60 ^{o}C. This means that these components have a low boiling point and they easily evaporate at the normal classroom temperature. Uhara *et al*. (2009), Cantú (2012) and Cantú (2015) say that when ink writings are exposed to the air, the solvents in them evaporate and this makes the writing to dry. In the process, they contaminate the classroom indoor air.

These result findings agree with research study carried out by Anderson and Anderson (2003) who carried out gas chromatography on emissions of felt pens and whiteboard cleaners. He found that they contained a mixture of alcohols, acetates and ketones. Castorina *et al*. (2016) measured emission rates of VOCs of different markers under controlled laboratory conditions and found that alcohols were the most highly emitted class of VOCs from dry erase markers.

The percentage composition of the components in the ink vapour was calculated based on the area under the curve for each component. The results indicate that the quantities of the different solvents in each of the ink were different with ink 1 having more methanol than acetone. Ink 2 had more acetone than hexane while ink 3 had a very high percentage of hexane (Table 4.6).

Table 4.6: Percentage composition of ink vapour

Solvent		Acetone	Hexane	Methanol	Ethanol	Total
% of solvent in the ink vapour	Ink1	40		57.9		97.9
	Ink2	50.1	49.9			100
	Ink3		73.8		26.2	100

When the ink vapours were run through a gas chromatograph using a non -polar column, single peaks eluted. These peaks were compared with those obtained from air samples from the schools using each of the ink brands for identification. All the peaks of both the ink vapours and air samples were well shaped and well resolved (Appendices V, VI, VII, VIII, IX and X). The retention times and shapes of the peaks were compared to confirm the identity of the air samples from the classrooms.

The retention times fluctuated at the different times of analysis. This agrees with the findings of Portari *et al.* (2008) and Cristescu *et al*. (2013) who found that manual sampling resulted in inconsistencies of the retention times. Portari *et al*. (2008) analyzed air samples containing ethanol, acetaldehyde and acetone. He did five runs of each of the analyte sample and found different retention times. On the other hand, Cristescu *et al*. (2013) previewed literature and found that the manual injection of the analyte into a gas chromatograph results in different retention times making it not easily reproducible. However, Portari *et al*. (2008) quotes the criteria of the International Conference on Harmonization (ICH) to state that the different retention times are acceptable if the coefficient of variation (CV) does not exceed 15%. In this study, the retention times were within this range (Table 4.7) and therefore they are acceptable. It is an indication that these air samples (appendices VI, VIII and X) contain the ink vapours (V, VII, IX) in them because their retention times were all within the ink vapour CV of less than 15%.

Table 4.7: Retention times of ink and air samples

Ink	Mean of t_R of pure ink vapour (minutes)	Acceptable range of t_R (minutes) (CV%=15%)	Observed range of t_R for air samples (minutes)	Observed (CV %)
1	0.9580	0.814-1.102	0.944-0.979	1.5-2.2
2	0.9613	0.817-1.105	0.941-0.989	2.1-2.9
3	0.9664	0.821-1.111	0.955-0.984	1.2-1.8

There were 30 different mixtures of VOCs (based on the different retention times) that were encountered in the classrooms. These could have been formed when the ink VOCs mixed with the other VOCs present in the classrooms. Chatzidiakou (2012) in an extensive review of published evidence reported that benzene, toluene, trichloroethylene (T3CE), tetrachloroethylene (T4CE), pinene, limonene, naphthalene and formaldehyde were commonly present in educational environments. These can mix with the ink VOCs as they spread in the classroom forming new VOC mixtures. Mira *et al.* (2016) found that the VOCs in a room easily mix forming mixtures. The new mixtures of ink and other VOCs increase the likelihood of eye irritation occurring because mixing VOCs increases the sensory detection and reaction (Nielsen *et al*., 2007).

Some VOC mixtures (18) were common occurring in two or more parts of a classroom or in more than one classroom. The similarity in the type of mixtures in different classrooms is an indication that the VOCs that mixed with ink VOCs originated from the environment in which the classrooms were found or from use of common products such as cleaning agents (Dunagan *et al*., 2011; Chin *et al*., 2015; Zhong *et al*., 2017). It could also indicate the presence of similar biological VOCs from healthy individuals in these classrooms since the normal physiological processes result in some specific products (Mazzatenta *et al*., 2015).

Some VOC mixtures (12) were found only once at one part of a classroom. This indicates the presence of unique VOCs at the specific part of the classroom. This could be a result of interactions between ink VOCs and those from human individuals in the classrooms. Individual differences in terms of health status may result in unique mixtures since the exhaled VOCs are influenced by the diseases present in the human body (Probert *et al*., 2009). Some students may also use unique personal products which can emit some VOCs. The between the schools differences is an indication that some of the VOCs originated from the environments where the different schools were located. Zhong *et al*. (2017) says that environmental sources of VOCs are responsible for interschool variation.

4.3.2 Concentration of ink vapour components in the air samples

The concentration of ink vapour in the air samples was determined by comparing the area under the curve with the area under the curve of ethanol which was used as an external standard. Since the ethanol gave different areas at different times of analysis (Table 4.8), the average response factor was calculated and was then used to calculate the concentration of the ink vapours in the air samples. The chromatograms of ethanol at different times are in Appendix IV.

Table 4.8: Calculated response factors for ethanol

Volume of ethanol used(μl)	Area under the curve (counts)	Calculated response factor for 1μl volume $\frac{area\ under\ the\ curve}{amount\ in\ ppm}$
1.0	6496597	8.224
1.0	6535961	8.273
1.0	6593618	8.346
1.0	6168599	7.808
0.1	599925	7.594
0.1	591990	7.493
0.1	615594	7.779

The human errors during the sampling and injection as well as the errors in the accuracy of the different syringes may have resulted in the slight differences in the calculated response factors. Internal parameters of the machine (Peri *et al.*, 2010) as well as the differences between the two columns used at the different times contributed to the differences in the calculated response factors. The final response factor was obtained by averaging the response factors and was found to be 7.931.

The average concentration of ink VOCs in the air samples from the classrooms that used ink 1 was 261.3 ppm and the highest concentration encountered was 754.9 ppm. The highest concentration of ink VOCs encountered was 16843 ppm and756.8 ppm in the classrooms that used ink 2 and ink 3 respectively. Table 4.9 summarizes these findings.

Table 4.9: Concentration of ink VOCs in the classroom

Ink used in the classroom where air was sampled	Concentration of ink VOCs in the air samples (ppm)			
	Max	Min	Mean	Median
Ink 1	754.9	50.7	261.3	181.8
Ink 2	16843.3	69.6	1986.4	143.0
Ink 3	756.8	58.1	249.4	166.1

The concentrations of the VOCs mixtures of ink vapour in air samples from the classrooms were used to calculate the concentration of each of the different ink components in the air sample. These concentrations were compared with the acceptable exposure limits (Table 4.10). These were threshold limit values (TLV), recommended exposure limits (REL) and permissible exposure limits (PEL). These are limits which have been outlined by different mandated bodies in order to ensure that the worker is safe at the work place (CDC, 2016). Different terms are used by the different regulatory bodies as indicated in Table 4.10. All these limits are expressed as time weighted average (TWA) or short term exposure limit (STEL). STEL as a limit ensure that a worker is not exposed to dangerous levels of a hazardous compound for a long time to prevent the worker from suffering from irritation, chronic or irreversible tissue damage. There is no STEL values for very dangerous chemicals indicating that the provided limits should not be exceeded. A TWA is the average exposure over a specified period usually eight hours (CDC, 2016).

Table 4.10: Concentration of solvents in the air samples

Solvent	Concentration (ppm) in air samples of ink						Exposure Limits					
	Ink 1		Ink 2		Ink 3		ACGIH (TLV) TWA	ACGIH (TLV) STEL	CAL/ OSHA (PEL) TWA	CAL/ OSHA (PEL) STEL	NIOSH (REL) TWA	NIOSH (REL) STEL
	Highest	Average	Highest	Average	Highest	Average						
Acetone	301	105	8438	995			250	500	500	750	250	
Methanol	437	151					200	250	200	250	200	250
Hexane			8404	991	558	184	50		50		50	
Ethanol					198	65	1000		1000		1000	

Acetone and hexane in the air samples from schools that used ink 2 were found to be at higher concentration than the recommended exposure levels. However, the average concentration of acetone in the air samples from schools that used ink 1 was within the acceptable range. Although the average concentration of methanol in the air samples from schools that used ink 1 was within the acceptable range (TWA), the highest concentration encountered was higher than the STEL, (CDC, 2016). These results indicate that the concentrations of most of the components in the air samples were higher than the acceptable levels. But since the components did not exist individually but were found as a mixture in the air samples, the concentration of the mixture of the VOCs was also compared with the threshold of recommended concentrations of TVOCs.

The results show that 50.0% of the studied schools had VOC concentrations exceeding 200µg/m^3 which is the threshold of discomfort and distinct acute health issues (Salthammer, 2011). The overall ink vapour concentration in the classrooms ranged from 50.7 ppm to 16843.3 ppm with an average concentration of 758.65 ppm. This agrees with Daisey *et al*. (2003) who, in an extensive review of published evidence, reported higher average TVOCs concentrations than 200 $\mu g/m^3$ in three US and 47 European schools.

There was variation in the concentrations of the vapours in the air in the different classrooms (SD=2991.424). However there was no association (p=0.425) between the ink brand and the concentration of ink VOCs in the classrooms (Table 4. 11).

Table 4.11: Comparison of mean concentrations of VOCs from different ink brands

	Sum of Squares	df	Mean Square	F	Sig.
Between Groups	15929715.802	2	7964857.901	.882	.425
Within Groups	252944114.240	28	9033718.366		
Total	268873830.041	30			

This is an indication that the three different ink brands did not differ significantly in their rates of emission of VOCs and that the variation in the concentration of vapours in the different classrooms was due to the variations in classroom occupants' behavior. Some teachers wrote more than others producing more ink vapours while some classrooms had most of their windows open. The opening and closing of the window is based on thermal comfort of the classroom occupants (Lazović *et al*., 2015). The occupants are likely to close the windows during cold weather and open during the hot weather resulting in high and low concentrations of VOCs respectively.

When the concentration of ink VOCs in the two categories of classrooms was compared, the girls' classrooms were found to have higher concentration than the boys' classrooms (Figure 4.14).

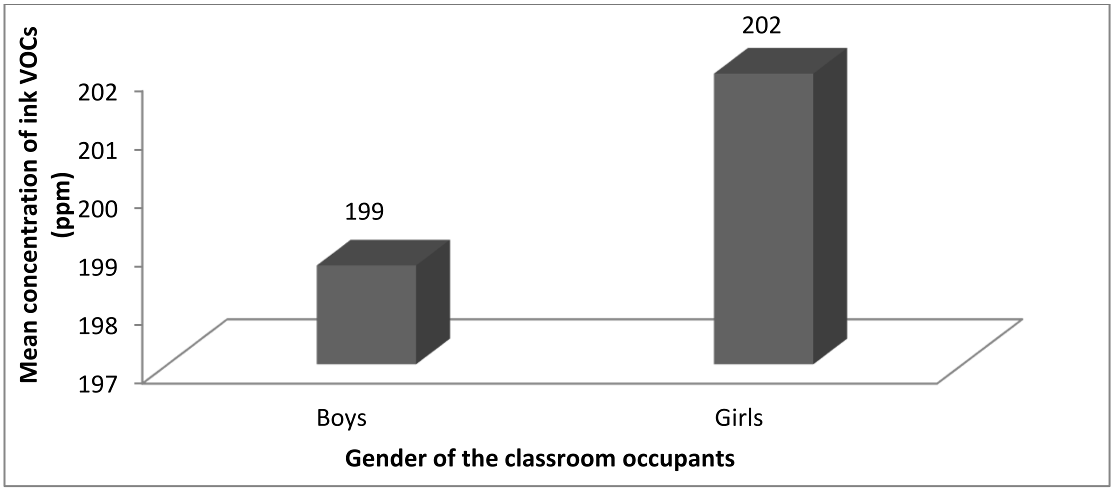


Figure 4.14: Relationship between gender of the classroom occupants and concentration of ink VOCs

When the mean concentration of ink VOCs in the two categories of classrooms was statistically compared using one way ANOVA, the results indicated that the mean concentrations in the two categories of classrooms were significantly different (p=0.048) (Table 4.12).

Table 4.12: One way ANOVA for concentration of ink vapours between girls' and boys' classrooms

	Sum of Squares	df	Mean Square	F	Sig.
Between Groups	107739599 4.747	1	107739599 4.747	4.114	.048
Within Groups	120470083 38.511	46	261891485 .620		
Total	131244043 33.258	47			

This study found that many of the windows (3/4) in the girls' classrooms were closed at the time of visit. This abates ventilation in the classrooms allowing accumulation of the ink VOCs in the classroom. This agrees with Du *et al*. (2015) and Jin *et al*. (2014) who associate abated ventilation with increased concentration of VOCs. Du *et al*. (2015) found that low air exchange rates in residences in Detroit resulted in high concentration of VOCs while Jin *et al*. (2014) found that good ventilation reduced the air pollutants responsible for development of lung cancer among the Chinese population. In the current study, the classrooms of the boys had ¾ or more of their windows open at the time of visit resulting in good air exchange rate.

4.4 Distribution of the VOCs in the classroom

The ink VOCs were distributed in the classroom such that 41% (311ppm) was found at 1.5m above the floor at the front of the classroom while 29 % (220 ppm) was found at 1.5m above the floor at the back of the classroom. This is an indication that the vapours are not evenly distributed in the classrooms. Figure 4.15 summarizes these results.

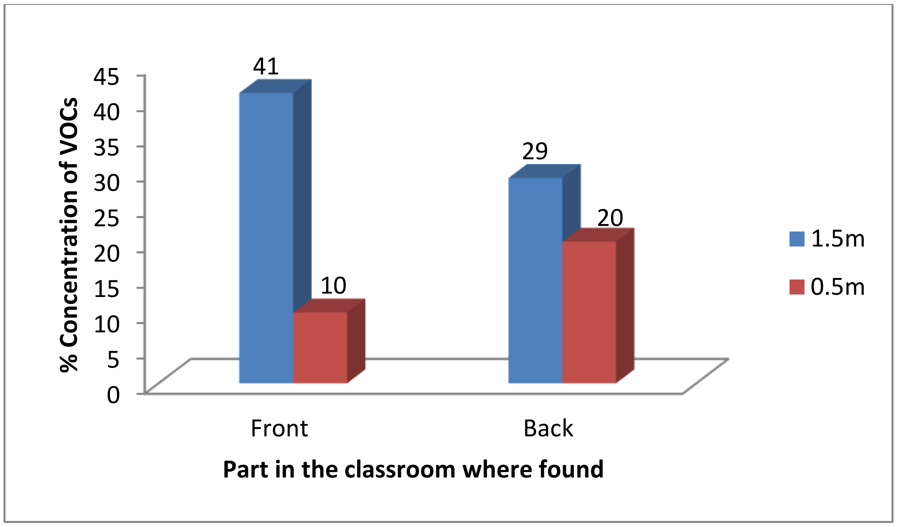


Figure 4.15: Distribution of ink VOCs in the classroom

The results indicate that more VOCs from the ink were found at the front of the classroom at 1.5m above the floor. This corresponds to the point where most of the writing was done by most of the teachers in the classrooms visited. The results agree with Noguchi *et al*. (2016) who found that the concentration of the VOCs is higher at a point close to where they are produced. Du *et al*. (2015) also found the concentration of VOCs from gasoline were highest in the garage where they were emitted by the stored gasoline. High concentration at the point of production is an indication of inefficiency in the spread of the VOCS or lack of dilution by the outdoor air. Seppänen and Kurnitski (2009), in their literature review, found that the dilution of the VOCs is dependent on the ventilation rate.

Mahyuddin *et al*. (2014) found that exhaled gases tend to move upward in a room. This may push upward the VOCs making the concentration of VOCs to be high at the upper parts. This explains the observation in this study where the concentration of ink VOCs was higher at 1.5m above the floor than at the lower parts (0.5m above the floor) of the classroom. The concentration at the front at 0.5m above the floor was lowest (10%) because the teachers opened the classroom door as they walked out after the lesson ended. This allowed entry of the air at the front which pushed the ink to the back before it could spread to the lower parts of the classroom.

Desks, chairs and other materials in the classrooms can act as buffers for VOCs reducing peak concentrations at some parts of the classroom (Meininghaus *et al*., 2000; Kim, 2008). The concentration of ink VOCs was therefore lower at the lower levels (0.5m above the floor) of the classroom where desks and chairs were. However some of the materials act as a sink for these VOCs reducing the concentration but later re-emitting the same back to the room when ink VOC production reduces (Meininghaus *et al*., 2000; Kim, 2008; Ho *et al*., 2011). This may have contributed to the higher concentration of ink VOCs at the back at 0.5m above the floor than at the front at the same level since the desks and chairs at the back may have been re-emitting the VOCs that they may have earlier absorbed. There were no chairs at the front close to the whiteboard except a single teacher's table in some of the classrooms.

The materials in the classrooms also allow sorption of the ink VOCs as well as diffusion through them prolonging their life in the room (Meininghaus *et al*., 2000; Kim, 2008). This allows the ink VOCs to have sufficient time to react with the air components converting into new VOCs, some of which may have harmful health effects (Wei *et al*., 2017; Mira *et al*, 2016). Figures 4.16 and 4.17 demonstrate the conversion of the ink VOCs in an air sample collected and analyzed during this study. The chromatogram in Figure 4.16 was obtained when the sampled air from a classroom was analyzed within an hour of collection. Some of the same air sample was then placed in a vacuum tube under pressure for 48 hours. It was then analyzed and it produced a different chromatogram (Figure 4.17) from the first one.

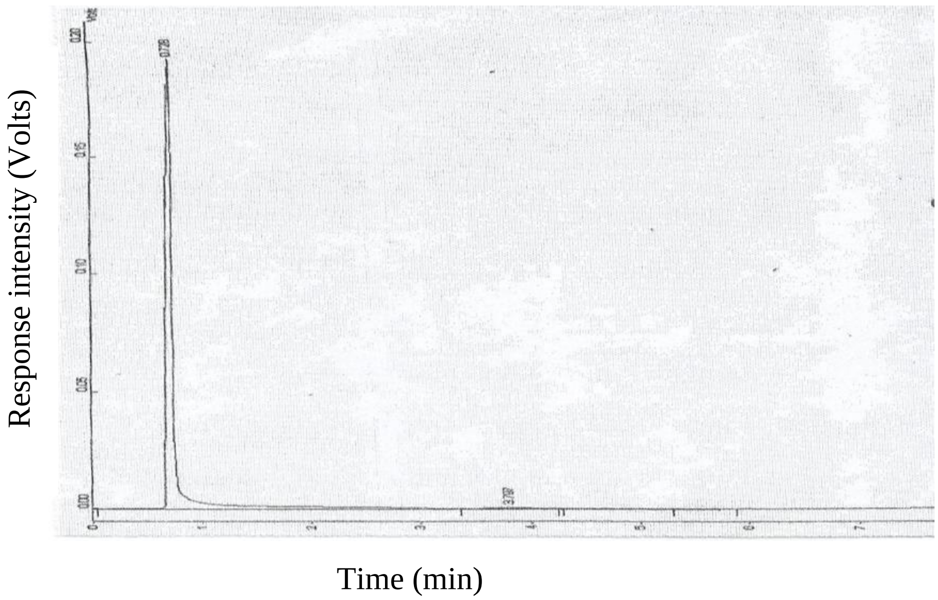


Figure 4.16: Chromatography of air sample with ink vapour (1 hour after sampling)

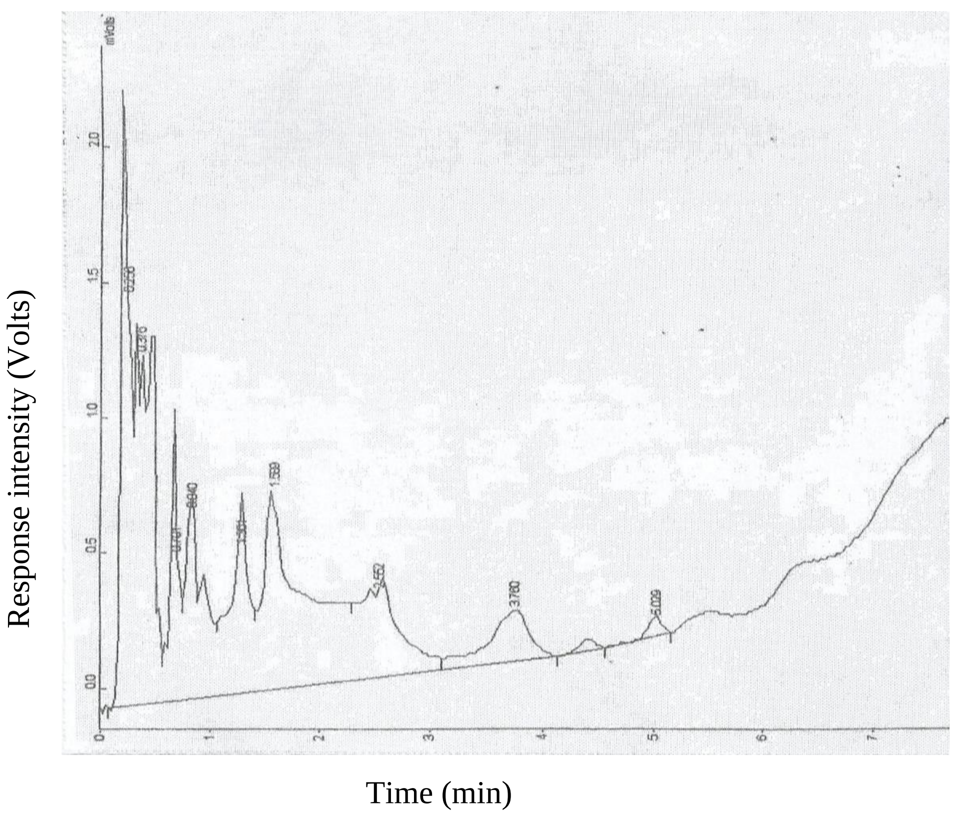


Figure 4.17: Chromatography of air sample with ink vapour (48 hours after sampling)

The fact that the second chromatogram was different from the first one is an indication that the VOCs in the air sample had undergone through some changes forming a new combination of compounds with different retention times. These findings agree with those of other research studies who identified presence of a complex indoor chemistry of VOCs resulting in new pollutants. They suggested that the chemistry may involve, among other, reactions between ozone, free radicals and VOCs yielding new products. These may have different health effects from those caused by the initial mixtures (Zhang and Lioy, 1994). Conversion of original VOCs mixtures exposes the teachers to new VOCs mixtures.

4.5 Knowledge, attitude and practice of teachers

The teachers' knowledge and attitude on the whiteboard marker pen ink were studied using a Likert Scale with a scale of five ratings (strongly agree, agree, neutral, disagree and strongly disagree). The practice of the teachers related to the use of the marker pen was studied by use of an observation checklist which was filled by the researcher in the classroom as the teacher taught the students.

4.5.1 Knowledge of teachers on safety issues related to whiteboard marker pen ink

Level of knowledge was studied using a Likert scale with five items (Appendix I). The questions were then rephrased during analysis to ensure a common direction. The average score was obtained by dividing the total score obtained by the number of the questions. One was considered as very knowledgeable if he/she scored an average of 5. Those that had an average of 4 were considered as having fair knowledge while those who had 3 and below were considered to be unknowledgeable. The results showed that 79.9% of the teachers were not knowledgeable while only 0.6% of the teachers had good knowledge on the safety aspects of the marker pen ink (Figure 4.18).

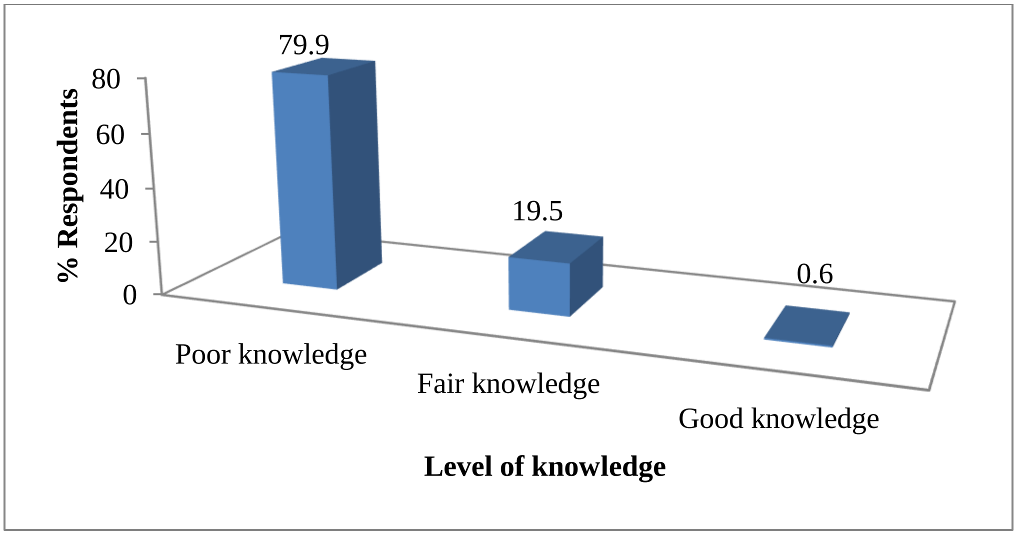


Figure 4.18: Knowledge levels of teachers on marker pen ink safety

The whiteboards were simply fixed on top of the black boards in the classrooms and teachers seemed to have taken up the use of the marker pen as a simple replacement of the chalk. As such the traditional way of teaching and learning was not interfered with and therefore the teachers were not bothered to know more about the marker pen ink. Clarke and Pittaway (2014) say that teachers take any form of technology for granted if they do not seem to interfere with the traditional mode of instruction. Also, there was no material safety data sheet available and its absence contributes to lack of information on chemical safety (Eastlake *et al*., 2012). Absence of material safety data sheets is in line with the findings of Suleiman and Svendsen (2014) that many suppliers of commodities are less conscientious when it comes to informing users on health risks.

Mytton *et al*. (2010) and NPCS (2017) outline the need for training as a way of improving knowledge on chemicals and technology. Occupational Safety and Health Act (2010) also require that an occupier trains the employees and provides information to ensure the safety and health at work. Lack of training on the ink use of the marker pen may therefore have contributed to lack of knowledge among the teachers. Lack of knowledge on a new technology among the teachers agrees with several research studies which found that teachers lacked knowledge on new technologies introduced in schools (Lawless and Pellegrino, 2007; Ertmer and Ottenbreit-Leftwich, 2010). Although these studies dealt with computer technologies, the technology considered was equally new just as the whiteboard marker pen use in the studied schools and therefore the studies can be compared with the current study. These studies attributed the lack of knowledge on lack of effective training of the teachers on the use of the new technologies.

Lack of knowledge on the whiteboard marker pen ink makes the teacher ignorant on the hazards associated with the chemicals present in the ink. This increases the risk of exposure to these chemicals during the use of the marker pen because an ignorant teacher cannot work safely or protect himself/herself or other persons in the school. He is therefore likely to contravene Occupational Safety and Health Act of 2010 that outlines the duties of the employee to include ensuring his safety and health and that of other persons who may be affected by his acts or omissions at the workplace. Lack of knowledge would also hinder the response to any poisoning from the chemicals in the ink because knowledge determines the type and effectiveness of response accorded to the victims (WHO, 2004).

Teachers who used science chemicals in teaching did not have higher levels (18.6%) of good knowledge than those who did not use the science chemicals (24.4%). These findings are summarized in Figure 4.19

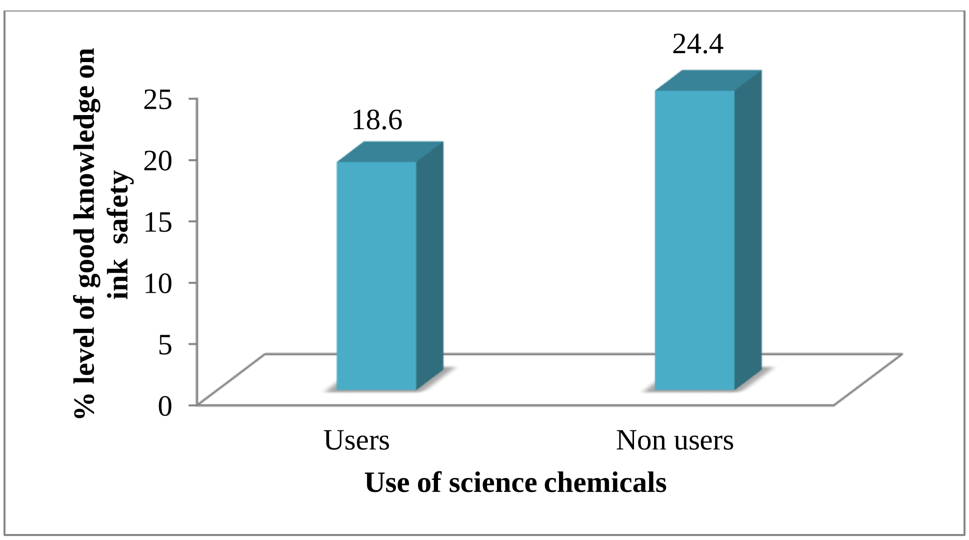


Figure 4.19: Level of good knowledge on ink safety among the users and non users of Science chemicals

Statistical test showed that there was no significant association (χ^2=1.429; p=0.489) between use of science chemicals and level of good knowledge on ink safety (Table 4.13)

Table 4.13: Comparison between levels of good knowledge between users and non users of science chemicals

	Value	df	Asymptotic Significance (2-sided)
Pearson Chi-Square	1.429	2	.489
Likelihood Ratio	1.817	2	.403
Linear-by-Linear Association	.782	1	.377
N of Valid Cases	88		

Knowledge on science laboratory chemicals did to influence the knowledge on ink safety. This is because the teachers who taught science were taught about laboratory safety rules and safety concerning the chemicals which were encountered in the science laboratory only (Muange *et al*., 2015). It is an indication that the training of the science teachers on science chemicals safety does not make them more knowledgeable about other chemicals in the school environment than the other teachers who do not teach science. They are therefore likely to handle the marker pen ink the same way as the rest of the teachers making them equally exposed.

4.5.2 Attitude of teachers on use of marker pen ink

The attitude of teachers on the use of whiteboard marker pens was studied using a Likert Scale with five items (Appendix I). The questions in the questionnaire were in both direction of positive and negative and therefore they were rephrased during analysis to ensure a common direction. The mean score was obtained by dividing the total score obtained by the number of the questions. One was considered to have a positive attitude towards the use of the whiteboard marker pen ink if he/she scored an average of 4 or 5. Those that had an average of 3 were considered as being neutral, while those who had 2 and below were considered to have a negative attitude towards the use of whiteboard marker pen ink. The results showed that 64.8% of the teachers had a positive attitude towards the use of whiteboard marker pens while only

0.9% had a negative attitude towards the use of the marker pens on the whiteboards (Figure 4.20).

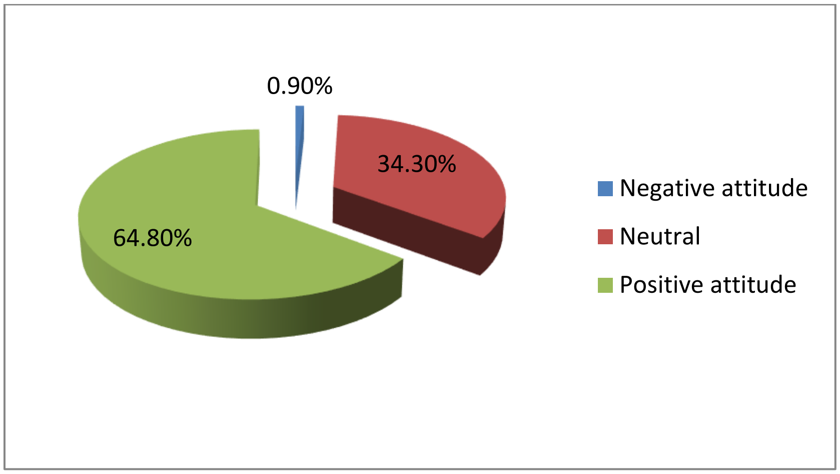


Figure 4.20: Attitudes of teachers on use of whiteboard marker pen

The results indicate that the teachers had a positive attitude towards the use of the marker pens to write on the whiteboards. They were therefore more likely to use the pens as user attitude influences the intention to use (Moon and Chang, 2014). The acceptance may have been influenced by the fact that the pen was easy to use. Merschbrock and Nordahl-Rolfsen (2016) demonstrated that the workers who found the use of technology easy accepted it and were positive in utilizing it. This is also in line with the technology acceptance model which predicts that the acceptance of a new technology by workers depend on usefulness and perceived ease of use (Davis *et al*., 1989; Hsu and Lin, 2008).

Clarke and Pittaway (2014) says that teachers do not fear or hate a new technology as long as it does not bring about new groupings of students, the role of the teacher is not reduced and the teacher does not have to learn new skills. In this study the whiteboard replaced the chalkboard and the marker pens replaced the chalk in the classrooms leaving the rest of teaching and learning approaches intact. The technology did not interfere with the teacher’s authority or role and the teachers did not have to learn new skills. They therefore embraced the technology willingly.

Many of the teachers (76.5%) believed that the pens had already gone through the checking by Kenya Bureau of Standards (KEBS) which is the body mandated to ensure quality and safety of products in Kenya (GoK, 2012). Wu and Jang (2013) found that consumers' awareness of a certified product has a positive influence on perceived quality and safety. Priest (2010) says that people are more likely to support that which they believe is safe. Positive attitude combined with lack of knowledge on safety aspects of the whiteboard marker pen ink make the teachers to embrace the use of the marker pen without any safety precautions (Eastlake *et al*., 2012). This exposes them to the hazards associated with this technology such as inhaling the vapours from the ink as well as some of the ink vapours getting into their eyes.

All the teachers above 55 years of age (100%) had poor attitude while a majority (88.2%) of the teachers below 25 years of age had good attitude towards the use of whiteboard marker pens (Figure 4.21).

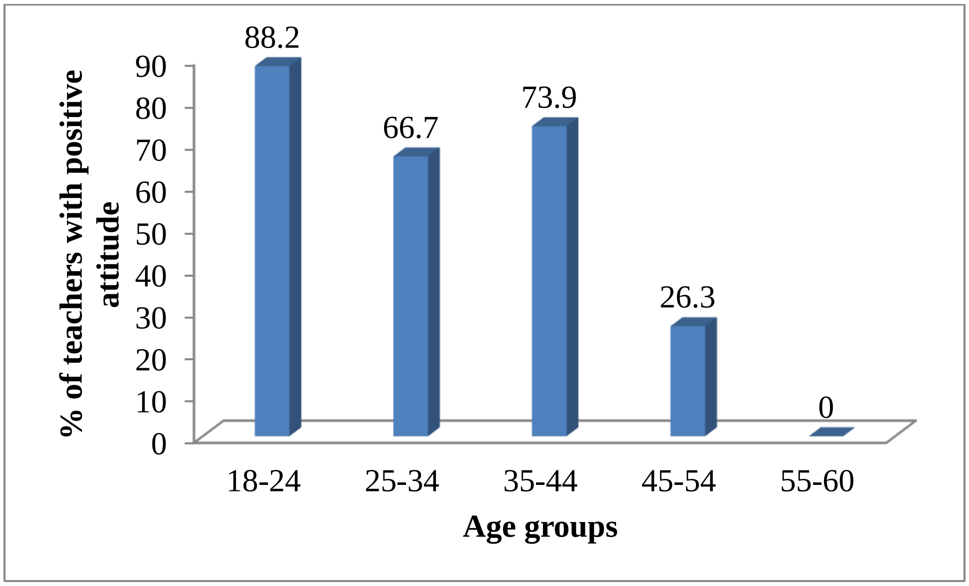


Figure 4.21: Distribution of positive attitudes on dry erase use in the different age groups

Statistical testing showed that there was a significant association between attitude and age of the respondents (χ^2=122.897; p=0.000).

Table 4.14: Comparison of positive attitudes on dry erase use in the different age groups

	Value	df	Asymptotic Significance (2-sided)
Pearson Chi-Square	122.897	12	.000
Likelihood Ratio	31.717	12	.002
Linear-by-Linear Association	17.334	1	.000
N of Valid Cases	102		

This agrees with Krosnick and Alwin (1989) who found that the younger persons are more likely to have a positive attitude towards new technology. This is explained using the impressionable years hypothesis which outlines that individuals are highly susceptible to attitude change during late adolescence and early childhood and that the susceptibility drops later in life and remains low at old age (Krosnick and Alwin ,1989). The older people are not flexible to change and would want to have the status quo remain at their places of work.

Male teachers had higher levels of positive attitude than the female teachers towards the use of the whiteboard marker pens. (Figure 4.22).

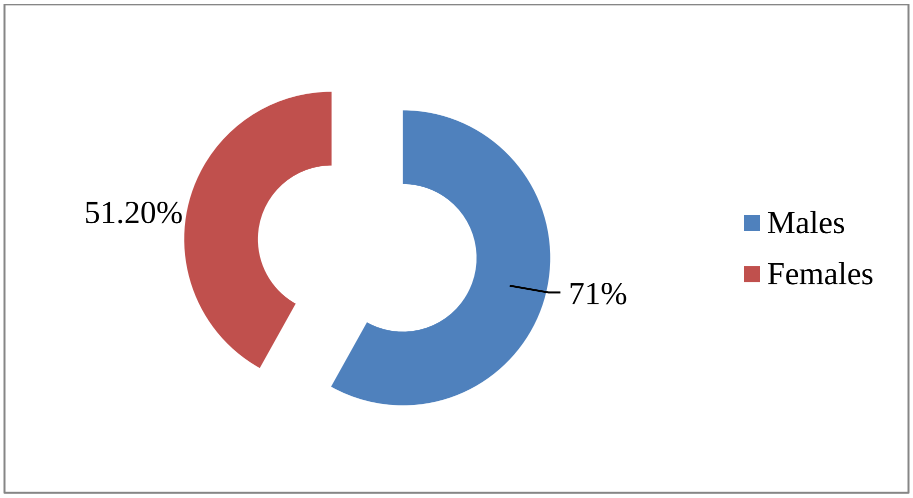


Figure 4.22: Levels of positive attitude towards ink use among the male and female teachers

Statistical test showed that there was a significant association (χ^2= 4.134: p=0.042) between the gender and attitude on the use of whiteboard marker pen ink (Table 4.15).

Table 4.15: Relationship between gender and attitude towards ink use

	Value	df	Asymptotic Significance (2-sided)	Exact Sig. (2-sided)	Exact Sig. (1-sided)
Pearson Chi-Square	4.134	1	.042		
Continuity Correction	3.329	1	.068		
Likelihood Ratio	4.111	1	.043		
Fisher's Exact Test				.060	.034
Linear-by-Linear Association	4.094	1	.043		
N of Valid Cases	103				

These findings agree with Ray et al. (1999) who found that the males had more positive attitudes towards new technology than did the females. Goswami and Dutta (2016) say that attitudes towards a technology are gender specific and culturally learned. Males are socialized to be proficient in all technological issues. The females are more sensitive to suggestions of the peers and hence the effect of social influence is stronger when forming the intention to use a technology. Since the use of the whiteboard marker pen ink in the studied schools was new, there had not been sufficient time for the social influence to set in to influence the attitudes. This is in line with the theory of diffusion of innovations which explain that it takes time for a new technology to be understood and become appreciated (Rogers, 1995).

Majority of teachers who used gas as a main fuel at home had a higher levels of positive attitude towards the use of whiteboard marker pen ink than those who used the traditional solid fuels. Figure 4.23 shows the levels of positive attitude among the teachers who used different types of fuels at home.

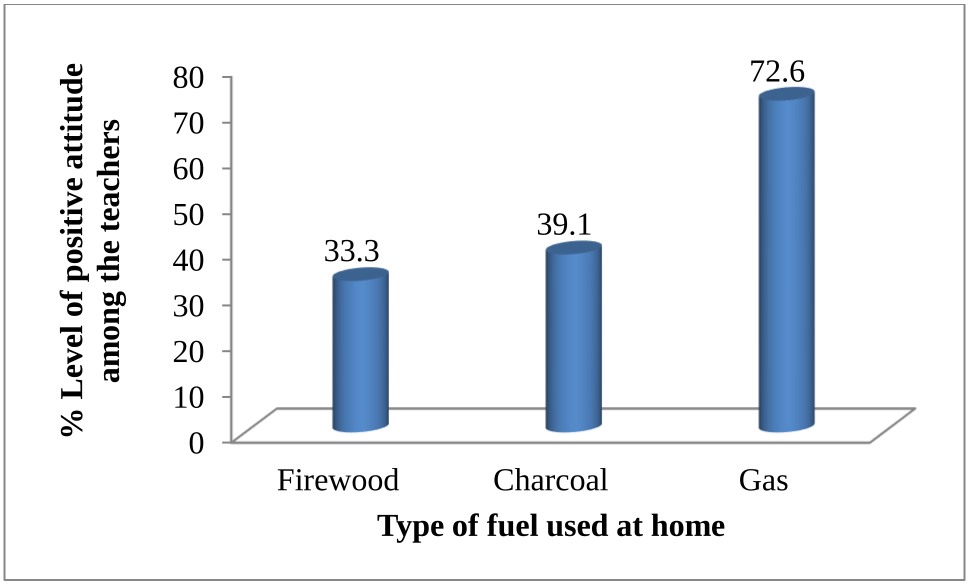


Figure 4.23: Levels of positive attitude towards use of dry erase among the teachers using different fuels at home

Statistical test showed that there was a significant association (χ^2= 10.742: p=0.005) between the attitude towards use of whiteboard marker ink and the type of fuel used at home by the respondents (Table 4.16)

Table 4.16: Comparison of levels of positive attitude towards dry erase among teachers using different fuels at home

	Value	df	Asymptotic Significance (2-sided)
Pearson Chi-Square	10.742	2	.005
Likelihood Ratio	10.547	2	.005
Linear-by-Linear Association	10.447	1	.001
N of Valid Cases	102		

Majority (80%) of the teachers who used gas as the main fuel at home were aged below 45 years. This agrees with the finding of Shen et al. (2014) who found that the young prefer to try out the newer types of fuels while the old cling to the traditional solid fuels in daily cooking and heating. This is an indication that the young do not hold strongly to the traditional way of doing things but are willing to embrace the new ways. Use of gas as a relatively newer fuel is an indication of the ability to break away from the old and traditional ways. As such the teachers who were able to embrace the use of the new and cleaner types of fuels were able to embrace the new technology in their schools involving the use of whiteboard marker pens. Those teachers who stuck to the traditional types of fuel were equally unable to embrace the new technology involving the use of marker pens in their schools.

The single teachers had higher levels of positive attitude (85.7%) than the married teachers (50.7%). These findings are summarized in Figure 4.24

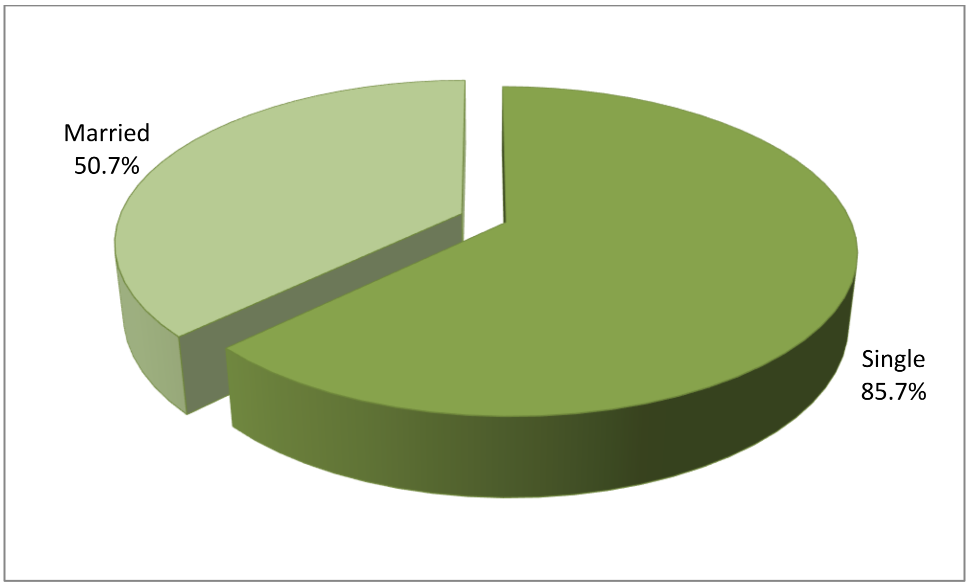


Figure 4.24: Distribution of positive attitude on ink use based on marital status of respondents

When statistical test was carried out, it was found that there was a significant association (χ^2= 12.026: p=0.001) between the marital status of the respondents and the level of positive attitude towards the use of whiteboard marker pen ink (Table 4.17).

Table 4.17: Relationship between levels of positive attitude towards ink use and marital status of the respondents

	Value	df	Asymptotic Significance (2-sided)	Exact Sig. (2-sided)	Exact Sig. (1-sided)
Pearson Chi-Square	12.026	1	.001		
Continuity Correction	10.577	1	.001		
Likelihood Ratio	13.126	1	.000		
Fisher's Exact Test				.001	.000
Linear-by-Linear Association	11.908	1	.001		
N of Valid Cases	102				

Several studies have found an association between the marital status of teachers and the different aspects in teaching. Islahi and Nasreen (2013) study found that teacher's effectiveness was significantly influenced by the marital status of the teacher. Tyagi (2013) found that unmarried teachers had higher level of classroom management than the married teachers. The teacher's marital status therefore influences the overall teaching aspect of a teacher including the use of the whiteboard marker pens in the schools.

4.5.3 Practices of teachers related to use of whiteboard marker pens

The practice of the teachers related to use of marker pens was studied as the teachers were teaching in the classrooms. The practices of teachers which were likely to increase the exposure of the teachers to the VOCs from the ink as well as the whole ink were identified.

Occupational Safety and Health Act of 2010 outlines the duties of the employee and they include ensuring his safety and health and that of other persons who may be affected by his acts or omissions at the workplace. This means that the teacher should have practices at school which do not contribute to hazards so that he can be safe as well as the other persons at school such as his fellow teachers and students. However the results in general showed that majority of the teachers lacked safe practices in relation to the use of whiteboard marker pen ink. Embracing the use of whiteboard marker pen ink without knowledge on chemical safety make the teachers to have unsafe practices and in the process contravene the OSHA of 2010. Table 4.18 summarizes the findings concerning the practices of the teachers in the classrooms.

Table 4.18: Practices of teachers related to use of marker pens

Observed practice	Never		Rarely		Often	
	n	%	n	%	n	%
Replacing the lid when the pen is not in use during the lesson	40	**80**	7	14	3	6
Rubbing the board with bare hands	4	8	12	24	34	**68**
Rubbing the eye with hands	11	22	26	52	13	**26**
Placing the pen close to the face when not writing	15	30	15	30	20	**40**
Moving away from the board	30	**60**	10	20	10	20
Rubbing the board with the duster	3	6	15	30	32	64
Sitting down during the lesson	46	**92**	3	6	1	2
Writing with the face very close to the white board	3	6	5	10	42	**84**

Among the studied teachers, 80% did not replace the lid of the marker pen when it was not in use. At the start of the lesson, some teachers would remember to replace the lid as soon as they stopped writing. However, they would soon forget about replacing the lid as the lesson progressed. When the marker pen is left uncovered, the ink may continue to vaporize from the tip of the marker pen and in the process expose the teacher especially if the teacher holds the pen close to the eyes or the face. This is based on the findings of Anderson and Anderson (2003) who studied the effects of VOCs from the felt tips on mice and found that the concentration of the VOCs from the tips were similar to those generated from a marking pen in use. Uncovered felt tips therefore continue to release the VOCs and can increase their concentrations in the classroom.

Forty percent of the teachers placed the pen close to the face when not in use while 84% had their face very close to the whiteboard as they wrote. Placing the pen close to the eyes or the face reduces the distance that the VOCs have to travel from the felt tip to reach the eyes of the teacher. Writing on the whiteboard with the face very close to the whiteboard also shortens the distance between the writings and the eyes. The shorter the distance the higher the rate of diffusion (MoE, 2018).This increases the concentration of the VOCs that can reach the eyes of the teacher.

Sixty percent of the teachers remained in front of the classroom close to the whiteboard throughout the lesson. This agrees with Epri (2016) who found that many teachers in Papua New Guinea spent a lot of time in front of the classroom. Rands and Gansemer-Topf, (2017) says that the movement of the teacher in the classroom is hindered by the large number of students or the arrangement of furniture. The study to establish whether the teacher stays close to the whiteboard was based on the findings of Noguchi *et al*. (2016) who found that the concentration of the VOCs was highest closer to the carpet which was the source in a newly built day care center in Kashiwa City of Japan. It was therefore expected that the concentration of VOCs would be highest close to the whiteboard where the writing was being done. Ninety two percent of the teachers stood throughout the entire lesson time. They therefore remained exposed to the high levels of ink VOCs at 1.5m above the floor.

Many would rub the board with the duster at the beginning of the lesson but would switch to the use of the hands to rub especially if the amount of writing to be rubbed was little. Subconsciously a few (26%) would go ahead and rub their eyes with hands as they continued teaching after rubbing the whiteboards with bare hands. When one rubs the whiteboard with bare hands, the ink sticks on the hands. If the ink is wet and the solvents have not yet evaporated, the teacher can transfer the whole ink into the eyes when he/she rubs the eyes with bare hands. Bloomfield *et al*. (2016) indicate that hands can transfer pollutants to the eyes when one rubs the eyes with bare hands.

Rubbing the board with the duster ensures that the teacher does not come into direct contact with the ink and does not transfer whole ink into the eyes. However, rubbing the writings from the whiteboards separates out the markings and this increases the surface area of the marks increasing the rate of evaporation of the solvents (Brady, 2007). This therefore increases the rate of emission of VOCs from the ink and this increases their concentration in the classroom. If left alone to dry, they evaporate slowly releasing the VOCs slowly and therefore the concentration is expected to remain low but consistent.

4.6 Influence of classroom factors on occupational exposure of teachers to ink VOCs

Classroom factors that influence the exposure to white board marker ink were studied. These were ventilation and temperature. Temperature is related to the rate of emission while ventilation influences the dilution and dispersion of VOCs in the classrooms. This determines the exposure levels of VOCs to the teacher. Concentration of carbon dioxide was used as a surrogate measure of ventilation efficiency. High concentration of carbon dioxide indicates ventilation inefficiency while concentrations close to those in outdoor air are an indication of efficiency of the ventilation (Lazović *et al*., 2016).

4.6.1 Carbon dioxide

The results showed that the overall carbon dioxide concentrations ranged from 335 ppm to 2207 ppm with an average of 621.39 ppm. The median was 533 ppm with 37% of the classrooms having more than 600 ppm while 74.1% of the classrooms had 100 ppm and above being the difference between the indoor and outdoor concentration of carbon dioxide (dCO_2). The ventilations were effective when open allowing the classroom air dilution to a concentration of 335 ppm which is close to that of the outdoor air (306 ppm). The standard deviation was very high (339.173) indicating lack of consistency in the concentration of carbon dioxide in the classrooms at the different times of sampling.

The results from this study show that the concentration of the carbon dioxide kept changing in the course of the day. The mean concentration of carbon dioxide was found to be 949.73 ppm at 8.00 am during morning prep, 639.24 ppm at 12.40 pm just before lunch break and 319.00 ppm at 2.00 pm just before the afternoon lessons started (Figure 4.25).

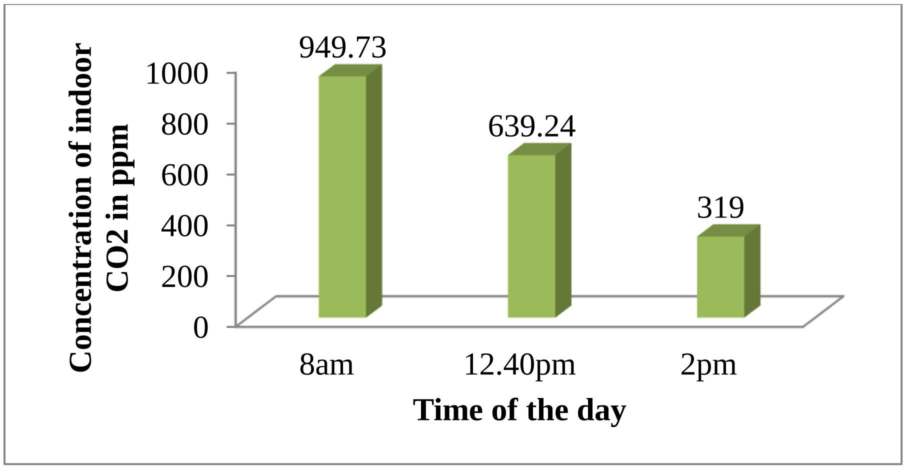


Figure 4.25: Concentration of CO_2 at different times of the day

The concentration of carbon dioxide at the different times was found to be significantly different (p=0.042) when tested using one way ANOVA (Table 4.19).

Table 4.19: Comparison of concentration of CO_2 at different times of the day

	Sum of Squares	df	Mean Square	F	Sig.
Between Groups	1357841.107	2	678920.554	3.358	.042
Within Groups	10512875.802	52	202170.688		
Total	11870716.909	54			

The concentration of carbon dioxide was lowest at 2 pm because the students had moved out to take lunch. This reduced the production of carbon dioxide by the classroom occupants and also allowed for dilution as the students opened the doors as they went out. The concentration of carbon dioxide was higher during the morning prep than during the afternoon (12.40 pm) lesson because it was colder in the morning (20.6 ^{o}C) than in the afternoon (26.7 ^{o}C). Most of the classroom operable windows (3/4 and above) were therefore closed in all the classrooms during the prep time at the times of visit. This agrees with the findings of Lazović *et al*. (2015) who found that thermal comfort influences the management of operable ventilations. Closing the windows limits ventilation and abated ventilation increase the concentration of carbon dioxide in a classroom (Lu *et al*., 2015). In this study, temperature was found to be negatively correlated with the concentration of carbon dioxide (r=-0.113) (Table 4.20). Decrease in temperature therefore resulted in increase in the concentration of carbon dioxide.

Table 4.20: Relationship between CO_2 and temperature

		Temperature
CO_2	Pearson Correlation	-.113
	Sig. (2-tailed)	.368
	N	65

The concentration of carbon dioxide was lowest during the lunch break (2.00 pm) because the classrooms were empty or had the least occupancy. The students had moved out of the room to take their lunch. Statistical test showed that the concentration of carbon dioxide was significantly correlated with the number of students in the classroom (r=+0.333; p=0.007) (Table 4.21). Such a strong correlation has been observed by Mahyuddin and others (2014) in which the major indoor source of carbon dioxide was shown to be the classroom occupants. Lu *et al*. (2015) also found an increase in the concentration of CO_2 with increase in the number of workers in a building located in Taipei City.

Table 4.21: Relationship between concentration of CO_2 and number of students

		Number of students per classroom
CO_2	Pearson Correlation	.333
	Sig. (2-tailed)	.007
	N	65

The classrooms occupied by the girls had higher concentration of carbon dioxide than that found in the boys' classrooms (Figure 4.26).

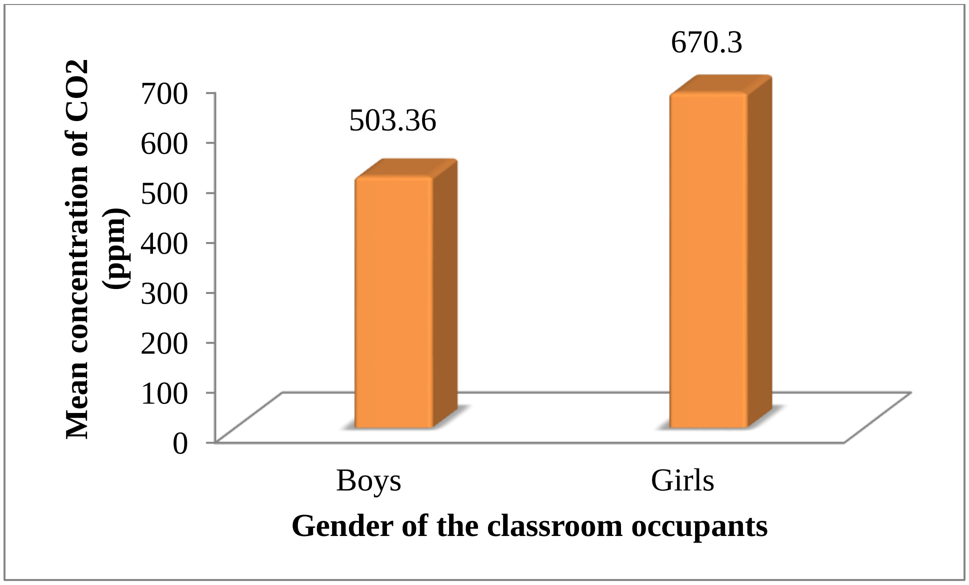


Figure 4.26: Relationship between gender of the classroom occupants and concentration of CO_2

Statistical testing showed that there was a significant difference in the concentration of carbon dioxide between the girls' and boys' classrooms (t=2.152; p=0.043) indicating poor ventilation in girls' classrooms (Table 4.22).

Table 4.22: CO_2 mean concentrations in girls' and boys' classrooms

Classroom	Mean of CO_2 concentration (ppm)	Statistics t value	df	P value (2-tailed)
Girls' classroom	670.30	2.152	22	0.043
Boys' classroom	503.36			

It was observed that all the girls' classrooms had ¾ or more of the windows closed during the times of visit. This could be attributed to the fact that girls tend to feel colder than the boys (Cheung, 2015). This is due to the fact that they have a thicker and a more evenly distributed layer of fat just below the skin surface compared to the males (Westerbacka, 2004; Tarulli *et al.*, 2007; Olesen, 2015). When they get cold, they constrict their blood vessels to the skin faster than the males reducing the flow of blood to the skin significantly (Kaciuba-Uscilko and Grucza, 2001; Olesen, 2015). The layer of fat under the skin act as an effective insulator preventing the heat from the body to reach the skin making the skin of the females to feel colder than that of the males. They also have lower heat generation to heat loss surface area ratio (Kaciuba-Uscilko and Grucza, 2001) making the heat loss more effective than its generation.

When the relationship between carbon dioxide and ink vapour was tested, the results showed a positive correlation (r =+0.087; p=0.730) (Table 4.23).

Table 4.23: Relationship between CO_2 and ink VOCs concentration

		concentration in ppm
CO_2	Pearson Correlation	.087
	Sig. (2-tailed)	.730
	N	18

High concentration of carbon dioxide is an indication of poor ventilation (Godwin and Batterman, 2007; Lu *et al*., 2015) allowing the VOCs produced from a marker pen to accumulate in the classroom. Increase in concentration of ink VOCs with reduced ventilation agrees with the findings of several studies. Lu *et al*. (2015) in his study on Sick Building Syndrome (SBS) among the workers in a building in Taipei City found that the TVOCs compounds increased in a room with reduced ventilation. Du *et al*. (2015) studied the effects of air exchange rates on the migration of VOCs from the basement in Detroit residences and found that good ventilation which results in high air exchange rates diluted the indoor VOCs and resulted in a reduced VOCs concentration.

Lack of significance (p=0.730) in the relationship between carbon dioxide and the concentration of ink VOCs was because the two components have different origins. The carbon dioxide is majorly produced by the classroom occupants through exhaled air during their stay in the room (Lazović *et al*., 2015; Chiu *et al*., 2015) as well as some of it entering into the classroom with the outdoor air since carbon dioxide is a natural air component (Hussin *et al*., 2017). On the other hand, the productions of whiteboard marker pen ink vapours depend on the voluntary behavior of the teacher to either write or not. Some teachers write a lot on the whiteboard while others hardly write depending on the subject and topic being taught.

4.6.2 Temperature

The mean temperatures were different in the different schools. Also, the range of the temperatures was higher in some schools than in others (Table 4.24).

Table 4.24: Temperatures of different schools during the study

School code	Mean (ºC)	Std. Deviation
1	28.225	.7500
2	27.471	.2138
3	25.800	2.8902
4	24.536	3.6915
5	22.133	2.7500
6	24.900	6.0094

Differences in temperature between the schools agree with the findings of Scott *et al*. (2017) who found temperature islands in different parts of a city. The standard deviation of the temperature was highest (6.0094) in a school that had some of the classrooms having permanently open windows while the other classrooms had operable windows. The classroom with the permanently open windows had its indoor temperature greatly influenced by the outdoor temperatures while the classrooms that had operable windows were able to regulate their indoor temperatures by either closing or opening the windows. Nguyen *et al*. (2015) studied the relationship between outdoor and indoor ambient weather in homes in Greater Boston and found that open windows make the indoor temperature to be closely related to the external temperatures.

Temperatures also fluctuated during the different times of the day. It was hottest in the afternoon (26.7 ºC) and coldest in the mornings (20.6 ºC) (Figure 4.27).

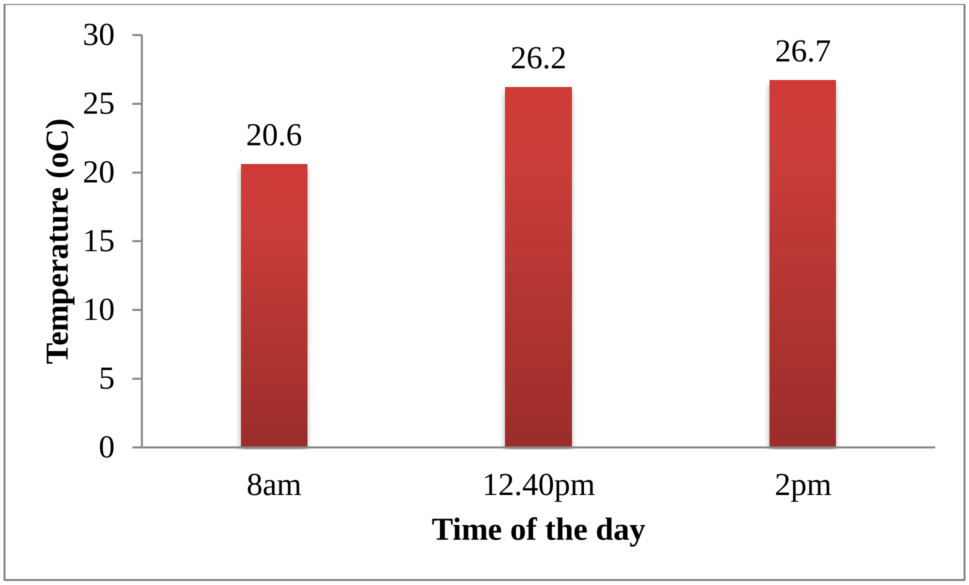


Figure 4.27: Indoor temperature at different times of the day

The statistical test (one way ANOVA) showed that the temperatures at the three times of the day were significantly different (p=0.000) (Table 4.25).

Table 4.25: Comparison of temperature at different times of the day

	Sum of Squares	df	Mean Square	F	Sig.
Between Groups	409.453	2	204.727	29.675	.000
Within Groups	365.641	53	6.899		
Total	775.094	55			

In his book on atmosphere-ocean interface, Considine and Considine (2013) says that the temperature tend to reach its maximum about 2-3 hours after a local noon and its minimum at sunrise. This is because the earth takes time to absorb sufficient heat from the sun to start emitting it back to the air in the process raising the air temperature.

Different seasons also resulted in different temperatures in the classrooms. The lowest temperature (17.3 ^{o}C) was encountered during a cold season while the highest (35.4 ^{o}C) was encountered during a hot season. The classroom occupants trended to open the windows more during the hot season than the cold season in order to prevent the entry of cold air into the classrooms. As such, the indoor temperature was closely associated with the outdoor temperatures during the hot season but not during the cold season. Opening windows causes the mixing of outdoor and indoor air and this reduces the differences between the outdoor and indoor temperatures (Nguyen *et al*., 2015).

The results show that the concentration of ink VOCs increased as the temperature increased (r= +0.089) (Table 4.26).

Table 4.26: Relationship between temperature and the concentration of ink VOCs

		concentration in ppm
Temperature	Pearson Correlation	.089
	Sig. (2-tailed)	.718
	N	19

These results agree with Lim *et al.* (2013) who found that high temperature increases the rate of evaporation of ink solvents in the process drying it. Low temperature on the other hand was found to slow down the rate of evaporation of ink solvents. However increase in temperature did not increase the concentration of the ink VOCs significantly (p= 0.718) because at high temperatures, the students are also likely to open the operable ventilations (Lazović *et al*., 2015) which can aid in the clearance of some of the ink vapours. Also, the temperature variation was small through the different seasons because the occupants were able to regulate their thermal comfort by managing the operable ventilations. The internally generated heat was as a result of physiological body activities and this temperature is usually regulated through the process of homeostasis (Cowan *et al*., 2010) making the range of internal temperature to remain low. Also the amount of writing on the whiteboard was not constant but kept on changing depending on the teacher, the subject and the topic being taught.

4.7 Seasonal variations of incidences of symptoms of allergic conjunctivitis

The incidences of symptoms of allergic conjunctivitis reduced between the July -August and the September -October sampling times of observations among the teachers who were not exposed to the white board marker ink (Figure 4.28)

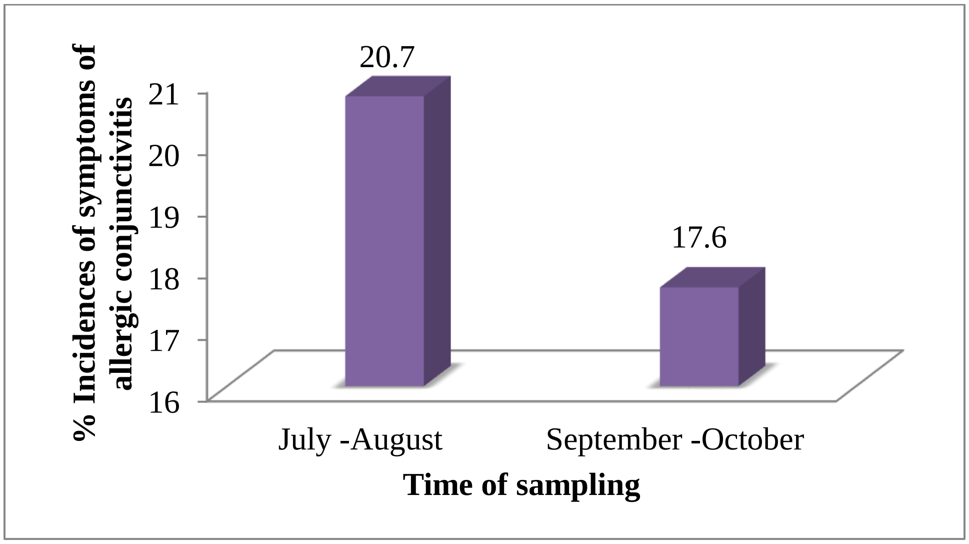


Figure 4.28: Seasonal variation of incidences of symptoms of allergic conjunctivitis among the non-exposed teachers

However, when the incidences of symptoms of allergic conjunctivitis between the July-August and the September–October sampling periods were compared using one way ANOVA for repeated measure, they were found not to be significantly different (p=0.717) (Tables 4.27).

Table 4.27: Comparison of incidences of symptoms of allergic conjunctivitis during July -August and the September –October sampling periods among the non-exposed teachers

Source	Time	Type III Sum of Squares	df	Mean Square	F	Sig.
Factor1	Linear	.024	1	.024	.132	.717
Error(factor1)	Linear	14.976	81	.185		

The incidences also reduced between the September-October and the January-February sampling times when the exposure status was held constant (Figure 4.29).

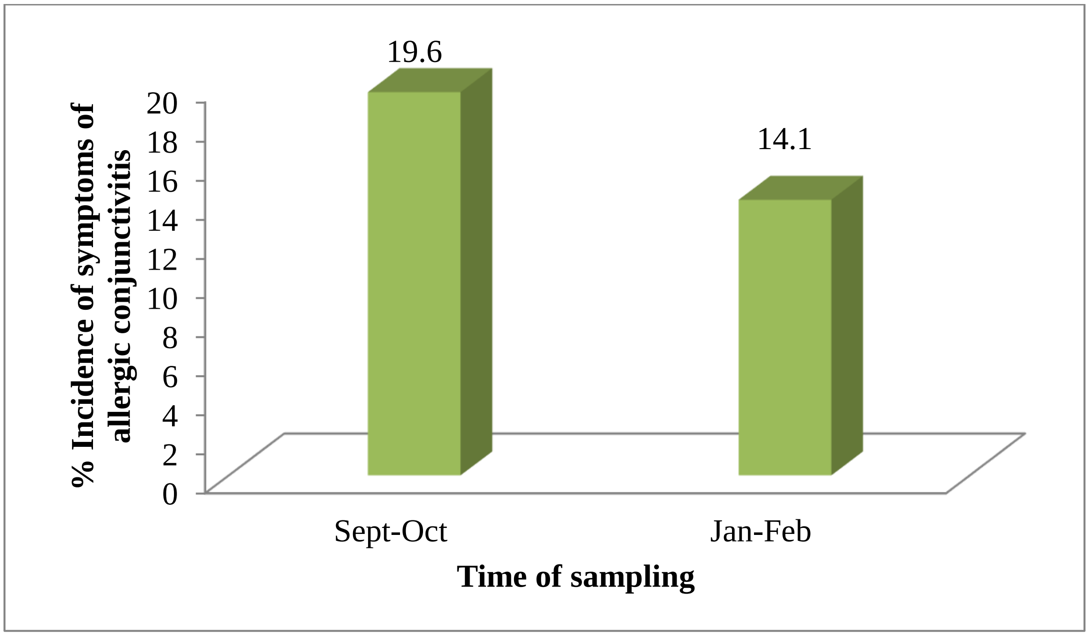


Figure 4.29: Seasonal variation of incidences of symptoms of allergic conjunctivitis among the exposed teachers

The incidences of symptoms of allergic conjunctivitis during September–October and the January-February sampling periods were also found not to be significantly different when tested using one way ANOVA for repeated measure (Tables 4.28).

Table 4.28: Comparison of incidences of symptoms of allergic conjunctivitis during September –October and January-February sampling periods among exposed teachers

Source	Factor	Type III Sum of Squares	df	Mean Square	F	Sig.
Factor	Linear	.018	1	.018	.142	.707
Error(factor)	Linear	13.982	110	.127		

The current study finding agree with those of Singh *et al*. (2010) who found the months of June and July to be the peak months for ocular allergy in United States and attributed it to the production of pollen grains. Highest incidence of symptoms of itchy eyes in this study coincided with the season when maize pollen grains are produced as Nakuru County is a maize growing area (Ariga and Jayne, 2009; KNBS, 2015). Oldenburg *et al*., (2011) found an association between maize pollen and the development of allergic conjunctivitis among the members of a German biological research department whose work was to pollinate the maize. July was also found to be the coldest term during the research with room temperatures as low as 17^{o}C compared to high temperatures (35.4 ^{o}C) during the January to February time. Low temperatures are associated with increased incidences of symptoms of allergy (Raatikka *et al*., 2007; Koskela, 2007; Hyrkäs *et al*., 2014) because the classroom occupants tend to close the windows and doors to maintain their thermal comfort (BRANZ, 2007; Lazović *et al*., 2015). This allows the allergens to accumulate in the room regardless of their origin (Canha *et al*., 2017).

The lowest incidence of the symptoms of allergic conjunctivitis (14.3%) was recorded during the January –February observation time. This was a hot season with temperatures going as high as 35.4 ^{o}C. This made many of the classroom occupants to open the windows most of the time and good ventilation is associated with good health (Satish, 2012; Rosbach *et al*., 2013). The incidences of symptoms of allergic conjunctivitis in the different times of sampling were not significantly different because there were no extreme seasonal variations of weather in Nakuru County during the times of this study. This agrees with the findings of Williams and others (2013) that countries at the equator do not experience extreme conditions of weather.

The incidence of symptoms of allergic conjunctivitis was higher among the females than among the males during both the cold (July to August) and hot seasons (January to February) (Figure 4.30).

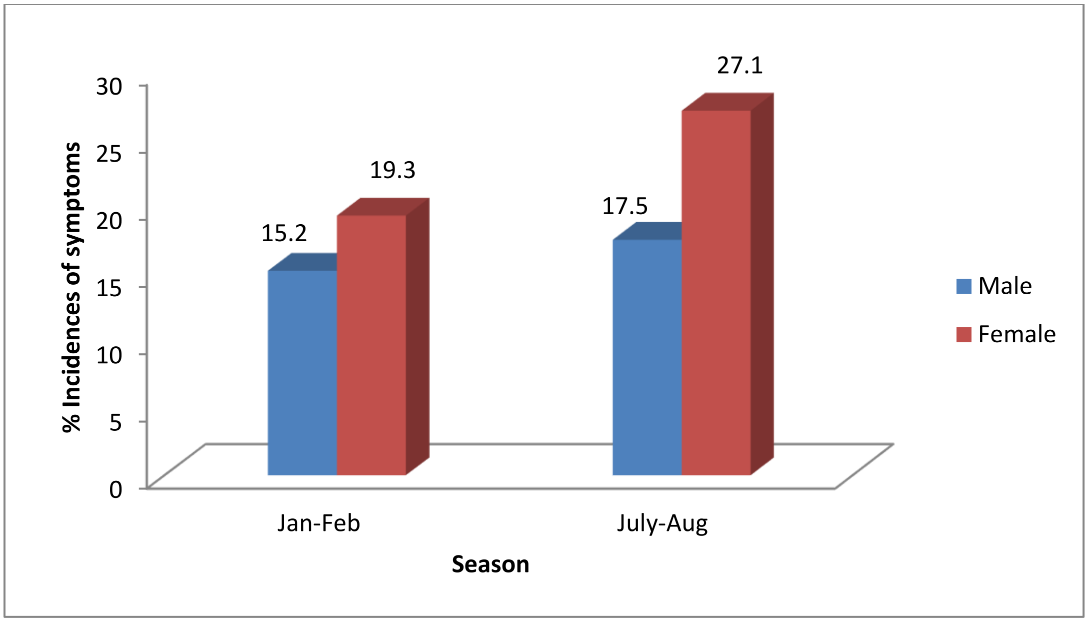


Figure 4.30: Incidences of symptoms of allergic conjunctivitis among male and female teachers during Jan-Feb and July-Aug sampling times

The findings that the females had higher incidences of symptoms of allergic conjunctivitis agree with several studies. Michailopoulos *et al.* (2017) found that allergic conjunctivitis was more common among women. Ramprasad and Maruthi (2015) found that female teachers are more likely to experience physical risks at the workplace. The gender differences are linked to immunological and hormonal factors as well as the differences in gender specific responses to environmental or occupational exposure. Sacchetti *et al*. (2015) reported that sex hormone metabolism and balance may be a predisposing factor to immune-mediated diseases including allergy.

4.8 Influence of exposure to ink VOCs on the development of symptoms of allergic conjunctivitis

The teachers from girls' schools had higher incidences of symptoms (21.7%) of allergic conjunctivitis than those from the boys' schools (8.2%) (Figure 4.31)

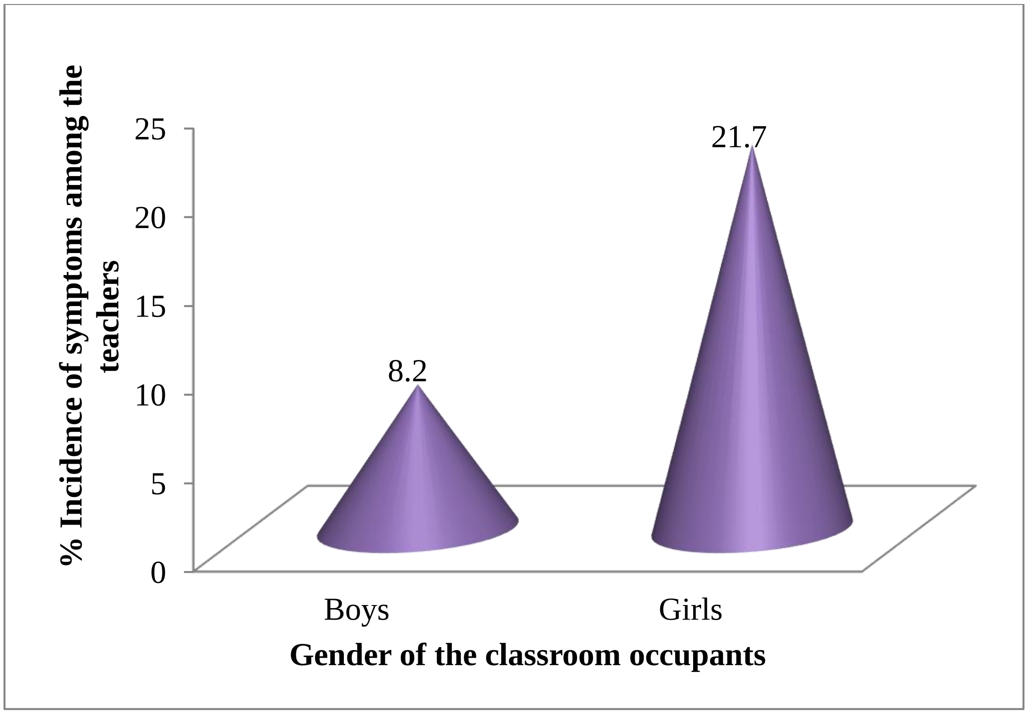


Figure 4.31: Influence of gender of classroom occupants on the development of symptoms among the teachers

When Chi-Square of independence was carried out, the results showed that there was a significant association between symptoms of allergic conjunctivitis among teachers and the type of students in the classrooms where they taught when ink was in use (χ^2= 5.145; p=0.023) (Table 4.29).

Table 4.29: Influence of the gender of students on the development of symptoms of allergic Conjunctivitis among teachers

	Value	df	Asymptotic Significance (2-sided)	Exact Sig. (2-sided)	Exact Sig. (1-sided)
Pearson Chi-Square	5.145	1	.023		
Continuity Correction	4.128	1	.042		
Likelihood Ratio	5.272	1	.022		
Fisher's Exact Test				.032	.020
Linear-by-Linear Association	5.109	1	.024		
N of Valid Cases	142				

These findings agree with those of Dales et al. (2013) who found that reductions in pulmonary function due to poor air quality was influenced by gender and he associated this with the use of personal body products by the females. Sun and Yang (2013) reviewed literature and found that the concentration of exhaled VOCs of female subject were of higher concentration and higher emission rate than male subjects. Poor ventilation in the girls' classrooms made the ink vapours to accumulate in the classrooms. The VOCs from the beauty products used by the girls and the highly concentrated exhaled VOCs may also have interacted with the ink VOCs resulting in a more potent mixture than that found in the boys' classrooms. Mixtures are more likely to have a health effect on a person than individual VOC components (Nielsen *et al*., 2007).

Opening the windows in boys' classrooms (more than ¾ of the windows were open during the time of visit) increased the air exchange rates and the air quality of the indoor classrooms in the process reducing the incidences of symptoms of allergic conjunctivitis among the teachers who attended those classes. This agrees with the findings of Smedje and Norbäck (2000) who found reduced symptoms of allergy among the students in schools in Sweden when the ventilation was improved.

The incidences of symptoms of allergic conjunctivitis increased with increase in concentration of ink VOCs in the classrooms (Figure 4.22). This was established by taking the mean concentration of the ink VOCs in the air samples collected in each of the six schools. Regression was used to assess the relationship between the concentration and the percentage incidence of the symptoms of allergic conjunctivitis among the teachers in those schools during that time of observation (Figure 4.32).

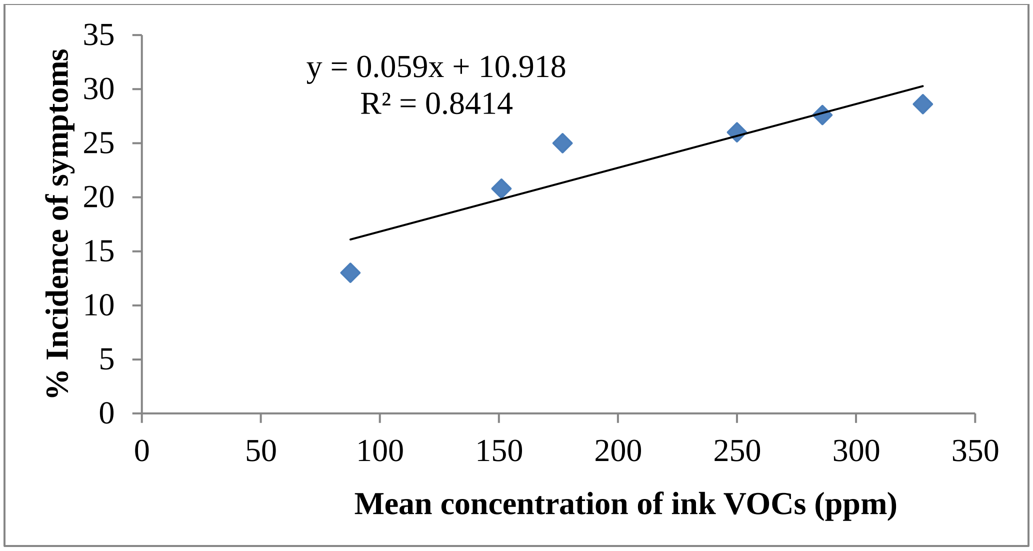


Figure 4.32: Relationship between incidences of symptoms of allergic conjunctivitis and concentration of ink vapours

When the relationship between the concentration of ink VOCs and the symptoms of allergic conjunctivitis was statistically tested, the results showed that the relationship was significant (F=21.163; p=.010) (Table 4.30).

Table 4.30: Relationship between incidences of symptoms of allergic conjunctivitis and concentration of ink VOCs

Model		Sum of Squares	df	Mean Square	F	Sig.
1	Regression	142.017	1	142.017	21.163	.010
	Residual	26.843	4	6.711		
	Total	168.860	5			

Increase of symptoms with increase in the concentration of VOCs agrees with Madureira *et al*. (2009) who found a significant correlation between the levels of TVOCs and the development of upper mucosal irritation among the Portuguese teachers. Postolache *et al*. (2008) also found that more persons at Baltimore and Washington, DC, experienced allergic symptoms during high pollen season than during low pollen period. Blom *et al*. (2013) found that different persons at the University Medical Centre Groningen required different amounts of allergens to elicit a response. Increase in the concentration of the ink VOCs therefore increases the number of persons whose threshold is reached. Increase in concentration of VOCs also increases the severity of eye allergy making many to recognize the symptoms. This is in line with the findings of Schuster *et al*. (2018) who found that increased intake of vitamin A increased the production of IgE and thereby the severity of airway inflammation in mice model. Increase in incidences of the symptoms with increased exposure (biological gradient) is an indication of a causal-effect-relationship between the whiteboard marker pen ink and the symptoms of allergic conjunctivitis. This is according to Hills criteria as reported by several authors (Rothman and Greenland, 2005; Swaen and van Amelsvcort, 2009; Fedak *et al*., 2015).

Different teachers had different workloads. Majority of teachers had a high load of 4-5 lessons per day (Figure 4.33).

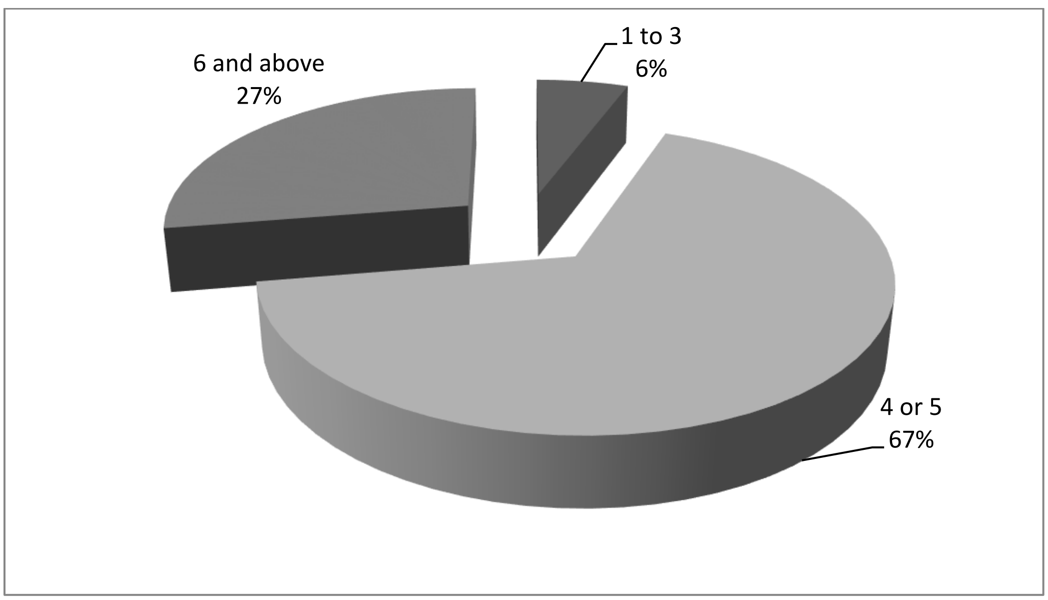


Figure 4.33: Workload of teachers

The workload determined the duration of exposure of teachers to the ink VOCs in the classrooms. Those who had high workload remained in classrooms longer than those who had lower workload. The incidence of symptoms of allergic conjunctivitis increased with increase in the number of lessons taught by a teacher as shown in Figure 4. 34.

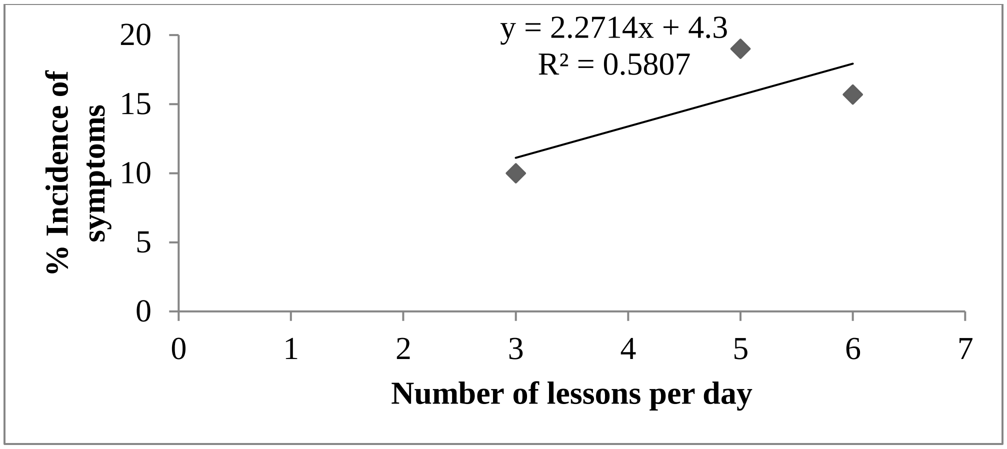


Figure 4.34: Relationship between workload and development of symptoms of allergic conjunctivitis

Those who had many lessons to attend would be in the classrooms longer than those who attended just a few lessons per day. These teachers would get exposed to ink vapours that had accumulated during the earlier lessons as well as those produced during their lessons. The concentration of the ink VOCs on the eye surface would therefore increase with time resulting in the development of symptoms. These result findings agree with those of Health Effects Institute (HEI) (2010) who previewed literature and found that prolonged exposure to atmospheric pollution increased mortality among the population in Asia. Elliott (2005) also found that increased duration at work for workers at an animal laboratory increased the incidences of allergy among those that were allergic to the specific animals. However, the relationship between workload and the development of symptoms of allergic conjunctivitis was not significant (p=.448) (Table 4.31).

Table 4.31: Relationship between workload and development of symptoms of allergic conjunctivitis

Model		Sum of Squares	df	Mean Square	F	Sig.
1	Regression	24.077	1	24.077	1.385	.448
	Residual	17.383	1	17.383		
	Total	41.460	2			

Lack of a significant relationship between the workload and the development of symptoms of allergic conjunctivitis could be due to the fact that different teachers used the whiteboard marker pens differently. Some teachers attended more lessons but wrote very little on the whiteboards. Also some teachers who had many lessons may have had their lessons after breaks when the accumulated ink VOCs had already cleared from the room since breaks allowed a lot of movement of the students and the opening of the doors allowed the outside air to enter and dilute the indoor air. Some of the ink VOCs could also have been pushed outside especially where the windows opposite to the door were open at the time of opening of the door. This could make the concentration of the indoor ink VOCs to be low during a lesson immediately after a break.

The incidence of eye irritation was higher among teachers when the marker pen ink was in use (27.1%) than when it was not in use (21.4%). Ink was not used during the July- August observation because the students were doing their end term examination. However marker pen ink was in use during the January-February observation because teaching was going on in all the schools (Figure 4.35).

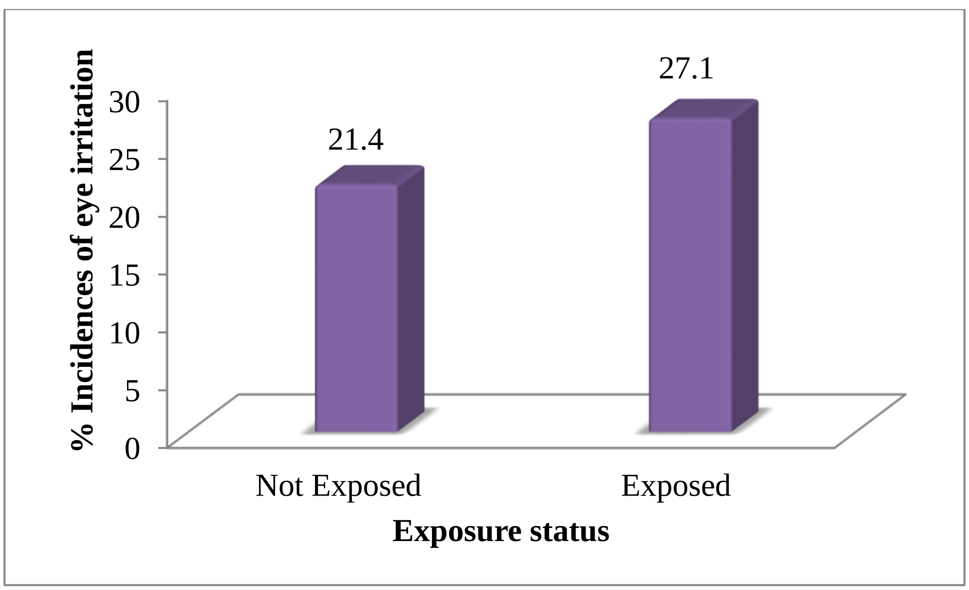


Figure 4.35: Influence of marker pen ink on eye irritation

These findings agree with ATSDR (2015) who reported that the components of dry erase ink are irritants. However, the incidences of eye irritation during the different exposure status was not significantly different because seasonal factors acted as confounders (p=0.164) (Table 4.32).

Table 4. 32: Comparison of incidences of eye irritation during exposure and non-exposure times of observation

Source	Factor	Type III Sum of Squares	df	Mean Square	F	Sig.
Factor	Linear	.369	1	.369	1.955	.164
Error(factor)	Linear	36.631	194	.189		

The incidence of eye irritation was highest among the teachers who used ink 3 (ethanol and hexane) and lowest among the teachers who used ink 1 (methanol and acetone) (Figure 4.36).

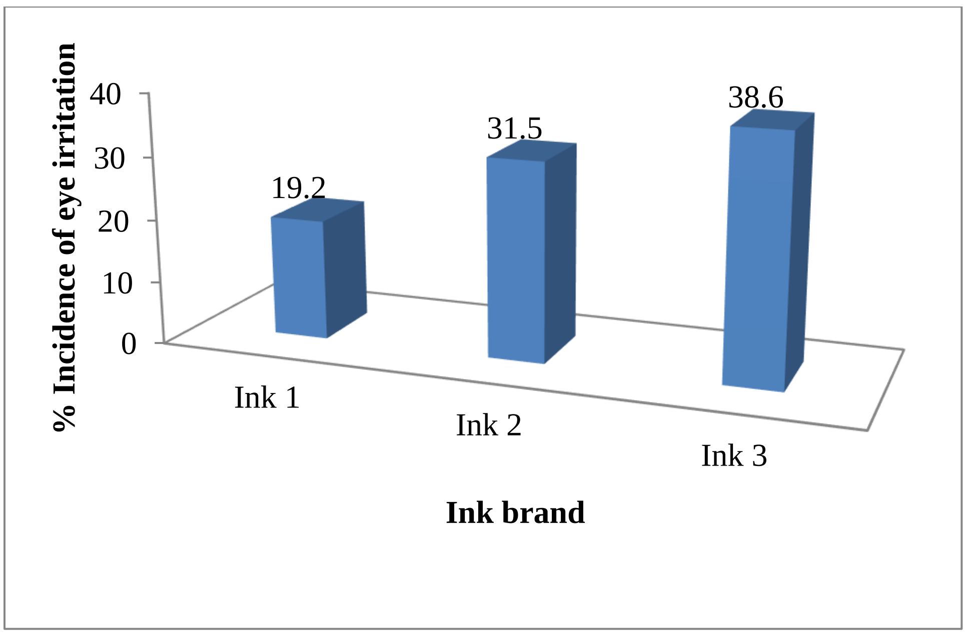


Figure 4.36: Relationship between ink brand and eye irritation

Statistical testing showed that there was a significant association between the brand of ink and the development of eye irritation among the teachers during the use of the ink (χ^2 =6.933; p=0.031) (Table 4.33).

Table 4.33: Association between ink brand and eye irritation

	Value	df	Asymptotic Significance (2-sided)
Pearson Chi-Square	6.933	2	.031
Likelihood Ratio	6.951	2	.031
Linear-by-Linear Association	6.749	1	.009
N of Valid Cases	221		

Post hoc test was carried out to establish which of the inks was significantly different in their ability to cause eye irritation. The statistical test (one way ANOVA) showed that there was no significant difference between the ink 2 and ink 3 (p=0.435) (Table 4.34).

Table 4. 34: Comparison of incidences of eye irritation between those who used ink 2 and ink 3

	Sum of Squares	df	Mean Square	F	Sig.
Between Groups	.140	1	.140	.613	.435
Within Groups	26.185	115	.228		
Total	26.325	116			

The Odds of developing eye irritation by teachers using ink 2 and ink 3 was compared with that of those who used ink 1 because ink 2 and ink 3 were found not to be significantly different in their ability to cause eye irritation. The results showed that the Odds of developing eye irritation by a teacher using ink 2 or 3 was significantly (p=0.02) higher than the Odds of developing eye irritation by a teacher using ink 1(Odds ratio= 2.182; 95 C.I.=1.174-4.054) (Table 4. 35).

Table 4.35: Risk Estimate for those who use ink 2 or 3

	Value	95% Confidence Lower	Interval Upper
Odds Ratio for inks for odds ratio test (2 or 3 / 1)	2.182	1.174	4.054
For cohort whether eyes feel irritated = yes	1.778	1.114	2.837
For cohort whether eyes feel irritated = no	.815	.694	.957
N of Valid Cases	221		

The mixture of methanol and acetone had the lowest potency of eliciting eye irritation while those mixtures that had hexane had a high potency. This agree with Ernstgård et al. (2005) who did not find significant irritation from methanol vapour in their study on the disposition of methanol vapor in humans. Maurer et al. (2001) found that acetone is associated with mild irritation while Cometto- Muñiz et al. (2006) found that hexane vapour caused chemesthetic stimulation resulting in sharp eye irritation. Oh et al. (2013) found that dry eye syndrome, which is associated with ocular inflammation or eye irritation is more prevalent among those exposed to ethanol. Different VOCs also react differently with air and other pollutants in the indoor air resulting in different mixtures which have different health effects (EPA, 2018). Capello and Gaddi (2018) say that groups of VOCs are more potent irritants than the individual VOCs. A mixture is therefore different from the sum addition of its components. The inks may therefore have shared some individual components (both ink 1 and ink 2 had acetone) but each had a different composition of VOCs in the mixture (ink 1 had acetone and methanol while ink 2 had acetone and hexane) explaining the differences in their ability to cause eye irritation. This means that teachers who use the dry erase with methanol and acetone mixture are safer than their counterparts who use dry erase inks with hexane and acetone or hexane and ethanol mixtures. These findings also indicate that substitution method can be used to control these irritants. Substituting inks 2 and 3 with ink 1 can aid in the control of the eye irritation.

CHAPTER FIVE

SUMMARY, CONCLUSIONS AND RECOMMENDATIONS

5.1 Introduction

This chapter presents the summary of the research study, the conclusions drawn from the study as well as the recommendations made as an outgrowth of this study.

5.2 Summary

The main purpose of the study was to assess the influence of occupational exposure to the whiteboard marker ink on the development of symptoms of allergic conjunctivitis among the school teachers. The objectives of the study were

i. To establish the composition of the VOCs produced by the whiteboard marker ink
ii. To analyze the distribution of the VOCs from the whiteboard marker ink in a school classroom
iii. To study the knowledge, attitude and practice (KAP) of teachers related to use of white board markers
iv. To assess the influence of classroom factors on the occupational exposure levels of teachers to VOCs from the whiteboard marker ink.
v. To establish the seasonal variations of symptoms of allergic conjunctivitis among the teachers
vi. To assess the influence of exposure to the whiteboard marker ink on the development of symptoms of allergic conjunctivitis among the teachers

The study was conducted in Nakuru County. Secondary schools that used whiteboards were selected purposefully while the teachers in the schools were randomly and proportionately sampled from the two categories of schools separated by their way of scheduling their midterm exams. Below is a summary of the findings:

i. The VOCs produced from the marker pens used to write on whiteboards in the secondary schools in Nakuru County contained, methanol, acetone, hexane and ethanol. Some of them were found to be at higher concentrations (758.65 ppm) in the classroom air than the recommended (200 $\mu g/m^3$) exposure levels.

ii. The concentrations of VOCs from the ink were more at 1.5 m than at 0.5 m above the floor of the classrooms. The average concentration was higher at the front at 1.5m above the floor (311 ppm) than at the back at the same height (220 ppm). An average of 76ppm and 152 ppm were found at 0.5m above the floor at the front and back of the classroom respectively.

iii. Majority of teachers (79.9%) were not knowledgeable on ink safety while 64.5% had a positive attitude towards the use of whiteboard marker pens. A positive attitude towards adoption coupled with no knowledge on safety predisposes the teachers to poor practices thus enhancing their occupational exposure.

iv. The concentration of ink VOCs increased with increase in temperature ($r=+0.089$) and concentration of carbon dioxide ($r=+0.087$) in the classroom. These aspects were linked to poor ventilation in the classrooms. However the relationships were weak and not significant ($p>0.05$).

v. The highest percentage incidence (20.7%) of symptoms of allergic conjunctivitis was in the coldest months of July and August, followed by September–October season (18.6%). The lowest incidence (14%) of symptoms of allergic conjunctivitis was during the hottest time of the year in the months of January and February.

vi. Increase in concentration of ink VOCs increased the incidences of symptoms of allergic conjunctivitis ($r^2=0.8414$) significantly ($p=0.010$). Increase in the duration of exposure to whiteboard marker ink also increased the incidences of symptoms of allergic conjunctivitis ($r^2=0.5807$). However the relationship between workload and development of the incidences of symptoms of allergic conjunctivitis was not significant ($p=0.448$).

5.3 Conclusions

This study makes the following conclusions based on the findings

i. Teachers are more likely to develop symptoms of allergic conjunctivitis since the marker pens contain hexane which is associated with eye irritation

ii. The teachers are highly exposed to ink VOCs because they remain standing and the VOCs are more concentrated at 1.5m above the floor which is the breathing level of a standing teacher

iii. Teachers have poor knowledge on marker pen ink safety and this coupled with positive attitudes predisposes them to poor practices in the process exposing them to ink VOCs

iv. Poor ventilation results in increased concentration of ink VOCs and this increases the occupational exposure of teachers to ink VOCs in the poorly ventilated classrooms

v. Incidences of symptoms of allergic conjunctivitis among the secondary school teachers are higher during the cold season

5.4 Recommendations

5.4.1 Recommendations from this work

Based on the above conclusions, the following recommendations are made:-

i. Create effective ventilation at the upper parts of the classrooms to ensure effective clearance of the ink VOCs.

ii. Regulatory bodies to monitor the ink supplies and ensure that the manufacturers avail the material safety data sheets with every supply so that the teachers can be knowledgeable on the health effects of the components of the ink.

iii. The policy makers should ensure that the teachers are trained on chemical safety especially the chemicals in the ink.

iv. The teachers and students should also be made aware of the importance of opening the windows so that the ventilation is effective to prevent the accumulation of ink VOCs in the classroom.

v. The schools should substitute ink 2 and 3 with ink 1 which does not have hexane to reduce the risk of eye irritation.

5.4.2 Recommendations for further research

The study makes the following recommendations for further studies

i. That further research be carried out to establish the potency of other marker pen ink brands so that the regulatory body can ensure that only those brands with minimal negative health effects are allowed in the market.

ii. That a study be carried out to establish the identity of the compounds which are formed when the ink vapours mix with other pollutants found in a classroom.

iii. That a research be carried out to establish the health effects of chronic occupational exposure to VOCs in whiteboard markers.

iv. That a study be carried out on the health effects of the whiteboard maker pen ink VOCs on the students

v. That a study be carried out on the health effects of the whiteboard maker pen ink on the workers in the dry erase manufacturing companies.

REFERENCES

Ackerman, S., Smith, L. M. and Gomes, P. J. (2016). Ocular itch associated with allergic conjunctivitis: latest evidence and clinical management. *Therapeutic Advances in Chronic Disease, 7*(1): 52-67

Adkinson, N. F., Bochner, B. S., Burks, W., Busse, W. W., Holgate, S. T., Lemanske, R. F. and O'Hehir, R. E. (Ed)(2014). *Middleton's Allergy Principles and Practice* (8th Edition). Philadelphia. Elsevier Saunders.

Agency for Toxic Substances and Disease Registry (2015). *Toxicological Profile*. Atlanta: U.S. Department of Health and Human Services, Public Health Service.

Agency for Toxic Substances and Disease Registry (2007). *Toxicological Profile*. Atlanta: U.S. Department of Health and Human Services, Public Health Service.

Ahmed, S., Anjum, F., Kebab, M., Ibraheem, N., Darwich, H., Mohammed, N., John, L. J., Arifulla, M. and Sreedharan, J. (2014). Prevalence of allergies among University students: a study from Ajman, United Arab Emirates. *Gulf Medical Journal, 1(S2): S173-S178.*

Ait-Khaled, N., Pearce, N., Anderson, H. R., Ellywood, P., Montefort, S. and Shah, J. (2007). Prevalence of symptoms of asthma, rhinitis and eczema in 13 to 14 year old children in Africa: The international study of asthma and allergies in childhood phase three. *Allergy, 62*(3), 247-258.

Ajzen, I. (1991). *The Theory of Planned Behavior. Organization Behavior and Human Decision Processes*. Massachusetts. Academic Press.

Al-Bukhaiti, W. Q., Noman, A., Qasim, A. S. and Al-Farga, A. (2017). Gas chromatography: Principles, advantages and applications in food analysis. *International Journal of Agriculture Innovations and Research, 6*(1): 123-128

Anderson, R. and Anderson, J. (2003). Acute toxicity of marking pen emissions. *Journal of Toxicology and Environmental Health, 66*(9): 829-845

Andrews, J. H. and Hirano, S. S. (Ed)(2012). *Microbial Ecology of Leaves*. New York. Springer-Verlag.

Annika, G. (2012). *Chemical Emissions from Building Structures: Emission Sources and their Impact on Indoor Air*. Umea. Print and Media.

Ariga, J. and Jayne, T. S. (2009). Private sector responses to public investments and policy reforms. The case of fertilizer and maize market development in Kenya. *IFPRI Discussion Paper, 00921*

Armstrong, M. (2009). *Handbook of Human Resources Management Practices* (11^{th} edn). London. Kogan page.

Atkinson, J., Chartier, Y., Pessoa-Silva, C. L. (Eds)(2009). *Natural Ventilation for Infection Control in Health-Care Settings*. Geneva. World Health Organization.

Atwopetu, O. O. and Bello, I. T. (2017). Design of an automatic cleaning dry-wipe and presentation board. *International Journal of Scientific and Engineering Research, 8*(9): 880-891

Bag, N., Yap, D. H. and Wohland, T. (2014). Temperature dependence of diffusion in model and live cell membranes characterized by imaging fluorescence correlation spectroscopy. *Biochimica et Biophysica Acta Biomembranes, 1838*(3):802-813

Batterman, S., Jia, C., Godwin, C. and Hatzivasilis, G. (2007). A dorminant source of VOC exposure: attached garages. *Epidemiology, 17*(6): S350

Bauerle, D., (2011). *Laser Processing and Chemistry* (4^{th} edn). New York. Springer.

Beisheim, M. (2015). *Reviewing the Post-2015 Sustainable Development Goals and Partnerships*. Berlin. Stiftung Wissenschaft und Politik.

Belgü, A. U., Uçal, Y. O., Ekinci, A., Aliș, M. G., Yildirim, Ö. and Dizdar, D. (2014). Assessment of quality of life and coexistent allergic conjunctivitis in patients with allergic rhinitis in Van Province. *Turkish Archives of Otolaryngology, 52*: 87-92

Berman, H. (2016). *Sample size: Stratified Random Samples.* Retrieved from http://stattrek.com/sample-size/stratified-sample.aspx on 2/6/2016

Bielory, L. and Friedlaender, M. H. (2008). Allergic Conjunctivitis. *Immunology and Allergy Clinics of North America, 28*(1), 43-58.

Blom, W. M., Vlieg-Boerstra, B. J., Kruizinga, A. G., Heide, S., Houben, G. F. and Dubois, A. E. J. (2013). Threshold dose distributions for 5 major allergenic foods in children. *The Journal of Allergy and Clinical Immunology, 131*(1): 172–179

Blooma, J., Nkhoma, M. and Leung, N. (2013). *Proceedings of the 4th International Conference on Information Systems Management and Evaluation*. Ho Chi Minh. Academic conferences and publishing limited.

Bloomfield, S. F., Rook, G. A.W., Scott, E. A., Shanahan, F., Stanwell-Smith, R. and Turner, P. (2016). Time to abandon the hygiene hypothesis: new perspectives on allergic disease, the human microbiome, infectious disease prevention and the role of targeted hygiene. *Perspectives in Public Health, 136*(4): 213–224.

Borak, J. and Brosseau, L. M. (2015). The past and future of occupational exposure limits. *Journal of Occupational and Environmental Hygiene, 12*(1):S1-S3.

Brady, J. E. (2007). *The Study of Matter and its Changes* (5th Ed). New Jersey. John Wiley and Sons.

Breen, M. S., Breen, M., Williams, R.W. and Schultz, B.D. (2010). Predicting residential air exchange rates from questionnaires and meteorology: model evaluation in central North Carolina. *Environmental Science and Technology, 44*(24): 9349-9356

Brevard, H., Cantergiani, E., Cachet, T., Chaintreau, A., Demyttenaere, J., French,L., Gassenmeier, K., Joulain, D., Koenig, T., Leijs, H., Liddle, P., Loesing, G., Marchant, M., Saito, K., Scanlan, F., Schippa, C. , Scotti, A., Sekiya, F. and Sherlock, A. (2011). Guidelines for the quantitative gas chromatography of volatile flavouring substances, from the Working Group on Methods of Analysis of the International Organization of the Flavor Industry (IOFI), *Flavour and Fragrance Journal*, *26*: 297-299.

Building Research Association of New Zealand (2007). *Designing Quality Learning Spaces: Heating and Insulation*. Porirua. Building Research Association of New Zealand.

Canha, N., Lage, J., Candeias, S., Alves, C. and Almeida, S. M. (2017). Indoor air quality during sleep under different ventilation patterns. *Atmospheric Pollution Research, 8* (6): 1132-1142

Cantú, A. A. (2012). A study of the evaporation of a solvent from a solution- application to writing ink aging. *Forensic Science International*, *219*(1-3): 119-128

Cantú, A. A. (2015). Evaporation of a non-ideal solution and its application to writing ink aging. *Forensic Science International, 247*: 69-78

Capello, F. and Gaddi, A. V. (Eds) (2018). *Clinical handbook of air pollution-related diseases*. Liverpool. Springer.

Carroll, C. C. and Valenti, M. A. (2006). *Dry erase ink composition*. Spartanburg. Parks Williams

Castorina, R., Tysman, M., Bradman, A., Hoover, S., Lyer, S., Russell, M., Sultana, D. and Maddalena, R. (2016). Volatile organic compound emissions from markers used in preschools, schools and homes. *International Journal of Environmental Analytical Chemistry, 96*(3): 1247-1263

Centre for Disease Control and Prevention (2016). *NIOSH pocket guide to chemical hazards*. Atlanta. Centre for Disease Control and Prevention.

Chatzidiakou, L., Mumovic, D., and Summerfield, A. J. (2012). What do we know about indoor air quality in school classrooms? A critical review of the literature. *Intelligent Building International, 4*(4): 228-259

Cheung, S. S. (2015). Responses of the hands and feet to cold exposure. *Temperature, 2*(1): 105-120

Chigbu, G. I. and Minhas, B. K. (2018). Immunopathology of allergic conjunctivitis. *European Medical Journal, 3*(1): 76-83.

Chin, J.-Y., Godwin, C., Parker, E., Robins, T., Leiws, T., Harbin, P. and Batterman, S. (2015). Levels and sources of volatile organic compounds in homes of children with asthma *Indoor Air, 24*(4): 403-415

Chittleborough , C. R., Nicholson, A. L., Basker, E., Bell, S. and Campbell, R. (2013). Factors influencing hand washing behaviour in primary schools: process evaluation within a randomised controlled trial. *Health Education Research, 27*(6), 1055–1068.

Chiu, C.-F. Chen, M.-H. and Chang, F.-H. (2015). Carbon Dioxide Concentrations and Temperatures within Tour Buses under Real-Time Traffic Conditions. *PLoS One,10*(14): *e125117*

Chowdhury, B. (2013). Allergic conjunctivitis-a review. *Dehli Ophthalmogical Society Times, 19*: 41-47

Chung, Y-J., Cho, I-K., Lee, K-L., Bae, S-H., Lee, J-W., Chung, P-S. and Mo, J-H. (2012). Seasonal specificity of seasonal allergens and validation of the ARIA classification in Korea. *Allergy, Asthma and Immunology Research, 5*(2): 75-80.

Clarke, M. and Pittaway, S. (2014). *Marsh's becoming a teacher* (6th edn). Sydney. Pearson.

Clary, J. J. (eds)(2013). *The toxicology of methanol*. New Jersey. John Wiley and Sons, Inc.

Cometto-Muniz, J.E., Cain, W. S. and Abraham, M. H. (2004). Detection of single and mixed VOCs by smell and by sensory irritation. *Indoor Air, 14*(8): 108-117

Conner, N. (2009). *Living green: The missing manual*. Sebastopol. O'Reilly Media, Inc.

Considine, D.M. and Considine, G. D. (2013). *Van nostrand's scientific encyclopedia* (8th edition). New York. Springer.

Courduff, J., Szapkiw, A. and Wendt, J. L. (2016). *Journal of Special Education Technology, 31*(1): 26-38

Cowan, J. M., Burris, J. M., Hughes, J. R. and Cunningham, M. P. (2010).The relationship of normal body temperature, end-expired breath temperature, and BAC/BrAC ratio in 98 physically fit human test subjects. *Journal of Analytical Toxicology, 34*(5): 238-242

Cristescu, S.M., Mandon, J., Arslanov, D., De Pessemier, J., Hermans, C. and Harren, F. M. (2013). Current methods for detecting ethylene in plants. *Annals of Botany, 111*: 347-360

Daisey, J. M., Angell, W. J. and Apte, M. G. (2003). Indoor air quality, ventilation and health symptoms in schools: an analysis of existing information. *Indoor Air, 13*(1): 53-64.

Dales, R. E., Cakmat, S., Leech, J. and Liu, L. (2013). The association between personal care products and lung function. *Annals of Epidemiology, 23*(2): 49-53

D'Amato G, Holgate, S. T., Pawankar, R. (2015). Meteorological conditions, climate change, new emerging factors, and asthma and related allergic disorders. A statement of the World Allergy Organization. *World Allergy Organization Journal*, *8*(1): 25

D'Amato, G., Vitale, C., De Martino, A., Viegi, G., Lanza, M., Molino, A., Sanduzzi, A., Vatrella, A., Annesi-Maesano, I. and D'Amato, M. (2015). Effects on asthma and respiratory allergy of Climate change and air pollution. *Multidisciplinary Respiratory Medicine, 10*: 39

Davis, F. D., Bogozzi, R. P., & Warshaw, P. R. (1989). User acceptance of computer technology: A comparison of two theoretical models. *Management Science, 35*, 982-1003.

Dewulf, J., Langenhove, H. V. and Wittmann, G. (2002). Analysis of volatile organic compounds using gas chromatography. *Trends In Analytical Chemistry*, *21*(9-10): 637-646

Dick, F. D. (2006). Solvent neurotoxicity. *Occupational and Environmental Medicine, 63:* 221-226

Dikshith, T. S. (2011). *Handbook of chemicals and safety*. New York. CRC press.

Du, L., Batterman, S., Godwin, C., Rowe, Z. and Chin, J. Y. (2015). Air exchange rates and migration of VOCs in basements and residences. *Indoor Air, 25*(6): 598-609.

Dunagan, S. C., Dodson, R.E. and Brody, J. G. (2011). Toxics use reduction in the home: lessons learned from household exposure studies. *Journal of Cleaner Production., 19*(5): 438-444

Eastlake, A., Hodson, L., Geraci, C. and Crawford, C. (2012). A critical evaluation of material safety data sheets (MSDSs) for engineered nanomaterials. *Journal of Chemical Health and Safety, 19*(5): 1–8.

Elliott, L., Heederk, D., Marshall, S., Peden, D. and Loomis, D. (2005). Incidence of allergy and allergy symptoms among workers exposed to laboratory animals. *Occupational and Environmental Medicine, 62*(11): 766-771

Environmental Protection Agency (2006). *Chemical management resource guide for school administrators*. Rockville. U.S. Environmental Protection Agency.

Environmental Protection Agency (2015). *Contaminated site clean-up information. Field Analytic Technologies.* Rockville. U.S. Environmental Protection Agency.

Environmental Health and Safety (2015). *Isopropyl alcohol*. San Francisco**.** Environmental Health and Safety

Environmental Protection Agency (2018). *VOCs and Sensory Irritation Symptoms or Sick Building Syndrome Symptoms*. Rockville. U.S. Environmental Protection Agency.

Environmental Protection Agency (2018). *VOCs from indoor chemical reactions and health.* Rockville. U.S. Environmental Protection Agency.

Epri, M.L. (2016). A case study on the impact of large classes on student learning. *DWU Research Journal, 24*: 95-109.

Ertmer, P.A. and Ottenbreit-Leftwich, A. T. (2010). Teacher Technology Change: How Knowledge, Confidence, Beliefs, and Culture Intersect. *Journal of Research on Technology in Education, 42* (3): 255–284

Fedak, K. M., Capshaw, Z. A. and Gross, S. (2015). Applying the Bradford Hill criteria in the 21st Century: how data integration has changed causal inference in molecular epidemiology. *Emerging Themes in Epidemiology, 12*:14

Felizardo, S., Ribeiro, E. and Amante, M. J. (2016). Parental adjustment to disability, stress indicators and the influence of social support. *Procedia-Social and Behavioral Sciences, 217*: 830-837.

Fishbein, M., and Ajzen, I. (1975). *Belief, attitude, intention, and behavior: An introduction to theory and research*. Ontario. Addison-Wesley Pub. Co.

Fisher, A. A., Laing, J. E., Stoeckel, J. E. and Townsend, J.W. (1999). *Handbook for Family Planning Operations Research Design* (2nd Edition). New York: Population Council.

Fivizzani, K. P. (2007). *Chemical safety manual for small businesses*. Washington, DC. American Chemical Society.

Foliaki, S. Annesi-Maesano, I., Daniel, R., Fakakovikaetau, T., Magatongia, M., Tuuau-Potoi, N., Waqatakirewa, L., Cheng, S.K. and Pearce, N. (2007). Prevalence of symptoms of childhood asthma, allergic rhinoconjunctivitis and eczema in the pacific: The International Study of Asthma and Allergies in Childhood (ISAAC). *Allergy, 62*(3): 259-264.

Forensic Scientist Manager (2015). *Technical Procedure for Gas Chromatography*.Virginia. Forensic Scientist Manager.

Friedlaender, M. H. (2011). Ocular allergy. *Current Opinion In Allergy and Clinical Immunology, 11*(5): 477-482

Gaceri, K. A. (2015). Factors affecting the implementation of health and safety in supermarkets in Kenya. *International Journal of Human Resource Studies, 5*(2): 2162-3058

Gall, M. D., Borg, R. W. and Gall, P. G. (1996). *Educational research: An introduction*. New York: Longman.

Gergen, K. J. and Black, K. W. (1966). Communication in the interview and disengaged respondent. *Public Opinion Quarterly, 30*: 385-398

Glanz, K., Marcus, L. F. and Rimer, B.K. (1997). *Theory at a Glance: A Guide for Health Promotion Practice*. Bethsaida. National Institute of Health.

Glen, N. D. (1974). Aging and conservatism. *Annals of the Academy of Political and Social Science, 415*: 176-186

Godwin, C. and Batterman, S. (2007). Indoor air quality in Michigan schools. *Indoor Air, 17*(2): 109-121.

Goodhue, D. L. and Thompson, R. L. (1995). Task technology fit and individual performance. *MIS Quarterly*, *19*: 213-236.

Görgényi, M., Dewulf, J., Van Langenhove, H. and Király, Z. (2005). Solubility of volatile organic compounds in aqueous ammonia solution. *Chemosphere, 59*(8):1083-1090.

Goswami, A. and Dutta, S. (2016). Gender differences in technology usage. A literature review. *Open Journal of Business and Management, 4*. 51-59

Government of Kenya (1968). *The Local Government (Building) By laws*. Nairobi. Government printers.

Government of Kenya (2006). *Early childhood development service standard guidelines for Kenya*. Nairobi. Government printers.

Government of Kenya (2007). *The Employment Act*. Nairobi. Government printers.

Government of Kenya (2007). *Tobacco control Act.* Nairobi. Government printers

Government of Kenya (2009). *KS Code: Building Code of the Republic of Kenya*. Nairobi. Government printers.

Government of Kenya (2010). *The constitution*. Nairobi. Government printers

Government of Kenya (2010). *Occupational Safety and Health Act*. Nairobi. Government Printers.

Government of Kenya (2012). *Environmental Management and Coordination Act*. Nairobi. Government Printers.

Government of Kenya (2012). *Radiation Protection Act*. Nairobi. Government printers

Government of Kenya (2012). *Teachers Service Commission Act*. Nairobi. Government Printers

Government of Kenya (2012). *The Pest Control Products Act*. Nairobi. Government printers

Government of Kenya (2012). *The Standards Act*. Nairobi. Government printers.

Government of Kenya (2017). Public Health Act. Nairobi. Government printers.

Gravetter, F. J. (2008). *Essentials of statistics for the behavioral sciences* (6th edn). New York. Thomson Wardsworth.

Greenberg, M. I., Hamilton, R. J., Phillips, S. D. and Mccluskey, G. J. (Eds) (2003). *Occupational, industrial and environmental toxicology* (2ndedn). Philadelphia. Mosby, Inc.

Griffith, M. E. and Kocsis, A. (2011). *How to be successful in your first year of teaching middle school: Everything you need to know that they don't teach you in school*. Ocala. Atlantic Publishing Group, Inc.

Halverson, C. (2011). *Markers*. Albany. Healthy Schools Network Inc.

Hathaway, G. J. and Proctor, N. H. (2004). *Proctor and Hughes' chemical hazards of the workplace* (5th edn). New Jersey. John Wiley and Sons, Inc.

Health and Safety Executive (2000). *General ventilation in the workplace. Guidance for employers*. Norwich. Crown.

Health Effects Institute International Scientific Oversight Committee (2010). *Outdoor air pollution and health in developing countries of Asia: a comprehensive review. Special Report 18*. Boston. Health effects institute.

Hellen, H., Tykka, T. and Hakola, H. (2012). Importance of monoterpenes and isoprene in urban air in northern Europe. *Atmospheric Environment, 59*:59–66.

Heppner, F. (2007). *Teaching the large college class; A guide book for instructors with multitudes*. San Francisco. John Wiley and Sons Inc.

Hinks, M. L., Brady, M.V., Lignell, H., Song, M., Grayson, J.W., Bertram, A. K., Lin, P., Laskin, A., Laskin, J., Nizkorodov, S. A. (2016). Effect of viscosity on photodegradation rates in complex secondary organic aerosol materials. *Physical Chemistry Chemical Physics, 18*: 8785–8793.

Her Majesty's Government (2010). *Building Regulations 2000: Approved Document F1: Means of ventilation*. London. NBS.

Ho, D. X., Kim, K. H., Sohn, J. R., Oh, Y. H. and Ahn, J.W. (2011). Emission rates of volatile organic compounds released from newly produced household furniture products using a large-scale chamber testing method. *Scientific World Journal, 11*: 1597-1622

Holøs, S. B., Yang, A., Lind, M., Thunshelle, K., Schild, P. and Mysen, M. (2018). VOC emission rates in newly built and renovated buildings, and the influence of ventilation- a review and meta-analysis. *International Journal of Ventilation, 17*(2): 1-14

Hsu, H. L. and Lin, J. C. C. (2008). Acceptance of blog usage: the roles of technology acceptance, social influence and knowledge sharing motivation. *Information and Management*, 45: 65–74.

Huang, S., Xiong, J., Cai, C., Xu, W. and Zhang, Y. (2016). Influence of humidity on the initial emittable concentration of formaldehyde and hexaldehyde in building materials: experimental observation and correlation. *Scientific Reports, 6*: 23388

Husain, M. Y., Mustapha, R. and Malik, S. A. (2014). Review of measurement item of engineering students' learning environment: confirmatory factor analysis. *Journal of Technical Education and Training, 6*(11): 142-156.

Hussin, M., Ismail, M. R and Ahmad, M. S. (2017). Air-conditioned university laboratories: Comparing CO_2 measurement for centralized and split-unit systems. *Journal of King Saud University - Engineering Sciences, 29* (2): 191-201

Hyrkäs, H., Jaakkola, M. S., Ikäheimo, T. M., Hugg, T. T. and Jaakkola, J. J. (2014). Asthma and allergic rhinitis increase respiratory symptoms in cold weather among young adults. *Respiratory Medicine*, *108* (1): 63-70

Imonikhe, R., Flynn, T. H. and Mearza, A. A. (2011). Determination of seasonal allergic conjunctivitis variation using internet search engine data. *Eye, 25*(12):1663

International Covenant on Economic, Social and Cultural Rights (16 December 1966). *United Nations, Treaty Series, (993).* accessed online on 19 April 2016 at: http://www.refworld.org/docid/3ae6b36c0.html

International Labour Organization (2004). *Global strategy on occupational safety and health*. Geneva. International Labour Organization.

International Labour Organization (2006). *Promotional Framework for occupational safety and health*. Geneva. International Labour Organization.

International Labour Organization (2016). *National Labour Law Profile: Kenya*. Geneva. International Labour Organization.

Irungu, C. (2015). List of schools with whiteboards. *Timtex records.* Unpublished raw data

Ishidao,T., Ishimatsu, S. and Hori, H. (2005). Measurement of volatile organic compounds concentration in indoor air of school buildings in an University (part 2). *Journal of Work, Environment and Health, 26*: 52-57

Islahi, F. and Nasreen, D. (2013). Who make effective teachers, men or women? An Indian perspective. *Universal Journal of Educational Research, 1*(4): 285-293

Jahan, K., Mahmood, D. and Fahim, M. (2015). Effects of methanol in blood pressure and heart rate in the rat. *Journal of Pharmacy Bioallied Sciences.*, *7*(1): 60-64

Jia, C., Batterman, S. and Godwin, C. (2008). VOCs in industrial, urban and suburban neighborhoods-Part 2: Factors affecting indoor and outdoor concentrations. *Atmospheric Environment, 42*(9): 2101-2116

Jin, Z. Y., Wu, M., Han, R. Q., Zhang, X. F., Wang, X. S., Liu, A. M., Zhou, J. Y., Lu, Q. Y., Kim, C. H., Mu, L., Zhang, Z. F. and Zhao, J. K. (2014). Household ventilation may reduce effects of indoor air pollutants for prevention of lung cancer: A case-control study in a Chinese population. *PLoS One, 9*(7): e102685

Jo, W.-J. and Sohn, J.-Y. (2009). The effect of environmental and structural factors on indoor air quality of apartments in Korea. *Building and Environment, 44*(9): 1794-1802

Jobrack, B. (2012). *Tyranny of the textbook: An insider exposes how educational materials undermine reforms*. New York. Rowman and Littlefield Publishers, Inc.

Kaciuba-Uscilko, H. and Grucza, R. (2001). Gender differences in thermoregulation. *Current Opinion In Clinical Nutrition and Metabolic* Care, *4*: 533-536.

Kandyala, R., Phani, S. Raghavendra, C. and Rajasekharan, S. T. (2010). Xylene: An overview of its health hazards and preventive measures. *Journal of Oral Maxillofacial Pathology*, *14* (1): 1–5

Kang, D. H., Choi, D. H., Lee, S. M., Yeo, M. S. and Kin K.W. (2010). Effect of bake-out on reducing VOC emissions and concentrations in a residential housing unit with a radiant floor heating system. *Building and Environment, 45*(8): 1816-1825

Kari, O. and Saari, K. M. (2010). Updates in the treatment of ocular allergies. *Journal of Asthma and Allergy*, 3(24): 149-158

Kay, A. B., Kaplan, A. P., Bousquet, J. and Holt, P. G. (Eds) (2009). *Allergy and allergic diseases. The scientific basis of allergy* (2nd edn). London. John Wiley and Sons.

Kembel, S. W., Jones, E., Kline, J., Northcutt, D., Stenson, J., Womack, A. M., Bohannan, B. J. M., Brown, G. Z. and Green, J. L. (2012). Architectural design influences the diversity and structure of the built environment microbiome. *ISME Journal*, *6*(8): 1469-1479

Kennedy, K. (2011). *Resurface old boards*. Cape town. Eduboard.

Kenya National Bureau of Statistics (2014). *Kenya Demographic and Health Survey*. Nairobi. Government printers.

Kenya National Bureau of Statistics (2015). *County statistical abstract.* Nairobi. Government printers.

Kenya National Bureau of Statistics (2013). *Statistical abstract.* Nairobi. Government printers.

Kenya National Bureau of Statistics and Society for International Development (2013). *Exploring Kenya's Inequality. Pulling Apart or Pooling Together*? Nairobi. Government printers.

Kerlinger, F. N. (1983). *Foundations of behavioural research*. London: Holt Rhinehart and Winston.

Kim, S. (2008). The reduction of air pollutant from wood-based composite by adding pozzolan for building materials. *Construction and Building Materials, 23*: 2319-2323

Kimball, B. A., Russell, J. H., Griffin, D. L. and Johnston, J .J. (2005). Response factor considerations for the quantitative analysis of western redcedar (*Thuja plicata*) foliar monoterpense. *Journal of Chromatographic Science*, *43*(5): 253-258

Kirk, M. A. and Deaton, M .L. (2007). Bringing order out of chaos: effective strategies for medical response to mass chemical exposure. *Emergency Medicine Clinics of North America, 25*(2): 527-548

Kleerekoper, L., van Esch, M. and Salcedo, T. B. (2012). How to make a city climate-proof, addressing the urban heat island effect. *Resources, Conservation and Recycling, 64*: 30-38

Koh, D. and Takahashi, K. (Ed)(2011). *Textbook of occupational Medicine Practice* (3rd Edition). Singapore. World Scientific.

Koskela, H. O. (2007). Cold air-provoked respiratory symptoms: the mechanisms and management. *International Journal of Circumpolar Health, 66* (2): 91-100

Krosnick, J. A. and Alwin, D. F. (1989). Aging and susceptibility to attitude change. *Journal of Personality and Social Psychology, 57*: 416-425

Kushwah, D., Patel, H. B., Sinha, P. K. and Jana, P. K. (2011). Practical approach for the determining of response factors of impurities in drugs by HPLC. *E-Journal of Chemistry, 8*(4): 1504-1511.

La Rosa, M., Lionetti, E., Reibaldi, M., Russo, A., Longo, A., Leonardi, S., Tomarchio, S., Avitabile, T. and Reibaldi, A. (2013). Allergic conjunctivitis: a comprehensive review of literature. *Italian Journal of Pediatrics, 39*(18): 1-8

Langer, S. and Bekö, G. (2013). Indoor air quality in the Swedish housing stock and its dependence on building characteristics. *Building and Environment, 69*: 44-54

Lawless, K. A. and Pellegrino, J. W. (2007). Professional development in integrating technology into teaching and learning: Knowns, unknowns, and ways to pursue better questions and answers. *Review of Educational Research, 77*: 575–614.

Lawson, J. (2010). *Texts in statistical science. Design and analysis of experiments with SAS*. London. CRC Press.

Lazović, I., Jovašević-Stojanović, M., Živković, M., Tasić, V. and Stevanović, Ž. (2015) PM and CO2 variability and relationship in different school environments. *Chemical Industry and Chemical Engineering Quarterly, 21* (1): 179−187.

Lazović, I. M., Stevanović, Ž. M., Jovašević-Stojanović, M. V., Živković, M. M. and Banjac, M. J. (2016). Impact of CO2 concentration on indoor air quality and correlation with relative humidity and indoor air temperature in school buildings, Serbia. *Thermal Science, 20* (1): 297-307

Leonardi, A. (2013). Allergy and allergic mediators in tears. *Experimental Eye Research, 117*: 106-117

Leonardi, E., Bogacka, J. L., Fauquert, M. L., Kowalski, A., Groblewska, M. and Jedrzejczak, C. (2012). Ocular allergy: Recognizing and diagnosing hypersensitivity disorders of the ocular surface. *Allergy, 67*: 1327-1337

Liang, Y. (2014). *Novel methods of characterizing phthalate emissions and their fate and transport in residential indoor environments*. PhD Dissertation. University of Texas at Austin

Lim, T., Han, S., Chung, J., Chung, J. T., Ko, S. and Grigoropoulos, C. P. (2013). Experimental study on spreading and evaporation of inkjet printed pico-liter droplet on a heated substrate. *International Journal of Heat and Mass Transfer, 52*: 431-441.

Lin, C. C., Yu, K. P., Zhao, P. and Lee, G. M. (2009). Evaluation of impact factors on VOC emissions and concentrations from wooden flooring based on chamber tests. *Building and Environment, 44:* 525-533

Lu, C., Lin, J., Chen, Y. and Chen, Y. (2015). Building-related symptoms among office employees associated with indoor carbon dioxide and total volatile organic compounds. *International Journal of Environmental Research and Public Health, 12*(6): 5833–5845

Madureira , J., Alvim-Ferraz , M. M., Rodrigues, S. Gonçalves, C., Azevedo, M. C., Pinto, E. and Mayan, O. (2009). Indoor air quality in schools and health symptoms among Portuguese teachers. *Human and Ecological Risk Assessment: An International Journal, 15*(1): 159-169

Madureira, J., Paciencia, I., Ramos, E., Barros, H., Pereira, C., Teixeira, J. P. and Fernandes, E. O. (2015). Children's health and indoor air quality in primary schools and homes in Portugal-study design. *Journal of Toxicology and Environmental Health, Part A, 78* (13-14): 915-930.

Mahyuddin, N., Awbi, H. B. and Alshitawi, M. (2014). The spartial distribution of carbon dioxide in rooms with particular application to classrooms. *Indoor and Built Environment, 23*(3): 433-448

Maillefer, S., Lehr, C. R. and Cullen, W. R. (2003). The analysis of volatile trace compounds in landfill gases compost heaps and forest air. *Applied Organometallic Chemistry, 17*: 154-160

Malik, S., Ajaz, N. and Jumani, N. B. (2016). Professional knowledge, attitude and practice o of teachers. *Pakistan Journal of Social Sciences, 36*(1): 199-208

Marr, D., Mason, M., Mosley, R. and Liu, X. (2011). The influence of opening windows and doors on the natural ventilation rate of a residential building. *HVAC and R Research, 18*(1): 195-203.

Matysik, S., Ramadan, A. B. and Schlink, U. (2010). Spatial and temporal variation of outdoor and indoor exposure of volatile organic compounds in Greater Cairo. *Atmospheric Pollution Research, 1*: 94-101.

Maurer, J. K., Molai, A., Parker, R. D., Li, L. I., Carr, G. J., Petrol, W. M., Cavanagh, H. D. and Jester, J. V. (2001). Pathology of ocular irritation with acetone, cyclohexanol, parafluoroaniline, and formaldehyde in the rabbit low-volume eye test. *Toxicologic Pathology, 29*(2): 187-189

Mazzatenta, A., Pokorski, M. and Di Giulio, C. (2015). Real time analysis of volatile organic compounds (VOCs) in centenarians. *Respiratory Physiology and Neurobiology, 209*: 47-51

Mbugua, N. S., Gori, M. J. and Tanui, E. (2015). Integration of information communication technology in teaching in public secondary schools in Nakuru County, Kenya. *International Journal of Education and Research, 3*(8): 271-282

McKee, R. H., Adenuga, M. D. and Carrillo, J. C. (2017). The reciprocal calculation procedure for setting occupational exposure limits for hydrocarbon solvents: an update. *Journal of Occupational and Environmental Hygiene, 14*(8): 573-582

Meghouar, H. (2016). *Corporate takeover targets. Acquisition probability*. Hoboken. John Wiley and Sons Inc.

Meininghaus, R., Gunnarsen, L. and Knudsen, H. N. (2000). Diffusion and sorption of volatile organic compounds in building materials−impact on indoor air quality. *Environmental Science and Technology*, *34* (15): 3101–3108

Merschbrock, C and Nordahl-Rolfsen, C. (2016). BIM technology acceptance among reinforcement workers – the case of Oslo airport's terminal 2. *Journal of Information Technology in Construction , 21*: 1-12

Michailopoulos, P., Almaliotis, D., Georgiadou, I., Papakosta, D., Gougoulias, K., Giouleka, P., Gioulekas, D., Siempis, T. and Karampatakis, V. (2017). Allergic conjunctivitis in patients with respiratory allergic symptoms; A retrospective study in Greece. *Medical Hypothesis*, *Discovery* and *Innovation* in *Ophthalmology*, 6(1): 3–9.

Ministry of Education (2008). *Safety Standards Manual for Schools in Kenya* (1st edn). Nairobi. Government printers.

Ministry of Labour (2012). *The National Occupational Safety and Health Policy*. Nairobi. Government printers.

Mira, S., Hill, L. M. , González-Benito, M. E., Ibáñez, M. A. and Walters, C. (2016). Volatile emission in dry a way to seeds as probe chemical reactions during initial asymptomatic deterioration. *Journal of Experimental Botany, 67* (6):1783-93

Miraldi, U. V. and Kaufman, A. (2014). Allergic eye disease. *Pediatric Clinics of North America, 61*: 607-620

Mochalski , P. and Unterkofler, K. (2016). Quantification of selected volatile organic compounds in human urine by gas chromatography selective reagent ionization time of flight mass spectrometry (GC-SRI-TOF-MS) coupled with head-space solid-phase micro extraction (HS-SPME). *Analyst*, *141*(15): 4796-4803.

Moghaddan, E. H., Amindeldar, S. and Besharatizadeh, A. (2011). New approach to natural ventilation in public buildings inspired by Iranian's traditional windcatcher. *Procedia Engineering, 21*: 42-52

Mølhave, L., Clausen, G., Berglund, B., Ceaurriz, J. D., Kettrup, A. Lindvall, T. Maroni, M., Pickering, A. C., Risse, U., Rothweiler, H., Seifert, B. and Younes, M. (1997). "Total Volatile Organic Compounds (TVOC) in indoor air quality investigations". *Indoor Air, 7*: 225-240.

Moon, B. C. and Chang, H. (2014). Technology acceptance and adoption of innovative smartphone uses among hospital employees. *Healthcare Information Research, 20*(4): 304–312.

Morawska, L., He, C. R., Johnson, G., Guo, H., Uhde, E. and Ayoko, G. (2009). Ultrafine particles in indoor air of a school: Possible role of secondary organic aerosols. *Environmental Science and Technology, 43*: 9103-9109

Muange, C. M., Ogutu, E. A., Wambua, R. K., Emoru, R. A. and Mango, S. M. (2015). *Secondary Chemistry. Form One Students' Book*. Nairobi. Kenya Literature Bereau

Mubea, K. and Menz, G. (2012). Monitoring Land-Use Change in Nakuru (Kenya) Using Multi Sensor Satellite Data. *Advances in Remote Sensing, 1*(3): 74-84

Muchemi, S. (2011). *Factors associated with occupational allergic conjunctivitis among school teachers in Bahati Division, Nakuru North District, Kenya*. Unpublished Masters Thesis, Kenyatta University, Nairobi.

Mugenda, O. M. and Mugenda, A. (1999*). Research methods. Quantitative and qualitative approaches*. Nairobi: Acts Press.

Muigua, K. (2012*). Realizing occupational safety and health as a fundamental human right in Kenya*. A paper presented to University of Nairobi. Nairobi.

Muttappallymyalil, J., Mendis, S., John, L. J., Shanthakumari, N. Sreedharan, J. and Shaikh, R. B. (2016). Evolution of technology in teaching: Blackboard and beyond in Medical Education. *Nepal Journal of Epidemiology* 6(3): 588–592

Mwangi, N. (2000). *A study on the perceptions of the influence of teaching practice projects on the teaching of science in selected secondary schools in Kenya*. Unpublished Doctoral Dissertation, Egerton University, Njoro.

Mytton, O. T., Velazquez, A., Banken, R., Mathew, J. L., Ikonen, T. S., Taylor, K., Painter, F., Jean-Baptiste, R., Poon, A. and Ruelas, E. (2010). Introducing new technology safely. *Quality and Safety in Health Care, 19* (2): 9-14

Nagi, M. (2017). *Global traditional whiteboard market outlook, trend and opportunity, analysis Competitive insight, actionable segmentation and forecast 2023*. Dehradun. Energias Market Research.

Nagpal, J., Kumar, A., Kakar, S. and Bhartia, A. (2010). The development of quality life instrument for Indian diabetes patients (QOLID): A validation and reliability study in middle and higher income groups. *JAPI, 58*: 295-304

Ngara, R. and Magwa, S. (2015). School Safety: Practices and Issues in Gweru Urban Schools in Zimbabwe. *Greener Journal of Educational Research, 5*(4): 127-133

Nguyen, J. L., Schwartz, J. and Dockery, D. W. (2015). The relationship between indoor and outdoor temperature, apparent temperature, relative humidity and absolute humidity. *Indoor Air, 24*(1): 103-112.

Nielsen, G. D., Wolkoff, P. and Alarie, Y. (2007). Sensory irritation: Risk assessment approaches. *Regulatory Toxicology and Pharmacology, 48*: 6-18

Niir Project Consultancy Services (2017). *Manufacture of thinners and solvents. Properties, uses, production, formulation with machinery details*. Delhi. Niir Project Consultancy Services.

Noguchi, M., Mizukoshi, A., Yanagisawa, Y. and Yamasaki, A. (2016). Measurements of volatile organic compounds in a newly built daycare Center. *International Journal of Environmental Research and Public Health, 13*(7): 736.

Notas, G., Briotakis, M., Kalogrias,V., Andrianaki, M., Azariadis, K., Kampouri, E., Theodoropoulou, K., Lavrentaki, K., Kastrinakis, S., Kampa, M., Agouridakis, P., Pirintsos, S. and Castanas, E. (2015). Accurate prediction of severe allergic reactions by a small set of environmental parameters (ndvi, temperature). *PLoS One, 10*(3). e0121475

Ojwan'g, M. A. (2016). Effects of the restructuring of teacher placement on teacher and gender distribution in public secondary schools in Nakuru County. Kenya. *Baraton Interdisciplinary Research Journal, 6*: 83-92

Okoth, D. (2013, Oct. 24). Slow transition from use of asbestos raises concern as cancer cases rise. *The standard,* Retrieved from https://www.standardmedia.co.ke

Oldenburg, M., Petersen, A. and Baur, X. (2011). Maize pollen is an important allergen in occupationally exposed workers. *Journal of Occupational medicine and Toxicology, 6*: 32-36

Olesen, B.W. (2015). Are women feeling colder than men in air-conditioning buildings? *REHVA Journal, 5*: 12-13

Olumayede, E. G. and Okuo, J. M. (2013). Ambient air pollution and assessment of ozone creation potential for reactive volatile organic compounds in urban atmosphere of southwestern, Nigeria. *African Journal of Environmental Science and Technology, 7*(8): 815-823

Ono, S. J. and Abelson, M. B. (2005). Allergic conjunctivitis update on pathophysiology and prospects for future treatment. *Allergy in Clinical Immunology, 115*(1), 118-122.

Ottenbreit-Leftwich, A. T., Glazewski, K. D., Newby, T. J. and Ertmer, P. A. (2010). Teacher value beliefs associated with using technology: Addressing professional and student needs. *Computers and Education, 55*: 1321 1335.

Oyier, C. R. (2017). *Effect of budgeting process on utilization of science instructional resources in secondary schools in Nairobi County, Kenya*. PhD thesis. University of Nairobi, Nairobi.

Panagopoulos, I. K., Karayannis, A. N., Kassomenos, P. and Aravossis, K. (2011). A CFD simulation study of VOC and formaldehyde indoor air pollution dispersion in an apartment as part of an indoor pollution management plan. *Aerosol and Air Quality Research, 11*: 758-762

Parthasarathy, S., Maddalena, R. L., Russell, M. L. and Apte, M. G. (2011). Effect of temperature and humidity on formaldehyde emissions in temporary housing units. *Journal of the Air and Waste Management Association, 61*: 689-695

Pazwash, H. (2011). *Urban storm water management*. New York. CRC Press.

Peil, M. (1995). *Social science research methods: a handbook for Africa*. Nairobi: East African Educational Publishers.

Peri, T., Bödeker, B., Jünger, M., Nolte, J. and Vautz, W. (2010). Alignment of retention time obtained from multicapillary column gas chromatography used for VOC analysis with ion mobility spectrometry. *Analytical and Bioanalytical Chemistry*, *397*(6): 2385-2394.

Pitt, A. D., Smith, A. F., Lindsell, L., Voon, L. W., Rose, P. W. and Bron, A. J. (2004). Economic and quality of life impact of seasonal allergic conjunctivitis in Oxfordshire. *Ophthalmic Epidemiology*, 11(1): 17-33

Ponni, M. and Baskar, R. (2015). A study on indoor temperature and comfort temperature. *International Journal of Engineering Science Invention, 4*(3): 7-14.

Portari, G. V., Marchini, J. J. and Jordao, A. F. (2008). Validation of a manual headspace gas chromatography method for determining volatile compounds in biological fluids. *Labmedicine, 39*(1).

Postolache, T.T., Langenberg, P., Zimmerman, S. A., Lapidus, M., Komarow, H., Mcdonald, J. S., Furst, N., Dzhanashvili, N., Scrandis, D., Bai, J., Postolache, B., Soriano, J. J., Vittone, B., Guzman, A., Woo, J. M., Stiller, J., Hamilton, R. G. and Tonelli, L. H. (2008). Changes in severity of allergy and anxiety symptoms are positively correlated in patients with recurrent mood disorders who are exposed to seasonal peaks of aeroallergens. *International Journal of Child Health and Human Development, 1*(3): 313-322.

Priest, S. H. (Ed) (2010). *Encyclopedia of science and technology communication*. Singapore. SAGE.

Probert, C. J., Khalid, T., Ahmed, I., Johnson, E., Smith, S. and Ratcliffe, N. M. (2009) Volatile organic compounds as diagnostic biomarkers in gastrointestinal and liver diseases. *Journal of Gastrointestinal and Liver Disease*, *18*(3): 337-343.

Raatikka, V. P., Rytkonen, M., Nayha, S. and Hassi, J. (2007). Prevalence of cold-related complaints, symptoms and injuries in the general population: the FINRISK 2002 cold sub study. *International Journal of Biometeorology, 51*(5): 441-448

Ramprasad, S. and Maruthi, Y. A. (2015). A cohort study on physical and psychological risks in teachers of Visakhapatnam city, India. *International Journal of Medical and Health Sciences, 4*(2): 182-185

Rands, M. L. and Gansemer-Topf, A. M. (2017). The room itself is active: How classroom design impacts student engagement. *Journal of Learning Spaces, 6*(1): 26-33

Raub, A. (1982). *Correlates of computer anxiety in college students*. Unpublished doctoral Dissertation, University of Pennsylvania, Philadelphia.

Ray, C. M., Sormunem, C. and Harris, T. M. (1999). Men's and women's attitudes towards computer technology: A comparison. *Office Systems Research Journal, 17*(1): 1-8

Republic of Kenya (2007). *Kenya Vision 2030*. Nairobi. Government printers.

Rogers, E. M. (1995). *Diffusion of Innovations.* (4th edn). New York. The Free Press.

Rosario, N. and Bielory, L. (2011). Epidemiology of allergic conjunctivitis. *Current Opinion in Allergy and Clinical Immunology, 11*(5): 471-476.

Rosbach, J. T., Vonk, M., Duijm, F., Ginkel, J. T., Gehring, U. and Brunekreef B. (2013). A ventilation intervention study in classrooms to improve indoor air quality: the FRESH study. *Environmental Health, 12*: 110-120

Rösch, C., Kohajda, T., Röder, S., Bergen, M. and Schlink, U. (2014). Relationship between sources and patterns of VOCs in indoor air. *Atmospheric Pollution Research*, *5* (1): 129-137.

Rothman, K. J. and Greenland, S. (2005). Causation and causal inference in epidemiology. *American Journal of Public Health, 9*(1): S144-S150

Rout, B. K. and Sikdar, B. K. (2017). Hazard identification, risk assessment, and control measures as an effective tool of occupational health assessment of hazardous process in an iron ore pelletizing industry. *Indian Journal of Occupational and Environmental Medicine*, 21(2): 56-76

Sacchetti, M., Lambiase, A., Moretti, C., Mantelli, F. and Bonini, S. (2015). Sex hormones in allergic conjunctivitis: Altered levels of circulating androgens and estrogens in children and adolescents with Vernal Keratoconjunctivitis. *Journal of Immunology Research, 2015*:1-8

Salthammer, T. (2011). Critical evaluation of approaches in setting indoor air quality guidelines and reference values. *Chemosphere, 82* (11): 1507-1517.

Salthammer, T. and Bahadir, M. (2009). Occurrence, dynamics and reactions of organic pollutants in the indoor environment. *Clean–Soil Air Water, 37*: 417-435

Salthammer, T. (Ed). (2008). *Air pollutants occurrence-measurement-evaluation*. New York. Wiley-VCH.

Sánchez, M. C., Parra, B. F., Matheu, V., Navarro, A., Ibáñez, M. D., Dávila, I., Dordal, M.T., Bernal, M. L., Rondón, C., Montoro, J., Antón, E., Colás, C. and Valero, A. (2011). Allergic conjunctivitis. *Journal of Investigational Allergology and Clinical Immunology, 21*(2):1-19

Sanders, M. J. (Ed) (2012). *Mosby's parametric textbook* (4th Edition). Burlington. Jones and Barllet learning, LLC.

Sannik, S. (2013). *Validation of the gas chromatographic method for determination of volatile organic compounds (VOCs) in industrial workplace air*. Unpublished masters thesis, University of Tartu. Estonia.

Santacreu, A. M. (2016). Long-run economic effects of changes in the age dependency ratio. *Economic synopsis, 17*: 1-2

Satish, U., Mendell, M. J., Shekhar, K., Hotchi, T., Sullivan, D., Streufert, S. and Fisk, W. J. (2012). Is CO_2 an indoor pollutant? Direct effects of low-moderate CO_2 concentrations on human decision-making performance. *Environmental Health Perspective, 120*(12): 1671-1677

Schenk, L., Hansson, S.O., Rudén, C., Gilek, M. (2008). Occupational exposure limits: A comparative study. *Regulatory Toxicology and Pharmacology, 50*:261-270

Schlink, U., Thiem, A., Kohajda, T., Richter, M. and Strebel, K. (2010). Quantile regression of indoor air concentrations of volatile organic compounds (VOC). *Science of the Total Environment, 408*(18): 3840-3851.

Schuster, G. U., Kenyon, N. J. and Stephensen, C. B. (2018). Vitamin A deficiency decreases and high dietary vitamin A increases disease severity in the mouse model of asthma. *The Journal of Immunology, 180*: 1834-1842

Scott, A. A., Misiani, H., Okoth. J., Jordan, A., Gohlke, J., Ouma, G., Ariighi, J., Zaitchik, B. F., Jjemba, E., Verjee, S. and Waugh, D. W. (2017). Temperature and heat in informal settlements in Nairobi. *PloS One, 12*(11): e0187300

Sekaran, U. (2003). *Research methods for business: A skill building approach* (2nd Edn.). New York. John Wiley and Sons Inc.

Sengupta, A. and Sarkar, C. K. (2015). *Introduction to Nano: Basics to Nanoscience and Nanotechnology*. New York. Springer.

Seppänen, O. and Kurnitski, J. (2009). Moisture control and ventilation. In*: WHO Guidelines for Indoor Air Quality: Dampness and Mould.* Geneva: World Health Organization.

Sethi, S., Nanda, R. and Chakraborty, T. (2013). Clinical application of volatile organic compounds analysis for detecting infectious diseases. *Clinical Microbiology Reviews, 26*(3): 462–475.

Shendell, D. G., Winer, A. M., Stock, T. H., Zhang, L., Zhang, J. J., Maberti, S., and Colome, S. D. (2005). Air concentrations of VOCs in portable and traditional classrooms: Results of a pilot study in Los Angeles County. *Indoor Air, 14* (1): 44-59

Shen, G., Lin, W., Yue, D., Liu, Z., Chen, Y. and Yang, C. (2014). *Factors Influencing the Adoption and Sustainable Use of Clean Fuels and Cookstoves in China-A Chinese Literature Review (REP13-1).* Washington. Global Alliance of Clean Cookstoves.

Silbergeld, E. K. (2012). Toxicology. In *Encyclopaedia of occupational health and safety* (4^{th} Edition). Retrieved from www.ilocis.org/documents/chpt33e.htm

Singer, B. C., Hult, E. L. and Willem, H. (2014). *Ventilation and source control to reduce formaldehyde in new homes*. Berkeley. Lawrence Berkeley National Laboratory.

Singh, K., Axelrod, S. and Bielory, L. (2010). The epidemiology of ocular and nasal allergy in the United States, 1988-1994. *Journal of Allergy and Clinical Immunology, 126*(4): 778-783.

Smedje, G. and Norbäck, D. (2000). New ventilation systems at select schools in sweden- Effects on asthma and exposure. *Archives of Environmental Health, 55*: 18-25

Soto-Garcia, L., Ashley, W. J., Bregg, S., Walier, D., LeBouf, R., Hopke, P. K. and Rossner, A. (2015). VOCs emissions from multiple wood pellet types and concentrations in indoor air. *Energy and Fuels, 29*(10): 6485-6493

Srivastava, A. and Mazumdar, D. (2011). Monitoring and Reporting VOCs in Ambient Air.In N.Mazzeo (Ed.), *Air quality monitoring, assessment and management.* Shanghai. InTech.

Suleiman, A. M. and Svendsen, K.V. (2014). Are safety data sheets for cleaning products used in Norway a factor contributing to the risk of workers exposure to chemicals? *International Journal of Occupational Medicine and Environmental Health, 27* (5): 840-853

Sun, X. and Yang, X. (2013). Volatile organic compounds in normal human exhaled breath: a long neglected pollutant source. *WIT Transactions on the Built Environment, 134*: 773-783

Susser, E., Schwartz, S., Morabia, A. and Bromet, E. J. (2006*). Psychiatric epidemiology: Searching for causes of mental disorders*. New York. Oxford University Press.

Swaen, G. and Van Amelsvcort, L. A. (2009). Weight of evidence approach to causal inference. *Journal of Clinical Epidemiology*, *62*(3): 270-277

Świebocka, E. M., Siergiejko, P., Rapiejko, P. and Siergiejko, Z. (2014). Long-term intense exposure to grass pollen can mask positive effects of allergenic immunotherapy on non-specific bronchial hyperresponsiveness, *Archives of Medical Science*,*10*(4): 711–716.

Tadesse, T. and Admassu, M. (2006). *Occupational Health and Safety*. Addis Ababa. USAID.

Tarulli, A.W. Chin, A. B. Lee, K. S. and Rutkov, S. B (2007). Impact of Skin-Subcutaneous Fat Layer Thickness on Electrical Impedance Myography Measurements: An Initial Assessment. *Clinical Neurophysiology*, *118*(11): 2393–2397.

Taylor, S. and Todd, P. A. (1995). Understanding Information Technology Usage: A Test of Competing Models. *Information Systems Research*, *6*: 144-176

Teachers Service Commission (2010). *Listing of schools*. Nairobi. Government printer.

Tindall, W. N., Sedrack, M. M. and Boltri, J. M. (2014). *Patient-centered pharmacology: learning system for the conscientious prescriber*. Philadelphia. F. A. Davis Company.

Tyagi, S. (2013). A study of teaching effectiveness of secondary school teachers in relation to their demographic characteristics. *International Journal of Engineering and Innovative Technology*, *3*(1): 288-295

Uhara, H., Koga, H., Takata, M. and Saida, T. (2009). The whiteboard marker as a useful tool for the dermoscopic furrow test. *Archives of Dermatology*, *145* (11): 1331-1332

United Nations (1948). *Universal Declaration of Human Rights*. Geneva. United Nations.

United Nations Children's Fund (2009). *Child- friendly schools manual.* New York. UNICEF.

United States Agency for International Development (2015). *Report to the people*. Nairobi. United States Agency for International Development.

Vally, M. and Irhuma, M. E. (2017). Allergic conjunctivitis. *South African Family Practice, 59*(5): 5-10

Venkatesh, V. and Bala, H. (2008). Technology acceptance model 3 and a research agenda on interventions. *Decision Science*, *39*(2): 273-312

Venkatesh, V., and Davis, F. D. (2000). A Theoretical Extension of the Technology Acceptance Model: Four Longitudinal Field Studies. *Management Science*, *46*(2): 186-204.

Venkatesh, V., Morris, M. G., Davis, F. D., and Davis, G. B. (2003). User Acceptance of Information Technology: Toward a Unified View. *MIS Quarterly, 27*: 425-478.

Vilceková, S., Apostoloski, I. Z.,Meciarová, L., Burdová, E. K. and Kiselák, J. (2017). Investigation of indoor air quality in houses of Macedonia. *International Journal of Environmental Research and Public Health, 14*(1). 37

Vinodkumar, M.N. and Bhasi, M. (2010). Safety management practices and safety behavior: Assessing the mediating role of safety knowledge and motivation. *Accident, Analysis and Prevention, 42*(6): 2082-2093

Wambugu, S. (2010, Oct. 9). The writing is on the wall for old messy chalkboard. *Daily, Nation* retrieved from https://www.nation.co.ke

Wanjohi, A. N. (Ed) (2013). *Secondary Schools in Nakuru County*. Nairobi. KENPRO
Wargocki, P. and Wyon, D. P. (2006). "Effects of HVAC on student performance''.*American Society of Heating, Refrigerating and Air-conditioning Engneering Journal*, *48*: 22-23

Watson, G. (2006). Technology professional development: long-term effects on teacher self-efficacy. *Journal of Technology and Teacher Education, 14*(1), 151–165.

Watson, N., Davies, S. and Wevill, D. (2012). Air monitoring: new advances in sampling and detection. *Scientific World Journal, 11*: 2582-2598

Weekes, J. (2017). *Why is safety education so important? Health and safety handbook*. South Melbourne. Portner press.

Wei, W., Mandin, C. and Ramalho, O. (2017). Reactivity of semivolatile organic compounds with hydroxyl radicals, nitrate radicals, and ozone in indoor air. *International Journal of Chemical Kinetics, 49*(7): 506-521

Westerbacka, J. Cornér, A., Tiikkainen, M., Tamminen, M., Vehkavaara, S., Häkkinen, A. M., Fredriksson, J. and Yki-Järvinen, H. (2004). Women and men have similar amounts of liver and intra-abdominal fat, despite more subcutaneous fat in women: implications for sex differences in markers of cardiovascular risk. *Diabetologia. 47*(8):1360-1369.

Willem, H., Hult, E. L., Hotchi, T., Russell, M. L., Maddalena, R. L. and Singer, B. C. (2013). *Ventilation Control of Volatile Organic Compounds in New U.S. Homes: Results of a Controlled Field Study in Nine Residential Units*. Berkeley. Lawrence Berkeley National Laboratory.

Williams, S., Ogletree, S., Woodburu, W. and Raffled, P. (1993). Gender roles, computer, attitudes and dyadic computer interaction performance in college students. *Sex Roles: A Journal of Research, 29* (7): 515-526

Williams, M., Puchta , H., Gerngross, G. and Lewis-Jones, P. (2013). *Super minds*. New York. Cambridge University Press.

World Bank (2008).*Textbooks and school library provision in secondary education in sub-saharan Africa*. Washington, D.C. The world Bank.

World Health Organization (2004). *International programme on chemical safety: Guidelines on the prevention of toxic exposures*. Geneva. World Health Organization.

World Health Organization (2011). *Chemical safety for sustainable development*. Geneva. World Health Organization.

World Health Organization (2013). *Health effects of particulate matter. Policy implications for countries in Eastern Europe, Caucasus and Central Asia*. Denmark. World Health Organization.

Wu, S. and Jang, J. (2013). The impact of ISO certification on consumers' purchase intention. *Total Quality Management and Business Excellence, 25* (3-4): 412-426

Wyon, D. P. and Wargocki, P. (2008). Window opening behavior when classroom temperature and air quality are maintained experimentally. *Indoor Air, 119* (17-22): 1-6

Xiong, J. Y., Wei, W. J., Huang, S. D. and Zhang, Y. P. (2013). Association between the emission rate and temperature for chemical pollutants in building materials: General correlation and understanding. *Environmental Science and Technolology, 47*: 8540-8547.

Xu, J., Zhang, J. S., Liu, X. and Gao, Z. (2012). Determination of partition and diffusion coefficients of formaldehyde in selected building materials and impact of relative humidity. *Journal of the Air and Waste Management Association, 62*(6): 671-679

Yacan, S. (2014). *Impacts of daylighting on preschool students' social and cognitive skills*. Unpublished masters thesis, University of Nebraska. Lincoln.

Yang, X. and Chen, Q. (2001). A coupled airflow and source/sink model for simulating Indoor VOC exposures. *Indoor Air, 11*(4): 257-269

Zhang, J. and Lioy, P. J. (1994). Ozone in residential air: concentrations, i/o ratios, indoor chemistry, and exposures. *Indoor Air, 4*: 95-105

Zhong, L., Su, F. and Batterman, S. (2017). Volatile Organic Compounds (VOCs) in Conventional and High Performance School Buildings in the U.S. *International Journal of Environmental Research and Public Health, 14*(1): 100-114

APPENDICES

APPENDIX I: QUESTIONNAIRE FOR TEACHERS

My name is Sabina Muthoni Muchemi. I am a student at Egerton University pursuing a PhD degree in Environmental and Occupational Health. This research study aims at establishing the impact of whiteboard marker pen ink on the eyes of teachers. You have been selected to participate in the study. Please fill the questionnaire below as honestly as possible. The information collected will be used for the research study purpose only and will be treated with maximum confidentiality. Please tick where applicable.

Section A- Social demographic variables

1. Sex: Male ☐ female ☐
2. Age in years: 15-24☐ 25-34☐ 35-44☐ 45-54☐ 55-60☐
3. Marital status. ☐ Married ☐ single ☐ widowed
4. Level of education: ☐diploma ☐ degree ☐postgraduate diploma ☐ Masters ☐ PhD
5. a) Area of residence--------------------------- (please specify)

   How long have you resided in this area?

   0-5 years ☐ 5-10 years ☐ above 10 years☐
6. What is the weather of your area of residence?

   Warm☐ Cool☐ Very cold ☐ ☐Others (Please specify)……
7. Is your area of residence very dusty? Yes☐ No ☐
8. Do you use insecticides, pesticides or herbicides Yes☐ No ☐

   If yes, how often do you use them? Please specify……………………….
9. What kind of a house do you live in?

   Stone house with cemented floor☐ Wooden house with cemented floor☐

   Wooden house without cemented floor☐ Mud house☐

   ☐Others (please specify)……………………………………
10. What is the most commonly used fuel for cooking in your house?

    ☐Firewood ☐Charcoal ☐Kerosene ☐Gas ☐Electricity

    ☐Combination (please specify the fuels)--------------------------
11. Do you smoke? Yes ☐ No ☐
12. Do you get exposed to tobacco smoke from the smokers? Yes ☐ No ☐

    If yes, how often? ☐Rarely ☐Daily ☐Others (Please specify)……

13. Do you get exposed to other types of smoke on daily basis? Yes ☐ No ☐

    If yes, what type of smoke? (Please specify)……………………………

Section B- Occupational variables

1. How long have you been teaching in the current station?

   ☐0 – 5 years ☐6 – 10 years ☐others (please specify) …………

2. How long have you been teaching? ☐0-5 years ☐6-10 years☐11-15 years ☐16 – 20 years ☐21-25 years ☐Above 25 years
3. Do you use whiteboard marker pen at all? Yes☐ No ☐

   If yes, how often do you use it? ☐Daily ☐Weekly ☐Monthly ☐Others (specify)

4. What is your daily workload? ☐ 0 lessons ☐1-3 lessons ☐4-5 lessons ☐6 and above
5. What is the name of whiteboard marker pen ink that you use? (Please specify)---------
6. (a) What do you prefer to use in class? ☐chalk ☐marker pen

   Please give a reason for your answer in 7(a) above--------------------

7. Do you use chalk anywhere else? ☐Yes ☐No

   If yes, where and how often do you use it? Please specify………………………….

8. Do you know the composition of the ink that you use? ☐Yes ☐No

   If yes, state the components of that ink………………………………

9. Do you consider this ink as a health hazard? ☐Yes ☐No
10. If yes, do you protect yourself? ☐Yes ☐No

    If yes, Explain how you protect yourself……………………….

11. What material makes your duster? ☐ soft ☐ Not soft
12. Is it necessary to replace the lid when the marker pen is not in use? ☐Yes ☐No
13. Is it important to replace the lid of the marker pen every time that it is not in use?

    ☐Yes ☐No

14. Do you have a sink (including an improvised one) in your office? ☐Yes ☐No

    ☐not applicable

15. Does your staffroom have a sink (including an improvised one)?

☐Yes ☐No

16. Is the water easily accessible for washing hands all the time? Yes☐ No ☐

17. How often do the classes get washed?

☐Daily ☐Twice a week ☐Weekly ☐Not applicable

18. Do you teach during the midterm exams in your school? ☐Yes ☐No

If yes, what time do you give your midterm exam? Please specify----------------

Section C- For Science Teachers

19. Do you teach any science subject? Yes☐ No ☐

20. Do you use laboratory chemicals during teaching? Yes☐ No ☐

If yes, how often do you use them?

☐Once a week ☐2-3 times a week ☐4-5 times a week

☐others (Please specify)

21. Do you have a science lab? Yes☐ No☐

22. Is there a full time laboratory technician in your school? Yes☐ No☐

If not, who prepares the solutions and other chemicals for practicals?

☐Self ☐Others (Please specify) …………………

23. Do you wear goggles, gloves and masks in the school lab? ☐Yes ☐No

If yes, how often? ☐Every time in the lab ☐Once in a while

24. Do you have running water in the lab? ☐Yes ☐No

If yes, is it always available? Yes☐ No☐

Section D: Symptoms

1. Do you suffer from any eye problem? ☐Yes ☐No

If yes, please specify……………………………………

2. What do you do when you get an eye problem?

☐Visit a doctor ☐ Buy drugs from a chemist ☐ let it clear by itself

☐Others (please specify)………………. ☐N/A

3. Do you use eye medication every time when you have an eye problem?

☐Yes ☐No ☐N/A

4. Do you usually buy eye medications as an over the counter drug without the doctors prescription? ☐ Yes ☐No

5. Do you always keep eye medications? Yes ☐ No ☐

If yes, does the doctor prescribe it? Yes ☐ No ☐

6. Do you suffer from any eye allergy? ☐Yes ☐No
7. Do you suffer from any other type of allergy? ☐Yes ☐No

   If yes, what type of allergy? ☐Food allergy ☐ sneezing ☐wheezing

   ☐ Skin allergy ☐others (please specify)…………… ☐N/A
8. Have your both eyes felt itchy within the last two days? Yes☐ No ☐
9. Have your both eyes swollen within the last two days? Yes☐ No ☐
10. Have your both eyes turned red within the last two days? Yes☐ No ☐
11. Have your both eyes become watery within the last two days? Yes☐ No ☐
12. Have your both eyes felt irritated within the last two days? Yes ☐ No ☐
13. Have your both eyes pained within the last two days? Yes ☐ No ☐
14. Have your both eyes felt like there are foreign bodies in the eyes within the last two days? Yes ☐ No ☐
15. Do you wear spectacles? Yes ☐ No ☐

    If yes, for what eye defect?

☐Long sightedness ☐Short sightedness ☐Long sightedness and light effects

☐Short sightedness and light effects ☐Others (please specify)……

16. Do you suffer from asthma? Yes ☐ No ☐
17. a. Do the eyes of any of your parents or siblings get itchy? Yes ☐ No☐

    b. Do the eyes of any of your parents or siblings get watery? Yes ☐ No☐

    c. Do the eyes of any of your parents or siblings get irritated or hurt? Yes ☐ No☐

    d. Do the eyes of any of your parents or siblings get red? Yes ☐ No☐

    e. Do the eyes of any of your parents or siblings get swollen? Yes ☐ No☐

Section E: Attitude

Please tick where applicable

Key

1-Strongly Disagree

2- Disagree

3-Neutral

4- Agree

5- Strongly Agree

		1	2	3	4	5
1	The smell of the ink is unbearable					
2	The pen is easy to use					
3	The marker pen stains the whiteboard with stains which are difficulty to rub					
4	The marker pen ink is more economical than chalk					
5	Writing of notes for students on the board is boring when using a marker pen					
6	The clothes remain clean when one uses the marker pen					
7	I write slowly using a whiteboard marker pen					
8	I believe that the marker pen is safe to use					
9	The writing from a marker pen does not dry fast enough allowing the lines to become blurred with time					
10	The safety of the marker has been checked by the KEBs					
11	I mind the fact that I was not consulted when the marker pen use was introduced in my school					

Section F: Knowledge

Please tick where applicable

Key

1-Strongly Disagree

2- Disagree

3-Neutral

4- Agree

5- Strongly Agree

		1	2	3	4	5
1	The marker pen irritates the nose, eyes and throat					
2	The marker pen ink is non toxic and therefore safe					
3	If inhaled directly it can cause harm to the body					
4	Vapours released as the ink dries have no effect on the person					
5	It is necessary to open the windows when using the marker pen					
6	The marker pen ink is not safe for all persons including the asthmatic patients					
7	One should use protection against the ink vapours					

APPENDIX II: OBSERVATION CHECKLIST

Teacher Code No. ....School Code No............Classroom Code No.................

(The codes will be such that they can be used to identify the school by the researcher but other persons cannot relate the information to the school, teacher and class to ensure confidentiality of information).

1. Is the teacher keen on replacing the lid of the marker pen every time it is not in use in class ☐Yes ☐No
2. Where does the teacher place the marker pen when not using it?..........................
3. How does the teacher hold the pen e.g close to the face, away from the face etc…
4. Who rubs the board? ☐teacher ☐student ☐both
5. Does the teacher rub any writing using the bare hands? ☐Yes ☐No
6. Does the teacher rub the eyes with fingers during the lesson? ☐Yes ☐No
7. If yes, how often? ☐often ☐once in a while
8. Are there windows on both sides of classroom? Yes☐ No ☐

   If not explain………………………………..

   If yes, are they of the same size………………….
9. How high are the windows (approximate height in metres)…………
10. What is the approximate size of the operable area of the window?..........
11. Are all the windows open?............
12. If not, how many are open?
13. What is the area of the open space of the total windows?..................
14. Are there mechanical fans or ventilators? Yes☐ No ☐

    If yes, where are they positioned in the classroom? Please specify………………..
15. Are students in the classes congested? Yes☐ No ☐
16. Where does the teacher spend most of the time during the lesson? ☐moving around the class ☐close to the board
17. What type of structures make the classrooms?

    ☐Permanent with cemented floors ☐Permanent without cemented floors

    ☐Temporary with cemented floors ☐Temporary without cemented floors
18. How is the school compound? ☐Very dusty ☐Dusty☐Not dusty
19. Are there other solid particles in the air at the school ☐Yes ☐No

If yes, please specify……………………………………

20. What is the temperature of the room?………………

21. What is the concentration of carbon dioxide in the classroom?……..

APPENDIX III: INFORMED CONSENT

Respondent's statement

I have been explained to concerning the study in a language that I understand the procedures to be followed in the study and the risks and benefits involved. I have been given an opportunity to ask questions and my questions have been answered to my satisfaction. My involvement in this study is entirely voluntary. I understand that my records will be kept private and that I can leave the study at any time.

I therefore: ☐ Agree to participate ☐ Decline to participate (Tick where applicable)

Name of Participant…………………………………………………………

____________________________________ ______________________

Signature Date

Researcher's statement

I, the undersigned, have explained to the volunteer in a language she understands, the procedures to be followed in the study and the risks and benefits involved

Name of Interviewer……………………………………………………………………

____________________________________ ______________________

Signature Date

APPENDIX IV: CHROMATOGRAMS OF ETHANOL

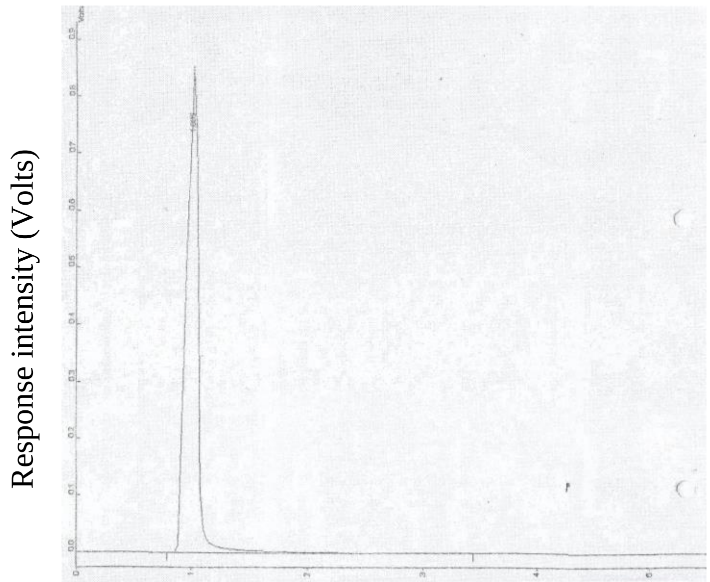


Figure 7.1: Chromatogram of Ethanol

t_R=1.005; Area under the curve= 615594; Volume=0.1µm

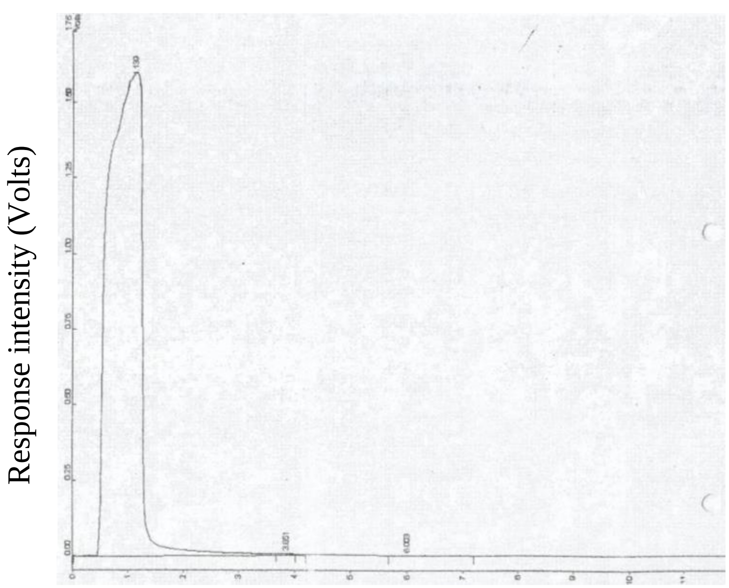


Figure 7.2: Chromatogram of Ethanol

t_R=1.139; Area under the curve= 6496597; Volume=1µm

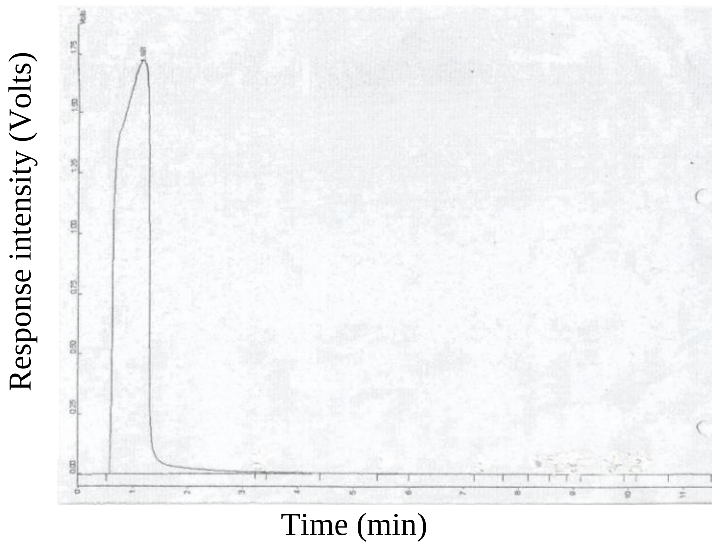


Figure 7.3: Chromatogram of Ethanol

t_R=1.181; Area under the curve= 6535961; Volume=1µm

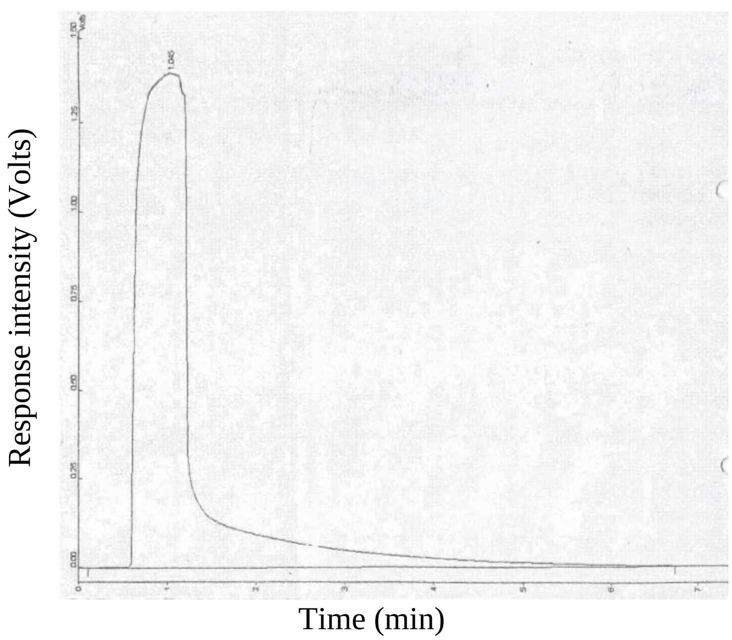


Figure 7.4: Chromatogram of Ethanol

t_R=1.045 ; Area under the curve= 6168599; Volume=1µm

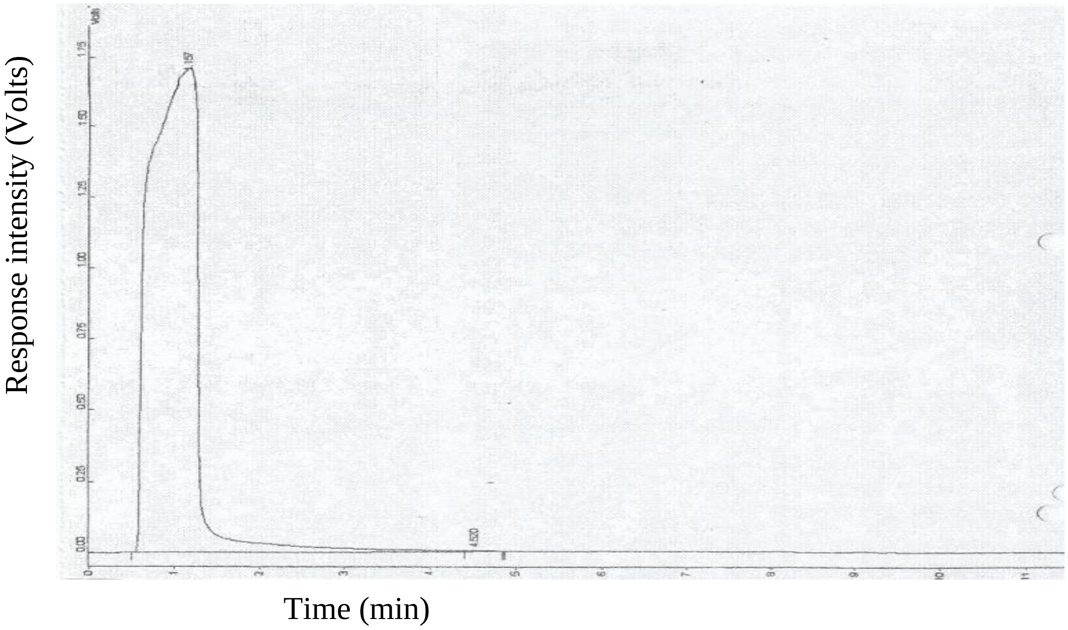


Figure 7.5: Chromatogram of Ethanol
t_R=1.157 ; Area under the curve= 6593618; Volume=1µm

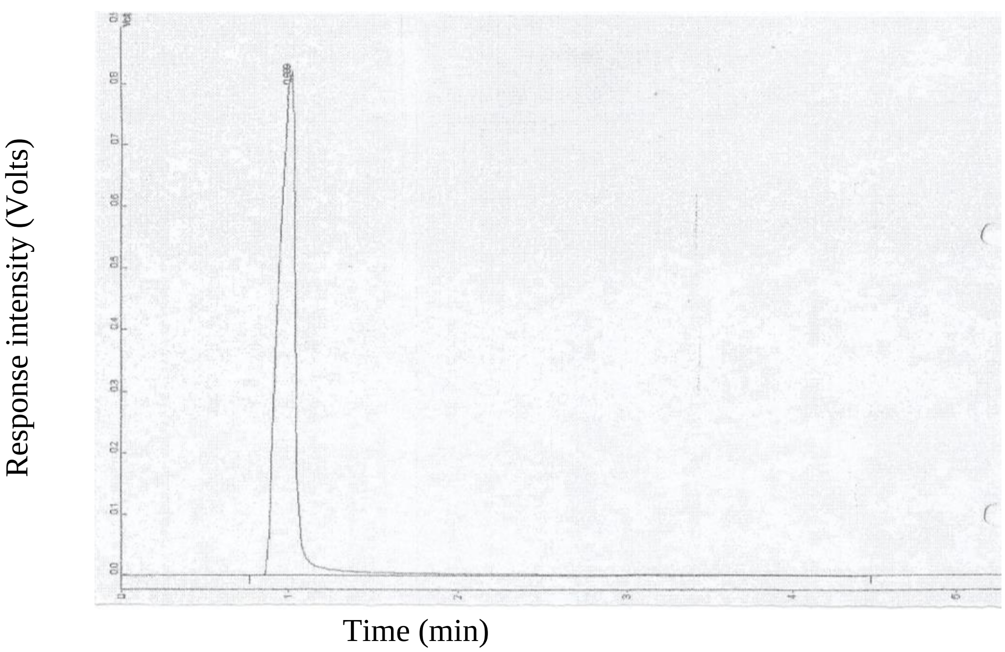


Figure 7.6: Chromatogram of Ethanol
t_R=0.989; Area under the curve= 591990; Volume=0.1µm

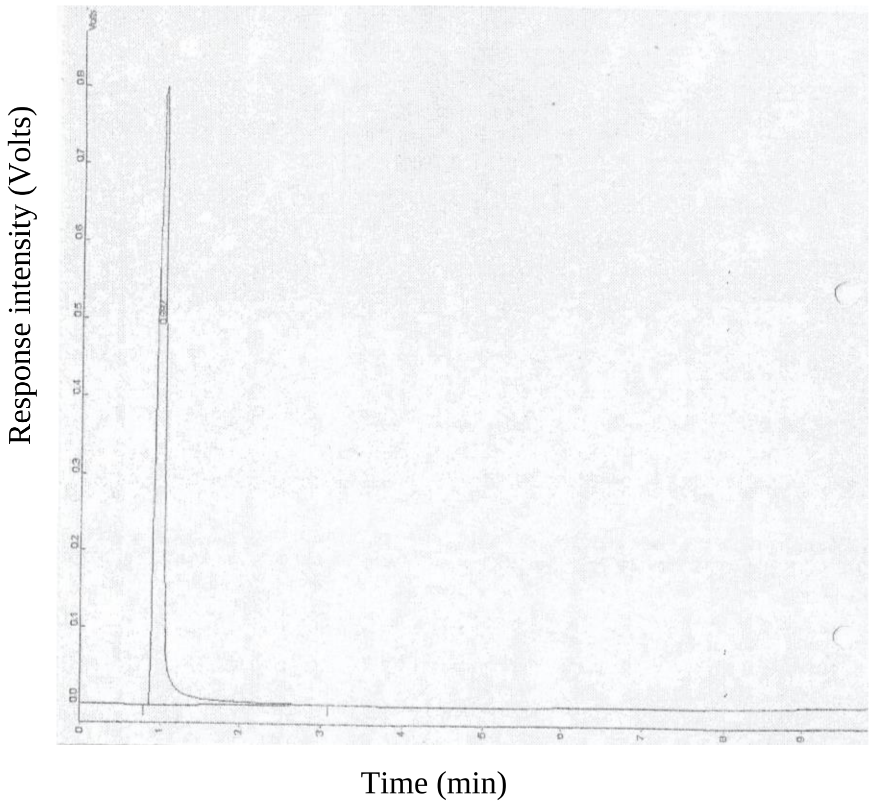


Figure 7.7: Chromatogram of Ethanol
t_R=0.992; Area under the curve= 599925; Volume=0.1µm

APPENDIX V: CHROMATOGRAMS OF INK 1 VOCS FROM THE INK HEADSPACE

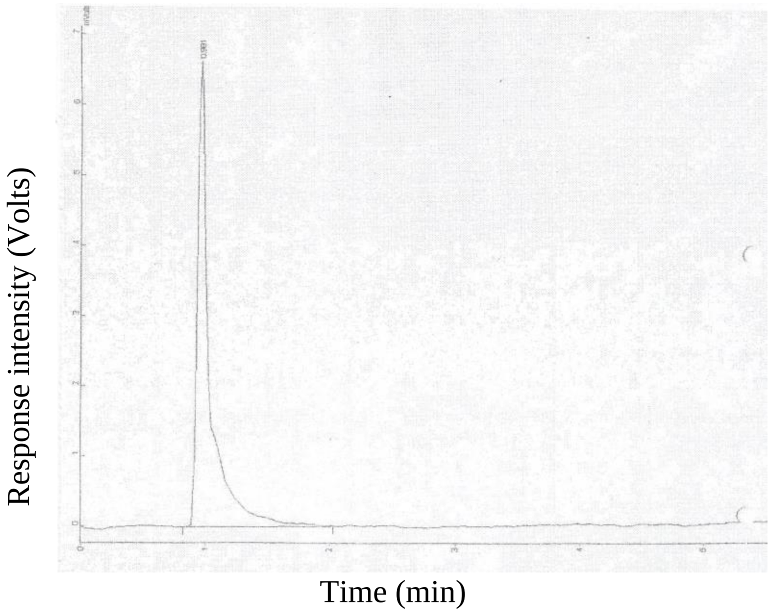


Figure 7.8: Chromatogram of ink 1 headspace

t_R=0.981

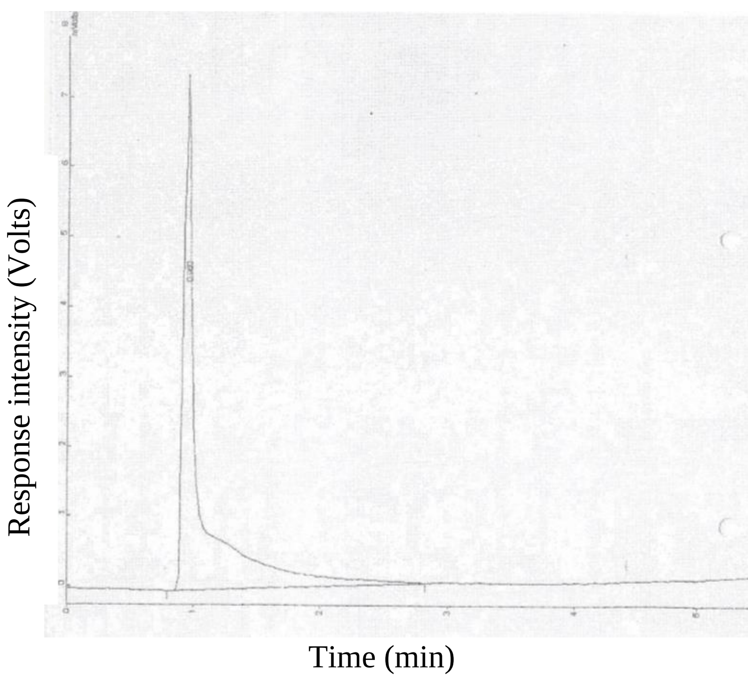


Figure 7.9: Chromatogram of ink 1 headspace

t_R=0.960

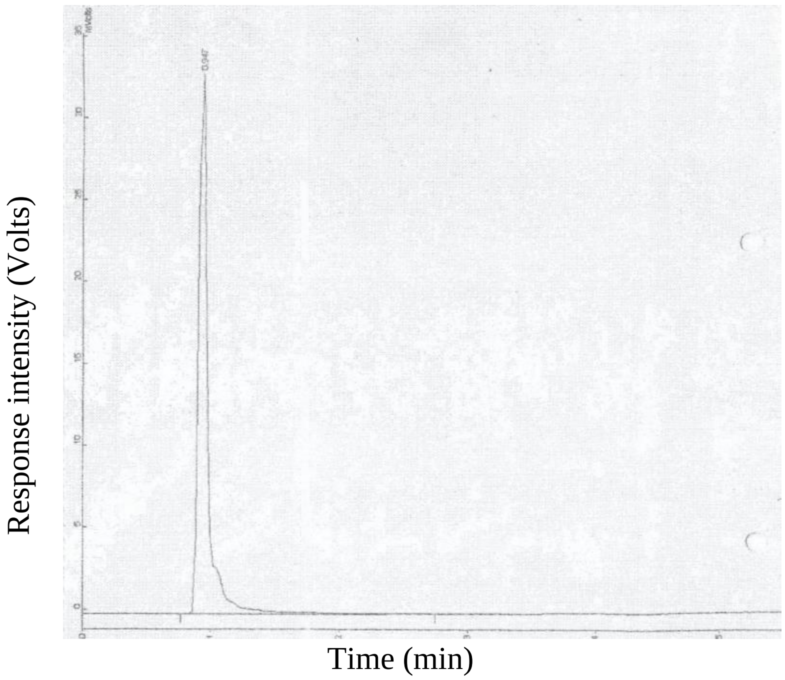


Figure 7.10: Chromatogram of ink 1 headspace

t_R=0.947

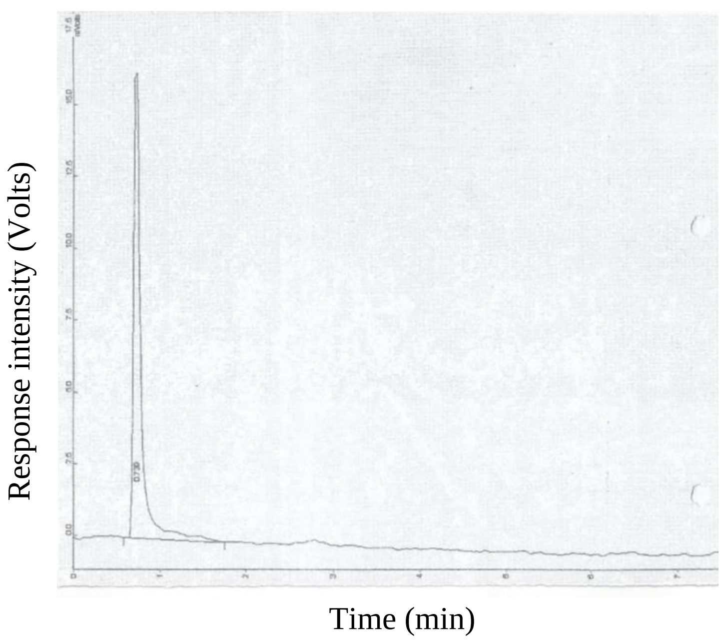


Figure 7.11: Chromatogram of ink 1 headspace

t_R=0.739

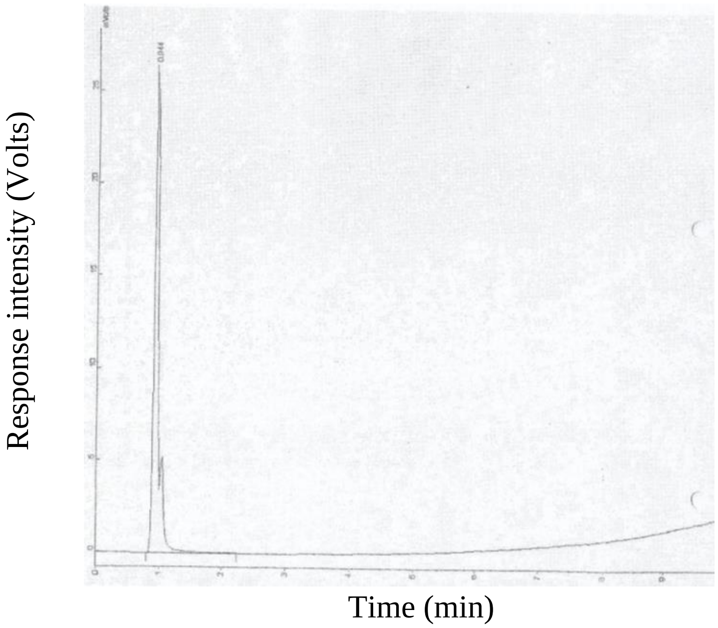


Figure 7.12: Chromatogram of ink 1 headspace

t_R=0.944

APPENDIX VI: CHROMATOGRAMS OF AIR SAMPLES FROM SCHOOLS USING INK 1

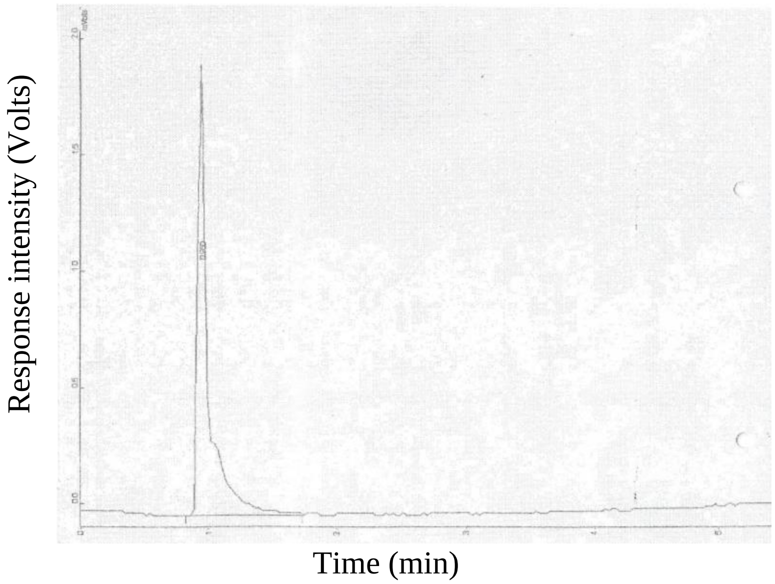


Figure 7.13: Chromatogram of air sample from school no. 3 room 2

t_R=0.960; Sampled at the back 0.5m above the floor; Area under the curve=1088

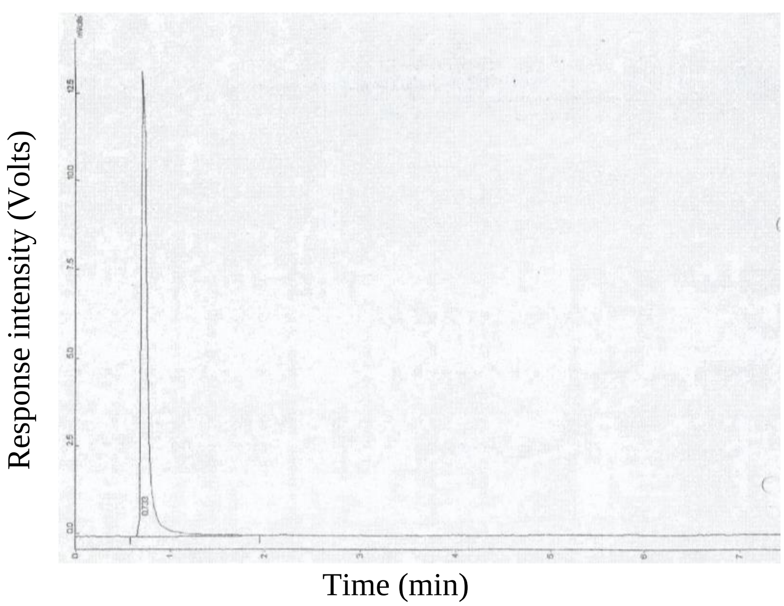


Figure 7.14: Chromatogram of air sample from school no. 6 room 1

t_R=0.733; Sampled at the front 1.5m above the floor; Area under the curve=5987

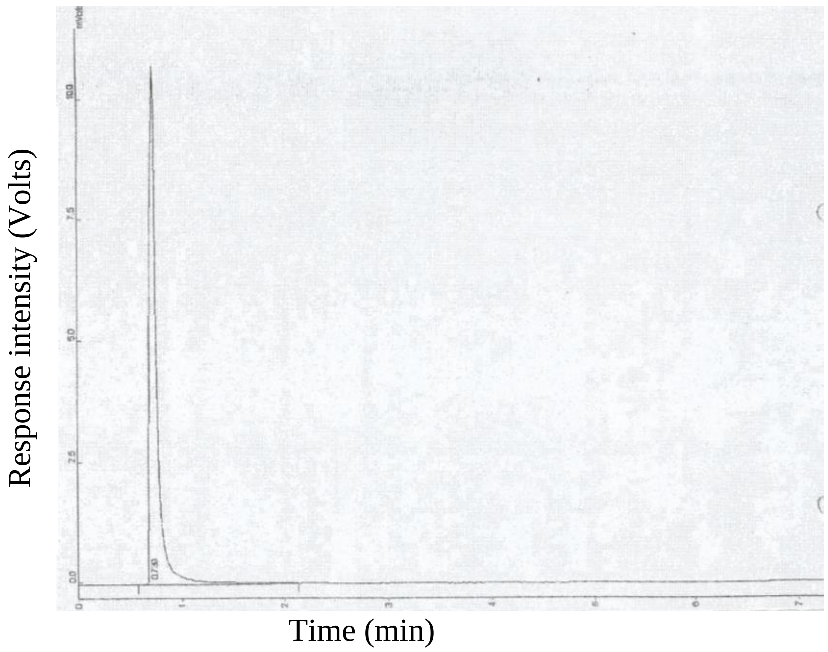


Figure 7.15: Chromatogram of air sample from school no. 3 room 2

t_R=0.739; Sampled at the front 1.5m above the floor; Area under the curve= 5138

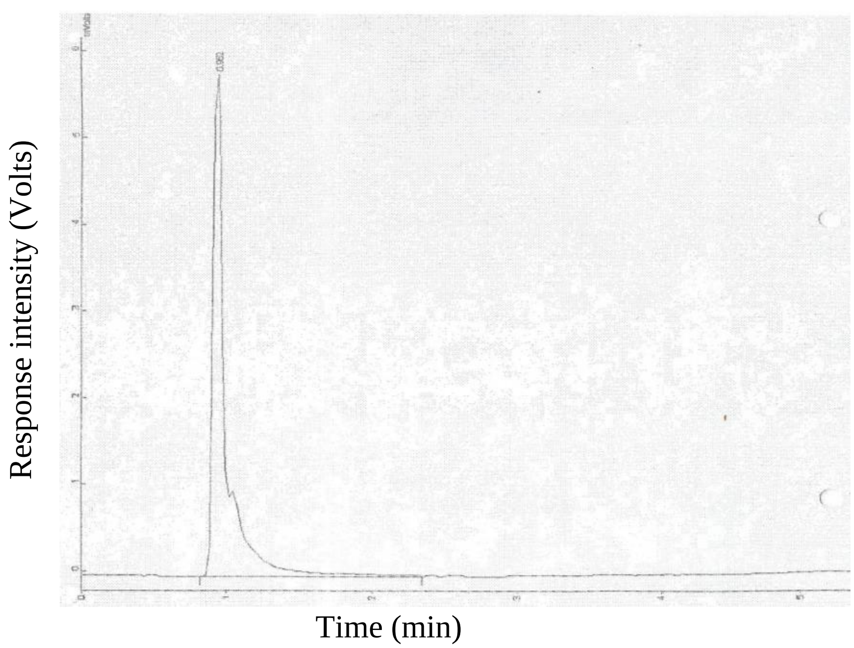


Figure 7.16: Chromatogram of air sample from school no.3 room 2

t_R=0.952; Sampled at the front 1.5m above the floor; Area under the curve=3486

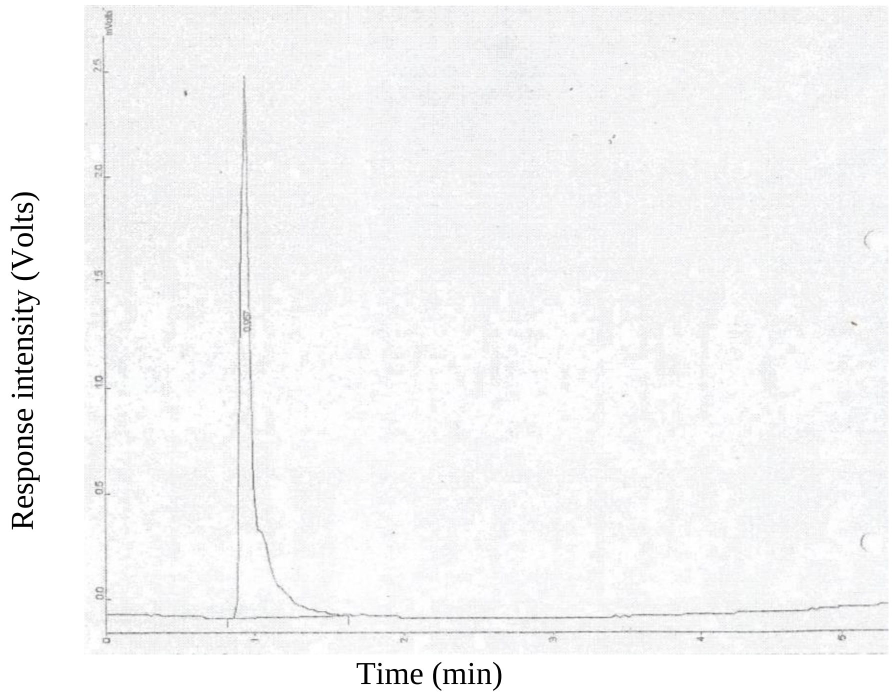


Figure 7.17: Chromatogram of air sample from school no. 3 room 1

t_R=0.957; Sampled at the back 0.5m above the floor; Area under the curve=1442

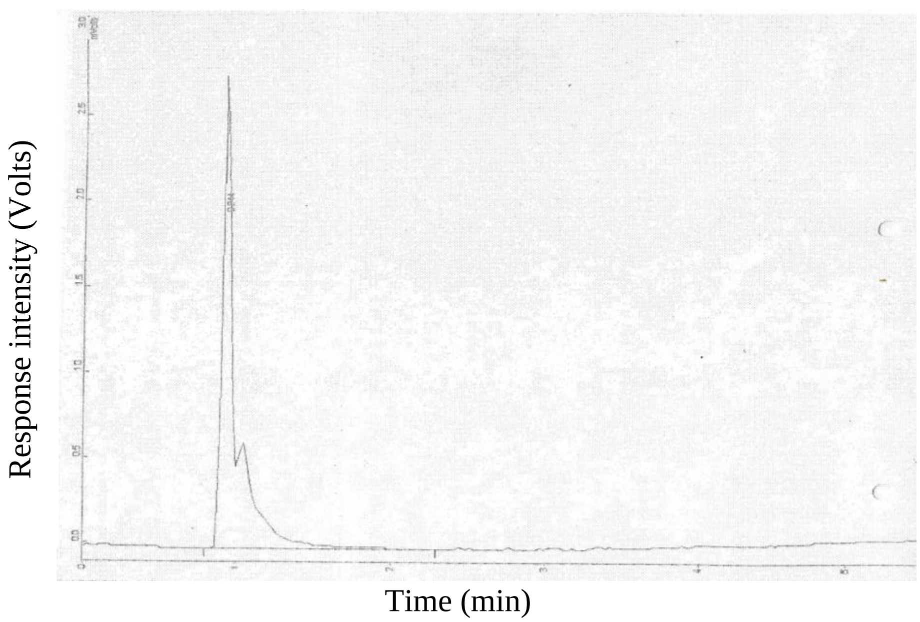


Figure 7.18: Chromatogram of air sample from school no. 3 room 1

t_R=0.944; Sampled at the back 1.5m above the floor; Area under the curve=1643

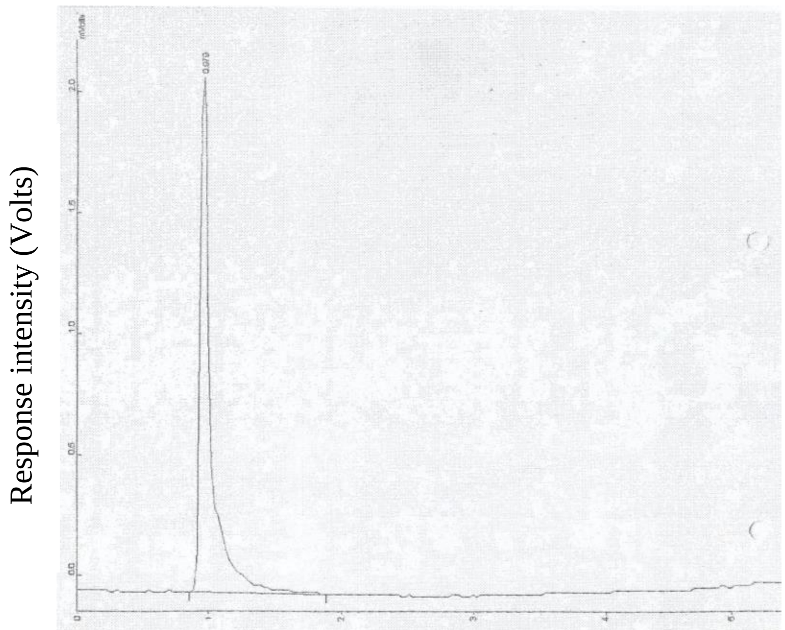


Figure 7.19: Chromatogram of air sample from school no. 3 room 1

t_R=0.979; Sampled at the front 0.5m above the floor; Area under the curve=1265

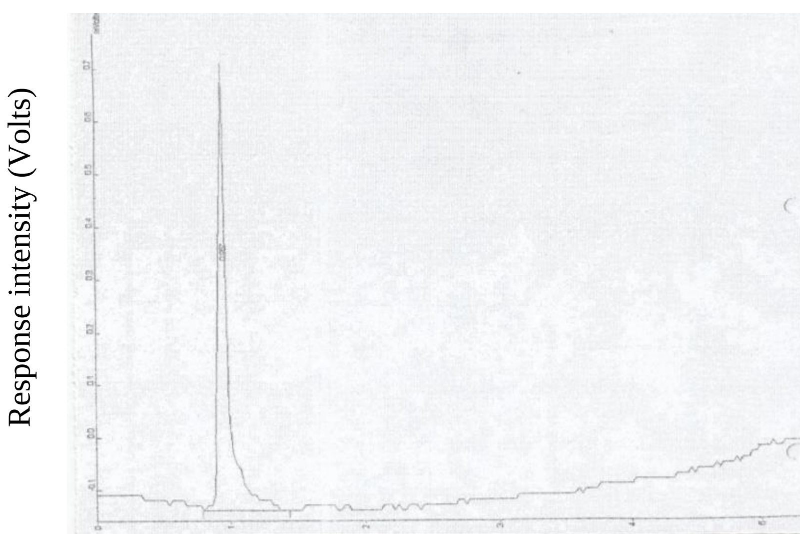


Figure 7.20: Chromatogram of air sample from school no. 6 room 2

t_R=0.957; Sampled at the front 1.5m above the floor; Area under the curve= 402

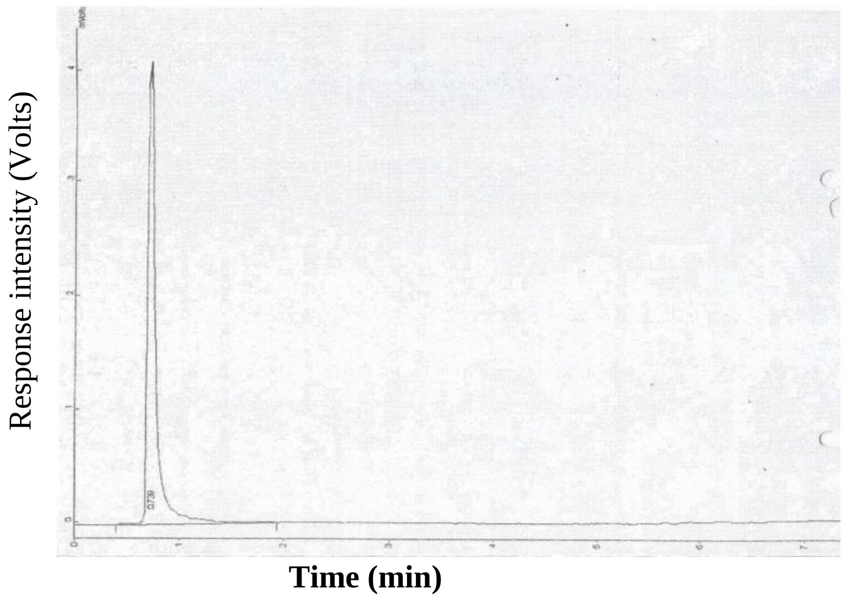


Figure 7.21: Chromatogram of air sample from school no. 6 room 1

t_R=0.739 ; Sampled at the back 1.5m above the floor; Area under the curve=2228

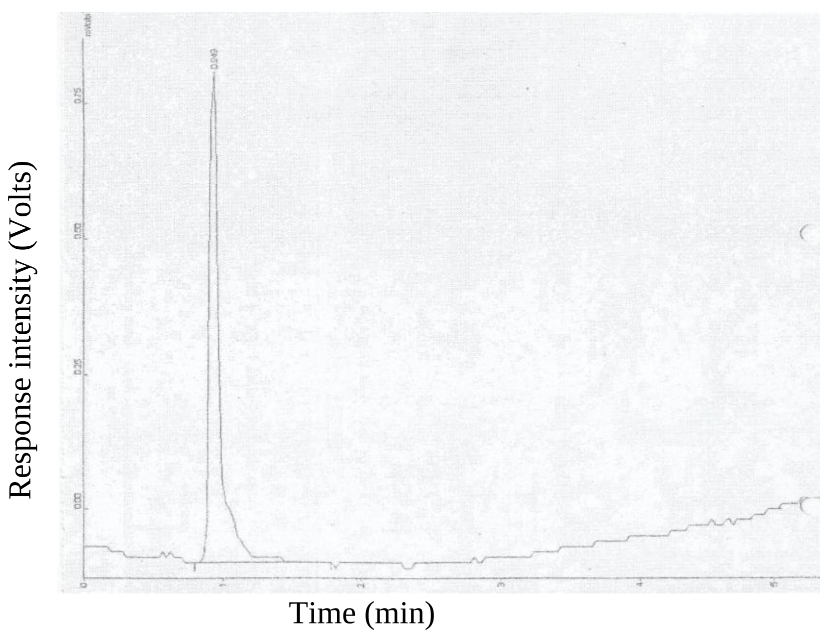


Figure 7.22: Chromatogram of air sample from school no. 6 room 2

t_R=0.949; Sampled at the back 1.5m above the floor; Area under the curve= 464

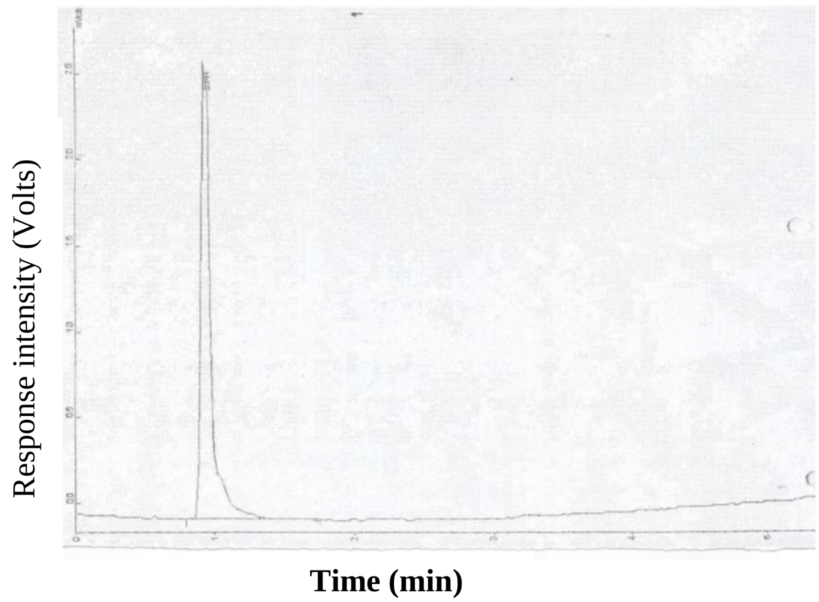


Figure 7.23: Chromatogram of air sample from school no. 3 room 2

t_R=0.944; Sampled at the back 1.5m above the floor; Area under the curve= 1278

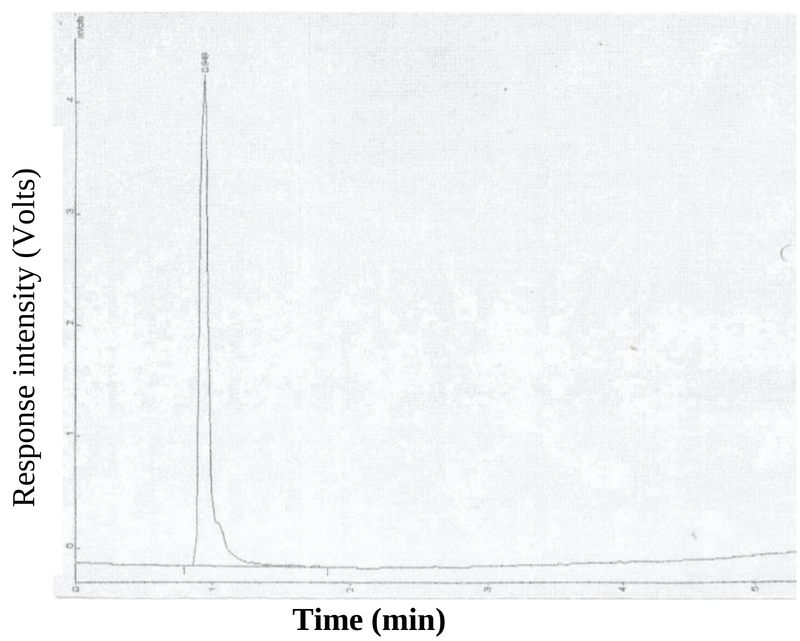


Figure 7.24: Chromatogram of air sample from school no. 3 room 2

t_R=0.949; Sampled at the front 1.5m above the floor; Area under the curve= 2076

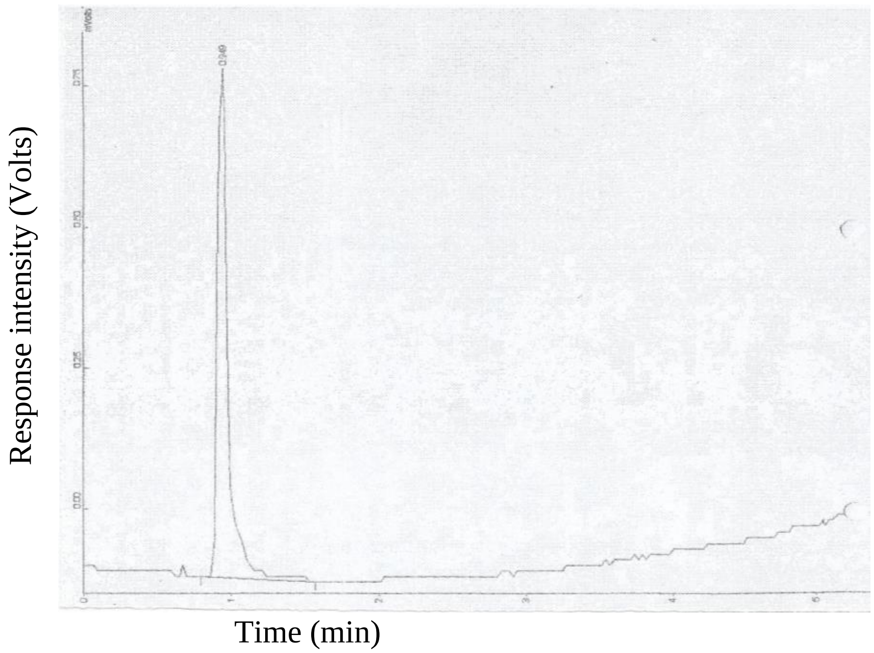
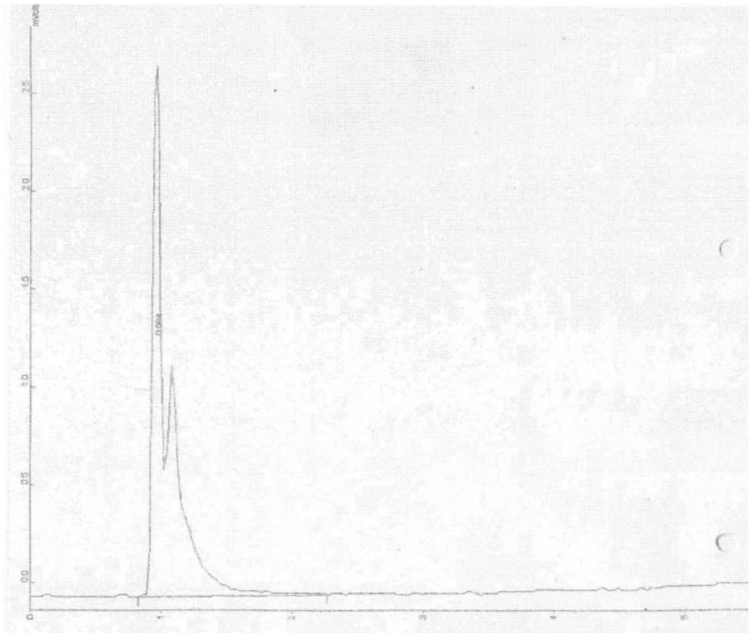


Figure 7.25: Chromatogram of air sample from school no. 3 room 1

t_R=0.949; Sampled at the front 0.5m above the floor; Area under the curve= 444

APPENDIX VII: CHROMATOGRAMS OF INK 2 VOCS FROM THE INK HEADSPACE

Response intensity (Volts)

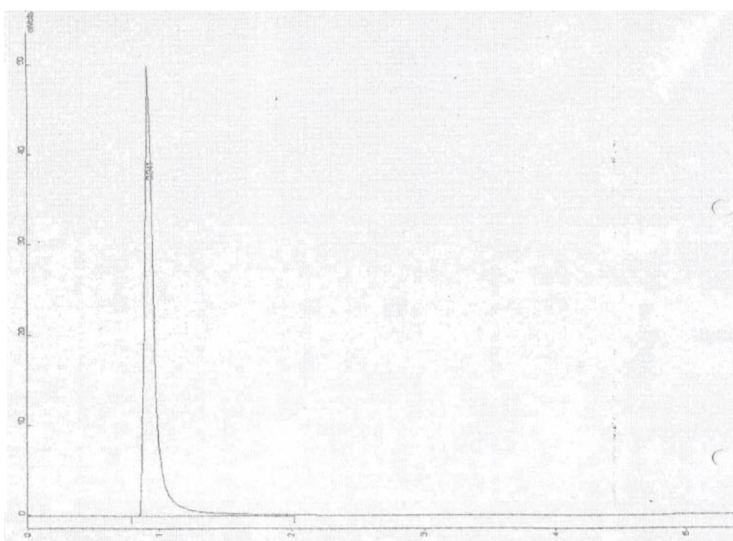


Time (min)

Figure 7.26: Chromatogram of ink 2 headspace

t_R=0.984

Response intensity (Volts)



Time (min)

Figure 7.27: chromatogram of ink 2 headspace

t_R=0.941

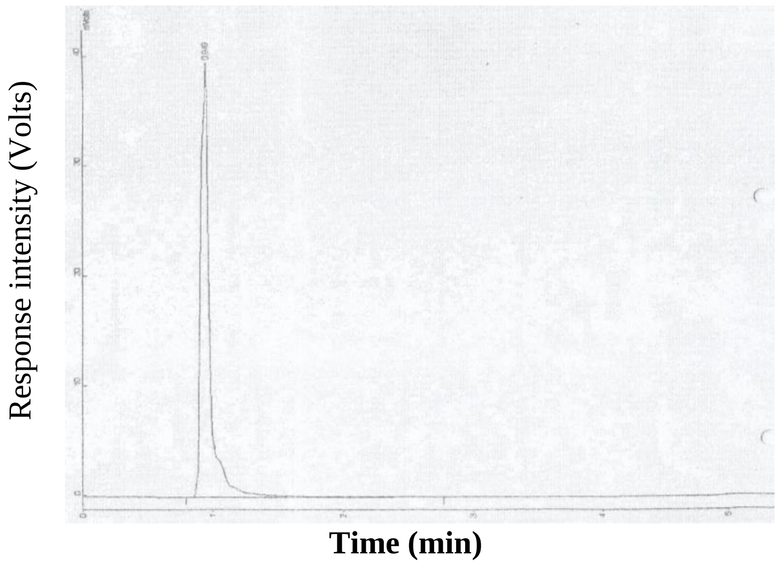


Figure 7.28: Chromatogram of ink 2 headspace

t_R=0.949

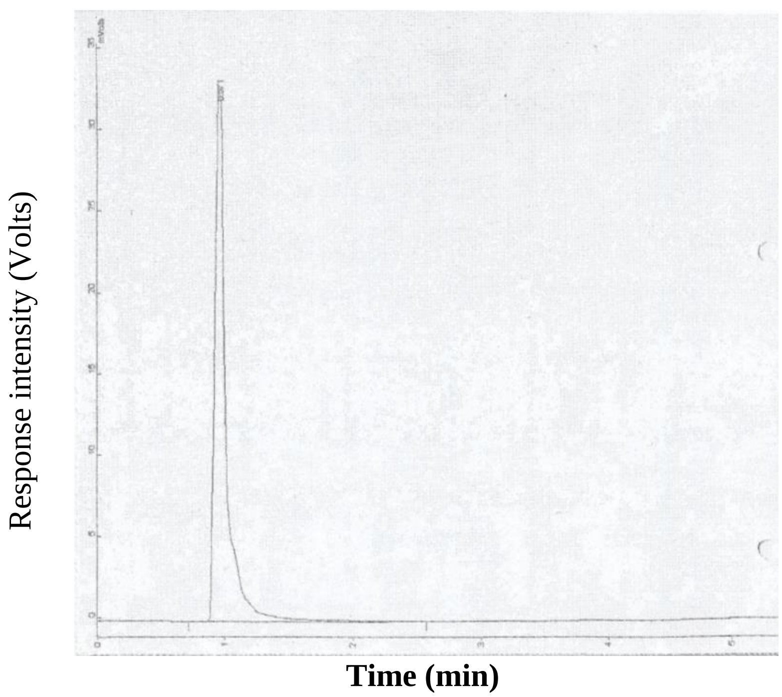


Figure 7.29: Chromatogram of ink 2 headspace

t_R=0.971

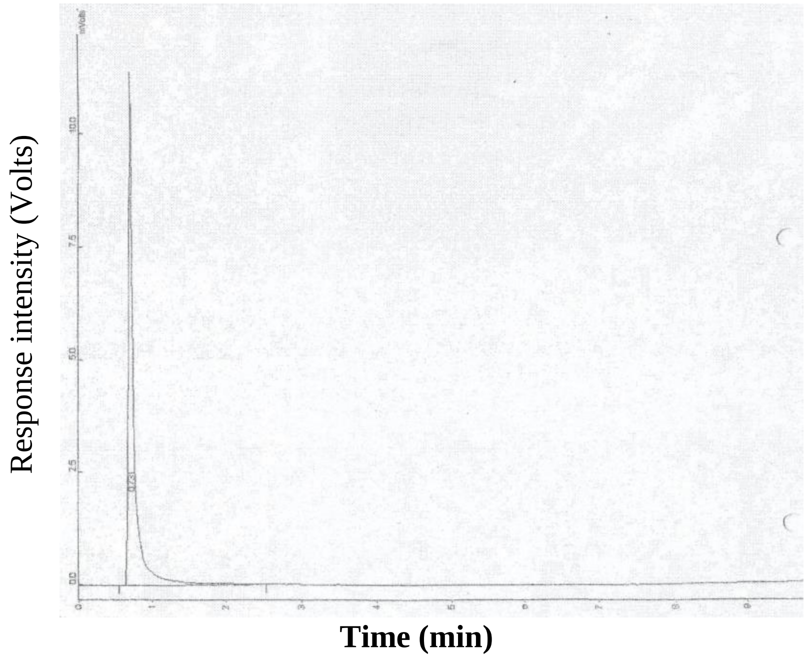


Figure 7.30: Chromatogram of ink 2 headspace

t_R=0.731

APPENDIX VIII: CHROMATOGRAMS OF AIR SAMPLES FROM SCHOOLS USING INK 2

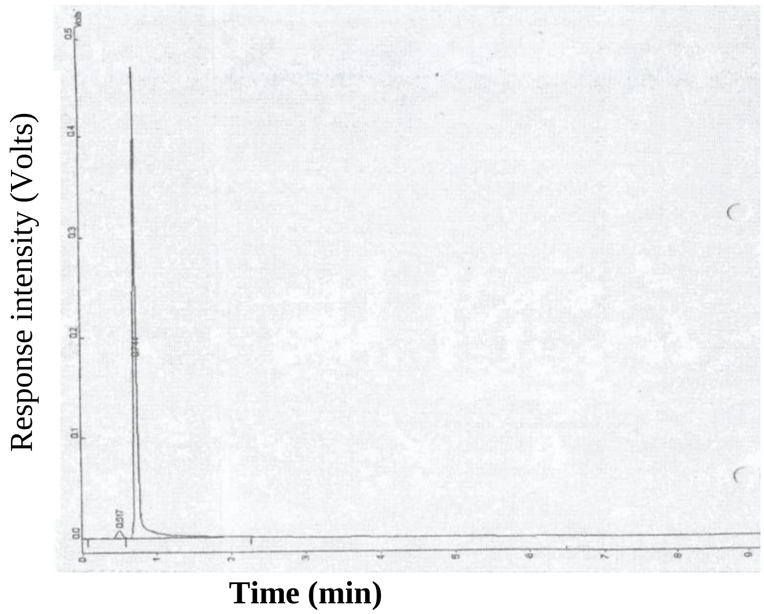


Figure 7.31: Chromatogram of air sample from school no. 4 room 2

t_R=0.744 ; Sampled at the front 1.5m above the floor; Area under the curve= 133584

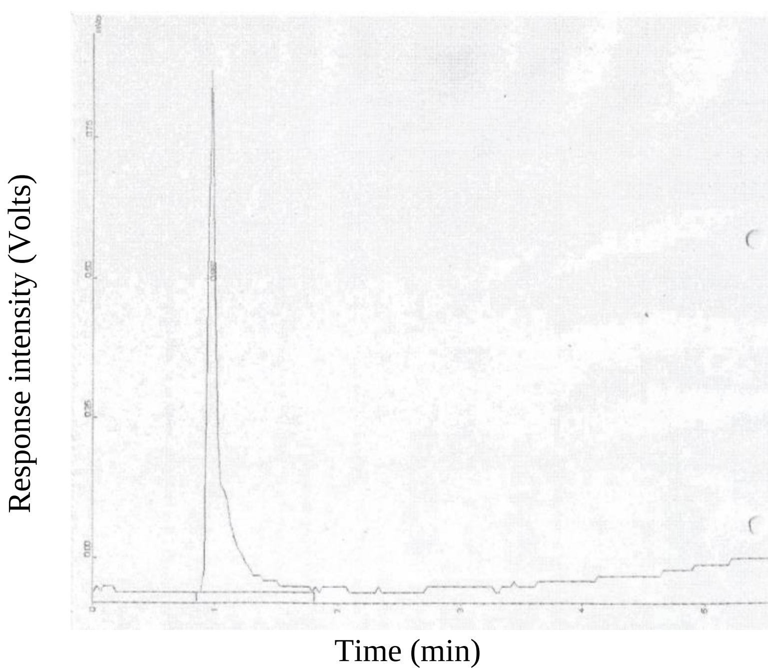


Figure 7.32: Chromatogram of air sample from school no. 2 room 1

t_R=0.987; Sampled at the back 0.5m above the floor; Area under the cureve=606

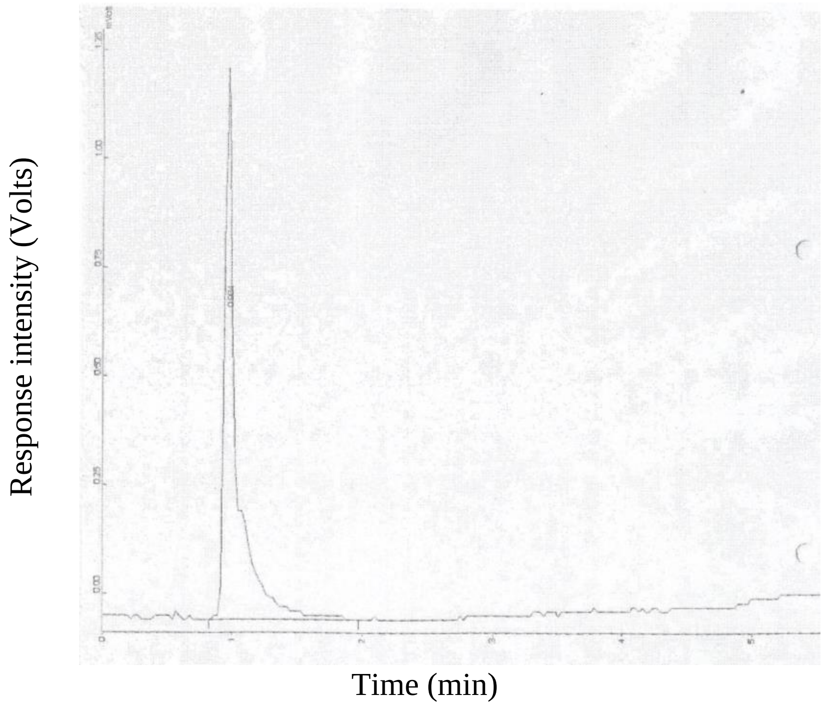


Figure 7.33: Chromatogram of air sample from school no. 2 room 1

t_R=0.984; Sampled at the back 1.5m above the floor; Area under the curve=832

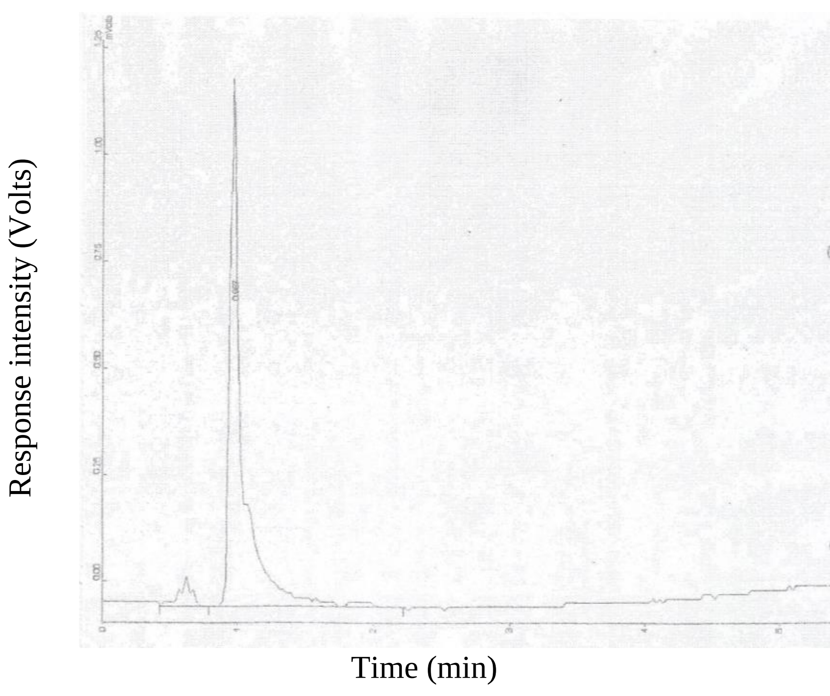


Figure 7.34: Chromatogram of air sample from school no.2 room 1

t_R=0.987; Sampled at the front 1.5m above the floor; Area under the curve=790

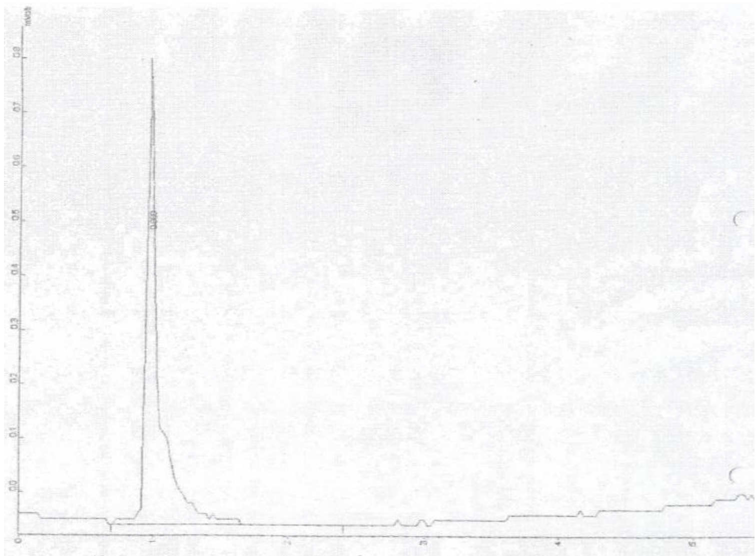


Figure 7.35: Chromatogram of air sample from school no.2 room 2

t_R=0.989; Sampled at the back 1.5m above the floor; Area under the curve=552

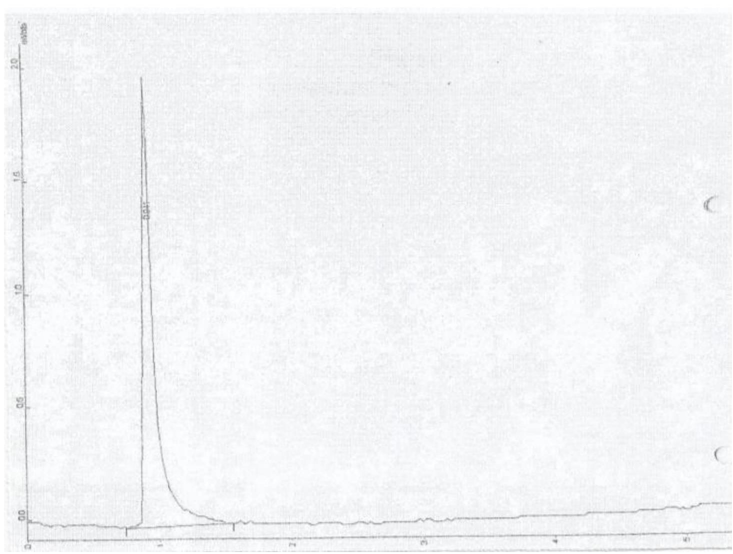


Figure 7.36: Chromatogram of air sample from school no. 4 room 1

t_R=0.941; Sampled at back 1.5m above the floor; Area under the curve= 1134

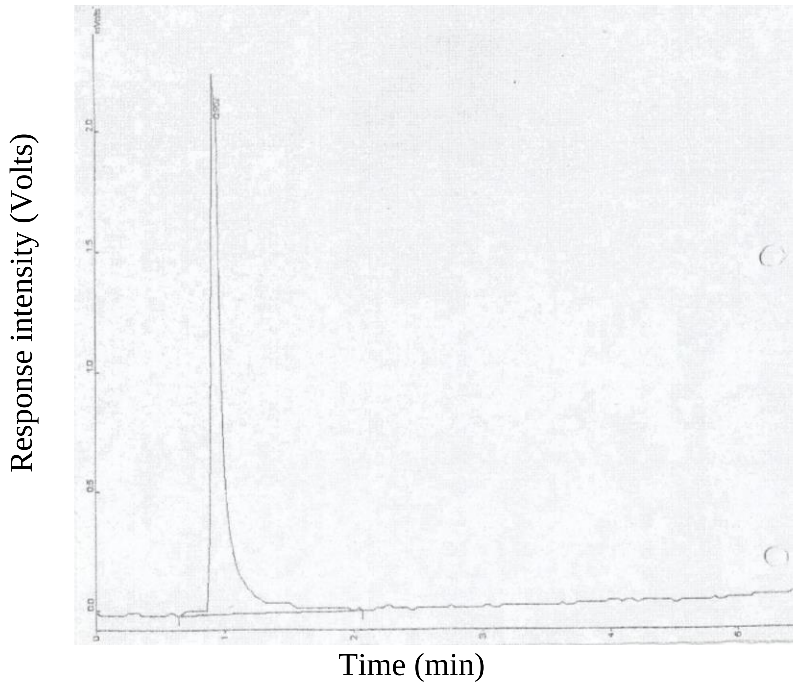


Figure 7.37: Chromatogram of air sample from school no. 4 room 1

t_R=0.952; Sampled at front 0.5m above the floor; Area under the curve= 1468

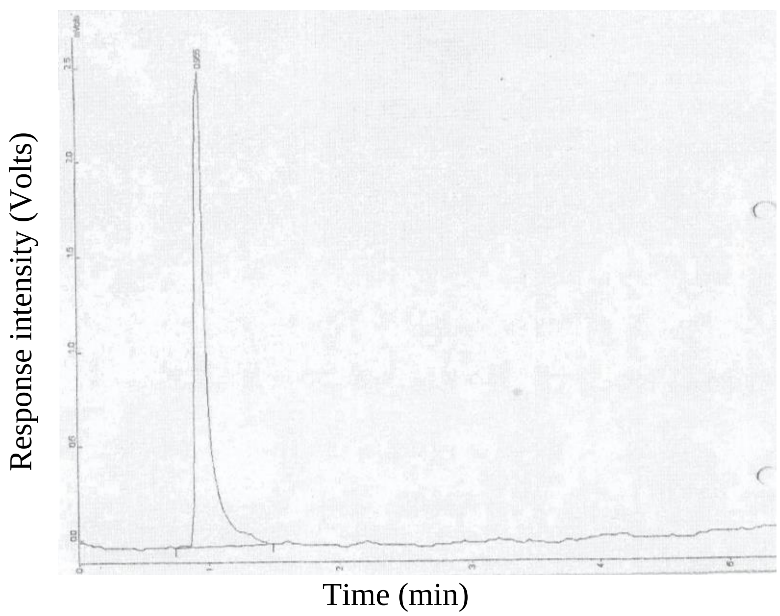


Figure 7.38: Chromatogram of air sample from school no. 4 room 1

t_R=0.955; Sampled at front 1.5m above the floor; Area under the curve= 1539

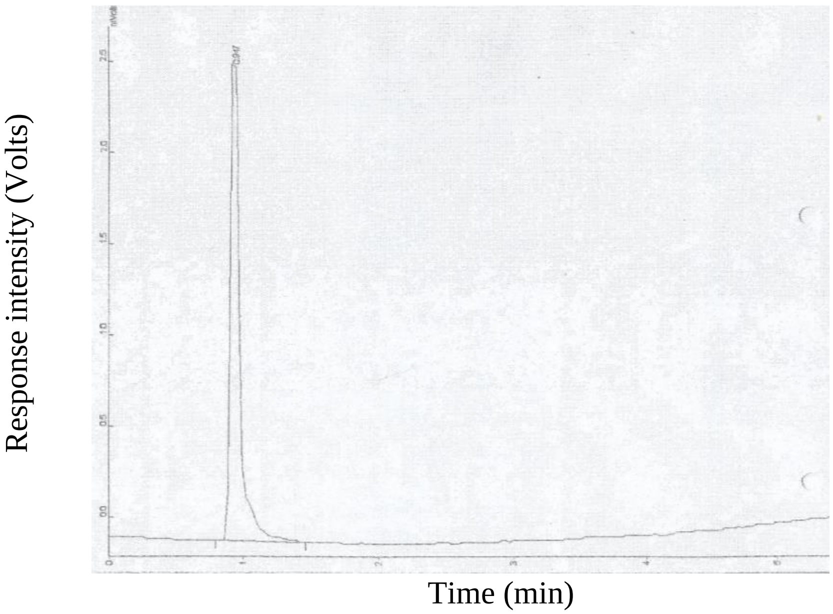


Figure 7.39: Chromatogram of air sample from school no.4 room 2

t_R=0.947; Sampled at back 1.5m above the floor; Area under the curve= 1279

APPENDIX IX: CHROMATOGRAMS OF INK 3 VOCS FROM THE INK HEADSPACE

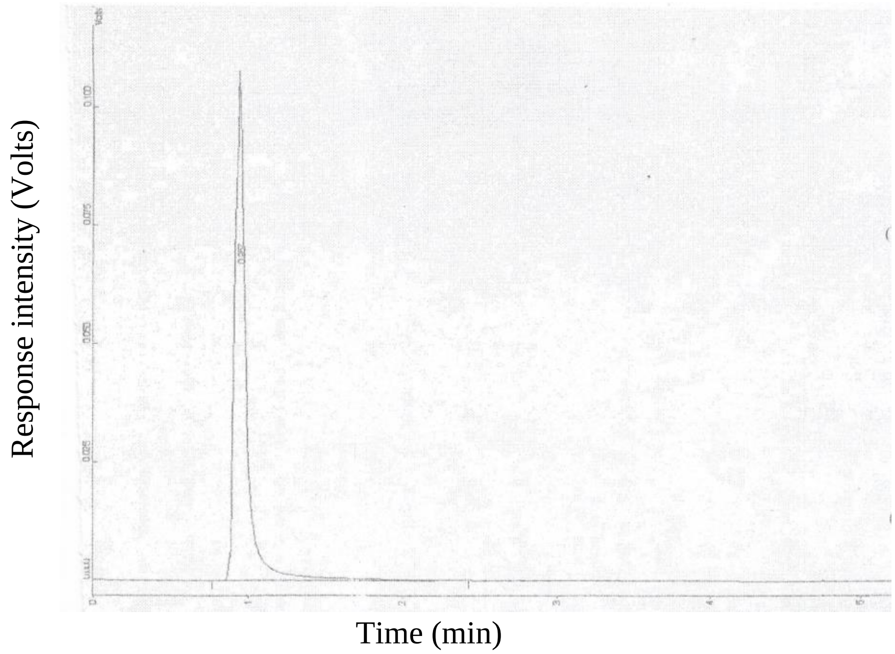


Figure 7.40: Chromatogram of ink 3 headspace

t_R=0.957

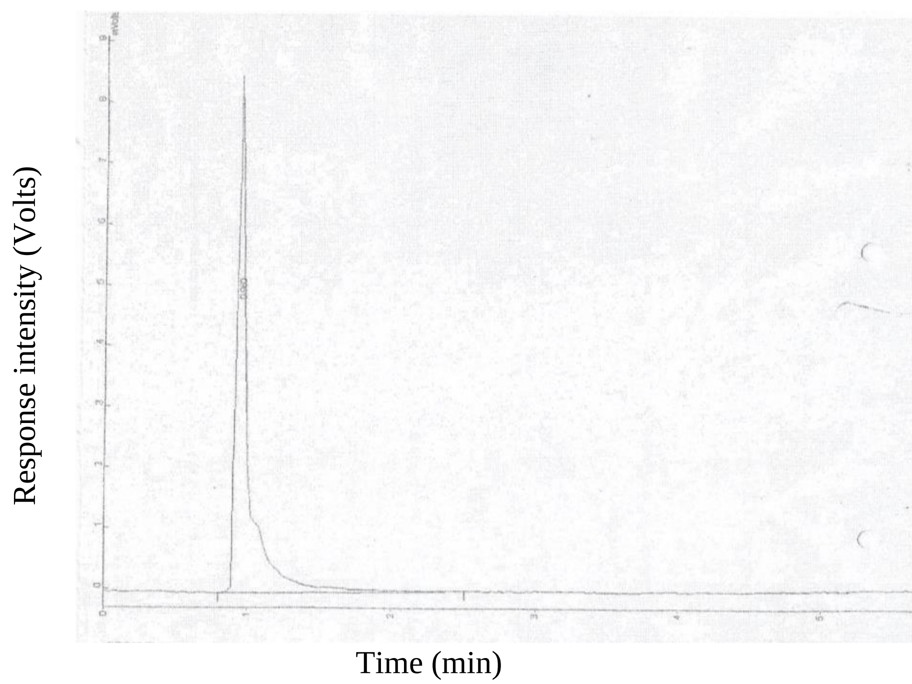


Figure 7.41: Chromatogram of ink 3 headspace

t_R=0.960

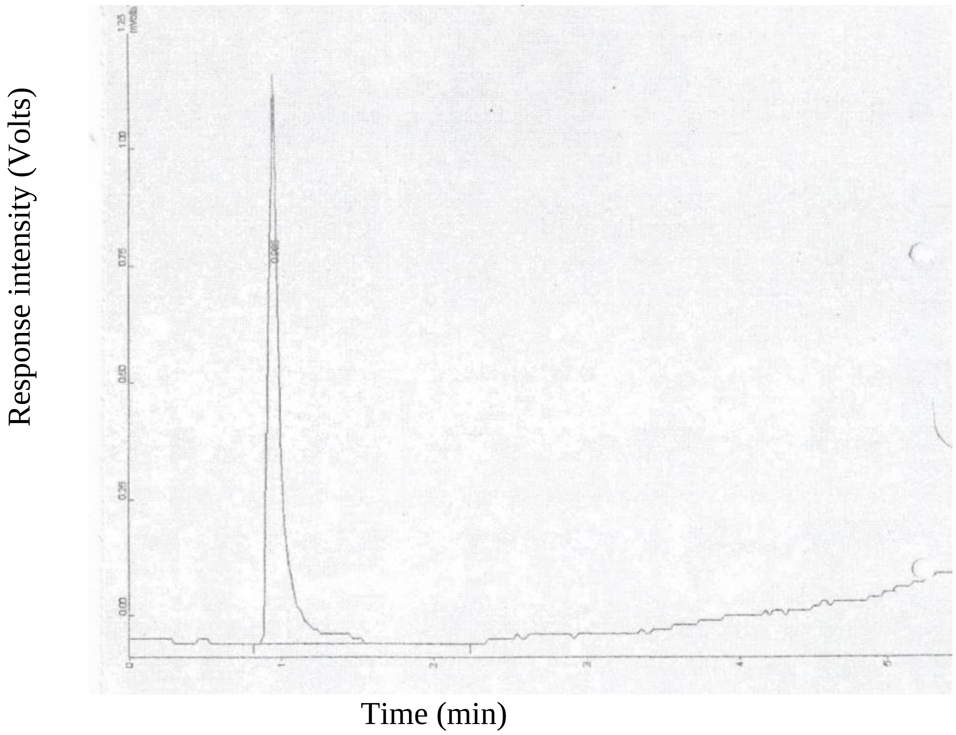


Figure 7.42: Chromatogram of ink 3 headspace

t_R=0.965

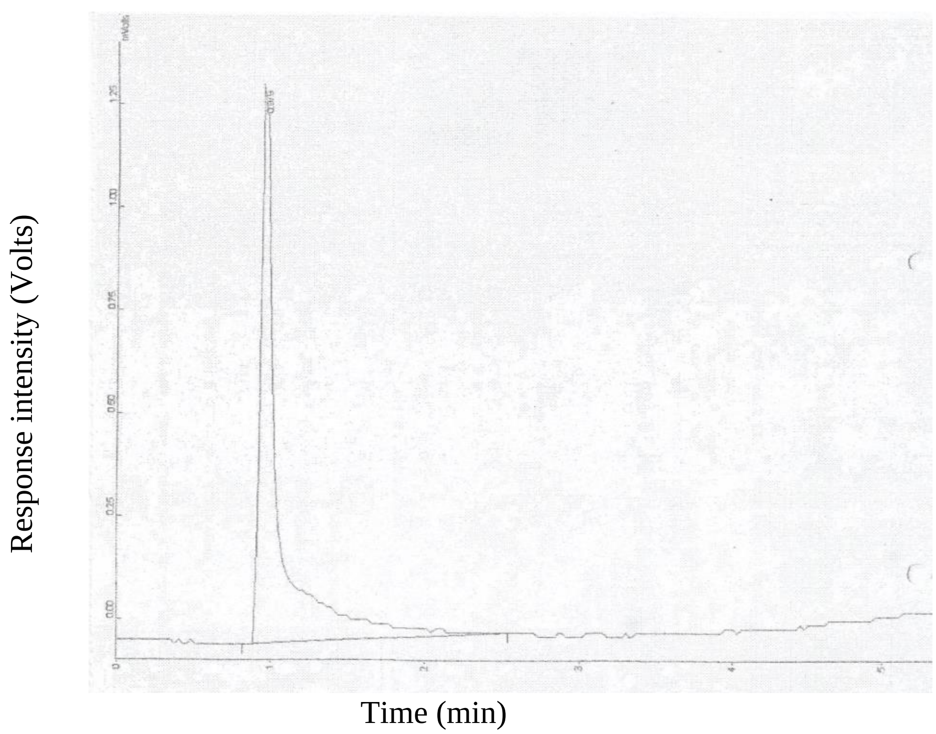


Figure 7.43: Chromatogram of ink 3 headspace

t_R=0.979

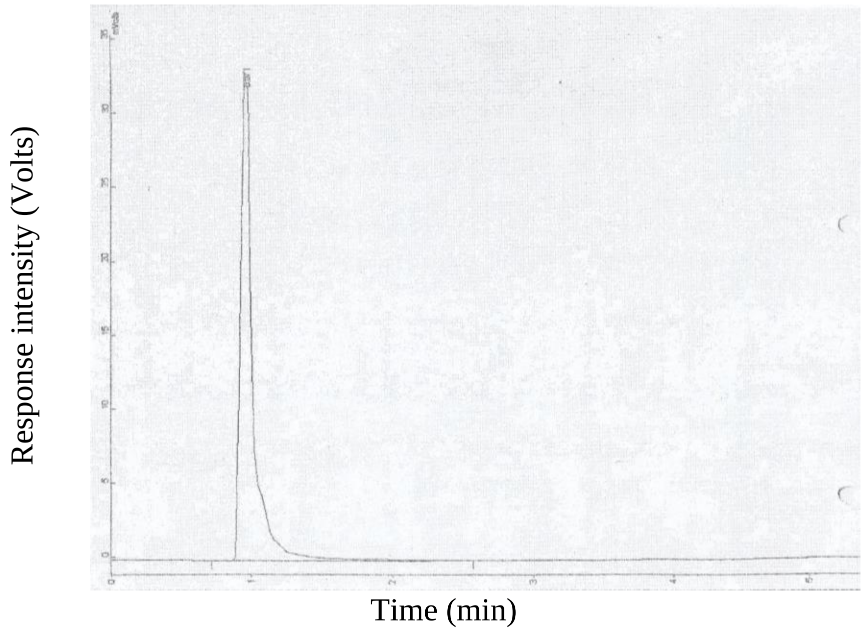


Figure 7.44: Chromatogram of ink 3 headspace

t_R=0.971

APPENDIX X: CHROMATOGRAMS OF AIR SAMPLES FROM SCHOOLS USING INK 3

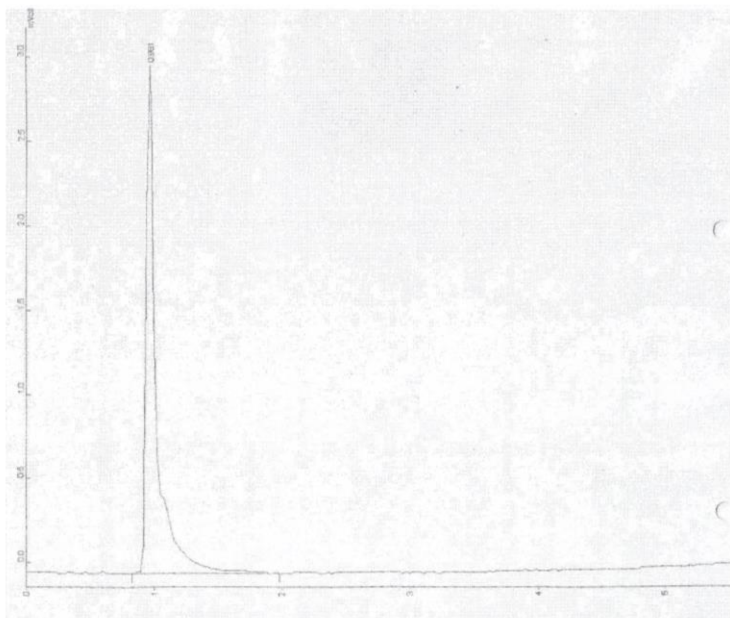


Figure 7.45: Chromatogram of air sample from school no. 1 room 2
t_R=0.981; Sampled at front 1.5m above the floor; Area under the curve=1743

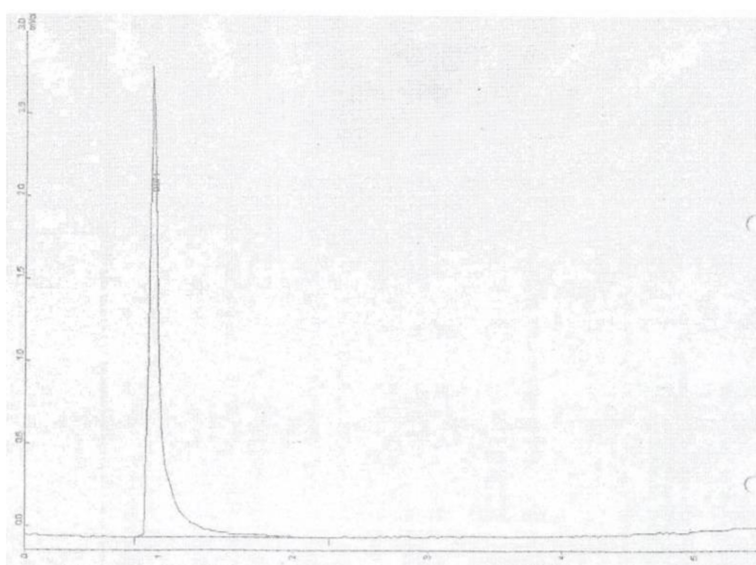


Figure 7.46: Chromatogram of air sample from school no. 1 room 1
t_R=0.971; Sampled at front 1.5m above the floor; Area under the curve=1600

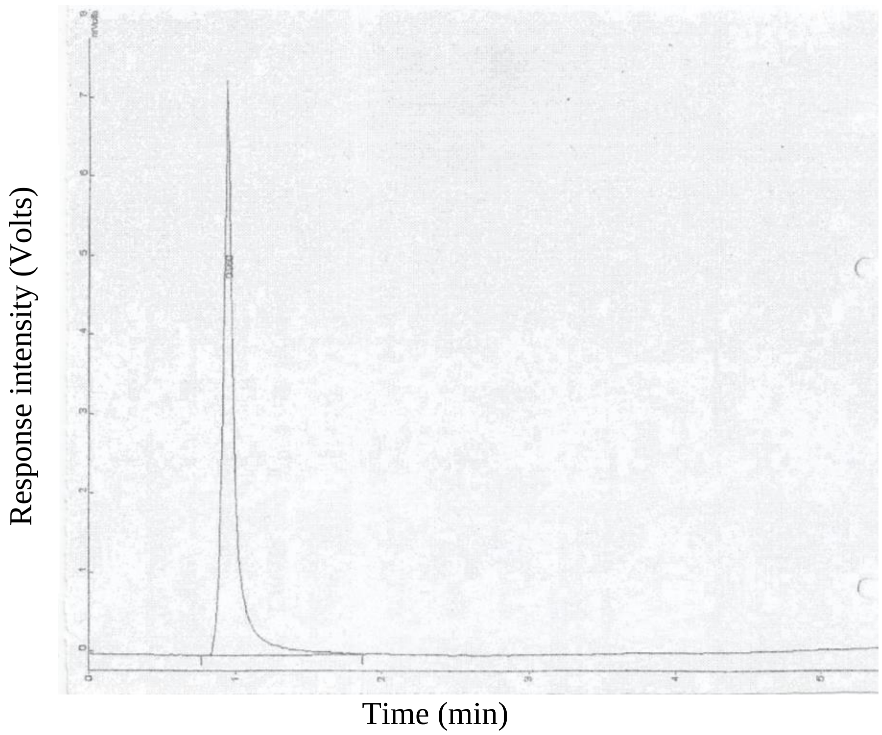


Figure 7.47: Chromatogram of air sample from school no. 5 room 2
t_R=0.960; Sampled at back 1.5m above the floor; Area under the curve = 3817

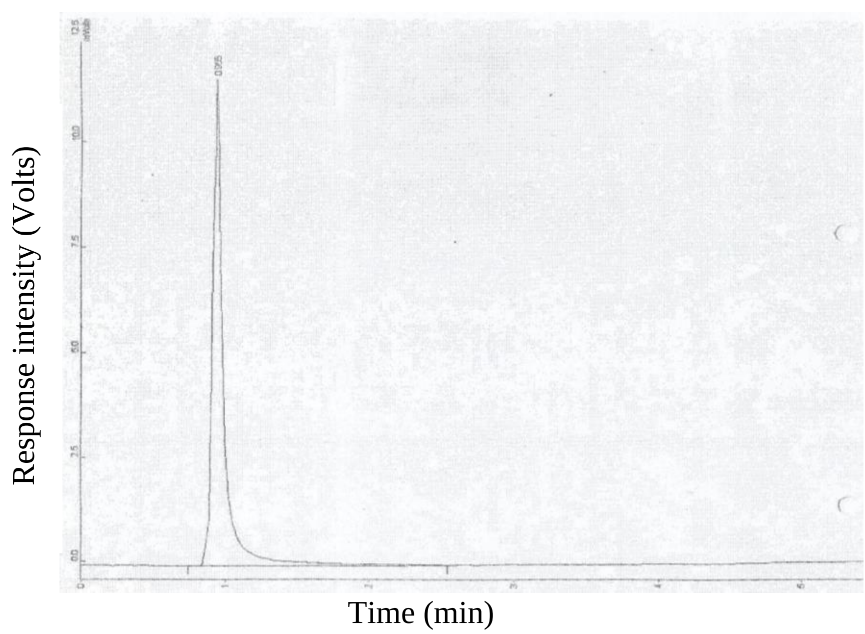


Figure 7.48: Chromatogram of air sample from school no. 5 room 2
t_R=0.955; Sampled at back 0.5m above the floor; Area under the curve = 6002

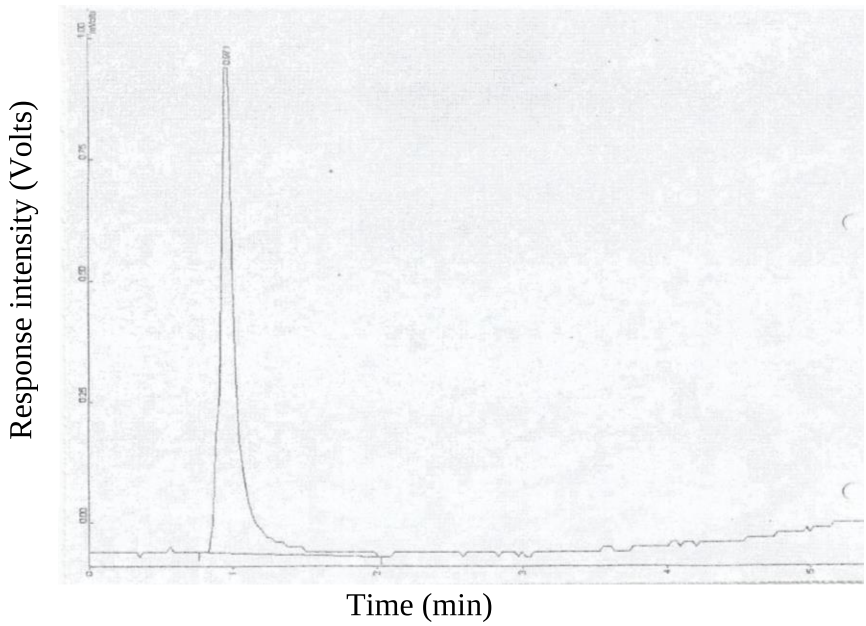


Figure 7.49: Chromatogram of air sample from school no. 5 room 1

t_R=0.971; Sampled at back 1.5m above the floor; Area under the curve= 756

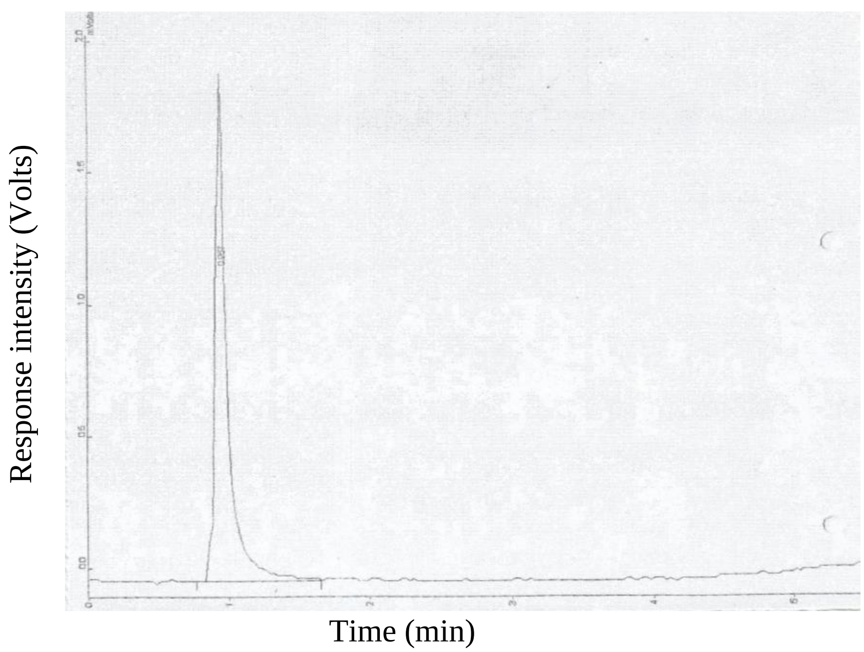


Figure 7.50: Chromatogram of air sample from school no. 5 room 1

t_R=0.957; Sampled at back 0.5m above the floor; Area under the curve= 1114

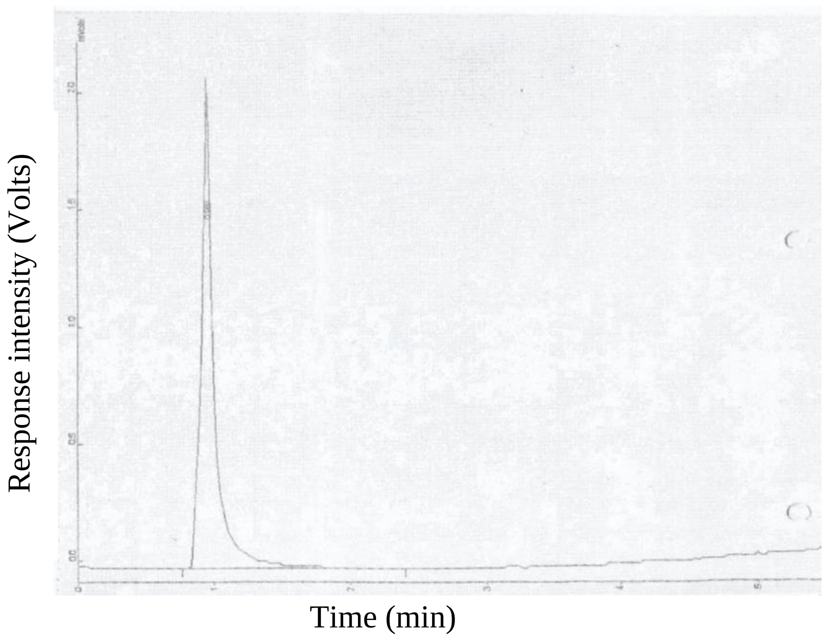


Figure 7.51: Chromatogram of air sample from school no.5 room 1

t_R=0.957; Sampled at front 0.5m above the floor; Area under the curve= 1317

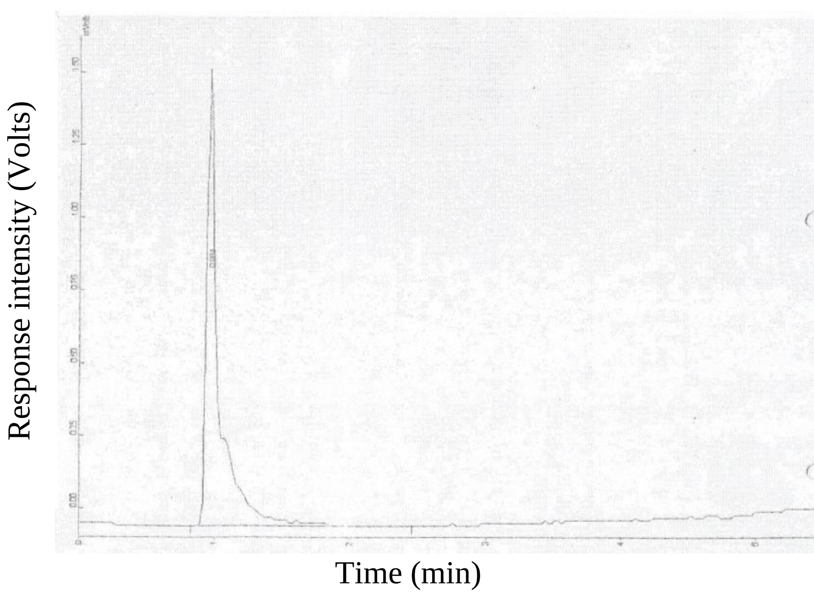


Figure 7.52: Chromatogram of air sample from school no. 1 room 2

t_R=0.984; Sampled at back 1.5m above the floor; Area under the curve= 989

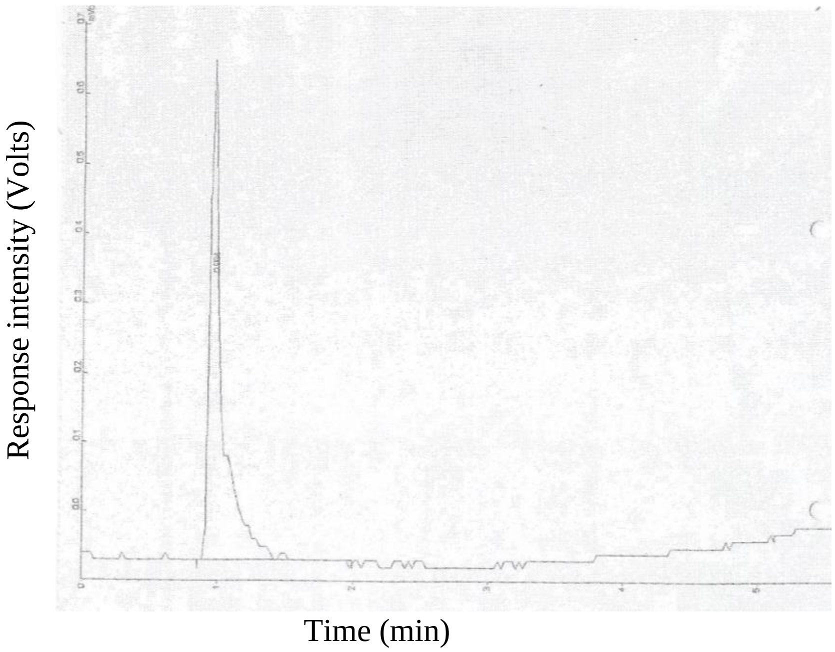


Figure 7.53: Chromatogram of air sample from school no. 1 room 2

t_R=0.984; Sampled at front 0.5m above the floor; Area under the curve= 461

APPENDIX XI: PERMIT FROM NACOSTI

NATIONAL COMMISSION FORSCIENCE, TECHNOLOGY ANDINNOVATION

Telephone:+254-20-2213471,
2241349,3310571,2219420
Fax: +254-20-318245,318249
Email: dg@nacosti.go.ke
Website: www.nacosti.go.ke
When replying please quote

9thFloor, Utalii House
Uhuru Highway
P.O. Box 30623-00100
NAIROBI-KENYA

Ref: No. **NACOSTI/P/17/65086/17518**

Date: **3rd July, 2017**

Sabina Muthoni Muchemi
Egerton University
P.O. Box 536-20115
EGERTON.

RE: RESEARCH AUTHORIZATION

Following your application for authority to carry out research on ***"Assessment of influence of occupational exposure to white board marker ink on symptoms of allergic conjunctivitis among school teachers in Nakuru County, Kenya,"*** I am pleased to inform you that you have been authorized to undertake research in **Nakuru County** for the period ending **19th June, 2018.**

You are advised to report to **the County Commissioner and the County Director of Education, Nakuru County** before embarking on the research project.

On completion of the research, you are expected to submit **two hard copies and one soft copy in pdf** of the research report/thesis to our office.

GODFREY P. KALERWA MSc., MBA, MKIM
FOR: DIRECTOR-GENERAL/CEO

Copy to:

The County Commissioner
Nakuru County.

The County Director of Education
Nakuru County.

APPENDIX XII: PERMIT FROM NAKURU COUNTY DIRECTOR OF EDUCATION

MINISTRY OF EDUCATION
STATE DEPARTMENT OF BASIC EDUCATION

Telegrams: "**EDUCATION**",
Telephone: **051-2216917**
When replying please quote

Ref.CDE/NKU/GEN/4/21/VOL.VI/35

COUNTY DIRECTOR OF EDUCATION
NAKURU COUNTY
P. O. BOX 259,
NAKURU.

15th November, 2017

TO WHOM IT MAY CONCERN

RE: RESEARCH AUTHORIZATION –SABINA MUTHONI MUCHEMI
PERMIT NO. NACOSTI/P/17/65086/17518

Reference is made to letter NACOSTI/P/17/65086/17518
Dated 3rd July, 2017.

Authority is hereby granted to the above named to carry out research on "***Assessment of influence of occupational exposure to white board marker ink on symptoms of allergic conjunctivitis among school teachers in Nakuru County, Kenya***" for a period ending 19th June, 2018.

Kindly accord her the necessary assistance.

KIMANI G.N
FOR: COUNTY DIRECTOR OF EDUCATION
NAKURU COUNTY

Copy to:

Egerton University
P.O Box 536-20115
EGERTON