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Assessment of the indoor air quality for workers in plastic factory (Gerri)

تقييم جودة الهواء الداخلي للعاملين في مصنع بلاستيك (قري)

A Thesis Submitted in Partial Fulfillment for the Requirement the Degree of M.Sc in Environmental Engineering

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October 2019

DEDICATION

Every challenging work always requires a self-dedication and a certain support and guidance. I would like to dedicate this thesis to my parents whose affection, encouragement, and prayers makes me capable to complete this thesis. I would also like to dedicate this to my hardworking respected teachers.

ACKNOWLEDGMENTS

First of all, I would like to thank my supervisor, Dr. Arman Mohammed Abdallah, from Sudan University of science and technology, for his guidance/support and valuable information provided during this thesis.

Also I would like to express my gratitude plastic factory of Garri for allowing me to utilize monitoring equipment and providing me all logistic support in the completion of this thesis.

Abstract

Measurement of air quality and environmental conditions in the places where people are used to spend a large amount of their time is essential. Hazardous substances emitted by anthropogenic activities, building construction materials, indoor equipment or heating & cooling system may lead to broad range of health problems. Therefore, it is vital to investigate the quality of the indoor workplace environment. These accumulative effects have added a concern that air quality of indoor environment should be monitored, analyzed, and reported properly.

This research study of air pollutants inside a plastic factory in Gerri for 14 locations.Ten parameters including(carbon monoxide(CO), nitrogen dioxide ($NO_{2,}$)carbon dioxide (CO2), sulfur dioxide (SO_2) total volatile organic compounds(TVOCs), particulate matter($PM_{2.5}$),temperature, relative humidity(RH) Noise and light) were measured using WOLF Pack Area Monitor, Thermo Scientific pDR-1500 personal Data RAM, Sound level meter and Lux light meter.

All locations have been evaluated based on different international standards such as Occupational Safety and Health Administration (OSHA) and American Society of Heating, Refrigerating and Air Conditioning Engineers (ASHRAE). Accordingly the indoor air quality and environmental conditions of all locations were categorized as acceptable and not acceptable as per permissible limits defined for each parameter.

Nine parameters (CO, $NO_{2,}$ CO2, $SO_{2,}$ TVOCs, $PM_{2.5,}$ RH, Noise, light)were detected.at acceptable levels except some locations the noise is above the upper permissible range as recommended by OSHA i.e. $<$85db.

Also some locations not acceptable where the TVOCs is above the upper permissible range as recommended by OSHA i.e.$< 1ppm$.

Another location not acceptable where the light is under the permissible range as recommended by OSHA i.e.$\geq 322lux$.

Also the temperature in all locations is above the upper of permissible range as recommended by OSHA i.e. (20-26).

Overall, this study highlighted that the air quality and environmental conditions in most of the locations is considered to be healthy and the parameters monitored during indoor air quality and environmental conditions survey were within the ASHRAE and OSHA limits. This study can be used as a baseline for any future detailed indoor air quality and environmental conditions investigation for plastic factories and other factories in Sudan.

المستخلص

قياس جودة الهواء والظروف البيئية في الأماكن التي اعتاد الناس علي قضاء وقتهم فيها ضروري جدا . قد تؤدي المواد الخطرة المنبعثة من الأنشطة البشرية أو مواد إنشاء المباني أو المعدات الداخلية أو نظام التدفئة والتبريد إلى مجموعة واسعة من المشكلات الصحية. لذلك من الأهمية بمكان استكشاف جودة بيئة العمل الداخلية. أضافت هذه الآثار التراكمية قلقًا من وجوب مراقبة جودة الهواء في البيئة الداخلية وتحليلها والإبلاغ عنها بشكل صحيح.

هذا البحث تناول دراسة ملوثات الهواء داخل مصنع البلاستيك في منطقة قري لعدد 14 موقع ،حيث تم قياس(أول أكسيد الكربون (CO) ، ثاني أكسيد النيتروجين (NO2)، ثاني أكسيد الكربون (CO2) ، ثاني أكسيد الكبريت (SO2) ، المركبات العضوية المتطايرة الكلية (TVOCs) ، الغبار (PM2.5) ، درجة الحرارة ، الرطوبة النسبية (RH) الضوضاء والضوء باستخدام جهاز مراقبة جودة الهواء الداخلي (WOLFPACK Area Monitor)و جهاز قياس الغبار (Thermo Scientific pDR-1500 personal Data RAM)وجهاز قياس الضوضاء(Sound level meter) و جهاز قياس الاضاءة(Lux light meter).

تم تقييم جميع المواقع بناءً على معايير دولية مختلفة مثل و إدارة السلامة والصحة المهنية(OSHA) والجمعية الأمريكية لمهندسي التدفئة والتبريد وتكييف الهواء(ASHRAE). ووفقًا لذلك تم تصنيف جودة الهواء الداخلي والظروف البيئية على أنها مقبولة وغير مقبولة وفقًا للحدود المسموح بها.

حيث تم الكشف عن تسع مقاييس(CO، NO2، CO2، SO2، TVOCs، PM2.5، RH ، الضوضاء ، الضوء) على انها مستويات مقبولة باستثناء بعض المواقع حيث تكون الضوضاء أعلى من النطاق المسموح به على النحو الموصى به من قبل OSHA اي اقل من 85ديسبيل.

أيضًا هنالك بعض المواقع غير مقبولة حيث تكون TVOCs أعلى من النطاق المسموح به على النحو الموصى به من قبل OSHA أي اقل من 1 جزء من المليون.

هناك موقع آخر غير مقبول حيث يكون الضوء تحت النطاق المسموح به من قبل OSHA أي اكبر من 322 لوكس .

ولوحظ أن درجة الحرارة في جميع المواقع أعلى من النطاق المسموح به من قبل OSHA أي (20-26).

بشكل عام ، سلطت هذه الدراسة الضوء على أن جودة الهواء والظروف البيئية، معظم المواقع تعتبر صحية وأن الغازات التي تم رصدها خلال المسح لجودة الهواء الداخلي والظروف البيئية كانت ضمن حدود ASHRAE و OSHA. يمكن استخدام هذه الدراسة كقاعدة أساسية لأي تحقيق مفصل في المستقبل عن جودة الهواء الداخلي والظروف البيئية لمصانع البلاستيك وغيرها من المصانع في السودان.

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List of abbreviations

Abbreviation	Meaning
US EPA	United States Environmental Protection Agency
USA	United States of America
CDC	Center for Disease Control and Prevention
WHO	World Health Organization
NIOSH	National Institute of Occupational Safety and Health
IAQ	Indoor Air Quality
HVAC	Heating, Ventilation and Air Conditioning
PAHs	Polycyclic aromatic hydrocarbons
Co	Carbon monoxide
NO_2	Nitrogen dioxide
CO2	Carbon dioxide
SO_2	Sulphur dioxide
TVOCs	Total Volatile organic compounds
$PM_{2.5}$	Particulate matter have a diameter less than 2.5 micrometers
PM10	Particulate matter have a diameter less than 10 micrometers
Tem	Temperature
RH	Relative Humidity
ASHRAE	American Society of Heating Refrigeration and Air-Conditioning Engineers
OSHA	Occupational Safety and Health Administration
gNO	Gaseous nitrogen oxide
COHb	Carboxy hemoglobin
Re	Resolution
pDR	personal Data RAM

CHATPER ONE

Introduction

CHATPER ONE

1-1 Introduction:

Air is a valuable resource supplies us with oxygen, which is essential for our life. Pure air is a mixture of several gases that are invisible and odorless.

Air consists of about 78% nitrogen, 21% oxygen, and less than 1% of argon, carbon dioxide, and other gases as well as water vapor. Adults breathe in about 10-20 cubic meters of air every day. (Diamond and Grimsrud, 1983).

Globally, air pollution is considered as one of the major environmental concerns. Worldwide, air pollution, especially in large cities, is directly related to the increased number of lung and heart disease cases which eventually result in high death rate(Bruce, Perez-Padilla and Albalak, 2000).Quality of air is meticulously related to the activities of human. Currently, different methods have been used to confirm the impacts of human effects on the natural environment.

Indoor air quality and environmental conditions of the buildings and industrial factory has become a main concern for the worker in recent years .It can affect the wellbeing, health, luxury, happiness, and productivity of residents. The US EPA has listed indoor air quality as one of the top 5 public health risks (USEPA) In the USA, Center for Disease Control and Prevention (CDC) has given an estimation that normally residents of the country spend 90% of their time indoor which is the major reason for being exposed to indoor air pollutants more than outdoor air pollutants.(MUKHTAR, 2018).

There has also been a substantial worldwide change in the economy from the manufacturing sector to the service and knowledge-based sectors which has increased diversity and level of indoor pollution. In urban and industrial environment, a wide use of air-conditioning has decreased ventilation, which had increased probability of high concentration of indoor pollutants. Therefore, it is vital to study and investigate the quality of the indoor workplace environment.

Air Pollution coming from sources like vehicles, industrial areas and from human activities are typically argued, but indoor pollution generally remains ignored. Exposure to indoor air pollutants is common but public awareness regarding this issue is very limited when compared to outdoor air pollutants (MUKHTAR, 2018). Since, indoor air pollutants are known to cause significant health problems across the globe, it is important to understand the hazardous nature of these pollutants as well as to take necessary steps to reduce their effects and minimize human exposure. Different age groups have different sensitivity when exposed to these pollutants (WHO). According to the WHO global air quality guidelines, 1.6 million deaths per year were the result of increased concentrations of particulate matter and gasses in indoor air (WHO). Similarly, a recent study published by WHO in 2012 highlighted that 4.3 million people died because of indoor air pollutants as compared with 3.7 million due to outdoor air pollutants.

1-2 Area study:

This study was conducted for a plastic factory in the industrial area of Gerri. It is located north of Khartoum city near the Jaili refinery.

The factory consist of weavig,printing,conversion,sack press, extruding, store raw material, store finishing material ,lab, center of the yard, work shop, north east of factory, in front of the main gate of the factory and between solid container and water chiller.

1-3 Problem statement:

The significance of this researched will rely on the indoor data collected and analyzed for plastic factory. The result of this study would be helpful in the upcoming investigation on issues like; human's health and correlation between indoor air quality and designs of the building factory.

Plastic factory may be emissions toxic gages such as: sulfur oxides, nitrous oxides, methanol, ethylene oxide particulate matter, and volatile organic compounds.

Also this study is helpful for evaluating the existing policies and proposing tackle the issue the public will be able to recognize the harmful effects of indoor air pollutants upon their health.
In this research we assessment the indoor air quality for plastic factory and the suitable environmental condition for the worker in this factory.

1-4 Research Objectives:

1-4-1 General objectives:

The main objective of the study was to investigate the indoor air quality of workplace environment and to identify suitable environmental conditions for worker at the plastic factory.

1-4-2 Specific objectives:

The sub-objectives of the study were;

1. To measure and collect data for plastic factory.
2. To identify main source of indoor air pollution in plastic factory.
3. To assess the indoor air quality and environmental condition for plastic factory.
4. To identify the health risk from indoor air pollution to office buildings by monitoring the quality of air to which occupants are exposed.
5. To identify the exposure standards limits to pollutants for workers.
6. To help industry to improve the designs consideration before construction that can sustain acceptable levels of indoor air quality.

Fig (1-1) Area study

CHAPTER TWO

LITERATURE REVIEW

CHAPTER TWO

LITERATURE REVIEW

2-1 Introduction:

To investigate deeply into the problem, an extensive review of the relevant literature was carried out on indoor air pollutants and environmental conditions, their source materials, their negative impacts on human health and productivity, particularly in industrial buildings. A study conducted by National Institute of Occupational Safety and Health (NIOSH) showed different sources of indoor air pollution. Among the various causative factors of indoor air pollution, inadequate ventilation came out to be the main reason of affecting indoor air quality (IAQ) and environmental conditions(MUKHTAR, 2018). The causes of indoor air pollution have been summarized in Table (2.1). Sources of indoor air pollutants can be from inside building and can be drawn in from outdoor sources. Sources from outside building can be pollen, dust, fungal spores, industrial pollutants, general vehicle exhaust, emissions generating from nearby sources (e.g. odors from dumpsters, loading docks etc.), soil gas (radon, leakage from underground fuel tanks, pesticides etc.), moisture or standing water promoting excess microbial growth (rooftops after rainfall, crawlspace), HVAC equipment (dust or dirt in the duct work or other components, microbiological growth in dripping pans, ductwork, coil, improper use of biocides, sealants and cleaning compounds, improper venting of combustion products, refrigerant leakage, human activities (smoking, cooking, cosmetic orders, maintenance activities), building components and furnishings locations that produce or collect dust or fibers, unsanitary conditions and water damage, and chemicals released from building components or furnishings.

Table 2-1 Different Sources of Indoor Pollution (NIOSH)

Pollutants	**Percentage**
Inadequate Ventilation	53%
Inside Contamination	15%
Unknown Causes	13%
Out-side Contamination	10%
Bioaerosol	5%
Building Products	4%

2-2 plastic factory processes:

Plastic sacks factory is weaving from raw materials such as polypropylene or polyethylene and used for packing sugar. In this plastic industry a yarn production line is used with a compact yarn tightening unit.

We will briefly mention production processes stages in this paragraph:

First stage: The production process begins by heating the raw materials and then extruding them into a large slice. And they are cutting into threads to pass through the tensile and forming stage and the thread is wrapped on rollers.

Second stage: Then threads rollers are placed in a circular machine for the weaving industry and are controlled by a micro-computer where the diameter of the desired weaving is controlled.

Third stage: is the stage of cutting the required lengths of the resulting weaving rollers by selecting the appropriate length automatically.

Four stage: At this stage, the lower and upper extremities of the weaving are sewing.

Five stage: is Printing Machine used to print words, pictures and brands on weaving bags and sacks.

2-3 Indoor Environment Pollutants:

People spend almost 90% of their time in the indoor environment but it is very unfortunate that the least attention is being paid to this facet of congenial work environment(MUKHTAR, 2018). It is rather a height of oblivion that governments are all-out to adopt measures that may address the outdoor airborne pollutants instead of indoor ones. In the following section, however, the origin and producers of several indoor air pollutants includes the following pollutants like nitrogen oxides, volatile organic compounds, formaldehyde sulfur dioxide, carbon monoxide, ozone, particulate matter and radon, as identified by the United States Environmental Protection (USEPA) (Table 2.2).

Table 2-2 Major Indoor Air Pollutants (MUKHTAR, 2018)

Pollutants	**Source**
By-means of Combustion (e.g. CO, CO_2, NOx)	Gas & kerosene heaters and stoves, wood and gas hearths, automobile exhausting in garages, tobacco smoke, leaking furnaces and chimneys
Tobacco smoke	Cigars, cigarette pipes
Formaldehyde	Products of pressed wood (plywood, hardboard, fiberboard ,particleboard and wall paneling,) used in furniture and buildings, pressed textiles, foam insulation, glue, tobacco smoke, fireplaces, stoves, vehicle exhaust
Other Volatile Organic Compounds	Aerosol sprays, wood preservatives, paints, dry cleaned clothes, cleaners and disinfectants, solvents, moth repellents, and air fresheners
Radon	Water, soil, rocks
Bioaerosols	Humidifiers, pets, drip pans, ventilation systems, moist surfaces, outside air, plants,

2-4 Indoor Air Quality and Polycyclic aromatic hydrocarbons:

Indoor air quality (IAQ) is a term referring to the air quality within and around buildings and structures, its significance especially being its relation to the health and comfort of building occupants. In recent years, scientists and the public have put much concern about indoor air quality, since most people spend their time more than 70 -90 % indoors (e.g. office and workplace).(Muhamad-darus, Zain-ahmed and Talib, 2011).

Polycyclic aromatic hydrocarbons (PAHs) are also taken into consideration when studying indoor and outdoor air quality(MUKHTAR, 2018). Polycyclic aromatic hydrocarbons (PAHs), formed mainly during carbonization and incomplete combustion of organic materials (and have been widely investigated due to their potentially carcinogenic and mutagenic nature . They are also generated by combustion sources inside workplaces, such as burning of candles and incense, cigrate smoking, cooking, fuel burning, domestic heating, and so on. In addition, people spend more than 80% of their time indoors , thus is important to evaluate indoor and outdoor PAH characteristics for assessing total human exposure to PAH(Masih *et al.*, 2012).

2-5 Determinants of Indoor Air Quality:

Determinants of indoor air quality (IAQ) include a variety of compounds, such as TVOCs, CO2, CO,NO2 and SO2. In case of poor ventilation volatile organic compounds (VOCs) can be five time higher as compared to outdoor environment .This increase can have many acute and chronic effects on residents like dizziness, tiredness, irritation and drowsiness.(MUKHTAR, 2018).

In paragraphs below, each determinant factor is described in detail:

Temperature is a very important factor, directly linked to the comfort of building occupants (The standard of American Society of Heating Refrigeration and Air-Conditioning Engineers (ASHRAE) stated that this comfort level of occupants can be achieved if the operating temperature is maintained-between 19 to 27°C.

Humans have difficulties perceiving changes of the relative humidity (RH), due to lack of sensory receptors for humidity. In contrast, specific sensors exist for the perception of the temperature. However, reporting of "dry air" has been associated with poor indoor air quality (IAQ).(Wolkoff and Kjærgaard, 2007).

An important aspect of **relative humidity (RH)** is encouraging microbial growth in the carpets and other possible potential sources. ASHRAE standard recommends maintaining RH between (30-60%). A higher concentration will facilitate growth of mildew, mold, bacterial, fungi and dust mites. Similarly, a relative humidity less than 30% will aggravate discomfort among occupants/residents, and may allow spread of viral infections.

Carbon monoxide (CO) is a colorless, odorless gas formed when carbon in fuel is not burned completely. CO can cause harmful health effects by reducing the delivery of oxygen to the body's organs and tissues. At low levels of exposure, CO can be poisonous, creating headaches, nausea and sleepiness. Higher levels can be life-threatening and are often found indoors. CO exposure also may injure the eyes, reduce work capacity, make manual and complex tasks more difficult, and hamper learning ability. The CO is added to the atmosphere through countless sources, such as kerosene and gas stoves and heaters, wood and gas hearths, vehicle exhaust, tobacco smoke, leaking furnaces and chimneys.CO is a source of indoor air pollution produced because of combustion processes. It poses high risk to living organisms leading to poisoning, cardiovascular diseases, and sometimes deaths. The behavior and chemical nature of pollutants and the ventilation processes indoors are important to evaluate the toxicity and the harm it can cause to occupants of the building.

Carbon dioxide (CO_2) is a well-known naturally produced gas by the process of respiration. In evaluation of indoor air quality, it is used as an indicator of whether the ventilation systems are competent in replacing carbon dioxide with fresh air or not. Inefficient removal of carbon dioxide eventually results in its accumulation in microenvironments and hence, increases its concentration. Increased carbon dioxide concentration is not healthy for the occupants in offices or accommodations as it can displace oxygen as well as cause dizziness, suffocation and other such health risks.

Nitrogen dioxide (NO_2) is an ill-smelling and irritating odor reddish-brown gas which occurs in the atmosphere abundantly and particularly when there is excessive lightning, thundering and flashing. It irritates lungs and causes bronchitis and asthma if it is inhaled in high concentrations. Nitrogen dioxide is another lethal pollutant which comes from the sources like boilers, hot water heaters, fireplaces and gas ranges.

NO_2 effects on humans studied widely exposure to yet should be reduced in any case. In some studies, higher concentration of indoor NO_2 is linked to increased symptoms of asthma. Other health conditions such as chest tightness, respiratory problems, and cough are also outcomes of exposure to NO2.(MUKHTAR, 2018).

Nitrogen dioxide (NO2) is a ubiquitous pollutant in urban environments. It is a byproduct of high-temperature fossil fuel combustion that can come from a variety of indoor and outdoor sources. The primary anthropogenic sources of outdoor NO2 are vehicles, fossil fuel-burning power plants, and industrial boilers. Indoor NO2 concentrations are influenced both by outdoor levels and by indoor sources such as gas stoves, kerosene heaters, and cigarette smoke. In addition, indoor NO2 concentrations are affected by such household variables as surface adsorption properties, ventilation of combustion appliances, and ventilation of the indoor environment.(Levy *et al.*, 1998)

Gaseous nitrogen oxide (gNO) is an important indoor and outdoor air pollutant. Many studies have indicated gNO causes lung tissue damage by its oxidation properties and free radicals.

However, there are considerably few data on the association between lung cancer and gNO exposure(Chen *et al.*, 2008).

In industrial devices No reacts with O2 to form No2, a brown gas that is serious respiratory irritant .Its color is strong enough that it is often possible to see a distinct brown color emerging from a power plant stack or from the vent of any process using nitric acid , which releases No2.No and No2 often treated together as one problem or as a quasi-specie , and written NOx . Most regulations for NOx emissions base all numerical values on the assumption that all of the NO is converted to NO2. One sees this written as (NOx expressed asNO2).(De Nevers, 2010).

Sulphur dioxide (SO_2) one of the components of a gaseous group of sulfur oxides (SO_x), is a non-combustible, colorless, and non-explosive gas. Combustion of fossil fuel by power plants and other natural processes such as volcanoes eruptions and industrial processes like extraction of metals from ores and sources like locomotives, ships and heavy equipment that burn fuel with a sulfur content are the chief sources of SO_2 emission (USEPA, 2009). However, combustion of coal in power plants is commonly mentioned sources of SO_2(MUKHTAR, 2018).

Total Volatile organic compounds (TVOCs) comprise an important group of chemicals that evaporate easily at room temperature, and are commonly present in indoor air.(Barro *et al.*, 2009).

Total Volatile organic compounds (TVOCs) are irritants and indoor sources include solvents, floor adhesive, paint, cleaning products, furnishings, polishes, and room fresheners.. Indoor exposure to TVOCs has been related to asthma and asthmatic symptoms such as nocturnal breathlessness, and decreased lung function.(Rumchev *et al.*, 2004).

2-6 indoor air quality and Associated Health risks:

Ideal indoor air quality (IAQ) means the air we breathe everyday inside the building does not contain any contaminant either in the form of biological (mould, fungi or bacteria), chemical (gaseous which might become poisoning if excessively present in the breathing air like Carbon Dioxide (CO2), Carbon Monoxide (CO), or Total Volatile organic compounds (TVOCs) or physical contaminants like dust (particulate matter; PM10, PM2.5 or ultrafine particle).(Nur Fadilah and Juliana, 2012).

IAQ is one of the emerging health issues worldwide. The severity of the issue is vivid through the fact that the citizens spend most of their time (almost 90%) in confined indoors such as offices, labs , workshops and others .Such lifestyle increases the human exposure to certain chemicals and compounds found indoors. Various studies unveiled the relationship of cardiovascular and respiratory diseases with particulate matter. Recent studies have also proved this correlation .One of the very common ailments associated with indoor air pollution, as named by the World Health Organization (WHO, 1983) is Sick Building Syndrome (SBS). SBS is felt by most of the people working in the offices. Symptoms of SBS include headache, fatigue, and irritation in nose, eye, throat and erythema. (Nur Fadilah and Juliana, 2012).

Carbon monoxide (CO) lays serious effects on human health. Humans' exposure to CO for continuous eight hours can cause death . Through blood circulation, hemoglobin carries oxygen to all body parts. But hemoglobin is more prone bind with CO than with oxygen (240:1). Human exposure to higher concentrations of CO forms carboxy hemoglobin (COHb) within five minutes may cause death . Patients of chronic cardiovascular and pulmonary diseases are more vulnerable to the increased supplies of CO (USEPA).

Oxides of nitrogen participate in different pathological and physiological processes such as inflammation, vasodilatation, malignant transformation and lung carcinogenesis It has been proved through various studies that oxides of nitrogen cause damage to the respiratory tract and continuous exposure to low levels of these oxides leads to the lungs infection and high levels to emphysema (American Lung Association, 2008). Exposure of NO_2 even at minimum levels results into respiratory infections and at extremely high levels lung injury and pulmonary edema may occur (USEPA).

Hence, these were the primary indoor air pollutant TVOCs extensively affect human health. Nearly, all the TVOCs affect negatively on occupant's health. The effects may include irritation in the throat, nose, and eyes, lowering the liver functions, dyspnea, rhinitis, allergies and in severe cases of central nervous system failure. Also, most of the TVOCs are carcinogens, mutagens and teratogens.

Particulate matter (PM) is an important environmental pollutant for many different cardiopulmonary diseases and lung cancer.

The size of suspended particulate matter ranges over a wide scale. The different-sized fractions of PM are mixtures of several components and can consist of solid particles or liquid droplets as well as semi volatile components.

The aero dynamic diameter of airborne PM can range from approximately 0.005 to 100 μm.

The chemical composition of PM varies greatly and depends on many factors, such as combustion sources, climate, season, and type of urban or industrial pollution. The major components of PM are organic compounds adsorbed onto particles, which can be volatile or semi volatile organic species (e.g. PAHs) transition metals (iron, nickel, copper, etc.) ions (sulfate, nitrate, acidity), reactive gases (ozone, peroxides, aldehydes) particle core of carbonaceous material (mainly from combustion processes and vehicular exhaust particles).(Davidson, Phalen and Solomon, 2005).

Noise pollution is an annoyance to human beings. The noise is usually machine-created sound that disrupts activity or balance of human's way of life. It is a growing environmental problem that is increasingly becoming an omnipresent, yet unnoticed form of pollution not only in developed countries but also in the developing countries. The word noise is derived from Latin word ''Nausea'' implying ''unwanted sound'' or sound that is loud, unpleasant or unexpected. It can be defined as wrong sound, in the wrong place and at the wrong time.

Noise pollution is not a new phenomenon to mankind. Society has attempted to regulate noise since the early days of the Romans, who by decree prohibited the movement of chariots in the streets at night. But it was not until the late 1960s that people started to protest against a specific highway or airport and claimed that citizens must be protected from the adverse impact of noise pollution followed by passage of nuisance lawsuits in different parts of the world. First of all things changed rapidly in the United States as Most of the people do not consider it as a pollutant and accept it as a part of their routine life. Of late, it has been recognized as a pollutant. In the late 1990s, it was considered necessary to regulate and control noise producing sources with the objective of maintaining the ambient air quality standards. Afterwards, Noise Pollution Regulation and Control Rules, 2000 was framed under the Environment Protection Act 1986 with defined set of guidelines for regulation and control of noise with respect to industrial, commercial, silent and residential zones.(Firdaus and Ahmad, 2010).

Noise is now the most common global environmental problem of urban areas. Unlike other forms of pollution, such as air, water and solid waste, noise does not remain long in the environment; however, its effects are immediate in terms of annoyance, sleep disturbance and interference with communication, etc. These effects can be cumulative in terms of temporary or permanent, leading to hearing loss. Noise can interfere with complex task performance, modify social behavior and cause many psychological problems. The major health problems that can result from noise pollution include: damage to hearing that in turn may lead to depression, anxiety, paranoia and social isolation; intensification of health problems, irritation, stress, temporary increase in blood pressure, weakened immune system, beep phobia (i.e. phobia of noise created from pressure horn or acoustic phobia), heart disease, psychosomatic illness and cardio circulatory problems. Exposure to excessive noise during pregnancy may result in high-frequency hearing loss in new borns, Noise pollution can play havoc with the nervous system affecting the physical and psychological behavior of the individuals. It may cause nausea, vomiting, pain, hypertension, high blood pressure, cardiovascular problems, sleep disturbance, restlessness, depression, fatigue, allergy and mental stress.(Sagar and Rao, 2006).

The amount of **light** is an important issue in several scenarios ranging from scenic design, light pollution study, robots navigation, occupational health and safety, illumination engineering, agriculture, medical appliances and many more. It is typically determined by using an illumination meter. The meter, also known as lux meter is used to measure the density of light in an area which measured in lx unit. It is used in photometry as a measure of the intensity, as perceived by the human eye of light that hits or passes through a surface. As in normal meter, the lux value was obviously a displayed value, and hardly used for embedded application as well as for lighting monitoring considering its expensive price. This limits the lighting monitoring in certain critical field(Ismail *et al.*, 2013).

2.7 Pollutant Minimization and Reduction Technologies:

Besides conventional approaches (i.e. ventilation, source control and air cleaning) of air pollutant minimization, some modern approaches like air filtration, dehumidification and source isolation are becoming more and more popular. Controlling the source has always been difficult in multistoried buildings of factory. Moreover, variety of airborne pollutants rushes into the indoor through ventilation. Therefore, the only option left with occupants of the buildings is air cleaning. Among the conventional approaches, air cleaning has become most effective way to improve indoor air quality.

On the other hand, advanced oxidation has become most effective method of air purification, a modern approach. Advanced oxidation is a process through which air contaminants are oxidized to water and carbon dioxide. Thermal oxidation destruction and photo catalytic oxidation are the commonly used processes of advanced oxidation.

Destruction of thermal oxidation occurs at extreme temperature ranging from 200 to 1200 ºC. Thermal oxidation destruction proves very costly and particularly when the concentrations of pollutants is very low. On the other hand, photo catalytic oxidation occurs at ordinary temperature and pressure conditions.

Moreover, photo catalytic Oxidation is a procedure to cure polluted air caused by bacteria and TVOCs .This technology, therefore, is more cost-effective technology to get rid of VOCs and bacteria from the environment than other technologies like thermal oxidation destruction.

Numerous researches have proved photo catalytic oxidation as a promising technology. These investigations have resulted into devising variety of photo catalyst systems. Variety of photo catalytic reactors are already out in the market speaking of which are flat plate fluidized bed reactors, fixed layer photo catalytic reactors, annular photo catalytic reactors, photo catalytic reactors with fiber optic bundles, just to name a few .

Ozone is strong oxidizing agent. Ozonation of the porous material results into the reduction TVOCs in indoor air. In a catalytic reaction occurring in the porous structures, the residual ozone is also reduced. TVOCs from the indoor air can also be controlled using activated carbons or zeolite solutions on the larger surface area of the porous material. In this way, absorption capacity of the porous materials increases .Activated carbon, hence, is the best way of decreasing concentrations of indoor pollutants. On the other hand, under humid condition a mesoporous molecular sieve effectively adsorbs the present number of VOCs.

Additionally, to develop techniques for T VOCs from the indoor air, various efforts have been made during the past 30 years. Because of these efforts, a technique named carbon nanotubes was developed. Since these tubes were made of amorphous and crystalline carbon they have ability to effectively absorb pollutants .There are two types of carbon nanotubes; single-walled and multi-walled. Multi-walled carbon nanotube was the first one being launch to the market and then followed by single-walled carbon nanotubes.(MUKHTAR, 2018).

CHATER THREE

Methodology

CHATER THREE

Methodology

To achieve the objectives of this study, the following methodology will be applied. Various methods of data collection, quantitative, and qualitative analyses through observation, reports, books, articles, and internet search were used.

3-1 Measuring Equipment of Indoor Air Pollutants:

3-1-1 Wolf Pack Area Monitor:

A monitoring instrument called Gray Wolf Direct Sense-IAQ was used to measure the levels of indoor air pollutants. Each Probe (shown in figure 3.1) is fixed on main IAQ pack. These probes can measure 4-5 parameters.. Uncertainty factor, ranges from 1 to 5.85% for different parameter with operating temperature 0-50 °C.

This instrument allows the researcher to determine and recognize any IAQ matter which may cause harm to the occupants. This portable device allows the users to perform any needed analysis for a particular area more easily. It is suitable not just for walk-through investigation but also for consistent long-term measurements, as it determines the accurate ratio/amount of the corresponding air components in such a way that it affords a pure picture of the IAQ status.

Data was logged for parameters, such as CO_2, CO, Ozone, temperature, relative humidity, dew point and others. After logging, data was downloaded, and analysis of readings was recorded.

Gray Wolf IAQ kits include an Advanced Sense meter (or mobile computer), plus multisensory indoor air quality probe.

Fig (3-1) Wolf Pack Area Monitor

3-1-2 Thermo Scientific pDR-1500 personal Data RAM:

The Thermo Scientific personal Data RAM (pDR-1500) is an advanced instrument designed to actively measure the concentration of airborne particulate matter (liquid or solid), providing data logging and a continuous readout.

The pDR-1500 is a highly sensitive nephelometric (i.e., photometric) monitor whose legacy light scattering sensing configuration has been optimized for the measurement of the respirable fraction of airborne dust, smoke, fumes and mists in industrial and other indoor and outdoor environments. The pDR-1500 incorporates a temperature and relative humidity (RH) sensor to mitigate the positive bias with elevated ambient RH.

The 1500-pDR is an active sampling device, where the pump is used to draw a sample of the surrounding air into the instrument's optical dust chamber and then ultimately through a final filter. The device allows for classification of the dust sample before the optical sampling chamber by allowing the integration of a cyclone, such as the Dorr-Oliver cyclone, into the built-in collection circuit.

The built-in collection circuit includes a 1500-pDR filter assembly that uses a 37-mm filter placed in an open-faced enclosure. Specifically, the open-faced enclosure containing the 37-mm filter is vulnerable to potential filter contamination when changing filters outside a controlled atmosphere. Contamination can interfere with filter weights, resulting in incorrect respirable dust concentrations. To help eliminate this vulnerability, care must be taken when changing filters.(Reed *et al.,* 2013).

Fig (3-2) Thermo Scientific pDR-1500 personal Data RAM

3-1-3 Sound level meter:

Sound level meters provide instantaneous noise measurements for screening purposes Figure(3.3). During an initial walk around, a sound level meter helps identify areas with elevated noise levels where full-shift noise dosimetry should be performed. Sound level meters are useful for:

- Spot-checking noise dosimeter performance.
- Determining a worker's noise dose whenever a noise dosimeter is unavailable or inappropriate.
- Identifying and evaluating individual noise sources for abatement purposes.
- Aiding in engineering control feasibility analysis for individual noise sources being considered for abatement.

Sound level meters are affected by temperature and humidity; however, these instruments are intended to provide reliable readings within the normal range of workplace temperatures.

Using a Sound Level Meter

Different work environments and different sound level meter microphones might require variations in measurement procedures. For practical purposes, however, certain basic steps apply in most circumstances .

Confirm that the sound level meter is properly calibrated and temperature-stabilized. Then, position the microphone in the monitored worker's hearing zone. OSHA defines the hearing zone as a 2-foot-wide sphere surrounding the head. Considerations of practicality and safety will dictate the actual microphone placement at each survey location. Note that when noise levels at a worker's two ears are different, the higher level must be sampled for compliance determinations.

Keep in mind that your body or surrounding equipment can influence the noise level, acting as a barrier between the noise source and the microphone. Hold the sound level meter away from your body to minimize this effect Consult the manufacturer for any specific instructions for positioning the model of sound level meter you plan to use. This may be particularly important when measuring in unusual settings. For example, the manufacturer may have specific instructions for sound level readings in a non-reverberant environment.

Use a wind screen to reduce measurement errors caused by wind turbulence over the microphone. Typical wind screens are made of soft foam rubber and are designed to fit over the microphone . Although not necessarily needed indoors if air movement is minimal, a wind screen can be left in place for all measurements. Collected measurements can be affected by anything that comes across the face of the sound level meter microphone, such as hair, shirt collars, scarves, or other objects. The use of a wind screen reduces the effects of this incidental contact. Wind screens have the added advantage of protecting the microphone, at least somewhat, from damage resulting from impact, dust, paint overspray, and moisture.(OSHA Noise and Hearing Conservation).

Fig (3-3) Sound Level Meter

3-1-4 Lux light meter:

Lux meter is used to measure the density of light in an area which measured in lux unit. It is used in photometry as a measure of the intensity, as perceived by the human eye of light that hits or passes through a surface. As in normal meter, the lux value was obviously a displayed value, and hardly used for embedded application as well as for lighting monitoring considering its expensive price. This limits the lighting monitoring in certain critical field.

A lux meter is a handheld device for measuring brightness. It specifically measures the intensity in which the brightness appears to the human eye. This is different than measurements of the actual light energy produced by or reflected from an object or light source. The lux is a unit of measurement of brightness, or more accurately, luminance. It ultimately derives from the candela, the standard unit of measurement for the power of light. A candela is a fixed amount, roughly equivalent to the brightness of one candle. While the candela is a unit of energy, it has an equivalent unit known as the lumen, which measures the same light in terms of its perception by the human eye. One lumen is equivalent to the light produced in one direction from a light source rated at one candela. The lux takes into account the surface area over which this light is spread, which affects how bright it appears. One lux equals one lumen of light spread across a surface one square meter. A lux meter works by using a photo cell to capture light. The meter then converts this light to an electrical current. Measuring this current allows the device to calculate the lux value of the light it captured. A lux meter is in meeting health and safety regulations. It can be used to check whether the brightness of a room is enough to meet any rules designed to protect workers from suffering damage to their eyesight. Using a lux meter takes into account the size of the room in a way that simply measuring the intensity of the light source in lumens would not.(Ismail *et al.*, 2013).

Fig (3-4) lux light meter

CHAPTER FOUR

Results and Discussion

CHAPTER FOUR

Results and Discussion

4-1 Results:

The data collected and analyzed indoor air quality of fourteenth locations in the Plastic factory is shown in Table 4-1 and set of figure (4.1 up to 4.10)

Table 4-1 the data of indoor air quality of 14 locations in the Plastic factory

location	parameter	Co	NO_2	CO2	SO_2	TVOCs	$PM_{2.5}$	Tem	RH	Noise	Light
	unit	ppm	ppm	ppm	ppm	ppm	mg/m³	˚C	%	dB	Lux
	limit	50 OSHA 26 Re 24	5 OSHA 3 Re 24	5000 OSHA	5 OSHA 2 Re 24	<1 OSHA	5 OSHA	20-26 OSHA ASHRAE	20-60 OSHA	85 SSMO	300 Re24 322.9 OSHA
Weaving(1)		6.87	0.011	6.509	0.02	0.425	0.1180	33.95	24.50	86.1	675 -377
Weaving(2)		8.38	0.044	6.510	0.0	0.400	0.1147	34.77	23.94	90.4	365-902
printing		11.17	0.072	5.520	0.0	0.987	0.1146	36.05	19.98	72	125- 927
conversion		15.77	0.084	5.541	0.0	0.867	0.1108	36.04	20.02	71.5	675 - 932
Sack press		15.61	0.027	9.566	0.0	1.023	0.1173	36.81	19.12	85.5	514-710
extruding		13.10	0.100	7.558	0.0	0.409	0.1129	36.99	19.05	67.5	163- 470
Raw materials store		4.30	0.051	1.504	0.0	0.128	0.1238	39.12	12.59	57.4	475-1029
Finishing materials store		3.73	0.159	5.529	0.0	0.153	0.1116	38.93	13.13	44.5	425-1061
LAB		9.90	0.230	9.1401	0.09	0.683	0.869	31.51	18.26	41.5	185-239
Center of the yard		0.0	0.675	0.600	0.0	0.040	–	41.56	9.29	50.1	–
Work shop &spare parts store		0.28	0.458	3.539	0.0	0.090	–	41.97	10.63	47.1	–
North east of factory		0.0	0.458	6.538	0.0	0.100	–	43.66	10.06	53.3	–
In front of the main gate of the factory		0.0	0.502	0.617	0.03	0.090	–	40.43	10.16	43.7	–
Between solid container and water chiller		1.79	0.381	8.532	0.0	0.100	–	39.62	11.08	60.5	–

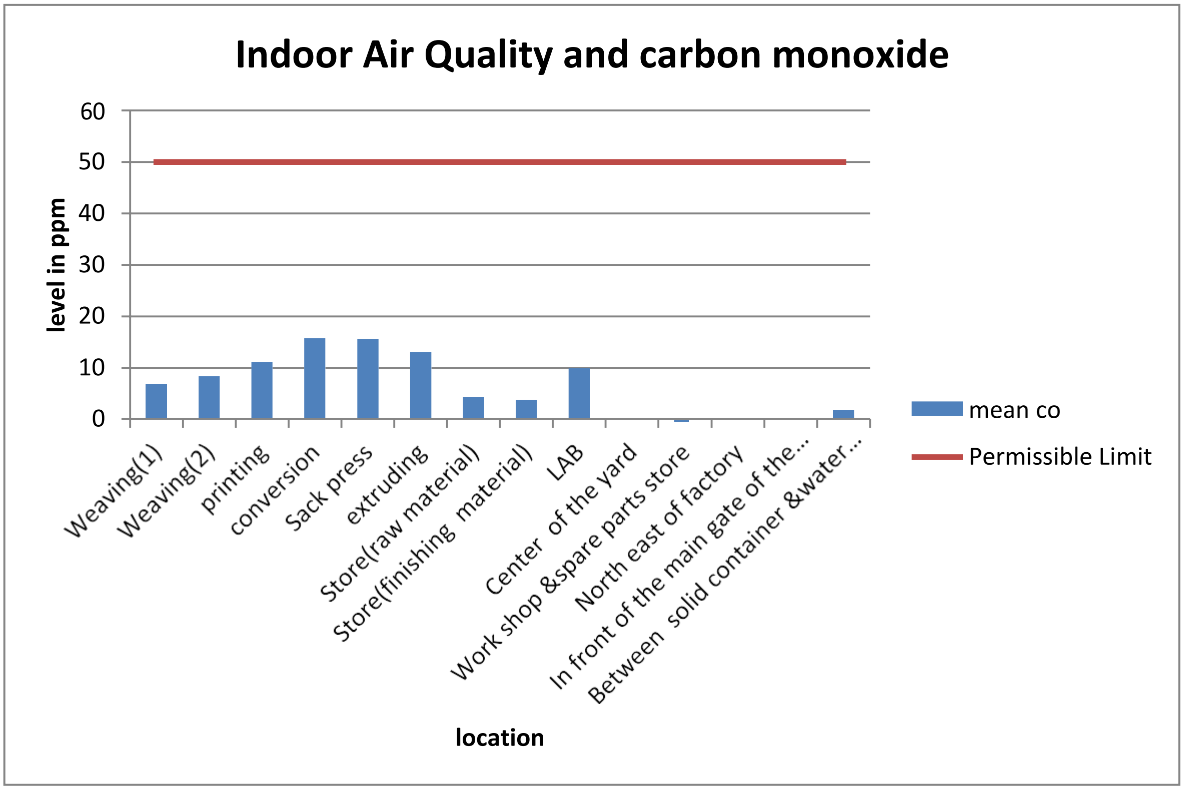

Fig (4-1) Mean Carbon monoxide (CO) readings on 14 monitoring locations compared with

Permissible limit (red)

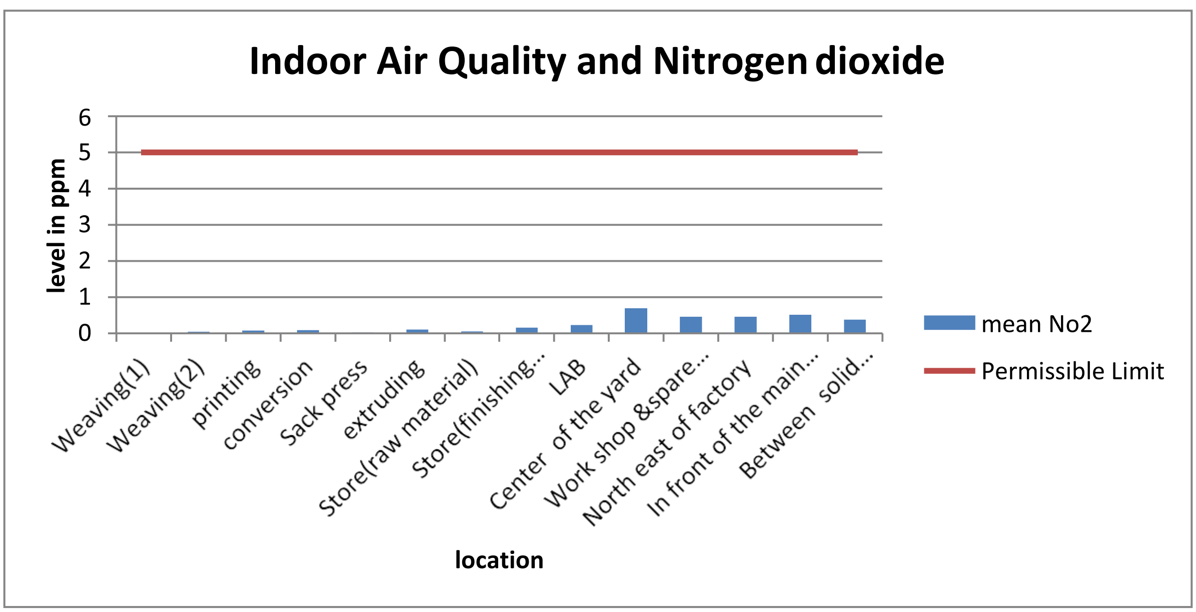

Fig (4-2) Mean Nitrogen dioxide (NO_2) readings on 14 monitoring locations compared with Permissible limit (red)

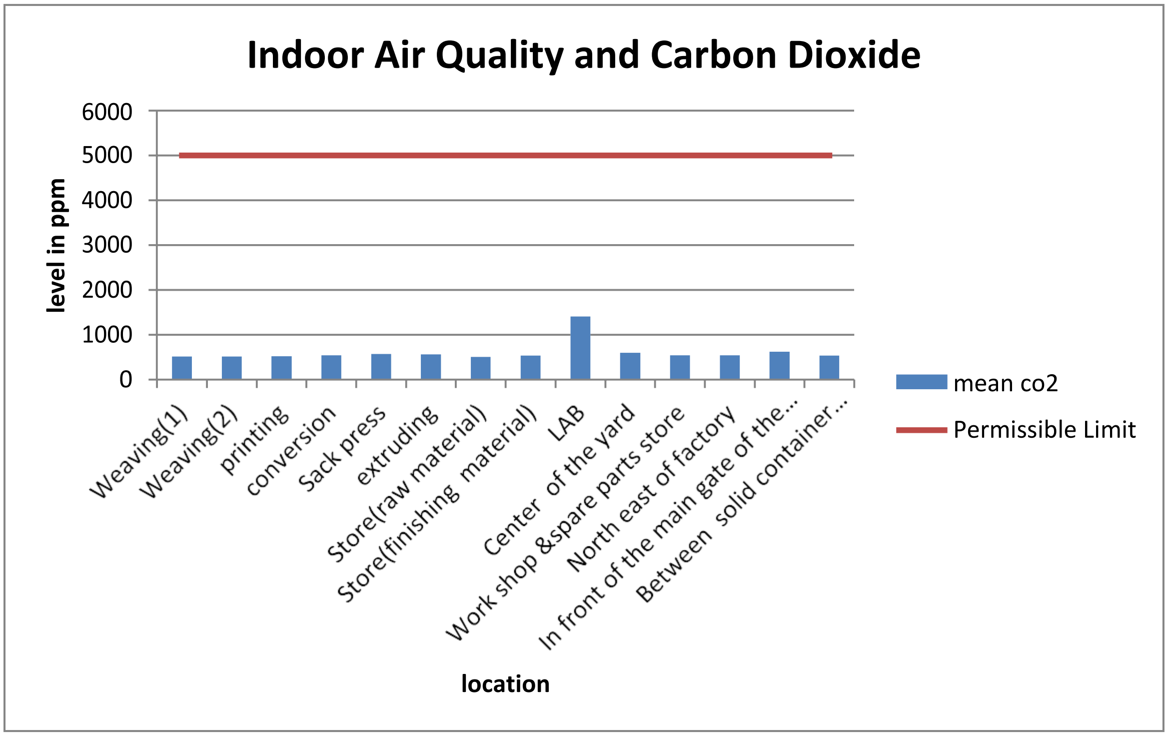

Fig (4-3) Mean Carbon dioxide (CO2) readings on 14 monitoring locations compared with Permissible limit (red)

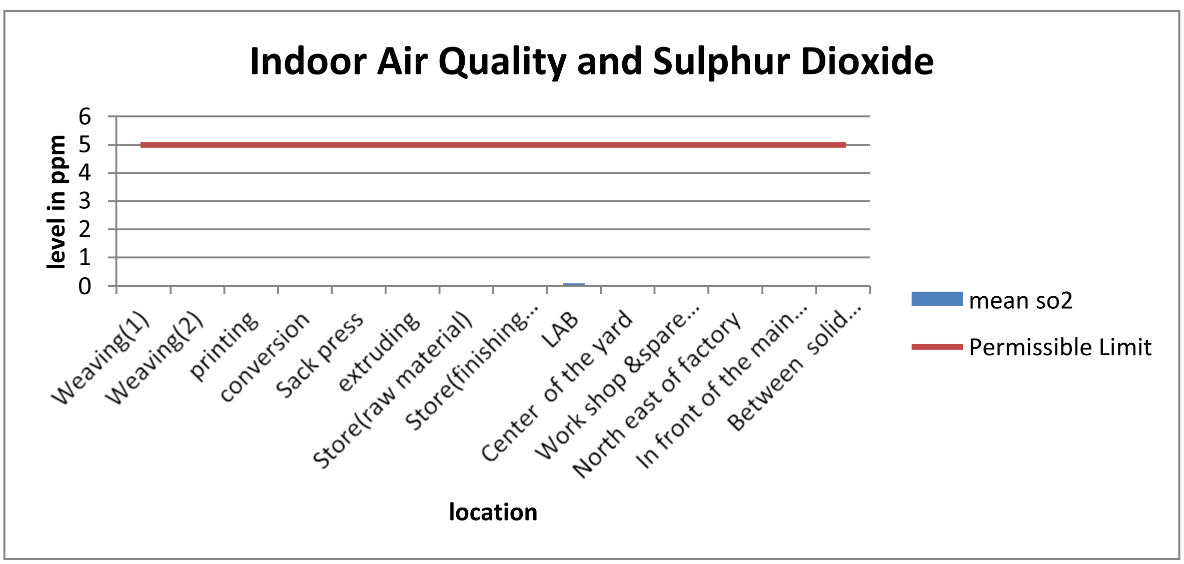

Fig (4-4) Mean Sulphur Dioxide (SO_2) readings on 14 monitoring locations compared with Permissible limit (red)

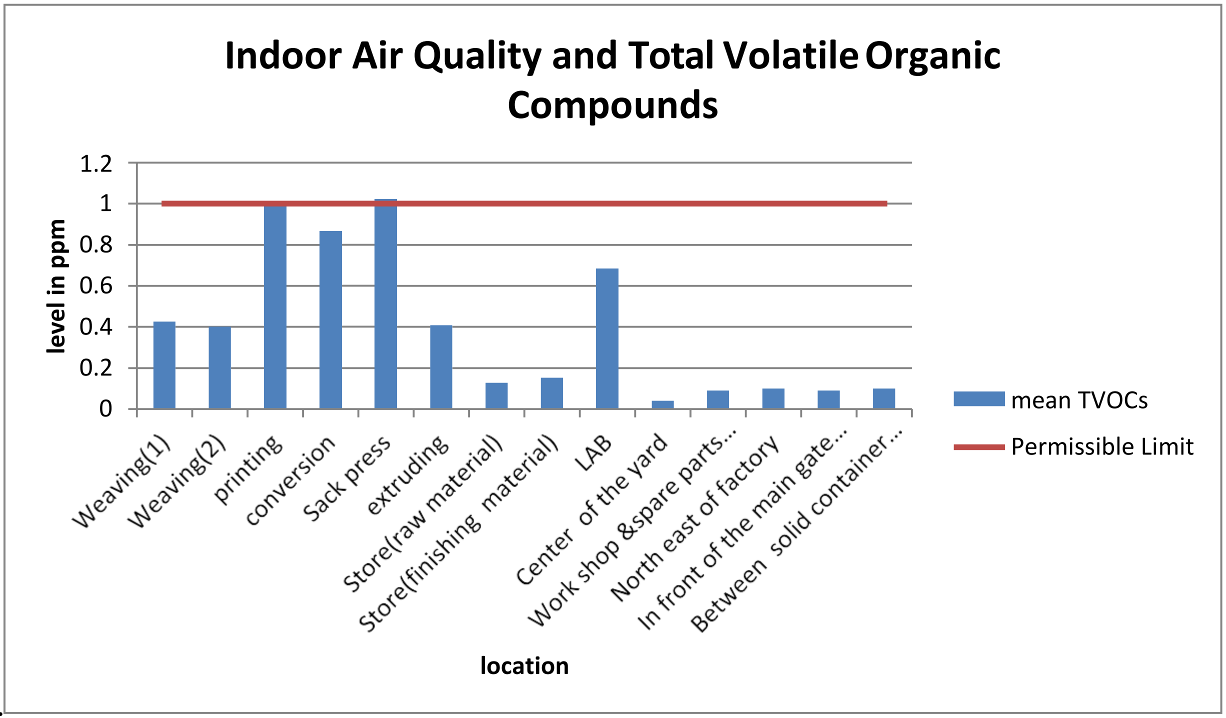

Fig (4-5) Mean Total Volatile Organic Compounds (TVOCs) readings on 11 monitoring locations compared with permissible limit (red)

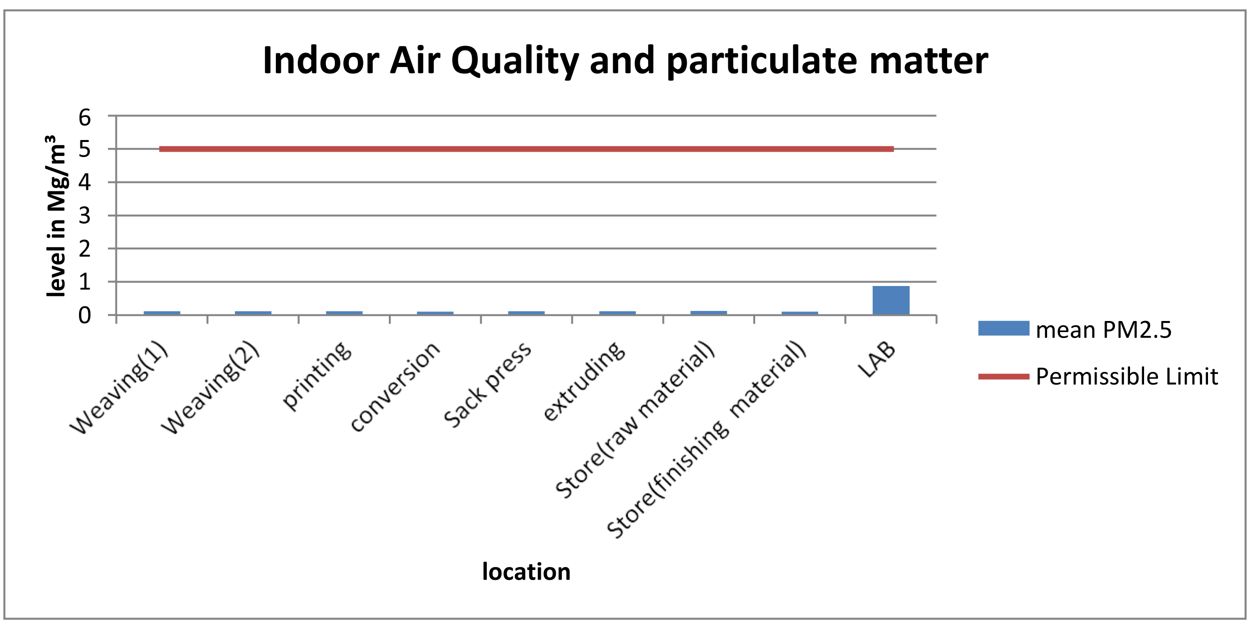

Fig (4-6) Mean particulate matter readings on 9 monitoring locations compared with permissible limit (red)

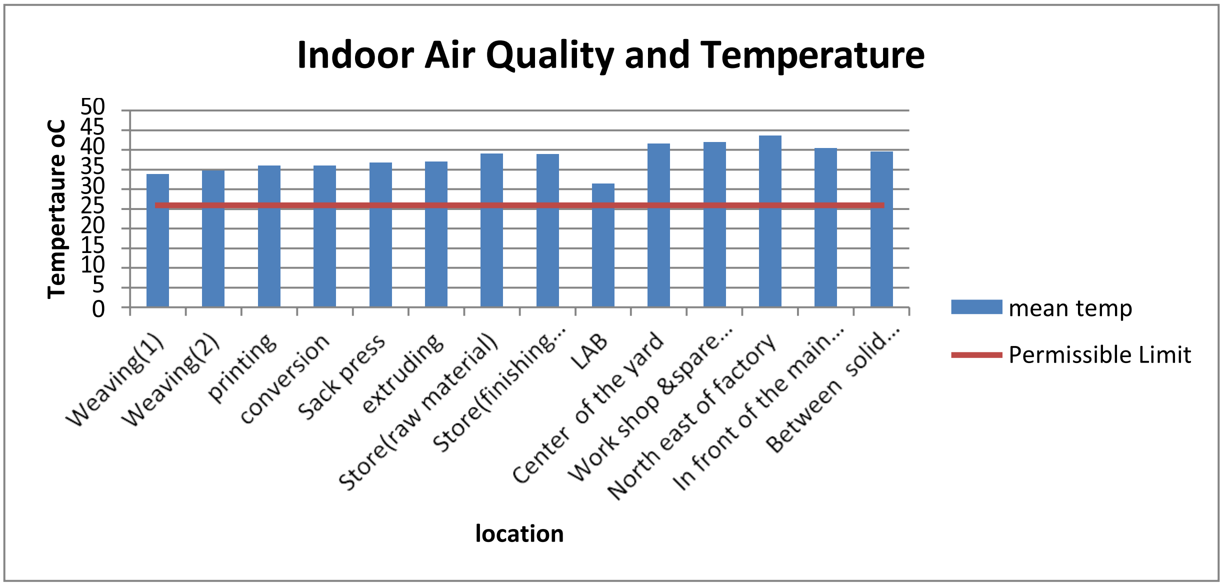

Fig (4-7) Mean Temperature readings on 14 monitoring locations compared with Permissible limit (red)

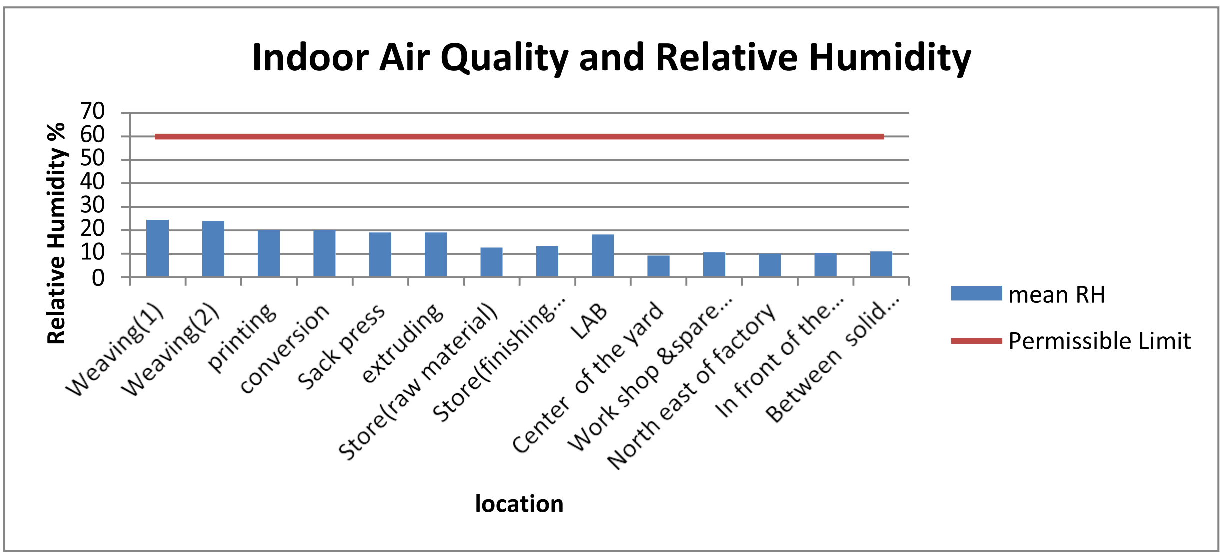

Fig (4-8) Mean relative humidity (RH) readings on 14 monitoring locations compared with permissible limit (red)

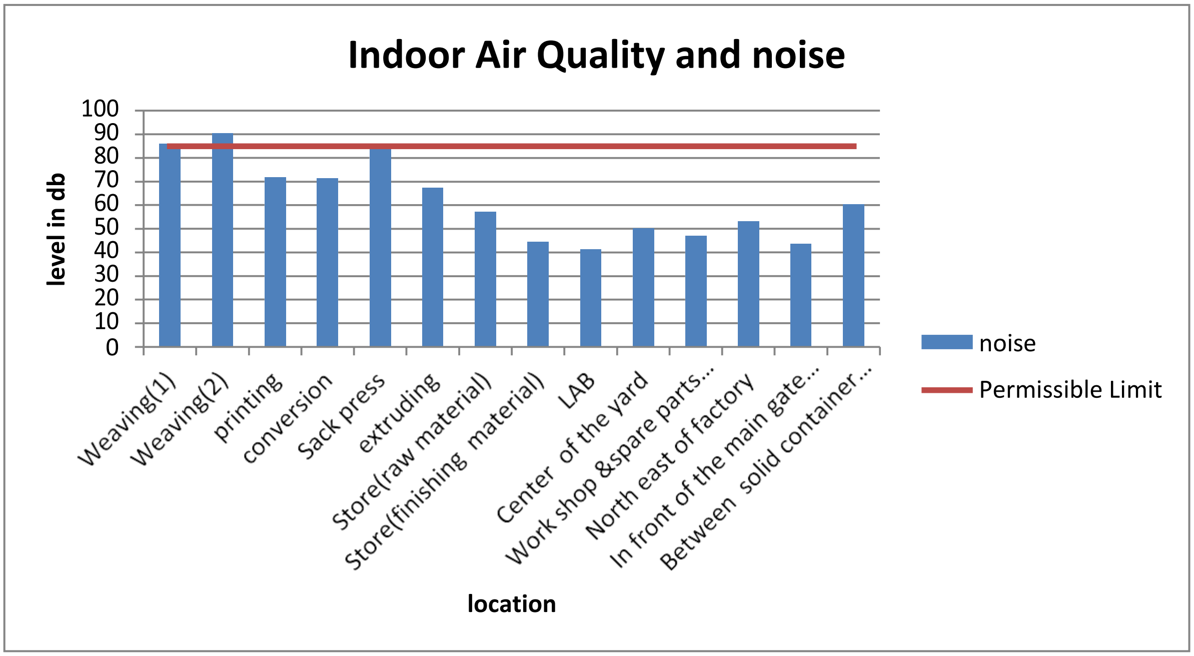

Fig (4-9) **Noise** readings on 14 monitoring locations compared with permissible limit (red)

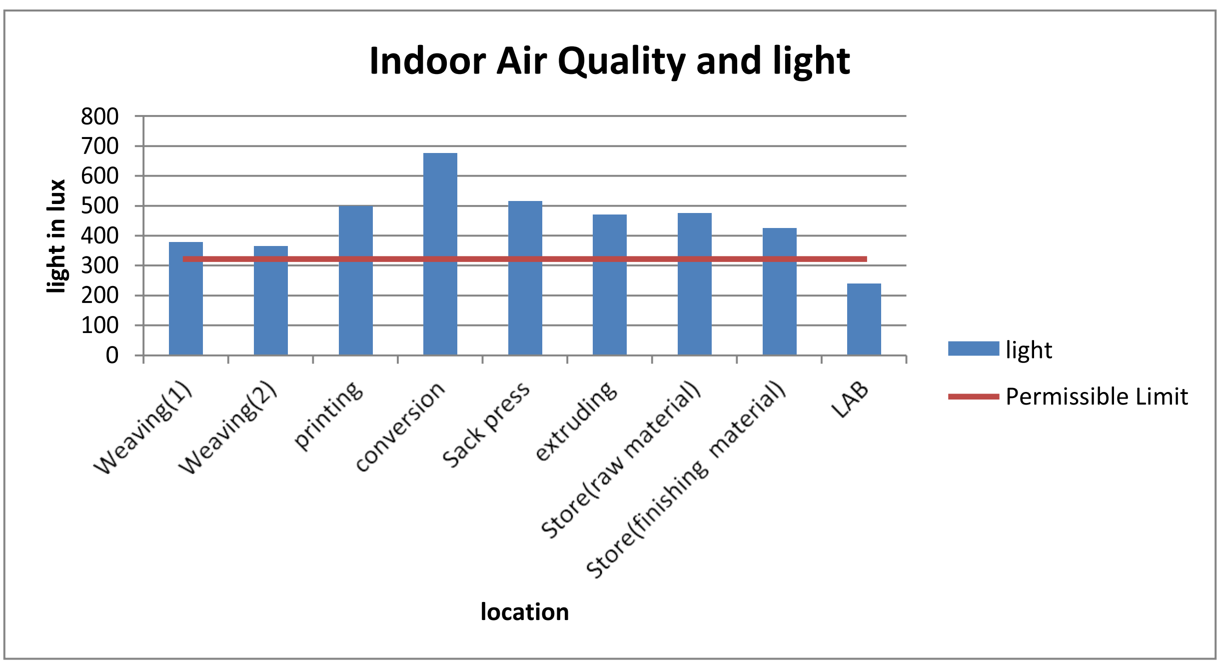

Fig (4-10) *Light* readings on 9 monitoring locations compared with permissible limit (red)

4-2 Discussion:

- **Carbon monoxide (CO)** in all locations, as shown in figure (4.1), is below the permissible limit as recommended by OSHA i.e. <5000ppm, (Also see Table 4. 1).

  We can see some locations such as (conversion and sack press) have significance concentration due to operation process; this will lead to some problem in long term. We need to install carbon monoxide detectors which can be placed near these locations. Besides improving the ventilation system to prevent this problem.
- **Nitrogen dioxide (NO_2)** in all locations, as shown in figure (4.2), is below the lower extreme of the permissible range as recommended by OSHA i.e. < 5 ppm, (Also see Table 4.1).
- **Carbon dioxide (CO2)** in all locations, as shown in figure (4.3), is below the lower permissible range as recommended by OSHA i.e. <5000ppm, (Also see Table 4.1).

As we see the concentration of (CO2) in the lab is higher than other locations due to the

Lab design is in closed and the ventilation is very poor.

We suggest improving the ventilation system and installation of suction fans.

- **Mean Sulphur Dioxide (SO_2)** in all location, as shown in figure (4.4), is below the permissible range as recommended by OSHA i.e. <5ppm,(Also see Table 4.1).

The low concentration of (SO_2) which we see in the lab is result from using some chemicals.

- **Mean Total Volatile Organic Compounds** concentration in the most locations, as shown in figure(4.5), is below the lower permissible range as recommended by OSHA<1 ppm ,(Also see Table 4.1), except (sack press and printing) TVOC values found very near to permissible limit because of use chemicals and paints in the Process Of printing. We recommend to improve ventilation system of this locations by installation of local ventilation device that is designed to reduce the exposure of fumes and vapors those are possibly increasing the TVOCs.
- **Mean particulate matter** in all locations, as shown in figure (4.6), is below the permissible range as recommended by OSHA i.e. <5 Mg/m^3,(Also see Table 4.1).
- **The mean temperatures** in all locations, as shown in figure (4.7), are above the upper permissible range as recommended by OSHA i.e.(20_26 $^{\circ}C$) ,(Also see Table 4.1). When

investigated it was found that increase in temperature in all locations is due to operations of certain equipment’s that can operate only on recommended temperature levels, so it cannot be reduced to bring at permissible levels. While in Lab room a slight variation found above the upper limit because of chemical use.

- **The mean relative humidity (RH)** in all locations, as shown in figure (4. 8), was below the upper permissible range as recommended by OSHA that is (20 to 60 %), (Also see Table 4.1).
- **Noise** in the most locations, as shown in figure (4.9), is below the permissible range as recommended by OSHA<85 dB, (Also see Table 4.1). Except (weaving1,2 and sack press) are above the upper permissible range as recommended by OSHA i.e.<85 db. When investigated it was found that increase noise in this locations is due to operations of certain equipment’s t hose can operate only at this levels of noise, so it cannot be reduced to bring at permissible levels.
- **Light** in all locations as shown in figure (4.10), in the permissible range as recommended by OSHA i.e. 322 lux,(Also see Table 4.1).Except the lab is lower from the permissible limit due to some problem in the lam.

CHAPTER FIVE

Conclusion and Recommendation

CHAPTER FIVE

Conclusion and Recommendation

5-1 Conclusion:

This study is about investigation of indoor air quality and environmental conditions of workplace at Plastic factory (Garri). Overall it was fund that almost all the locations found with acceptable indoor air quality environmental conditions as complying with the ASHRAE and OSHA limits.

Different parameters were used to assess the indoor air quality environmental conditions; however; relative humidity and temperature are two key factors which influence the presence of indoor air pollutants significantly. Both parameters are interdependent. Their percentage varies from summer to winter. A relative humidity of more than 60% allows significant enhancement in growth of dust mites, bacteria, fungi and other microbial organisms. Simultaneously a decrease in RH less than 30% aggravate discomfort among occupants. Keeping these factors in mind, all the 14 locations were categorized as acceptable and not acceptable as per permissible limits defined for each parameter.

Nine parameters, **CO, NO_2, CO2, SO_2, TVOCs, $PM_{2.5}$, RH, Noise, light** were detected.at acceptable levels except some locations. In (weaving 1, weaving2, and sack press) where the noise is above the upper extreme of the permissible range as recommended by OSHA i.e. 85db. When investigated it was found that increase in noise was due to operations of certain equipment's those can operate only at this levels of noise, so it cannot be reduced to bring at permissible levels.

Also some locations not acceptable like **(printing and sack press) where the TVOCs is above the** upper extreme of the permissible range as recommended by OSHA i.e1ppm.Because of the using chemicals and paints in this locations.

Another location not acceptable is lab where the light is under the permissible range as recommended by OSHA i.e. .due problem in the lam.

As we see the temperature in all locations is above the upper permissible range as recommended by OSHA i.e. (20-26 °C).due to high temperature of the weather of Sudan and

The operations of certain equipment's that can operate only on recommended temperature levels.

5-2 Recommendation:

1- It is recommended that to continue monitoring indoor air quality in the observation location of the factory.

2-It is recommended that to improve ventilation system by installation of local ventilation devices those should be designed to reduce the exposure of fumes and vapors use of chemicals are possibly increasing the TVOCs in the locations such as (sack press and printing).

3- It is recommended that to use personal protective equipment to reduce exposure to noise from the location such as (weaving1, weaving2 and sack press).

4- It is recommended that to improve the light in the lab by using a large number of lam to solve lighting problem in the lab.

5- Temperature also plays an important role in maintaining a suitable and healthy environment. For this we recommended to improve refrigeration system to solve the increase in temperature in the all locations.

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Appendix:

Wolf pack area monitor

Sound level meter

Sound level meter

Thermo Scientific pDR-1500 personal Data RAM

Lux light meter