Environmental and health impacts of printing and photocopying: Measurement, evaluation and mitigation

A thesis submitted to the

University of Petroleum and Energy Studies

For the award of

Doctor of Philosophy

in

Health Safety & Environmental Engineering

BY

Abhishek Nandan

September 2020

SUPERVISOR (s)

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Department of HSE & Civil Engineering

School of Engineering

University of Petroleum and Energy Studies

Dehradun-248007; Uttarakhand

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December 2020

DECLARATION

I declare that the thesis entitled **"Environmental and health impacts of printing and photocopying: measurement, evaluation and mitigation"** has been prepared by me under the guidance of Dr. Nihal Anwar Siddiqui, Professor of HSE & Civil Engineering department, University of Petroleum and Energy Studies, Dehradun and Dr. Pankaj Kumar, Professor, Department of Applied Sciences and Humanities (Chemistry), University of Petroleum and Energy Studies, Dehradun. No part of this thesis has formed the basis for the award of any degree or fellowship previously.

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CERTIFICATE

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THESIS COMPLETION CERTIFICATE

This is to certify that the thesis on ***"Environmental and Health impacts of printing and photocopying: measurement, evaluation and mitigation"*** by **Abhishek Nandan** in partial completion of the requirements for the award of the degree of doctor of philosophy (in engineering) is an original work carried out by him under our joint supervision and guidance.

It is certified that the work has not been submitted anywhere else for the award of any other diploma or degree of this or any other university.

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ABSTRACT

‘Knowledge is power’ and distribution of knowledge is fueled by printing and photocopying industry. Even as printing and photocopying industry have revolutionized the availability of documents and perceptible image quickly at extremely inexpensive and affordable cost, the boon of its revolution has turned into a bane by irresponsible, uncontrolled and extensive use, causing irreversible degradation to not only ecosystem by continuous release of ozone and other volatile organic compounds (VOCs) but also the health of workers occupationally exposed to it. Indoor Ozone level due to emission from different photocopying equipment’s increases drastically and the condition of other air quality parameters are not different. This situation is particularly sedate in extremely sensitive educational and research industry where sharing of knowledge is extremely important to meet the demands.

Printing and photocopying industry have revolutionized the availability of documents and perceptible image quickly at extremely inexpensive and affordable cost. Sadly, irresponsible, uncontrolled and extensive use, causing irreversible degradation to not only ecosystem by continuous release of ozone and other volatile organic compounds (VOCs) but also the health of workers occupationally exposed to it.

Photocopy/printing machines are part of everyday environment of millions of people around the world, which make it unavoidable in offices, industries, shops, schools, laboratories etc. Hence the question of harmful effects of operating this device and what extent does the air is polluted is an important concern of the public. Due to increase in the use of printing/photocopying since early 1990s, people are

facing the deleterious effect of ozone, for a building without photocopying machines the ambient ozone concentration in many times less compared to outside due to filtration through walls, however, due to the use of photocopying machine the indoor ozone concentration becomes significantly high.

This study concludes in assessing Socioeconomic, ergonomical & environmental assessment of printing/photocopying and tools for assessment of cancer risk and ergonomics hazards has been developed.

The socioeconomic data obtained lead to the confirmation that these sectors is somehow under the category of unskilled and of semi-skilled because of increase illiteracy. Furthermore, it was seen the welfare conditions are poor and unregulated, which leads to the increasing concern of occupational health hazards of the workers and these concerns are not addressed anywhere. The workers in photocopying centers lack the welfare and social security support that ultimately increases liability and decreases work performance. The assessment provides that 50 percent of the correspondent fall under the category of 15-30 years of age group and 75 percent of the correspondents does not have a formal education, which indicates the high illiteracy rate in the unorganized sector.

Observation based on ergonomics data suggest that majority of the operators (40%) worked for 8 – 10 hours while the job rotation was not observed at any center. Extensive working hours and long working years may be a contributor of, back pain, wrist pain, numbness and other occupational health issues. Itching was most common health issue among the photocopy operators while numbness and Back pain were the most common health outcomes affecting all age groups almost in the same frequency. Ergonomic issue comparison showed that neck pain and swelling of feet was most frequent while Back pain was most common ergonomic problem affecting all the age groups. Photocopy machine operators are exposed to physical, chemical and ergonomic hazards at work. Noise, particulate matter, carbon

monoxide and ergonomics are posing a threat to health and safety of workers at photocopy shops.

Indoor air quality of photocopy centers were assessed for all the seasons and total five major indoor pollutant due to photocopy operation have been considered. Sampling and analysis for all five pollutant namely CO_2, CO, VOC, HCHO & Ozone, their relationship with multiple environmental condition has been determined. Environmental data analysis suggests that pollutant concentration and emission majorly depends on ventilation available, rate of photocopy/printing and work duration i.e. operation time of electronic machine.

Maximum concentration of CO_2 has been observed highest in the photocopy center having least ventilation system available i.e. 0-5% of the total floor area. Highest CO_2 concentration was 1980 PPM (Threshold Limit value(TLV),1000 PPM,ASHRE) while the lowest value 400 PPM was observed with highest ventilation center i.e. 0-20% total floor area with exhaust system installed. High carbon dioxide intensities shows insufficient ventilation per occupant and high indoor contaminants intensities, resulting in the Sick Building Syndrome. Highest CO concentration was 11 PPM with lowest available ventilation area i.e. 0-5% while the lowest value 0.8 PPM was observed with highest ventilation center i.e. 0-20% total floor area with exhaust system installed. Highest Ozone concentration was 1.87 ppm with lowest available ventilation area i.e. 0-5% while the lowest value 0.02 ppm was observed with highest ventilation center i.e. 0-20% total floor area with exhaust system installed. Highest VOC concentration was 1.93 ppm with lowest available ventilation area i.e. 0-5% while the lowest value 0.01 ppm was observed with highest ventilation center i.e. 0-20% total floor area with exhaust system installed. Highest HCHO concentration was 46 ppm with lowest available ventilation area i.e. 0-5% while the lowest value 7.2 ppm was observed with highest ventilation center i.e. 0-20% total floor area with exhaust system installed.

A Computer coded assessment tool has been developed with the help of the “Python coding” language and creating the “Graphic user interface” to estimating the Cancer risk due to the exposure of the various toxic substances present in photocopy/printing centers. This tool was designed by the coding using the python language in which the dictionary of the 184 toxic chemicals potency factor was stored into the directory and the corresponding cancer risk was calculated by manually entering the duration for the exposure and the concentration.

Postural analysis tool has been developed specially for occupant working at photocopy/printing centers using Rapid upper limb assessment (RULA) and Rapid entire body assessment (REBA). This ergonomic study sheds light on posture analysis of the workers in photocopy/printing centers.

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Abhishek Nandan

Date: -------- 2020

Nomenclature:

VOCs : Volatile Organic Compound

AQI : Air Quality Index

SVOCs : Semi Volatile Organic Compound

TLV : Threshold Limit Value

TPE : Toner-Based printing Equipment

ENM : Improved Nanomaterial

NEP : Nano-Enabled Products

EPA : Environmental Protection Agency

OSHA : Occupational Safety and Health Administration

TWA : Time Weighted Average

FDA : Food and Drug Administration

TVOCs : Total Volatile Organic Compound

BTXS : Benzene, Toluene, Styrene, Xylene and, limonene (terpenes)

VVOCs : Very Volatile Organic Compounds

NIOSH : National Institute for Occupational Safety and Health

ASHRAE : The American Society of Heating, Refrigerating and Air-Conditioning Engineers

RULA : Rapid Upper Limb Assessment

REBA : Rapid Entire Body Assessment

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CHAPTER-1

1. Title of thesis:

"Environmental and health impacts of printing and photocopying**:** Measurement, evaluation and mitigation"

1.1 Statement of the proposal

1.2 Problem statement:

In recent past due to increase in population and their movement towards city to get better employment, education and many other facilities, increased environmental load as well as residential load in city, which resulted in degradation of environmental quality adversely in urban area. Environmental quality parameters have been effected drastically due to population movement and unplanned utilization of resource in urban area, indoor air pollution as well as ambient air pollution in recent time is the concern for most of the people, which is effecting health as well as environment[1, 2]. . Availability of limited space, high population density and nature of job for occupant in urban areas are limited mostly to indoor condition where the most of the time is spent. In working organization the occupants are in indoor environment, home or in common public buildings is inhaling higher concentration of many pollutant available in indoor air due to ill ventilation system installed buildings as well as many pollutant sources present inside the buildings such as printers/photocopying machine and other factors[3, 4]. In this fast moving world most of the office have the facility like printing machine , photocopying equipment's , fax and other electronic gadgets, all these are the primary sources of air pollution such as Volatile Organic Compound, Semi Volatile Organic Compound ,Ozone, and Respirable Suspended Particulate Matter (RSPM)[5].

Ozone in indoor air is present due to its production by multiple electrical and electronic gadgets like printing equipment's, photocopying machines ,fax machines and ozone generator [6, 7]. Electrostatic air cleaner is also a source of ozone preset in indoor condition due to corona discharge [8]. Sharing of documents in short, duration with optimum price making printing and photocopying equipment is very common in office environment as well as in educational buildings. Knowing the fact that printing/photocopying is important for knowledge sharing in educational buildings as well as in commercial building, it is a major source of VOC and ozone in indoor environment. Drum inside photocopy machine utilize negative charge and during process of it's charging as well as discharging releases higher concentration of ozone which has significant health and environmental impact[9-11]. UV radiation from fluorescent lamp as well as visible range radiation is other pollutant generated from photocopying equipment's[11].

Human respiratory organs like trachea, nostril upper throat due to long exposure duration have been observed adversely affected, some other organs include eyes and skin. Chronic disease associated to lung with reduced lung capacity, as well as cardiovascular diseases are much common in occupant working for longer duration in indoor condition due to high oxidative stress as well as systemic inflammation[12].

1.3 Background:

Due to increase in use of photocopying since early 1990s, people are facing the deleterious effect of Ozone. For a building without photocopying machines the ambient ozone concentration in 250 times less compared to outside due to filtration through walls, however, due to the use of photocopying machine the indoor ozone concentration becomes significantly high[13, 14].

Photocopying machine, electrical and electronics devices, printing machine and fax are major contributor of ozone in indoor condition [15]., Heat, radiation, toner used

,ozone, VOCs, SVOCs, noise and particulate matter are critical sources of health concern due to photocopy/printing machine.

During most of the operation in health sector specially in hospital sterilization is a common practice where UV lamp is mostly used which is a source of ozone, UV lamp is not only limited to health sectors but also for food industry and laboratories. Ozone generators, which is being used to reduce the pollutants in indoor condition, is itself a source of ozone in indoor condition. According to Lithuanian hygiene standard HN 35:2002 acceptable concentration level of concentration in indoor is 200 $\mu g/m^3$ [6]. Some other sources suggest the acceptable value of ozone at workplace is 100 $\mu g/m^3$[16].

Half-life of Ozone at standard condition is between seven to ten minutes in indoor condition [17] and its concentration primarily depends on two parameters i.e. Surface removal and exchange rate of air. Few other studies suggest that in offices with specific ventilation, ozone has a half-life of ten minutes [18]. Air quality at workplace especially in indoor condition depends on two basic components: Rate of emission of environmental pollutants air exchange rate that is volume of air, which is diluting the pollutant, emitted. Emission of air pollutant due to photocopy/printing machine depends on many factors type of machine, process use, level of technology, duration of operation, and toner used[19].

The proposed work focuses to analyze the emission from Photocopy machine and in brief, Individual occupationally present in this process for their sustenance should be skilled and have enough knowledge for the chronic disease occurs due to exposure to ozone and other emissions from photocopy machine. The manufactures as well as occupant should be informed regarding ozone, VOCs, SVOCs, particulate matters, radiation, temperature and other significant emission, so that precautionary measures can be taken.

1.4 Research Gap

- Work done earlier suggested that multiple indoor air pollutant is released during photocopy/printing operations. VOCs, SVOCs, Ozone, Heavy Metals, Radiation and Particulate matters are the major pollutants. These pollutants are not only deteriorating environment but also the occupant exposed to it.
- Very little study has been done in India to catalogue all the occupational hazard, socio-economical hazard and environmental hazard associated to photocopier operation and their mitigation method has even not been touched upon.
- It is the need of this time to find either the toner used in the printing/photocopying has risk to the humans as well as environment, which can be done by systematic and well-structured epidemiological study. The purpose of the study is to find the relationships between different indoor environmental condition and pollutant behavior as and its socioeconomical and ergonomical impacts.

1.5 Motivation/need for research:

'Knowledge is power' and distribution of knowledge is fueled by printing and photocopying industry. Even as printing and photocopying industry have revolutionized the availability of documents and perceptible image quickly at extremely inexpensive and affordable cost, the boon of its revolution has turned into a bane by irresponsible, uncontrolled and extensive use, causing irreversible degradation to not only ecosystem by continuous release of ozone and other volatile organic compounds (VOCs) but also the health of workers occupationally exposed to it. Indoor Ozone level due to emission from different photocopying equipment's increases drastically and the condition of other air quality parameters are not different. This situation is particularly sedate in extremely sensitive educational and research industry where sharing of knowledge is extremely important to meet the demands.

Printing and photocopying industry have revolutionized the availability of documents and perceptible image quickly at extremely inexpensive and affordable

cost. Sadly, irresponsible, uncontrolled and extensive use, causing irreversible degradation to not only ecosystem by continuous release of ozone and other VOCs but also the health of workers occupationally exposed to it.

This work explore all inherently safer approaches to identify hazard associated with photocopy machine, its quantification and its health risk to the occupationally exposed individuals. The outcome of this study will empower the occupant with information regarding significant emission and occupational hazard, so that occupant can design their room specific to printing/photocopying as well as manufactures will be get an idea of redesigning it to reduce hazards associated to this operation.

Increasing population and urbanization started putting a toll on the environmental and residential loads in a city. Indoor air pollution is also a growing concern and with most of the job roles having activities confined to the indoor environment of an office or an industry, it is essential to monitor indoor air quality. The proposed work focuses on analyzing the emission from Photocopy machines in brief. Very little study has been carried out in India to identify and catalogue all the occupational hazard, socio-economic hazard and environmental hazard associated with photocopying machines. This work explores all the inherently safer practices to identify, quantify and assess the health risks to exposed individuals. The outcome of this study provide information regarding significant emission and occupational hazard to occupants and employers so that better preventive measures can be taken and implemented.

1.6 Objectives

- Identification of various hazardous emissions from printing & photocopying machines in offices and commercial buildings.
- Quantification and correlation of the level of hazardous emissions with type of machine, working conditions and effective time of operation of printing and photocopying machines.
- Estimation of health (Cancer Risk and Occupational risk,) and environmental impacts.
- Development of a predictive tool to analyze the effect of photocopying and printing activities.

CHAPTER-2

2 Review of Literature

"Indoor air pollution" in basic terms is the pollution of air in a confined space, which is a common issue in our daily life. Productive and corrective strategies are earnestly expected to battle the issue of indoor air quality. In recent past, people concern has grown rapidly over the poor quality of indoor air specially in urban areas where printing and photocopying is more common than rural area and comparatively have more effects on human health[1, 2]. Decades ago both dwellings, non-dwellings were living in more ventilated buildings than they are now. Now a day's air-conditioned buildings in everyday lives are more common in almost all parts of the world and the majority of these are responsible for the recirculation of a high portion of air. The individual lifestyle of building inhabitant, comprising the person who smokes indoors, has also altered. These alterations have distorted the type and concentration of chemicals that the people are facing in their homes and offices. It is observed that the individual exposures are significantly larger than the estimated exposure of an average pollutant indoor concentrations, because of the closeness of individual over extensive periods to the source of emission [20]. In most of the working places, indoor air pollution is extensively distinguished as one of the most grave potential environment hazard to human health as per 'WHO Indoor air quality research' [21].

Residences, public building or offices is the most common place where people spend most of their time indoor where abundance of indoor air pollutant are most

common due to poor ventilation and multiple sources of VOC's[3, 4]. More than half of the respiration done, in this modern scenario, during an individual's life time is air inhaled in these confined spaces be it home or office[22, 23].Human beings adapt with the surrounding in which they exist and facilitates a constant gas interchange; making the process of respiration the fundamental passageway of contaminants. The indoor toxins are infinite and their sources are present everywhere [24].Their levels of concentration may change after some time and relics mainly upon the idea of the origin ,ventilation, habits, and activities completed by the people present in these regions.

Presently due to urbanization and rapid increase in population number of offices uses fax machine, laser printer, photocopying machine and other electronic gadgets for rapid transfer of information, which releases multiple primary pollutants like VOC's, ozone, SVOC's and particulate matter [5].

It is notable that equipment such as photocopiers, printers etc. radiate several chemicals like ozone, acetone, and particulate toner matter. The constituents of toner will respond differently when affected by light and increased temperature because of some complex chemical processes and thus emit these particulate matter [25]. Previous research proves the unfriendly impacts of these machines on human wellbeing and its significance in accordance with the field of Occupational Health and Safety [22, 26]. A meticulous study in Aveiro, Portugal showed continuous estimation of size-segregated particulate matter, total VOCs, O_3, CH_2O, comfort parameters for example-temperature and relative humidity as well as Carbon monoxide and this research suggested multiple health complications [27, 28] in an office environment due to indoor air pollutant.

Electrical devices like laser printers, photocopying machines, and ozone generators are the reasons due to which Indoor ozone is generally generated [6, 7]. Indoor ozone can also be delivered by the corona release from electrostatic air cleaner machines [8]. The essential facility are the photocopies that is being provided in

most of the commercial office and educational institution so, even if photocopying is important, it is unfortunately also contributing to ozone emission. Photocopying machine use a direct supply of electron and the electrostatic drum which is an integral part which carry a negative charge and produces excess amount of ozone while charging and releasing of the drum [9]. Studies shows that photocopy machine and printers significantly producing both VOC's and ozone [10, 29]. These machines can also emit light in ultra violet as well as visible range radiation. The Fluorescent lamp present inside the photocopier is responsible for ultra violet radiation [29]. In photocopy centers, ozone radiated amid photocopying activity may upgrade the potential danger of health on representatives and guests or customers visiting it.

Throat ,eyes and human nostril, are more strongly affected due to ozone and long duration release from the photocopy machine not only lead to reduced lung functions but also leads to higher risk of cardiovascular diseases and high stress and systematic inflammation [12].

Previous work [30] highlights the emission of sixty different type of volatile organic compound from office equipment's like printing and photocopy machine and due to their potential health effect toluene, styrene, ethylbenzene and benzene and their carcinogenic activity[20, 31] have attracted much attention for their assessment and management to sustain our growth. Indoor air quality of the place where the photocopier machine functions, has been observed poor due the release of the Volatile Organic Compound (VOC) like Benzene [32], [33]. Longer operation of this equipment leads to higher discharge rates of VOCs, SVOCs ,Ozone and heavy metals per copy due to high chamber temperature (e.g., a 20% increase came due to expanding temperature from 23°C to 32°C) and changing from single side printing to double sided printing (40% expansion) [32].

It was also observed that the emission of this VOC depend upon the toner that which we are using in the photocopier it is also observed that the toner which has thickness less than 0.01 has less emission of VOC than others [34] mainly O_3. Plus

amounts of individual volatile was within recommended maximum exposure limits for a reasonable number of printers in an all-around ventilated office condition [32]. Several studies have shown that during photocopier operation, the occupant's health is affected by the indoor air quality problems due to the emission of ozone and several volatile organic compounds (VOCs). Very little study has been done in India to catalogue all the occupational hazard associated to photocopier operation and their mitigation method has even not been touched upon. It is important to affirm whether toner represents a hazard to people or not by a very efficient epidemiological examination. The reason for this investigation is to inspect the connection between printer/copying machine toner-exposed work and respiratory disorder.

2.1 Emission from Photocopy/Printing Machine:

Photocopy/printing machines is a part of millions of people around the world for everyday, which make it unavoidable in offices, industries, shops, schools, laboratories etc. Hence the question of harmful effects of operating this device and what extent does the air is polluted is an important concern of the public [35].
Due to increase in the use of printing/photocopying since early 1990s, people are facing the deleterious effect of ozone, for a building without photocopying machines the ambient ozone concentration in many times less compared to outside due to filtration through walls, however, due to the use of photocopying machine the indoor ozone concentration becomes significantly high[13, 14].

The results of pollution are volatile organic compounds(VOCs), particulate matter and ozone[36]. Dry process printers have been considered as a significant factor contributing to indoor air quality issues. Cadmium, selenium and arsenic have been reported as other pollutants from photocopy machines [37].

Printing machines, printers are the one of the reason for the presence of Ozone in the indoor air along with other anthropogenic sources [15]. The sources of possible

health concerns from the printing machine are - carbon black toner, resins of different polymers, O_3, UV light, etc. Ultra Violet radiation can also result in formation of Ozone (for example, UV lamps are used in hospitals and industries to ensure sterility from the bacteria). Commercial use of Ozone for removing the air borne contaminants can also act as sources of ozone in the indoors. The Lithuanian hygiene standard HN 35:2002 states that the TLV (Threshold Limit Value) for the concentration of ozone in the work area is 200 $\mu g/m^3$ over eight hours exposure [6]. Different sources [16] give that the allowable concentration in the work area in 100 $\mu g/m^3$. Ozone is a very unstable compound due to its high reactivity.

The ½ life of the Ozone lies between 7 – 10mins in indoor environment in normal conditions [17] which can be determined by air exchange and surface removal. Other observation stated [18] that half-life of ozone in an building is less than 10 minutes. Rate of emission of hazardous substance and the volume of air that dilutes the released substances are the two basic parameters on which the pollutants concentration present in the workplace depends. Emission from the printing/photocopying machine and other electrical devices depends on many factors, the technology standard used, types of machines, operation duration and rate, process conditions, and so on [19].

It has been observed that, toner formulations utilized by photocopiers (PC), popularly known as "toner-based printing equipment" (TPE), are Nano-enabled products (NEP) in light of the fact that these machines consist of multiple improved nanomaterial (ENM) which enhance the performance of toner [38]. There is convincing confirmation that the PM0.1 is biologically active that releases from TPE and have enough potential for inciting oxidative stress and cancer. It has been observed that, prevalence of wheezing, constant cough, nasal blockage , breathing challenges, and shortness of breath among users [29]. The prolonged exposure can lead to cardiovascular, respiratory, immunological, and different disorders. "Sick Syndrome" a condition related with impacts of photocopiers has been currently distinguished [27, 39].

The fact we need to comprehend is that the danger postured by these machines is prominent and cannot be disregarded. "Indoor air quality" ought to be intended to ensure and enhance the well-being of employees. Despite the fact that work proficiency expanded, it bargained air quality which is not worthy [40]. It has been proven by research that engaging in activities alongside a printer in operation is equal to breathe in tobacco smoke or to inhale debilitate vapor of congested driving conditions, for our respiratory system there is no distinction [25].

The toner used in printing and printing/photocopying machine is known to cause respiratory diseases if inhaled or else cause irritation to skin. Ultraviolet radiation used in photocopy machines have the potential to cause harm. These machines use visible and invisible light like UV rays. Risks to having skin cancer is high when humans are exposed to such environment. [41]. Particulate matter other emission from this equipment causes respiratory issues, problems to lungs. Systemic inflammation is caused due to such toxic exposures causing a high risk of cardiovascular diseases. Benzene, xylene and toluene are produced from such machines of which benzene and styrene are carcinogens.[42]. Noise pollution is another issue leading to risks of hearing due to high amount of exposure to loud noise of photocopy machines which may lead to fatigue and distraction [43].

The proposed work will focus to analyze the emission from printing/photocopying machine and outcome of this study will provide enough knowledge to the individual occupationally involved in this operation for the acute as well as chronic problems due to VOCs, SVOCs, heavy metals, ozone and other emissions from printing/photocopying machine.

2.2 Associated hazards from printing/photocopying machine:

Study reveals that there are even emission of the UV radiations because of this photocopier machine and these are also harmful to the person who is taking this as the profession and it also said there is no relation between the emission of the ozone

and the UV radiations[10, 44]. Based on the available literature, the following hazards have been observed during various operation of photocopy/printing:

- Heavy Metals
- VOC
- Ozone & Multiple gases
- Particulate Matter
- Radiation
- Temperature

2.3 Sources of heavy metals in air:

The intake of heavy or trace metals containing food will be radically reducing some of vital form of vitamins and nutrients from the body that is responsible for reducing substantial metals, which are already present in the earth, because of the naturally occurring and other anthropogenic activities.

People are exposed to the heavy metal namely [arsenic, chromium, barium, lead, selenium, mercury, silver, cadmium] through different pathways [45, 46]. Humans are always exposed to these heavy metals also called as (Trace elements) by either ingestion or inhalation. The wastewater contains large amounts of harmful heavy metals that cause potential problems in the agricultural production[47]. Heavy metals presence in the earth and plants is pertain to potential harmful human and adverse health effects and the risks associated with it. The food chain contamination has been the most important path as being considered for entry of the specified toxic heavy metals in to body of human beings[45]. Important sources of air pollution has been categorized in Figure 1 and some potential anthropogenic sources has been discussed below:

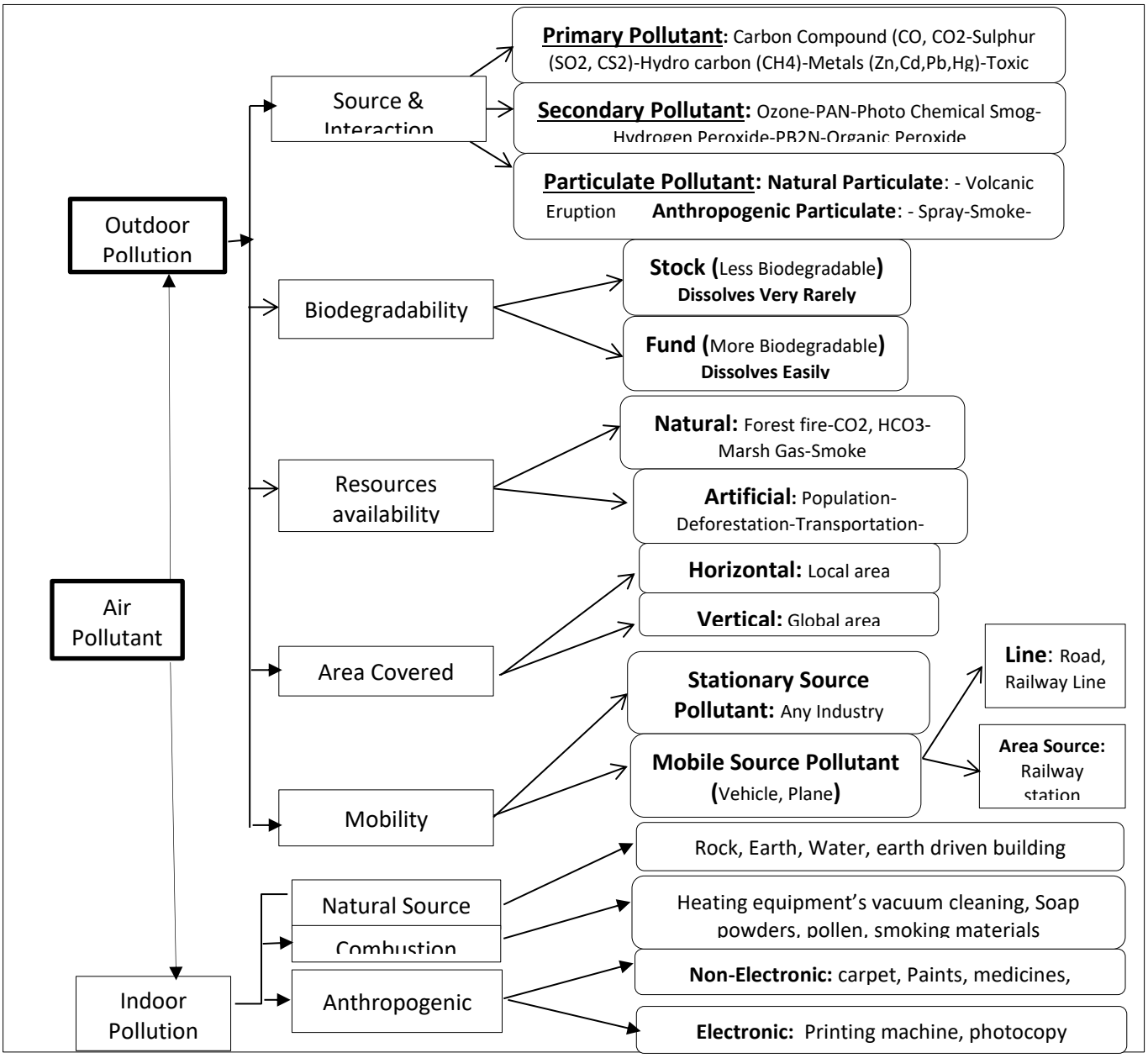

Figure 1: Different sources of air pollution [47-50]

2.4 Air borne heavy metals sources:

Air borne particles of heavy metals consists a part from the stack, pipe outflows of gas or vapor streams, and emissions from the storing locations, or accumulated waste dumbs. Airborne metal particles are mostly discharged as particulates that are in the gaseous form [48]. A few metals Cd, As and Pb can be volatile at extreme temperature while processed. The metals present can change over to oxides and get condensed as small particulate matter unless a reducing type atmosphere is kept over[49].

2.5 Urbanization:

Urbanization and movement of traffic, mechanical and rural agricultural exercises, waste burning and mining have altogether added to the entering of metal particles through breathing into the human body[50]. In the urban atmosphere Co, Cu, Cr, In, Fe, Mo, Ni, As, Cd, Hg, Mn, are present as the most important heavy metals [51]. Lead and cadmium are highly contained in the urban atmosphere. Other heavy metals Cr, Ni, Cu, Zn concentration are less compared to other trace elements[52].

2.6 Vehicular Traffic:

In urban zones, the road dust related substantial metal contamination emerges from a large number of sources like water transported material, dry and wet conditions of atmospheric deposition, street surface wear, street paint debasement, vehicle wear, vehicular particulate discharges[53, 54]. The areas that are close to the roads which are have dense traffic is likely to found with more Zn, Pb, Cu, Cd[55]. Being in that way, in urban regions road activity will make the critical contribution to individual's exposure. Discharges coming from street traffic in thickly populated urban areas contribute to increase adverse health effects[56].

2.7 Industries and Factories:

In urban cities, steel plants along with other industrial and mechanical activities, effluent burning plants, foundries and energy generation plants also produces significant amount of heavy metals.

Pesticides: Pesticides contain copper mixture used as fungicidal showers like Bordeaux blend and copper oxychloride. Lead arsenate utilized for organic product plantations to control some parasitic bugs. Arsenic containing mixes are utilized to effectively bring down cattle growing ticks and reduce the other pests in banana plantations. Pesticides and fertilizers of some kind also contain sources of arsenic which can released into the environment[46].

2.8 Other sources of heavy metals in food chain:

Emission factors of streets in urban area regarding concentration of heavy metals can be estimated using Gaussian Dispersion Air quality modelling[57].Solid form like pools of Ni, Cu, Cd, Zn, Cr , Pb, could be parted into five characterized portions that are interchangeable compounds and also operational , bounded to carbonate compounds, bounded to Fe and Manganese oxides, which are bound to natural matter and residue occurring[53].

Hg, Ag, Pb, Ni are some of the heavy metals that are persistent and bio accumulative in nature, and doesn't reduce down in to the environment or else is never so easily metabolized [47]. These heavy metals get accumulated on to the ecological form of food chain by modes of the uptake through the various trophic level and initial through the primary producer and after that through the consecutive consumer levels. Heavy metals presence in plants will depend upon the plant species [45, 50].

Vegetables that are cultivated in the waste water irrigated soils absorb the heavy metals in much larger amount is the antecedent for potential harmful health effects to the human beings in the immune system defenses, internal uterus growth problems, impairing mental and the social abilities, disability in relation with the inadequate nutrition and also high chance in the occurrence of the gastro related intestinal cancer rates [45, 46]. Drinking water sources when contaminated with heavy metals can lead to major ailments like renal failures, liver cirrhosis, hair fall and hair loss, and chronic anaemia[58].

The heavy metals like the Cd, Ni, Arsenic and Chromium possess a large count of harmful hazards to the humans[59]. Heavy metals is also the prime potential carcinogens. Cadmium (Cd) ingestion causes the itai- itai named syndrome and the mercury (Hg) ingestion causes the minimata named syndrome. Other forms of heavy metals like the Arsenic (As) can cause toxic effect in the drinking water. Few of the heavy metals like Cu, Mn , Ni ,Mo, Fe, Co, In are called the Micronutrients, and can be toxic only when in taken above the required level [50].

The very essential and important heavy metals like (Mo, Cu, Fe, In, Mn) does bio chemical and many physical function in both the animals and plants. Most important function for the heavy metals include involvement in the reducing and oxidation reaction and the direct involvement due to the important part of the all other enzymes[60].

Copper is a very important heavy metal in higher order plants and the green algae, mostly prime important in the photosynthesis. Cu is the component of primary electron donator in the photosynthesis, known as the Copper (Cu) protein plastocyanin. It's due to the Cu which can very reactively oxidise and reduce electron[50]. (In) another heavy metal that is present in enzymes such as superoxide dismutase, carbonic anhydrase, the RNA polymerase, alcohol dehydrogenase, is necessary to make up the overall structure for the ribosomes. Nickel another content of urease enzyme that is important for the working and also for the good physical health condition in the animals[50].

Lead and Cd has been considered as the potential harmful carcinogenic metals and are related to a many diseases, namely cardiovascular, nervous system, bone, blood and kidney diseases. Dietary form of ingestion is the main path to the harmful exposure to the human beings, even though inhalation can be causing a vital role in contaminated locations[61]. Hence the details regarding heavy metal various chemical concentrations and their harmful effects in food products and dietary form ingestion, water intake and other forms of ingestion and inhalation is important method in calculating the threat associated to human being health[62].

People who work in or live in places which is in close proximity to an industry like photocopy machine and printing, which utilize the metals and its compositions can lead to increased threat on exposing, or to the people living near to a location where the heavy metals has been unsafely disposed [46, 58].

Authors from the previous study suggested the presence of heavy metals in the emissions from photocopy machines and it includes iron, zinc, nickel, chromium, arsenic, cadmium etc. [63-65] exposure to these pollutants lead to adverse health effects. The lifetime cancer risks premature ageing, irritation to eyes, headaches are major risk to health[66]. Maintenance personnel are exposed to toner powder at the time of maintenance rather than pollutants emitted during the photo copying operation[67].

2.9 Heavy metals from Printing and photocopy machine:

Following different heavy metals emissions from photocopy and printing machine has been observed in past studies, which has adverse effect on health safety and environment:

- Arsenic
- Barium
- Cadmium
- Chromium
- Zinc
- Nickel
- Iron

Arsenic: Emission from photocopier and its effect on health Safety and Environment

Arsenic is discharged in bigger amounts through volcanic action, disintegration of mineral rock deposits, timberland flames, and manmade action. The wooden industry that preserves wood utilizes a majority of the industrial arsenic. It's also found in paints, various drugs, metals, semi-conductors and soaps. Other sources include copper and lead smelting, mining operations or coal combustion[46].

Arsenic is very toxic in nature and its exposure to human and animals can leads to various dieses. Arsenic may occur in two forms namely organic form and inorganic form[68]. There are many manmade source of arsenic such as smelting of metals, combustion of coal and burning of waste when arsenic. However elemental analysis of toner powder of printer revealed the presence of Arsenic (As) at respectable particle size of 2.4μg/m^3. while monitoring the indoor air quality at different photocopier center it was found that the concentration of Arsenic was within the Indian ambient air standards [40, 69]it can be absorbed by ingestion or inhalation as it is present in toner powder[70].

Health Effects: It is a cancer causing agent and can cause skin related cancer, urinary bladder, lungs and liver associated cancers also, very low level of exposure to the arsenic can cause vomiting and nausea, reduction in the of red platelets and white platelets , abnormality in the heart rate, harm in the blood vessels, pin as well as needle effects in the hand and foots, darkening on skin and visible presence of small corn on the inner and outer sides of palms[46, 71].

Regulatory Limits: According to the Environmental Protection Agency (EPA) the recommended limit for water is 0.01ppm. TWA (time weighted average limit) as per OSHA (Occupational Safety & Health Administration) is 10 μg/m^3 which is calculated for 8 hours per shift and 40 hours a week in work place[46, 72].

Barium:

Barium mixes, like barium-nickel compounds are utilized for spark plugs in vehicles and to vacuum tubes, oxygen-expelling chemical reagents, barium sulphide is utilized as a part of fluorescent lights, barium sulphate is utilized as a part of indicative medicine, barium nitrate and its chlorate form is used to give firecrackers a green coloring. Barium mixes are utilized for penetrating muds, paint, blocks, ceramics production, glass, and industrial rubber[46, 73]. The persons working with photocopying machines and printers have been effected with the increased basal DNA loss due to the usage of the particulate matters of below 2.5 and toners using harmful chemicals like barium sulfate and other organic[65]. At

the point when the machine is in task the DNA repair process had demonstrated a colossal increment in first but later it proved to be the decrease in the DNA mechanism which shows the effect of the chemicals like barium sulfate , organic compound and radiation on the DNA of the people[74].

Health effects: Mild exposure to the barium can cause vomiting, abdominal related cramps, problems while breathing, blood pressure variations, weaknesses of muscles[46]. Large Exposure of barium concentration can lead to increased blood pressure and heart rate changes and abnormality and possible fatality[75].
Regulatory Limits: As per EPA it is 2 ppm for drinking water [46].OSHA standard is set to 0.5 mg/m^3 TWA which is calculated for 8 hours per shift and 40 hours a week in work place.

Cadmium:
Cd is one of the poisonous metals which we shall find in industrial workplaces has significant hazards effect on health and environment due to its overexposures. In printing/photocopy machines most of the heavy metals like cadmium, chromium, arsenic, lead etc. are used as pigment coloring materials other sources are rechargeable batteries, printer drums, toners, printer's inks and Cathode Ray Tube screens, etc. [76]. The photoconductive material in photocopy machine is generally Cd and some photocopy machine use a drum impregnated with cadmium sulphide [77].In earlier studies Cadmium and cadmium compound exposure from the copying process have been reported as 0.2 micrograms per cubic meter [78].

Health effects: Smokers get presented to more cadmium intake levels than non-smokers. Cadmium and its mixes are cancer-causing agents [79]. The lungs may be seriously harmed by inhaling abnormal amounts of cadmium. Ingestion of abnormal states seriously bothers the stomach, and can lead to puking and loose bowels. Long-duration presentation to lower levels prompts to development inside kidneys and conceivable kidney sickness, lung harm, what's more, delicate

bones[80, 81]. The gas released from materials especially when it is become hot can cause throat irritation and major risk involves for staff while cleaning or grinding the surface of the printer drum. The exposure to cadmium fumes causes flu traces that cause weakness, headache, sweating, chills & musculoskeletal disorder (MSD). The main health risks due to continuous exposure are lung cancer and damage in kidney. Cadmium presence is also resulted to cause bone disease such as osteoporosis and pulmonary emphysema [82].

Regulatory Limits: EPA describes 5 parts for each billion [ppb] i.e. [0.005 (ppm)] of cadmium as limit for water for consuming. Food and Drug Administration [FDA] focuses on packaged water for drinking shouldn't surpass 0.005 ppm. Occupational Safety and Health Administration standard mentions a normal of 5 $\mu g/m^3$ for an 8-hour workday, 40-hour work per week[83].

Chromium:

Cr mainly originates from mineral rocks, flora and fauna and in soil and is present in all the three states of matter. Chromium is utilized as a part of metal amalgams, stainless steel, electroplating, producing magnetic coated tapes; and paints, bond, paper, elastic, in synthesis floor material covering dissolvable forms are utilized as a part of wood additives[84].

Chromium used in printing inks are in various forms such as Chrome Yellow (3.2-1)PbCrO4, Molybdate Orange (25)PbCrO4, Chromium Green[85].Chromium is considered as atmospheric toxant due to its wide industrial use. Chromium toxicity depends on valency state; Cr(6) is highly poisonous than Cr(3) [86].Atmospheric exposure to radiation in RF range of 100 kHz-300GHz for photocopiers can lead to health hazards , at field strengths lower to these require to create thermal effects. Maximum exposure of magnetic field is usually 200 mg. Studies shows that magnetic field limit in occupational & residential areas lies between 0.2-0.3(2.5mg) which is more hazardous than electric field[87].

Health effects: Cr and its mixes are poisons and known as human cancer-causing agents, though Chromium (III) is a basic supplement. Breathing abnormal states can make disturbance the coating of nose, runny nose, breathing issues, asthma, hack and nose ulcers [88]. Contact on the skin can bring about skin ulcers. Unfavorable susceptibility causes skin redness and swelling. Long term introduction can make harm liver , nerve tissues and kidney circulatory [89].

Regulatory Limits: EPA mentions 0.1 ppm in water used for drinking. FDA – ought not to surpass 1 mg for every litre (1 ppm) in filtered water. OSHA mentions a normal of in the vicinity of 0.0005 and 1.0 mg/m^3 of working environment air for a 8 hr workday, 40 hr of work in a week, contingent upon the compound[90].

Lead:

Petroleum derivative consuming, assembling and mining, lead and its mixes could be found. This incorporates air, soil, and water. It is used to create batteries, ammo, metal items like weld, funnels, and X-ray protecting gadgets[91]. Lead is a very harmful metal because of its utilization in a few items like fuel, paints, and pipe weld. Water pipes in more established homes, lead in specific beauty care products and toys, and lead-coated ceramics[92].

Health effects: EPA mentions it as a human cancer-causing agent. Lead is very toxic to each organ and framework of the body. Prolong introduction of grown-ups bring about diminished execution of the sensory system; shortcoming in fingers, lower legs ,wrists, little increments in circulatory strain; and paleness[93]. Prolong susceptivity to high lead concentrations may extremely harm the cerebrum and affect kidneys and eventually cause fatality. In ladies who are expecting, abnormal amounts of introduction to Pb may bring about unsuccessful delivery and higher level introduction in men can harm the organs in charge of sperm creation[94].

Regulatory Limits: According EPA, 15 parts per billion in drinking water, 0.15µgm for each m^3 in air[95].

Mercury:

Heavy Metals like mercury, cadmium, arsenic, chromium, thalium and lead are metals having high densities, atomic weight or atomic number. Some heavy metals are useful like iron cobalt zinc but can also be toxic if consumed in large amount. High pressure mercury light is used in projectors and another type of similar light source or high pressure mercury light is used in photocopy machines [96].

Health effects:

Mercuric chloride and methyl mercury has been verified as conceivable human cancer-causing agents as per EPA. Mercury is extremely sensitive to nervous system. Exposure to abnormal states can forever harm the brain, kidneys, and creating fetuses. Consequences for brain working may bring about crabbiness, bashfulness, and tremors, vision related problems, hearing disorders and can also cause memory issues. Short-term introduction to abnormal amounts of mercury vapours may bring about lung harm, queasiness, vomiting, looseness of the bowels, increments in circulatory strain or heart rate, infection in skin.

Regulatory Limits: EPA describes 2 ppb in drinking water. FDA describes 1 ppm of methyl mercury of fish. OSHA describes 0.1 mg of natural mercury per metre cube of work environment air and 0.05 mg for each metre cube of metallic mercury vapour for eight hours shifts and forty hours. work week[97].

Zinc and some other elements:

Primarily used in industrial processes that deals with Galvanization. Zinc is essential element for the diet, at the same time too much zinc is harmful to health. The zinc inhalation can cause metal fume fever [64] and products of zinc stearate has been observed during photocopy operation

In toners most abundant element found to be iron(0.9 to 4.2%) and then titanium followed (0.05 to 0.09%).It was also found that the element composition changes from colour to colour and manufactures to manufactures [65].

Health Effects: The most commonly occurring health effects is metal fume fever (MFF) that is mainly caused due to the intake of fresh metal fumes containing zinc oxide with size of the particle < 1 μm. It effects several organs of our body[98].

The main side effects include lethargy, neuronal deficits, respiratory tract infection leading to disorders on inhalation of zinc smoke, MFF, nausea, high risk of prostate cancer, epigastric or gastro related problems[99].

Regulatory Limits: Compared to the Cadmium, Lead and mercury the LD50 value for Zinc is very much higher making the element less toxic than the other trace elements. LD50 value for humans is 3g/kg of body weight[100]. The admissible intake restrain as indicated by the OSHA standard is 5 mg/m3 for ZnO (metal fumes along with dust particles) in work environment air amid an 8 hrs. workday, 40 hrs. work week[98].

Nickel:

In printers, the documents are read and printed using a laser beam. These types of machines use charging rollers to shift the toner to the paper while shifting the toner it get emitted to the atmosphere[21]. Toner dust may spilled inside the machine which passes into the room through fans and also due to human carelessness[46].For the average person, inhalation accounts for approximately 0.1 – 1µ g nickel daily who is working in these industries[101]. Some of the main routes of exposure are- inhalation, dermal contact and gastrointestinal ingestion[102]. The nickel exposure may cause lung cancer, also affect liver and kidney[103].

Health Effects: Inhalation of the Nickel fumes effects the respiratory track and the immune defense system of our body. It's responsible for allergic diseases on dermal contact[104]. High sensitivity of Nickel also causes asthma, inflammation and conjunctivitis[105]. It is also a potential cancer causing agent, mainly due to the release from anthropogenic sources[106].

Regulatory Limits: The TLV limit as per OSHA for metallic Nickel is 1.5 milligram/m^3 and 0.2 milligram/m^3 Nickel in water insoluble types of organic compounds, for water soluble types 0.1 mg/m^3, 0.35 mg/m^3 for nickel carbonyl type. TWA for metallic nickel is 0.5 mg/m^3.[105]

2.10 VOC from Photocopy/printing machine and its health impacts:

Volatile organic compounds are broadly categorized of organic compounds, which we have exposed regularly, and at room temperature at high vapor pressure. VOCs are emissions in gaseous form originating from some definite type of solid; VOCs consist of different type of chemicals, out of which few may affect the human health on short term or long term basis. Building materials, furniture's, cosmetics and cleaning products are some of the potential sources of VOCs. As there are numerous VOCs present in the environment, the exact health effects to the exposure is still unknown. Some of the adverse health effects include cancer, sensory irritation, and respiratory symptoms. The quality of the air we breathe plays an important role for our health and the primary exposure to VOCs is through breathing. Emissions from vehicles, industries, factories as well as indoor environments like office, home has become vital source of exposure to a large range of VOCs[107].However, it is seen that outdoor has more VOC concentration compared to indoors. Emission of VOCs and (TVOCs), is from a wide range of products and printing /photocopy machine is a major source [20, 66, 103, 108]. Earlier studies suggest higher concentration of VOC and TVOC inside a building with photocopy/printing ,machine than a building without photocopy machine[21, 103].

The toxic change of VOC are the prominent variations caused by VOCs on a person as compared to a person who is not exposed. Apart from the common health effects of VOC, there are some special health effects which include effects on the immune system, visual or auditory defects, apathy, compulsive behavior, memory loss[109], As VOCs are frequent air pollutants, buildings and furniture materials emit VOCs and pollutants which includes VOCs from outside are transported by ventilation to the inside environment and hence the system of ventilation is also a Volatile Organic Compounds source[110]. Maintenance activities, cleaning activities smoking, spray cans, printing machines, glue, paints, and preservatives are also major sources of VOCs which may result in improper respiratory system that are chronic[111]. VOCs are the important category of chemicals that occurring in air

that is in indoor environment[112]. As VOCs are classified on the basis of boiling point, the most common is BTXS (Benzene, Toluene, Styrene, Xylene and, limonene (terpenes). Their volatile character and their uses in household things-waxes, varnishes, paints, cleaning products, solvents, detergents etc. is the reason of their broad occurrences[113].

Benzene is widely used in toner of printing machine/photocopier[114],varnishes, thinners, paints and gasoline as industrial solvents[115]. It is used as a raw material during the synthesis of Phenol, Styrene, Aniline and Alkyl Benzenes for manufacturing various detergents, resins, plastics and sources also include emissions of consumer products, smoking and burning[116]. Toluene or Methylbenzene is used in a wide range of toner[117], household products which includes cleaning agents, paints, coatings, thinners, adhesives, etc. as solvent. Benzene is also used to increase the Octane value in Petroleum industry[113, 118]. It is highly emitted in hospitals due to the use of disinfectants and cleaning products[119].Xylene or Dimethylbenzene is a hydrocarbon which is aromatic. Xylene is used as solvents in the Chemical industry for products which includes paints, dyes, adhesives, detergents, pharmaceuticals. Xylene is also emitted from smoking[120].Styrene is a Volatile Organic Compound that is widely used. Styrene has double bond and is able to polymerize[113]. It is used in wide number of products. The Styrene Butadine Rubber and the Styrene Butadine Latex in house hold products are the main components from which Styrene is emitted. It is also emitted from smoking[121].

VVOCs are significant group of pollutants that are found indoor and they spread over a wide range of chemical substances[122].Some VOCS result due to chemical reactions, some from products that are used indoors and some results as reactive predecessors from secondary products[122, 123].VVOCs acts a vital role for the checking of the quality of indoor air[122, 124].

There are several possibilities and different sources of Very Volatile Organic Compounds. The unsaturated organic compounds reactions may give rise to VVOCs[125]. Some VVOCs like Methanol, Ethanol, Formaldehyde,

Acetaldehyde, Formic Acid are the result of biogenic emissions[126]. Human activities such as printing, cooking, baking; heating of glycerin containing foods are also significant sources of VVOCs[127, 128]. VVOCs are also present in paints, adhesives, cleaning materials, waxes and other chemical products[122, 123]. Wood, paper and wood composites also contain several types of VVOCs such as Acetaldehyde, Ethanol[129].

Contact to Very Volatile Organic Compounds (VOCs) can result in several health effects. High concentrations of CO_2 (more than 15%) leads to headache and fatigue[130]. Napthalene causes major toxic effects such as Haemolytic Anaemia, jaundice and ocular effects[125]. Some other toxic effects from VVOCs are cataract, eye irritation, nasal irritation, optical neuritis, mould growth, burning eyes, allergic reaction[122, 123, 125].

SVOCs are chemical substances that are used in construction materials or other consumer products[131].SVOCs are contaminants that arises from other sources and are partitioned to many compartments like gas or settled dust[132].They are found in gaseous or condensed phase and are redistributed from the original source to the air of indoor environment[129].

Semi Volatile Organic Compounds have several sources which include chemical compounds such as paints, adhesives, disinfectants, electronic products, cleaning agents, flame retardants, plasticizers, products of personal care[133, 134]. Consumer products, building additives are also sources of SVOCs[135].

The health Effects associated with Semi Volatile Organic Compounds are nausea, head ache, eye irritation, throat irritation, loss in coordination, cancer, kidney damage, liver damage, shortness of breathing, harm to the nervous system, skin problems[129, 132, 136, 137].

2.11 Ozone & Multiple Gas during Photocopy Operation:

In a current well controlled work environment, the worsening of respiratory issues associated to toner's dust contact was least possible to happen, particularly whether the powered toner was cautiously handled but to accumulate more epidemiological proof on the Biological effects of toner's dust breathing is important if possible

using a longitudinal study design[138]. With different printing speeds of the commercial colour printers the correlation was found that printing is directly proportional to average mobility equivalent particle diameter but inversely proportional to average particle number concentration[139].

Indoor air quality is influenced by the very reactive ozone gas indirectly as a result of the reaction involving high molecular VOCs where organic acid, free radicals and aldehydes are formed. When ozone reacts with unsaturated aerosol-associated compounds it produces both volatile and nonvolatile products. As the space inside the printers is very small, the concentration of ozone inside the printers is found to be quite high during printing[7].In the laser printing operation, huge amounts of VOCs are discharged to atmosphere. Since, ozone concentration trend is found to be inversely proportional to that of total organic compounds, this behavior has led to the confirmation of the existence of reactions between ozone and organic compound[140].

During photocopying process, a larger part of ozone is created while the drum and paper is being charged and released. Ultraviolet emission from the photocopier lamp also produce ozone[28]. In laser printer styrene and ozone was found, and in inkjet alcohol were detected. [141]. Production of Ozone is incident during many printing activities where emission of UV radiations occurs, during curing of printing inks, use of projection lamps, varnishes, lacquers etc. [142].

Currently, concentration levels for ozone as per OSHA standard for residential buildings is fixed at 0.10 ppm[21]. It is probably the first ever attempt made by the author to catalogue the adverse effects of ozone release from photocopy machines and printing machine where he found that ozone content after emission was between 30.0 and 60.0 ppb at a certain distance from the printing machine[143]. But [6]found the ultimate ozone emission as 94 $\mu g/m^3$ (47.0 ppb) at a distance of 0.5m from the machines. In the recent years studies have shown that concentrations of certain gases in the atmosphere indicate that the level exceeds the value of the OSHA and NIOSH standards[144].The level of ozone accumulated in confined

rooms exceeds the Occupational Exposure Standard [142]. Results from the experiment reflect that concentrations of the ambient ozone are directly related to Total volatile organic compounds conc. and significant utilization of ultraviolet (UV) lamps during screen and digital printing operation. 0.05 ppm is the maximum allowable concentration of ozone[145].

Ozone and particulate matter are linked to occupational side effects like throat, eyes, nose irritation, headache and fatigue. Volatile organic compounds[146]. Laser printers and photocopy machines can sometime emit ozone in small amounts and if it is there in adequate amounts, can cause irritation in the lungs, nasal passage, throat and eyes of employees and visitors. It was calculated that there can be an increment in risk of death by 4 % if approximately a 0.01 ppm is the level of ozone increases.[147]Confirmed that the female staff in a workplace is more prone to diarrhea and weight reduction as side effects of emissions from these electronic equipment's.

Author also observed that variation in the level of ozone relay on type of chemical composition and printing processes used as raw material, various ventilation system installed in environmental condition and printing machine. Ozone has much higher effect on human health as compared to VOC's[148]. Several factors like gender, age, smoking, disease, genetic, nutritional status variation may lead to different health effects of exposure of ozone [143]. It has been found that ozone at ground level is not environment friendly whether outdoor or indoor. Troposphere ozone is in direct contact with flora and fauna, it causes damage to the surface tissue of animals and plants, and is also harmful to human respiratory system[149].

Some of the measures that are needed to be taken to counter, cope and reduce the harmful effects of ozone emitted from printers and photocopy machines include, room supposed to be properly ventilated so as to let the fresh air in and increase dilution; the lid of the photocopy machine should be kept completely closed and a gas mask should be worn by operators at all times to avoid exposure to harmful gases emitting from the machines. Awareness of ozone gas and its implicit cause and harmful effect on human and environment has to be made among the user of

laser printers and photocopy machines. In addition to this, there should be rotation of task among workers so as to avoid continuous and prolonged exposure[10].

Based on the various printing process the concentration of O_3 varies. Variations are associated to combination of chemicals like used natural substances, environmental situations and air exhaust system within the photocopier mechanism. The individual impacts of ozone on human wellbeing is significantly higher than the individual impacts of VOCs[148]. Gases such as fine particles, various VOCs, ozone and ultra-fine materials are let out into air [150].

Ozone reactions with aerosol-related particles lead to the generation of both nonvolatile and volatile particles. Due to the little area inside photocopier, the concentration of ozone inside photocopier is elevated while working with them [7]. Very high rate of organic compound are thrown out during the laser printing procedure. As the ozone concentration scenario is not directly related to that of total organic compounds, this character seems to strengthen the presence of reactions between O_3 and organic compounds [140].

Printing procedure produces ultrafine powders, volatile organic compounds and ozone. Substances like this led to various bad effects to human body and environment. Therefore it's a must to eradicate the problems of emitted particles and attaining complete secure assessment on printing procedure [151]. Concentration of ozone increase with rise of VOCs concentration [152].

Photocopiers and laser printer generate less ozone quantities which, if exist in enough amount, can aggravate the lungs, eyes, nasal and throat cavities of workers and other staffs. When there is a 0.01 raise in ppm there is a raise in risk of fatality by 4 to 5 %. The larger part of the ozone in photocopier get discharged when the releasing and charging of the paper and drum happens. UV emissions from the photocopying light also produce ozone [28]. Particulate matter and ozone are related with problems such as throat, nose or eye vexation, tiredness and headache [146].

In the tropospheric level of the air ozone is a tricky poison, however in the stratospheric level it pieces aperture of perilous bright beams to the Earth. Without stratospheric ozone life on Earth would not have been practicable. Tropospheric ozone is in coordinate association with living creatures, hurting the surface tissue of plants and creatures, and it is harming to human well-being (respiratory framework)[149].

More and more exposure to elevated ozone dosage results initially in an increased pulmonary function response within 12-48 hour but after 3-5 days of exposure cause an diminished pulmonary function responsiveness [80]. Prior venture to eliminate contaminants have embraced particulate filters, ozone filters, and aldehyde filters, in association with cooling fans, ductwork, and temperature indicators. Catalytic filters are also frequently used to perish ozone within ozone filled air from charging subsystems into non-toxic materials [153].

The laser printer and photocopier users should be well informed about gases like ozone and their possible damaging effects. The present OSHA value for the level of ozone in inhabited buildings is 0.10 ppm [21]. Numerous components, for example, age, sex, malady, wholesome level, smoking and hereditary change may confer to the wellbeing impacts of O_3 presentation [143]. In the presence of (NOx) and secondary contaminants, such as O_3, aldehydes, nitrates, can also be easily produced [154].

Ozone is generated during many printing procedures whereas UV radiation is produced, during curing of printing inks, varnishes, lacquers, use of projection lights, etc. The level of ozone collected in insufficiently ventilated rooms exceeds the Occupational Exposure Standards (OES) [142]. Results of experiments tells that concentrations of ozone increase with raise of volatile organic compounds level and high usage of Ultraviolet bulbs throughout screen and digital printing methods. The utmost allowable level of O_3 present in workplace is 0.05 ppm [145].

Ozone has affinity to absorb heat and it in increases the temperature of surrounding. The exposure to VOC's will increase as the temperature increases and lead to acute

as well as chronic health problems. UV radiation and Infrared increases the temperature of surrounding which in turn adds up heat into the room with heat released by machine during operation and various external factors. When size of room is small and no proper ventilation is provided or no air condition is installed in room the temperature of room gradually increases. UV absorption analyzer was used to measure presence of O_3 in the surrounding air. The amount of ozone helped to calculate the change in temperature.[155]. Photocopy machine such as adequate ventilation, fresh air in room, sufficient dilution in room, use of gas mask when multiple machines are operating simultaneously, Repeated exposure should be prevented. Wolkoff, Wilkins et al. observed that 60 various VOCs are produced during dealing with photocopying [66].VOC emission rates increased with chamber temperature. The highest rates emission was ethyl benzene (28,000 µg/hour), ethyl-hexanol (14,000 µg/hour) xylenes (29,000 µg/hour), and styrene (12,000 µg/hour). Toluene being the highest concentration in BETXS (Benzene, Toluene, Ethyl benzene, Xylenes & Styrene) [103].

Mostly indoor ozone producing devices are photocopier machine, ozone generators, laser printers and other electrical devices [6, 7]. Indoor ozone is furthermore conveyed by the corona discharge from electrostatic air cleaner contraptions [8]. Photocopiers are an important utility in commercial offices as well as educational institutions. Inspire all of its importance, it also act as a source of emission of ozone. Printer utilize a negative direct current process with the electrostatic drum passing on a negative charge which produces enormous measure of ozone in the midst of the charging and discharging of the drum [9]. Many studies already states that photocopiers and printers are accounted for O_3 emission as well as VOCs[10, 29]. Emission of ultra violet and visible range radiation is comes from photocopier machines. Fluorescent lamp act as a source of UV radiation in photocopier[29]. Emission of ozone while photocopying operation increases the implicit risk of bad health on visitors and employees in photocopy centers

It is perceived that the impacts of ozone on human eyes, nostril and throat are considerably more grounded than any other pollutant. Long term introduction to

outflows from printers was related with diminished lung work, as well as brought about high oxidative pressure and systemic inflammation prompting high danger of cardiovascular sicknesses[12].

2.12 Particulate Matter from photocopy machine:

Toners have thermoplastic polymers of tiny particles, and its diameter varies in the range of 2-10 micrometer with an average of 5 micrometer. These are grouped as fine dust (analogue PM 10) yet not as nanoparticles. When inhaling even small amount of toner, person with existing, in most situations developed unspecified bronchial or nasal hypersensitivity could build up symptoms alike sternutation, cough, rhinitis, and whistling breathing & rhonchus[35].

Sarcoidosis is associated with consistently utilizing a printer, and regularly changing scanner toner or doing printer support and it has been observed that scanner toner in small quantity might act as formerly unidentified antigen in the Patho-physiology of a few patients determined to have Sarcoidosis[156].

2.13 Radiation & Temperature during Photocopy Operation:

Temperature is one of the major hazard when printing/photocopy machines are operated. Photocopy machines look harmless but they are not, these machines work using xerograph which involves application of heat or high voltage on tonner which releases the colour.[157] UV radiation and Infrared increases the temperature of surrounding which in turn adds up heat into the room. When size of room is small and no proper ventilation is provided or no air condition is installed in room the temperature of room gradually increases.[10] During operation of photocopying machine it was found that as the level of Ozone, VOC's, Infrared, UV radiation and working time of machine increased the temperature of room increased with time.[158] Since this experiment was done in small size room with glass door and window with no air condition the operators were facing discomfort while working. Long term exposure temperature above 35 degree Celsius effects sperm production which effects personal life. When the machine is operated for long time the glass

panel of the machine gets heated up which can cause minor burn. Increasing temperature even causes headache and even reduce performance of operator.

Indoor air contamination has turned into a noteworthy worry in the current decades. In spite of the fact that the majority of the general population are unaware about this term, many of them are becoming prey to this deadly pollution day by day. Pollutants which are present in the inside room atmosphere are said to cause numerous health problems which include throat infection, suffocation and other respiratory diseases.[159] Some surveys conducted in the past years show many reasons for indoor pollution. Among them the main contributors are the radiation from electronic machines used in the indoor environment such as printers, photocopy machines etc.[10].

Radiation can be known as an energy which is produced from unstable atoms or are produced by machines. Radiation also means that to an emitted energy that travels as electromagnetic waves, Radiation has different forms and sources, visible light and sound are the most familiar forms of radiation. Others are ultraviolet light, microwaves, gas flaring, television signals, infrared (a form of heat energy) and photocopiers[160].

The copying technology has helped the mankind in easy information transfer and saved the many useful productive man hours. The photocopying machine works on intermediary light conduction process. In this process the UV light is allowed to pass through the original document, which copies the content and is printed on the separate paper giving us the exact copy of the original document. [161].

High energy operations are required to produce the flash which is required in photocopying process. Huge amount of energy is spend, which results in high amount of radiation. Sometimes this radiation can lead to partial disintegration of toner elements which can cause serious breathing problems once inhaled.[162].

Frame shift diseases are caused by prolonged exposure to radiation which are resulting in the harmful mutation of human genes. DNA damage and several other disorders are reported in persons who are exposed to these radiations for a prolong

.[163].The harmful particles that makes entry into the human body produces abnormalities to usual and regular state and behavior of the genetic information storage areas which further causes chromosome changes in body related organs and germ cells.[164]

The specialists might be viewed as a slight hazard assemble based on looking at the chromosomal dissimilarities, for nature in which they work is debased with volatile inorganic and organic compounds, segments of toner, formaldehyde, ozone, styrene and polycyclic aromatic hydrocarbons. Additionally, if the machine is harmed or inadequately introduced in congested environment there are chance for a specialist to be in contact to UV radiation..[86].

There are permissible allowances of radiation levels emitted by these machines. A comparative study on the printing machine with UV lamps and textile printing machines showed that Digital printing machine having UV lamps releases huge amount of radiation. There is a decrease in the radiation levels during the non-operating mode.[145].

Environmental chambers are mainly used to identify and quantify the emissions of the office equipment's. Quartz or non-abrasive steel chambers operates at room temperature (21 to 23 1C) with humidity of (45 to 55% RH) are used to measure the emissions from printers or photocopy machines. These emissions are then compared with permissible amount of the radiation levels. Most of the machines produce only less radiation to the allowed level[20].

The continuous exposure to longer period of time will only cause some abnormalities in the individuals.[20].The exact problems of pollutants on health of an individual are practically very hard to obtain, as different individual has different traits and resistances. [144].

UV radiations leads to various chronic and acute effects on eye, skin and immune system it also affects skin erythema [165]. UV can also damage collagen fiber and further enhance ageing of the skin. They also destroy Vitamin C in the skin, which may cause further damage. High intensities of UV radiation are hazardous to the eyes and can cause welder's flash and may lead to cataracts formation [166]. Also

due to increase in temperature of the machine, the operator is induced to stress and muscle fatigue [167]. It can even reduce sperm quality in the males. So to avoid the health hazards from the machine due to radiation, the operator should use appropriate personal protective equipment which will reduce exposure from harmful radiation [168].

As per the studies carried out by the author, location of the photocopying machines also plays important role to cause hazards to the environment around the machine. Mostly the location the machine in the office and institutions at the basement or at the ground floor of the building [169]. Most of the time, The rooms of the photocopy focuses are described by clay tile floor, painted solid roof divider, aluminum confined glass entryways and furniture. Since there is no proper ventilation provided at the basement, the operator is more expose to the radiation from the machine compare to the ground floor area [10].

One of the major reasons for radiation is also the utilization of the machine. In the single day, at the peak time, when machine is in continuous use, intensity of radiation increases which causes direct impact on the body of operator which absorbs the radiation to some extent [170]. Also due to continuous use of machine, temperature of the machine increases which will in turn increases the temperature of the room and cause discomfort to the operator. Photo copy sheets must be encapsulated by radiation sensitive composite material to avoid the radiation emitted by the photo copy machine [171].

Although photocopy/printing machines are important in our daily life, but they come with health issues which we neglect. Some very hazardous radiations like UV rays, affect the human health those who spends their most of the time around the operating machines. There is have to take after some preparatory measures while operating Xerox/printing machine such as adequate ventilation, fresh air in room, sufficient dilution in room, use of gas mask when multiple machines are operating simultaneously, Repeated exposure should be prevented. Muscles feel stress and fatigue when they are continuously subjected to high temperature and heat.

Following safety measures and proper precautions while operating will help to prevent hazard associated with printing and photocopy machines. Also the regulations provided by the authority should be followed to prevent serious health hazard.

The operator should maintain 1 meter distance while working to prevent heat and temperature exposure from machine[172]. Proper ventilation, air condition and separate the room for photocopying measures can reduce hazard associated with photocopying/printing. Proper ventilation helps to increase heat dilution in the room and reduces the temperature even air conditioning helps to maintain room temperature. It is always suggested to use devices like computer, printer, and photocopy machines in cool room so as to prevent temperature hazard. Work rotation can help the operator to prevent temperature exposure.

2.14 Safety Measures & Discussion:

Printing and photocopying industry have revolutionized the availability of documents and perceptible image quickly at extremely inexpensive and affordable cost. Sadly, irresponsible, uncontrolled and extensive use, causing irreversible degradation to not only ecosystem by continuous release of O_3 and other VOCs but also the health of workers occupationally exposed to it.

Indoor air quality from photocopy centers of a city or for a large area in India has not been reported previously but reported for smaller area or for a center around the world by many researcher. Concentration of particulate matter has been observed twice or even more than the allowable limit during their work period. Photocopier discharge elevated amounts of particulate issue. Long haul introduction to outflows from scanners was not related with diminished lung work, but rather brought about high oxidative pressure and fundamental aggravation prompting high danger of cardiovascular illness.

However ,a person operating in photocopying machine spends an average life of 7-9 hours every day in his whole life up to a maximum age of 60 years[86] shows

normal hematological characteristics . There are no standards in our country for the indoor air quality as the hazards of the machine operation are not known to anyone. The major problem that is encountered by the people operating the machine is genetic changes in their body slowly and immediate effects are the breathing problems and lung disorders due to the toners coming out from the machine such as lead barium and many particulate matters below 2.5 which is toxic and sometimes may prove fatal also[35]. From the various studies & research conducted by the author it has been observed that indoor air pollution is cause of great concern as most of the time spent by a person is indoor & talking about the emission from photocopy machine it can be reduced to below permissible limits by taking some precautionary measures like having adequate ventilation for the flow of fresh air[173], proper maintenance of machine, using good quality of toners in photocopy machines, by closing the lid during the photocopy operation.

Emission of VOC's is more compared to emission of compounds like styrene, benzene etc. [174]. Ozone particles emitted from printers combine with VOCs to form harmful secondary pollutants.[175]. UF aerosol particles are also emitted. Computers emit higher amount of VOCs compared to PM. [176]. PM of different sizes viz, $PM_{0.1,}$ $PM_{0.1\text{-}2.5}$ are released into the air. Emission of low level of ozone, VOCs form secondary higher pollutants. [177].Dizziness, headache, nausea, irritation, inhalation etc., issues are caused by the emission of such elements in the air. PM has two different concentrations $PM_{0.1}$. $PM_{0.1\text{-}2}$. Cleaning and maintaining these products also cause health issues [178].

2.15 Safety Measures for construction of building having photocopy operation:

In modern time, photocopy/printing machines are the essential pieces of Office equipment [141]. Setting aside advantages & commercial utilization of the photocopiers, it has been observed that they are also sources of air pollution. In this process, pollutants like O_3, hydrocarbons, Volatile Organic Compounds and dust are released causing Indoor air quality problems.[42]. Among this gases, Ozone is

highly toxic gas and it is one of the most serious health risk which results into health issues such as headache, dryness in eyes, mucous irritation & tight and dry facial skin [179].

From different examinations, it has been accounted for that there was hoisted DNA harm, among administrators in the printer focuses [180].The operators of the photocopier machines, have a very high prevalence of breathing or respiratory problems such as excessive sputum production, blockage in the nasal and breathing troubles when it was compared to the control subjects. The reason behind this might be due to high exposure to particulate matter. This can further contribute to increase in respiratory symptoms and paranasal sinus diseases and also chronic nasal [181].

The process of mixing or replacing contaminated indoor air with the fresh air coming from outside the building in order to decrease the level of its indoor contaminants is called Ventilation. The types of Ventilation methods used are Mixed Ventilation (MV), Displacement Ventilation (DV), Personalized Ventilation (PeV) and Hybrid Air Distribution (HAD) [182]. The main purpose of providing Ventilation is to supply occupants with a suitable and good quality of inhaled air, and also to dilute the airborne contamination present in it.

Nowadays, in many office settings, the Ventilation Rate Procedure is preferable. It has been observed from studies that the minimum suitable exhaust rate for printing and copying rooms is 0.5 cfm/ft2 (i.e., cubic feet per minute per square foot of the floor space)[183]. And it should be replaced with the same volume of fresh or pure outside air or with adequately filtered, and re-circulated air delivered with requisite mixing [184]. There should be a minimum of 10% outside air to be mixed with the re-circulated air for office buildings. The emissions can be diluted to acceptable levels with the help of this method of allowing enough clean air to the space [185].

For some photocopy machines, printers, or duplicators, there are Ventilation kits available, these are exhaust ventilation systems, which removes the air directly from machine to an exterior location. An acceptable quality of air related with usual emissions from the machine is attained when a ventilation kit is installed [186]. In ventilation, the outdoor air supply rate should be 2.5-10 L/s according to Standards and Guidelines [187].To measure ventilation, the parameter called RCH (Room air Changes per Hour) has been used earlier. In Ventilation rate procedure, the ventilation rate that has been specified is expressed in terms of RCH, but it completely depends on the parameters - room ceiling, its height and the floor area [188]. The World Health Organization (WHO) recommended that the continuous ozone exposure should be controlled below 0.05 ppm.

The idea that all air in a space can be changed is dependent on the completeness of new air displacing existing air, which is dependent on circulation and dispersion. Air changing requires that in- flowing air Q be equal to out-flowing air Q (Q in = Q out). Air change rates depend on the usage of the space but generally range between 2 (2 air changes per hour) and 20 for high use spaces like paint shops, for example [189]. In the 1950's, some high-rise building fire protection systems neglected air change resulting in catastrophic death rates from smoke under fire conditions. Venting systems are very concerned with indoor air quality. Venting systems work to change the air in a room or space for air quality purposes. It has been found from studies that the use of a ventilator decreases an average concentration of ozone near its source up to 50 µg/m3,which is from an initial of 280±63 to a final of 235±52 µg/m [17].

CHAPTER-3

3 Research methodology

3.1 Theoretical framework-

Previous work [30] highlights the emission of different type of volatile organic compound from office equipment's like printing and photocopy machine and due to their potential health effect toluene, styrene, ethylbenzene and benzene and their carcinogenic activity[20] have attracted much attention for their assessment and management for sustainable development. Indoor air quality of the place where the photocopier machine functions has been observed poor due the release of the Volatile Organic Compound (VOC) like Benzene[32],[33] and emission rate increased with increase in indoor temperature [32].

It was also observed that the emission of this VOC depend upon the toner that which we are using in the photocopier it is also observed that the toner which has thickness less than 0.01 has less emission of VOC than others [34]mainly ozone. In a ventilated office condition, the sums experienced for singular unpredictable were inside suggested exposure limits for a well-maintained density of printers [32].

Study reveals that there are even emission of the UV radiations because of this photocopier machine and these are also harmful to the person who is taking this as the profession and it also said there is no relation between the emission of the ozone and the UV radiations[10, 44]. Numerous word related medical problems like eye, nasopharyngeal, and skin indications, migraines and torpidity, just as to the event of wheezing, cough mucus production, sinusitis, and intense bronchitis [44, 190] has been observed.

3.2 Source of data-

Primary data has been collected through active monitoring of hazardous emissions in photocopying and printing areas. As no equipment is present by which ergonomics can be measured so it was assessed by observation and posture related ill effects among the workers while carrying out the field survey and interviewing

the workers. A questionnaire was used to collect data regarding the Socio-economics, health and ergonomic issues related to photocopying and printing. An exhaustive literature review with approx. 200 literature has be done to collect secondary data.

3.3 Sampling & Analysis -

3.3.1.1 ***Indoor Air Quality Analysis (Environmental assessment):***

Different hazardous emission sampling from photocopy and printing machine qualitative and quantitative information about local sources, no of worker, area of working, topography, climatology were collected based on the objective.

The study was conducted at Dehradun, field survey of 95- photocopy centers were done for data collection while air quality assessment was done at 85-photocopy center. Convenience sampling technique (where the sample is taken from a group of people easy to contact or to reach) was used. Socio economic survey using semi-structured questionnaire of 183 photocopy operators was done.

The photocopy machine operation has been divided into four season and sample was collected for all four season (duration of 3 month each season) for precise result, four seasons considered were (Jan-March, April-June, July-Sep, and Oct-Dec).

Indoor air quality of photocopy centers were assessed for all the seasons and total five major indoor pollutant due to photocopy operation have been considered. Sampling and analysis for all five pollutant namely CO_2, CO, VOC, HCHO & Ozone, their relationship with multiple environmental condition has been determined. Parameters considered for environmental (indoor air quality assessment) were:

a) Ventilation rate & concentration of pollutant
b) Number of photocopy/print & concentration of pollutant
c) Working duration (machine operation) & pollutant concentration

The equipment used for sampling and analysis were:

i. **SKY8000 Gas Analyzer,Safegaser-**

CO, CO_2,SO_X,NO_2.HCHO,C6H6**:** Various principle sensors can be combined - catalytic combustion principle or infrared principle; oxygen: electrochemical principle; toxic: electrochemical principle; CO_2: infrared principle.

Figure 2:SKY8000 Gas Analyzer,Safegaser

Operating procedure:-

- After the instrument is turned on and enters the detection interface, the standard gas with known concentration is connected to the instrument's inlet through the PTFE pipe.
- Enter the instrument "Concentration Calibration", select the gas channel by using the “Λ” and “V” keys, and enter the "Concentration Calibration Point" submenu by using the "OK" keys.
- According to the actual standard gas concentration value (550PPM), the nearest calibration point (secondary concentration) is selected by using the “Λ” and “V” bonds.
- Press the "OK" button and enter the setting parameter mode. Modify the right value (setting value) to be the same as the standard gas used.
- Open the standard gas valve and input the standard gas of the target gas to the instrument at a flow rate of more than 500 mL/min (milliliter/minute). After the real-time concentration (upper and middle) displayed by the instrument is basically stable (about 1-3 minutes, the stabilization time of different sensors is different), press the "OK" button, and the instrument head "beep" to calibrate the state. Display "Succeed", that is, complete the calibration operation.

- In the "concentration calibration" submenu, you can press the "ESC" key to return to the upper menu at any time, or press the "MENU" key to return to the detection interface.
- When performing this operation function, it is necessary to confirm that the standard gas pipeline has been connected. The calibration can be carried out only after the value of the instrument is stable, otherwise the display data will be inaccurate.
- Setting value: the actual concentration of the current standard gas is input.
- When selecting the calibration point, the principle of " Zero point < First point < second point < Third point" should be followed, otherwise the instrument calibration will fail.
- In the main menu interface, use the four directional keys of“∧”、“∨”、“＜”、“＞” to move the cursor and select the option of, then press the OK key to enter the, Datalog sub-menu
- Press the ESC key in the submenu interface to return to the main menu interface.
- In the "View Date" option, it indicates that you want to view the historical data or curve of the specified date, use the "OK" key to enter the setting parameter mode, use the "<" and ">" keys to move the parameter bit to be set, use the"<" and ">" keys to modify the value, and then press the "OK" key to complete the setting.
- In the "View Type" option, it means to view the stored data according to the specified type. There are "History Data" and "History Curve", respectively. Use the "<" and ">" keys to switch the type of view.
- In the "Datalog" interface, use the “∧” and “∨” two directional keys to move the cursor to select the "Data Export" option, and then press the "OK" key to enter the "Data Export" sub-menu.
- Press the ESC key in the submenu interface to return to the Data Storage interface.

ii. **Handheld Gas Monitor Model, 275:** O_3 Sensor Head Model SH-EOZ with Measuring range: 0-100 ppm.

Figure 3: Handheld Gas Monitor Model,275 with O_3 Sensor

Operating procedure:-

- Press and hold the force button until the screen enacts. The screen will turn on and it will show display.
- To enter, look down in the set up menu and select "Units".
- Choose between ppm or mg/m3 by means of the parchment catch and press enter to affirm the unit determination
- If there is a temperature and moistness sensor appended there is the choice to browse either °C or °F.
- To enter, look down in the set up menu and select "MAX MIN AV"
- Select "start" to start the estimation cycle and come back to the arrangement menu
- To select the area ID, look down in the set up menu and select "Area ID".
- Press "enter" to affirm the ID and come back to the set up menu.
- The output sensor can be found under "Screen SETUP", look down in the screen set up menu and select "output SENSOR" and select the important parameters.
- Take the estimation and interface the screen with the PC and download the information for planning the focus chart.

iii. **Pho-Check Tiger (PPB Range) PID Detector:** VOCs Wide Detection Range:1 PPB to 20,000 ppm

Figure 4: Pho-Check Tiger (PPB Range) PID Detector

Operating procedure:-

- Press and hold the force button until the screen enacts. The screen will turn on and the presentation.
- To enter, look down in the set up menu and select "Units".
- Choose between ppm or mg/m3 by means of the parchment catch and press enter to affirm the unit determination
- If there is a temperature and stickiness sensor appended there is the alternative to look over either °C or °F.
- To enter, look down in the set up menu and select "MAX MIN AV"
- Select "start" to start the estimation cycle and come back to the arrangement menu
- To select the area ID, look down in the set up menu and select "Area ID"
- Press, "enter" to affirm the ID and come back to the set up menu.
- The output sensor can be found under "Screen SETUP", look down in the screen set up menu and select "output SENSOR" and select the significant boundary.
- Take the estimation, associate the screen with the PC, and download the information for structuring the fixation chart.

3.4 Validation of experimental data:

Based on the number of photocopies per hour as well as temperature the concentrations of emissions, toxic chemicals, varies and these values were computed and validated using ANSYS (Fluent 2015) software. The values obtained

are grid independent. The dimensions of a room are taken according to ASHRAE (The American Society of Heating, Refrigerating and Air-Conditioning Engineers) standards.

The flow of air in and air out is calculated using the below formula:

Q= KAV (ASHRE)

Where K= coefficient of effectiveness (depends on direction of wind)

A= area of smaller openings in m^2

V= wind speed in m / second

Q= air flow rate in m^3 / hour

Transport of VOCs ant their diffusion in indoor condition has been considered for development of CFD based model.

CFD based model hypothesis:

- VOC-air mixture ,fluid
- Mixture air-VOCs, ideal gas of perfect gases (air and VOCs);
- Newtonian fluid -Mixture air-VOCs, incompressible.
- Chemicals considered as non-reactive to each other.
- Within the mixture mass transfer and heat, transfer was considered as insignificant.
- Ideal gas law for - Density of mixture air-VOCs,
- Specific heat capacity of mixture air-VOCs, mixing law formulation
- Thermal conductivity and viscosity of mixture air-VOCs, expressed through kinetic theory;
- Diffusion coefficient of VOCs in air has been taken from the observed data.

CHAPTER-4

4 Results & Discussion:

- **Socioeconomic Assessment**
- **Assessment of ergonomics (occupant involve in this operation)**
- **Environmental Assessment (Indoor air quality)**
- **Tool for Cancer Risk assessment**
- **Tool for occupant ergonomics assessment**

4.1 Socioeconomic Assessment

Most of the population worldwide especially in underdeveloped and developing country have very less or no control over various social, economic, cultural and environmental issues. Week section of the society (economically as well as in literacy) are the critical component of the community as they are the most common people exposed to multiple hazards due t6o their week work. Multiple workplace hazards are very common in the work place like educational sector and different types of corporate office where printing and photocopying is very common.

In a country like India, unorganized sector has always played a crucial role on the employment of larger workforce in different sectors. Unorganized Sectors are those where workers and tiny economic units that are not registered, recorded or regulated by any formal code of practice[191]. Any country growth has highly dependent on all the informal sectors across different types of occupation. The labor under these sectors is somehow under the category of unskilled and of semi-skilled because of increase illiteracy. Statistically Unorganized sector in India accounts for 92 percent out of the 376 million of workers [192]. This gives us an understanding of their involvement and ultimately defines a sole source of all economy. Hence it is very necessary to give importance to socio economic and welfare conditions of these sectors. Even though the labor working in these sectors are contributes a major

share to the economy are elusive of social security and backwards in case of socio economically, literacy rate, politically and other aspects [193].

The labors of the unorganized sector do not have any access to organized social security system due to absence of enforcement by any regulatory board. This also excludes them to avail organized health services. This fails to look after their health and ultimately contracting acute or chronic diseases or disability arising from the occupational health hazards. The lack of social security will increase the liability of the occupational health hazard on the workers. The majority of the workers are unable to identify the OH&S hazards due to lack of awareness and knowledge, thus exposing to several risks [194].

This work was an attempt to analyses the socio- economic and working condition of workers in unorganized sector with special emphasis on photocopying. The assessment with respect to multiple indoor air pollutant (Ozone, Volatile Organic Compound (VOC), Particulate Matter, Compounds of Sulfur and Nitrogen) provides that 50 percent of the correspondent fall under the category of 15-30 years of age group and 75 percent of the correspondents does not have a formal education, which indicates the high illiteracy rate in the unorganized sector.

4.2 Working Conditions of the Workers at Photocopier Centers:

Generally, the working condition in photocopier centers refer to the working hour; skill and competency of the worker, nature of job undertaken, a surrounding area where the job has to be performed. Since there is no pre-determined job they have to perform at a specified time, the workload is directly proportional to the number of customers and the required number of photocopies. Typically, the working hour is between 10-12 hours a day and the opening and closure of the shop is dependent on the weather. The absence of provision for working hours for workers has led to increased shift timing without any additional overtime wages. The ordinary wages of the workers comparatively lower to the organized sector of similar skill sets. The worker in this sector are not completely devoid by labour laws comparatively to the formal sectors whereas laws such as equal remuneration, hazardous nature of work,

abolition of child and bonded labour etc are applicable to these sectors also [195]. During the site survey, it was also observed that 90 percent of the photocopier centers were ill-ventilated, only a few of them found to be equipped with mechanical exhaust ventilation and proper natural ventilation by windows openings and doors. As discussed earlier photocopier machines emit hazardous pollutants that are dangerous to the workers and may contract the chronic disease if not ventilated properly. On average the photocopier centers were occupied by four to seven people at a time which sometimes makes the space overcrowded to an extent hazardous to the workers employed therein. During the personal interviews, some of the workers also reported having facing problems while performing the activity such as back pain, hearing disorder and irritation of eyes and skin. It is also difficult to distinguish between the diseases already has been there before joining this job or they contracted as an occupational disease while working on it due to the absence of a medical surveillance program.

This study draws the co-relation between several aspects of working conditions to the workers' health. All these aspects have numerous impacts on the worker's mental and physical health which directly related to worker performance. For the most of photocopier centers surveyed, the average height of the photocopier machine is to be found between 2.5 ft.to 4.5 ft. of different models so to a better understanding of ergonomic conditions we took a mean value i.e. of 3.5 ft. Consequently, to work at this height a good posture has to maintain to avoid ergonomic problems to the workers. Since the daily photocopying is varied with customer demand but although the calculated mean was nearly 300.

4.3 Socioeconomic Estimation:

This section assesses the condition of work and life in the unorganized sector in photocopier centers across the Dehradun City and based upon the current scenario it pushes the greater need for social security of these informal workers. This study is stratified by self-employed workers, casual wage workers, salaried workers, and support visitors. The earnings from this source of informal sectors are irregular and

often inadequate and it also doesn't provide any income security[196]. The welfare conditions are inadequate and workers are exposed to hazardous working conditions daily. There is no regulation for paid leave or sick leave in this sector or workers are elusive of any other necessary benefits.

During the study, the majority of the workers were found to be between 15-30 years of age and most of them were unmarried. The social status was mixed with the least of general category workers and maximum correspondents were living in the individual nature of family. The chart also depicts the education qualification of the correspondents in which a very less percentage of them attained formal education. The average age of the photocopiers workers was found to be in the mid-'30s around 70 percent to be found illiterate and the majority of those who can read and write were having attained primary education. The fact that the majority portion remained uneducated is due to the lack of social security and socio-economic condition of their families. The workers feel less empowered politically and economically due to a lack of support by the absence of regulation [197].

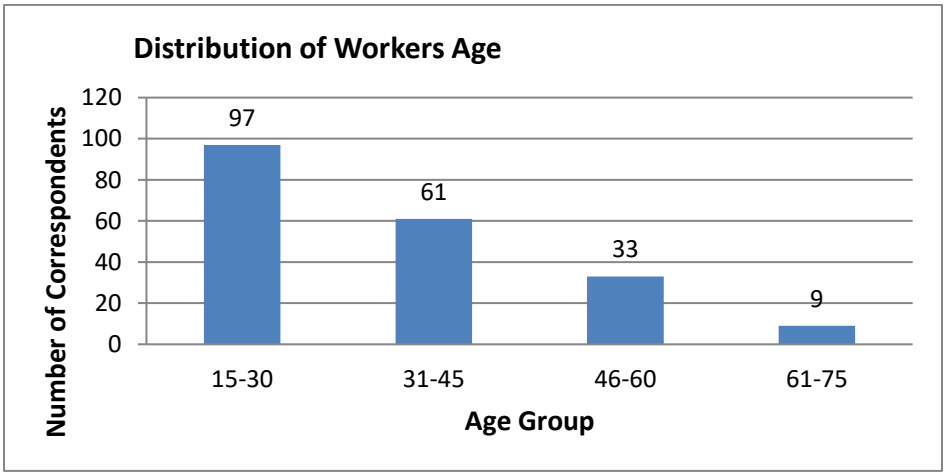

Figure 5: Age group of workers

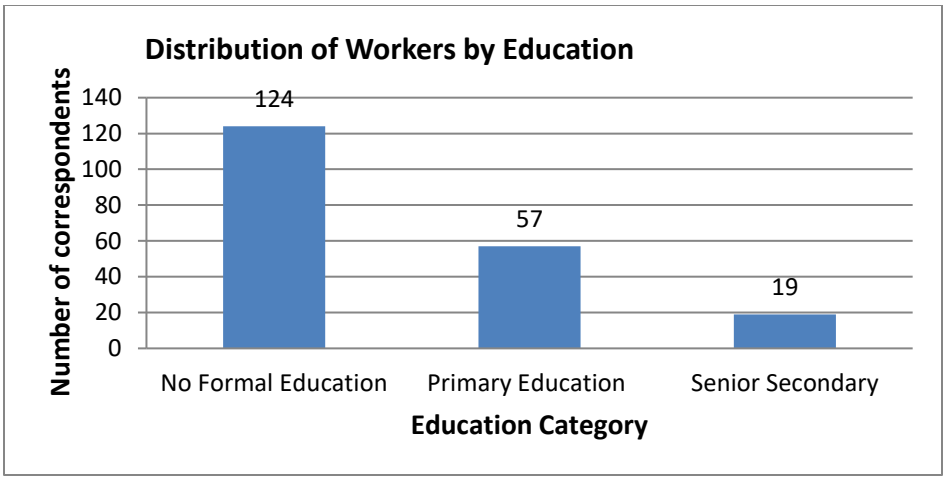

Figure 6: Educational background of occupant

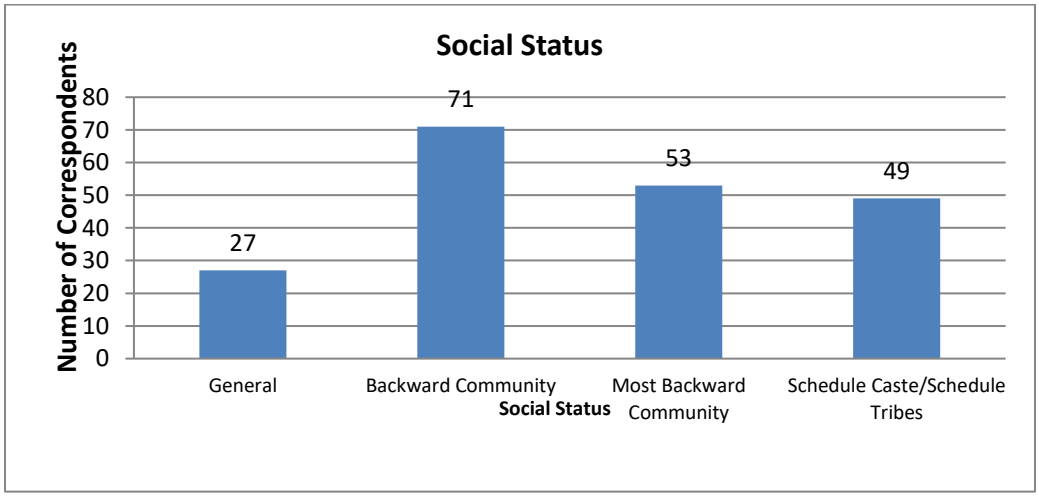

Figure 7: Social Status of the occupant

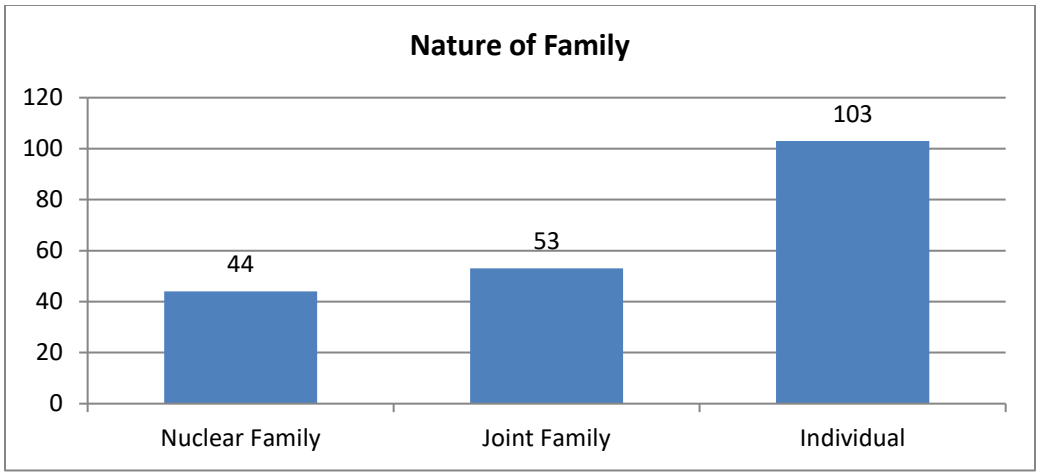

Figure 8: Family type of occupant

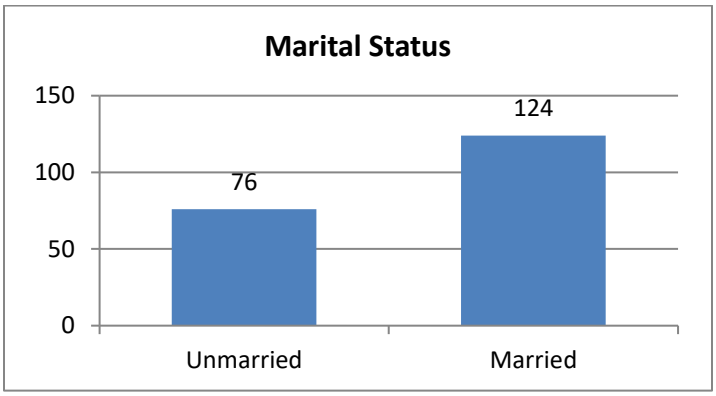

Figure 9: Marital status of the occupant

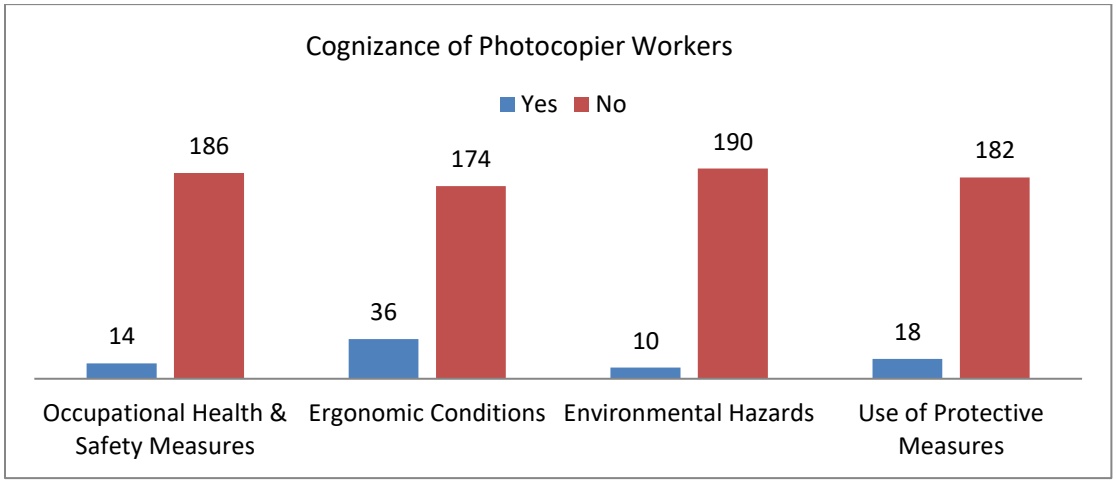

Figure 10: Cognizance of Photocopier Workers

The workers in photocopying centers lack the welfare and social security support that ultimately increases liability and decreases work performance. The assessment provides that 50 percent of the correspondent fall under the category of 15-30 years of age group and 75 percent of the correspondents does not have a formal education, which indicates the high illiteracy rate in the unorganized sector. The social status of the correspondents to be found in uniform in nature concerning all the categories but the majority of them found to be under a backward community. According to the findings of our survey, 75 percent of the correspondents were unmarried and the majority of the nature of family they were living in was Individual. Since there is a presence of certain social security schemes by the government of India but unfortunately due to the lack of awareness does not reach them.

4.4 Assessment of ergonomics:

Operators working in photocopy machines were classified into eight different groups. Figure 11 disclosed that from a total of 183 operators, major part (23%) belong to a range of 22- 27 years, whereas 4% belong to 51-55 years. Statistical study regarding the period of employment of 183 workers, showed that nearly 32% of the operators were found to be employed on these machines from 3-8 years, whereas 3% of them were found to be working on this machine from 19 -21 years (Figure 12). Vast number of the operators (40%) were employed for 8-10 hours but the job rotation was not observed at any center. It was found that ample work hours and lengthy work years could be a major contributor to back pain, wrist pain, numbness and other occupational health issues (figure14). Divergent problems due to awkward working postures were significant amidst the employees (figure 15). Lack of monetary funds and competent OHS personnel are the primary concerns to lead a proper health and safety culture at work environment. Insufficient generic knowledge can create a huge issue among the workers. Lengthy years of work can perturb the strength, work practice, adjustment with the environment and other environmental aspects and related hazards. Data analysis in figure 12 represents the effect on health with respect to the period of work years.

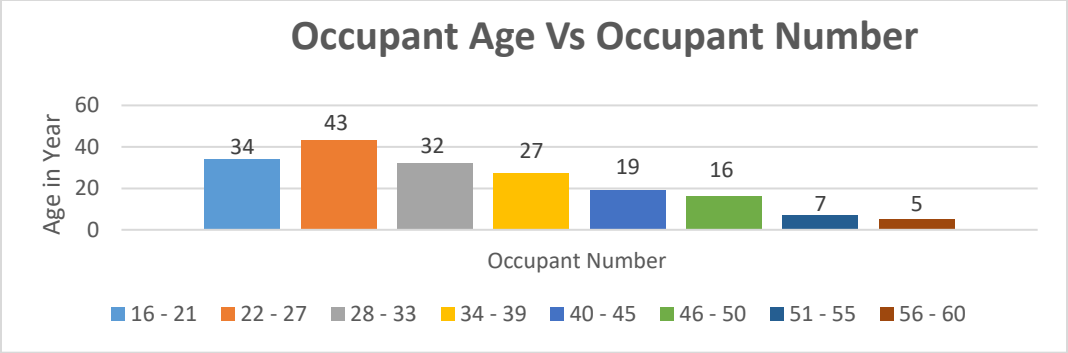

Figure 11: Occupant age at photocopy/printing center

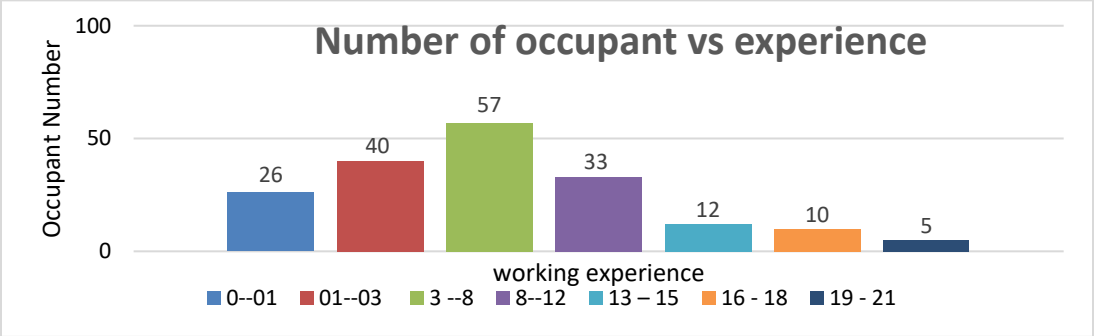

Figure 12: Work experience of occupant at photocopy/printing center

Just 33% had enough knowledge with respect to the working stances/body posture and its effects. The absence of awareness to these working stances/body postures brings about agony in various body parts and decrease in profitability. Dominant part (65%) of the copier operators did not thought about the protective measures. These low awareness level results in exposure of these occupants to possibly hazardous conditions and circumstances, manual topping off cartridges and cleaning toner powder with uncovered hands subsequently amplifying skin contact, absence of appropriate hand washing before food edibles advances admission of toner into occupant's body. A large population (71%) believed ventilation of work place to be significant. Greater part (53%) operators had no worry about the plan/territory of work place. As occupant stays longer duration at work place and they are prone to this hazardous condition, a proper height must be provided to safeguard them.

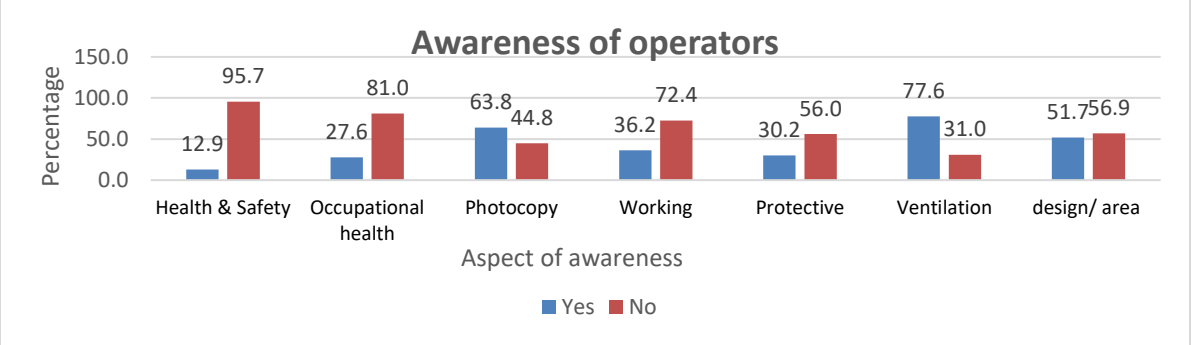

Figure 13: Awareness of occupant

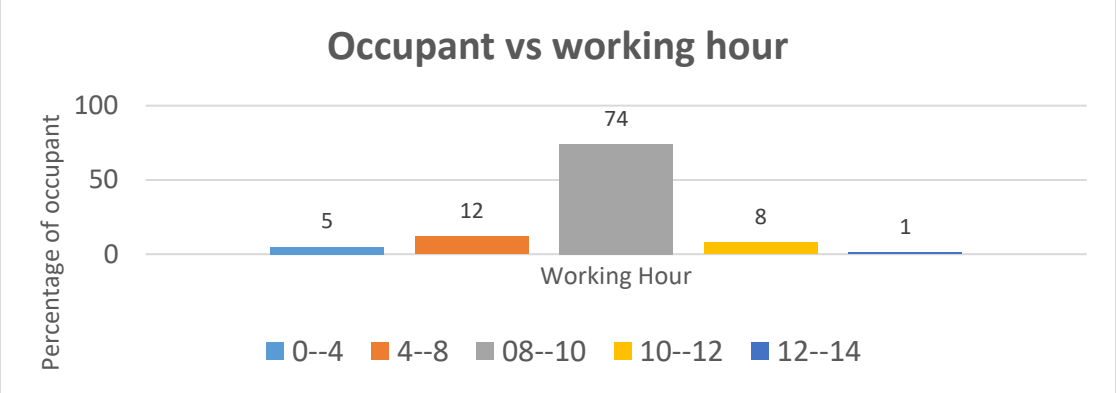

Figure14: Working hour of occupant at photocopy/printing center

There are many factors in the workplace that will affect the worker while he is working, out of which the area and the kind of arrangement available for seating has a greater influence on the worker satisfaction, posture, and efficiency. Figure 15 represents the data obtained for various aspects like height at which the worker is working, awkward posture, work injuries, temperature at the workplace etc., Workplace that does not have proper means to keep the working environment cool can cause lot of discomfort to the employees like headache, body pain, fatigue etc.

This can be reduced by providing proper ventilation either through natural or by artificial means. Of the total 183 workers who were questioned, 675 of the workers complained about the temperature of the working environment, 44% complained about having stress due to heat, 52% told that they worked with a proper posture and 48% of the workers told that there was no need for any external ventilation. Proper work postures while carrying out work, will help to reduce fatigue, muscle

strains, tendons and decreases the risk of the MSDs injury. 655 of the photocopy machine workers claimed that they always kept the lid of the machine open before they did any photocopying, due to which 47% of them claimed that they had irritation in their eyes. In case of noise, only 27% of the operators felt that they were getting disturbed whereas the remaining 73% were not having any signs. 20% of the workers were exposed to have hearing problem. This type of hearing problem is mainly due to continuous long term exposure and closeness to the source.

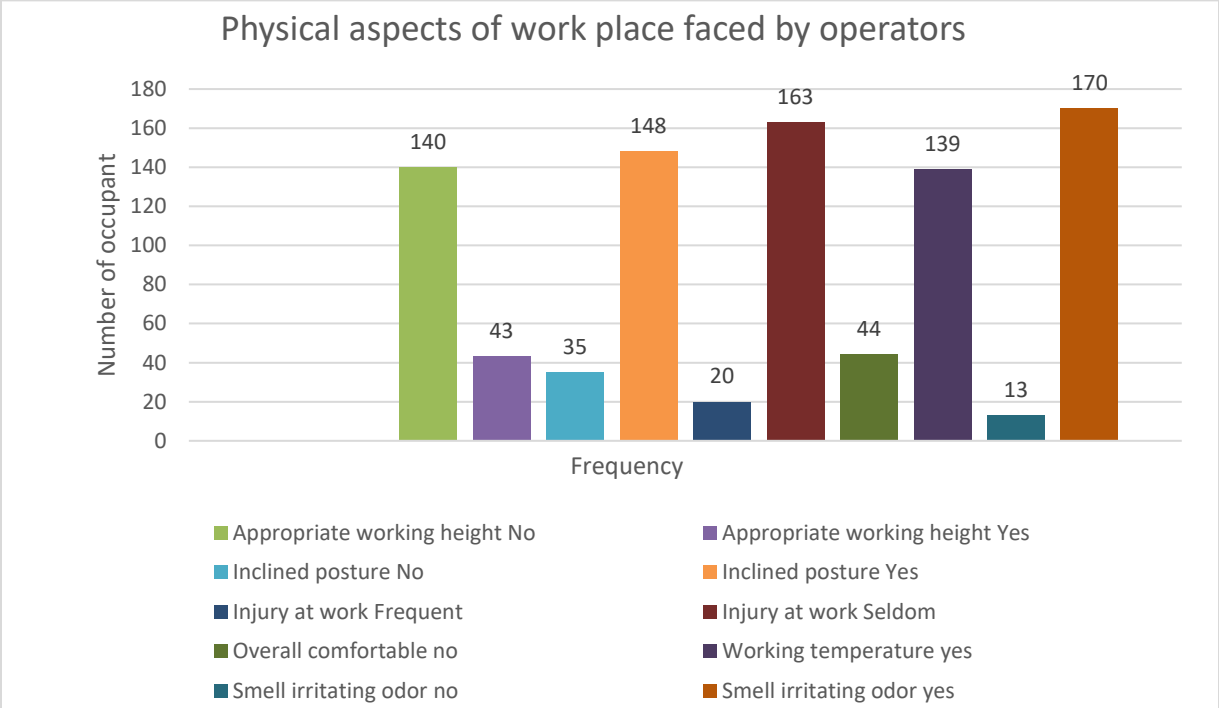

Figure15: Physical aspect of workplace faced by operators

Survey conducted regarding health issues showed that, 41 workers suffered from dryness in the mouth, 78 had itching issues, 72 had pain in the back, 69 had problem related with respiratory track, skin rashes were prevalent among 73 workers, 30 had dryness in the eyes, 43 workers had abdominal pain, 21 experienced fatigue, 23 had anxiety issues, 4 suffered from fragility, and 47 had pain in the wrist (Figure 16). The hazards prevalent in the confined spaces are larger than in general work environment as they are mostly confined. Improper sleeping pattern, excess job time are the results of mental stress and mood swings in the workers. Diseases

associated with eyes, nose, throat etc. are very common among these workers because of emission from the machines.

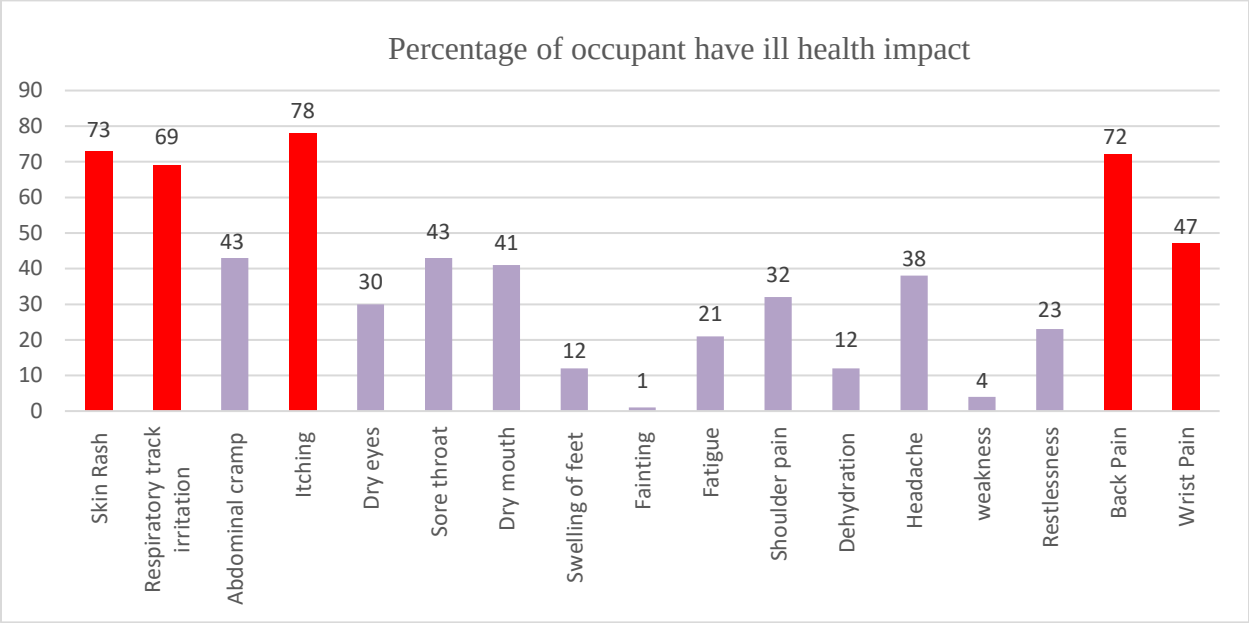

Figure 16: Occupational ill effect

Skin rashes (40%), Back pain fatigue (39%), respiratory track irritation (38%), and itching (43%) were common among the employees employed for 1 to 3 years. Almost similar kind of health effects were found among people having work exposure of 4 to 6 years. Survey done among workers employed for 7 to 9 ears, revealed that 59% suffered from back ache, 64% from exhaustion, and they also had mouth dryness, throat ache and irritation in the respiratory tract. Back pain and itching were the major and most prevalent health issue among all the age group. Improper hours of work, poorly designed work surface and surroundings can result in weakness, stress, strain among the workers. Among the workers employed for 4 to 6 years, the most common and recurring ergonomic related problem was back ache. For 13 to 15 year employed group it was pain in the shoulders and for people working for more than 15 years it was inflammation of heat and leg numbness.

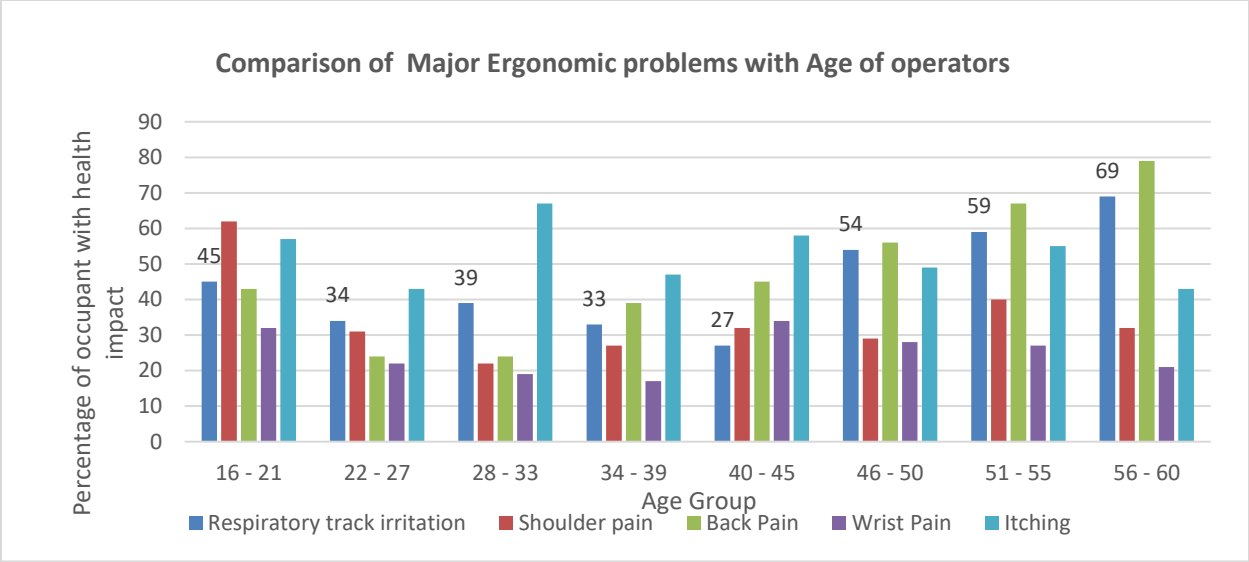

Figure 17:Major ergonomic issues with occupant

Appropriate ergonomic designs with respect to machine height (in most of the center it was not appropriate, figure 18) and shift base work are required to prevent recurring stress and strain. Using Pearson correlation the emissions from the machine were correlated from each other and it was found that there was a strong relation among each other. Itching, fatigue and head ache were very common health issue among the workers, of which fatigue and headache was found to affect all the age groups. Comparison of the ergonomic problems revealed that pain in the neck and swelling were most common.

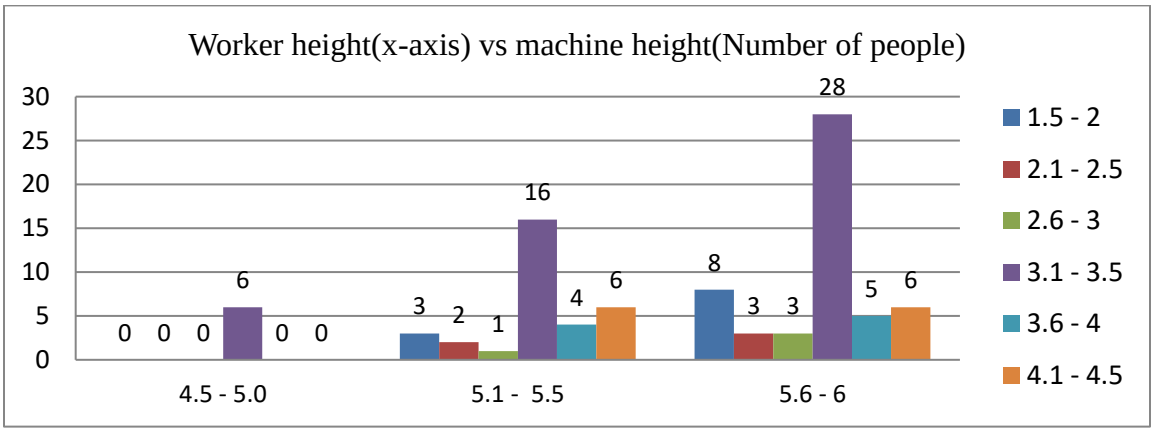

Figure 18: machine height v/s workers height

It is recommended that people employed in the photocopy machine should be given trainings and awareness to make them understand the hazards and prevent the injuries, also provide periodic health checkups to monitor the health conditions. Design the workplace appropriately to decrease the diseases arising from the work environment. Ventilation should be provided irrespective of the season to ensure sufficient air flow within the workplace.

The workers must put to practice efficient preventive measures while performing any specific operations like maintenance work, replacing the jams in the machine, filling the toner cartridge as these activities may expose the worker to more hazards. Always the lid of the machine must be kept closed in order to avoid the reflection of light which in turn troubles the eyes and cause disturbances. The workers must be given training about the postures which will make them comfortable during the work. To decrease the level of stress and strain experienced by the workers they should be provided with ergonomically designed workplace and shift based work. The workers involved in housekeeping of the machines must be given proper training.

4.5 Environmental Assessment (Indoor air quality)

People working in photocopy machines are susceptible to have health issues such as respiratory problems, Physical, and musculoskeletal system. This analysis particularly investigate the indoor air quality of different photocopy/printing center with respect to concentration of pollutant and its variation with different parameters. Data Analysis suggests that pollutant concentration and emission majorly depends on ventilation available, rate of photocopy/printing and work duration i.e. operation time of electronic machine.

4.6 Concentration of indoor pollutant at different environmental condition in photocopy/printing center

Indoor air quality of photocopy centers were assessed for all the seasons and total five major indoor pollutant due to photocopy operation have been considered. Sampling and analysis for all five pollutant namely CO_2, CO, VOC, HCHO &

Ozone, their relationship with multiple environmental condition has been determined. Parameters considered for environmental (indoor air quality assessment) were:

a) Ventilation rate & concentration of pollutant
b) Number of photocopy/print & concentration of pollutant
c) Working duration (machine operation) & pollutant concentration

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4.6.1.1 *Concentration of CO_2 at different environmental condition in photocopy/printing center*

In order to address issues related to environment, enormous amount of effort are put in place. Physical work environment related health issues has two approach, which includes proper design of the work environment for a healthy diet, life style and controlling the issues affecting the environment due to the presence of toxics, pollutants etc. Adequate space for layout, which enables easy movement in the workplace, usage of stairs, space for fitness, room for eating, or biophilic design are the aspects on which the health promoting environmental design focuses on. Controlling and monitoring factors of the environment stresses upon concepts like indoor air quality, temperature, acoustics and lighting. Ventilation play a major role in ensuring thermal comfort and good indoor air quality. There are several reasons for installing a ventilation system. First, is to supply sufficient fresh air for metabolism and contaminant dilution. Through air extraction, a ventilation system removes contaminants, unwanted heat and moisture from a room. Besides, a ventilation system supplies enough oxygen for combustion purposes, ventilation systems separate different of an indoor environment in order to isolate a polluted zone. A smoking room is one example of isolation. Ventilation systems create a pressure difference between rooms to avoid pollutants getting in or out.

Quality of air in the indoor areas depends on lot of variables such as outdoor air quality, ventilation design, air conditioning provided, maintenance system, dividing the buildings into compartments and the amount of contaminants present inside the indoor areas and the quantity.

Insufficient ventilation and contaminants that are found indoors are the most common cause that results in lot of defects. Insufficient ventilation are caused due to improper air supply, inappropriate design in the workplace to allow air into the building, poor dispersal and improper air mixing. All the above reasons can lead to unforeseen pressure which pave way for undesired air currents, frequent change in the thermo hygrometric characteristics as one walks around the building. Five major pollutant has been taken under consideration based on literature review; CO_2, CO, VOC, HCHO & Ozone.

Figure 19 represents the variation in CO_2 concentration with respect to ventilation available for the entire photocopy center. The sample has been analyzed for all the season and maximum concentration of CO_2 has been observed highest in the photocopy center having least ventilation system available i.e. 0-5% of the total floor area. Highest CO_2 concentration was 1980 PPM (Threshold Limit value(TLV),1000 PPM,ASHRE) while the lowest value 400 PPM was observed with highest ventilation center i.e. 0-20% total floor area with exhaust system installed (figure 19). Sick Building Syndrome can occur due to inadequate ventilation per personnel which is caused by increase in carbon dioxide concentration.

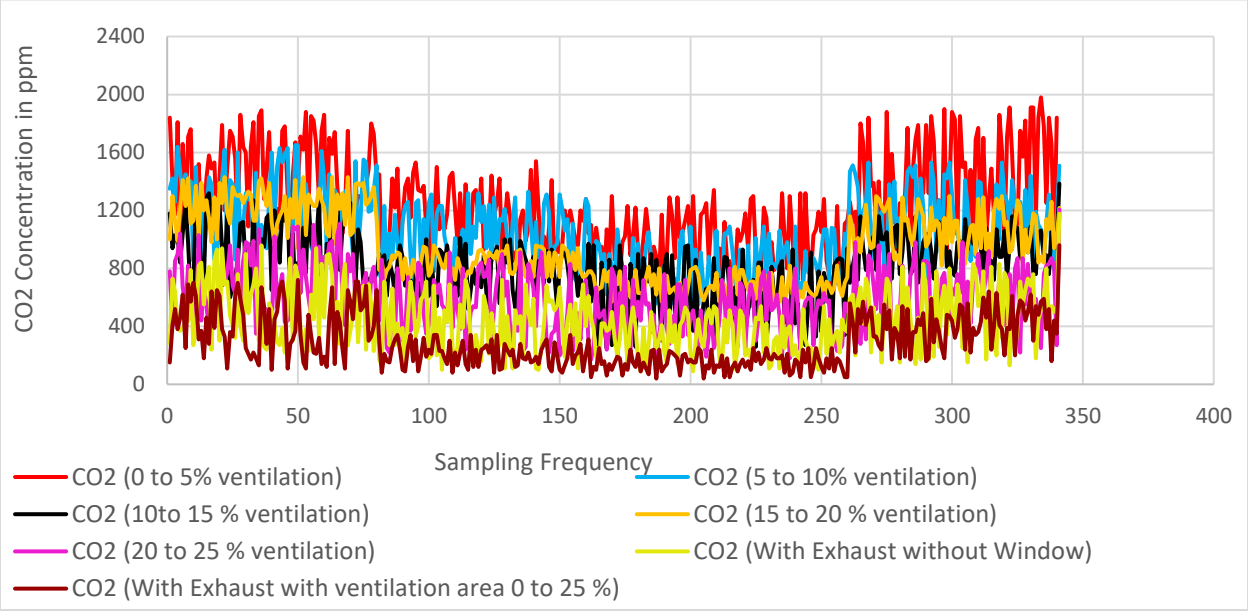

Figure 19: Variation in CO_2 Concentration with vantiltion available at different photocopy center

Furthermore, it was observed that concentration of CO_2 increases with number of photocopy (Figure 21) as well as time of operation (Figure 20) of the equipment. This increase in the emission is due to increase in temperature of equipment, which leads to higher concentration.

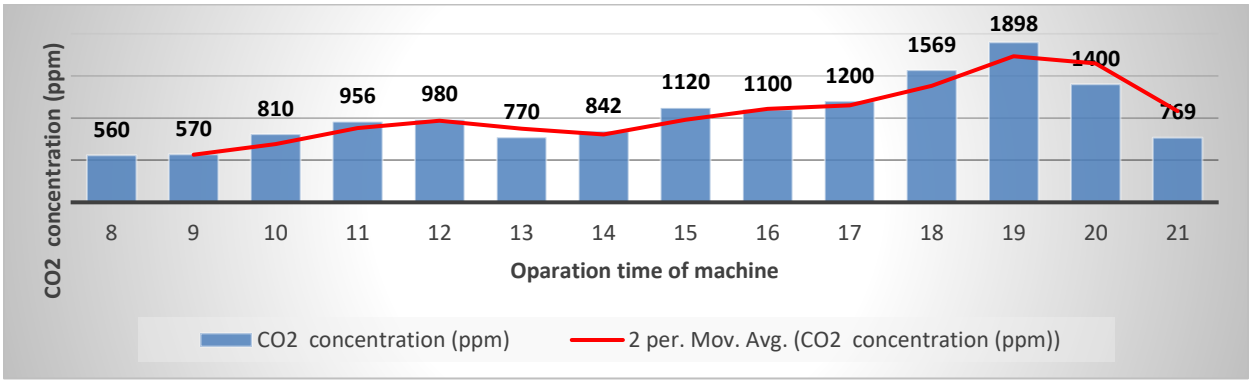

Figure 20 variation in CO_2 concentration with time of operation

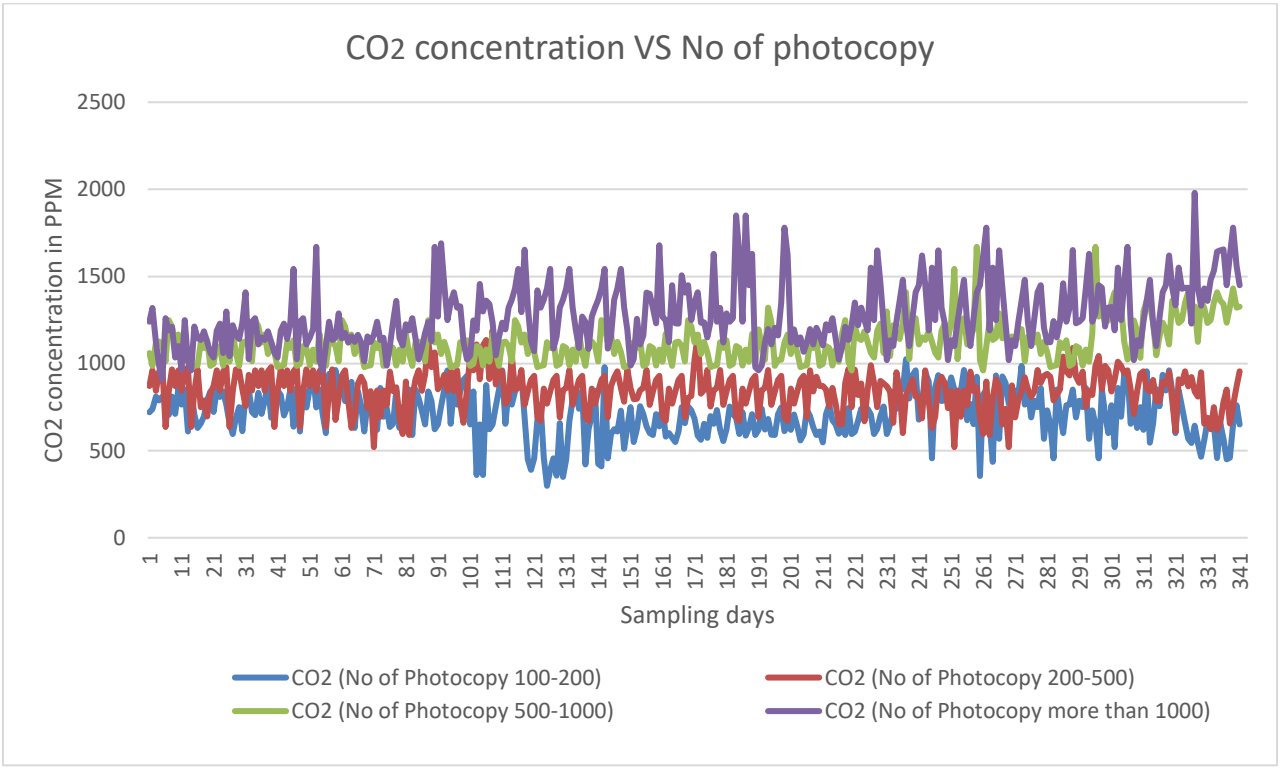

Figure 21: indoor CO_2 concentration v/s No of photocopy

When the indoor CO2 concentration goes beyond 1000 ppm, it is believed to show ventilation rates that are very offensive in terms of smell of body. Those having

levels lower than 1000 ppm, shows that ventilation rate is insufficient to remove the contamination. It is difficult to classify the carbon dioxide concentration found indoor as it is always evaluated on the basis of the occupancy and ventilation rate as it varies based on the time. Total CO_2 evaluations in the photocopy centers gives a crucial ratio of printing/photocopying center which is not likely to satisfy the ASHRAE Standard 62-1999. This kind of scenarios are more prevalent in the printing industries, which is endorsed by variety of calculations. There is no valid reason that, increase in the CO2 concentration were only for specific photocopy centers. There is no proper investigation that symbolizes that, there is circulation of Carbon dioxide in the photocopy centers. Release of different contaminants from the people occupying the place, the materials and fittings used in the building must fulfill the provided criteria. Study shows that apart from the various health issues, common cold and flu must be given special mention because they are the respiratory illness caused due to decreased rate of ventilation.

4.6.1.2 *: Concentration of CO at different environmental condition in photocopy/printing center*

Highest CO concentration was 11 PPM with lowest available ventilation area i.e. 0-5% while the lowest value 0.8 PPM was observed with highest ventilation center i.e. 0-20% total floor area with exhaust system installed (figure 22). The analysis revealed that, the concentration of Carbon Monoxide (CO) is higher in indoor levels of printing/photocopying center (11ppm) than the acceptable concentration i.e. 0.2—4.1 (WHO, 2010). Recent study does not focus on the penetration of Carbon Monoxide present in the atmosphere into the indoor areas. This is in relation with the results of analysis where CO concentrations in printing/photocopying center was higher than outdoor air. Dry toner at high heat produces CO due to incomplete

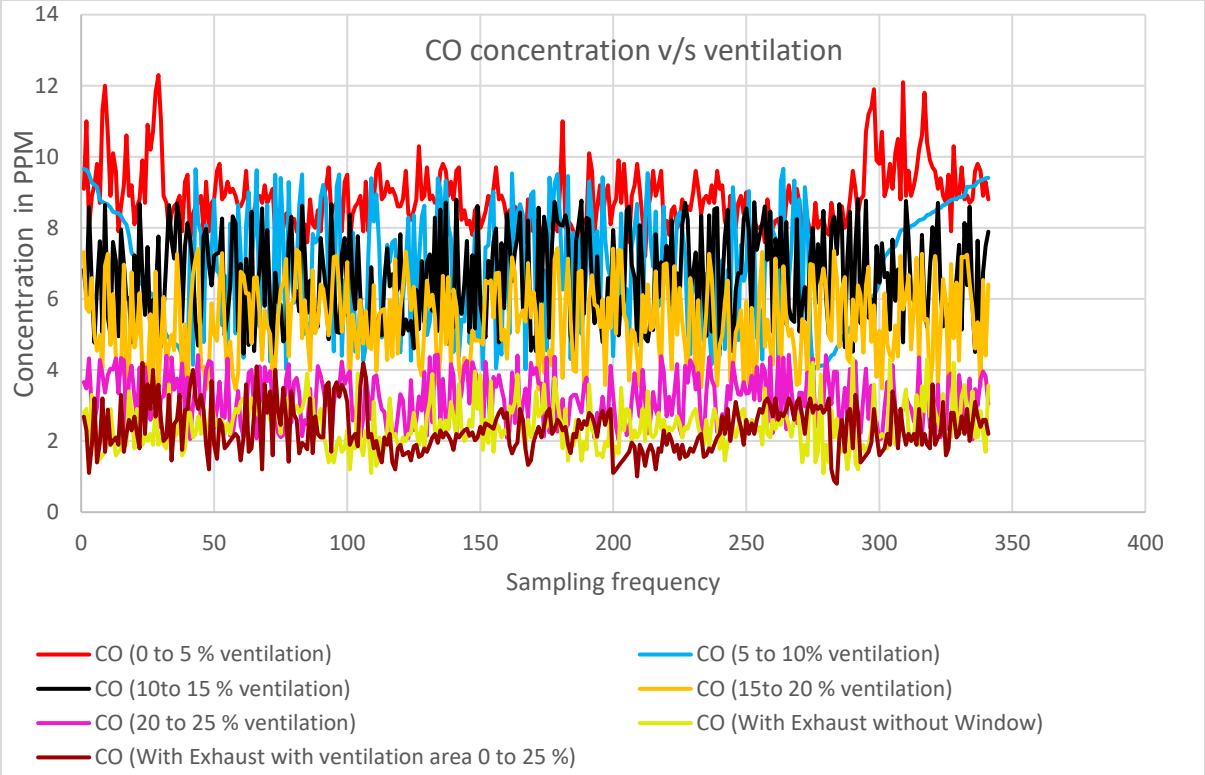

Figure 22: Variation in CO Concentration with ventilation available at different photocopy center

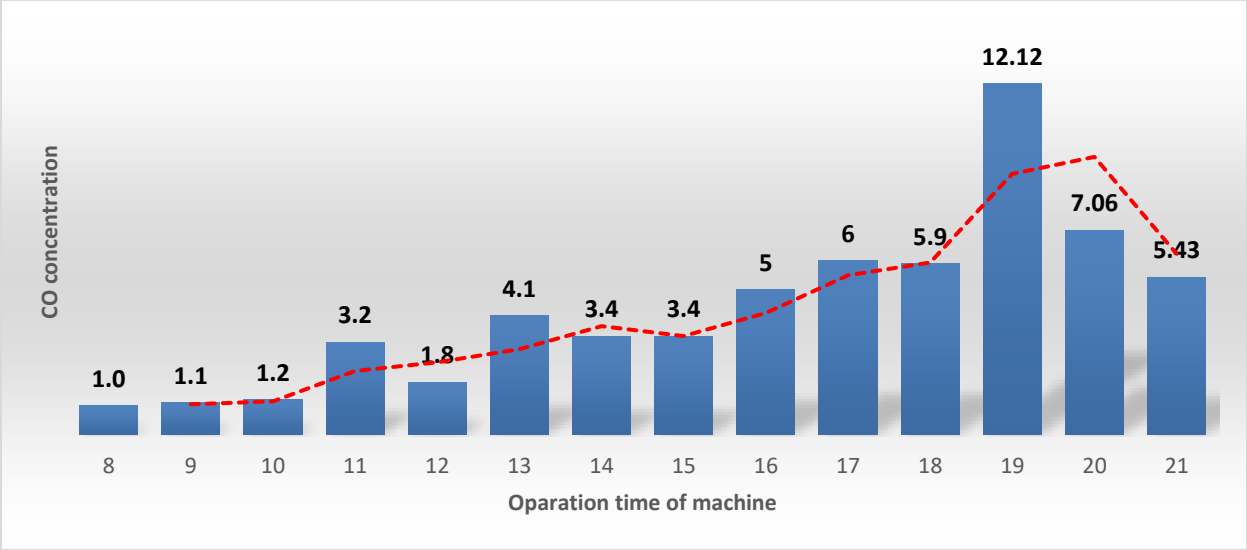

Figure 23: Variation in CO concentration with time of operation

Furthermore, it was observed that concentration of CO increases with number of photocopy (Figure 24) as well as time of operation (Figure 23) of the equipment. This increase in the emission is due to increase in temperature of equipment, which leads to higher concentration.

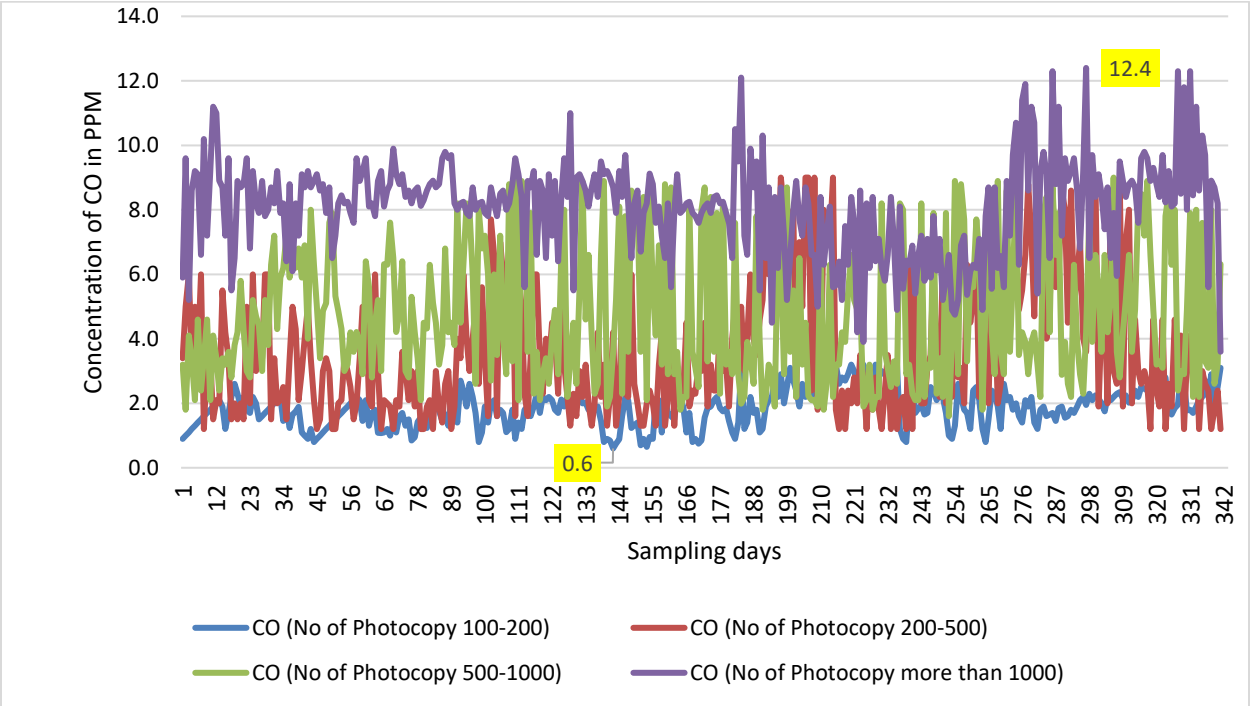

Figure 24: indoor CO concentration v/s No of photocopy

4.6.1.3 ***: Concentration of Ozone at different environmental condition in photocopy/printing center***

Highest Ozone concentration was 1.87 ppm with lowest available ventilation area i.e. 0-5% while the lowest value 0.02 ppm was observed with highest ventilation center i.e. 0-20% total floor area with exhaust system installed (figure 25). This is due to insufficient ventilation and during photocopying process, a larger part of ozone is created while the drum and paper is being charged. Ultraviolet emission from the photocopier lamp also produce ozone. In laser printer styrene and ozone was found, and in inkjet alcohol were detected. Production of Ozone is incident during many printing activities where emission of UV radiations occurs, during curing of printing inks, use of projection lamps, varnishes, lacquers etc. Currently, concentration levels for ozone as per OSHA standard for residential buildings is fixed at 0.10 ppm.

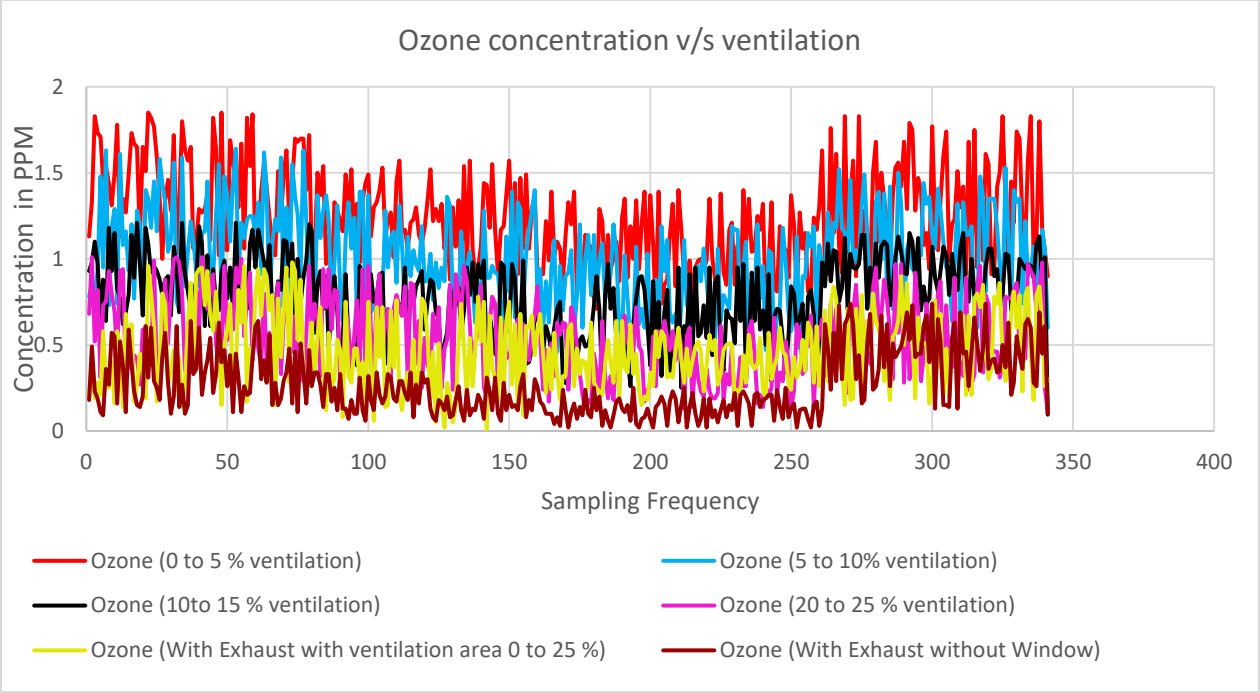

Figure 25: Variation in Ozone Concentration with ventilation available at different photocopy center

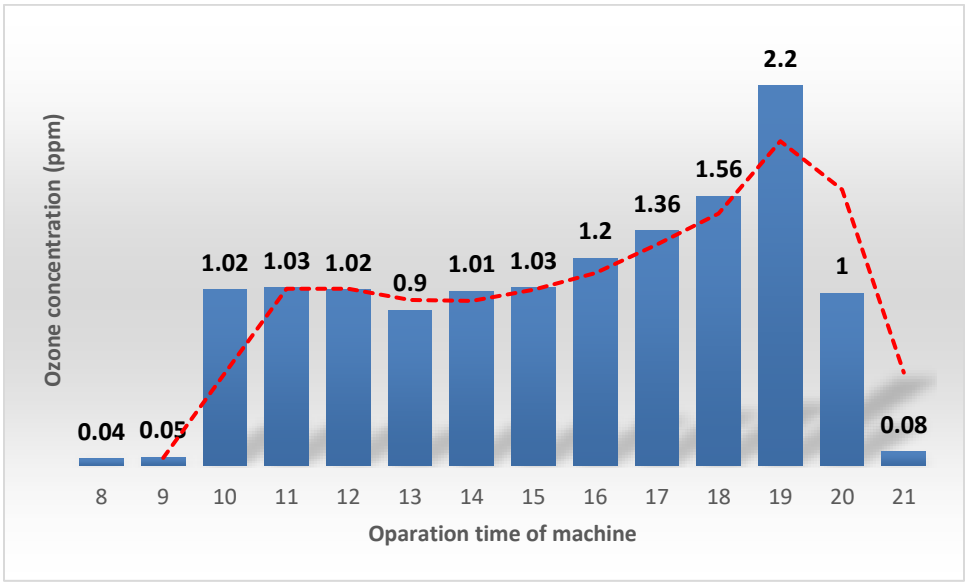

Figure 26: Variation in Ozone concentration with time of operation

Furthermore, it was observed that concentration of Ozone increases with number of photocopy (Figure 27) as well as time of operation (Figure 26) of the equipment. This increase in the emission is due to increase in temperature of equipment, which leads to higher concentration.

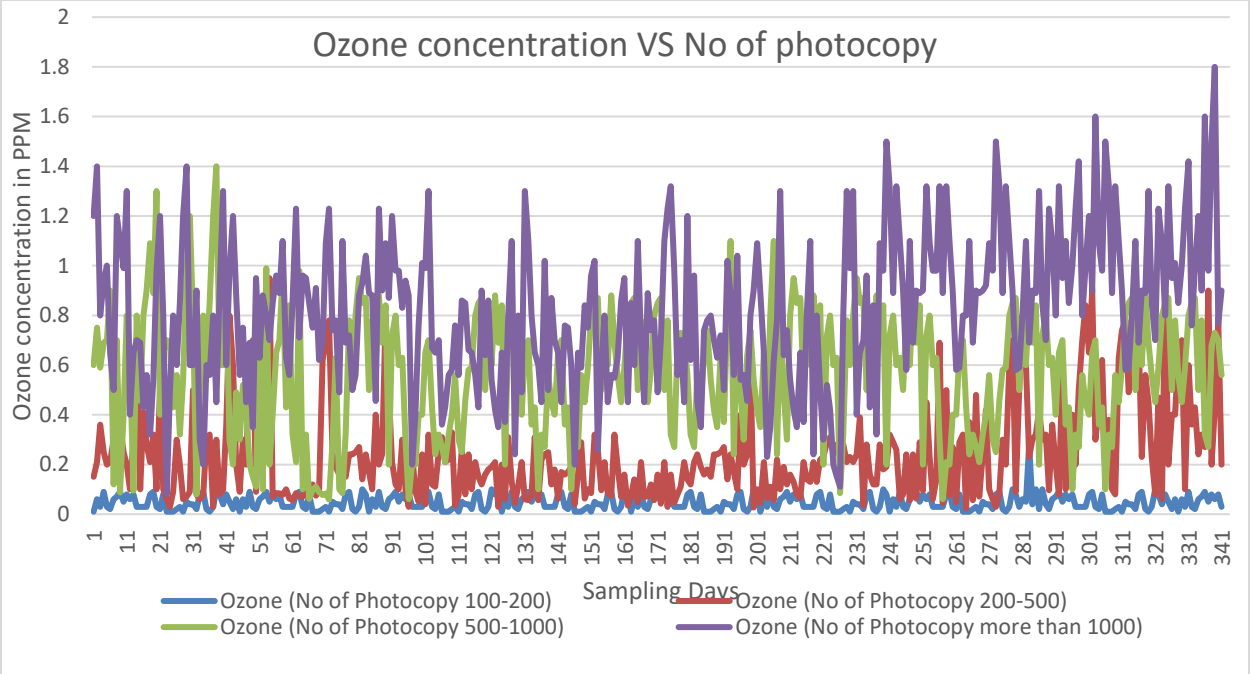

Figure 27: indoor Ozone concentration v/s No of photocopy

4.6.1.4 ***: Concentration of VOC at different environmental condition in photocopy/printing center***

Highest VOC concentration was 1.93 ppm with lowest available ventilation area i.e. 0-5% while the lowest value 0.01 ppm was observed with highest ventilation center i.e. 0-20% total floor area with exhaust system installed (figure 28), this is due to adequate ventilation and high operating temperature of photocopy/printing machine. Various applications like developing prototypes, construction of industrial and medical components for science and Technology, and for educational purpose requires the need of printers. Fused Filament Fabrication runs by making the thermoplastic filament coil hot, and then releasing the filament from the nozzle, on a platform that is moving and then slowly forming the object layer by layer. For FFF variety of filaments are present and they are generally mixture of thermoplastics (polylactic acid (PLA), thermoplastic polyurethane (TPU), acrylonitrile butadiene styrene (ABS), nylon, and polycarbonate (PC)) with dye colors metal, wood and various other additives. The thermoplastics mentioned

above are generally heated between 180 °C–270 °C, but it can go up to 500 °C. This process of heating gives rise to volatile gas and ultra-fine particles emissions.

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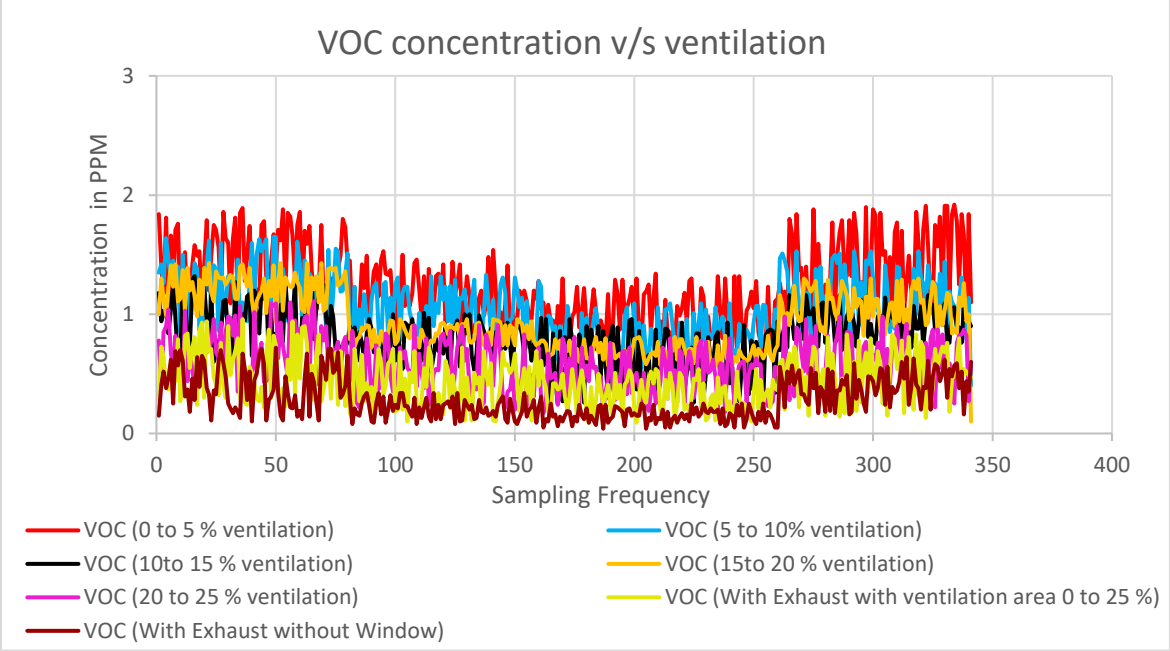


Figure 28: Variation in VOC Concentration with ventilation available at different photocopy center

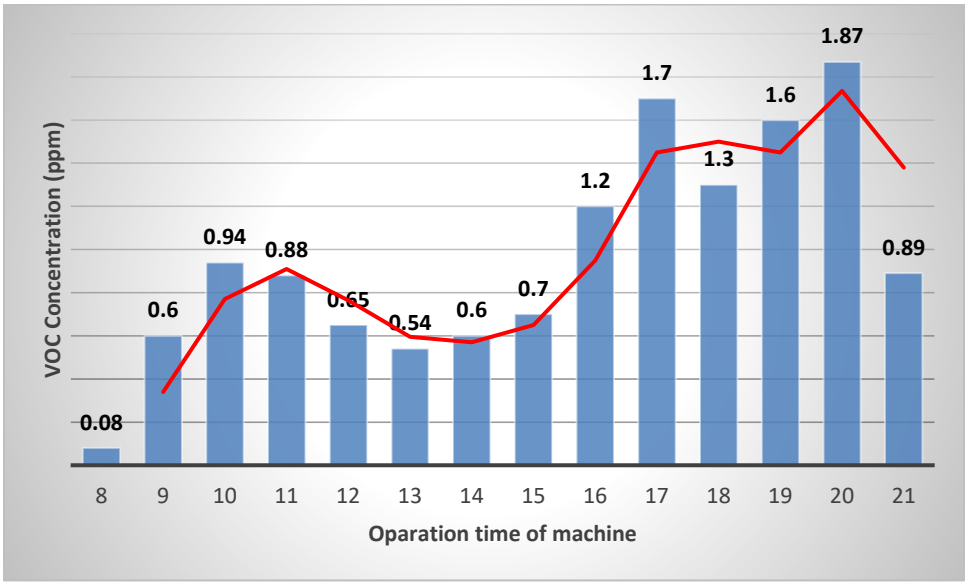


Figure 29: Variation in VOC concentration with time of operation

Furthermore, it was observed that concentration of VOC increases with number of photocopy (Figure 30) as well as time of operation (Figure 29) of the equipment.

This increase in the emission is due to increase in temperature of equipment, which leads to higher concentration.

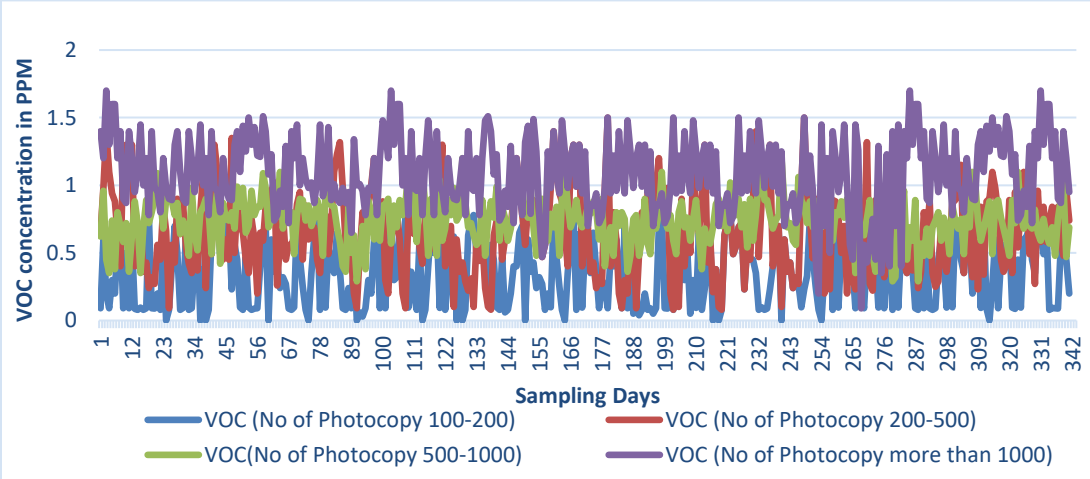


Figure 30: indoor VOC concentration v/s No of photocopy

4.6.1.5 *:Concentration of HCHO at different environmental condition in photocopy/printing center*

Figure 31 represents the most common VOC i.e. formaldehyde and its concentration with available ventilation. Highest HCHO concentration was 46 ppm with lowest available ventilation area i.e. 0-5% while the lowest value 7.2 ppm as observed with highest ventilation center i.e. 0-20% total floor area with exhaust system installed (figure 31).

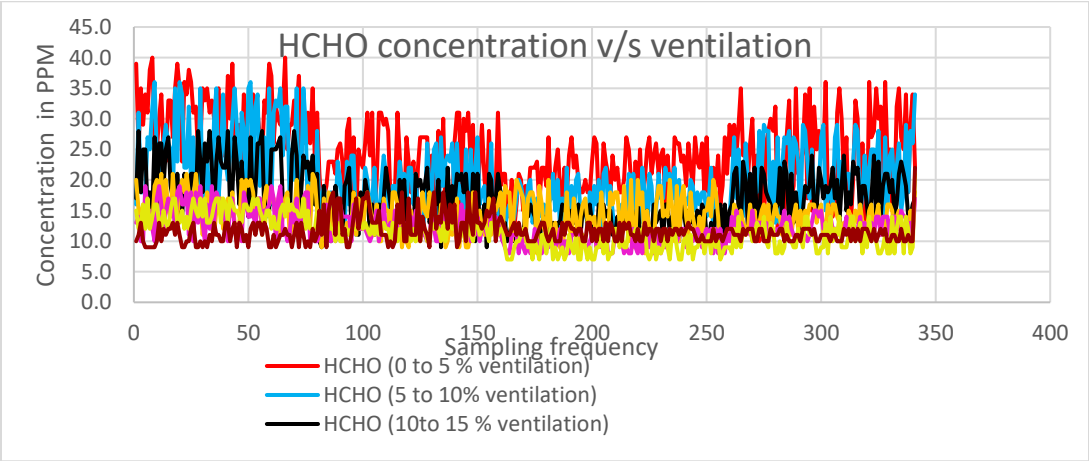


Figure 31: Variation in HCHO Concentration with ventilation available at different photocopy center

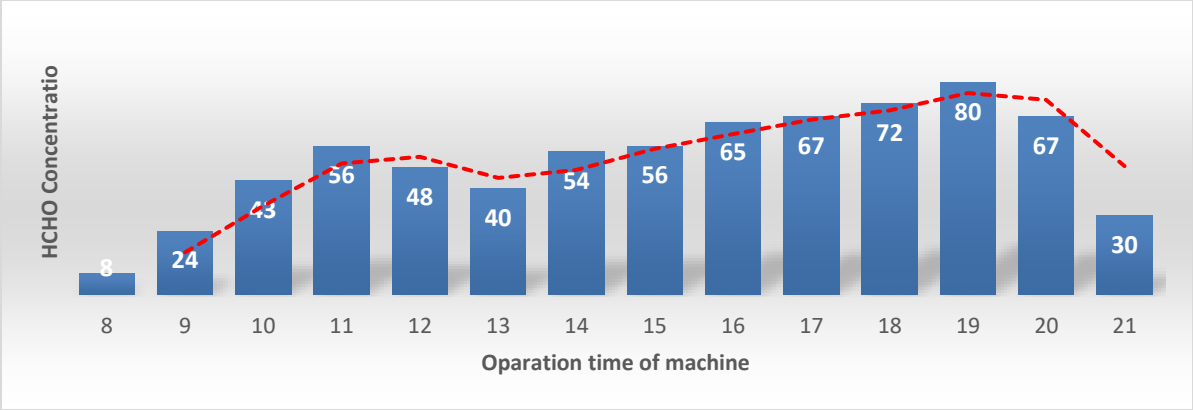


Figure 32: Variation in HCHO concentration with time of operation

Furthermore, it was observed that concentration of HCHO increases with number of photocopy (Figure 33) as well as time of operation (Figure 32) of the equipment. This increase in the emission is due to increase in temperature of equipment, which leads to higher concentration.

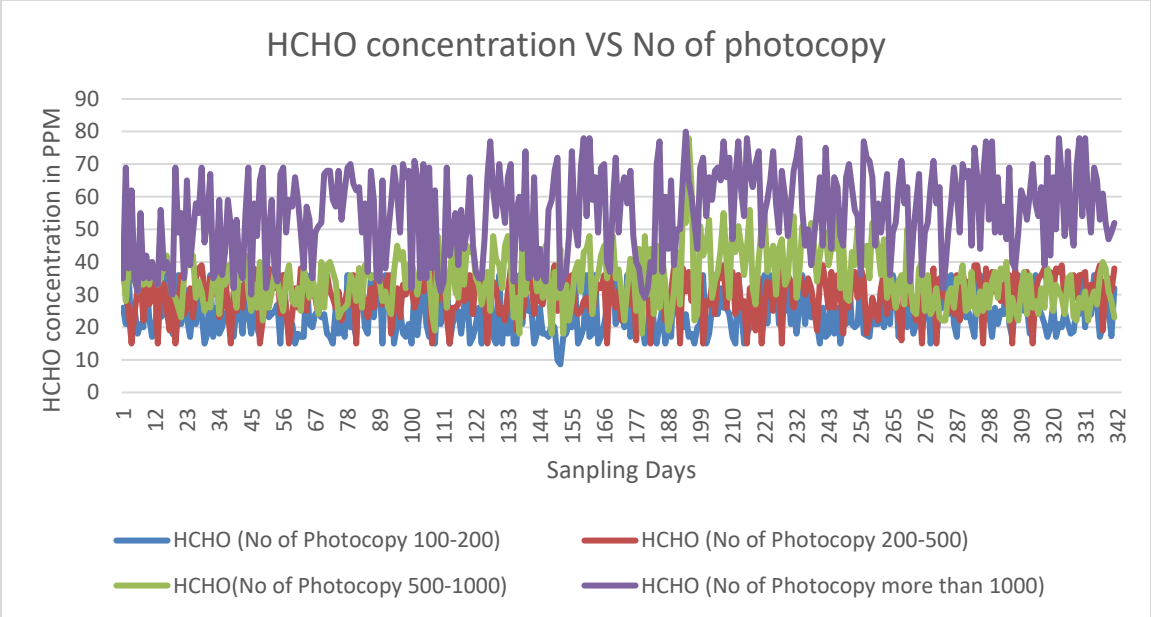


Figure 33: indoor HCHO concentration v/s No of photocopy.

It is recommended that photocopy machine operators must use proper standards of quality for lasers, copiers and toners. As per "Blue Angel" which is an

environmental label, series of requirements are made applicable to copiers, printers and other devices. There must be no hazardous substance in the toners and inks that are being used. Usually the ALARP principle is used when there is contamination of heavy metals in relation to the manufacturing process. In accordance with a given test method, device emissions are to be determined by a testing institute qualified for this test and must be presented. The emission rate for CO_2, CO, VOC, and HCHO & Ozone for must not be exceeded.

Furthermore, it should be supported by environmental comfort by providing adequate ventilation and for higher number of photocopy one should have minimum two printers to avoid heating by alternate use of machine, which ultimately will result in reduction of pollutant inside photocopy/printing center.

4.7 Validated of experimental work by ANSYS (Fluent) software:

The main scope of this study was to formulate a method in accordance with the integration of VOC emissions because of the equipment found in the workplace in computational fluid dynamics (CFD) simulations. In stimulation diffusion and transportation phenomena of VOCs generally consider the CFD model by conserving the mass fraction equations for each VOCs that is to be taken care. Mass of VOC on the basis of VOC generation rate are used in this equation. These equations on the other hand are added to the basic equations describing turbulent confined non-isothermal flows (conservation of mass, momentum, energy, and turbulent quantities) in CFD modelling. Assessment of the various health hazards are carried out by using the CFD model of the five VOCs, Benzene and toluene. Values of VOC concentration in the indoor environment can be obtained by using this CFD model. The analysis reviewed that, the VOC levels are increasing with respect to temperature and the rate of copy per hour.

4.8 VOC Concentration, temperature and numbers of photocopy:

Values of VOC concentration in the indoor environment can be obtained by using this CFD model. This method helps in IAQ investigation, which is found to be an excellent option for experimental studies but it's hard to conduct in situ. On addition to that, the numerical model enables the forecasting of the VOC values indoor in a comprehensive manner. This makes it easy for the assessment of VOC levels near to the occupant, which gives a more correct data. Additionally, the description of numerical of the VOCs for CFD model can also be used for other indoor VOC models (e.g. carpets, furniture, paints, building materials, etc.).

This work represents the estimated of volatile organic compounds (VOC), benzene, and toluene during photocopy. The numerical validation of results was done using Fluent, which is an application based software which helps in physical modeling describes air flow and effect of multiple parameter on it like temperature and no of printing/photocopy (in proposed experiment) with respect to time. It has been observed from the results that the emissions of volatile organic compounds (VOC), benzene, and toluene increases from 0.09 PPM to 1.13 PPM, 0.17 PPM to 1.87 PPM and 30 PPM to 235 PPM respectively as the operating duration, temperature (35^{0C} to 40^{0C}) and rate of printing/photocopying increase (120/hr to 200/hr), it is because printer/photocopy machine uses heat and pressure to fix an image on the paper surface which subsequently result is higher emission. Multiple adverse health, safety and environmental impacts due to operation of photocopy/printing call for in-depth study, guidance and monitoring of the workers occupationally associated to this operation for their well-being.

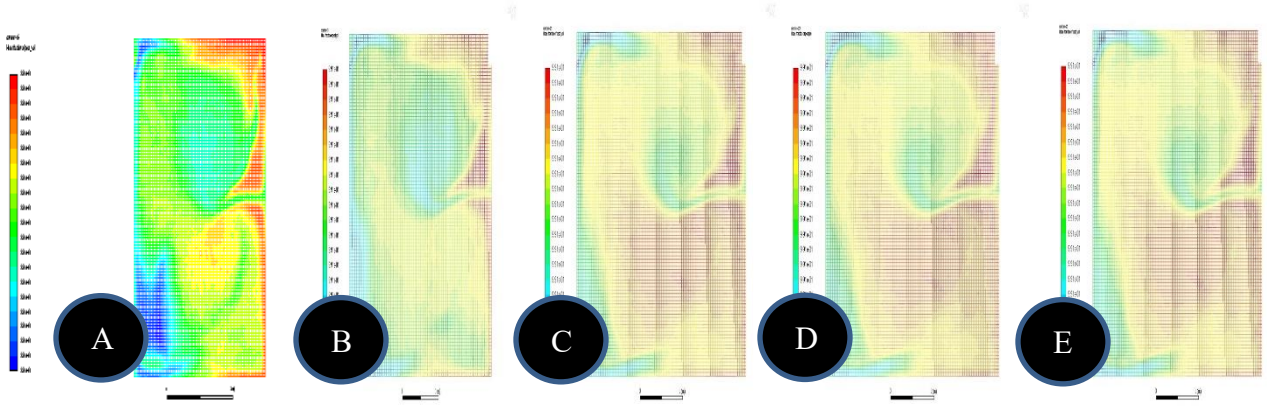


Figure 34: Variation in VOCs concentration with number of photocopy/print

The final conclusion from the case study which reveals that the VOC values which were estimated for the photocopying equipment were found to be more than the threshold limit value. These results are on the basis of emission of VOCs from electronic devices. In this simulation, the VOCs from other sources are not considered. Furthermore, in spite of high concentrations of indoor VOCs from electronic devices numerically assessed in this study, long short as well as term exposure could harmful to the occupant health. Figure 34(A,B,C,D,E) represents VOCs concentration with respect to number of photocopy per hour (120,140,160,180,200 respectively) and figure 35(A,B,C,D,E) represent VOCs concentration with respect to temperature (36^{OC},37^{OC},38^{OC},39^{OC},40^{OC} respectively).

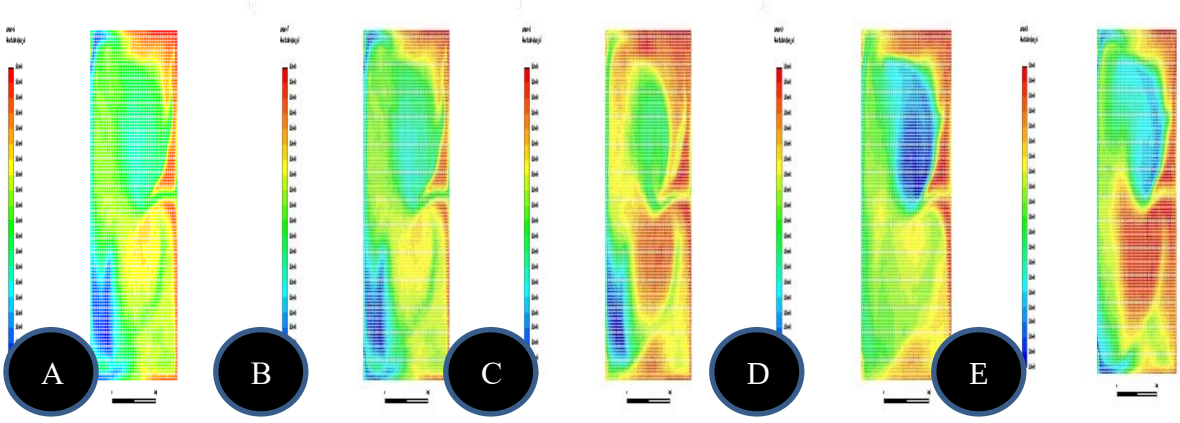


Figure 35: Variation in VOCs concentration v/s temperature

Simulation result revels that VOC concentration changes with change in temperature due to its operation and observed values were 0.09 PPM to 1.13 PPM respectively at 36OC and 40^{OC}. Concentration of VOC changed slightly when no of photocopy per hour was taken under consideration, it was 0.87 ppm to 1.138 ppm for 120 to 200 photocopy per hour, and this result suggest the parallel concentration as observed in experimental analysis.

Figure 34(A,B,C,D,E) represents VOCs concentration with respect to number of photocopy per hour (120,140,160,180,200 respectively) and figure 35(A,B,C,D,E) represent VOCs concentration with respect to temperature (36^{OC},37^{OC},38^{OC},39^{OC},40^{OC} respectively).

4.9 : Benzene concentration temperature and numbers of photocopy:

Simulation result revels that Benzene concentration changes with change in temperature due to its operation and observed values were 0.17 PPM to 1.87 PPM respectively at 36^{OC} and 40^{OC}. Concentration of VOC changed slightly when no of photocopy per hour was taken under consideration, it was 0.18 ppm to 1.892 ppm for 120 to 200 photocopy per hour, and this result suggest the parallel concentration as observed in experimental analysis.

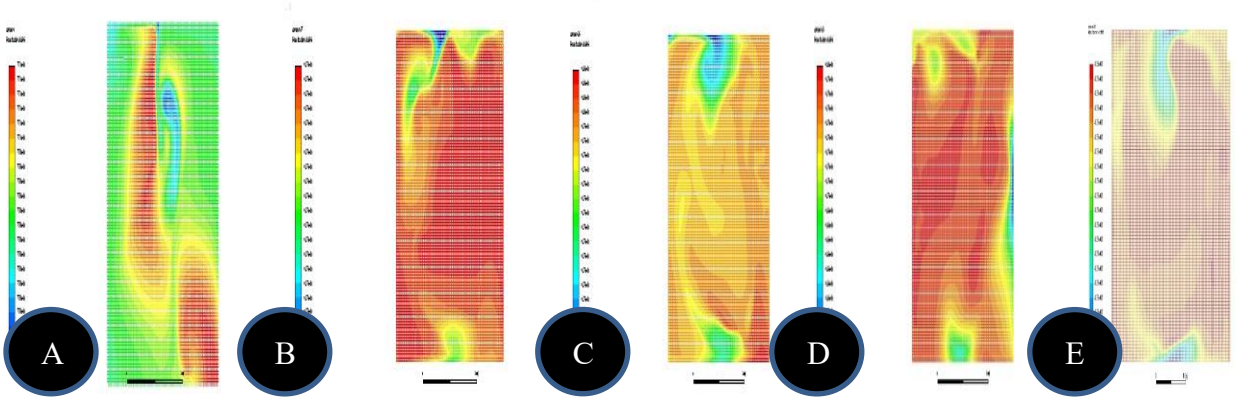


Figure 36: Variation in benzene concentration with number of photocopy/print

Figure 36(A,B,C,D,E) represents Benzene concentration with respect to number of photocopy per hour (120,140,160,180,200 respectively) and figure 37(A,B,C,D,E)

represent Benzene concentration with respect to temperature (36^{OC},37^{OC},38^{OC},39^{OC},40^{OC} respectively).

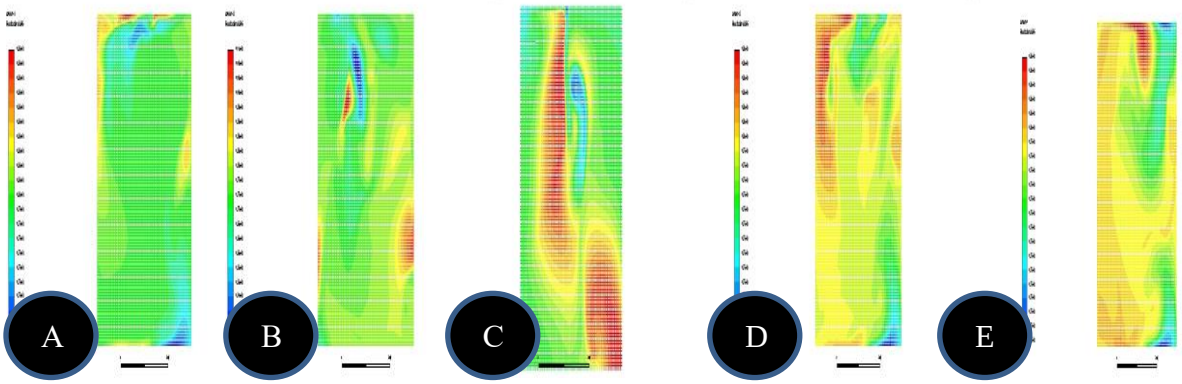


Figure 37: Variation in Benzene concentration v/s temperature

4.10 : Toluene concentration temperature and numbers of photocopy:

Simulation result revels that Toluene concentration changes with change in temperature due to its operation and observed values were 30 PPM to 235 PPM respectively at 36^{OC} and 40^{OC}. Concentration of VOC changed slightly when no of photocopy per hour was taken under consideration, it was 37 ppm to 219 ppm for 120 to 200 photocopy per hour, and this result suggest the parallel concentration as observed in experimental analysis.

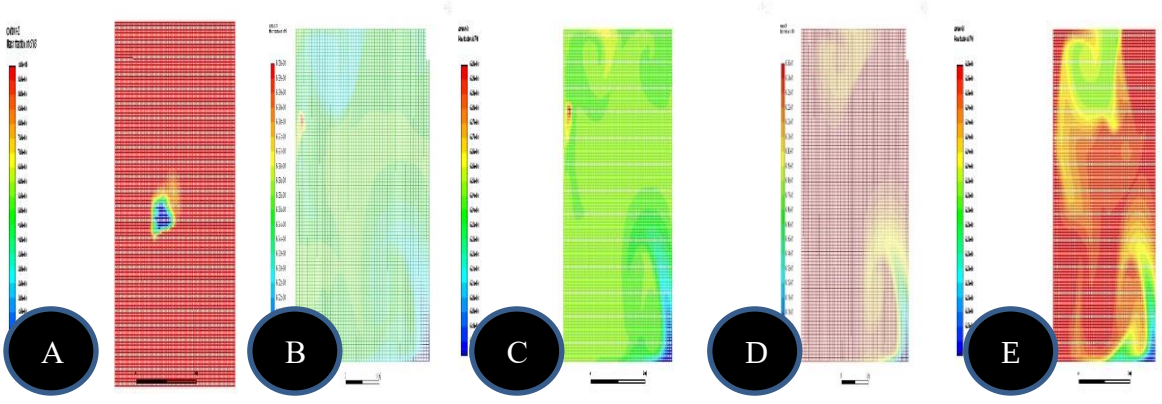


Figure 38: Variation in Toluene concentration with number of photocopy/print

Figure 38(A,B,C,D,E) represents Toluene concentration with respect to number of photocopy per hour (120,140,160,180,200 respectively) and figure 39(A,B,C,D,E) represent Toluene concentration with respect to temperature (36^{OC},37^{OC},38^{OC},39^{OC},40^{OC} respectively).

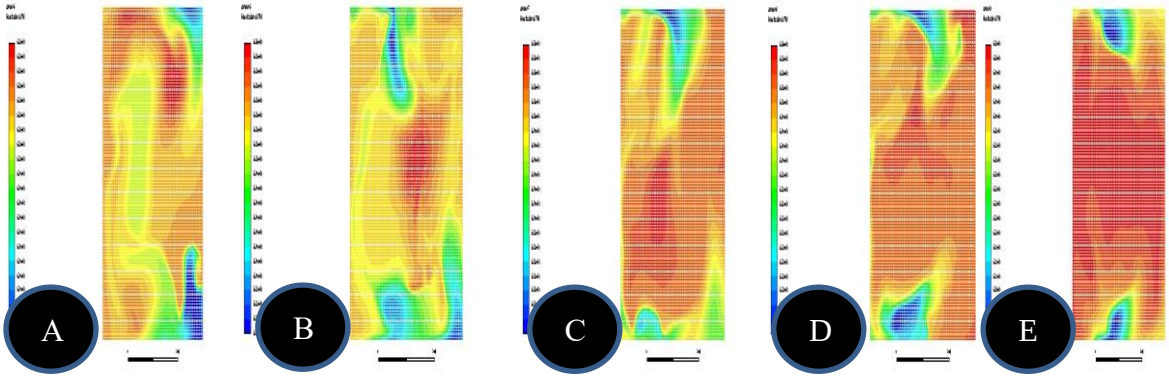


Figure 39: Variation in toluene concentration v/s temperature

The results have thus shown that the most of the workers working in the photocopying and printing centers were illiterate and uneducated and are working in dilapidated situations where they are exposed to multiple hazards. The assessment for several age groups and people from different socio - economic backgrounds were done to analyse for working conditions and the ergonomics of the workplace. Results of the assessment of the indoor air quality contaminating pollutants and its adverse effects on the workers were also elaborated along with the estimation and validation of the volatile organic compounds using CFD model.

CHAPTER-5

5 Development of tools for health and ergonomics assessment:

5.1 Tool for Cancer risk assessment:

Cancer Risk Assessment is the analysis of risk linked to the carcinogen intake and exposure to humans over a certain period. The amalgamation of genetic and external factors which act concurrently and subsequently results in the multi-factorial infection called as cancer. Various confirmations reveals that, anthropogenic environmental activities are the principle cause leading to different types of cancer. Multi-generation migrants studies conducted at various countries provided a base for these findings. Furthermore, analysis comprising of identical twins showed that environment contributes more towards the cancer spread and not the genes. In general population, considerable percentage of cancer spread was due to imprints of both environment and genetic factors. Inhalation, injection and ingestion are the different modes of entry by which chemical substances enter into the human body. The at most proportion of chemical ingestion should be mandatorily assessed on a regular basis, to prevent diseases. Hence there is a necessity to determine the Acceptable Daily Intake (ADI). ADI is also known as TDI in the case of pesticides remnants and food adulterants.

Average Daily Intake in the terms of CRA can be explained as permissible exposure intake. Permissible exposure limit (PEL) is a managerial limit which measures the concentration of a particular substance in air. This is calculated on the basis of time weighted average (TWA) and short-term exposure limits (STEL). Workplace

environmental exposure limit (WEEL) can be demonstrated as TWA as well. Cancer risk can be calculated based on below mention formula (USEPA)

Cancer Risk= Average Daily Intake (**ADI**) × Potency Factor/Cancer slope factor (CSF)

ADI=

$$\frac{\text{Concentration of substance} * \text{Frequency of exposure} * \text{Duration of exposure in days}}{\text{Average body weight} * \text{Life expectancy (in days)}}$$

The factor used to evaluate the cancer risk involved when a person is exposed to a cancer causing substance (Carcinogen) is known as **Cancer slope factors (CSF)** or Potency Factor. It is estimated in units of proportion (of a population) affected per mg of substance/kg body weight-day.

A Computer coded assessment tool has been developed with the help of the "Python coding" language and creating the "Graphic user interface" to estimating the Cancer risk due to the exposure of the various toxic substances present in photocopy/printing centers.

This tool was designed by the coding using the python language in which the dictionary of the 184 toxic chemicals potency factor was stored into the directory and the corresponding risk of cancer was evaluated by manually entering the duration for the exposure and the concentration.

5.2 Inputs of the tool are as follows:-

1. Enter the Gender (m or f)
2. Display of the corresponding average body weight of either male or female
3. Enter the Toxic Substance
4. Enter the concentration in (mg/m3)
5. Enter the Duration in days

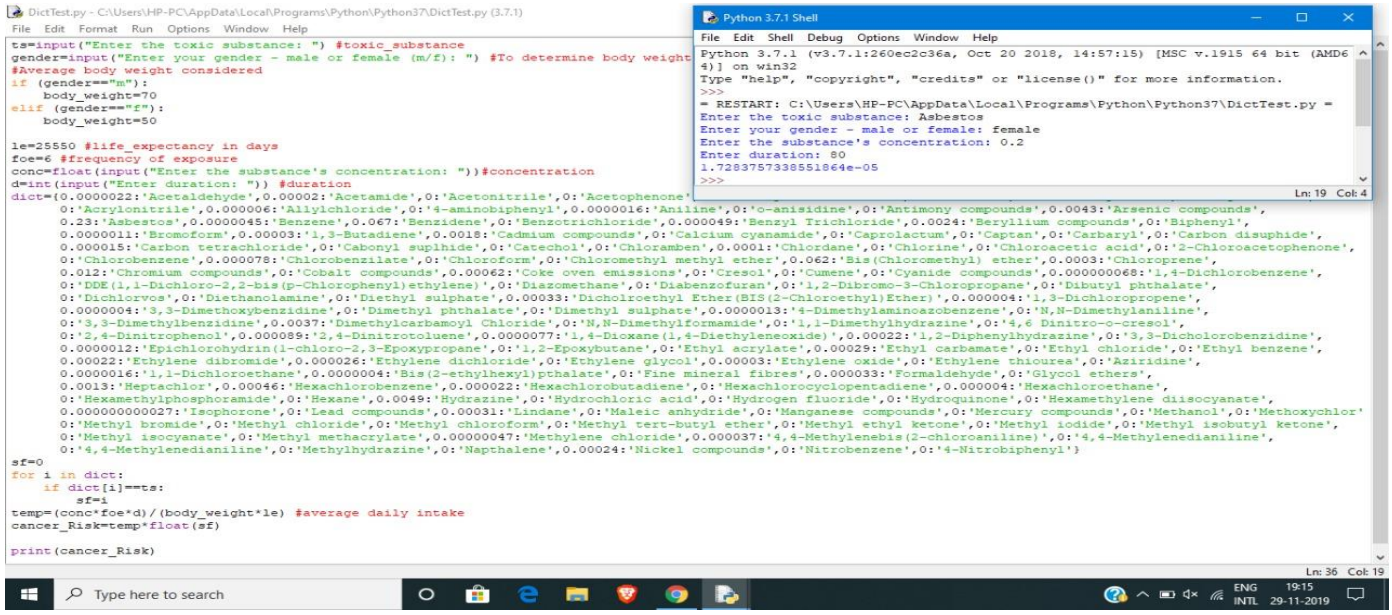
6. Calculated Cancer risk

5.3 Methodology adopted:

- Collection of datasheets of 184 toxic chemicals from the source of EPA for its slope factor and the potential risk values.
- Compilation of all the raw data in a detailed format for the purpose of the cancer risk calculation and for creating dictionary in computer coding
- Calculating the cancer risk for the carcinogens by applying the Cancer risk formula in excel data.
- Creating a code in the Python language
- The program runs on the principle that the respective slope factor of the chemical is the key and the name of the chemical is the index.
- After creating, the code in the python Graphic user interface is also developed for easier estimation.
- Input parameters can be given after the running of the code
- Finally, it gives the value of Cancer risk.

5.4 Coding in Python language:

Input Code in the python Language with the corresponding output



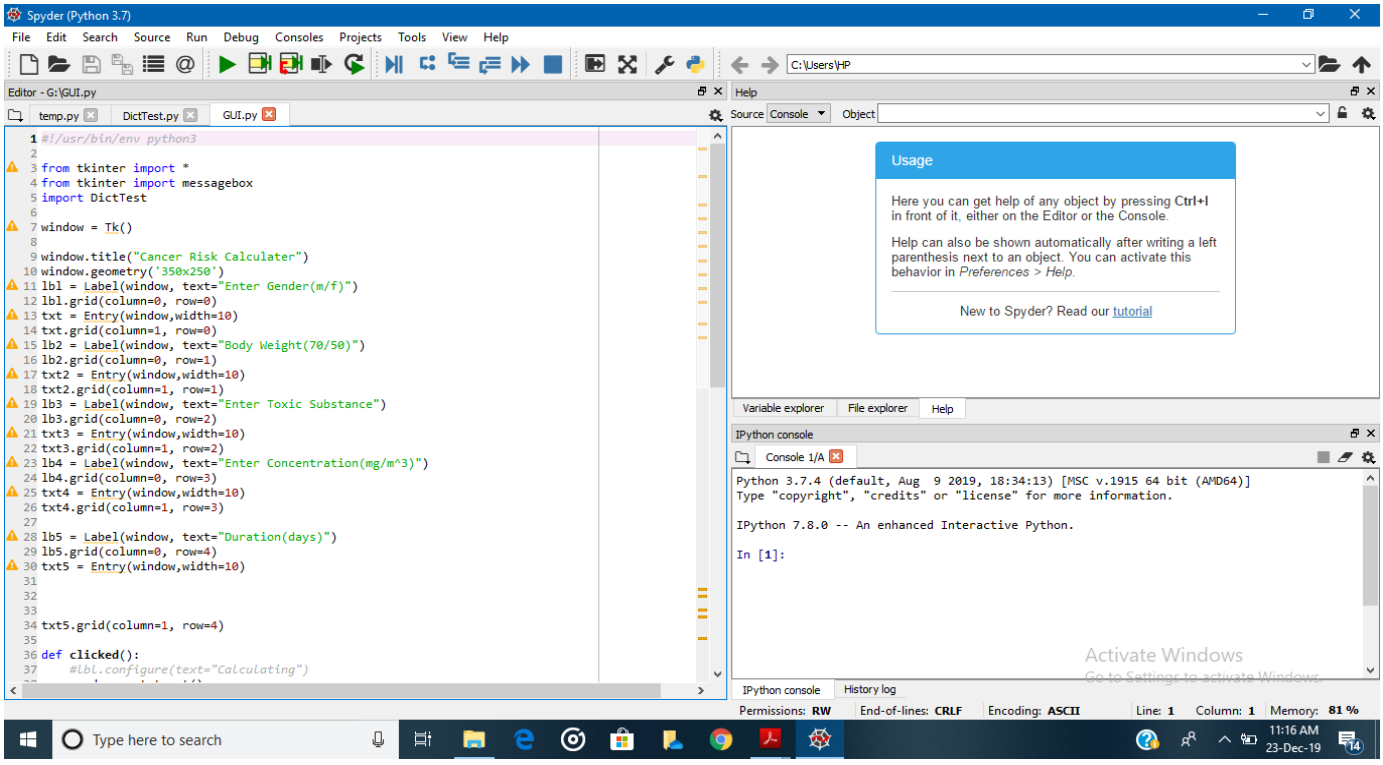
```
ts=input("Enter the toxic substance: ") #toxic_substance
gender=input("Enter your gender - male or female (m/f): ") #To determine body weight
#Average body weight considered
if (gender=="m"):
    body_weight=70
elif (gender=="f"):
    body_weight=50

le=25550 #life_expectancy in days
foe=6 #frequency of exposure
conc=float(input("Enter the substance's concentration: "))#concentration
d=int(input("Enter duration: ")) #duration
dict={0.0000022:'Acetaldehyde',0.00002:'Acetamide',0:'Acetonitrile',0:'Acetophenone',
      0:'Acrylonitrile',0.000006:'Allylchloride',0:'4-aminobiphenyl',0.0000016:'Aniline',0:'o-anisidine',0:'Antimony compounds',0.0043:'Arsenic compounds',
      0.23:'Asbestos',0.0000045:'Benzene',0.067:'Benzidene',0:'Benzotrichloride',0.000049:'Benzyl Trichloride',0.0024:'Beryllium compounds',0:'Biphenyl',
      0.0000011:'Bromoform',0.00003:'1,3-Butadiene',0.0018:'Cadmium compounds',0:'Calcium cyanamide',0:'Caprolactum',0:'Captan',0:'Carbaryl',0:'Carbon disuphide',
      0.000015:'Carbon tetrachloride',0:'Cabonyl suphide',0:'Catechol',0:'Chlorambem',0.0001:'Chlordane',0:'Chlorine',0:'Chloroacetic acid',0:'2-Chloroacetophenone',
      0:'Chlorobenzene',0.000078:'Chlorobenzilate',0:'Chloroform',0:'Chloromethyl methyl ether',0.062:'Bis(Chloromethyl) ether',0.0003:'Chloroprene',
      0.012:'Chromium compounds',0:'Cobalt compounds',0.00062:'Coke oven emissions',0:'Cresol',0:'Cumene',0:'Cyanide compounds',0.000000068:'1,4-Dichlorobenzene',
      0:'DDE(1,1-Dichloro-2,2-bis(p-Chlorophenyl)ethylene)',0:'Diazomethane',0:'Diabenzofuran',0:'1,2-Dibromo-3-Chloropropane',0:'Dibutyl phthalate',
      0:'Dichlorvos',0:'Diethanolamine',0:'Diethyl sulphate',0.00033:'Dicholroethyl Ether(BIS(2-Chloroethyl)Ether)',0.000004:'1,3-Dichloropropene',
      0.0000004:'3,3-Dimethoxybenzidine',0:'Dimethyl phthalate',0:'Dimethyl sulphate',0.0000013:'4-Dimethylaminoazobenzene',0:'N,N-Dimethylaniline',
      0:'3,3-Dimethylbenzidine',0.0037:'Dimethylcarbamoyl Chloride',0:'N,N-Dimethylformamide',0:'1,1-Dimethylhydrazine',0:'4,6 Dinitro-o-cresol',
      0:'2,4-Dinitrophenol',0.000089:'2,4-Dinitrotoluene',0.0000077:'1,4-Dioxane(1,4-Diethyleneoxide)',0.00022:'1,2-Diphenylhydrazine',0:'3,3-Dicholorobenzidine',
      0.0000012:'Epichlorohydrin(1-chloro-2,3-Epoxypropane',0:'1,2-Epoxybutane',0:'Ethyl acrylate',0.00029:'Ethyl carbamate',0:'Ethyl chloride',0:'Ethyl benzene',
      0.00022:'Ethylene dibromide',0.000026:'Ethylene dichloride',0:'Ethylene glycol',0.00003:'Ethylene oxide',0:'Ethylene thiourea',0:'Aziridine',
      0.000016:'1,1-Dichloroethane',0.0000004:'Bis(2-ethylhexyl)pthalate',0:'Fine mineral fibres',0.000033:'Formaldehyde',0:'Glycol ethers',
      0.0013:'Heptachlor',0.00046:'Hexachlorobenzene',0.000022:'Hexachlorobutadiene',0:'Hexachlorocyclopentadiene',0.0000004:'Hexachloroethane',
      0:'Hexamethylphosphoramide',0:'Hexane',0.0049:'Hydrazine',0:'Hydrochloric acid',0:'Hydrogen fluoride',0:'Hydroquinone',0:'Hexamethylene diisocyanate',
      0.000000000027:'Isophorone',0:'Lead compounds',0.00031:'Lindane',0:'Maleic anhydride',0:'Manganese compounds',0:'Mercury compounds',0:'Methanol',0:'Methoxychlor
      0:'Methyl bromide',0:'Methyl chloride',0:'Methyl chloroform',0:'Methyl tert-butyl ether',0:'Methyl ethyl ketone',0:'Methyl iodide',0:'Methyl isobutyl ketone',
      0:'Methyl isocyanate',0:'Methyl methacrylate',0.00000047:'Methylene chloride',0.000037:'4,4-Methylenebis(2-chloroaniline)',0:'4,4-Methylenedianiline',
      0:'4,4-Methylenedianiline',0:'Methylhydrazine',0:'Napthalene',0.00024:'Nickel compounds',0:'Nitrobenzene',0:'4-Nitrobiphenyl'}
sf=0
for i in dict:
    if dict[i]==ts:
        sf=i
temp=(conc*foe*d)/(body_weight*le) #average daily intake
cancer_Risk=temp*float(sf)

print(cancer_Risk)
```

```
Python 3.7.1 (v3.7.1:260ec2c36a, Oct 20 2018, 14:57:15) [MSC v.1915 64 bit (AMD6
4)] on win32
Type "help", "copyright", "credits" or "license()" for more information.
>>>
= RESTART: C:\Users\HP-PC\AppData\Local\Programs\Python\Python37\DictTest.py =
Enter the toxic substance: Asbestos
Enter your gender - male or female: female
Enter the substance's concentration: 0.2
Enter duration: 80
1.7283757338551864e-05
>>>
```

Figure 40: Creation of complete dictionary of the 184 chemicals potency factor



```
#!/usr/bin/env python3

from tkinter import *
from tkinter import messagebox
import DictTest

window = Tk()

window.title("Cancer Risk Calculater")
window.geometry('350x250')
lbl = Label(window, text="Enter Gender(m/f)")
lbl.grid(column=0, row=0)
txt = Entry(window,width=10)
txt.grid(column=1, row=0)
lb2 = Label(window, text="Body Weight(70/50)")
lb2.grid(column=0, row=1)
txt2 = Entry(window,width=10)
txt2.grid(column=1, row=1)
lb3 = Label(window, text="Enter Toxic Substance")
lb3.grid(column=0, row=2)
txt3 = Entry(window,width=10)
txt3.grid(column=1, row=2)
lb4 = Label(window, text="Enter Concentration(mg/m^3)")
lb4.grid(column=0, row=3)
txt4 = Entry(window,width=10)
txt4.grid(column=1, row=3)

lb5 = Label(window, text="Duration(days)")
lb5.grid(column=0, row=4)
txt5 = Entry(window,width=10)



txt5.grid(column=1, row=4)

def clicked():
    #lbl.configure(text="Calculating")
```

```
Python 3.7.4 (default, Aug  9 2019, 18:34:13) [MSC v.1915 64 bit (AMD64)]
Type "copyright", "credits" or "license" for more information.

IPython 7.8.0 -- An enhanced Interactive Python.

In [1]:
```

Figure 41:Coding in the python for creating the Graphic User Interface

Estimation of the cancer risk using the python code by running the code, we will get the calculator window for calculating the cancer risk for the corresponding chemicals.

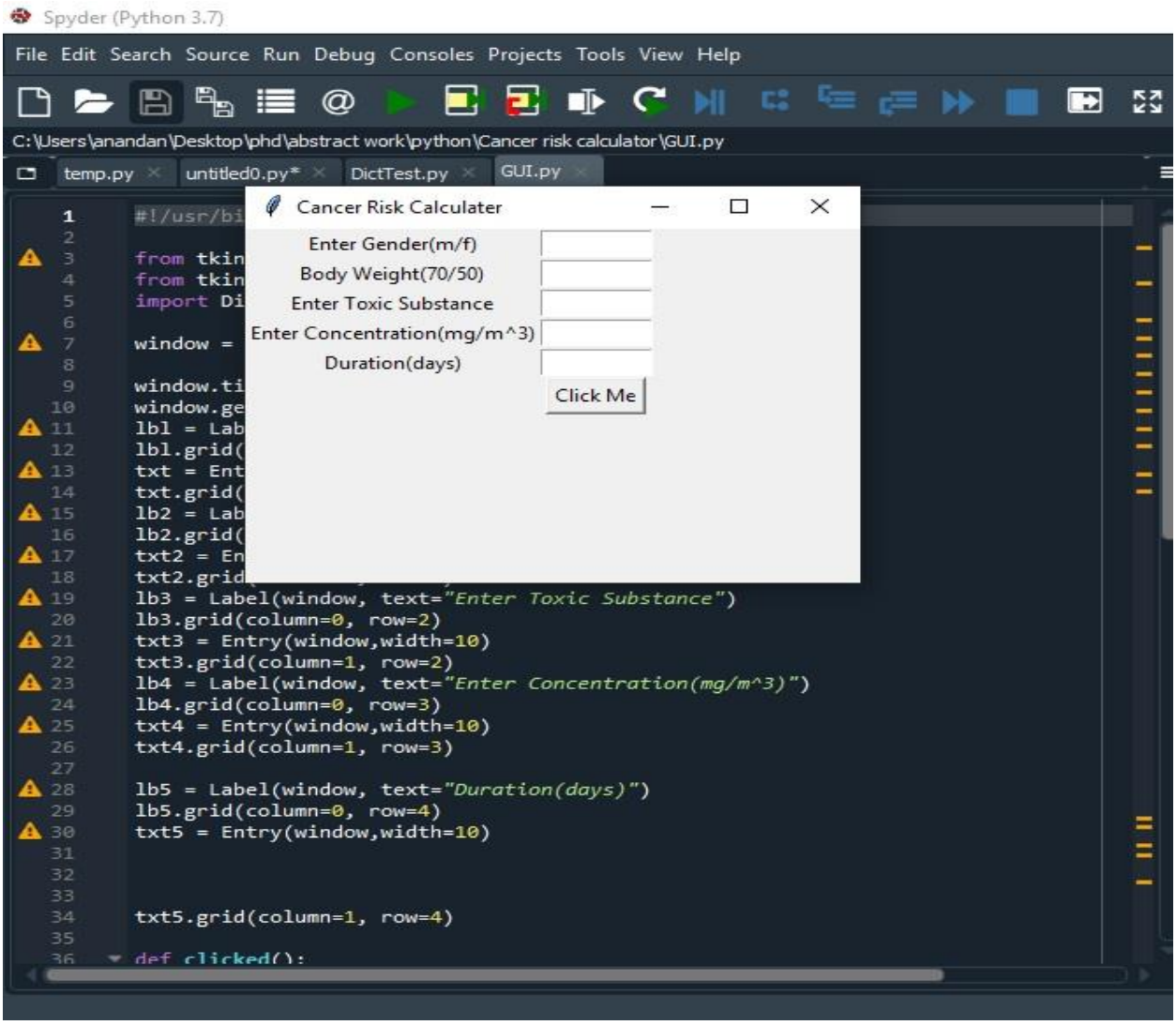


Figure 42: Input window in the spyder software

Output screen for the user will give the cancer risk value based on input chemical and exposure as represented in figure 43.

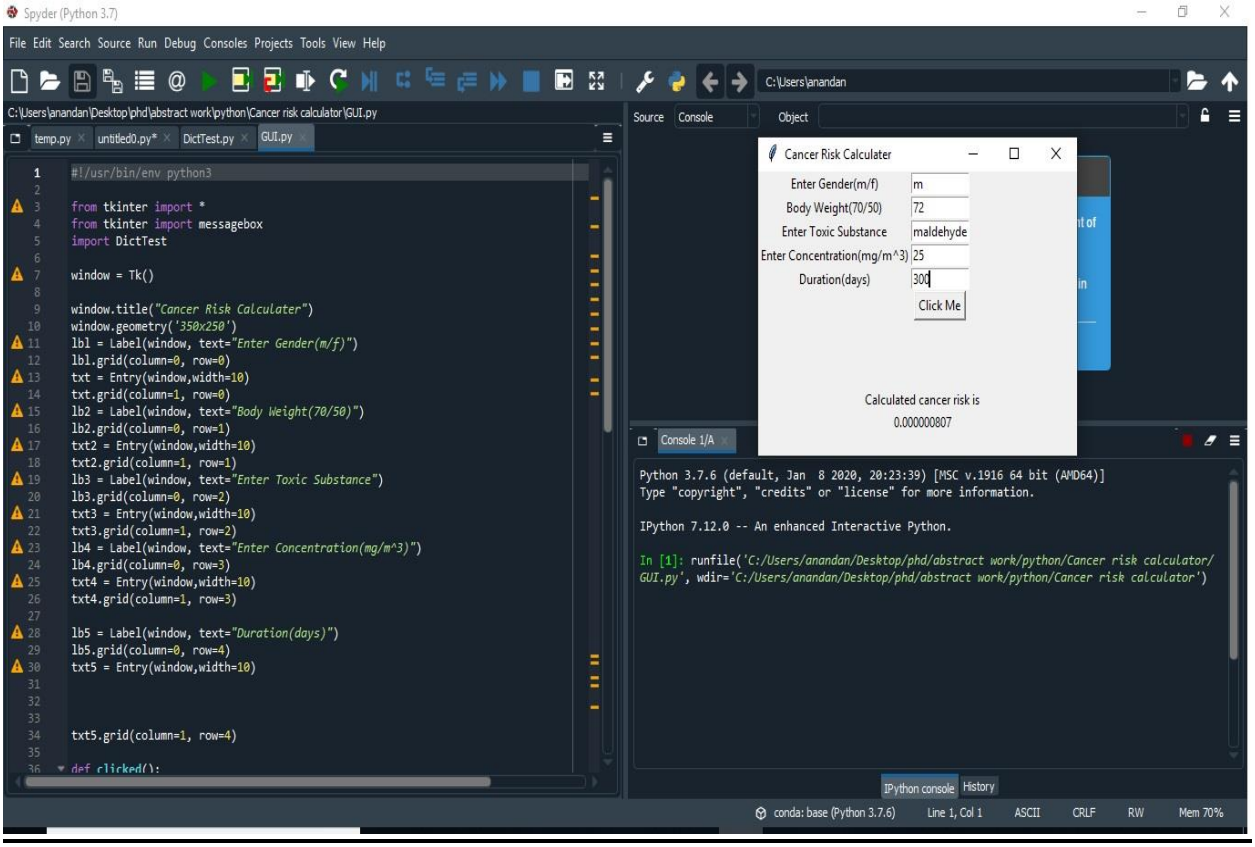


Figure 43: Successful opening of the calculator window for getting the final output of cancer risk for corresponding chemical

5.5 Tool for assessment of ergonomics risk:

In India musculoskeletal disorders are the prevalent occupational issue among the workers. Small scale industries employs large number of manual operations, because of which MSDs disorders are of great concern.

A tool for analyzing the postures has been developed specially for occupant working at photocopy/printing centers using Rapid upper limb assessment (RULA) and Rapid entire body assessment (REBA). This ergonomic analysis sheds light on posture analysis of the workers in photocopy/printing centers. The tool was first used to conduct on 64 workers engaged in Photocopy/printing centers situated Dehradun India. Visual Recordings on various activities of the workers was created and then pictorial evidences were snipped from it for the study. Risk and their

potential has been suggested and mapped by referring OHSAS and IOSH standard based on work posture of workers engaged in photocopy/printing.

Evaluation method has been developed to carry out RULA and REBA for photocopy/printing workers. From the RULA analysis carried out, it was evident that larger number of workers were exposed to high levels of risks and needed change on an urgent basis. REBA analysis gave a combination of both high and low risk. These studies revealed that small scale industries did not have adequate apprehension about the ergonomics. Postural analysis showed that labors are working at a limit slightly above the safe zone. Most of the workers were found to be working with awkward postures, such workers are under risk of moderate to high level of MSDs.Base on the activities identified proper modification has been done to find Rapid Upper Limb Assessment (RULA) and Rapid Entire Body Assessment (REBA).

5.6 Input data require for RULA & REBA:

Input data require for RULA & REBA for photocopy/printing workers are:

Sl No.	**Input for RULA for photocopy/printing workers**	**Input for REBA for photocopy/printing workers**
1	Upper arm position	Trunk: 2
2	Upper arm adjustment	Load/Force: 0
3	Lower arm position	Coupling: 0
4	Lower arm Adjustment	Upper arm: 2
5	Wrist position	Neck: 1
6	Arm muscle use	Lower arm: 1
7	Force load for	Activity: 1
9	Neck position	Legs: 2
10	Neck adjustment	Wrist: 2
11	Trunk	
12	Trunk Adjustment	

Sl No.	Input for RULA for photocopy/printing workers	Input for REBA for photocopy/printing workers
13	Wrist twist	
14	Legs	
15	Upper muscle use	
16	Force load	

Rapid Upper Limb Assessment for **photocopy/printing workers** was formulated with several objectives:

1) To screen the risk associated with the upper extremity disorders among the workers.
2) To determine the muscle fatigue involved while performing static or repetitive work.
3) To furnish scores along with the action level required which determines the level of urgency.
4) To create a feasible analysis tool which involves minimum equipment, time and effort.

5.7 Limitations of Rapid Upper Limb Assessment:

1) Work duration, time required for recovery or hand-arm vibration is not specified.
2) Enables the user to evaluate only single worker awkward posture at a time.
3) Assessing the different sides of the body such as right and left sides, which requires separate assessment.

Risk Factor for RULA & REBA:

Risk factor for RULA	
Score	**Level of MSD Risk**
2	Negligible , no need of action
4	Minimal risk, action may be required
6	Medium risk, further investigation, implementation required
6+	Very high risk, immediate change required

Risk factor for REBA	
Score	**Level of MSD Risk**
1	least, no need of action
3	minimal , action may be needed
7	Medium risk, further investigation, implementation required
8	High risk, investigate and implement change
11	Very high risk, immediate change required

5.7.1.1 ***Risk Assessment:***

Probable posture images of workers doing their work at the photocopying centers are shown in Figure 44 and 45. Thorough evaluation of the data observed and the visual recordings has been performed.

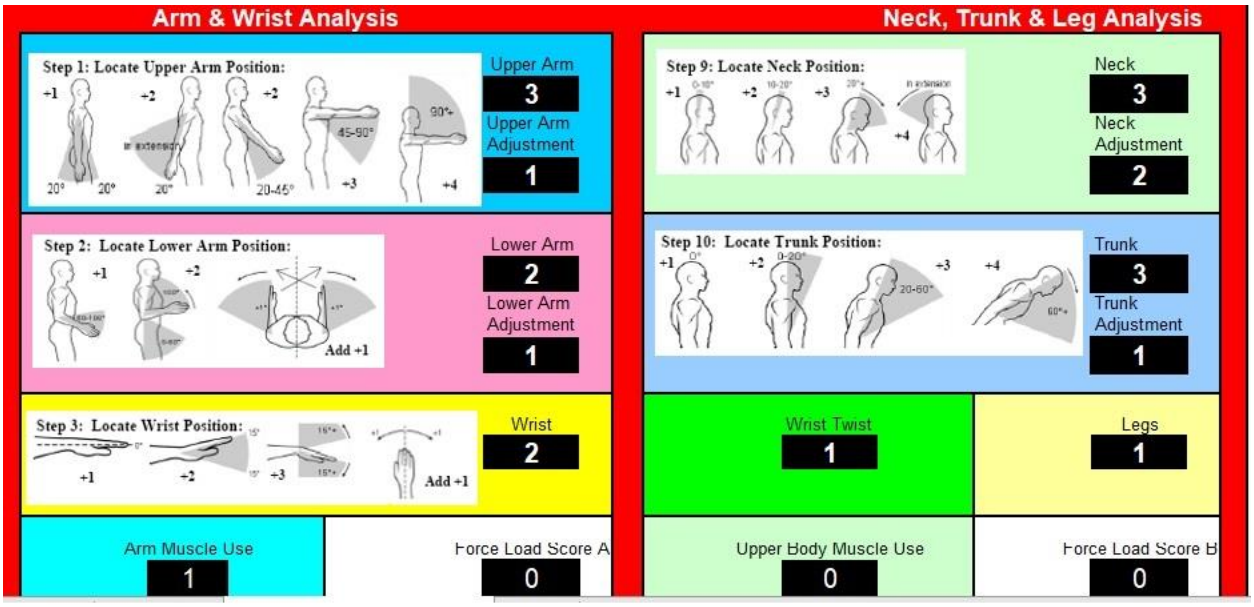


Figure 44: RULA risk input sheet based on workers posture

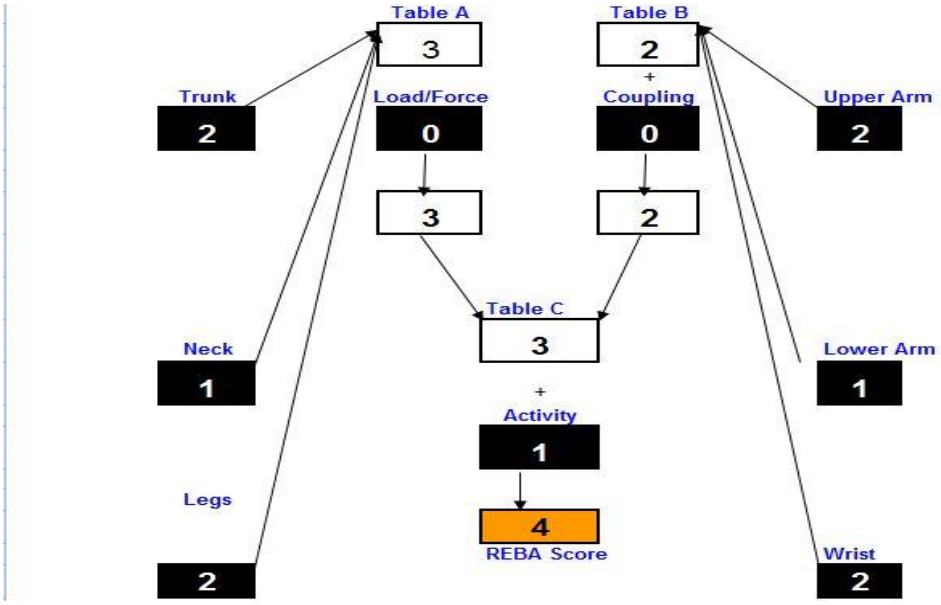


Figure 45: REBA risk input sheet based on workers posture

The person conducting the analysis, should interview the worker so as to comprehend more about the task in which they are involved and also they must also have a keen watch on the activities and the postures during work. Posture selection depends on the following:

- Awkward postures and working conditions
- The posture maintained by the worker for more amount of time or
- The posture which exerts more force load

The RULA analysis, is a quick process where we can easily evaluate the different work postures and the tasks during their work period without much effort and time. In this process, either the left or the right part of the body can be assessed at a single time. After performing the complete evaluation, which includes an interview and observation of the worker, the analyst can decide if both or either one of the arm needs to be assessed. The result obtained enables the analyst to identify the risk factor involved in the work. RULA score sheet is used to analyze the posture of arm and wrist, and the movement range of each body part is categorized into sections.

The sections are further assigned different scores. Score 1 represents the risk that are minimum. Higher number of score is given for risk with extreme posture. The scores of exposure based on RULA are 0, 1, 2 and 3 which signifies low, medium and high respectively. Risks which come under the scale of medium and high, needs to be changed immediately. REBA, which is a handwritten technique, enables us to assess the task which requires entire body as well limb area movements. In REBA, also the different parts of the body are classified into various divisions and they are given scores based on the ranges in their motion.

Scores are provided based on the risk factors, i.e., for parts of the body involving high risk factor are given high scores and those with low risk are assigned with low

scores. These scores range from 0 to 4 which implies negligible, low, medium, high and very high respectively. Here the scores showing, medium high and very high must be given attention urgently.

Once the entry have been made, calculate buttons are used to obtain the results. The final RULA score and Index is shown on the calculator. From the obtained RULA scores, the risk associated with MSDs can be calculated. The lowest RULA score being 1 and 7 being the highest score. RULA score of 3 represents the ideal situation. The risk index obtained gives a clear idea about the significance of the risk involved. A value lesser than 1 as per the index, shows normal risk to the workers and value either 1 or more than 1, represents possibilities of having high risk. Higher value of risk index indicates a sharp increase in the MSDs risk. Hence for proper design the risk index value must be either 1 or lower than that.

The study carried out showed a score of 7 on the RULA scale and 8 on the REBA scale, which implies that it requires further investigation and implementation of control measures.

Cancer and the factors that lead to getting diagnosed with cancer that are both genetic and environmental factors and their roles were discussed. Factors such as PEL, TWA, STEL, WEEL, ADI and their importance in regard to getting cancer and cancer risk calculation was clearly explained. A computer coded assessment tool was made using the software PYTHON coding language and a Graphic user interface, to estimate the Cancer risk due to the exposure of the various toxic substances present in photocopy/printing centers by inputting various parameters. For each chemical, the cancer risk value could be calculated easily by filling in the input parameters such as gender, body weight, toxic substance name, and concentration in days in the respective units specified.

An MSD analysis was conducted on photocopy/printing centers in Dehradun, India, on 64 workers using RULA and REBA techniques. Pictorial evidence was snipped from visual recordings. Risk potential was derived from OSHAS and IOSH

standards. RULA analysis revealed that the workers were exposed to high levels of risk, while REBA analysis gave a combination of both high and low risks. Both REBA and RULA analysis was done and the REBA score was 8 and the RULA was 7 indicating a high risk for getting MSD and as a result more investigation needs to be done and apt control measures should be adopted as well.

CHAPTER-6

6 Conclusion:

The study summarizes that the workers employed in the photocopy machine were exposed to environmental, physical, chemical and ergonomic hazards at work. Ventilation, number of copies, temperature, VOC, SVOC, Ozone, CO_2, CO and work designs are major threat to health and safety of the workers. It is recommended that these workers should be educated about the hazard, identifying these hazards and in prevention of the damage caused. Operators must undergo regular health checkups. Ergonomics must be considered in the workplace to decrease the level of risk involved in that particular work. Proper ventilation must be provided irrespective of the season (summer/ winter) so that proper air movement is enabled to reduce the level of built in pollutants.

Statistical analysis done on the emissions emitted, showed that volatile compounds, oxides of sulfur, carbon monoxide and ozone emissions are significantly released from these machines. The operators complained of back and neck pain, while wrist pain and upper respiratory throat infection were prevalent among different age groups. There was variations in the level of VOC, Ozone, and Carbon monoxide, HCHO, CO_2 emitted, based on the season.

The workers must put to practice efficient preventive measures while performing any specific operations like maintenance work, replacing the jams in the machine, filling the toner cartridge as these activities may expose the worker to more hazards. Always the lid of the machine must be kept closed in order to avoid the reflection of light which in turn troubles the eyes and cause disturbances. The workers must be given training about the postures which will make them comfortable during the work. To decrease the level of stress and strain experienced by the workers they should be provided with ergonomically designed workplace and shift based work.

The workers involved in housekeeping of the machines must be given proper training.

In order to decrease the level of risk and work load involved in these tasks, various administrative controls are adopted. Some examples are listed below:

- Workers must be given breaks at regular intervals to decrease the strain experienced
- Incorporating work adjustments
- Job rotation among the workers
- Keep the objects and equipment's in a position where people can easily access
- More manual power can be employed to carry out strenuous work
- Engineering controls like Backstretch belt, improved work techniques, flexible work place can be suggested.
- Administrative controls like change in- work procedures, rules, supervision, frequency and reduction in exposure to emissions, which cause inhalation hazards, can be implemented in the workplace.

6.1 Ways to safeguard occupant health:

Multiple engineering controls and administrative control can be adopted to safeguard the occupant health at work place, few suggestions are:

6.1.1 Choose low-emission photocopiers:

Selection of dry-process photocopiers/printers can be given priority over wet process photocopiers/printers as the dry process photocopiers/printers generates less amount of heat which finally results in reduced amount of environmental pollutant generation like ozone ,VOC and other oxides. Various advancements in the machine has led to the decrease in the emission of ozone.

6.1.2 Need for an Ozone filter:

Equip the photocopying machine with an ozone filter, which can readily breakdown the gas, which is present in the machines vent in turn converting it to normal oxygen. Replace these filters after printing nearly 50,000 sheets.

6.1.3 Maintaining distance:

Place the photocopy machine in such a manner that the emissions coming from the exhaust does not circulate all over the workplace or the people employed. Always make sure that the machine are kept in an isolated room with exhaust ventilation.

6.1.4 Ensuring proper ventilation:

Ventilate the room in which the photocopy machine is kept, either mechanically or naturally. Otherwise, there will be accumulation of high amount of ozone. If possible, place the machine in a separate room.

6.1.5 Proper Maintenance:

Proper maintenance of the machine should be carried out regularly. For example, the EPA analyze the emission of ozone from five photo copy machines before and after the maintenance. It was found to be 16 µg/copy to131 µg/copy before maintenance to 1 µg/copy to 4 µg/copy after maintenance.

6.1.6 Management of refills and spillages:

Carrying out refilling operations for toners in dry (xerographic) machines with at most care and also prevent spillages as much as possible. In case of any spillage, clean the area immediately and carefully. Avoid brushing of the area in which spillage has occurred, instead use vacuum to suck the spillage and wipe and clean the remaining with a damp cloth. People with respiratory illness must not be allowed to work.

6.1.7 Photocopy machine safety

The employer must maintain safety data sheet for the chemicals used in the machinery and provide it to their workers.

6.1.8 Suggestions for the specific place design to reduce the difference:

A block with a height of one feet with the perimeter of the machine is to be placed below the photocopiers/printers to lift the machine up which in turn bring the surface nearer to the employee. By this, one can make the controls and usual aids be at a height of 40'' – 48'' for a standing employee and could bring 12'' – 21'' for a sitting employee. Using this idea, we can actually reduce the movements of the body to an extent that extra force and number of repetitions decrease leading to a smooth flow of work activities without involving much stress.

Although photocopying/printing machine are important in our daily life, but they come with health issues which we neglect. Precautionary measure has to be taken while operating printing/photocopying machine such as adequate ventilation, fresh air in room, sufficient dilution in room when multiple machines are operating simultaneously, repeated exposure should be prevented. These machines emit radiations such as Infrared, Ultraviolet radiations which in turn increases the temperature of room. Installation of photocopier in poorly ventilated confined place leads the emission of multiple hazardous gases like Ozone, VOCs, SVOCs and heavy metals symptoms like fatigue, shortness of breath, headache, dizziness and nausea are the initial stage of poisoning of due to these hazards. Identification and quantification of concentrations of various specific particulate matters, ozone, SVOC and VOCs, emitted by major categories of photocopy machine plays a critical role in controlling air pollution. Characterizing the effects of emission on different age group at different time is a major area of concern which has been touched upon. Advancement of the importance of operational components which can be exploited to lessen outflow of contamination frame photocopy machine is require at some point or another for economic improvement.

Hence to conclude on the research, ample evidence is provided to the reader owing to the fact that there are adverse health implications and it is high time to take necessary measures. Much of the impact of photocopier machines can be put to limit by introducing engineering controls and administrative controls in work places, adopting clean photocopy innovations, proper engineering measures, and a well-designed awareness campaign to enhance the environmental safety and design of these enclosed spaces. Thus ensuring increased work productivity with utmost importance on individual health, ergonomics and ensuring the safe working of photocopier machines, regulating a routine check and use of dust/chemical collectors, which prevent the outflow of various particles accounting as a hazard to human health. As a customary rule, high usage of a photocopier or it may be duplicating machinery; there should be a separate ventilation room with mechanical exhaust.

Major Publications

- Nandan A*, Siddiqui N, Kumar P. Estimation of indoor air pollutant during photocopy/printing operation: a computational fluid dynamics (CFD)-based study. *Environmental Geochemistry and Health*. 2020. 2. (SCI, IF-3.252)
- Nandan A*, Siddiqui N, Kumar P. Assessment of environmental and ergonomic hazard associated to printing and photocopying: a review. *Environmental Geochemistry and Health*. 2018:1-25. (SCI, IF-3.252)

- Nandan A*, Tauseef S, Siddiqui N. Assessment of Ambient Air Quality Parameters in Various Industries of Uttarakhand, India. *Materials, Energy and Environment Engineering*: Springer, Singapore; 2017. p. 279-90. (Springer, Singapore)

- Jha K, Nandan A*, Siddiqui NA, Mondal P. Sources of Heavy Metal in Indoor Air Quality. *Advances in Air Pollution Profiling and Control*: Springer, Singapore; 2020. p. 203-10. (Springer, Singapore)

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8 ANNEXURE-I Table for major literature, reviewed

Table 1:List of previous work done to determine the various impact of Photocopying and printing

S No.	***Area of Impact assessment***	***Study Objectives and aspects covered***	***Methodology***	***Key Findings***	***Hazards identified***	***References***
1	Environment & Human Health	Concentration of Nano particles ($PM_{0.1}$) from photocopier machine Estimation of deposition of particles in human body when exposed to photocopiers	• Eight Photocopier centers were selected with at least one employee working as full time with more than 1000 xerox per day and have people working from the most common manufacturer of that area.	• Sulfide occupied the largest fraction in the elemental analysis done for $PM_{0.1\ mixture}$ of Zn, Fe, Al, Cu, Ni, Mn and Ti which led to increase reactive oxygen species and reactivity. • Deposition of Nano particles varied from 28% to 40% in the lung region, 14% to 20% in jaw area, 5% to 7% in head region and 7% to 13 % in thoracic region leading to major respiratory abnormalities. • Organic carbon was found using thermal optical analyzer.	Ergonomic & Environmental: PM0.1, heavy metals, Nano particles.	[65]
2	Human health	To assess the oxidative status and genotoxicity in	• Study exposed 5 men and women at 8 different photocopy centres working 5 hrs a day processing	• significant increase in in erythrocytes during photocopier operation	Ozone, UV-radiation, toner used in printing operation and	[180]

S No.	*Area of Impact assessment*	*Study Objectives and aspects covered*	*Methodology*	*Key Findings*	*Hazards identified*	*References*
		photocopier operators	approximately 32000 papers per days.		ergonomic.	
3	Human health	To conduct a cross-sectional study on respiratory effect of toner exposure	• Chest X-beam assessment Direct radiography was performed. The - beams were deciphered dependent on the worldwide grouping of pneumoconiosis and acquired pictures were electronically put away utilizing a film Digitizer. •	• From the toner dust exposure status personal exposure varied widely, but the average was below the exposure limit.	Toner used in the process.	[198]
4	Environment	Major components being emitted from the photocopier machine	• A Stainless steel chamber of 4 m X 3 m X 2.75 m with a 4m duct mounted on ceiling fan, floor too had two such ducts for circulation and re circulation of air. • Temperature, ventilation rate and humidity were controlled by PID with heat ex changer installed at the duct for recirculation. • Samples were taken during first 2 hr off state of machine, next 2 hr hour idle state then after 100min and 150 min	• Volatile Organic compounds were the most emitted pollutants consisting almost 80%. • Single sided photocopy emitted lesser VOCs than double sided copier.	Volatile Organic Compounds.	[199]

S No.	*Area of Impact assessment*	*Study Objectives and aspects covered*	*Methodology*	*Key Findings*	*Hazards identified*	*References*
			running of machine respectively.			
5	Health	Occupational health hazard identification	• Group people aged between 20-40were brought under the scanner for lung and blood tests to know the effect of exposure to photocopier	• High risk of problems in breathing, nasal blockage and abnormal increase in sputum production. • High Particulate matter causing risk of cardiovascular diseases Inflammation and oxidative stress.	Particulate matter.	[31]
6	Human Health	An assessment of ozone levels, UV radiation and their occupational health hazard estimation during photocopying operation	• Measurement of ozone was carried out by an ozone analyzer.	• Ozone concentration decreases when the no. of visitors increases as human body consume ozone.	Ozone, UV-radiation	[10]
7	Human Health	Respiratory health problems on photocopy and printing machine workers.	• Standard questionnaire was prepared to evaluate respiratory symptoms and the pulmonary function indexes and ratio were calculated conducting *t*-test, Chi Square and multiple logistic regressions.	• The prevalence of excess respiratory symptoms and occupational respiratory diseases.	Indoor environment	*[200]*

S No.	***Area of Impact assessment***	***Study Objectives and aspects covered***	***Methodology***	***Key Findings***	***Hazards identified***	***References***
8	Human Health	To determine negative Effect of Photocopier Toner on Alveolar Macrophages by *In Vitro* Magneto metric Evaluation	• *Cytomagnetometry* • *DNA ladder method* • *Statistical analysis*	• The electrophoretogram indicates no fragmentation of nucleosome units exposed to toner.	Ergonomic: Silica particles and particles from Toner.	[201]
9	Human Health	Emissions from photocopiers and its effect.	• assessment of pulmonary function by relationships between cumulative exposure, lung function and inflammatory markers	• Photocopiers/printers emit high levels of particulate matter which leads to high risk of cardiovascular diseases.	Ergonomic: Particulate matter	[202]
10	Human Health	Assessment of responses of nanoparticles from photocopiers in human cell	• Three cell types were used: THP-1, primary human nasal- and small airway epithelial cells.	• Copier-transmitted nanoparticles instigated the arrival of supportive of incendiary cytokines, apoptosis and unassuming cytotoxicity yet no DNA harm in each of the three-human cell lines.	Nano-particles emissions.	[11]
11	Environment	Fine Particles from devices	• An 8 days experiment was conducted in two centers where the centers were monitored 2 hours before and after closing.	• Diffusion is more in case of the fully ventilated center than the air conditioned center.	Inadequately ventilated workplace.	[203]
12	Environment	Investigation of Indoor air quality in	• The indoor concentrations of PM_{10}, $PM_{2.5}$, PM_1 and CO of a selected classroom with 43	• In winters the Indoor concentrations of PM_{10} and $PM_{2.5}$ were exceeding the	CO, particulate matter PM10 and $PM2_{.5}$	*[204]*

S No.	*Area of Impact assessment*	*Study Objectives and aspects covered*	*Methodology*	*Key Findings*	*Hazards identified*	*References*
		naturally ventilated school building situated nearby urban roadway	number of occupants were measured for 60 days; winter (34 days) and summer (26 days). • The mass concentrations of PM_{10}, $PM_{2.5}$, PM_1 were monitored using GRIMM environmental dust monitor model 1.107.	NAAQS 79% of time and 41% of time respectively. It was 34% and 8% for PM_{10} and $PM_{2.5}$ during summers. • The 8h average levels of CO during winter and summer seasons were found to be less than NAAQS specified value. Presence of CO concentrations inside the classroom was majorly due to the vehicular movement from the adjacent street. • The concentration of Particulate Matter was significantly higher, on comparing when it was occupied and then when it was empty.		
13	Environment and Human health	Assessing the indoor air concentrations of VOCs (volatile organic compound) and BTEX (benzene, toluene, ethylbenzene and xylene)	• On the basis of various features like room characteristics, size, on-going activities, occupants and materials kept eight different locations were selected within the library of the JNU campus for monitoring of TVOC and BTEX. • For measurement of TVOC a portable Phocheck 5000 PID	• The concentrations of TVOC and BTEX indoor were higher for winter season as compared to summer season. Amongst the BTEX, toluene had greater mean value. Out of all the selected 8 locations the photo-copy room was found out to be most polluted in both the seasons. • The I/O values for TVOC and BTEX were greater than unity;	Volatile organic compounds.	*[205]*

S No.	*Area of Impact assessment*	*Study Objectives and aspects covered*	*Methodology*	*Key Findings*	*Hazards identified*	*References*
			with 10.6eV UV lamp was used and for BTEX measurement a handy sampler was used which has activated charcoal.	which confirms that the dominant source of pollution majorly came from indoors.		
14	Environment	Assessing indoor $PM_{2.5}$ in various residential environments like living-room, kitchen and bedroom across 6 different Kuwaiti provinces. Comparing the analyzed results from the study with USEPA and WHO guidelines.	• In order to measure the concentration, of particulate matter within the houses, a Dust-Trak aerosol monitor was used with a detection range of 0.001 to 100 mg m^{-3}. • Samples were collected from living room, bedroom and kitchens of 4 houses chosen from different locations • $PM_{2.5}$ was measured over a 24h period, samples were collected 1m from floor. During the period of study, air condition was ON and all ambient ventilation sources were closed..	• The $PM_{2.5}$ concentrations recorded at 4 out of 6 residential areas were higher than EPA standard for 24h (35 $\mu g\ m^{-3}$). It was found out to be highest in the kitchen due to cooking activities. In bedrooms the lowest $PM_{2.5}$ concentrations were recorded. • The study indicates that houses in Kuwait have highly indoor polluted environment compared with other international standards, houses with smoker occupants had higher $PM_{2.5}$ concentrations than houses with non-smoker occupants.	Environment: particulate matter $PM_{2.5}$	*[206]*
15	Human health	Evaluation of indoor air quality variability within Bolpur,	• For the assessment of indoor air quality in the houses data was collected from June 2006 to July 2007. CO, CO_2, NO, NO_2, SO_2, O_3 (gaseous	• The concentrations of indoor air pollutants were greater in all the houses located at 0.5 km from the main road and similarly, the lowest levels of pollutants were	CO, ozone, oxides of nitrogen.	*[207]*

S No.	*Area of Impact assessment*	*Study Objectives and aspects covered*	*Methodology*	*Key Findings*	*Hazards identified*	*References*
		West Bengal. The study also assesses the impact of indoor air quality on the health of children	pollutants) were measured using a portable multigas monitor and for Suspended particulate matter (SPM) a handy sampler was used. • The city was divided into 3 areas based on the distance from the main road, 20 houses were selected from each selected area and the study of respiratory symptoms in the children was carried out on the basis of questionnaire. • 453 children aged between 6 to 10 year were part of the study, various lung function parameters were measured using an electronic Spiro meter and the test data was further transferred to computer for analysis.	recorded in houses located at 5.0 km from the main road. According to the study, indoor air pollutants have a significant impact on the prevalence of respiratory symptoms. The children living at 0.5 km distance from main road were found to be at higher risk than those living in houses at 5.0km from the main road.		
16	Environment	Indoor air quality monitoring in terms of VOCs within a multi-storey shopping complex with parking area	• For the assessment of TVOC 32 indoor locations were selected across two storehouses and different departments of a supermarket. The monitoring was done in two campaigns each of 1-week.	• On calculation of I/O values for each area it was found that benzene concentrations were majorly due to outdoor sources, the parking showed aromatic compounds concentrations 3-4 times higher than outdoor concentrations.	Volatile organic Compounds	*[208]*

S No.	*Area of Impact assessment*	*Study Objectives and aspects covered*	*Methodology*	*Key Findings*	*Hazards identified*	*References*
		and supermarket.	• VOC was sampled using a diffusive sampler, then the samplers were analyzed using a gas chromatography mass spectrometry. The sampling period for VOC was 48h, for measuring the indoor temperature and relative humidity portable thermo hygrometric probes were used.	• From the study it was also confirmed that higher concentrations of toluene were due to various important indoor sources. • The higher concentrations of TVOC were because of less efficient air intake and exchange systems.		
17	Environment	Measurements of indoor and outdoor concentrations of CO & NO_x	The indoor concentrations were measured for 8h, the sampling was done in the living room of all the houses, for outdoor full day i.e. 24h sampling was carried out. A portable YES-205 multi-gas monitor was used for measuring the concentrations of CO and NOx. • The instrument was positioned at a height of 2m from the floor for measurement of the pollutants. • From each location i.e. urban, roadside and rural 5 houses were selected, overall	• Houses at roadside location had maximum CO level dur to presence of constant traffic. • Concentrations of NOx were maximum for houses at urban locations, the outdoor environment affected the indoor environment. Hence, a positive correlation was found between the indoor and outdoor concentrations of NOx.	Environment: CO and oxides of nitrogen	*[209]*

S No.	*Area of Impact assessment*	*Study Objectives and aspects covered*	*Methodology*	*Key Findings*	*Hazards identified*	*References*
			15 houses were monitored during the period of study.			
18	Environment and health	Investigation of indoor air pollutants across various areas of hospitals throughout Taiwan and examining their possible association with the types of air-conditioning systems.	• 37 hospitals were selected for indoor air quality measurements, from November 2007 to January 2008, sampling was carried out at nurse stations, clinic and waiting area, pharmacy and wards. Mixed air-conditioning system was investigated. Measurement of particulate matter levels of PM_{10} and $PM_{2.5}$ were done using a DUST-TRAK Aerosol monitor, sampling was done for 24h whereas for examination of CO and CO_2 levels Q-TRAK monitor was used and sampling was done for minimum 8h at each site location.	• In the ward and pharmacy area of the hospitals higher concentrations of CO_2 and TVOC was found as compared to other areas of the hospitals. • The CO levels were higher in hospitals equipped with mechanical air conditioning system. • Hospitals equipped with central AC systems had lower levels of particulate matter than those with non-central AC systems.	Ergonomic, CO_2, Volatile Organic Compounds.	*[210]*
19	Human health	Effect of indoor air pollutants on people working in an office. Impact of	• The adverse effect of indoor air pollutants in office environment is found out through various questionnaires categorized on the basis of health	• The concentration levels of VOCs in office environment are too low to cause any irritation in eyes whereas some VOCs, like formaldehyde results in reported irritation in	Ergonomic hazards	*[23]*

S No.	*Area of Impact assessment*	*Study Objectives and aspects covered*	*Methodology*	*Key Findings*	*Hazards identified*	*References*
		concentration levels of VOCs in office on lungs and its inflammatory effects	symptoms.	eyes and upper airways • High concentrations of VOCs results in decreased lung function.		
20	Environment	To investigate indoor air pollutants in school buildings based on the operation of mechanical ventilation systems.	• 3 classrooms at 2 elementary schools and 4 classrooms at 2 different kindergartens in Korea were selected for measurement of IAQ parameters like VOCs, CO, CO_2, O_3, NO_2, PM_{10} and total bacteria counts. • The differences in the concentrations of above-mentioned pollutants with and without the action of ventilation systems were calculated and analyzed. • The following instruments were used to measure the levels of respective pollutants: i. PM_{10} – mini volume air sampler equipped with a pall flex filter. ii. CO & CO_2 – non dispersive infrared analyzer.	• The results from the study shows that the operation of ventilation systems can result in lowering the concentration levels of formaldehyde and TVOC by 65.5% and 35.5% respectively. • There were no changes in the levels of CO_2 either with or without the operation of ventilation system	HCHO, Volatile Organic compounds, CO_2.	*[211]*

S No.	*Area of Impact assessment*	*Study Objectives and aspects covered*	*Methodology*	*Key Findings*	*Hazards identified*	*References*
			iii. NO_2 – NO_2 analyzer 200E. iv. O_3 – UV photometric analyzer 400E. v. Total bacteria count – MAS impactor. vi. TVOC – samples collected through Tenax-TA tubes and analysis done by gas chromatography.			
21	Environment	To assess the indoor air quality in terms of VOC at nine public locations in the city of Mumbai.	• At all the locations air was sampled for a period of 4h using a battery-operated low volume personal air sampler equipped with absorbing cartridges (Chromosorb 106) for VOCs estimation. • Estimation of O_3 was done using alkaline potassium iodide method. • The observed levels of all the 40 VOCs identified at various locations, 10 of them were reported as hazardous air pollutants. Levels of the VOCs were compared to the Public places and offices guidelines by Hong Kong.	• The concentration levels of benzene, toluene, chloroform and carbon tetrachloride were found in excess to the permissible levels by Hong Kong Air quality guidelines. • Concentration levels of rest of the VOCs were found out to be within the prescribed limit. • The concentration of TVOC decreases on ozonization, which indicates that concentration of various VOCs is reduced up on reaction with O_3. • The study suggests to restrict the use of consumer goods which contains VOCs	Indoor Environment	*[212]*
22	Environment and human health	Estimation of indoor air quality and its	• Concentrations of CO, NO_2, SO_2, CO_2, PM_{10}, H_2S, Chlorine and polycyclic	• The I/O values for CO_2 were close to unity, whereas for CO, NO_2 it was greater than 1; for	Environment: CO, oxides of nitrogen and	*[213]*

S No.	*Area of Impact assessment*	*Study Objectives and aspects covered*	*Methodology*	*Key Findings*	*Hazards identified*	*References*
		health effect on the occupants of houses situated in urban environment of the city Agra. To characterize the I/O relationship of pollutants and their seasonal variation.	aromatic hydrocarbons (PAH) were measured in the living room of all the selected 20 houses; 10 were from the typical urban area and remaining 10 were adjacent to national highway. • The following instruments were used to record the concentrations of the above-mentioned pollutants: i. CO, NO_2, SO_2 – portable multigas monitor (YES-205). ii. CO_2 – portable YES-206 iii. PM_{10} – handy sampler iv. PAH – respiratory dust sampler. • Full day sampling indoor and outdoor of all the selected 20 houses was done from October 2004 to December 2005	PM_{10} it was greater than 1 for houses adjacent to national highway and less than 1 in urban locations; SO_2 I/O value was greater than 1 I urban locations and was found out to be 1 for roadside location. • The maximum concentrations were seen during the winter season, a general pattern was observed of increasing levels from rainy to summer to winter season. • All the gaseous pollutants were within the permissible limits.	Sulphur.	
23	Women health	Improvement in indoor air quality while using smokeless stove in Nepal.	• Comparative study was done before and after using traditional and smokeless stove. •	• Decrease in the concentration of emission of RSP, CO and HCHO could be estimated.	Socio-economic, HCHO, CO	[214]

S No.	***Area of Impact assessment***	***Study Objectives and aspects covered***	***Methodology***	***Key Findings***	***Hazards identified***	***References***
24	Environment and health	To estimate the indoor air pollutant from photocopy and printing process Occupational health risks associated with these operations.	• Concentration of toxic chemicals were computed using ANSYS (Fluent 2015) software, the air flow is calculated then CFD simulation is done, which requires material properties and boundary • Conditions. The flow, effect of temperature and number of prints from the device is examined using ANSYS fluent.	• The study observes that with the increase in frequency of prints/photocopy from the device the temperature of the device also increases which leads to higher environmental as well as occupational hazards. • It was further observed that printing operation in confined spaces with inadequate ventilation systems lead to the emission of CO, VOCs, odorless gases and particulate matter which may give rise to various health related issues.	Ergonomic, CO and Volatile organic compounds.	*[215]*
25	Environment	Development of statistical model to characterize common air pollutants in offices with air-conditioned ventilation system.	• In search of manageable and cost-effective parameters out of 12 IAQ parameters, the mathematical expressions were derived for sampling of 3 independent IAQ parameters i.e., TVOC, CO_2 and respirable suspended particulates (RSP) in office environment.	• Determinations of all the IAQ parameters consumes lots of time and requires more resources. • From the results, a set of 3 parameters i.e., TVOC, CO_2 and RSP was proposed as indicators for IAQ in offices.	Environment: CO_2, respirable suspended particulates and VOCs	*[216]*

S No.	***Area of Impact assessment***	***Study Objectives and aspects covered***	***Methodology***	***Key Findings***	***Hazards identified***	***References***
26	Environment	Estimation of reference values for Indoor air pollutants in new residential buildings	• Sampling was done in newly finished buildings and after a period of 6 and 12 months. 14 apartments in 8 residential buildings were sampled for the study. • For VOCs air samples were collected on Tenax-TA tubes and analysis was done by gas chromatography. • The air-exchange rate was measured with AXD-530 thermo anemometer • For temperature and relative humidity Vaisala HMP41 moisture detector was used.	• The concentrations of NH_3, HCHO showed seasonal variations i.e., higher during summers. • The VOCs concentrations are high in newly finished building.	Ammonia, formaldehyde and VOCs	*[217]*
27	Environment and health	Determination of association between the symptoms of Sick building syndrome (SBS) and indoor air quality parameters.	• To assess the symptoms of SBS a questionnaire-based survey was carried out for the selected 3 buildings. • TSI velocicalc instrument was used to measure the concentration of CO, CO_2, air velocity and relative humidity; SAS IAQ air sampler was used to measure the total fungal count with incubation period of 5 days at 25 ^oC.	• One of the 3 buildings can be designated as a sick building, it had higher CO_2 concentration and the reason for that was found out to be poor ventilation, because of imbalanced ventilation and high percentage of relative humidity total fungi count was also the highest when compared to other 2 buildings.	Environment: CO_2, CO. Imbalanced ventilation.	*[218]*

S No.	***Area of Impact assessment***	***Study Objectives and aspects covered***	***Methodology***	***Key Findings***	***Hazards identified***	***References***
28	Human health	To review epidemiological studies that assess the quantitative effects of indoor air pollutants on pulmonary diseases.	• Several papers from peer-reviewed journals were summarized to determine the association between indoor air pollutants and their respiratory outcomes.	• Chronic exposures of indoor air pollutants even at low concentrations may be responsible for adverse health effects.	Indoor environment	*[219]*
29	Human health	To assess elders exposure to indoor air pollutants in and characterize the IAQ in Elderly Care centers	• 10 elderly care centers were selected for the study in urban and sub-urban areas of the district. • CO, CO_2, TVOC, O_3 concentrations were measured with photoionization probe; particulate matter with diffusion optical light and HCHO • (Formaldehyde) with electrochemical formaldehyde sensor-based instrument.	• Only one ECC had mechanical ventilation as a result of which ventilation rates were insufficient in facilities lacking the mechanical ventilation system. • CO_2, O_3 and PM_{10} concentrations exceeded the established limit values	Environment: CO_2, Ozone and PM_{10}	*[220]*

S No.	***Area of Impact assessment***	***Study Objectives and aspects covered***	***Methodology***	***Key Findings***	***Hazards identified***	***References***
30	Environment	To determine the sources of primary and secondary emissions from building material and furnishing products used in various household activities	• Various papers were summarized for identifying the sources of primary and secondary emissions form building materials.	• Possible reactive products within the indoor environment with potential reactants and their respective sources of emissions were identified.	Products forming Volatile organic compounds	*[221])*
31	Environment and health	Estimation of indoor air pollutants inside a subway station by cumulative calculation method based on average hourly concentrations.	• The average hourly concentrations of NO, NOx, PM_{10}, $PM_{2.5}$, CO, CO_2, temperature and humidity is monitored with tele-monitoring systems (TMS) installed at subway stations. • 1-year data from TMS is gathered for the study.	• Operators working at the subway stations are influenced by indoor air pollutants at a greater extent. • Cumulative air quality indices are suggested for comparison of cumulative indoor air quality parameters.	Environment: CO_2, NOx, CO and particulate matter.	*[222]*
32	Environment and human health	To identify the potential sources of indoor air pollution and	• Different sources of indoor air pollution and their impact on health have been identified after summarizing several papers	• Majority of these pollutants have indoor sources and they have negative impact on human health and with improved air-conditioning and ventilation	Imbalanced air-exchange rate.	*[223]*

S No.	*Area of Impact assessment*	*Study Objectives and aspects covered*	*Methodology*	*Key Findings*	*Hazards identified*	*References*
		their respective health effects. Methods for controlling the sources and cleaning the indoor air with improved ventilation systems.		systems, air-cleaning the concentrations of these pollutants can be reduce.		
33	Environment	To characterize and estimate the total concentrations of $PM_{2.5}$ poly cyclic aromatic compounds (PAHs) in households burning wood and charcoal in living-room/kitchen	• Samples were collected over 20 mm and 10 mm TEFLON coated filters using Sibata ATPS-20H dual impactor.	• The concentration of $PM_{2.5}$ PAHs decreases in the order of; kitchen-outdoor- living rooms. • Kitchens where biomass fuels are used they still remain to be a hazardous environment.	Socio-economic	*[224]*
34	Environment	To evaluate the result of printers on the indoor air	• Two laser and an ink-jet printer were used in this study. • The concentration of O_3 was	• The results from the study confirmed an increase in ozone and ultrafine particles concentrations during the	Ergonomic, Toner used in printing operation	*[141]*

S No.	*Area of Impact assessment*	*Study Objectives and aspects covered*	*Methodology*	*Key Findings*	*Hazards identified*	*References*
		quality of a room containing either laser/ink-jet printers	monitored using Ozone analyzer; ultarfine particles were measured with SMPS-CPC and VOCs samples were analyzed using gas chromatograph mass spectrometry.	printing operation. • The toner of the laser printer has been identified as a source of Styrene. • The increase in O_3 concentration is due to oxidation of VOC into other contaminants.		
35	Environment	To measure the concentrations of HCHO (formaldehyde) and TVOC and identifying their sources in underground malls	• 9 underground malls were investigated for concentration levels of formaldehyde and TVOC. • TVOC concentration was measured using MiniRAE VOC monitor; formaldehdye concentration was measured with Z-300XP monitor probes.	• The levels of formaldehyde and TVOC were exceeding the standards by 66.7% and 77.8% respectively. • Leather products, food cooking, cosmetics contributed to the concentration of HCHO and TVOC.	Ergonomic, environment-HCHO and VOCs	*[225]*
36	Environment and Human health	Assessment of IAQ of households with infants	• Monitoring of indoor air quality was done with an AirAdvice M7100 and following parameters were measured: CO, CO_2, TVOCs and $PM_{0.5}$. • The above mentioned parameters were measured in 10 homes.	• Levels of CO_2, TVOC and $PM_{0.5}$ exceeded the IAQ guidelines. • Gas stoves, remodeling of nursery and pets were identified as potential factors which affected the Indoor air quality of more than half of the houses.	CO_2, volatile organic compounds and CO.	*([226]*

S No.	***Area of Impact assessment***	***Study Objectives and aspects covered***	***Methodology***	***Key Findings***	***Hazards identified***	***References***
37	Environment and Human health	To provide allergists with useful information regarding the health effects of indoor air pollution.	• Review of existing literature for indoor air pollutants and their respective impact on human health.	• Providing allergists with information regarding the symptoms which arises from poor IAQ, so they can make suitable suggestions to patients seeking advice related to the indoor environment	Ergonomic, poor indoor environment.	*[227]*
38	Human health	To review the impact of relative humidity on IAQ	• Review of existing literature in major databases for the influence of indoor air qualtiy by relative humidity.	• Relative humidity about 40% is suggested for eyes and below 30% for upper airways.	Improper indoor environment	*[228]*
39	Human health	Effect of using room freshener and cleaning agent on indoor air quality index.	• Various studies were examined to give the conclusion.	• Use of such agent may lead to the formation of secondary air pollutant. • Certain chemicals used are hazardous to human health as they are listed toxic.	Volatile organic compounds	[180]
40	Children health	Assessment of indoor air pollutant in a tropical region.	• 158 children in Kula Lampur suffering from asthma were examined and questionnaire was prepared.	• Passive smoking and use of mosquito coil are major factor contributing to indoor air pollutant leading to asthma among children aged between one month to five year.	Environmental tobacco smoke (ETS)	[229]

S No.	*Area of Impact assessment*	*Study Objectives and aspects covered*	*Methodology*	*Key Findings*	*Hazards identified*	*References*
41	Women health	Domestic fuel as a major source of lung cancer among women in India.	• Questionnaire was formed from 67 women who were suffering from lung cancer. • Risk factor was calculated using class interval and odd ratio.	• 75% of women were nonsmoker and 25% were smokers. • Solid fuel act as primary source which contain carcinogenic substance. •	Socio-economic	[31]
42	Human health	Impact of using solid fuel for cooking in developing countries.	• Evidences were collected from various studies and survey performed by national agencies.	• From 13 studies it has been found that children where solid fuel is used have a chance of (2-3) times of being exposed to acute respiratory infection. • Chronic obstructive pulmonary disease leads to 1.5% and 16% of women death in India and china respectively. • It causes various other diseases such as lung cancer, cataract, asthma attack etc. • Young children and women are majorly affected. • Need of coal substitution for house hold work.	Socio-economic	[230]
43	Human health	Assessment of cigarette smoke inside a close room.	• Experiment was conducted in room where continuous measuring instrument were used for measuring concentration of NO_X , SO_2 and O_3 while two smoker remain inside the room.	• It has been found that while smoking in a controlled environment concentration of TVOC, NO_X and CO_2 increases by 10, 3 and 4 times respectively. • Initial concentration is achieved after 2 hours.	Environmental tobacco smoke (ETS)	[231]

S No.	*Area of Impact assessment*	*Study Objectives and aspects covered*	*Methodology*	*Key Findings*	*Hazards identified*	*References*
			• For measuring TVOC and CO_2 analyzers were used.			
44	Human health	Comparative study of different air pollutant at different buildings in Hong Kong.	• For investigation 39 sites were selected including school, commercial offices, shopping mall, residential flats. • CO_2, VOC, HCHO were examined using Q- track monitor, clean canister and SKC formaldehyde monitoring kit respectively.	• Highest concentration of CO_2 found in restaurant and least at home. • PM_{10} maximum concentration found in restaurant and least equally in office and air conditioning classroom. • Maximum concentration of HCHO found in restaurant and least equally in office and classroom.	Ergonomic, Environment-CO_2, particulate matter and HCHO	[199]
45	Human Health	Assessment of emission rate of VOCs from latex paint.	• Source emission model was used for estimating the emission rate. • Chamber testing was performed. • Use of sink studies.	• It has been found while using stainless steel substrate VOC emitted within few days. • Using gypsum board substrates it takes long time to emit VOC_s.	Volatile organic compounds	[232]
46	Human Health	Decrease in concentration of indoor air pollutant in Japan.	• Survey was conducted for a period of 6 years from 2000 to 2005. • Passive sampler were used to collect the sample and were analyzed using chromatography.	• Due to amendment in building standard law decrease in concentration of VOC_s was seen in year 2003. • Improvement in quality for construction material and use of ventilation under BSL were	VOCs	[233]

S No.	*Area of Impact assessment*	*Study Objectives and aspects covered*	*Methodology*	*Key Findings*	*Hazards identified*	*References*
			• Indoor temperature was measured. • Questionnaire was prepared. • All the data were merged to give productive result.	major factor for improvement in air quality.		
47	Children Health	Problem of acute respiratory illness among school children in Zimbabwe due to indoor air pollution.	• Study was done on 3559 children who were suffering from cough, ARI etc. • Logistic regression and questionnaire were used. • Comparative study was done in between those using biomass fuel and cleaner fuel.	• 66% of children were those where solid fuel was used and 16% of children were suffering from ARI. • They are almost twice in number of those who are using cleaner fuel. • Government need to take steps to encourage people for the use of cleaner fuel in order to reduce the risk of ARI.	Indoor Environment, socio-economic.	[234]
48	Human health and environment.	Assessment of indoor environment using active green wall in reducing VOC.	• Single pass efficiency protocol was developed. • Green wall having 63 plants was installed and 2-butanone was used as pollutant. • Air sampling was done and clean air delivery rate was calculated.	• Indoor plants help in improving the air quality. • It is low cost-effective technique.	Volatile organic compounds.	*[235]*
49	Human health	Respiratory health issue from biomass	• High volume sampler were used to monitor PM_{10} and CO monitoring done with hand	• Concentration of PM_{10} was 3 times higher than those who were using clean fuel for cooking as	Socio-economic	[180]

S No.	*Area of Impact assessment*	*Study Objectives and aspects covered*	*Methodology*	*Key Findings*	*Hazards identified*	*References*
		fuels used for cooking in Nepal.	pump Gastec. • Comparative study was done for the use of biomass and clean fuel. •	compared to those using biomass. • CO concentration was 6.67 times higher to those using clean fuel. • Poor people were mostly suffering due to poor ventilation system.		
50	Human health	Primary cause for lung cancer in Fuzhou, China through study.	• For the study, 120 patients were taken and information was derived using questionnaire and evolution of data is done using conditional logistic regression analysis.	• Burning coal inside house and smoking are major cause for lung cancer.	CO, CO_2 and inadequate ventilation	*[236]*
51	Human health	Assessment of air quality in fitness center.	• 11 fitness centers were taken and particulate matter, CO_2, CO, HCHO were measured using direct reading device along with temperature and humidity.	• Air quality is directly proportional to occupancy. • Concentration level of CO_2, HCHO and volatile organic compound is high. • Most of the centers are having bad ventilation.	CO_2, HCHO, VOCs and poor ventilation	[31]
52	Children health	Root cause for acute lower respiratory infection in children.	• 500 children aged between (1-5) years were taken and statistical analysis was done to get the result.	• Father smoking and women carrying children at back while cooking is major source for infection.	Environmental tobacco smoke (ETS), socio-economic	[237]

S No.	*Area of Impact assessment*	*Study Objectives and aspects covered*	*Methodology*	*Key Findings*	*Hazards identified*	*References*
53	Human health and environment	Effects of using candles and incense in air quality of church.	• Church in Geneva was taken for examination. • Church was renovated with new window panels and opening were closed for reducing heating cost. • Concentration of dust and polycyclic aromatic hydrocarbon was measured.	• Dust accumulated in the walls due to soot produced by candles and incense with incense as major source of PAH. • Mechanical ventilation and petrol lamps as a substitution of candles could be used.	Insufficient ventilation, Polycyclic aromatic hydrocarbons (PAHs)	[238]
54	Human health	Study of cosmetics in beauty salon acting as air pollutant.	• 4 beauty salons were taken for environment. • 10 eight-hour sample of particulate matter were taken inside and outside for comparison study for indoor and outdoor and carbon content was evaluated.	• Concentration of PM and carbon content evaluated was higher inside. • Use of cosmetics are source of air pollutant. • Proper ventilation should be there to avoid occupational risk. • PPE being ignored by workers but study shows the importance of use of PPE for salon workers.	Ergonomic, Indoor environment-Particulate matter and CO_2.	[239]
55	Human Health and environment	Assessment of air quality inside museum.	• Museum was selected for survey work which was done in summers and winter. • Sampling device was used for measuring the concentration of pollutant.	• Indoor air pollutant can destroy the material being stored. • Indoor to outdoor ratio is higher in summer season. • Particles and bacteria could be accumulated in carpet.	Particulate matter microbial environment	[240]
56	Human health	Effects of use of biomass fuel in Kenya.	• 55 houses were selected for examination including children infant and adult. Data on acute	• Substitution for biomass fuel required for the reduction of ARI and ALRI cases.	Socio-economic	[241]

S No.	*Area of Impact assessment*	*Study Objectives and aspects covered*	*Methodology*	*Key Findings*	*Hazards identified*	*References*
			respiratory infection and acute lower respiratory infection were taken and continuous monitoring for PM_{10} concentration was done			

9 Annexure-II Location & Survey data

S.NO	Name of place	Name of owner	Gender	Age	Marital Status	Social Status	Educational Qualification	Nature of Family	Establishment	No. of workers	Height worker(Ft.)	Photocopy Machine Model	No. of Photo-	Height machine(Ft.)	No. of xerox per day	Area of shop(sq.ft)	Working hours	Problems Facing (If Any)	No. Of Ventilation Points	Ventilation Area(Sq.Ft)	Specialised Ventilation Area
1	Project Point, Suddhowala	Hemant	M	25	UM	BC	JF	L	2014	1	5.6	`	1	4	300	12*7	12	Backpain ,Joint Pain, Hearing Problem	None Only Door	Door Area Is 12*7	none
2	Sai Mobile Repair, Premnagar	Bhuvnesh	M	28	UM	SC/ ST	NF	IL	2012	1	5.6	Konica Minotta AR55165, BIZHUB 206	2	2.5	300	12*12	12	No	None Only Door	Unspecified	NONE
3	Deep Cyber Café Premnagar	Virendar	M	25	UM	Mos t BC	JF	IL(B HS S)	2011	1	5.6	Sharp AR MI160	1	2.5	250	14*15	10	Backpain	2 Exhaust	Na	2 EXHAUS T FANS
4	Doon Communicat ions Suddhowala	Dhoom Singh	M	33	Mar ried	SC/ ST	NF	L	2007	1	5.7	Sharp 5168	1	2.5	150	9*12	12	Backpain , Hearing	None Only Door	None	none
5	Vardan Communicat ions Kehri Gaon	Kapil	M	29	UM	BC	IF	IL	2015	1	5.1 1	Epson,HP, Xerox 5024	3	5,2. 5	500	12*25	12	None	None Only Door	Unspecified	none
6	Vedika Enterprises Kehrigaon	Ashish	M	28	UM	Mos t BC	IF	IL(B HS S)	2014	1	5.5	Canon 2520	1	2.5	150	11*11	12	None	None Only Door	Unspecified	none
7	Photostat Shopee Premnagar	Mehendra	M	30	UM	SC/ ST	NF	L	2012	1	5.9	Canon 2520	1	3.5	150	8*12	12	Cough, Hearing Problem, Backpain	None Only Door	None	none

S.NO	Name of place	Name of owner	Gender	Age	Marital Status	Social Status	Educational Qualification	Nature of Family	Establishment	No. of workers	Height worker(Ft.)	Photocopy Machine Model	No. of Photo-	Height machine(Ft.)	No. of xerox per day	Area of shop(sq.ft)	Working hours	Problems Facing (If Any)	No. Of Ventilation Points	Ventilation Area(Sq.Ft)	Specialised Ventilation Area
8	Bittu Photocopy Premnagar	Harmanjeetsingh	M	60	Married	Most BC	JF	IL	2012	1	5.6	HP	1	4	120	8*12	12	None	None Only Door	None	none
9	Ahuja Stationary Premnagar	Nishant Kumar	M	18	UM	SC/ ST		L	2014	2	5.2	Cannon 3235	1	4	300	300	12	Hearing Problem,	None Only Door	6*5	none
10	Ahuja Stationary Premnagar	Kushal Thappa	M	19	UM	BC	NF	IL(BHSS)	2014	1	5.3	Cannon 3235	1	4	200	300	12	Skin Infection And Back Pain	None Only Door	6*5	none
11	Paint Shop, Premnagar	Ravi Sharma	M	30	M	Most BC	JF	IL	2013	1	5.11	HP	1	3.5	150	8*12	12	None	None Only Door	Na	none
12	Sushil Photocopiers, Sukhuwala	Akash Agarwal	M	60	M	EBC	NF	IL	1997	1	5.5	Cannon 32354	2	4.5	600	12*12	10	Skin Infection, Back Pain And Joint Pain	2 Doors	Na	2 EXHAUST FANS
13	Doon Cyber Café, Premnagar	Narender Singh	M	55	M	SC/ ST	IF	L	2012	1	5.7	Xerox 5024	1	4.5	250	12*14	9	Eye Irritation, Skin Infection, Backpain, Hearing Problems And Joint Pain	None	Na	None
14	Shiva Hostel, Premnagar	Fakir Chand Sharma	M	71	M	SC/ ST	JF	L	2014	1	5.4	Cannon 2520	1		200	12*12	11	Ringing Sound In Ears And Hearing Problem	None	Na	None
15	Chauhan Book Store, Suddhowala	Amit Kumar	M	39	M	EBC	JF	IL(BHSS)	2014	1		Epson L360	1		150	10*7	12	None	None Only Door	6*10	None

S.NO	Name of place	Name of owner	Gender	Age	Marital Status	Social Status	Educational Qualification	Nature of Family	Establishment	No. of workers	Height worker(Ft.)	Photocopy Machine Model	No. of Photo-	Height machine(Ft.)	No. of xerox per day	Area of shop(sq.ft)	Working hours	Problems Facing (If Any)	No. Of Ventilation Points	Ventilation Area(Sq.Ft)	Specialised Ventilation Area
16	Shri Sai It Sell, Premnagar	Manoj Chawla	M	32	M	BC	JF	IL(BHSS)	2015	1		Epson L220	1		70	120	12	None	None Only Door	2.5*7	None
17	Bharat Cctv Corporation Services	Karishma Jhosi	M	23	UM	SC/ST	JF	IL	2016	1		HP M100jmff, Epson L210	2		50	7*13	12	Backpain	None	None	none
18	Kumar Stationary	Gaurav Bhatia	M	30	M	G	NF	L	2012	1	6	Epson L220	3	3.5	200	400	10	None	None Only Door	110	none
19	Rai Photo Studio	Rahul Narula	M	32	UM	BC	IF	IL(BHSS)	2013	1	5.8	Canon 3300	1	3.5	100	8*10	8	None	None Only Door	2.5*6.5	none
20	Makin Cybercafe	Rajeev Makin	M	52	M	SC/ST	IF	IL	1991	1	6	Canon Irr3300	1	3.5	200	300	8	Back Pain	None	1	1 exhaust fan
21	Highway Cyber Café	2	M	24	UM	BC	JF	IL(BHSS)	2009	1	5.7	Canon Ir3300	1	3.5	500	7*11	11	Backpain	None	None	none
22	Tyagi Enterprises, Clock Tower	Ms. Shubham	F	25	UM	SC/ST	IF	IL	2015	1	5.11	HP	1	4.5	200	12*12	12	Back Pain	None Only Door	None	none
23	Hari Stationery, Clock Tower	Pankaj	M	35	M	BC	NF	IL(BHSS)	2013	1	5.8	HP	1		320	11*11	10	None	None	Not Specified	exhaust fan
24	Om Enterprices, Clocktower	Om	M	28	UM	G	IF	L	2014	1	5.6	Canon 2520	1	4.5	160	8*12	12	Skin Infection, Backpain	None	None	none
25	Royal Book Depot Stationery, Premnagar	Jaspreet Singh	M	57	M	SC/ST	JF	IL	2016	1		Cannon 3235	1		60	10*8	10	None	None	None	none
26	Bharat Cctv Corporation Services	Krishna Joshi	M	23	UM	BC	NF	L	2016	1	1.5	Epson L210	1		150	7*13	12	Backpain	None	None	none

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27	Sachinstationers,Ballupur	Sachin Khai	M	34	M	SC/ ST	IF	L	2012	2	5.7	Koica-Bizhub 195,164	2	2	500	150	12	Joint Pain	1 Door	70	none
28	Raj Enterprises, Ballupur	Sachin Kashyap	M	18	UM	G	IF	IL(BHSS)	2017	1	5.4	Canon 2200	1	2.5	100	150	12	Irritation In Eyes	1 Door	17.5	none
29	Prashant Photostat,Ballupur	Mukesh Dondhiyal	M	42	M	BC	NF	L	2007	1	5.7	Canon 3300	2	3.5	200	150	12	Black Deposition On Nostrils	1 Door	15	none
30	Jwala Communications,Ballupur	S K Verma	M	64	M	G	IF	IL	2013	1	5.3	Ricoh M1600L	1	1.5	150	160	12	None	1 Entrance	26	none
31	Shri Ganesh Enterprices, Ballupur	Amar Singh	M	63	M	BC	NF	IL	2014	1	5.2	Canon IR 2318L	1	2	200	300	8	None	2 Doors	30	none
32	Sonu Bengal Store,Railway Station	Raza Khan	M	17	UM	SC/ ST	NF	IL	2014	1	5.8	Toshiba Studio 161	1	2	100	90	11	None	1 Entrance	30	none
33	Sai Kripa Stationary, Canal Road	Navneet Panday	M	40	M	G	IF	IL(BHSS)	2016	1	5.8	Brother	1	2	60	70	12	Backpain	1 Entrance	63	none
34	Himgiri Enterprises, Gms Road	Manish Kumar	M	25	UM	BC	JF	IL(BHSS)	2016	1	6	Canon 3300IR	1	4	4000	60	10	Irritation In Eyes,Backpain	None	Na	1 Exhaust, 1 AC
35	Geeta Infoservices, Ballupur	Ankit Semwal	M	28	UM	SC/ ST	NF	IL(BHSS)	2014	1	5.7	Ricoh MP2014	1	1.5	100	150	12	None	1 Door	16.25	none
36	3g Zone,Ballupur Chowk	Ravinder Painuly	M	27	UM	SC/ ST	IF	L	2017	1	5.9	Xerox 5021	1	3	200	1500	11	None	1 Door	21	none

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37	Ahmed Telecom, Ballupur	Naushad Ahmed	M	26	UM	G	NF	L	2013	1	5.7	Sharp AR56785	1	2	200	130	12	Irritation In Eyes	1 Door	12	1 exhaust
38	Mohit Computers,Yamuna Colony,Chakrata Road	Mohit Aggarwal	M	32	M	SC/ ST	NF	IL	1988	1	5.8	Canon 3300	1	4	100	150	9	None	1 Door	17.5	1 Exhaust, 1 AC
39	Baba Photostat ,Kaulagarh	Sunil Kumar	M	36	M	BC	NF	IL	2013	1	5.4	Canon 3320	1	4	150	100	10	None	1 Enterance	100	none
40	Saini Studio,Kaulagarh	Vandana Saini	F	38	M	SC/ ST	JF	IL	2010	1	5.5	HP M1005 Mcp,Epson L565	2	1	50	112	10	None	1 Entrance	75	none
41	Siddhi Collection,Kaulagarh	Neeraj Mittal	M	44	M	SC/ ST	IF	IL	1997	1	5.8	Ricoh 1800L	1	2	500	240	11	Ringing Sound In Ears And Hearing Problem	2 Doors	112	none
42	Ahuja Photocopy,Clocktower	Ravi Ahuja	M	29	UM	BC	IF	IL	2013	1	5.4	Xerox 5024	1	4.5	200	Small	11	Sleep Deprivation	None	Na	none
43	Jop Point,Paltan Bazar	Ajay	M	41	M	G	NF	IL	1997	1	5.9	Canon 3300	1	3.5	500	250	10	None	1 Entrance	56	none
44	Pawan Flex,Paltan Bazar	Shivam	M	21	UM	BC	JF	IL	2016	1	5.6	Canon 2200	1	3.5	100	200	10	Backpain	1 Entrance	96	none
45	Gandhi Commercial, Paltan Bazar	Shiv Kumar	M	28	M	SC/ ST	JF	IL	2009	1	5.6	Canon 3300	1	3.5	800	96	14	Hearing Problem, Backpain	1 Door	9	none
46	Apex Computers,Paltan Bazar	Anil Dimri	M	32	M	G	JF	IL(B HS S)	2007	1	5.7	Canon 3300	2	3.5	5000	90	12	None	1 Entrance	24	1 AC
47	Jk Digital,Paltan Bazar	Siddharth	M	28	M	SC/ ST	JF	IL(B	2008	1	5.8	Canon 2200	1	3.5	400	40	11	Backpain	2 Doors	47	none

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								HSS)													
48	Shakuntalum,Court Road	Anil Tiwari	M	40	M	BC	JF	IL	1997	1	5.7	Konica ,Canon	4	3.5	500	240	12	Backpain	1 Enterance	20	none
49	My Store,Court Road	Monica	F	25	M	G	NF	IL(BHSS)	2017	1	4.5	Canon 3300	1	3.5	200	120	9	None	None	Na	1 exhaust
50	Sp Enterprises, Court Road	Paridhi Gupta	M	32	M	SC/ ST	NF	L	2014	1	4	Canon 3300	1	3.5	250	165	10	Back pain	1 Entrance	63	none
51	Sanchi Indrum,Court Road	Parul Bansal	F	24	UM	G	NF	IL(BHSS)	2012	1	4.5	Canon 3300	2	3.5	200	150	7	None	1 Entrance	80	none
52	Friends Photostat,Court Road	Sharad Bansal	M	59	M	BC	JF	L	1987	1	5.11	Canon Ir 2200	2	3.5	750	180	10	Backpain	1 Entrance	96	none
53	Brigu Photostat,Court Road	J B Garg	M	77	M	G	NF	IL	2002	1	5.3	Canon 3300	1	3.5	500	126	9	None	1 Entrance	36	none
54	Shubham Photostat,Court Road	Sachin Sharma	M	37	M	BC	IF	IL(BHSS)	2007	1	5.7	Canon Ir 3300	2	3.5	250	192	12	None	1 Entrance	100	none
55	Durga Photostat,Court Road	Neelum	F	21	UM	EBC	IF	IL	2017	1	4.3	Canon 3300	1	3.5	300	300	11	None	1 Entrance	165	none
56	Ganga Media,Court Road	Dinesh Kumar	M	30	M	BC	JF	IL(BHSS)	2016	3	5.6	Canon 3300	3	3.5	700	120	9	None	1 Enterance	100	none
57	Prem Stationary,Court Road	Shailendra Singh	M	50	M	EBC	IF	IL	2007	1	5.2	Canon Ir3300	1	3.5	100	55	9	None	1 Entrance	44	none

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58	Chawla Photostat,Court Road	Gurashish Chawla	M	26	UM	BC	IF	IL(BHSS)	2014	1	5.5	Canon Ir 2016J	1	3.5	800	70	9	None	1 Entrance	100	none
59	Ravish Cyber Cafe,Near Clocktower	Ravinder Sharma	M	52	M	G	JF	L	2007	1	5.11	Canon 2200	1	3.5	300	250	10	None	1 Entrance	108	none
60	Mitra Buissness Centre,Clock tower Road	Devashish Mitra	M	40	M	BC	IF	IL	2017	1	5.9	Canon 2420L	1	2	200	250	10	None	None	Na	1 exhaust
61	Goyal Colour ,Colocktower Road	Ravi Goyal	M	58	M	EBC	JF	IL	2012	1	5.9	Canon 2270	1	3.5	200	117	10	None	1 Door	12	none
62	Arora Studio,Cocktower Road	Sunil Arora	M	50	M	BC	IF	IL	1982	1	5.8	Canon 2870	1	3.5	400	800	10	None	None	Na	none
63	Chandra Watch,Clock tower	Anil	M	21	UM	G	IF	IL(BHSS)	2014	1	5.5	HP	1	3.5	200	36	9	None	None	Na	none
64	Satguru Communication,Chakkuwala	Arjun Behl	M	23	UM	BC	IF	IL	2015	1	5.7	Epson LT220	1	1.5	250	60	10	Sleep Deprivation	None	Na	none
65	Uttam Photocopies, Kaulagargh	Uttam	M	55	M	EBC	IF	IL(BHSS)	2001	1	5.5	Xerox 5755,440	2	3.5	100	63	9	Backpain ,Joint Pain	1 Door	13	none
66	Rama Sales,Kaulagarh	Ghanshyam Kandpal	M	50	M	BC	IF	IL	2002	1	5.9	Kyocera 3510i,1024	2	4,1	1000	63	8	None	2 Doors	40	none
67	Sanjeev Enterprises, Ballupur	Nisha Singh Rajput	F	26	UM	EBC	IF	IL(BHSS)	2007	3	5.3	Ricoh 2500,5000	3	4.5	1000	350	11	None	None	Na	1 Exhaust, 1 AC

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68	Talwar Watch,Near Railway Station	Pawan Kumar	M	44	M	G	IF	IL(BHSS)	2002	1	5.7	Canon 3300	1	3.5	200	150	11	Backpain ,Joint Pain	1 Entrance	63	none
69	Master Store,Railway Station Road	C L Nanda	F	60	M	EBC	IF	IL	2017	1	5.8	Ricoh 2000L	1	3.5	30	250	10	Frequent Coughs And Inflammation In Nasal Passage	1 Door	15	none
70	Sharma Photostat,Dhamawala	Dheeraj	M	35	M	BC	IF	IL(BHSS)	2009	1	5.9	Canon 3300	1	3.5	150	110	10	Frequent Irritation In Eyes,Joint Pain	None	Na	1 exhaust
71	Jain Photostat,Rajpur Road	Anupam Jain	M	27	M	EBC	IF	IL(BHSS)	2011	1	5.9	Canon 202N	1	4.5	40	136	8	Frequent Irritation In Eyes, Frequent Coughs And Inflammation In Nasal Passage	None	Na	none
72	Shubham Photostat,Panditwari	Anil	M	26	UM	BC	IF	IL(BHSS)	2012	1	5.8	Xerox	1	4.5	150	64	12	Backpain ,Joint Pain	None	Na	none
73	Deepak Enterprises	Deepak	M	36	M	EBC	IF	IL	2013	1	5.5	Xerox	1	4.5	150	Unspecified	10	Frequent Irritation In Eyes, Skin Infections , Back pain	None	Na	1 exhaust

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74	Vinayak Infotech,Rajpur Road	Sandeep	M	36	M	BC	IF	L	2011	1	5.8	Canon Ir 3310	2	4.5	200	157	11	Skin Infection, Backpain ,Jointpain	None	Na	none
75	Krissh Communication	Krishna Joshi	M	30	M	BC	IF	IL	2012	1	5.5	Canon 3300	1	4.5	100	Unspecified	12	Backpain ,Jointpain	None	Na	none
76	Rajpur Computers,Karanpur Road	Prabhat Kumar	M	22	UM	EBC	IF	L	2011	1	5.6	Xerox ,Canon	2	4	400	200	13	None	None	Na	none
77	Student Shoppee,Karanpur Road	Anant	M	30	UM	EBC	IF	L	2017	1	5.9	Canon 2200	1	3.5	150	154	9	None	None	Na	none
78	Sai Sharda Associate,Rajpur Road	Neil Ratan	F	47	M	EBC	IF	IL	2008	1	5.5	Canon 3300	1	3.5	200	150	10	Irritaion In Eyes,Inflamation In Nasal Passage ,Breathing Problem	1 Door	12	none
79	Chawla Communication,Survey Chowk	Monika Chawla	F	42	M	EBC	IF	L	1996	1	5.5	Canon 3500	1	3.5	500	144	12	Backpain ,Jointpain	None	Na	1 exhaust
80	Deepak Enterprises, Survey Chowk	Deepak	M	25	UM	BC	IF	IL	2014	1	5.6	Canon 3300	1	3.5	150	144	16	None	None	Na	none
81	Jaiswal Photostat,24 Ec Road	Shivam Jaiswal	M	27	UM	EBC	IF	L	2012	1	5.5	Canon 3300	2	3.5	250	96	14	None	1 Door	15	none
82	Prakash Photostat,Sahastra	Pranav Prakash	M	50	M	BC	IF	IL(B	2002	1	5.6	Canon 3300	2	3.5	300	150	11	Irritaion In Eyes,Bac	1 Door	14	none

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								HSS)										kpain ,Jointpain			
83	Neeraj Photostat,Dav College,Karanpur Rd	Neeraj	M	40	M	EBC	IF	IL	2002	1	5.7	Canon 3300	1	3.5	150	100	8	Backpain ,Jointpain	1 Entrance	50	none
84	Five Store,Karanpur Road	Animesh	M	35	M	BC	IF	IL	2012	1	5.11	Canon Ir3300	1	3.5	100	144	12	Backpain ,Jointpain	1 Door	14	none
85	Scholar's Communication,Karanpur Road	Jatin	M	29	UM	EBC	IF	IL	2012	1	5.8	Xerox	1	3.5	200	100	12	Backpain ,Sleep Deprivation	1 Door	18	none
86	Alag Bookseller,Ballupur	Alag	F	42	M	BC	IF	IL(BHSS)	2012	1	5.6	Canon 3300	1	3.5	150	160	12	Backpain ,Jointpain	1 Door	15	none
87	Royal Book Depot Stationery, Premnagar	Jaspreet Singh	M	40	M	EBC	JF	L	2012	1	5.11	Canon 3300	1	3.5	200	100	9	None	1 Door	13	none
88	Vishal Photostat,Sharanpur Chowk	Vishal	M	30	UM	BC	IF	IL	2015	1	5.8	Canon 330	1	3.5	250	100	9	Skin Infection, Backpain	1 Door	15	none
89	Vidhya Informatics, Vasant Vihar	Ravi	F	30	UM	EBC	IF	IL(BHSS)	2012	1	5.8	Canon 3300	2	4.5	500	120	10	Breathing Problem, Skin Infection, Backpain	2 Doors	13	none
90	Student Point,Vasant Vihar	Shivam	M	26	UM	SC/ ST	NF	L	2009	1	5.8	Canon 3300	1	3.5	200	100	6	Irritation In Eyes,Inflamation In Nasal Passage	1 Door	14	none

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																		,Skin Infection, Backpain ,Sleep Deprivation			
91	Wadhwa Book House,Chak kuwala	Sumit	M	45	M	SC/ ST	NF	IL	1980	1	5.9	Canon 3300	1	3.5	100	150	9	no	1 door	15	none

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PRIMARY SOURCES

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2	Bhupendra Pratap Singh, Amit Kumar, Deepak Singh, Monika Punia, Krishan Kumar, Vinod Kumar Jain. "An assessment of ozone levels, UV radiation and their occupational health hazard estimation during photocopying operation", Journal of Hazardous Materials,	<%1