The effect of indoor air quality on health and performance of labors in joinery factories

أثر جودة الهواء الداخلي على صحة وأداء العمال في مصانع الخشب

by

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Abstract:

Indoor air quality has fundamental aspects in the overall health, comfort, and wellbeing of occupants. People spend 90% of their time indoors, and this is more common in Dubai because of the hot and humid climate.

This study attempts to investigate the hazards of airborne particles, and wood dust inhalation in the joinery companies, as the wood dust is known as a critical indoor air.

UAE construction is growing very quickly, and in parallel, the demands for joinery works are increasing. Labors in the joinery factory play a vital role in woodworking products. Thus, their health and performance should be the most priority of each joinery factory. According to the WHO, one sixteen people are dying every year because of poor indoor air (WHO, 2016). By consideration of these factors, inhalation of poor air increases the health risk hazards.

The research is designed for creating a comprehensive view of exposure to poor indoor air and wood dust, and its impact on the workers. The reviewed factory is in Dubai Investment Park. The parallel design of field measurement and survey questionnaire was conducted between 50 labors in machine shops and sanding sections, where the majority of wood dust occurs. The survey questionnaire helped to collect data from the labors of each section. And a variety of instruments were used to collect data of IAQ parameters as follows, Ozone, CO2, CO, TVOC & Particulate Matter size.

The finding of this research envisages of airborne wood dust measurement in Indoor air and increases the body knowledge of wood dust exposure. It aims to control the wood dust in the wood industries by the design and plan of the targeted intervention.

نبذة مختصرة:

جودة الهواء في الأماكن المغلقة لها جوانب أساسية في الصحة العامة، والراحة، والرفاهية لشاغلي المنطقة. يقضي الناس 90% من وقتهم في الداخل، وهذا أكثر شيوعًا في دبي بسبب المناخ الحار والرطوبة العالية. تحاول هذه الدراسة التحقيق في مخاطر الجزيئات المنقوله جوا، واستنشاق غبار الخشب، كما يعرف ان غبار الخشب يشكل خطورة على الانسان اذا تم استنشاقه في الاماكن المغلقة

البناء في الإمارات العربية المتحدة ينمو بسرعة كبيرة وبالتوازي مع ذلك ، فإن المطالب لأعمال النجارة تتزايد. العمال في مصنع النجارة تلعب دورا حيويا في منتجات النجارة وبالتالي، ينبغي أن تكون صحتهم وأدائها الأولوية القصوى لكل مصانع النجارة.

وفقا لمنظمة الصحة العالمية 16 شخصا يموتون كل عام بسبب سوء الهواء في الأماكن المغلقة (منظمة الصحة العالمية، 2016) و من خلال النظر في هذه العوامل ، يؤدي استنشاق الهواء السيئ إلى زيادة المخاطر الصحية.

تم هذا البحث لخلق رؤية شاملة للتعرض للهواء الداخلي السى وغبار الخشب وتأثيرها على العمال. موقع المصنع الذي تمت مراجعته في مدينة دبي للاستثمار. تم إجراء استبيان بين 50 عامل في اقسام مختلفة و منها قسم الاليات و قسم تنعيم الخشب، حيث تحدث غالبية غبار الخشب. ساعد الاستبيان على جمع البيانات من عمال كل قسم. واستخدمت مجموعة متنوعة من الأدوات لجمع البيانات مثل ثاني اكسيد الكربون، أكسيد الكرب و حجم الجسيمات المادة. اكتشف هذا البحث عن قياس غبار الخشب المحمولة جوا في الهواء الداخلي و معرفة الاعراض للتعرض على غبار الخشب.

Acknowledgment

Most importantly, I would like to express my sincere thanks and appreciation to my top advisor, Prof. Riyad Sarji, for his continued support of my Master's education and research, for his patience, motivation, enthusiasm, and endless knowledge. His guidance helped me through this research.

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Abbreviations

UAE	United Arab Emirates
WHO	World Health Organization
HSE	Health and Safety Executive
ASHRAE	The American Society of Heating, Refrigerating and Air-Conditioning Engineers
PPM	Part per million
IEQ	Indoor Environmental Quality
OSHA	Occupational Safety and Health Administration
EPA	United States Environmental Protection Agency

Chapter 1: The Effect of Indoors air quality on Performance and Health of Laborer's in joinery Factories

1.1 Introduction

Dubai is one of the most flourish cities in the region. The lifeblood of UAE economy is construction industry, which is the pillar of Dubai's future progression. There are around 15,000 projects launched in UAE in 2019, based on BNC construction projects journal, whereas around 65 percentages of projects implemented in Dubai. In addition, the foundation of development has a significant rise since 2013 when EXPO 2020 awarded to Dubai. The expected annual construction growth rate predicted around 4.64 percent during 2019 till 2023 based on Pinsent Masons' annual GCC construction survey whiles 33.1 percentage of Dubai construction covers residential projects. Accordingly, Dubai UAE population has a steadily move since 2010. The population of people in UAE is 9.68 million in 2019 whilst Dubai hast the largest population by 35.7 percentages based on official UAE Government Status, 2018. The growing population and the rise number of investors have a huge impact on the construction industry, and the demand for joinery items will increase.

Wood has been well known for thousands of years as one of the first few natural renewable resources in the world (Rastogi et al. 1989). And still, it has its popularity. It is mostly because wood and wood products are known for minimizing the carbon dioxide in the atmosphere that has a lower carbon footprint. Despite the fact, joinery production produced considerable amount of wood dust, which are invisible fine particles in the air. In the wood industry, airborne wood dust has the highest prevalent occupational exposure for workers. According to the WHO in most developing countries, 12.2 million workers die because of an unsafe healthy work environment by active working age. The emitted airborne wood dust can

lead to an increment risk of different health problem especially, in the process of sanding, sawing, routing, and cutting. According to the International Agency for Research on Cancer (IARC), wood particles intervention the respiratory system, which decreasing the lung capacity and causes signs such as, allergic reaction, irritation of eyes, nose, and throat, and cancer (Sawane & Sawane 2017).

According to the health and social care legislation abolished by DHA, the health of the workers is considerable important. Considering that, health of labors plays the most vital prerequisite of their productivity, performance and great opportunities for businesses, which has the direct influence by the working place environment.

This study reveals the importance of the workers' health in woodworking industry and perceived the safe & healthy environment as per global IAQ standards. Considering the fact that the green technology made a remarkable improvement in the real world performance, the quality of indoor air has the same level of qualification as the healthy building's structure. The result of this research can have a significant impact on the health of workers, and joinery factories can redesign their facilities accordingly. Also, it can be a lead model for the future building if it ignores, the reputation of fatality and injuries of labors increased.

1.2 Indoor Air Quality & Wood Dust

People spend most of their times indoors. Indoor air plays an essential role of human health because of exposure lengthy time. The most precedence environmental health concern is Indoors air quality due to the reality that UAE population spend most of their times (around 21 hours per day) indoors and the poor air quality can arise the health risk effect of exposure to

those people (EPA, 2016). Contaminate of indoor air cause drastic chronic health issues (Bentayeb et al., 2015; Bentayeb et al., 2013;Maio et al., 2015). Previous researches mentioned the poor quality of indoor air in wood factories causes the acute health problems like phlegm, chronic bronchitis, eye and throat irritations, frequent headache and cough and nasal symptoms (Curtis et al., 2006). The estimation of work-related accidents and diseases causes the death of 2 million workers every year based on the ILO report (2008). The annual fatal injuries of workers estimated around 335,000 million and the accidents around 270 million based on International Labor Organization (ILO). 160 million people are affected by preventable occupational diseases each year. However, the global awareness and disquiet of occupational diseases stay moderate. The Global occupational injuries and work-related fatalities in wood industry and wood products result in the loss of 270 million and 2.2 million workers respectively, while the total number of global workforce is around 2.8 billion, which consist of 300,000 employed in wood industry (Muchemedzi., 2007). (Statistic Center in Abu Dhabi., 2014) published the percentage number of injured and dead worker by economic sector in Dubai. According to the report the largest percentage of the death is belong to construction sector with 47 percent, and the following sector is industry by 40 percentages. The cluelessness that most employees demonstrated has been attributed to the fact that human factors contribute about 80-90% of all industrial accidents. (Adu et al., 2007) posits that accidents occur when a person neglect recommended procedure and safety measures. The main standard of air quality in joinery industry should consist of OSHA, ACGIH and EPA standards (William F.Pentz., 2018). OSHA inspects nuisance as an only toxic in airborne wood dust, which means all the air particles should be below 30-miceons sizes. In other words, based on 1989 OSHA standard, the wood dust in the air should not exceed of five milligrams per cubic meter amount (William F.Pentz., 2018). As per ACGIH (American

conference of Industrial Hygienists) standards, the size of wood dust in the air should not overstep more than 1 milligram per cubic meter, which is five times lesser than OSHA standards. However, the medical experts claimed that inhalable dust under the size of 10 microns known as invisible fine particles. These particles can easily damage, inflame and make scars in our body's tissues, which become a permanent loss capacity in our respiratory system. With consideration of medical researches, EPA and the European Union conform the size of the airborne wood dust should not greater than 0.1 milligrams per cubic meter of air, which means fifty times lesser than OSHA (William F Pentz, 2018). The indoor air quality standards in UAE based on the Dubai Municipality standards must accordance with ASHRAE 62-2007. The impact of industrial accidents in the wood-processing context can be reduced if workers learn to follow the right procedures. In a bid to improved abidance to safety procedures and provisions, extensive employee education has been deemed necessary (Adu et al., 2007).

1-3 Motivation:

UAE geographical location encompasses a desert area with a hot, dry climate and the gradual sandstorm creates a higher level of pollution, which makes a difference in indoors air (Ministry of Environment, 2014). UAE developing drastically and the construction have a direct role with wood products. According to Dubai Municipality all types of woodworking industry must follow ASHRAE Standards (62-2007) especially when the industry activities generate health hazards for their employees (Green Building regulation, 2018). Following the Green building Regulation of UAE standards, all the new and existing building must trace the minimum rules as follows;

- Provide proper ventilation system and air distribution with the specified air filter.

- The proper design of exhausted air location, which does not let the air back to the building again. Also, consideration of the proper air intake distance from the contaminate sources.
- The separated air extraction system should provide for all the activities generate health risks.
- Consideration of openable windows where required.
- Regular maintenance of air intake & exhausted air system required.
- Following table accomplishes to certify the suitable indoor air quality in excising buildings (Green Building Regulations & Specifications, 2011).

Table 1: UAE INDOOR AIR SCHEDULE, DURATION OF SAMPLING & LIMIT FOR CONTAMINANTS

(GREEN BUILDING REGULATION & SPECIFICATION, 2011)

Sampling schedule	Type of samples	Maximum acceptable	Sampling durations
Initial test completed by 31 December 2011. Further testing within 5 years of last compliant test.	Formaldehyde	< 0.08 ppm	8- hour continuous monitoring (8 hour time-weighted average [TWA])
	Total Volatile Organic Compound (TVOC)	< 300 micrograms/ m3	
	Repairable Dust (<10 microns)	< 150 micrograms/ m3	
	Ozone	0.06 ppm (120 micrograms/ m3)	
	Carbon Dioxide	800 ppm (1440 microgram/ m3)	
	Carbon Monoxide	9 ppm (10 micrograms/ m3)	
	Bacteria	500 CFU/ m^3 (Algar plate)	
	Fungi	500 CFU/ m^3 (Algar plate)	

With consideration of above standards, there are many types of research on the poor quality of indoor air in residential & commercial building, offices, and schools but investigation on the air quality of joinery factories are very limited.

While, the impact of the indoor environment on labors' health becomes a serious hazard and the effect of exposure toxin and particulate results in a variety of health problems. They are the foundation of each industry and they are working hard and they have a hard life as well. Thus, their health should be a priority for the wood industry. Also, monitoring the quality of indoor air can decrease the maintenance cost.

1-4 Problem statement

This study focus on minimize of indoors air hazardous during sanding and assembling activities in joinery industry. It is not known how the wood dust influences the performance and overall health of workers on wood factories. To have a comfortable working environment consideration of circumstances of physical workers and the environment ergonomic characteristics manufacturing is essential. The overall problem identified by the researcher is the lack of adequate evidence to identify the impact of the wood dust on the health and performance of workers in wood factories. There are different conditions that never considerate such as insufficient lighting, ventilation system, poor indoors air circulation, high temperature and etc. however, the most environmental factors affect the health and performance of the labors is wood dust (Barli, 1996). As the basis of this study, the research problem is twofold – first, the effect of wood dust on performance of workers, and second, the impact of wood dust on health of workers are not adequately explored in this field. As much as there are a number of studies conducted in this field, there is no evidence to show how the impact of wood dust on performance and health

of workers is compared between two wood factories. Also, there is not research about wood dust in the UAE.

1-5 Significance of the Study

By the completion of this research, the significant would demonstrate how to design the building by consideration of the Environmental, Health, Safety Guidelines and comfort zone for manufactured wood products and sawmilling. The gathering data and analysis can assist the policymaker to consider the new construction rules, to control the poor indoor air & wood dust spread in joinery companies and developing appropriate strategies and policies to reduce the poor indoor quality effect. Besides, with the help of this report, the comprehensive information on appropriate monitoring of wood dust exposure would be achieved, which can increase the public awareness of the positive and negative impacts in the region. The importance of public awareness would encompass other sectors, such as the construction industry, which is the main source of the UAE's fast growth.

1-6 Dissertation Outline:

The brief descriptions of 5 chapters with the subsections are as below:

- Introduction (Chapter 1): In this section motivation and the background of the study reviewed. This research aims to distinguish the quality of indoor air in joinery factories in Dubai and realize the effect of low quality of indoor air and wood dust on the health and performance of the labors, which is the main factor or air pollutant in this industry. Moreover, this section describes the scope of research and the guidance of the

research study. Additionally, it provides the problem statement and the significance of the study. Also, the quality of indoor air in Dubai reviewed.

- Literature Review (Chapter2): In this chapter, the main impact of Indoors air in joinery companies described, as well as, reviewing the existing IAQ published. Also, the standard guidelines for indoor air are briefly analyzed.

- Methodology (Chapter 3): The gathered data in this section is base on the literature review, which provides the framework, and determines the investigation methods. It also provides a sampling time as well as, the analysis of data collection, and location of the factories.

- Results & Discussion (Chapter 4): This section comprises two sub-titles. The result of the survey and field measurement, which included the different spot measurements to present and analyze the airborne contaminant exposure with the standard IAQ parameters. Survey and measurement happened within a joinery factory to get the result. And the discussion result of the finding is determined.

- Conclusion (Chapter 5): The final section of this research determined the implication points for future construction field. And the finding shows the IAQ in Dubai's joinery companies and the impact of low quality of indoor air and wood dust on the health & performance of the labors in the region. The strategy recommendation draws the improvement in the indoor air environment in woodworking industry.

1-6 Research Objectives:

The objectives of the present research are to:

- Measure and analyze the indoor air quality in the joinery factory on the hot and humid climate.
- Evaluate the impact of some parameters like particle measurement, a respiratory mask for individuals and some management strategies and tools
- Analyze the factory types of machinery and tools and their cause of wood dust exposure
- Study the knowledge and behavior of workers to improve the working environment by promoting practical and comprehensive preventive strategies.
- Study the main causes of air pollutant and the reason for pollutant distribution to achieve the ideal air quality in a joinery factor

1-7 Research Questions and Hypotheses:

The primary research question is: What is the impact of wood dust on performance and health of workers in wood factories? Other research questions include:

RQ1: How to control the indoor air pollutant?

H1: Measuring and analyzing Co_2, Co, Ozone, TVOCs, and particulate matter size can lead to indoor air pollution control.

RQ2: What is the impact of extraction vacuums on exposure of indoor air quality and strategies for minimizing exposure of workers to wood dust/ air pollution?

H2: Using suitable protection equipment reduces exposure of workers to wood dusts hence increasing performance at the workplace.

RQ3: How is the wood factory layout in terms of machinery and isolation?

H3: The factory has the best arrangement plan for all the wood processing procedures and design of wood products.

RQ4: What is the comparison of the impact of wood dust/ air pollution on workers between the controlled and non-controlled wood factories' environments?

H4: There is no significant research on the joinery factories and the factories' environments in terms of the effect of wood dust/ air pollution on workers.

RQ5: What are the causes of air pollution and pollutant distribution in the joinery factories' environments?

H5: The air pollution and distribution of pollutants in joinery factories are caused by poor disposal of wood wastes and dust.

RQ6: What are the cause of educating workers about the health issues of poor indoor air quality and following the rules?

H6: The lack of education from the safety management or the lack of their knowledge cause many health issues on the long-term.

Chapter 2: Literature review

2-1 Introduction

One of the most essential living base that is very serious for the human health is indoor air quality. Based on the WHO report, 2.7 % of the global BOD (Burden of Diseases) is because of indoor air pollutant (World Health Organization, 2002). Besides, the provided report of WHO shows proofs of relationship between indoor air pollutant and human health risk (Indoor Air Pollution Health Effect, 2013).

Majority of the workers in joinery industry exposed to pollutant air especially wood dust.

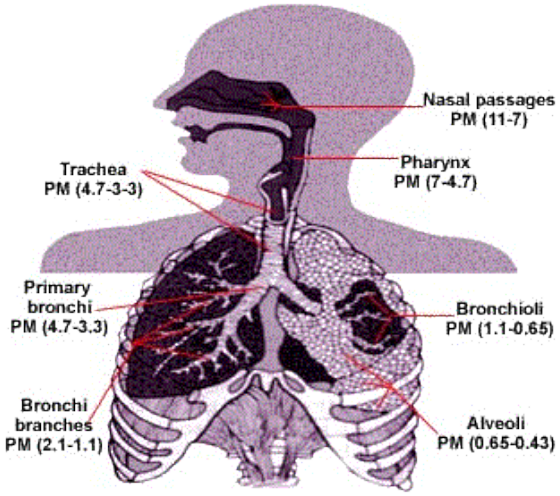


Figure 1: Particulate matter condition in respiratory system (Wilson, 1996)

According to the respiratory refraction, the size of the wood particles is different and all the particles do not cause health problem. The particles smaller than 0.1 microns can easily breathe out (Richard Wilson, Harvard Press, 1996).

Following the preceding studies, wood dust is the major health risk problem, however, other factors such as CO2, CO, TVOCS, and TMP play a significant role in the indoor air quality. According to the (Zhang, 2014) investigation, there are four types of respiratory fractions, which are as the following table.

Table 2: Size of indoor particles based on respiratory fraction (Zhang, 2014)

Respiratory Fraction	Size range
Inhalable	≤ 100 μm
Thoracic	≤10 μm
Repairable	≤4 μm
Diminutive	≤0.5 μm

The inhalable fraction total dust defines as particles surrounding our mouth and eyes to enter the body. And repairable dust precipitate in non-cartilage body system because of their smaller size (Bran, S., & Teul. 2007). Indoor air pollution gets more unpleasant with the wood particles distribution, which causes dermal, ocular, nasal and general health problem for workers (Fårm, 1997; Hausen, 1986; Estlander et al., 2001). The allergenic symptoms make skin eczema, skin irritation, bronchial sensitivity, caught, cancer, asthma, inflammation, lung infection, and hypersensitivity pneumonitis and humidifier fever. (Eriksson and Liljelind, 2000).

There are couple of research about the indoor air quality and Dr.Jacqueline MacDonald, who has spent more than a year on the research of air pollution and samples to record the number of the death in UAE expressed that the indoor and outdoor air quality should be monitored instantly because of the fast growing of construction (MacDonald J., 2009). Based on her research, UAE should track the air quality stations and subscribe more information with agencies to have a better vision on the outdoor air pollution, which cause 600 deaths every year. However, the indoor air pollution brings about 250 deaths a year (MacDonald J., 2009).

The advantage of collected public health researches is the reduction of environmental air pollution. As a beneficial result, the number of visits to the health-care facility reduced, and controlling indoor and outdoor pollutions prevented thousands of premature deaths at the workplace every year (Gibson, M.J., Thomsen, J., Launay, F., Harder, E., Defelice, N., 2013).

Following above researches, the Public Health section in Dubai (Dubai Municipality) mentioned that the wood dust and the particles are the principal issues of indoor air in the joinery industry in Dubai. To make sure about the health of the laborers, monitoring and controlling the indoor air is a must (Dubai Municipality, 2008). Below table shows the reason and the number of dearth on 2008 in UAE based on the help of Abu Dhabi Environmental Agency.

Table 3: Mortality case of poor air quality in UAE (ABU-Dhabi ENVIRONMENTAL AGENCY, 2008)

Exposure route	Cause of mortality	ICD-10 code(s)	Baseline mortality (deaths in 2008)	Pollutants	Exposure estimation method	Relative risk (95% CI)
Outdoor air pollution	All causes (adults>30)	N/A	8,865	$PM_{2.5}$ (average annual concentration, $\mu g/m^3$)	Abu Dhabi outdoor air quality monitors [14]	1.06 (1.02–1.11) (per 10 $\mu g/m^3$); see [25]
	Respiratory disease (children <5)	J00–99	27	PM_{10} (average daily concentration, $\mu g/m^3$)	Same as for $PM_{2.5}$	1.017 (1.0034, 1.03) (per 10 $\mu g/m^3$); see [26]
Indoor air pollution	Cardiovascular disease	I00–79	2,310	Environmental tobacco smoke (ETS), present or absent in home	Household surveys: ETS present in 19% of homes	Male nonsmokers: 1.25 (1.06, 1.47); female nonsmokers: 1.35 (1.11, 1.64) [27]
	Lung cancer	C33–4	120	ETS	Same as previous	Male nonsmokers: 1.1 (0.6, 1.8); female nonsmokers: (1.2 (0.8, 1.6) [28]
				Radon (average daily concentration, Bq/m^3)	Household measurements* (Abu Dhabi City and Sharjah only): Abu Dhabi, lognormal (mean = 14.4, sd = 7.37); Sharjah, triangular (8, 50.3, 164); assumed zero elsewhere	1.08 (1.13, 1.16) (per 100 Bq/m^3) [29]
				Incense use (frequency per week)	Household surveys: Daily users = 43.54% of population; intermittent users = 42.86%	Daily users: 1.8 (1.2, 2.6); intermittent users (1–5 times/week): 1.2 (0.9–1.6) [30]
Occupational exposures	Asthma	J45	10	Employment in occupation involving exposure to dusts, fumes	UAE Ministry of Economy data on workforce participation by industry sector and occupation within sector; see [20]	Varies by occupation and gender; see [20]
	Chronic obstructive pulmonary disease	J44	37	Employment in occupation involving exposure to dusts, fumes	Same as previous	Varies by exposure level and gender; see [20]
	Asbestosis	501	0	Asbestos exposure	NA	100% of observed cases
	Malignant mesothelioma	C45	6	Asbestos exposure	NA	90% of observed cases in males and 25% in females; see [20]
	Silicosis	502	0	Silica exposure	NA	100% of observed cases
	Leukemia	C91–5	130	Employment in occupation with exposure to diesel exhaust, benzene, ethylene oxide	UAE Ministry of Economy data on workforce employed by industry sector; Carcinogen Exposure (CAREX) database; see [20]	Low exposure: 1.9 (1.6, 2.2); high exposure: 4 (3.6, 4.4); see [20]
	Lung cancer	C33–4	120	Employment in occupation with exposure to arsenic, asbestos, beryllium, cadmium, chromium, nickel, silica	Same as previous	Low exposure: 1.21 (1.18, 1.24); high exposure: 1.77 (1.71,1.83); see [20]
Climate change	Cardiovascular disease	I00–79	2,310	Increase in ambient temperature attributable to global climate change	100% of population exposed	1.001 (1.000, 1.003) [31]
Drinking water contamination	Bladder cancer	C67, C68	23	Drinking chlorinated water	Citizens: 10.5% consume tap (chlorinated) water; non-citizens: tap water consumption represented as uniform (84%, 96.4%) distribution**	Males: 1.24 (0.97, 1.57); females: 1.17 (1.03, 1.34) [32
	Colon cancer	C18	80	Same as previous	Same as previous	Males: 1.09 (0.81, 1.48); females: 1.19 (0.93, 1.53) [32
	Rectal cancer	C19–21	30	Same as previous	Same as previous	Males: 1.24 (0.86, 1.79); females: 1.10 (0.90, 1.36) [32
	Gastroenteritis	A00–9	7	Access to regulated drinking water supply and sewage treatment	Population divided into two groups: (1) access to regulated water supply and sanitation (population fraction represented as triangular (0.96, 0.98, 1.0) distribution); (2) access to improved but unregulated water, no sanitation	Group 1: uniform (1, 4); grou 2: uniform (7.2, 10.2) [21,33]

People sensation to the workspace influenced with physical circumstances. The perceptional evaluation should be recorded for the drastic symptoms. There are meta-analysis in 20 experimental office researches including the relation of ventilation system and people health and the reaction of people symptoms with the ventilation levels in more than 3000 subjects has reviewed (Seppanen et al, 1999). Based on the results of almost all the researchers, the ventilation rates are below 10 l/s person, people's health outcomes are worse. In addition, the outcomes of some researches demonstrated the least health issues if the indoor ventilation rates are between 10 I/s person to 20 I/s person. There was a reduction in people's symptoms and the indoor air quality increased (Institute for health and consumer protection, 2003).

The source of diseases caused by indoor air quality can be persistent and make critical health problems for people. These symptoms bring stress, fidget, and affect their productivity and make them absent (Guardino X, 2011). Below figure represents the illnesses from indoor air quality.

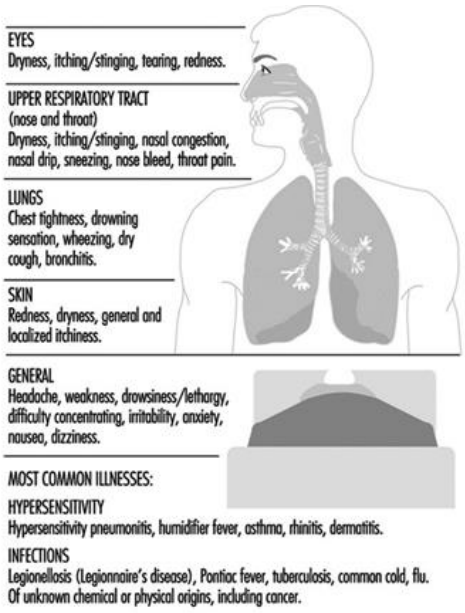


Figure 2: Effect of indoor air quality in human' body (Guardino X., 2011)

This chapter reviews the indoor air quality and the relationship of poor indoor air quality and wood dust on the wellbeing and performance of the workers, illness caused by joinery industry, indoor air contaminates and healthy building. The common indoor air particles are defined.

2-2 The Effect of Wood Dust on Performance and Health of Labourer's in Wood Factories

2-2-1 Indoor Air Quality and its contaminant

One of the environmental health hazards is poor indoor air that located in the fifth top grade of unhealthy surround (USEPA, 2016). Monitoring and controlling the indoor air quality can improve the occupants' wellbeing and reverse side; the pollution is the reason of health issues. By improving the IAQ in the workspace can increase the workers' productivity as well as make the happy environment to reduce the absenteeism and considerable return investment (ASHRAE, 2009). There are many studies documented about the consideration of indoor air quality in the workspace however, still there is lack of awareness and construction design. Following the ASHRAE (2009), "in most cases IAQ is still not a high-priority design or building management concern compared to function, cost, space, aesthetics, and other attributes such as location and parking."

According to Santamouri's researches, the role of an appropriate ventilation system can increase the performance of the labors and control the created wood dust (Santamouris et al., 2008). The ventilation system has a direct effect on the wood processing operation. In the joinery industry, the design of the ventilation system should capture the wood dust simultaneous the production time to create a better working environment for laborers (Zuzana Strakova., 2015).

Based on the (USEPA) United States Environmental Protection Agency on 2016, “Indoor Air Quality (IAQ) refers to the air quality within and around buildings and structures, especially as it relates to the health and comfort of building occupants.”

The concern of health risk in developing countries with multi-nationalities is more sensitive because of amalgamation in variety kinds of pollution. The indoor air quality concern might be quantitative or qualitative however, the major indoor sources of pollutant particles follow the same path as a physical condition of the labors (Shendell et al, 2004).

Most of the people think the outdoors air is more dangerous and pollutant in compares with indoor air however, the indoor air inside home, offices, public areas and industrial places is the main sources of hazard (Books and Davis, 1992). The tracked pollutant in the public areas and wood factories lead to CO2, Particular Matter, CO, Repairable dust, CO & TVOC.

2-2-2 Health hazards in Joinery industry

Most of the indoor air pollution contaminates in woodworking sections contain hazards to the health of workers. Building related illness (BRI) and sick building syndrome (SBS) are evaluate as roots of indoors air pollution (FormaCare, 2012). During the sanding, cutting, sawing and painting processes the wood dust spread out to air surrounding and other indoor air contaminants are also have higher health risk in those sections. Below explains certain types of indoor air pollutant compound in joinery industry.

2-2-2. 1 Volatile Organic Compounds (VOCs)

Volatile Organic Compounds (VOCs) are carbon containing chemicals, (vapor mode in an ambient temperature) release of specific liquids or solids materials. They also can emit form the human activities and derived materials, which have a long-term or short-term health effect

known as asthma and respiratory symptoms (Hawas al., 2002). The emission of VOCs in the furniture manufacturer mainly derive from the applied surface coating however, the first emission comes from all types of wood and their derivate because of their organic extractives origin. However, sometimes the odor emission of some natural substance in softwood is considered pleasant (Berglund et al., 1992). The emission on VOCs comes from variety sources. However, the long-term exposure separated into 2 parts, acute and chronic levels, which rely on the size and dose of exposure. Most of the sub-acute natures affects like headache, dizziness and lack of coordination is frequently and constantly increase over the time (Otto et al., 1990). The mucosal tissues of the eyes, nose, face skin, throat and hands are affected (MGlhave, 1991). There is serious effect of chronic that causes physical harm to the liver, central nervous system, damaging kidneys & circulatory systems and cancer (Barnhart S., 2000).

There are various countless types of VOCs ubiquitous in the wood products, which have a numerous affect in indoor air quality. However, there have been studies on the amount of VOCs emission rates, which point out the opposite relevance of heat and wood processing within production period (EPA, 2017) that can be named condition of storage, procedure time of pressing & temperature and structure of the surface (Makowski, M., M. Ohlmeyer., 2008).

In other words, the amount of VOCs emission in the wood is more than the wood manufacturing processes (HolzForrschung, 2014). VOCs sources exist in engineering woods (that include MDF, Particleboard, Plywood and etc.), solid wood, flooring products of wood and final coating such as painting, stains, lacquers, veneer and laminate (British Woodworking Federation, 2017). The high concentration of VOCs produced in vapors is depends on the type of woods (Yuan, 2004). Based on the sampling method of Oanh and Hung in 2005, the lower

boiling point of VOCs is around 50□C - 100□C and their upper boiling point is around 50□C - 100□C. Besides, the level of indoor VOCs pollutants is two to five times up than outside.

According to the WHO research, different fluctuations or boiling point of TVOC have caused variety classification, which summarized below,

- (VOCs) Volatile Organic Compounds
- (VVOCs) Very Volatile Organic Compounds
- (SVOCs) Semi-volatile Organic Compounds

Below classifications related to the carbon structure of molecular length, which origin of chemical formula of carbon atoms in TVOC.

Table 4: Classifications of Volatile Organic Compounds (WHO, 1989)

Class	Name	Typical Boiling Point (°C)	Typical Number of Carbon Molecules	Example
VVOC	Very Volatile Organic Compound	<0 to (50-100)	< C6	Formaldehyde
VOC	Volatile Organic Compound	(50-100) to (240-260)	C6 to C16	Benzene
SVOC	Semi Volatile Organic Compound	(240-260) to (380-400)	> C16	Diisononyl phthalate
TVOC	Total Volatile Organic Compound	Sum of all compounds listed above		

The total toxin and chemicals and the low level of VOCs combination intricately, which emitted from a group of compounds gasses in ambient air called TVOCs (Johnson, C., 2018). Total Volatile Compounds is considering as all the measurable level of condensation indoors VOCs in our surrounding (Mølhave, et. al., 1997). TVOCs measure only all the available VOCs subsets concomitantly, which exist in the air. TVOCs has differ chemical compounds that affect the quality of indoors air in offices.

The TVOCs pollutant condensation in workspace causes from the combination of net emission spread in the space and the function of ventilation system. The sources of high TOVCs emission emanating from the firm roots of indoors or outdoors emission or insufficient ventilation system. In both situations TVOC acts as CO2 in the workplace (De B M., Knoppel H., Pecchio E., Peil A., Rogora L., Schauenburg H., Schlitt H., Vissers H., 1986).

The Global general agreement of TVOCs standards of indoor air quality issued through different governmental associations such like Finland, Germany, Australia, Japan and Hong Kong. The suggested acceptable TVOCs emission is between 0.6 to 1mg/m3 (Environmental Protection Agency, 2017). Based on the WHO report, the emission of TVOC at the level of 1 mg/m3 and below affects the human sensory such as eyes, nose and skin irritation and dryness and the side effect of TVOC at 25 mg/m3 above convert to serious concerns (European Centre for Environment and Health, 2010).

Below table shows the TVOC classification level based on the German Health Department.

Table 5: TVOCs guideline (German Federal Environmental Agency, 2007)

Level	Hygienic Rating	Recommendation	Exposure Limit	TVOC (ppb)
5 Unhealthy	Situation not acceptable	Use only if unavoidable/ Intense ventilation necessary	Hours	2200-5500
4 Poor	Major objections	Intensified ventilation/airing necessary Search for sources	< 1 month	660-2200
3 Moderate	Some objections	Intensified ventilation/airing recommended Search for sources	< 12 month	220-660
2 Good	No relevant objections	Ventilation/airing recommended	No limit	65-220
1 Excellent	No objections	Target value	No limit	0-65

2-2-2.2 Formaldehyde

In the end of 1970s, when the energy crisis happened, the indoor air quality and formaldehyde emissions were considered (Zhang, L., et al., 2009). Formaldehyde is a colorless gas with the pungent, irritating odor and famed example of toxic VOCs. Formaldehyde is categorized in VVOCs (Very Volatile Organic Compounds) because of the low boiling point at minus 19 °. The wood products especially the furniture builds up pressed wood and adhesive with formaldehyde-based resin that used as glue in wood pressed manufacture process, particleboards, hardwood, plywood and medium density fiberboard (MDF) are the most common sources of formaldehyde (U.S Environmental Protection Agency, 2013). The level of formaldehyde emission in wood is mostly related to the chemical combination of wood types rather than the anatomy or physical construction (Hamilton K., Andersen H., 1986). The current use of formaldehyde-based resin is around 21 million tons yearly while, 50 percentage of this amount is related to the manufacture of phenol-formaldehyde, urea-formaldehyde and melamine formaldehyde resins (Global Insight Inc., 2006). On that point, the number of employed labors in these industries is about 3.4 percent.

Urea-formaldehyde (UF) and phenol formaldehyde (PF) are used as an adhesive in wood-based composite and they are the main factor of formaldehyde emission in the wood products. UF resin in wood-based products contains high emission of formaldehyde in compare with other resins (Lee et al., 2008). The highest proportion of urea-formaldehyde resin carried in the MDF in compare with the low emission rate of softwood plywood and oriented-strand board made of PB resin (NCS, 2010; EPA, 1997b; Lee et al, 2008; Mills, 2010). Based on the SRI consulting researches, the amount of UF resins from 2008 till 2018 increased around 32% (SRI, 2018). The main reasons of consumption are the low price of the material, supreme adherence to wood and

wide level of reactivity. These factors help the high reactivity of formaldehyde emission wider because of the low persistence to hydrolysis and free non-conducted tendency of formaldehyde (Athanassiadou E., 2000).

In addition, the work environment can increase the level of formaldehyde in the air especially in formaldehyde based wood products. The air condition like high humidity and high temperature is the most adhesive concern because of the summertime temperature in Dubai (Department of Australian Health, 2016).

The internal and external factors affect the formaldehyde emissions. Consideration of applied resins, operation status, pressing procedures, and the wood types and the age of panels affect internal factors. Other parameters such like the humidity of air, location of panels with evaluation of the room temperatures and the capacity of area and the air exchange rate are considered as external elements (Athanassiadou E., and M Ohlmeyer., 2009).

Below table demonstrate the formaldehyde emission limit of composite wood panels based on EPA rules.

Table 6: The Rule on Formaldehyde Emissions from Composite Wood Products (EPA, 2016)

*Hardwood plywood panel using particleboard or MDF in the core
**Maximum thickness of 8mm
***Chamber concentration according to ASTM E 1333 test method

Product	PHASE 2 LEVELS (ppm***)
Hardwood Plywood – Veneer Core	0.05
Hardwood Plywood – Composite Core*	0.05
Particleboard	0.09
MDF	0.11
Thin MDF**	0.13

The EPA's Integrated Risk Information System (IRIS) classified Formaldehyde as a first well-known group of human carcinogen in Group 1(EPA, 1991). Based on the U.S. EPA Integrated Risk Information System, the risk of cancer in the low concentration level estimated one in 10,000 people (Environmental Protection Agency, 2013). Formaldehyde is known as a potential cause of carcinogen. The side effects of formaldehyde are because of the high water solubility and fast dissolvers in liquid, which cause reduction of lung capacity and issue of respiratory system. The quick absorption inside the digestive system and respiratory tract is due to the high water solubility effect. Inhalation formaldehyde fumes in the wood factory in short terms period result in irritation of eyes, nose and throat. This side effect is based on the concentration above 0.1ppm level can cause inimical health problem (NCS, 2010). In the long-term period based on the Office Environment health Hazard Assessment (OEHHA, 2000) report, when the level of breathing continues 0,002 (2ppb, 3 μg/m3) the effect of irritation sensation cause health issues like respiratory symptoms, watery eyes, sinuses may get blocked, sneezing, runny nose, sore throat and nasopharyngeal cancer and leukemia.

2-2-2.3 Acetaldehyde

Acetaldehyde or ethanol with the formula CH3CHO is one of the utmost significant aldehydes being procreate on the wide industry scale, which has a pleasant fruity smell at the weaken condensation, in reverse; the shrilled suffocating odor is a common smell. The weight of acetaldehyde is 44.06 g/mol.

People spend most of their time indoors and ethanol as potential contaminants has a majority health effect on the workers life (John D., 2000). The emission of acetaldehyde in high

temperatures is more and in Dubai weather condition is quite worrying especially in summer time the temperature is high and the emission of acetaldehyde is increasing (DHA, 2012).

Acetaldehyde considers as a volatile organic compounds (VOCs) and it remarks as priority pollution to the health (Ohira T., 2004). The major origin of acetaldehyde in joinery industries come from wooden varnished, laminate, panel-shaped wood, painting process, plywood, chipboard, adhesives and, particle-boards. The wide amount of emission comes from adhesives rather than other wood base sources (Shinohara N., 2007).

Based on the Yagi et al reports, the maximum amount of acetaldehyde emission comes from panel-shape wood-based products. Besides, laminated lumber has the second emission rate of 535μg/m2 h (Yagi et al., 2004). Also, glue-laminated timber has a notable emission amount of acetaldehyde because of the mixture of ethanol with adhesive and the emission amount of acetaldehyde of glue-laminated timber and laminated veneer is greater than the natural wood. Generated acetaldehyde progress is from enzymatic of alcohol dehydrogenase inside the wood tissue (Tohmura S., Miyamoto K., 2005). Acetaldehyde emission created from wood-based product result in poor indoor-air even if the amount of dispersed acetaldehyde is very low (Shinohara N., 2007).

The health problem of acetaldehyde comprise into two categories of acute effects and chronic effects. Acetaldehyde categorized in Group B2 probabilistic human carcinogen. The side effects of aspiration exposure to acetaldehyde affect the eyes, skin, throat and respiratory tract. The first sensitive symptom is irritation of eyes, which occurs in concentration of 50 ppm and then noise irritation start at 100-ppm concentration and throat irritation reported at concentration of 200 ppm (Silverman et al. 1946; Sim and Pattle 1957; Muttray et al. 2009). The symptoms occur in higher level of exposure are coughing, pulmonary edema, necrosis and erythema and as

a result, high blood pressure and shorten of respiratory system, which cause bronchoconstriction in asthma or bronchiolitis obliterans happen (EPA, 1987). As per EPA report, acetaldehyde can be considered as a potential toxin. They used mathematical models to investigate on the health hazard of breathing acetaldehyde in air cause cancer in human. Based on their studies, if the workers incessantly exposure to acetaldehyde of 0.5 µg/m 3 (5 x 10 -4 mg/m 3, during their life time, the chance of getting cancer will be very low. The hazard causes in average amount of 2.2 x 10 -6 (µg/m 3) (IRIS, 1999).

According To the America conference of governmental industrial hygienists, continuously high-level exposure to acetaldehyde cause issues for heart, blood vessels and lungs. Smoking cigarette also, develop the risk of health hazard. Workers should use eye protection and wearing mask and gloves all the times. Besides, washing the working cloths are necessarily needed as they cause fire hazard (ACGIH, 2003).

2-2-2. 4 Carbon Dioxide:

Wood recognized as one of the vital construction product in UAE and in the world. Trees absorb carbon dioxide throughout their lifetime. Carbon dioxide is always remains stored until the end of the physical life of trees from the time they get harvested and used as timber for joinery products. The stored carbon dioxide is around one ton per meter cube (U.K Forest Product Association, 2015).

The worth of Joinery industry is €255 billion worldwide and UAE import more than 1.4 billion dollar wood (Arabian Business Industry, 2007). Carbon emission generates from different industries and joinery industry is one of the major ones (McDonough W., 2002). Based on the research of World Data Atlas, the emission of CO^2 in UAE was 31.07 metric tons in 1997

while the CO_2 emission declined gently to 23.06 metric tons in 2016 (World Data Atlas, 2016). Co_2 categorized as one of the most remarkable greenhouse gases that effect the environment and global warming by 64 percentages (Antov P., 2017). However, the Supreme Council of Energy in UAE announced their strategies to reduce the carbon emission around 16% by 2021, which is equal by 11 tons of carbon dioxide. Also, based on the Sheikh Mohammed Bin Rashid Al Maktoum' speech UAE will become a global hub of clean and clear sustainable energy by 2050 (Gulf news, 2017).

Based on the researches of United Nations Economic, CO_2 is not considered as toxic or detrimental gas. If the CO_2 condensation stays around 1%, which is 10,000 ppm, people start feel sleepy and the lungs feel stuffy (Friedman D., 2011). The side effect of 70,000 to 100,000 ppm of CO^2 condensation may cause serious symptoms in people within a few minutes to an hour even if the oxygen is sufficient, such like asphyxiation, headache, dizziness, abnormality of hearing and visual sense, and unconsciousness (U.S Environment protection agency, 2015). The subset of asphyxiation categorized in term of hypercapnia, which demonstrates the physiological side effects of dangerous carbon dioxide exposure. There are few studies based on International Space Station that demonstrate the side effect of long-term persistent CO_2 exposure below 1% (1000ppm) condensation. The result came up with the headache, inaction, and emotional irritation; sleep disruption and mental slowness (Law J., Watkins S., Alexander D., 2010). The remarkable effect of CO^2 exposure below 1% condensation in human for 2.5 hours sessions is cognitive abilities (Statish U., Mendell M J., Shekhar K, 2012). Below shows the main symptoms of carbon dioxide toxicity in the human body (Friedman D, 2009).

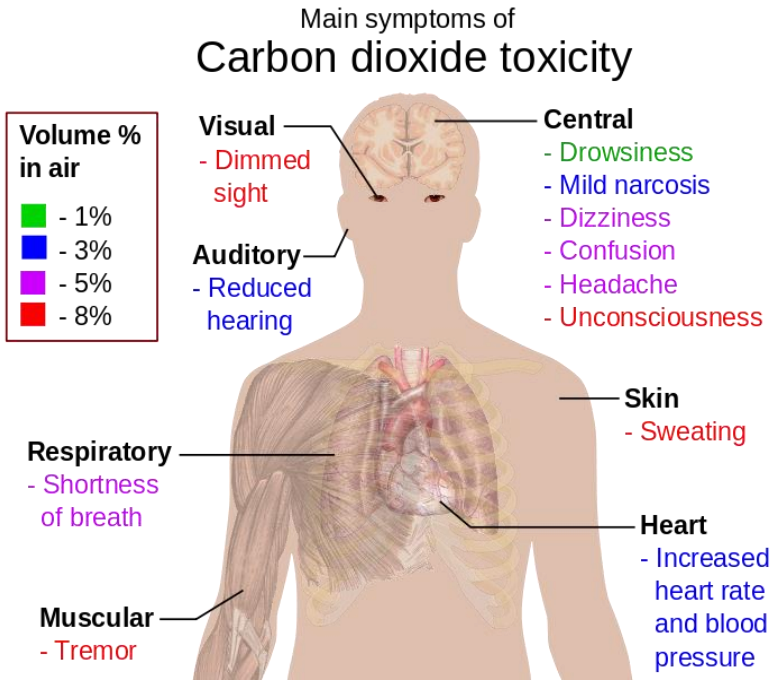


Figure 3: Toxicity of Carbon Dioxide Gas Exposure (Friedman Daniel, 2009)

According to the different health organizations like WHO, ASHARE and, OH & S, the standard level of Co^2 define in below table;

Table 7: Co_2 standard concentration level (Occupational Health and safety, 2016)

250- 400 ppm	Normal background concentration in outdoor ambient air
400-1000 ppm	Concentrations typical of occupied indoor spaces with good air exchange
1000-2000 ppm	Complaints of drowsiness and poor air.
2000-5000 ppm	Headaches, sleepiness and stagnant, stale, stuffy air. Poor concentration, loss of attention, increased heart rate and slight nausea may also be present.
5000 ppm	Workplace exposure limit (as 8-hour TWA) in most jurisdictions.

Carbon dioxide with the chemical formula of CO_2 is the greatest remarkable longevism greenhouse gas exists in the Earth's atmosphere. Carbon dioxide is a colorless and odorless gas

with the 60% superior density in compare with dry air. The odor of carbon monoxide in the high condensation is very acidic and sharp (Air product, 2009). Proper ventilation has a direct effect on the CO_2 density especially in the closed spaces when the movement of the air is not sufficient enough (Joseph A., 2016). As a result, the higher CO_2 concentrations reduce the performance, health and comfort of the labors.

2-2-2.5 Carbon Monoxide (CO)

Carbon Monoxide is a colorless, inodorous, and flavorless flammable gas composed of one atom of oxygen and one atom of carbon (National Institute for Occupational Safety and Health, 1994). Carbon monoxide is an invisible combustible gas with moderately less condensed than air that partially being oxidized from a combination of carbon-contain when the oxygen is insufficient (Penny D G., 2000).

Carbon monoxide is generating in the imperfect condition of carbon hold on the fuels contaminates such as oil, coal, wood, and gasoline. However, the main fountainhead of CO emission comes from the industrial process of ignition, gas stoves, space heaters, the motor of vehicles and charcoal grills. CO concentrations increase in the insufficient ventilation system and low temperature in an internal atmosphere (Harrop, 2002).

In many U.S. cities in the 1960s, the CO condensation growth and became an unsound environ because of the vehicle emissions. However, the CO emission decreased within 1980 to 1999 by 21 percentages, as well as the CO concentration environ by 57% after the implementation of the CO control system (EPA 2001a).

Regarding the wood products, carbon stored in dry mass of tress and the wood product for average life of 100 years and it remained in wood furniture for about 30 years and it wood

pallets for 6 years and it only can rolled back to the nature when the wood product gets burnt or decomposed (Leys J A., 2015).

Various organizations have commented on the standard level of carbon monoxide exposure as follows; OSHA placed a standard level of exposure of CO, which is 50 parts per million (PPM), which is 55 milligrams per cubic meter (mg/m3) for average of 8 hour daily in workplace (OSHA, 2012). If the emission exceed 100 parts per million (PPM), which means 105 milligrams per cubic meter (mg/m3) it considers a drastic infringement and the imminent hazard happens in exposure above 505 milligrams per cubic meter. However, the recommended standard level of exposure from National Institute for Occupational Safety and Health (NIOSH), considered 35 parts per million and the exposure above 200 parts per million is prohibited. All the written standard level of CO considered for the young generation without having of any health problem (OSHA, 2017).

The research of ACGIH (American Conference of Governmental industrial Hygienist) is based on the affiliation of carbon monoxide with hemoglobin and how carbon monoxide can replace itself with the oxygen in hemoglobin. Affiliation of carbon monoxide is 200 times greater than oxygen in hemoglobin and inhaling carbon monoxide has numerous fatal effects on humans. Carboxyhemoglobin is the result of the firm connectivity of CO with hemoglobin (Chichkova and Prockop, 2007). And the high amount of Carboxyhemoglobin (COHb), which estimate the threshold limit of carbon monoxide level is 25 ppm, which is 29 mg/m3 for 8 hour daily and 40 hour weekly (ACGIH, 1994). In the case of surpass of emission, hypoxia (shortage of oxygen) happens, which has a vital effect on the body organs via the bloodstream. It impacts the amount of receiving oxygen to the fundamental body organs and tissues such as the heart and

brain. Cardiovascular and respiratory sickness creates through the CO inhaling. (Chichkova P, 2007; Paavilainen et al., 2010).

The ideal level of CO condensation of indoors should be the same as the outdoor area. Besides, every country has a variety of legal or authorized levels of CO in the past period. Based on the Minnesota department of health, people get notice of the dangerous level of carbon poisoning when they become ill (Minnesota department of Health, 2018). Four levels are defined for carbon emission based on the United Technology Crop organization as followed table (UTC, 2019).

Table 8: Exposure range of carbon monoxide level (UTC Climate, 2019)

Carbon Monoxide level	Exposure range
Low level	> 50 PPM
Mid-level	51-100 PPM
High-level	>101 when nobody experienced the symptoms
Dangerous level	>101 when someone experienced the symptoms

Based on the conducted retrieved reports of New York Times on 2010, Carbon monoxide function is an ordinary neurotransmitter and it adjusts the inflaming reactions in our body with the natural manner (Kolata, G., 1993). It also plays a vital role in creation of ground-level of ozone.

According to the clinical trials, Carbon monoxides used as a biological regularize and the small quantity of carbon monoxide utilize in medication (Carolyn Y., 2009). In most body tissues carbon monoxide along with the other two gasses called Nitric oxide and hydrogen

sulfide work as anti-inflammatory, neovascularization growth and vasodilators (Moore PK., 2009). However, the big amount of carbon monoxide causes poisoning when it enters into the blood circulating it can stop the body from getting adequate oxygen and as a result it affects the body tissue (Poslusny C., 2018).

The health effect of CO emission has a direct result into the CO level and the duration of exposure, as well as the health situation of people. Also, Carbon Monoxide poisoning is similar to influenza and the symptoms are headache, dizzying, weakness feeling, infection, chest pain, nausea and vomiting. Based on the CDC research (Centers for disease control and Prevention) the number of people exposes to carbon monoxide poison is more than twenty thousand people every year while in a harmful condition, it resulting in eventual death (National Centre for Environmental Health, 2018).

The symptoms of carbon monoxide poisoning level summarized in below table.

Table 9: Carbon Monoxide level and the Symptoms (OSHA, NIOSH, UL, 2020)

Carbon Monoxide Level	Symptoms
50 PPM	None for healthy adults. According to the occupational safety & health administrations (OSHA), this is the maximum allowable concentration for continuous exposure for healthy adults in any eight-hour period.
200 PPM	NIOSH 15 min. slight headache, fatigue, dizziness, and nausea (Physical symptoms) after two to three hours
400 PPM	UL 10-15 Min. Frontal headaches & Alarm physical symptoms with one to two hours. Life threatening after three hours
800 PPM	Physical symptoms in 20 min. Fatal within 1 hour (UL)
1600 PPM	Physical symptoms within 5-10 Min. Fatal within 25-30 min (UL)

2-2-2.6 Ozone:

The history of Ozone discovery backed to 1785; when the Martinus van Marum, Dutch chemist did not recognize the unusual smell of his experiment of electrical sparking over the water, which causes electrical reactions generated Ozone (Gary T., 1880). Christian Friedrich Schönbein, a German-Swiss chemist notified the sharply strong odor similar to the thunderbolt smell in 1835. Four years later, he could separate the gassy chemical and called it "Ozone", which has a Greek root of ozein (ὄζειν) means, "to smell" (Mordecai B R., 2001). Invention of Ozone attributed to Schönbein (Jacewics N., 2017). And Jacques-Louis Sort distinguished Ozone's formula, O3, in 1865 (Soret J L., 1865). The formula acknowledged by Schönbein in 1867 (Mordecai B R., 2001).

The structure of Ozone was characterized in 1865. O3 molecule has a diamagnetic curved form and the oxygen structure consists of three molecules as a replacement of two in a standard structure (Cuthbertson C, 1914). The structure of ozone affected by ultraviolet light (UV) and electrical evacuation in the formed of dioxygen inside the Earth's atmosphere.

Density of ozone is 1.5 times higher than oxygen. Ozone color in standard situation is colorless or pale blue. When the temperature goes to -112° C, the color start to be dark blue and it becomes liquid because of compacted condition of ozone by increasingly frigorific temperatures. At -251.4° C temperature, ozone becomes violet-black solid freeze (Lotha G, 2019). Other features of Ozone is the speed of decomposes of gas with the existence of specific catalysts at about 100° C. also, ozone is a moderate dissolves in water and the solubility of non-polar solvent is more (Augustyn A, 2019).

Inhaling ozone at the ground level is detrimental for health of humans as the major component in "smog" (EPA, 2017). It considers as toxic air pollution and cause many health

problems. Long term exposure of ozone impact the healthy and unhealthy people. But the effect can be more drastic in people with lung issues like asthma. One of the major reason of asthma growth and worsening asthma is exposure to high condensation of ozone in long term and it might damage the lungs permanently (EPA, 2017). The reconsideration of Ozone primary and secondary level has been changed in 2015 based on EPA researches. The agreed standard level with consideration of eight hours daily test, for about 3 years consecutive has been done. The result of the standard levels agreed to 0.070 parts per million (ppm). There are two criteria based on the agreed standard level of Ozone, a primary standard and the secondary standard, which protect the public health and the public welfare in ecosystems (EPA, 2015).

The initial symptoms of ozone might vanish after a while, especially when the exposure of an unhealthy level of ozone resume in many days. Nevertheless, even if the symptoms are not considered, but it also hurts the lungs continuously (EPA, 2017). The below images demonstrated the inflaming of lungs lining in the right image and the left picture shows the healthy lung airways (Pentax Medical Company, 2012).

Figure 4: Demonstrating the healthy and the inflaming lungs (Pentax Medical Company, 2012)

The low amount of ozone emission aggravation respiratory system and it reduces the body's resistance to respiratory infection diseases. Also, it causes the irritation in throat, breath

shortage, pain in chest; coughing and it constrict the muscles' airways. Air trap in the alveoli and it causes breath shortage and wheezing (EPA, 2017).

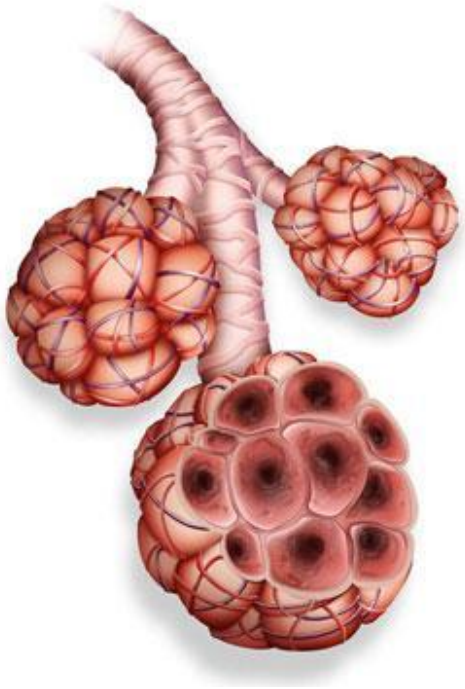


Figure 5: MUSCLES CONSTRICT IN AIRWAYS

Photos courtesy of PENTAX Medical Company (EPA, 2017)

The latest researches on short-term ozone emission and collected accidental fatality evidence prove the high risk of respiratory issues causes deaths. Collected documents show that the mortality of respiratory problems in short-term ozone exposure is higher than the long-term ozone exposure 9epa, 2017). Also, the impact of health recovery in the short-term exposure time with the low level of ozone is more harmful in compare with the higher levels of exposure with the long period of time (US EPA, 1996a, 1996b).

Based on the United State Environmental Protection Agency report, the different level of ozone exposure describes as below;

Table 10: Health association with ozone exposure level (EPA, 2009)

Air quality 1ndex	Heath protection
Good (0-50)	No health impacts are expected when air quality is in this range
Moderate (51-100)	Unusually sensitive people should consider limiting prolonged outdoor exertion
Unhealthy for Sensitive Groups (101-150)	The following groups should limit prolonged outdoor exertion: • People with lung disease, such as asthma • Children and older adults • People who are active outdoors
Unhealthy (151-200)	The following groups should avoid prolonged outdoor exertion: • People with lung disease, such as asthma • Children and older adults • People who are active outdoors Everyone else should limit prolonged outdoor exertion.
Very Unhealthy (201-300)	The following groups should avoid all outdoor exertion: • People with lung disease, such as asthma • Children and older adults • People who are active outdoors Everyone else should limit outdoor exertion.

Because of the weather condition in UAE, most of the times people spend their time indoors. Ozone as a reactive gas mixes with some kind of chemical components and produce variety air pollution, which has a huge impact in human's health and performance. In addition, there are possibilities of chemical repercussion of ozone with office/home furniture.

According to the Weschler researches, the percentage of exposure of ozone concentrations in indoors to outdoors areas are usually 45 to 75 percentage of the whole

exposures (Weschler, 2005). The breathing ratio of people in indoors is lesser than outdoors. The total ozone inhalation of indoor is usually 25 to 60 percentage of the whole ozone intake. The people who are old, infants and those who have respiratory and cardiovascular problems are the most affected.

2-2-2.7 Particulate Matter (PM)

Intricate admixture of liquid and/ or solid suspended particles in the air called particle pollution or particulate matter (PM). The difference between the particles is in their size, form or their combinations. EPA's concern is about the inhalable particles, which are 10 micrometers and smaller than this size (EPA, 2018). The level of indoor PM can be greater than the outdoor PM. There are two types of particulate matter; one type can see with naked eyes like smoke, soot, dust, and dirt. And another type, which is the small size, can see with the electron microscope (EPA, 2018). Particulate matters comprise:

Table 11: Particulate matters size (EPA, 2018)

PM $_{2.5}$	The size of $PM_{2.5}$ is mostly 2.5 micrometers or smaller (Fine inhalable particles)
PM $_{10}$	The size of PM_{10} is mostly 10 micrometers or smaller (Inhalable particles)

The length of time that the particles stay in the air depends on the size of the particles. $PM_{2.5}$ is a breathable particle and stays in the air for days or even weeks. However, the PM_{10}, which is a breathable particle but larger than the $PM_{2.5}$, stays in the air for minutes or hours. Therefore, the size of the smaller particles in the air stays longer and moves more than the larger particles (EPA, 2018). Following EPA reports, $PM_{2.5}$ and smaller size causes more harm. These particles stick to the respirational tract and eventually move to human' throat (EPA, 2018). Aerosols are the tiny and light particles suspended in the atmosphere. These particles in the air

are so small but they have a capability of changing weather (EPA, 2018). Saw dust or wood dust is some sort of particulate matter. Sanding is the worse reason for fine dust creation. And when the fine particles inhale, it creates health problems, especially in the heart and lungs and they also can get in bloodstream (EPA, 2018).

Exposure to particles matter cause many problems in human health such as itchy skin, sneezing, skin irritation, irregular heartbeats, asthma, coughing, difficulty in breathing, respiratory problems, lung function reduction, different kind of allergic, nasal cancer and lung cancer (EPA, 2018). People with the heart and lung problem are more in risk of premature death. The stage of these symptoms and diseases depends on the severity and duration of exposure to wood dust. People who their jobs are related to wood dust and similar function of dust have more in danger to get lung cancer than other people (EPA, 2018). Inhaling wood dust after 4 to 6 hours can cause some symptoms like shortness of breath, pyrexia, dry cough, tiredness, chest tightness, and shiver (Venkateshiah S., 2020).

The formation of wood dust depends on the type of wood. Sanding hardwoods cause more wood dust than softwoods. Hardwood trees are denser than softwood trees. Oak, teak, walnut, mahogany, beech, etc. categorized in hardwood trees, which are the most useable types of wood in joinery industries. Also, softwood trees exemplar are pine, redwood, fir, and etc. (hardwood vs. softwood, 2012). Wood dust average size is usually around 10 to 30 µm. However, the size diameter of processing wood can be 5µm. wood dust particles from the machineries produce with the usual speed of 10 m s-1. People can only inhale small particles and some big particles carry the small ones (Alwis 1999; Cavallo 2008). Based on the HSE and OSHA reports, the standard level of PM exposure in 8 hours is 3 mg/m^3 for hardwood dust (HSE, OSHA, 2020).

2-3 Wood dust and its impact on workers' health and performance

2-3-1 Effects of Wood Dust to Health of Workers

Raw material is used for constructing the wood products such as kitchen cabinet, wall cladding, vanity, wardrobe, furniture and doors. These products make of primary wood materials, which categorized in to two groups, solid wood and manufactured wood. Solid wood consists of hardwoods and softwoods. However, the manufactured wood is a compound of actual wood or combinations of materials (Green H., 2006).

Solid wood comes directly from a tree thus it is a pure lumber. Real wood categorized into hard wood and soft wood. The differences between hard wood and soft wood are the density and the type of tree. The density of hardwood is higher than softwood and the lumber that used in hardwood comes from deciduous trees such as oak, teak, beech, walnut, mahogany, hickory and maple. The duration of growth in these trees are very slow while, the lumber of coniferous type of trees are used as softwood, which the growth duration are quicker than the deciduous trees. The evergreen trees are pine, fir and spruce (Green H., 2006).

Engineered wood extracts from lumber and combination of adhesive and other synthetic materials to make a composite wood. Engineered wood classify into plywood and particleboard wood type. Plywood originates of 3 to 5 thin board of lumber attached with adhesive together. Particleboard called as fiberboard, which made of combination of tiny fibers with glue together and adhesive (Green H., 2006).

Wood dust is a wastage of wood products that comes from the operation of woodworking. Different activities cause wood fine particles such as routing, sanding, drilling,

sawing and milling. These processes come from wood working machines, transferable power tools or hand tools items (IARC, 1995). The health problem of wood dust in carpenters and joiners are 4 times higher than other workers (COSHH, 2002).

According to the Health and Safety Executive, sanding and cutting wood using power tools produces significant levels of dust that prompt effective control. Exposure to wood dust has been associated with various health issues in different studies. In fact, various studies have linked wood dust exposure to health issue such as carcinogenic and no carcinogenic impact to the lower and upper respiratory system (Visser et al. 2015). Accordingly, the international agency of research on cancer has classified wood dust as the main source of carcinogens in Humans. Consequently, committee of occupational exposure in European Union has indicated that exposures of 0.5mg/m3 result into lung symptoms comprising of occupational asthma, depression of lung functions as well as chronic respiratory diseases (Visser et al. 2015). Accordingly, studies have shown that workers in the cabinet workshops and furniture industries are associated with symptoms such as chest pain, asthma, cough and headaches. In that case, there is no doubt that wood dust can have adverse effect to the health wellbeing of wood industry workers.

Campbell's study on wood toxicity revealed that for centuries, it has become a well-known truth that some woods pose a higher toxicity degree to the human populace than others. To demystify the fact that difference in the toxicities of wood has been well understood, Campbell reports that from as early as 60 A.D, historical records availed by naturalists describe a case whereby four soldiers died after drinking wine that was stored in a hip flask made of yew. Another related cases of German sawyers who developed irritation of the eyes and the nose after sawing bald cypress demonstrated the difference in the toxicity of different trees. Although

Campell postulates that only 2 to 5% of the global population is allergic to at least one compound found in wood, working with wood for a prolonged period of time increases the chances of occurrence of an allergic reaction, and the symptoms become more profound with prolonged exposure. In this regard, it is evident that the severity of the symptoms manifested by a sawyer is not only dependent on the time of wood being sawed, but also the extent of the exposure to the dust.

Campbell hypothesizes that any dust including wood dust causes mild irritation of the sensitive mucous membrane linings of the nose and eye. The irritation manifested by the tearing and continuous sneezing. Given the aforementioned variation in the toxicity of wood, it can be projected that some woods such as red cedar and rosewood can be particularly bothersome and health ramifications are far-reaching. Some woods tend to have a more profound health outcome, which will be evidenced by the growth of a rash that can be classified as either as a symptom of allergic dermatitis or irritant dermatitis. The rash is usually characterized by swollen and uniformly swollen area that erupts in blisters. The rash first occurs as a web of skin between a victim's fingers and later develops into an excruciating painful growth. Woods that have such health manifestations are black locust, ebony, sequoia, satinwood, and cocobolo. Campbell further explains that for one to develop the rash, he or she must be allergic to one or more compound contained in the wood. The compounds that usually trigger allergic reactions are called sensitizers. The severity of the allergic reaction is determined by the extent of the contact with the sensitizer.

Based on the research of Eric Meier, each type of wood species is different in their reactions on body, the power of their affection on mind and the area of affected. Below is the summary of the most common wood species reactions in the UAE (Meier, E., 2007).

Table 12: Health effect of wood dust on the health of people (Meier, E., 2007)

Wood Type	Reaction	Area's affected	Potency
Ash wood	Irritant	Lungs, eyes, hands	2 out of 5
African blackwood	Irritant, sensitizer	Lungs, eyes, hands	2 out of 5
Mahogany (African)	Irritant, Sensitizer, NPC	Lungs, hands	3 out of 5
Ebony	Irritant	Hands	2 out of 5
Silky oak, Northern	Irritant	Hands	2 out of 5
Meranti	Irritant	Lungs, eyes, hands	2 out of 5
Walnut, African	Irritant, NPC, Systemic effects	Lungs, eyes, hands	3 out of 5
Silky oak, Southern	Irritant, sap may cause blistering of skin, eyelid inflammation	Hands, eyes	3 out of 5
Walnut, English	Irritant, NPC	Lungs, eyes, hands	2 out of 5
Walnut, Black	Irritant, NPC, sensitizer	Lungs, eyes, hands	2 out of 5
Olive	Irritant, sensitizer,	Lungs, eyes, hands	3 out of 5
Teak	Irritant, sensitizer, rash, nausea, asthma, vision effects, pink eyes, HP	Lungs, eyes, hands	3 out of 5

Campbell also states that that health problems associated with working in a wood processing plant is not limited to exposure to duster. Allergic reactions and irritability can also be triggered by repeated contact with fungicides and chemicals

According to studies undertaken among 72 wood mill workers in Thailand, it was evident that wood dusts adversely affected the peak expiratory flow rate (Kherde et al. 2017, p.68). In view of the pathophysiological aspect as well as the decreased peak expiratory flow rate, the results of the study clearly indicate that wood dust affects lung function and the impairment is associated with exposure to wood dust. Also, studies by Douwes at al. (2017) carried among 99 workers in joineries and furniture making factories have proved that wood dust has significant effects to the health of workers. Conversely, the research has indicated that exposure to wood dust is high among workers who use hand tools and those who deal with cleaning (Douwes at al. 2017, p.416).

Also, it was noted that extraction by use of vacuum and other cleaning methods reduces workplace exposure although it is insufficient when it comes to compliance with the occupational exposure limits (Ratnasingam, Ioras and Bennet, 2010). Likewise, research and analysis undertaken in Malaysian wooden furniture industry has shown that wooden furniture industry is associated with various risk factors (Ratnasingam, Ioras and Bennet 2010, p.353). In which case, there are risks associated with work environment including airborne dusts from machine operations as well as manual handling of wood materials. Ratnasingam et al. (2015) have also agreed on the effects of wood dust on health of workers citing that bamboo furniture manufacturing industry produces a high portion of fine dust particles that possess a risk to the health of wood manufacturing workers.

Additionally, Michalski et al. (2018), has pointed out that workers especially working in sanding operations have a high risk of developing cancer within the Sino-nasal. This is so due to the fact that airborne wood dusts concentration is high in the zones where workers engage in either machine or wood sanding. In fact, the same studies indicate that the concentration in the sanding zone is three times the concentration in the planning, drilling and sawing breathing zones. Hence, study reviews have suggested that nasal adenocarcinoma can be prevented in either the United States or eradicated in Europe if compliance by wood firms does not allow wood dust exposure to go beyond the 8hr time-weighted-average (Michalski et al., 2018, p.326).

Despite the documented biological effects of exposure to dust, Maciejewska et al. (1993) theorizes that the biological effects and the manifested symptoms depend on the composition and the content of microorganisms in the wood. Since dust is the most commonly encountered hazard in word processing, the extent of the problem goes beyond the word processing plant setting. According to Bhatti et al. (2011), about 600,000 persons in the United States are exposed to

wood dust; the magnitude of the exposure differs on the basis of the size of the woof processing industry in a nation. Bhatti et al. (2011) further noted that clinical observations undertakes in the 1960s in the High Wycombe region elucidates that people who undertook construction projects using hardwoods experienced an elevated predisposition to sinonasal adenocarcinoma. The study later determined that the risk of development of sinonasal adenocarcinoma increases 500-fold for people that work in wood factories as opposed to the general population.

Bhatti et al. (2011) acknowledge that wood dust has long been regarded as respiratory irritant and other studies have suggested that different tree dusts demonstrate different adverse conditions including asthma, a decline in the lung function, and chronic obstructive pulmonary disease. Other conditions resulting from exposure to dust include a decrease in the force vital capacity and nasal irritation. Although a myriad of studies have explore the correlation between lung function and exposure to dust, finding of studies that sought to debunk whether exposure to dust elevated an individual's predisposition to developing cancer have been inconclusive prompting further research. It is irrefutable that the impact of prolonged exposure to wood dust on the lungs is profound.

A study conducted by Nwajei and Iwegbue (2007) in the vicinity of Sawmill in Sapele, Nigeria revealed the presence of trace elements in the sawdust particle. The presence elements, which are likely to be deleterious to people living in the neighborhood undoubtedly would have a more profound health effect on the personnel working in the sawmill (Nwajei &Iwegbue, 2007). Since heavy metals are not biodegradable and they are carcinogenic, the health ramification of inhalation of the metals tends to be deleterious. Wood dust is considered a group 1 carcinogen, a substance that has the capacity to turn normal cells into cancerous cells with the ability to

metastasize. The toxicity of wood dust results from the conglomerate of compounds that constitute wood.

Studies on the genotoxicity of wood dust have determined that prolonged exposure to wood dust elevates an individual's chances of experiencing genetic damage. According to Rekhadevi, Mahboob, Rahman and Grover (2009), the genotoxicity of wood when analyzed by micronucleus test showed the inductions of the micronuclei in the subjects. The subjects of the test were mice that were treated with birchen wood dust, beech wood dust, and bass wood dust. When comet assay was used to evaluate the effect of prolonged exposure to wood dust for carpenters, a significant genetic effect was elucidated (Rekhadevi, Mahboob, Rahman, & Grover, 2009). The extent of the genetic damage caused by exposure to dust compromises the genetic wellness of one's offspring.

The health and safety hazards of working in a wood processing plant are not limited to exposure to dust. The risks encompass noise, vibrations, and chemical hazards. As discussed in the background section of this paper, exposure to chemical used in preparing wood for storage causes allergic reactions. Moreover, the commonness of noise-related deafness is common among wood processing workers.

2-3-2 Effects of Poor Health on Performance of Workers

The wood industry is associated with various health problems. As a matter of fact, the industry is linked to the many cases of occupational and environmental lung diseases given that the lung is among the most vulnerable parts to airborne hazards. In that case, there is no doubt that the health of workers is a crucial work environment component that has a high probability of affecting their performance. Price Waterhouse Cooper studies have shown that sickness of workers is costing a lot of organizations (Hatch and Tomé 2017). In fact, the costs are associated

with absent employee salary, additional stress on other staff, and cost of replacing labor as well as the time taken for a replacement. According to research by Chen at al. (2015), poor health of employees is directly proportional to their productivity. Accordingly, the health productivity loss can easily be measured through presenters and absenteeism. In which case the study clearly observe that high health related support is associated with lower rates of absenteeism among employees in the public sector (Chen et al. 2015, p. 143). Therefore, it is evident from the studies that wood manufacturing employees are exposed to a lot of health risks that affect their overall job performance. As studies suggest, employees with health problems are likely to spend much time taking care of their health well-being leading to increased absenteeism. Furthermore, Westgaard and Winkel (2011) in their studies have indicated that concerns on human health by the management are related to positive outcome on morale, motivation as well as organizational commitment. In a given organization, the ability to satisfy the stakeholder or rather organizational does not only depends on the activities undertaken but also the welfare of the workers. Research by Michalski et al. (2018) has shown that for carpentry workers, the basic necessity is safety in the workplace. In that connection, the main tool that will ensure improved conditions in the workplace is assessment of occupational health (Michalski et al. 2018, p.323). Hence, lack of risk assessment in the work place causes undesirable events including health related hazards that affect employee productivity. Similarly, a research undertaken to determine the effect of indoor environment on employee productivity showed that performance of workers is likely to be increased by achieving quality indoor environment (Arif et al. 2016). In the case, wood company's is obvious that workers spend 90% of their time in environments comprising of wood dust. Without proper handling of wood dust, it impacts employee's health and the overall organizational productivity.

Chapter 3: Research Methodology

3-1 Introduction:

The definition of Methodology is about using particular process or methods to measure the overall credibility and validity of the research topic. It shows the progresses of analysis, selected information and categorized data to make a better understand of readers. Research methodology ability is exploring the problems and develops the ideas and design to solve the issue to ideality. In real life, the case study of the research methodology includes complete comprehension of stated problem.

This research illustrates the connection of air containments with the health problem of the labors in joinery factories, which can appraise the effectiveness of the present air condition in line with the comfort and performance level of the labors in the factory. Thus, the indoor air quality of the factory in very significant impact on the labors health and performance. Measuring the air contaminants should follow the specific consideration. Sanding area of the joinery factory was under the investigation between 21st of Nov to 6th of Dec 2019.

The methodology of this research refers to reviewing the studies on indoor air quality conditions on the health and performance of the labors. It consists of study methods and measures the level of air pollutant, which used in this investigation, in order to increase the quality of the indoor air. The experiment of this research predated to be done while the labors are working in the factory. The following methods used in this field to approach the aim and subjective of this study.

- Field measurement
- Questionnaire
- Walk-through investigation

3-1-1 Walk through investigation

The walkthrough investigation was conducted in all areas of the factory in order to collect more information and observation of indoor environmental situation to reach an easier analysis. Observation and interview with the safety manager happened in this phase. Based on his comments, I collected below information about the health of labors.

- Company has an agent in India and before they hire anyone, they assure about the workers 'health.
- When they come to UAE, the ministry of health get some medical tests and if they are in a good health condition, they can get start their job.
- Safety manager always provide instructor about using face mask and dust mask at work
- Workers get warning if they do not use face mask for twice and if they continue of not using the mask, they will get half salary for one day and if it continues they get one day reduction and final stage is getting terminated
- There is a dust control machine in the factory and the concerned supplier company always checks the machine to remove the dust. Basically, there is a maintenance company to clean the dust control machine.
- Based on the Safety manager talk, they hire an indoor air company to check their indoor air. And the result was ideal.
- One of the significant parts of this section was the visual assessment of indoor environment condition and the safety and health of labors. Layout and documents, which is related to the mechanical system and indoor environment are observed and recorded. All the information and data were collected by observing interior design,

exterior design, and existence of vacuums dust controllers and performance of the labors. Camera and check list paper used in this part. Safety manager has a useful role to help of gathering information. However, based on my own visual observation, workers do not using facemask and eye protection most of the time. And the quality of the air is not ideal. In addition, labors have one-hour break time when they can have their food and take a nap. During this time, the factory is shut down and most of the labors slept in the floor inside the factory. They do not go outside the building hall during their break time.

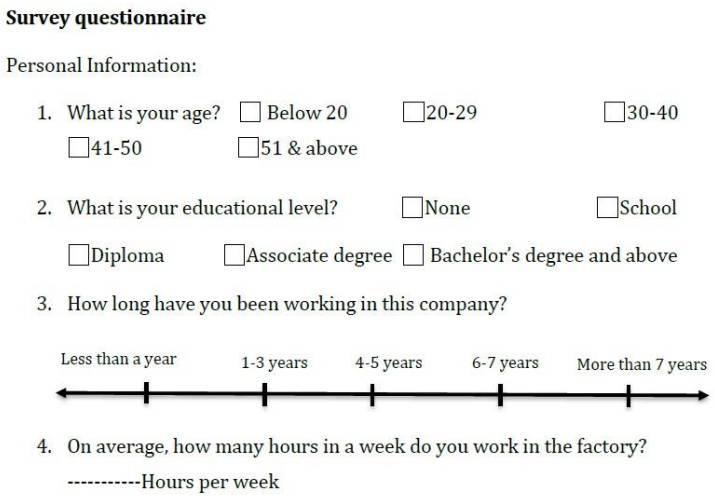
3-1-2 Questionnaire:

The main reason of using questionnaire was analysis of indoor air quality and the current situation of the health and performance of the labors in the factory. The major center of this questionnaire included the health of the labors and the symptoms of the health problem as they play the main role in the factory, so their health and performance is very important. The rest of the questionnaire focus was on the indoor air quality, wood dust, air pollution and their comfort.

The questionnaire prepared in two languages English and Hindi. As most employees speak Indian. The questionnaire distribute in 2 sections only. These sections have the most ratio of wood dust based on the factory manager speak. The reason for answering the questionnaire was given to the workers in full with the help of the manager of these two departments, and the workers answered this questionnaire at their own will. The questionnaire is designed so that the respondent is not identified based on individual characteristics. The questionnaire was also placed in a room that gave workers a sense of complete security, and after answering the questionnaire; they placed it in a box. The places that were surveyed are: machinery shop and

sanding area. These areas are known as the most pollutant areas in the factory because of the nature of the works happen in these places.

According to the above statements an example of the questionnaire is summarized below. An appendix of full survey questionnaire attached at the end of the research.



Survey questionnaire

Personal Information:

1. What is your age? ☐ Below 20 ☐20-29 ☐30-40
   ☐41-50 ☐51 & above
2. What is your educational level? ☐None ☐School
   ☐Diploma ☐Associate degree ☐ Bachelor's degree and above
3. How long have you been working in this company?

Less than a year | 1-3 years | 4-5 years | 6-7 years | More than 7 years

4. On average, how many hours in a week do you work in the factory?
   ----------Hours per week

Figure 6: Example of some questions of survey questionnaire

3-1-3 Field Investigation

The objective of field investigation was to measure the indoor air quality with the help of equipment. There were two different tools, which they measure the indoor air particles and the size of the particles. The measurement happened in the sanding area. The IAQ tools could measure the ozone, CO, TVOCs and CO2 and the Particle tools could measure the size of different particles. There are different particle sizes of PM, which can be harm for the health. These two main portable devices were used to measure the indoor air quality parameters.

- TSI, Optical Particle sizer
- Graywolf, Air Quality Meter

3-1-3.1 TSI- Optical Particle Sizer

TSI optical particle sizer is an air quality meter to measure the size of the existence particles on the air. This sizing instrument measures the size range of .03 nm to 10 micrometers. It is an easy use tools to show the size of particles and the counts number. During the field investigation phase this devise was used and places in the middle of sanding area to cover the whole area. The duration of collecting data from this device was 9 hours every day. Gathering data was at 4 pm every day.

Figure 7: TSI INSTRUMENT (TSI INCORPORATED, 2020)

3-1-3.2 Gray wolf- Air Quality Meter

Gray wolf sensing solution manufactured a direct sense of indoor air quality meter tool contain of portable monitoring device and PCC-10 security case that can record the carbon dioxide (CO^2), carbon monoxide (CO), Total Volatile Organic Compound (TVOCs) and ozone (O^3) levels in the air. It has a sensor connected to the digital screen to diagnose the air particles. With the help of this tool, we can control the opportunity of collecting information before the

major problems happened and affect the health, safety and performance of the workers. This device was located in the middle of the sanding area, surrounded with all the machineries in the sides. It placed almost the same level of the people's breathing heights. Data was collected every hour from 8 am till 4 pm.

Figure 8: Gray wolf sensing solution tool & PCC Security case (Gray wolf, 2020)

3-2 Dubai location and Climate:

Climate classification in the UAE is among the countries most vulnerable to climate change in the world. Thus, warmer weather condition, less rainfall, higher droughts, more sandstorms and higher sea level are the outcomes of this country in the future (Ministry of foreign affairs & International Corporation, 0ct.2019).

In the early 21st century, UAE has a huge thrive in oil industry. As a result, the population increased along with the high amount of people's consumptions. Also, it made the UAE as a 29th highest carbon dioxide country in the world because of the great amount of greenhouse gas emissions.

Dubai is located in desert and comprised two seasons, which has a dry long summer and short duration of winter. Summertime starts in May till September and wintertime is from

December until March. The temperatures in summer time is around 48 °C with the hot dry climate. In winter time the climate is moderate and the temperatures is around 15 °C. The hottest and coolest months of UAE is considered respectively July and January.

The average humidity (RH) levels of coastal areas in UAE are around 60 percentages, which is very high in compare with inside the island, which stand at 45 percentages. During May the average of humidity in May has the lowest level in the year. However, the highest level of humidity in wintertime reached the highest. Sandstorms are very usual in the country and it happens very unpredictable during the summer time. Regarding the speed of wind 2 meter above the earth level is basically reach 6km/HR (United Arab Emirate Ministry of Environment and Water (UAE MOEW), 2010).

Dubai's borderlines are with Abu Dhabi in the south and the northeast with Sharjah and the southeast with Oman. Dubai is located on the coast of the Persian Gulf in a sea level roughly, which is about 16 m or 52 ft. above. Dubai covers the total areas of 4,110 km2 (M. Al Serkal, 2016).

Figure 9: Dubai Map using Dubai online (Dubai-online, 2020)

3-3 Joinery company location and their layout:

The location of Joinery Company is in Dubai city. The joinery company was selected based on the production level and the size of the company. The location of Joinery Company is in Dubai Investment Park area between residential areas and industrial areas. There is a school near by the joinery building. The location is in the mix complex area where there are residential, schools and manufacturers. The size of the factory is about 15,000 sq.

The working times are from 7 am till 4 pm. Labors have Friday off depends on the work-louds. Sometimes they have 2 different shifts when the workloads are high. During my investigation, workers worked only one shift and they had Saturdays off.

The factory was built in 2014 and it consists of two floors. In the first floor is the main hall of the factory plus some offices, which related to the inquiries of labors such as health and safety manager room, clinic room and storage. In the second floor are the factory and all the remaining offices.

Parking area is in front of the entrance. There is a garden area and a place for cars. There are around 1200 labors working in different sections there.

The factory ventilation system in the offices is AC and in the factory is some floor fans and there are some doors in west and east of the building, which is open most of the year and the ventilation happen during these doors as well. In the second floor, there are windows in east and west side of the building. However, the windows are closed most of the times. The ventilation is through fans and the vacuum system in each department entrance. The factory walls were painted in white color and the lighting is artificial as a main source of lighting.

There is not much traffic near the factory during the summer time. However, the traffic is happening during the school time because of the nearest school beside the factory. The investigation occurred between 21st of November until 6th of December 2019.

There are different sectors in the factory, however, conducted field measurement of the research conducted in Sanding area where the most wood dust spread in the air and it is the most polluted area in the factory. Sanding area located in the left side of the factory and there is an open entrance to the main hall, where the big machineries for painting located.

Labors responsibilities in this section are sanding the natural wood by sandpaper or by machineries.

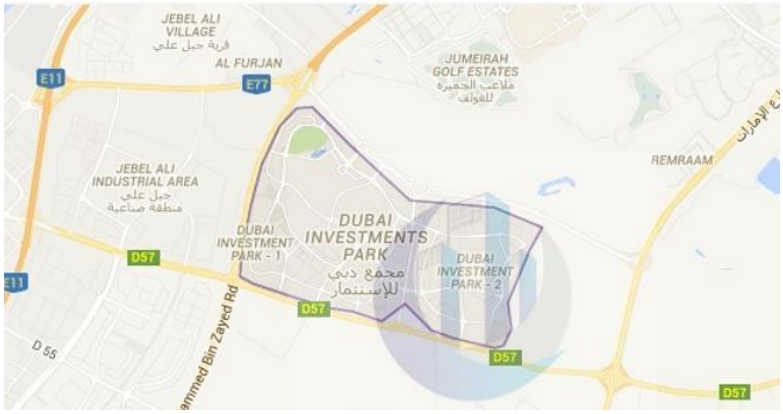


Figure 10: Joinery company location (Google map, 2020)

3-4 Limitation of the study:

There were several limitations in this study, which required to add as a concerning discussion. These limitations must be pointed out in order to illustrate the sections, which were not able to achieve a better result and elevate various procedures for future investigations for future researchers.

1. Seasonal research provide better result as the season change, the result is different. This research happened in wintertime (Nov-Dec) and it could be more effective result if it also conducted in summer time.
2. Photos were not allowed in this factory due to their personal reasons. They had done a lot of researches on the machineries in the factory, so photography was not allowed in the complex. . They spent so much time to study about buying these machines and taking photos show the machines.
3. Most of the joinery companies in Dubai are not willing to give a permission to do investigation in their factory because of their machineries and the systematic procedures they use for the production. However, two companies were interested to improve their indoor air quality, but due to the Coronavirus (Covid-19), the possibility of measuring indoor air particles and doing the survey was impossible in both factories. Thus, the investigation happened in one factory only.
4. Due to the Coronavirus (Covid-19) this study got limited and the research could only happen in one factory with limitations. Walking through observation happened during the March and April in 2020.
5. Most of the labors speak Hindi or Bangladeshi and explanation and communication, especially for questionnaire were a bit difficult because of language barrier.
6. The questionnaire was given to the workers twice. It translated to their language for a better understanding. A lot of them did not make the questionnaire serious and they did not reply well. Only few labors were honest with their replies. Second time was in Coronavirus (COVID-19) period and it was very difficult for the arrangement and collection of the result. Most of the questions were about the health of the workers

and their symptoms of the health issues. However, due to the current situation (Covid-19), the workers did not give the correct answers.

7. According to the person in charge for the architectural and mechanical drawing of the factory, these drawings were not completely available. By having the actual technical drawings, the assessment of this research and the comparison could be easier.
8. Based on the loads of the work, workers have different schedule of producing joinery products every day or every week and the wood materials may be vary. Thus, the result of the field investigation might be different based on the workloads and the wood types.

Chapter 4: Result and Discussion

4-1 Introduction

The discussion of this chapter includes indoor air quality analysis and collected data of gathering documents at joinery factory in Dubai. As iterate, the purpose of this research is to measure the indoor air quality in joinery factory as one of the main resources of fast growing business in UAE. This research is about mensuration of Carbon Monoxide (ppm), Carbon Dioxide (ppm), Ozone (ppm), TVOCs and Particulate size. The results of the stages during the menstruation show these air particles from the real places. Tables demonstrate the summery of minimum, maximum, average, 25 percentile, 75 percentile and standard deviation of all days. Data gets separated into two different categories of working days and off days. The average of each air particles compared with the day off and working days. All the gathered information followed the box plot chart to represent the 25 percentile, average, and 75 percentile of each air particles. The result of gathering information of tables happened in 7 hours of observation in sanding area of the factory. The survey questionnaire and discussion of results are also shown in this section. Survey outcomes and measurement of results on the site with the basic indicators and the general interpretation of the finding shown in discussion section. There is not much research about the indoor air quality in joinery factories. However, the available research studies with the similar topic subject support all the claims and exegesis of the current findings. Walkthrough investigation and interview with the safety manager is also part of this research. The final results and achieved data collection covered in this chapter.

4-1 Walkthrough investigation

The outcomes of the walkthrough observation and staff interviews were conducted in selected areas of the factory. The selected area of investigation and the effect of the indoor air quality have been explained. In the final result the critical components can be effective to reach the ideal result. The joinery and furniture industry is experiencing an extremely competitive era in UAE, because of the require demands. Thus they are struggling hard to find ways to decrease manufacturing costs and improving the quality of products. As an improvement strategy, joinery factories use a floor plan as one of their major optimization designs for dividing production sections. These sections consider the total area of the floor, which refers to the area occupied by the production line for every step of production. The floor plan also considers the flow multiple by distance, which is the sum of all the products flowing through a given system. And the distance between every station should follow the same. In this factory, all production parts are designed in a regular manner, considering the appropriate distance between the existing machines. The flooring finishes of this factory made of concrete for the loads of machineries and safety conditions. Walls and ceiling in the entire factory are painted white. There are different sections in the factory such as sanding area, paint shop, machine shop, storage, fit-out sections, assembling, packing section, laminate section, and etc. each section has around 100 workers. The types of machinery in each section are different from others for the specific work they required.

The wood factory layout takes into account the inherent safety of workers, in that dangerous processes or rules of the factory cannot be accessed without prior authorization. Fire alarm system and fire exist marked clearly in every section in the factory. There is no barrier in the emergency exists and the pathways designed clearly. The only issue of unclear pathways is in

the machine shops (Joiners shop), where the assemblies of the manufactured items take place due to loads of production works this place is full of manufactured items and laborers are not organized the items well.

The joinery factories should also consider the clarity of the material fellow by marking clear routes and create a good working environment with ventilated and well-lit rooms. In this factory lighting system is well designed and all the sections has a proper ceiling lighting. Having easy access to the coordination of activities and accessibility of types of machinery and other equipment for the maintenance work is also a major point of consideration. Natural ventilation through the opening (just a reiterate, there are big openings in the west and east side of the factory) happens in this factory in the ground floor and on the first floor, despite the large windows, air is transported through the entrance doors. And the windows never get open. In addition, there are couples of floor fans in each section. The weather condition in wintertime is ideal because of the opening and the low temperature of the air. However, in the summertime the indoor air is very hot. Based on the interview by the safety manager of this factory maintenance of the machines especially in the sanding areas where the dustiest place in the factory happen regularly. They have a contract with a maintenance company and they clean the duct collector machine. In addition, there is an air curtain at the hallway to enter the sanding section and there is another one at the entrance of sanding area. And all the sanding tables are connected to the main dust collector. Workers sweep their section regularly.

Based on the safety manager talks, laborers should wear the mask and eye protection while at work otherwise, they get fines and they get termination at the third time notice but based on the observation they barely used the mask and they do not use eye protection. Also, on their

break time, they mostly sleep in the floor of the factory. They barely go out of the factory in the yard area for fresh air.

Typical floor plan of joinery factories includes the raw stores for raw materials, the sanding room, the drying section, the operations or processing section, the strapping or packaging section, the finished goods storage sections, assembling section, painting section, laminate section, and the office section and etc.

The floor plan of a wood factory incorporates the entire wood factory activities sections summarized in Figure 1. Sanding area is located in between the i8 to M8 axes and i11 to m11 axes.

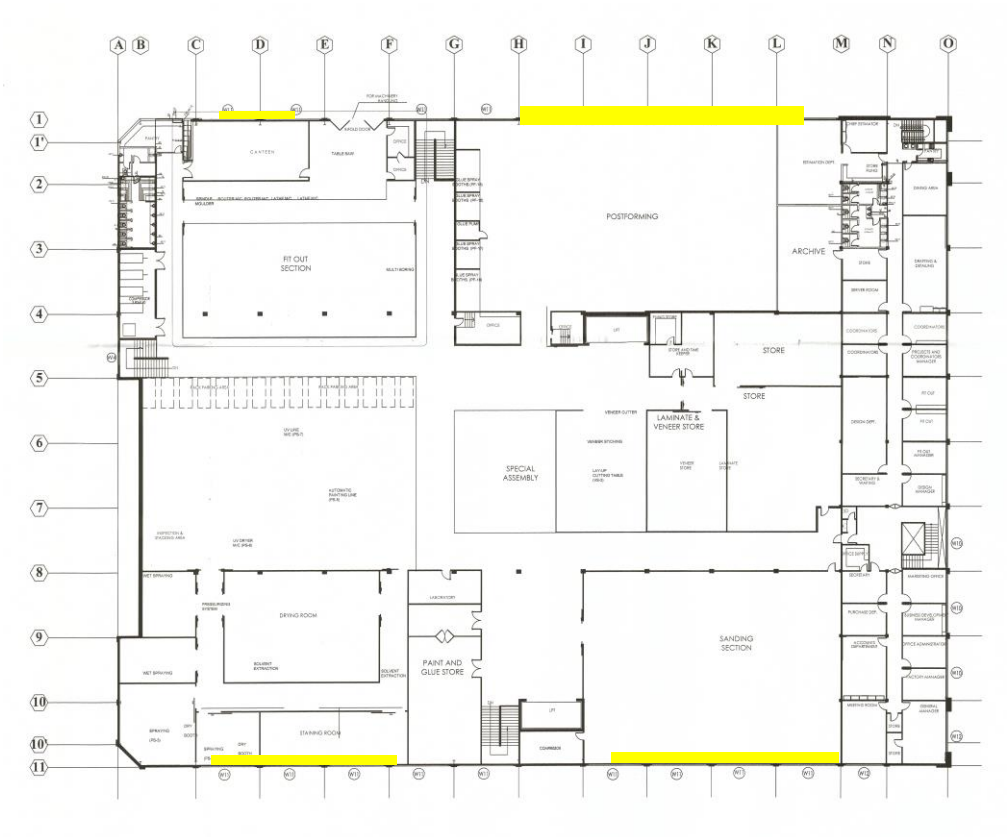


Figure 11: Floor plan of inspected joinery factory (Yellow highlights are natural opening)

4-2 Result Presentation/ Field measurement of Joinery Factory

Field measurement executed in sanding area of the factory. Operating different tools assist the research indoor parameters to interpretation of the outcomes. The collected data of indoor air contaminants include; CO_2 levels, CO levels, TVOCs level, Ozone levels and particulate size.

4-2-1 Carbon Dioxide:

The measurement was performed for nineteen consecutive days while five days were off. There are three Fridays and two national holidays. The off days are 22nd and 29th of November 2nd and 3rd of December and 6th of December. The evaluation happened between 9 am till 4 pm. The workers start their job at 8 am and finish at 4 pm. below table shows the measurements made from 19th of November till 7th of December 2020. Yellow highlights illustrated the off days.

CO2	9:00 AM	10:00 AM	11:00 AM	12:00 PM	1:00 PM	2:00 PM	3:00 PM	4:00 PM
19-11-19	587	623	756	972	2350	583	516	420
20-11-19	576	523	513	650	480	470	1147	2284
21-11-19	529	562	549	467	499	539	450	460
22-11-19	569	687	457	461	472	496	560	1264
23-11-19	596	500	425	437	504	469	475	515
24-11-19	505	501	555	475	549	555	575	535
25-11-19	501	485	478	507	545	465	465	485
26-11-19	475	508	495	531	525	522	487	484
27-11-19	543	507	575	531	552	526	488	501
28-11-19	520	490	490	484	495	475	485	465
29-11-19	437	488	471	480	518	470	473	494
1/12/2019	497	484	498	488	545	493	500	528
2/12/2019	504	412	436	446	450	440	445	442
3/12/2019	442	456	462	450	433	440	439	458
4/12/2019	542	570	527	532	589	576	570	609
5/12/2019	517	515	493	527	536	509	552	472
6/12/2019	-	574	494	506	528	544	486	481
7/12/2019	471	469	465	493	532	545	484	533

Table 13: Co_2 measurements in sanding area

Following the collective data the range of Co_2 emissions in working days is between 490 ppm to 850 ppm following table shows the measurements of working days except the first two

days, which is 19th and 20th of December, Co_2 concentrations are higher than other days. The reason of the high amount of emission explained below.

Table 14:CO_2 concentration of working days

CO2	9:00 AM	10:00 AM	11:00 AM	12:00 PM	1:00 PM	2:00 PM	3:00 PM	4:00 PM
19-11-19	587	623	756	972	2350	583	516	420
20-11-19	576	523	513	650	480	470	1147	2284
21-11-19	529	562	549	467	499	539	450	460
23-11-19	596	500	425	437	504	469	475	515
24-11-19	505	501	555	475	549	555	575	535
25-11-19	501	485	478	507	545	465	465	485
26-11-19	475	508	495	531	525	522	487	484
27-11-19	543	507	575	531	552	526	488	501
28-11-19	520	490	490	484	495	475	485	465
1/12/2019	497	484	498	488	545	493	500	528
4/12/2019	542	570	527	532	589	576	570	609
5/12/2019	517	515	493	527	536	509	552	472
7/12/2019	471	469	465	493	532	545	484	533

According to the table above, on 19 and 20 of November, fluctuating changes can be seen in the numbers obtained. Confirming to the manager of sanding department, on November 19, the workers were sanding the oak wood and the carbon monoxide emission was higher than other days and the maximum emission rate was seen at 1:00 pm by 2350 ppm. In addition, on 20th of November the emission of CO^2 increased from 2:00 pm onwards and the reason of increased number are MDFs sanding at that time. Based on the previous studies of Co^2 emission and distribution of Co^2 concentration during the machining process, MDFs has the highest CO^2 emission than softwood and hardwood. And between hardwoods oak wood causes more Co^2 emission than other types of wood. The emission of Co^2 in oak is about 30 percentages less than MDFs (British Occupational Hygiene Society, 2000). Thus, the high number of CO^2 emission and the pick number on 19th and 20th of December are related to high amount of Co^2 emission cause oak wood and MDFs board.

In addition, the average numbers obtained on off days are between 400 ppm to 500 ppm while the average of gathered information in working days is between 490 ppm to 850 ppm (Table 14). During the five off days, the only oscillation seen is related to 29th of November at 4 pm. The reason for this rise fluctuation is due to pest control and cleaning at this time in the sanding area.

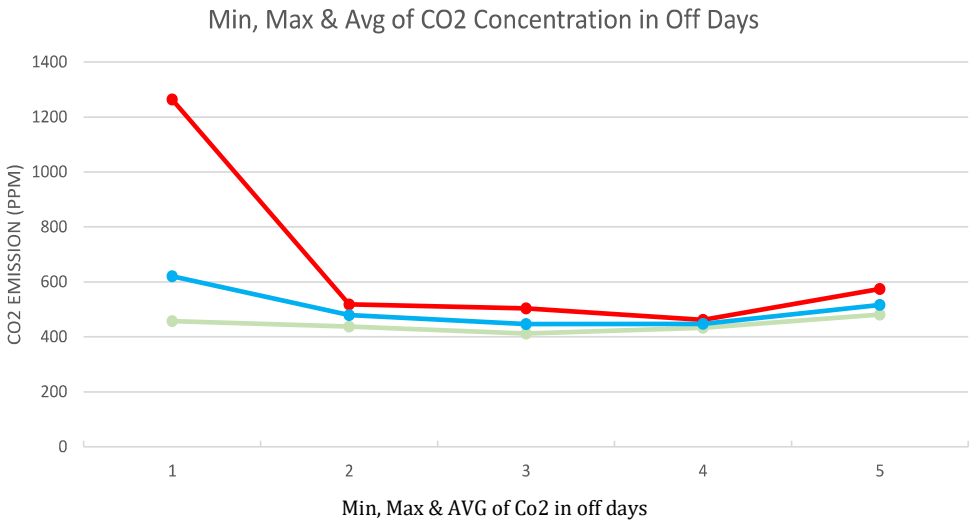


Figure 12:Min, Max and Average of Co_2 Concentration in off days

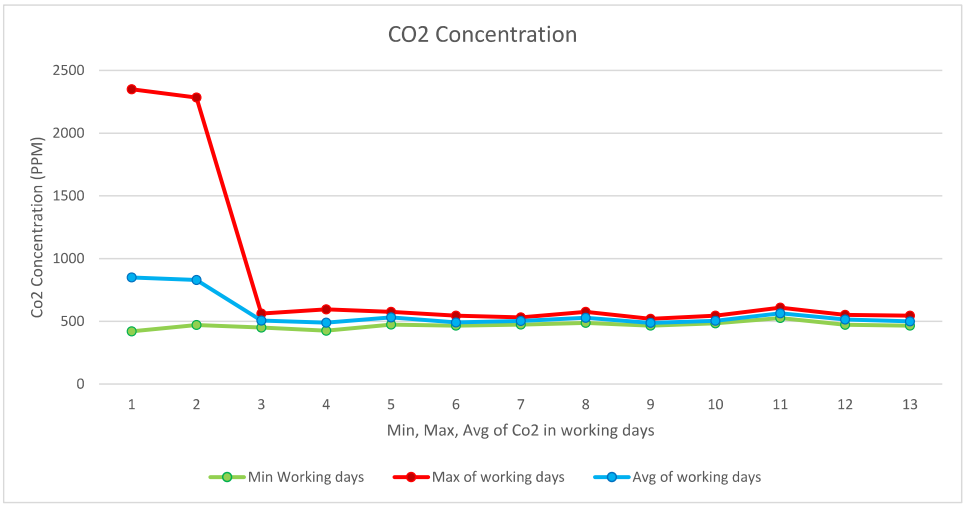


Figure 13: Min, Max and average of Co_2 Concentration in working days

Table 15 represents the minimum, maximum and average, 25 and 75 percentile and standard deviation of CO_2 emission in all days. Minimum of CO_2 emissions in most of the days are around 420 ppm and the maximum of CO_2 emissions are around 600 ppm. The average of CO_2 emissions in working and off days is almost the same. 25 percentile shows that 25 percentages of numbers is below the mentioned number and 75 percentile represents that 75 percentages of the collected numbers are below the shown number in the table. According to the numbers obtained from standard deviation we notice the scatter of numbers relative to the average number of that day.

Table 15: Min, Max, AVG, 25 and 75 percentile, and standard deviation of CO_2 emissions

CO2	Min	Max	Average	25 percentile	75 percentile	Standard deviation
19-11-19	420	2350	850.88	566.25	810	628.17
20-11-19	470	2284	830.38	504.75	774.25	627.73
21-11-19	450	562	506.88	465.25	541.5	43.78
22-11-19	457	1264	620.75	469.25	598.5	271.12
23-11-19	425	596	490.13	461	506.75	53.26
24-11-19	475	575	531.25	504	555	34.10
25-11-19	465	545	491.38	474.75	502.5	26.36
26-11-19	475	531	503.38	486.25	522.75	21.10
27-11-19	488	575	527.88	505.5	545.25	28.77
28-11-19	465	520	488	481.75	491.25	16.05
29-11-19	437	518	478.88	470.75	489.5	23.22
1/12/2019	484	545	504.13	491.75	507	21.16
2/12/2019	412	504	446.88	439	447	25.86
3/12/2019	433	462	447.5	439.75	456.5	10.47
4/12/2019	527	609	564.38	539.5	579.25	28.64
5/12/2019	472	552	515.13	505	529.25	24.86
6/12/2019	481	574	516.14	490	536	34.16
7/12/2019	465	545	499	470.5	532.25	32.65

To get the proportion of carbon monoxide released on working days and off days, the calculation of average total number of off days off and working days are essential. Following tables shows the minimum, maximum and average of the working days and off days. To get the base number of the total measured days, the average of the total average of the off days is

necessary. Blue highlight shows the total average of working days. And yellow highlight illustrates the total average of the off days, which counts as the base number of the total measures days.

Table 16: The total average of working days (Blue highlight) and off days (Yellow highlight)

Min	Max	Avg
420	2350	850.88
470	2284	830.38
450	562	506.88
425	596	490.13
475	575	531.25
465	545	491.38
475	531	503.38
488	575	527.88
465	520	488.00
484	545	504.13
527	609	564.38
472	552	515.13
465	545	499.00
		561.75

Min	Max	Avg
457	1264	620.75
437	518	478.88
504	504	446.88
433	462	447.5
481	574	516.14
		502.03

According to the collective data, the average of CO_2 emission in working days and off days is almost the same. In off days the average of CO_2 emission is 502.03 ppm and the average of CO_2 in working days is 561.75 ppm. Below following table displays the ratio of working days and off days, which stands at 1.12 ppm.

AVG CO2 Working Days	561.75	**Working/ Off**
AVG CO2 Off Days	502.03	**1.12**

Table 17: The comparison ratio of Co_2 Concentration in working days with off days

Chart 14 illustrates the comparison of Co_2 emissions in working days and off days. Based on the below chart, the average of most of the days is at the same emission distance spread which, clearly shows in the proportion difference between the working days and off days.

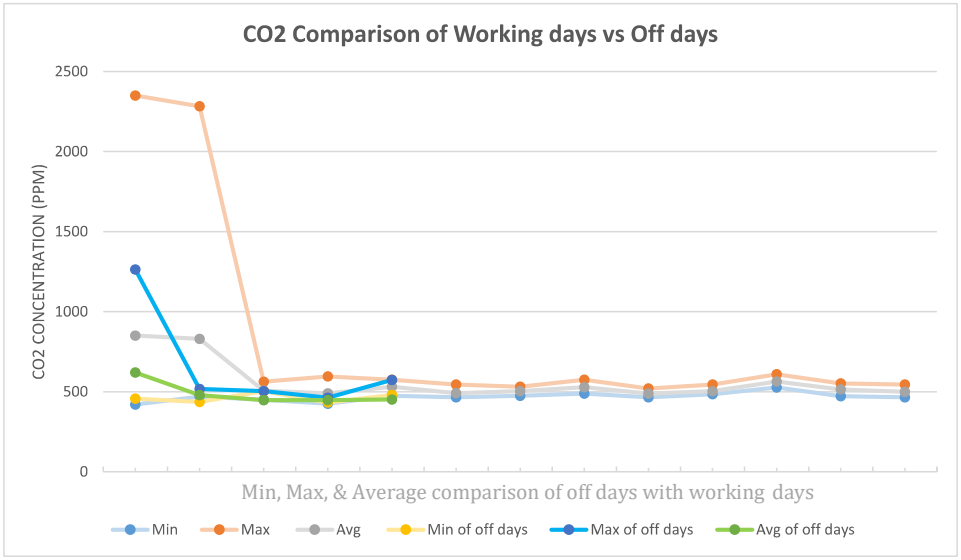


Figure 14:Co_2 comparison between working days and off days

For the better clear understandable picture of the collective data from the table 15 statistic chart can play a vital role to summarize the gathered data. In statistic chart with the help of whisker and box, the spread of main numbers shown in limited area, which include the mean point, minimum and maximum and all the distribution range remain in the box area. In the below chart, the minimum Co_2 emission is 420 ppm, which is the same amount as the table 15. The maximum emission rate in minimum series is 527 ppm, which is related to 4th of December at 9 am. In addition, the mean, 25 percentile and 75 percentile of minimum series stand at 461 ppm, 440 ppm and 475 ppm respectively. In the maximum series, the minimum Co_2 emission rate is 462 ppm, which is related to the 3rd of December (non-working date), the maximum and mean rates are 2350 ppm and 783 ppm respectively. 25 percentile stands at 534 ppm and 75 percentile

is 590 ppm. In average series the minimum and maximum rates are 446 ppm and 850-ppm orderly, which the minimum rate related to off days and the maximum rate related to working days. In 25 percentile series the minimum rate is 439 ppm that is in 2nd of December (off date) and the maximum rate is 566 ppm (working day). 25 percentile of the Co_2 emissions are less than 468 ppm and 75 percentile of the numbers are below 504 ppm. In 75-percentile whisker box series, the minimum number stands at 447 ppm and the maximum emission rate is related to 19th of December by 810 ppm. 75 percentile of the range numbers are above 503 ppm and 25 percentile of the range numbers are below 552 ppm. The difference between the statistic charts below is outliers. The role of outliers in statistic chart is to include the upper and below spread of numbers in whisker box. Outliers located in the first chart to show the range of Co_2 emissions in the measured dates (Chart 15). The second chart included the whole average of closed spread numbers in measured dates.

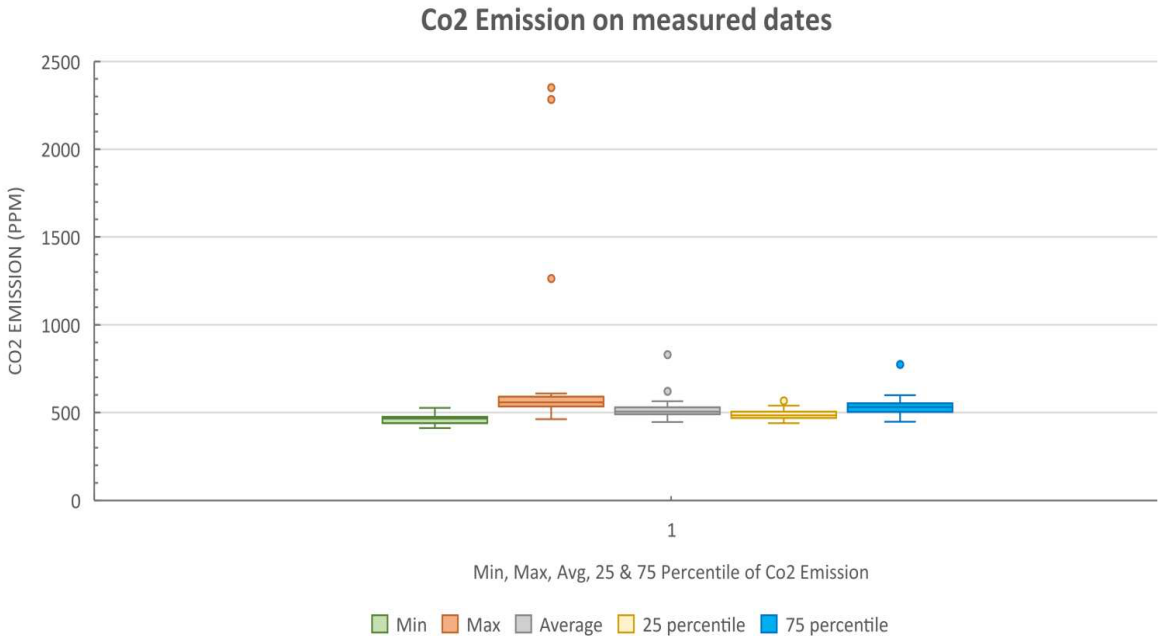


Figure 15: Collect all Co_2 Emission of the lowest, highest and average numbers of measured days (including outliers)

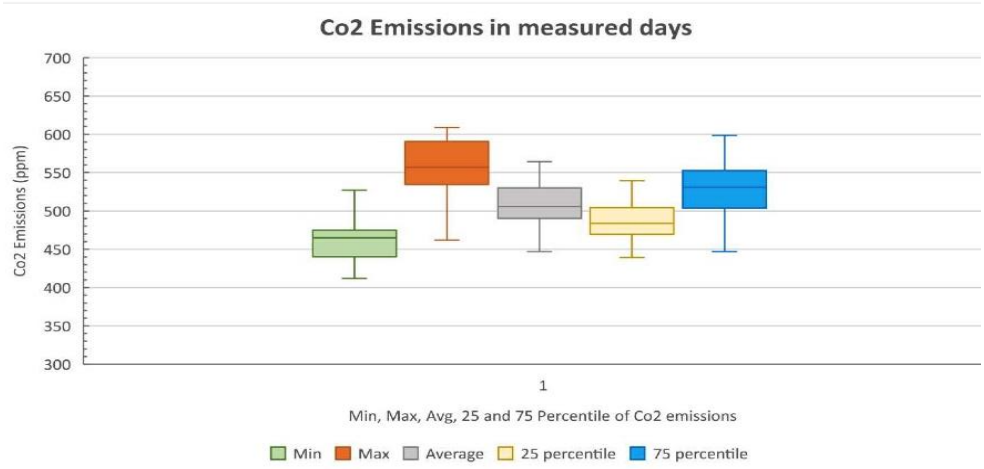


Figure 16: Collect all Co_2 Emission of the lowest, highest and average numbers of measured days (excluding outliers)

According to the tables and charts mentioned above and the information obtained, the comparison of minimum, maximum and average of the total off days and working days showed below. Based on the following chart, the minimum of working days and off days does not very different. The minimum of off days stands at 412 ppm and the minimum of working days is 420 ppm. The major difference between the working days and off days is expansion of Co_2 emission in maximum rate. The average of the off days is 502 ppm while the average of working days is 561 ppm. The notable rise happened in the maximum of working days by 2350 ppm and the maximum of off days is 1264 ppm.

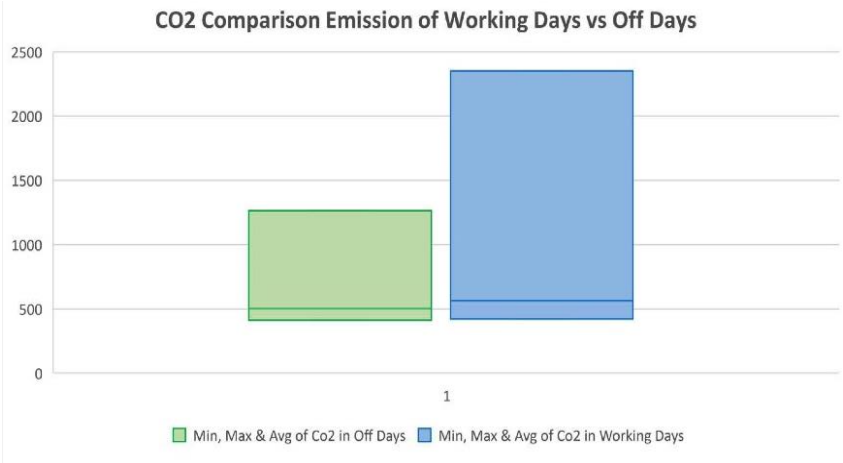


Figure 17:Min, Max & Avg of Co_2 comparison between working days and off days

Following statistic chart included the minimum, maximum, average and 25 percentile and 75 percentile of C_{o2} emission in working days and off days. Based on the below chart, 25 percentile of Co^2 emission in working days is above 490 ppm and 75 percentile of C_{o2} emission is below 1455 ppm. The C_{o2} spread has declined in off days. 25 percentile of $_{Co2}$ emission is above 457 ppm and 75 percentile of $_{Co2}$ emission is below 692 ppm.

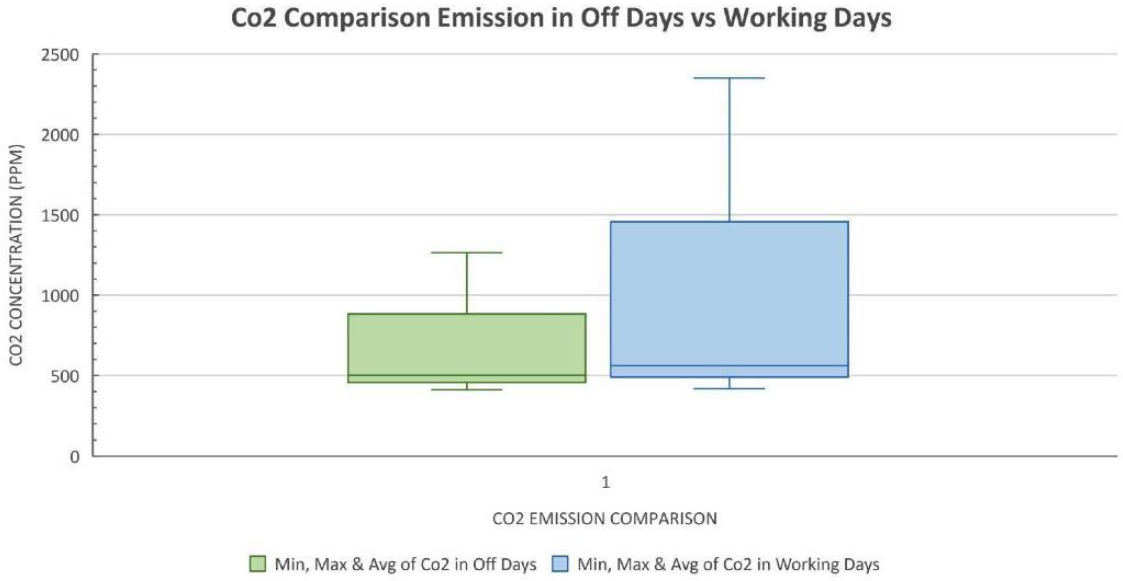


Figure 18:Min, Max, Avg, 25 & 75 percentile of Co_2 comparison between working days and off days

Co_2 emission in the first two days of measurement was at its pick. In 19th of November the pick emission rate stands at 2350 ppm. Meanwhile, carbon emissions have been steadily rising since the morning. The emission rate was 972 ppm at 9:00 am and at 1:00 pm the emission rate stands at 2350 ppm. In second date the emission rate was almost stable till 2:00 pm and at 3:00 pm, it rise to 1147 ppm. And it steadily increase to 2284 pm at 4:0 pm. From the third date, 21st of November onwards, Co_2 concentration was almost the same with a little bit different

between the working days and off days. It is obviously shows the emission rates difference between the blue line, which is the 21st of November and the first two dates.

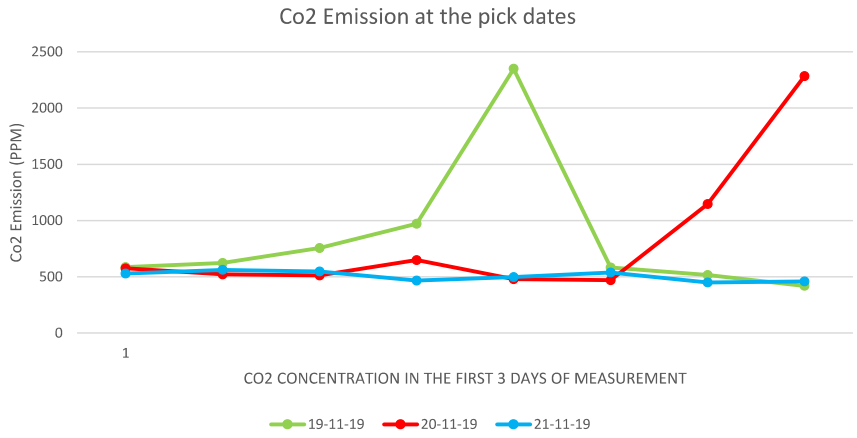


Figure 19: Comparing Peak time of Co_2 emission in the first two days with the third day

The task of the standard deviation is to represent the scatter of the numbers of a group from the mean that obtained from those numbers. Standard deviation divided into two categories; low and high rates. If the difference obtained from the standard deviation and the average number is less than one, it indicates a low standard deviation. And if it stands more than one, it demonstrates high standard deviation. Following table shows the spread out the numbers from the average of the measured dates are less than one. Thus, the propagation of numbers falls into the low standard deviation category.

Table 18: The ratio of standard deviation to the mean number

Standard deviation	Ratio of St/AVG
628.17	0.74
627.73	0.76
43.78	0.09
271.12	0.44
53.26	0.11
34.10	0.06
26.36	0.05
21.10	0.04
28.77	0.05
16.05	0.03
23.22	0.05
21.16	0.04
25.86	0.06
10.47	0.02
28.64	0.05
24.86	0.05
34.16	0.07
32.65	0.07

Another way to compare carbon monoxide emissions on weekdays and holidays is to find the majority of the Co_2 emission range, which can found within 10 to 90 percentile. The average emission rate of Co^2 in working days is 561.75 ppm while 10% of the numbers are below 490.38 ppm and 90% of them are above 490 ppm. Meanwhile, the average emission rate of off days stands at 502 ppm and only 10% of numbers are above 578 ppm and 90% of the range are below 578 ppm. Thus the range of the Co^2 emission in working days is mostly between 490 ppm to 777 ppm. And in off days, the range of the emission rates is between 447 ppm and 578 ppm.

Table 19:Co_2 comparison range rate in working days with off days

	Co2 Working days	Co2 Off days
90 Percentile	777.18	578.91
AVG	561.75	502.03
10 Percentile	490.38	447.13

According to the above table, the statistic chart declares the obtained range of Co_2 emission comparison in working days and off days by consideration of 10 and 90 percentile.

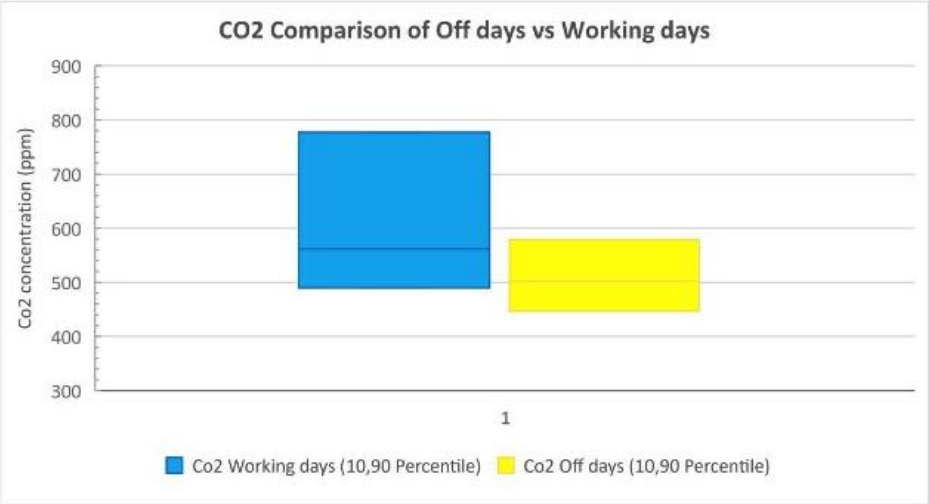


Figure 20:Co_2 comparison between off days and working days

By consideration of base case result, the ratio of every hour is shown in following table. According to the scales obtained in the table below most of the ratio rates are more than 1%, which means the ratio of most days are above base case result. The ratio in off days is between 0.84 percentages to 1.40 percentage. The ratio below 1 percentage shows the emission rate was below the base case result, which is the ideal numbers. The highest ratio is related to 19th of December at 1 pm, which is 4.80 percentage and it is because of oak wood sanding and types of machinery, as oak wood is categorized in hardwood and hardwoods produce more airborne than softwoods in the airborne. Also, sanding papers create a lot of wood dust on air.

Table 20: Ratio measurement according to the base case result of Co_2 emission

TVOCs	9:00 AM	10:00 AM	11:00 AM	12:00 PM	1:00 PM	2:00 PM	3:00 PM	4:00 PM
19-11-19	10585	11225	13548	15266	15882	14373	9907	2045
20-11-19	2086	3560	4067	5820	4550	6055	11805	1351
21-11-19	4833	1362	1740	2162	3740	7995	2670	2570
22-11-19	890	1666	3063	5284	5858	5090	3694	2085
23-11-19	2425	3832	4990	6622	11879	2858	2014	4919
24-11-19	9241	6188	7040	4010	4099	7650	8366	8030
25-11-19	7175	5776	5399	9067	16201	3166	2080	4099
26-11-19	9124	5473	4179	13404	4620	6188	5468	1046
27-11-19	4166	4778	5121	4890	4985	5780	6767	8756
28-11-19	7057	2908	3266	3263	3059	2711	2571	2174
29-11-19	1671	1219	1043	2711	3777	3854	5388	6192
1/12/2019	5700	6273	16203	10225	7084	16200	16195	16195
2/12/2019	3632	3196	3639	3572	7306	4712	5641	4769
3/12/2019	1402	1620	1634	2016	3567	4675	6198	6256
4/12/2019	7229	8290	10368	16167	16197	9654	8949	16199
5/12/2019	6666	4681	9052	9400	10325	5013	5041	7011
6/12/2019	3568	3786	4567	5987	6693	6628	4530	3073
7/12/2019	2263	2503	3180	9872	16895	20570	27701	12592

4-2-2 Total Volatile Organic Compound (TVOCs)

TVOCs measurement occurred the same days as the Co2. It started from 19th of November until 7th of December. The total days of measurements was nineteen days. The total

off days during the measurements was five days and 14 working days. Labors started their job at 8 morning time till 4:30 pm. Investigation happened between 9 am till 4 pm. According to the gathered data of TVOCs all the numbers are extremely high and there seems that there was a problem with calibration of the tool. Below table illustrates the statement.

Table 21: TVOCs measurements in sanding area

Date	Base	9:00 AM	10:00 AM	11:00 AM	12:00 PM	1:00 PM	2:00 PM	3:00 PM	4:00 PM
19-11-19	489.13	1.20	1.27	1.55	1.99	4.80	1.19	1.05	0.86
20-11-19		1.18	1.07	1.05	1.33	0.98	0.98	2.34	4.67
21-11-19		1.08	1.15	1.12	0.95	1.02	1.02	0.92	0.94
22-11-19		1.16	1.40	0.93	0.94	0.96	0.96	1.14	1.05
23-11-19		1.22	1.02	0.87	0.89	1.03	1.03	0.97	1.05
24-11-19		1.03	1.02	1.13	0.97	1.12	1.12	1.18	1.09
25-11-19		1.02	0.99	0.98	1.04	1.11	1.11	0.95	0.99
26-11-19		0.97	1.04	1.01	1.09	1.07	1.11	1.00	0.99
27-11-19		1.11	1.04	1.18	1.09	1.13	1.13	1.00	1.02
28-11-19		1.06	1.00	1.00	0.99	1.01	1.01	0.99	0.95
29-11-19		0.89	1.00	0.96	0.98	1.06	1.06	0.97	1.01
1/12/2019		1.02	0.99	1.02	1.00	1.11	1.11	1.02	1.08
2/12/2019		1.03	0.84	0.89	0.91	0.92	0.92	0.91	0.90
3/12/2019		0.90	0.93	0.94	0.92	0.89	0.89	0.90	0.94
4/12/2019		1.11	1.17	1.08	1.09	1.20	1.20	1.17	1.25
5/12/2019		1.06	1.06	1.01	1.08	1.10	1.10	1.13	0.96
6/12/2019		-	1.17	1.01	1.03	1.08	1.08	0.99	0.98
7/12/2019		0.96	0.96	1.01	1.01	1.09	1.09	0.99	1.09

4-2-3 Ozone:

Operation of wood furniture creates air pollution in indoor air. Wood dust is the main reason of rising Ozone emission in the air. In the joinery companies most of the areas like sanding, routing, sawing and etc. are creating wood dust and they become airborne. The high amounts of wood dust affect the respiratory body system. And it becomes a long-term health problem. There are three major health issues people face with wood dust; coughing, irritation and sneezing (Canadian Centre for occupational health and safety, 2017). However, wood dust emission depends on the type of woods. In some types of wood the spread of wood dust in

airborne is higher. Below table illustrate the high-risk potency of wood emission in the air and the body reaction to the wood dust (Meier, 2007).

Table 22: High risk wood emission from different wood species and their reactions

(Meier, 2007)

Wood type	Health cause
Ebony	Irritant, sensitizer, pink eye
Mahogany, African	Irritant, sensitizer, NPC (rare)
Olive	Irritant, sensitizer
Teak	Irritant, sensitizer, rash, nausea, asthma, vision effects
Walnut, African	Irritant, systemic effects, NPC (rare)

Ozone measurement was performed the same dates as other air emissions. The measurement conducted within nineteen days from 19th of November till 7th of December. Based on the below table yellow highlights demonstrated off days. Workers start at 8:00 am and the measurement happened at the same time. However, the gathered information was written from 9:00 am onwards. The factory timing for labors is from 8 am till 4 pm.

Table 23:Ozone measurements in sanding area

OZONE	9:00 AM	10:00 AM	11:00 AM	12:00 PM	1:00 PM	2:00 PM	3:00 PM	4:00 PM
11/19/2019	0.01	0.01	0.00	0.00	0.02	0.01	0.02	0.01
20-11-19	0	0.00	0.02	0.02	0.02	0.02	0.02	0.02
21-11-19	0.01	0.01	0.00	0.01	0.00	0.01	0.01	0.01
22-11-19	0	0.01	0.01	0.00	0.00	0.00	0.00	0.01
23-11-19	0.02	0.05	0.06	0.06	0.06	0.07	0.06	0.07
24-11-19	0.02	0.01	0.00	0.01	0.02	0.02	0.03	0.04
25-11-19	0.03	0.04	0.04	0.04	0.04	0.04	0.04	0.04
26-11-19	0	0.05	0.04	0.04	0.04	0.05	0.03	0.04
27-11-19	0.03	0.20	0.20	0.02	0.40	0.04	0.04	0.05
28-11-19	0.04	0.06	0.05	0.06	0.06	0.07	0.07	0.07
29-11-19	0.01	0.01	0.01	0.00	0.01	0.02	0.02	0.01
1/12/2019	0.02	0.04	0.04	0.05	0.06	0.05	0.06	0.05
2/12/2019	0.01	0.02	0.02	0.02	0.02	0.02	0.02	0.01
3/12/2019	0.01	0.01	0.01	0.02	0.02	0.02	0.02	0.01
4/12/2019	0.07	0.04	0.04	0.04	0.05	0.05	0.05	0.05
5/12/2019	0.04	0.04	0.05	0.05	0.05	0.06	0.05	0.06
6/12/2019	0	0.00	0.01	0.01	0.02	0.01	0.01	0.01
7/12/2019	0.05	0.04	0.04	0.04	0.05	0.05	0.05	0.05

Following the gathered information the average of Ozone concentration in working days is about 0.04 ppm. However, the fluctuation in gathered data is clearly showed. Ozone concentration in 23rd of November 27th and 28th of November 1st of December 4th and 5th of December has higher rates than other days. Following table presents the high amount of ozone concentration in mentioned dates.

Table 24: Ozone Concentration emission in pick dates

OZONE	9:00 AM	10:00 AM	11:00 AM	12:00 PM	1:00 PM	2:00 PM	3:00 PM	4:00 PM
23-11-19	0.02	0.05	0.06	0.06	0.06	0.07	0.06	0.07
27-11-19	0.03	0.20	0.20	0.02	0.40	0.04	0.04	0.05
28-11-19	0.04	0.06	0.05	0.06	0.06	0.07	0.07	0.07
1/12/2019	0.02	0.04	0.04	0.05	0.06	0.05	0.06	0.05
4/12/2019	0.07	0.04	0.04	0.04	0.05	0.05	0.05	0.05
5/12/2019	0.04	0.04	0.05	0.05	0.05	0.06	0.05	0.06

According to the above table, ozone concentration is slightly higher than other days and it related to the amount of wood dust creation and types of machinery in those dates. Earlier, we talk about the factors that increase the concentration of ozone in air. Wood dust is one of the major factors of increasing particles in the air and it is back to the origin of wood type and types of sanding machineries. Based on the factory manager conversation, the choice of wood types is selected by client.

Table 22 illustrates the most common types of wood this factory used. And they are considered as a high cause of wood dust. Duration of joinery items manufacturing is related to the workload and a project size. Each project has its own inquiry and it has a different manufacturer duration time. As stated by the sanding area manager, on 23rd of November, they had a small job and the request wood was Ebony. It took only a day for sanding. In addition, from 27th of November till 5th of December, workers were sanding the Mahogany and Walnut wood for another project. Thus, the high amounts of ozone concentration emission are related to

the high creation of wood dust in those dates. Below chart compare the amount of ozone concentration on the mentioned dates.

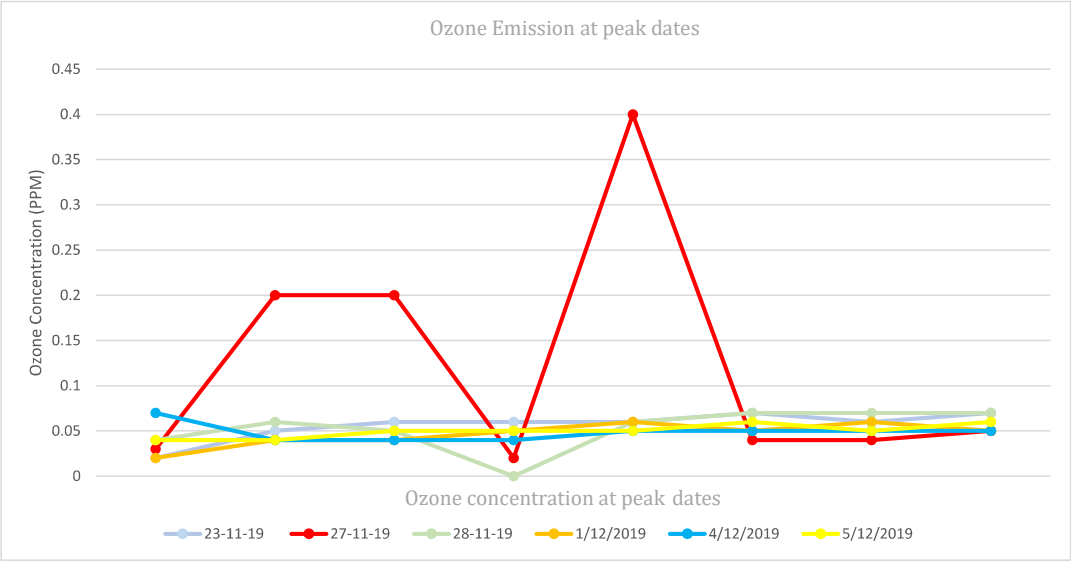


Figure 21: Comparison of ozone emissions on measured days that show the highest amount of ozone concentrations

Above chart represents the highest amount of ozone concentration is related to 27th of November. When the workers has to sand the walnut woods within two days before the National days holiday to prepare considerable numbers of sanded woods to proceed for production line. The workload in the first day of this production was high. Thus, it affects the significant rise in emission of ozone in sanding area.

Before we go more into the details of ozone concentration on working days and off days and the comparison of the emission rate in this two categorized, we take a look at the table of minimum, maximum and average of working days and off days. The most significant part of obtaining the ratio of ozone emission rate is related to the computation of the total average

number of off days and working days. Below table represents the minimum, maximum and average of ozone concentration in working days and off days.

The base emission rate of ozone in measured days achieved from the total average of off days. Blue highlight shows the total average of ozone emission in working days and yellow highlight represents the total average of ozone emission in off days.

Table 25: The total average of ozone emission in working days (Blue highlight) and off day (Yellow highlight)

MIN	MAX	AVERAGE
0.00	0.02	0.01
0.00	0.02	0.01
0.00	0.01	0.01
0.02	0.07	0.05
0.00	0.04	0.02
0.03	0.04	0.04
0.00	0.05	0.03
0.02	0.40	0.14
0.04	0.07	0.06
0.02	0.06	0.05
0.04	0.07	0.05
0.04	0.06	0.05
0.04	0.05	0.05
		0.04

MIN	MAX	AVERAGE	
0.00	0.01	0.00	
0.00	0.02	0.01	
0.01	0.02	0.02	
0.01	0.02	0.02	
0.00	0.02	0.01	
		0.01	BASE OF THE TOTAL /

Based on the gathered measurement, the average of ozone emission in off days is a quarter of working days. The emission rate of ozone in off days is 0.01 ppm and in working days is 0.04 ppm. Below table displays the proportion of ozone emission and its comparison on off days and working days.

Table 26:The ratio of ozone Concentration in working days and off days

AVG OF OFF DAYS	0.01	OFF DAYS/WORKING DAYS
AVG OF WORKING	0.04	**0.25**

Following chart represents the minimum, maximum and average of ozone emission in working days. The average rate of ozone emission in working days is 0.04 ppm. The minimum rate of ozone emission in zero and the highest emission rate is 0.4 ppm. This number is related to 27th of November.

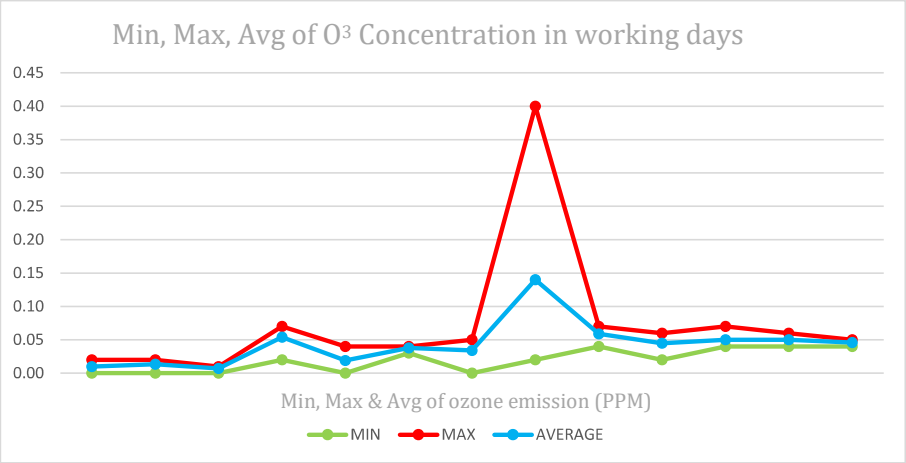


Figure 22:Min, Max, Average of ozone emission in working days

In off days, the difference between minimum ozone emission and maximum rate is not enormous. The emission rate from minimum to maximum range is from zero to .02 ppm. And the maximum rate concentration is almost stable in all days. Below chart supports the claims.

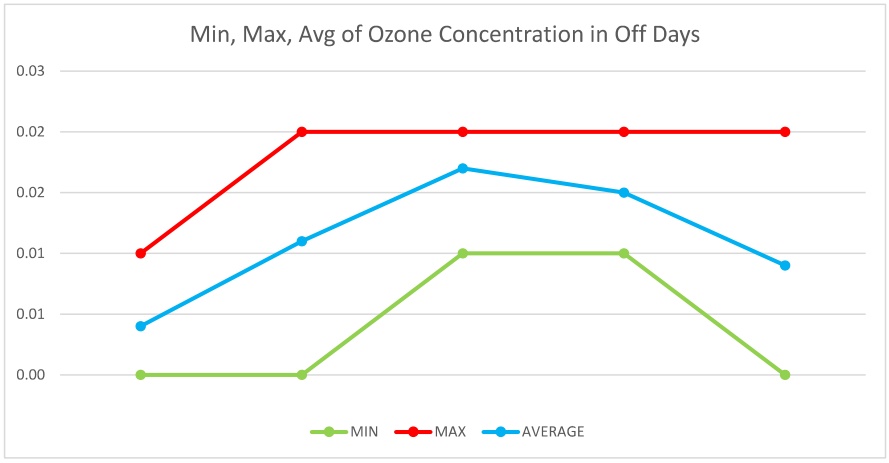


Figure 23:Min, Max, Average of ozone emission in off days

According to the above minimum, maximum and average of ozone emission in working and off days charts and better understanding of ozone emission in working days and off days, below chart represents the comparison of ozone concentration in working days and off days. According to the below chart, the maximum emission rate is 0.4 ppm and the maximum average of emission rate in working days is around 0.15 ppm. The ozone emission rate in all off days is almost the same.

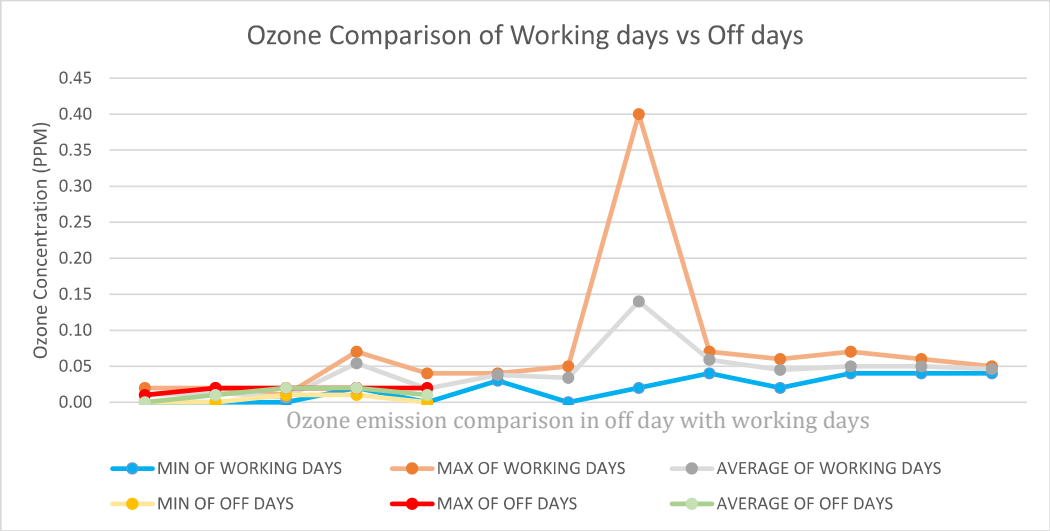


Figure 24:Ozone comparison emission in working days and off days

According to all the obtained gathered data above, the comparison of ozone emission in working and off days shows in the statistic chart below. Statistical chart provide a better understanding and clarification of the information obtained. Based on the following chart the difference in emission rate of ozone in working days and off days is clearly obvious. The minimum of ozone emission rate in both categories is 0.00 ppm. However, the maximum rate of emission rate made a huge difference in the column. Maximum rate of emission rate in off days is below 0.05 ppm and based on the OSHA, this rate is acceptable in working space (OSHA,

2019). The substantial ascension of ozone concentration occurred in the 27th of November by 0.4 ppm and the maximum of ozone concentration in off days is 0.02 ppm. Below table represents the comparison of ozone emission in off days and working days.

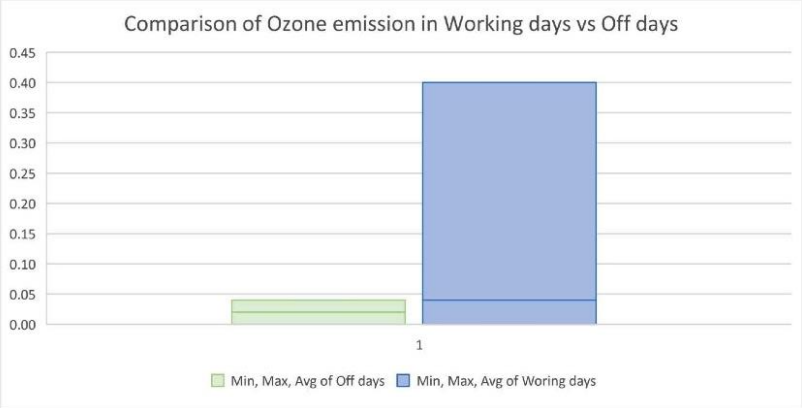


Figure 25:Comparison of ozone emission in working days and off days

Below statistic chart demonstrates the comparison of ozone emission in working and off days considering the 25 and 75 percentile of the gathered data in this two categories. As it shows in the table, 25 percentile of ozone emission rate in off days are above 0.009 ppm and the mean line stand at 0.01 ppm and 75 percentile of the numbers are below 0.015 ppm. In contrast, there is an emission rise in working days. 25 percentile of emission rate is above 0.02 ppm and 75 percentile of the numbers are below 0.05 ppm.

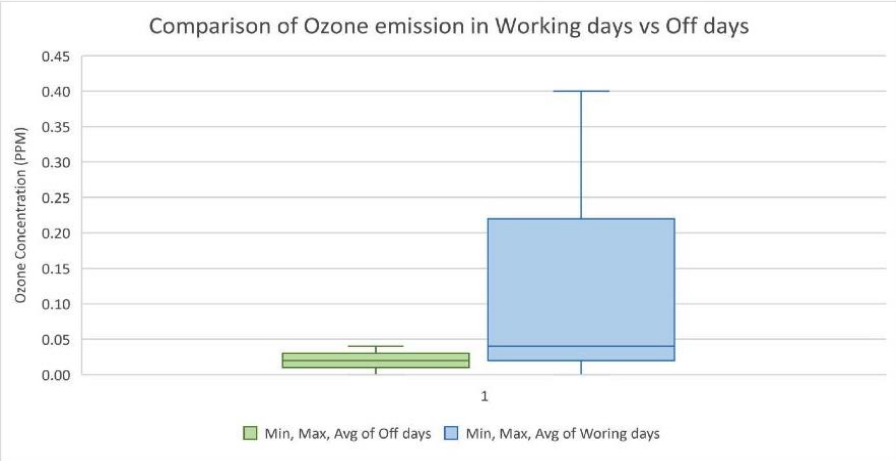


Figure 26:Statistic chart comparison of ozone emission in working days and off days

Following table demonstrates the minimum, maximum, average, 25 and 75 percentile, and standard deviation of collective data in all measured days. Based on the recorded information, minimum ozone emission in most of the days is zero, and in one day the emission rates are higher than the acceptable rates of ozone emission in working place, which is 27th of December by 0.4 ppm. According to the OSHA, the Occupational Safety and Health Administration, the average of ozone concentration in working place should not exceed more than 0.10 ppm in 8 hours working time (OSHA, 2019). 25 percentile in each day represent the 25% of the gathered numbers are above the recorded. And 75 percentile shows that 75% of numbers are below the record number on the table. In addition, with the help of standard deviation, we can obtain the distribution of emission rate based on the average number. Distribution of emission rate based on the standard deviation explained in the next page.

Table 27:Min, max, Average, 25 and 75 Percentile and Standard deviation of ozone emission in sanding area

OZONE	MIN	MAX	AVERAGE	25 PERCENTILE	75 PERCENTILE	Standard deviation
11/19/2019	0.00	0.02	0.01	0.01	0.02	0.01
20-11-19	0.00	0.02	0.01	0.02	0.02	0.01
21-11-19	0.00	0.01	0.01	0.01	0.01	0.00
22-11-19	0.00	0.01	0.00	0.00	0.01	0.01
23-11-19	0.02	0.07	0.05	0.06	0.06	0.02
24-11-19	0.00	0.04	0.02	0.01	0.03	0.01
25-11-19	0.03	0.04	0.04	0.04	0.04	0.00
26-11-19	0.00	0.05	0.03	0.04	0.05	0.02
27-11-19	0.02	0.40	0.14	0.04	0.20	0.13
28-11-19	0.04	0.07	0.06	0.06	0.07	0.01
29-11-19	0.00	0.02	0.01	0.01	0.01	0.01
1/12/2019	0.02	0.06	0.05	0.05	0.06	0.01
2/12/2019	0.01	0.02	0.02	0.02	0.02	0.00
3/12/2019	0.01	0.02	0.02	0.01	0.02	0.01
4/12/2019	0.04	0.07	0.05	0.04	0.05	0.01
5/12/2019	0.04	0.06	0.05	0.05	0.05	0.01
6/12/2019	0.00	0.02	0.01	0.01	0.01	0.01
7/12/2019	0.04	0.05	0.05	0.04	0.05	0.01

Standard deviation shows the spread of gathered numbers in every hour from the total obtained average number of that day. Following table represents standard deviation and the spread of numbers from the mean base. Gathered numbers in five days categorized in high rate. It means standard aviation in these days is higher than one. On the other hand, the emission rate in these dates is very fluctuating. The dates of these days include respectively 23rd, 24th, 26th and 27th of November, and 1st of December. Among all the gathered data, the highest amount of emission rate is related to 27th of November when the workload was too high in the sanding area and the maximum rate of ozone concentration is 0.4 ppm. This date has the highest rate of ozone concentration between all the measured days. Furthermore, standard deviation in off days categorize in low rate. Below table shows the standard deviation of ozone concentration on the measured dates and it represents the different distances of the numbers spread out on the measured days.

Table 28:Standard deviation of ozone concentration and the ratio of standard deviation to the mean number on the measured days

Standard deviation	Ratio of St/AVG
0.01	0.67
0.01	0.83
0.00	0.41
0.01	0.48
0.02	1.43
0.01	1.11
0.00	0.32
0.02	1.43
0.13	12.02
0.01	0.95
0.01	0.57
0.01	1.16
0.00	0.41
0.01	0.48
0.01	0.88
0.01	0.67
0.01	0.57
0.01	0.46

To have easier interpreted of collective data, statistical chart with a wide range of percentile can represent a clear pictorial presentation. Statistical chart with 10 to 90 percentile has this ability to clearly display data. As the below display table, the average of ozone emission rate in working days is 0.04 ppm and 10 percentage of the emission rate is above 0.01 ppm while 90 percentage of ozone emission is below 0.06 ppm. In contrast to this the average of ozone emission rate in off days is 0.01 ppm, which is almost one fourth of working days rate. And 10 percentage of gathered data are above 0.01 ppm and 90 percentage of emission rate is below 0.02 ppm. Below table represents the set of collective data.

Table 29:Comparison table of 10 and 90 percentile of ozone emission in working days with off days

	Ozone Working Days	Ozone off Days
90 Percentile	0.06	0.02
AVG	0.04	0.01
10 Percentile	0.01	0.01

According to the obtained gathered data from the table above, the statistical chart displays the clear pictorial of comparison of ozone emission rate in working days with off days.

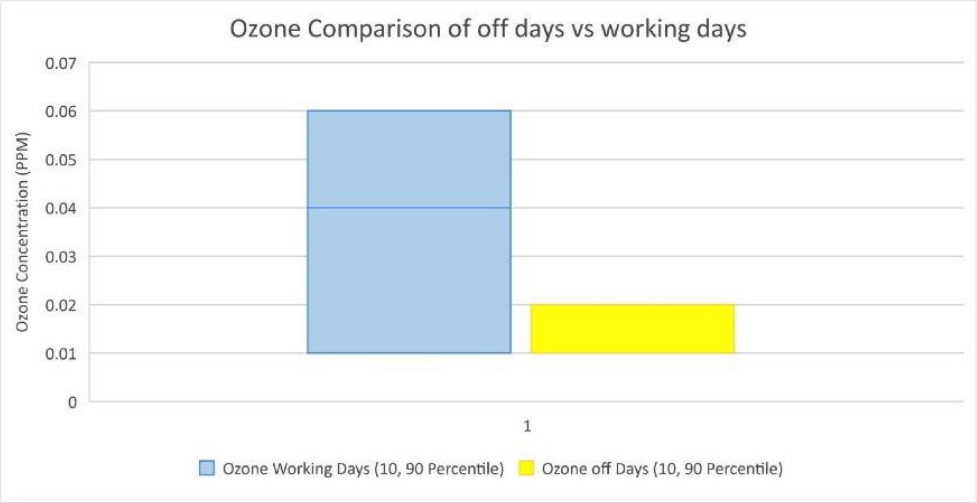


Figure 27:Ozone emission rate comparison in working days with off days

Base case result is obtained through the total average of off days and the ratio rates of ozone emission gain through the total base case outcome during the experimental hours. Ratio in most of the measured days is higher than one, which demonstrates the higher amount of emission rate from the base unit. The ratio in off days is between 0.00 to 2 percentages. However, in most of the measured days of working days, the ratio is higher than one and in 27th of November has the highest rate stand at 40. It is because of the type of wood and machinery and the workload on this date.

Table 30:Ratio measurement according to the base case result

OZONE	BASE	9:00 AM	10:00 AM	11:00 AM	12:00 PM	1:00 PM	2:00 PM	3:00 PM	4:00 PM
11/19/2019	0.01	1.00	1.00	1.00	0.00	2.00	1.00	2.00	1.00
20-11-19		0.00	0.00	2.00	2.00	2.00	2.00	2.00	2.00
21-11-19		1.00	1.00	0.00	1.00	0.00	1.00	1.00	1.00
22-11-19		0.00	1.00	1.00	0.00	0.00	0.00	0.00	1.00
23-11-19		2.00	5.00	6.00	6.00	6.00	7.00	6.00	7.00
24-11-19		2.00	1.00	0.00	1.00	2.00	2.00	3.00	4.00
25-11-19		3.00	4.00	4.00	4.00	4.00	4.00	4.00	4.00
26-11-19		0.00	5.00	4.00	4.00	4.00	5.00	3.00	4.00
27-11-19		3.00	20.00	20.00	2.00	40.00	4.00	4.00	5.00
28-11-19		4.00	6.00	5.00	6.00	6.00	7.00	7.00	7.00
29-11-19		1.00	1.00	1.00	1.00	1.00	2.00	2.00	1.00
1/12/2019		2.00	4.00	4.00	5.00	6.00	5.00	6.00	5.00
2/12/2019		1.00	2.00	2.00	2.00	2.00	2.00	2.00	1.00
3/12/2019		1.00	1.00	1.00	2.00	2.00	2.00	2.00	1.00
4/12/2019		7.00	4.00	4.00	4.00	5.00	5.00	5.00	5.00
5/12/2019		4.00	4.00	5.00	5.00	5.00	6.00	5.00	6.00
6/12/2019		0.00	0.00	1.00	1.00	2.00	1.00	1.00	1.00
7/12/2019		5.00	4.00	4.00	4.00	5.00	5.00	5.00	5.00

4-2-4 Carbon Monoxide (Co)

The presence of carbon monoxide in the air is not detectable because it is odorless and colorless gas. When the presence of the oxygen is not sufficient, carbon monoxide produced. Carbon monoxide and all other gases in joinery factories are due to high emission of wood dust. Each type of woods has a different effect on the producing gases in the air. Sanding of plywood, veneer and RC veneer increase carbon monoxide emission in the air (USEPA, 1995). Plywood is

made of thin layers of veneer stick with the glue together. The reason of high Carbon monoxide exposure of these three types of wood is because they come from the same family thus, they have a same effect in the air. Measurement of carbon monoxide in this factory happened in the same time and dates as all other gases emission. Before going into the details of Co emissions, we take a look at the emission rates in all measured days in below table.

Table 31:Carbon emission rates in measured dates (PPM)

CO	9:00 AM	10:00 AM	11:00 AM	12:00 PM	1:00 PM	2:00 PM	3:00 PM	4:00 PM
19-11-19	17	19	25	35	45	38	35	33
20-11-19	22	26	29	32	33	37	42	45
21-11-19	25	29	33	38	32	39	45	40
22-11-19	8	14	14	12	17	13	10	8
23-11-19	20	26	28	35	39	46	50	49
24-11-19	19	24	28	34	39	47	53	57
25-11-19	28	33	38	42	36	46	49	53
26-11-19	33	38	34	39	47	58	52	51
27-11-19	22	28	29	33	39	42	48	48
28-11-19	17	22	28	35	39	45	45	50
29-11-19	15	17	17	12	14	16	12	15
1/12/2019	25	29	38	35	39	42	37	34
2/12/2019	18	12	14	20	19	16	15	17
3/12/2019	15	15	17	20	15	18	18	16
4/12/2019	19	25	26	28	31	37	39	45
5/12/2019	21	26	28	29	33	37	35	36
6/12/2019	11	15	17	22	18	17	15	13
7/12/2019	25	29	45	43	38	29	23	23

Based on the OSHA standard guidelines, the acceptable level of Co emission in offices is 50 ppm for 8 hours work and 51-100 ppm considered as a mid-level emission and 101 ppm above considered as a high level of emission if employees do not have any symptoms and dangerous level is 101 ppm above if employees have symptoms (OSHA, 2019). According to the above table, Co emissions in off days are below 50 ppm. So the emission rate is acceptable based on the OSHA standards. However, in the working days, Co emission in three days stays on the mid-level emission. Following table represents the Co emission pick rates in measured dates. On 24th of November, the emission rates increased gradually and the highest emission rate stands at

57 ppm and it located in mid-level emission rate levels. In 25th of November, the emission rates are fluctuated and the highest emission rate is 53 ppm. And 26th of November, Co emissions are quite high in the whole day. The minimum emission rate is 34 ppm, which located in admissible Co emission rates. And the maximum Co emission rate is 52 ppm. Based on the collected information from the sanding department manager, workers were sanding the plywood on those dates. Thus, the high amount of emission rate, which is higher than the standard level, is related to the plywood sanding.

Table 32:High amount of Co Concentration in measured dates (PPM)

24-11-19	19	24	28	34	39	47	53	57
25-11-19	28	33	38	42	36	46	49	53
26-11-19	33	38	34	39	47	58	52	51

According to the above table, the high amount of Co emission is related to 24th till 26th of November. To better understand the amount of carbon monoxide emissions on measured days when emissions are higher, the chart below helps to understand it. Based on the chart below the highest amount of Co emission rate is related to the 26th of November and the minimum Co emission rate is related to the 24th of November.

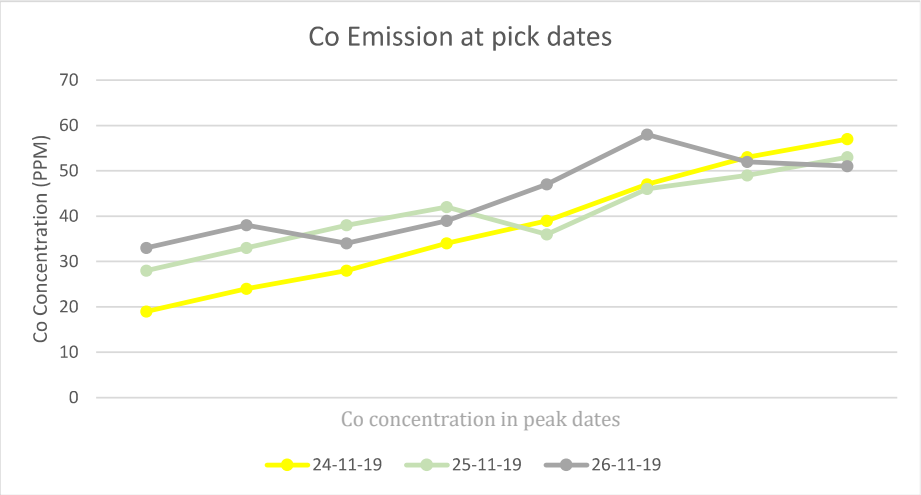


Figure 28: Highest amount of Co emission rate in measured dates

To have a constant size of all assets and to collect the obtained numbers, it is necessary to obtain the average number. Average number of collective data comes from the average of the total in off days. Below tables display minimum, maximum and average of Co emission in working and off days. Based on the attached information, the total base is 15.22 ppm, which collected from total average of off days. The average emission rate in working days is 35.19 ppm.

Table 33:Min, Max & Average of Co emission in working days (Blue highlight) and off days (Yellow highlight)

Min	Max	Avg
17.00	45.00	30.90
22.00	45.00	33.30
25.00	45.00	35.10
20.00	50.00	36.30
19.00	57.00	37.70
28.00	53.00	40.60
33.00	58.00	44.30
22.00	48.00	35.90
17.00	50.00	34.80
25.00	42.00	34.60
19.00	45.00	31.40
21.00	37.00	30.30
23.00	45.00	32.30
		35.19

Min	Max	Avg	
8.00	17.00	12.10	
12.00	17.00	14.70	
12.00	20.00	16.30	
15.00	20.00	16.90	
11.00	22.00	16.10	
		15.22	TOTAL BASE

Comparison of Co emission in working days and off days represents in below table. The total average of Co emission in working days is almost more than double of Co emission in off days. The comparison ratio between working and off days stands at 2.31 ppm.

Table 34:The ratio of Co Concentration in working days and off days

AVG OF OFF DAYS	15.22	OFF DAYS/WORKING DAYS
AVG OF WORKING	35.19	**2.31**

As we can see in the chart below, the emission rates of Co in between 17 ppm till 58 ppm. However, the average emission rate is around 35 ppm. However, most of the days the Co emission rate is below 50 ppm and it is acceptable as per the OSHA standards. Minimum emission rate level is between 10 ppm to 30 ppm.

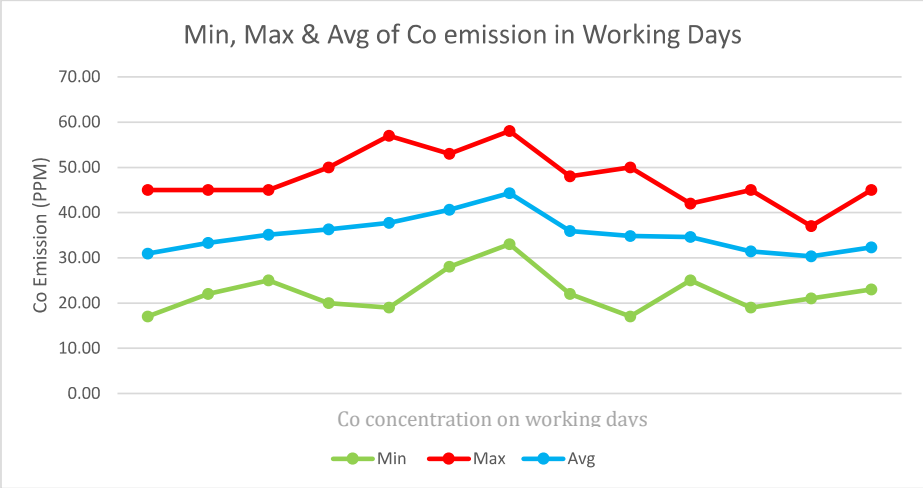


Figure 29:Min, Max and Avg of Co emission in off days

The emission rates in off days are below 25 ppm. And the minimum level of emission rate is between 5 ppm to 15 ppm. The total average of emission rate is around 15 ppm. And it is almost stable.

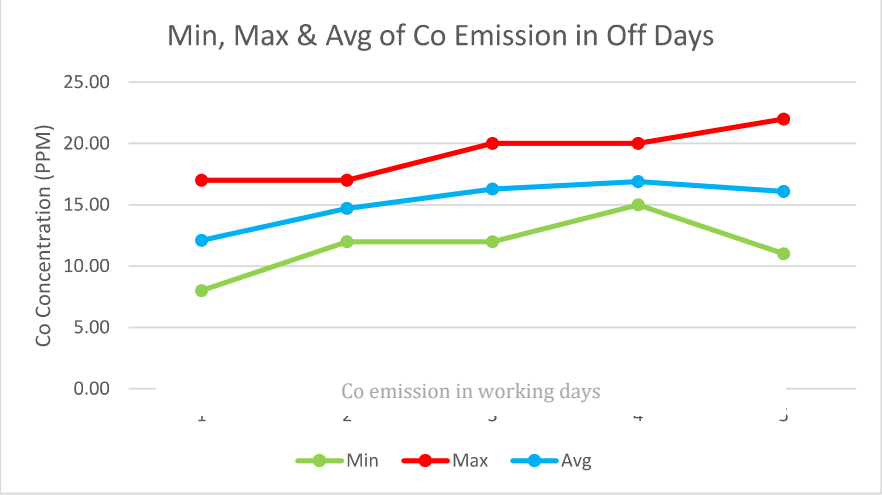


Figure 30:Min, Max & Avg of Co emission in off days

Following all the gathered information, the comparison rate of Carbon monoxide in off days and working days are clearly shows in the below chart. The emission rates in working days and off days are fluctuated. However, the emission rates in off days are less than working days. Co concentration range is between 8 ppm to 58 ppm. The gap between the minimum rates and maximum rates are quite wide. However, the Co emission rate is based on the OSHA standards except in three days and only in couple of hours and not the whole day. Below chart identifies the claims made

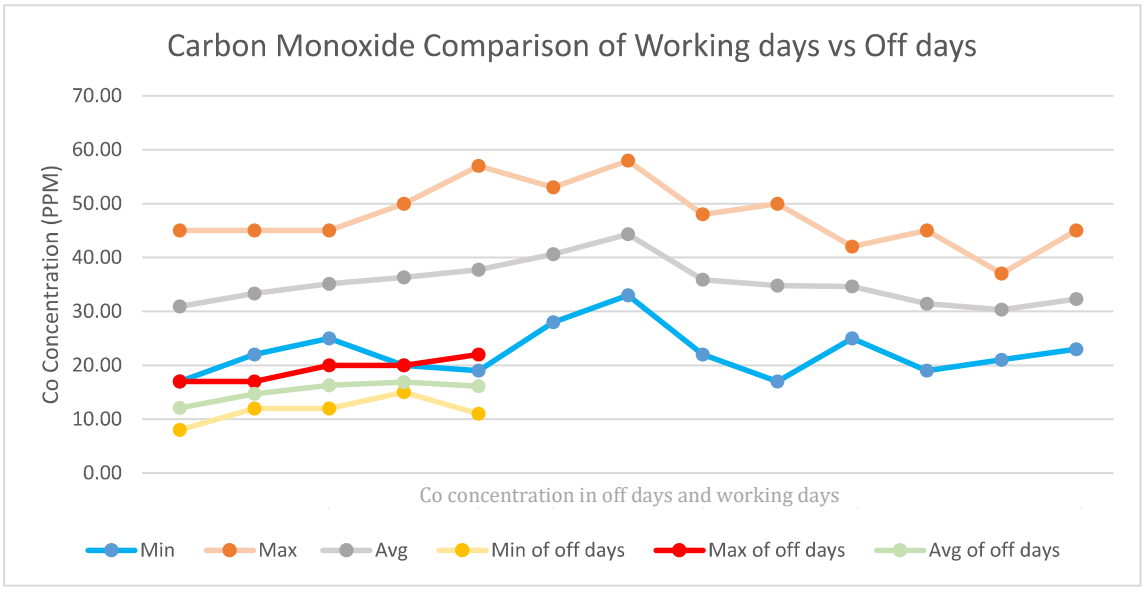


Figure 31: Co comparison emission in working days and off days

For further comprehension comparison of Co emission rates in working days with off days, statistical chart plays the vial role. In statistical chart, gathered information is easy to perceive. The emission difference in off days and working days is completely distinct. The Co emission rate in working days is twice greater than the emission rate in off days. In off days the minimum Co emission rate stands at 8 ppm and the maximum emission rate stands at 22 ppm. The average Co emission is 15 ppm. While, the Co emission rate in working days is quite higher

than off days. The minimum Co emission rate in working days is 17 ppm and the maximum emission rate is 58 ppm. The average rate of Co emission in working days is 35 ppm.

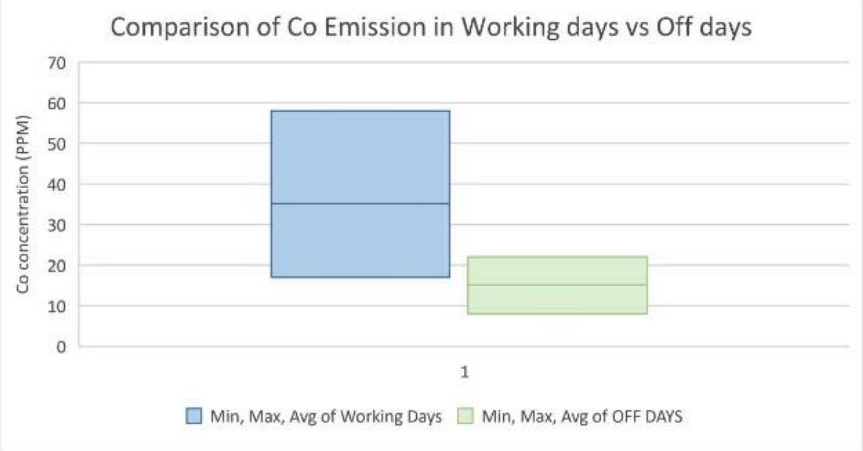


Figure 32:Comparison of Co emission in working days and off days

Another Statistical chart, shown below, is similar to the above statistical chart with a difference in consideration of 25 and 75 percentile in the two categories of off days and working days. As display below, 25 percentage of Co emission in off days is above 32 ppm and 75 percentage of Co emission rate in working days is below 36 ppm. In off days, 25 percentage of the Co emission rate is above 14 ppm and 75 percentage of Co emission rate is below 16 ppm. Above claims identified in below chart.

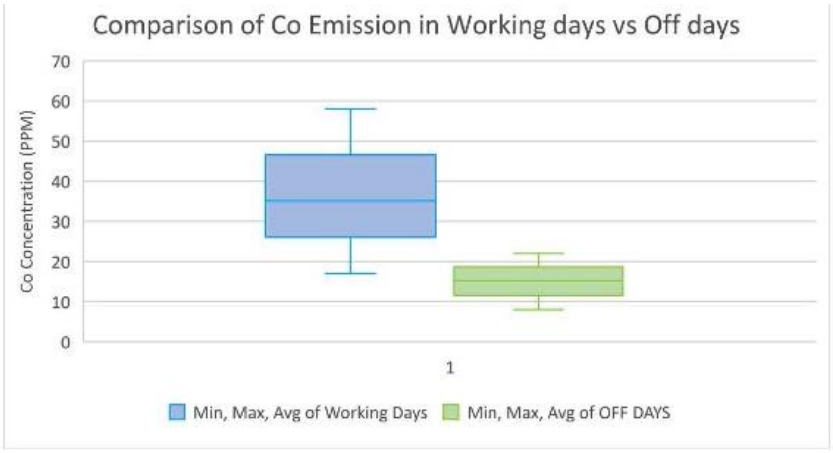


Figure 33:Statistic chart comparison of Co emission in working days and off days (considering 25 & 75 percentile)

According to the information acquired, minimum, maximum, average, 25 and 75 percentile, and standard deviation range of Co emission in the measured dates show below. Following recorded data display the minimum level of carbon monoxide is between 8 ppm to 25 ppm. And the maximum level of Co emission is around 17 ppm to 58 ppm. Following OSHA, the Occupational Safety and Health Administration, standard level of Co emission in working space should not exceed more than 50 ppm in 8 hours working time (OSHA, 2019). 25 percentile demonstrates the 25% of the collective data of the total recorded numbers in every day. And 75 percentile represents that 75% of gathered information are below the record number on the table. Furthermore, with the assist of standard deviation, spread of Co emission rates from the mean number has shown. Based on the standard deviation number, we can obtain the ratio of Co emission distribution from the mean number.

Table 35:Min, max, Avg, 25 and 75 Percentile and Standard deviation of Co emission in sanding area (PPM)

Min	Max	Avg	25 Percentile	75 Percentile	Standard Deviation
17.00	45.00	30.90	23.50	35.75	9.69
22.00	45.00	33.30	28.25	38.25	7.81
25.00	45.00	35.10	31.25	39.25	6.53
8.00	17.00	12.10	9.50	14.00	3.16
20.00	50.00	36.30	27.50	46.75	11.29
19.00	57.00	37.70	27.00	48.50	13.84
28.00	53.00	40.60	35.25	46.75	8.45
33.00	58.00	44.30	37.00	51.25	9.26
22.00	48.00	35.90	28.75	43.50	9.64
17.00	50.00	34.80	26.50	45.00	11.85
12.00	17.00	14.70	13.50	16.25	1.98
25.00	42.00	34.60	32.75	38.25	5.54
12.00	20.00	16.30	14.75	18.25	2.67
15.00	20.00	16.90	15.00	18.00	1.83
19.00	45.00	31.40	25.75	37.50	8.53
21.00	37.00	30.30	27.50	35.25	5.58
11.00	22.00	16.10	14.50	17.25	3.34
23.00	45.00	32.30	24.50	39.25	8.90

The obtained total average numbers of each day can represents the distribution of standard deviation from the mean number. According to the below table standard deviation and the distribution of the gathered information from the mean base is shown. Collective data represents that all the numbers categorized in low rate as the ratio of standard deviation from the mean number is in less than one. However, the emission ratio in off days is lesser than working days. Following table displays the standards deviation of Co concentration on the measured dates. Based on the table the distance between the standard deviation from the mean number is clearly shows.

Standard Deviation	Ratio St/Avg
9.69	0.64
7.81	0.51
6.53	0.43
3.16	0.21
11.29	0.74
13.84	0.91
8.45	0.56
9.26	0.61
9.64	0.63
11.85	0.78
1.98	0.13
5.54	0.36
2.67	0.18
1.83	0.12
8.53	0.56
5.58	0.37
3.34	0.22
8.90	0.58

Table 36:Standard deviation of co concentration and the ratio of standard deviation to the mean number on the measured days

To include more collected data from the measured dates, statistical chart with the 10 and 90 percentile can present that. Following table including 10 and 90 percentile clearly shows the 10 percentage of the Co emission rate in working days are above 40 ppm and 90 percentages of Co emission rates are below 31 ppm. While, the average emission rate of Co stands at 35 ppm. In off

days, the average of Co emission rate is 15 ppm and 10 percentages of the numbers are above 13 ppm and 90 percentages of the collective data is below 16 ppm.

Table 37: 10 and 90 percentile of Co comparison range rate in working days with off days

	Co Working Days	Co Off Days
90 Percentile	31.00	16.66
AVG	35.19	15.22
10 Percentile	40.02	13.14

According to the above table, the statistic chart expresses the 10 and 90 percentage of collective data in off days and working days. Based on the below chart the difference between off days and working days is clearly shown.

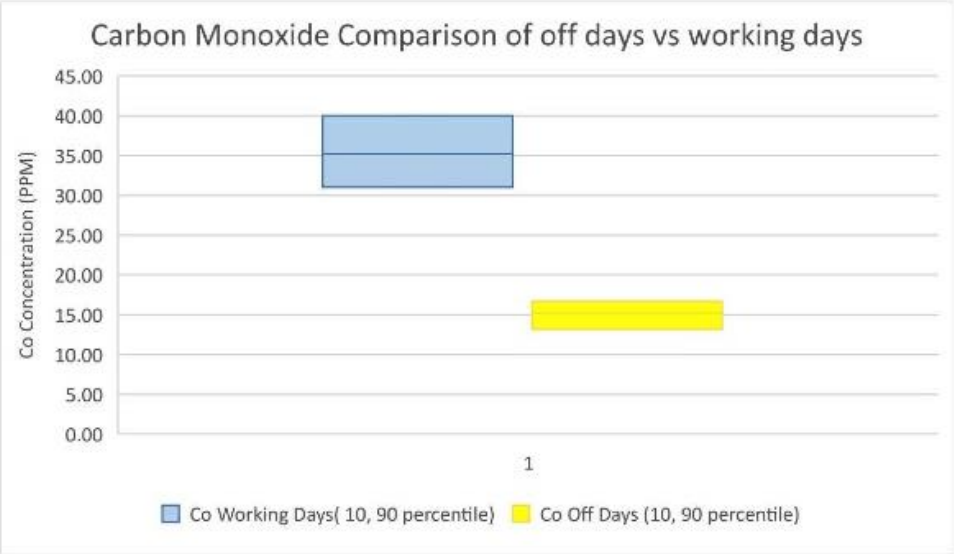


Figure 34: 10 and 90 percentile of Co comparison between off days and working days

Below table is including the ratio of every house based on the total mean. As per the below table most of the ratios are above 1%, which means the proportion of most days are above the total mean. The Co ratio in off days is between 0.25 percentages to 1.31 percentage. If the Co ratio is below 1 percentage, it shows the emission rate is below the mean number. In working days, most of the percentages are above 1. And the maximum percentage is 3.48 because of the plywood sanding and the specific wood dust creates from plywood.

Table 38: Co ratio measurement according to the base case result

CO	Base	9:00 AM	10:00 AM	11:00 AM	12:00 PM	1:00 PM	2:00 PM	3:00 PM	4:00 PM
19-11-19	15.22	1.12	1.25	1.64	2.30	2.96	2.50	2.30	2.17
20-11-19		1.45	1.71	1.91	2.10	2.17	2.43	2.76	2.96
21-11-19		1.64	1.91	2.17	2.50	2.10	2.56	2.96	2.63
22-11-19		0.53	0.92	0.92	0.79	1.12	0.85	0.66	0.53
23-11-19		1.31	1.71	1.84	2.30	2.56	3.02	3.29	3.22
24-11-19		1.25	1.58	1.84	2.23	2.56	3.09	3.48	3.75
25-11-19		1.84	2.17	2.50	2.76	2.37	3.02	3.22	3.48
26-11-19		2.17	2.50	2.23	2.56	3.09	3.81	3.42	3.35
27-11-19		1.45	1.84	1.91	2.17	2.56	2.76	3.15	3.15
28-11-19		1.12	1.45	1.84	2.30	2.56	2.96	2.96	3.29
29-11-19		0.99	1.12	1.12	0.79	0.92	0.79	0.79	0.99
1/12/2019		1.64	1.91	2.50	2.30	2.56	2.76	2.43	2.23
2/12/2019		1.18	0.79	0.25	1.31	1.25	1.05	0.99	1.12
3/12/2019		0.99	0.99	1.12	1.31	0.99	1.18	1.18	1.05
4/12/2019		1.25	1.64	1.71	1.84	2.04	2.43	2.56	2.96
5/12/2019		1.38	1.71	1.84	1.91	2.17	2.43	2.30	2.37
6/12/2019		0.72	0.99	1.12	1.45	1.18	1.12	0.99	0.85
7/12/2019		1.64	1.91	2.96	2.83	2.50	1.91	1.51	1.51

4-2-5 Particulate matter (PM)

There are two categorized of particulates matter classified by EPA. $PM_{2.5}$ and PM_{10} are the most dangerous size of particles, which attack and stick deeply to the respiratory tract (EPA, 2018). The main focus of EPA is on the inhalable particles, which are smaller than PM_{10}. Since 1997, EPA has been reviewing airborne particulate standards and revising standards in previous

years. Based on the latest standard levels of airborne particles on 2006, PM_{10} standard level is 150 $\mu g/m^3$ on 24 hours average and the annual standard level is 50 $\mu g/m^3$. Also, the standard level of $PM_{2.5}$ is 35 $\mu g/m^3$ in 24 hours average and 15 $\mu g/m^3$ on annual based on 2006. However, the standard level of $PM_{2.5}$ is changed on 2012 from 15 $\mu g/m^3$ to 12 $\mu g/m^3$ on annual based and the rest of standard levels remained the same (EPA, 2020). Wood dust is part of particulate matter in the airborne and when the wood dust increased it create more particles in the air (Seinfeld J., 1998).

Measurement of particulate matter happened in the same measured dates as all other gases. The tool measurement is called Optical Particle sizer (OPS) 3330. And the measured particle size is between 0.3 to 10 μm in adjustable 16 channel users.

Below table represents the particulate matter emission rate in measured dates.

Table 39: Particulate matter emission rate from 0.3 μm to 10 μm

PM	19-11-19	20-11-19	21-11-19	22/11/2019	23-11-19	24-11-19	25-11-19	26-11-19	27-11-19	28-11-19	29-11-19	1/12/2019	12/2/2019	3/12/2019	4/12/2019	5/12/2019	6/12/2019	7/12/2019
0.3-0.374	1.547	2.26	3.79	3.45	3.54	3.83	3.98	2.98	9.29	4.45	2.73	9.29	2.18	1.15	4.56	6.32	1.55	4.84
0.374-.0465	3.458	8.38	1.10	2.93	9.89	9.40	1.06	1.54	3.22	1.93	5.26	3.22	4.52	7.10	2.57	1.83	4.77	1.25
0.465-0.579	1.457	2.57	4.12	4.24	3.58	3.35	3.52	4.13	1.87	8.24	1.35	1.87	1.24	2.40	1.76	3.03	1.14	4.94
0.579-0.721	4.912	2.78	1.75	1.59	1.66	1.78	3.21	3.41	4.51	2.59	1.78	4.51	2.67	2.80	9.57	5.41	3.16	1.96
0.721-0.897	3.214	1.65	1.65	3.22	1.31	1.05	1.62	1.20	3.88	2.22	1.05	3.88	1.93	5.40	9.44	3.53	3.11	1.94
0.897-1.117	3.554	3.08	1.83	1.45	1.22	1.08	2.23	2.23	3.85	2.45	1.08	3.85	1.71	2.01	8.14	3.63	4.08	2.21
1.117-1.391	3.325	9.62	1.27	1.63	9.02	7.62	1.47	1.97	2.55	1.63	5.35	2.55	1.03	4.43	4.21	2.43	2.83	1.48
1.391-1.732	2.845	7.33	1.21	1.40	11.80	7.22	1.08	1.27	2.23	1.40	6.02	2.23	7.37	6.55	4.11	2.36	2.62	1.32
1.732-2.156	2.784	1.05	2.14	2.28	1.22	1.35	3.94	1.94	3.40	2.28	1.15	3.40	1.39	2.17	3.53	3.76	4.67	2.11
2.156-2.685	1.914	1.98	2.08	2.94	1.12	1.36	2.87	2.67	2.91	1.94	1.36	2.91	1.07	7.84	2.80	2.95	4.32	1.80
2.685-3.343	2.745	2.12	1.69	1.42	8.82	1.12	3.57	1.27	2.18	1.42	1.12	2.18	6.70	6.45	8.47	2.06	3.24	1.04
3.343-4.162	1.475	1.51	1.49	1.17	2.66	1.60	1.87	1.34	1.82	1.17	1.23	1.82	6.44	2.73	4.77	1.71	2.69	3.88
4.162-5.182	2.457	10.54	1.27	7.29	6.17	8.54	9.95	8.75	1.69	11.29	6.54	1.69	5.31	4.15	2.56	1.44	2.17	8.15
5.182-6.451	8.452	8.62	8.44	4.77	9.98	5.62	5.62	5.62	12.29	5.88	3.42	9.29	3.46	3.01	1.13	9.53	1.37	5.05
6.451-8.032	9.754	5.65	7.85	5.22	5.60	5.15	10.07	5.26	8.32	5.22	3.18	8.32	3.22	2.91	10.27	9.65	1.24	4.45
8.032-10	6.75	2.68	7.39	4.73	3.28	4.74	4.70	3.53	7.65	4.73	3.89	7.65	3.09	2.72	4.55	1.11	1.14	3.95

In joinery factories, wood dust are usually found everywhere, but the most common place, where wood dust are found is in the sanding section. Wood dust emission cause particles in the airborne. And base on the wood type and machinery types, the emission rates of particles change. Wood types have an impact on the amount of particles on the air. They can increase the

wood dust particles on the air, which cause more particulate matter. Below table displays the particles matters in off days. Based on the EPA standard level of Particulate matter, in off days all the emission rates located at standard level. The maximum level of PM emission rate is 7.84 μm related to the 2.156 to 2.685 μm.

Table 40: Particulate matters in off days

PM	22/11/19	29-11-19	12/2/2019	3/12/2019	6/12/2019
0.3-0.374	3.45	2.73	2.18	1.15	1.55
0.374-.0465	2.93	5.26	4.52	7.10	4.77
0.465-0.579	4.24	1.35	1.24	2.40	1.14
0.579-0.721	1.59	1.78	2.67	2.80	3.16
0.721-0.897	3.22	1.05	1.93	5.40	3.11
0.897-1.117	1.45	1.08	1.71	2.01	4.08
1.117-1.391	1.63	5.35	1.03	4.43	2.83
1.391-1.732	1.40	6.02	7.37	6.55	2.62
1.732-2.156	2.28	1.15	1.39	2.17	4.67
2.156-2.685	2.94	1.36	1.07	7.84	4.32
2.685-3.343	1.42	1.12	6.70	6.45	3.24
3.343-4.162	1.17	1.23	6.44	2.73	2.69
4.162-5.182	7.29	6.54	5.31	4.15	2.17
5.182-6.451	4.77	3.42	3.46	3.01	1.37
6.451-8.032	5.22	3.18	3.22	2.91	1.24
8.032-10	4.73	3.89	3.09	2.72	1.14

The below chart can ease the understanding of particle emission rates in off days. Based on the EPA standards, the level of PM2.5 should not exceed more than 12 μm in 24 hours and the emission level of PM10 should be below 150 μm in 24 hours. Below chart shows the PM is in the standard range.

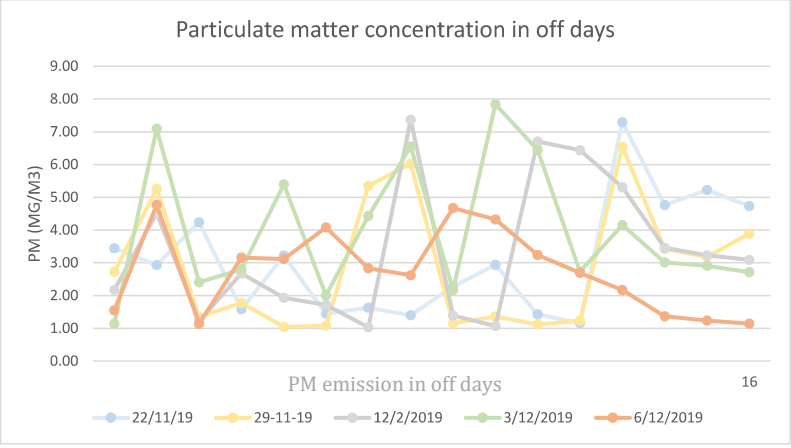


Figure 35: Particulate matter concentration in off days

Particulate matter in working days in compare with off days has higher emission rates. However, the emission rate is as per EPA standard level and below 12 μm in all days, except in 27th of November when the emission rate of 5.182 to 6.451 μm is 12.29 micrometers. Based on the previous ozone measurement, workers were sanding walnut wood in this date and the workloads were high.

Table 41: Particulate matters emission rate in working days

PM	19-11-19	20-11-19	21-11-19	23-11-19	24-11-19	25-11-19	26-11-19	27-11-19	28-11-19	1/12/2019	4/12/2019	5/12/2019	7/12/2019
0.3-0.374	1.547	2.26	3.79	3.54	3.83	3.98	2.98	9.29	4.45	9.29	4.56	6.32	4.84
0.374-.0465	3.458	8.38	1.10	9.89	9.40	1.06	1.54	3.22	1.93	3.22	2.57	1.83	1.25
0.465-0.579	1.457	2.57	4.12	3.58	3.35	3.52	4.13	1.87	8.24	1.87	1.76	3.03	4.94
0.579-0.721	4.912	2.78	1.75	1.66	1.78	3.21	3.41	4.51	2.59	4.51	9.57	5.41	1.96
0.721-0.897	3.214	1.65	1.65	1.31	1.05	1.62	1.20	3.88	2.22	3.88	9.44	3.53	1.94
0.897-1.117	3.554	3.08	1.83	1.22	1.08	2.23	2.23	3.85	2.45	3.85	8.14	3.63	2.21
1.117-1.391	3.325	9.62	1.27	9.02	7.62	1.47	1.97	2.55	1.63	2.55	4.21	2.43	1.48
1.391-1.732	2.845	7.33	1.21	11.80	7.22	1.08	1.27	2.23	1.40	2.23	4.11	2.36	1.32
1.732-2.156	2.784	1.05	2.14	1.22	1.35	3.94	1.94	3.40	2.28	3.40	3.53	3.76	2.11
2.156-2.685	1.914	1.98	2.08	1.12	1.36	2.87	2.67	2.91	1.94	2.91	2.80	2.95	1.80
2.685-3.343	2.745	2.12	1.69	8.82	1.12	3.57	1.27	2.18	1.42	2.18	8.47	2.06	1.04
3.343-4.162	1.475	1.51	1.49	2.66	1.60	1.87	1.34	1.82	1.17	1.82	4.77	1.71	3.88
4.162-5.182	2.457	10.54	1.27	6.17	8.54	9.95	8.75	1.69	11.29	1.69	2.56	1.44	8.15
5.182-6.451	8.452	8.62	8.44	9.98	5.62	5.62	5.62	12.29	5.88	9.29	1.13	9.53	5.05
6.451-8.032	9.754	5.65	7.85	5.60	5.15	10.07	5.26	8.32	5.22	8.32	10.27	9.65	4.45
8.032-10	6.75	2.68	7.39	3.28	4.74	4.70	3.53	7.65	4.73	7.65	4.55	1.11	3.95

By considering all the measurement of all other gases like Co_2, Co, TVOCs and Ozone, the amount of particles should have a direct effect on their emission rates. Based on the gathered data of Particulate matter, the emission rates on 19th, 20th, 23rd, and 24th till 28th of November, and 1st, 4th, and 5th of December are fluctuated and higher than other days. However, the whole emission ranges are at a standard level. On the 28th and 27thof November, the particle level is around 12 μm. And on the 4th of December, the Particle fluctuation is seen in the chart. Also, on 23rd of November, the particles emission rates have a fluctuation, however, the emission rates in below 10 μm.

Below chart represent the particulate matter emission rates in working days.

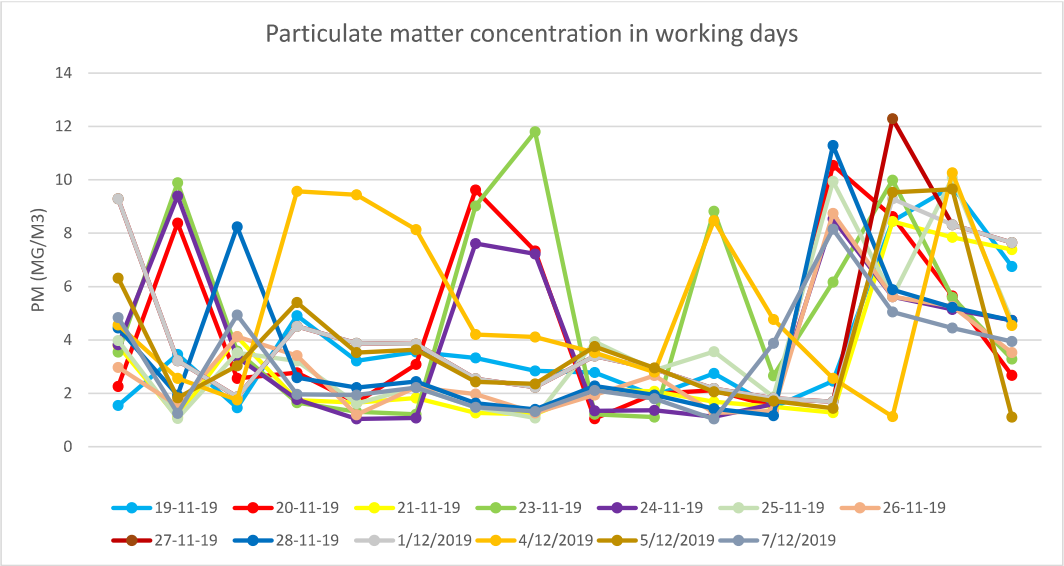


Figure 36: Particulate matter concentration in working days

4-3 Survey Result:

The questionnaire survey conducted among 50 workers in two different sections, where the amount of wood dust is high. These two sections are sanding area and machinery chops. Because of the nature of their work, the wood dust emission rates are high and it has a direct effect on the airborne particles and different gases. Also, questionnaire translated into Hindi for better understanding of the labors.

The main reason of survey questionnaire is to realize the indoor air quality relation with the employees' health and their performance. The questionnaire was prepared to collect information from the perspective of workers. They key questions included the symptoms of wood dust and its reaction on their body. Workers did not reply to all the questions. There are

some factors that might affect their responsibility of their honest answer. Questionnaire handed over during the Covid-19 period and this can be one of the reasons that they pretend they are in the perfect health. Because some of the symptoms of wood dust are similar to those of Covid-19, and it is quite understandable that they pretend to have no symptoms. The second hypothesis is their knowledge about health. Most of them, work in the factory for more than 7 years in this factory based on the chart 37. They may have become accustomed to these symptoms. The advantage of knowing how long workers work in this factory is to understand the effects of wood dust on workers' health over a long exposure period of time.

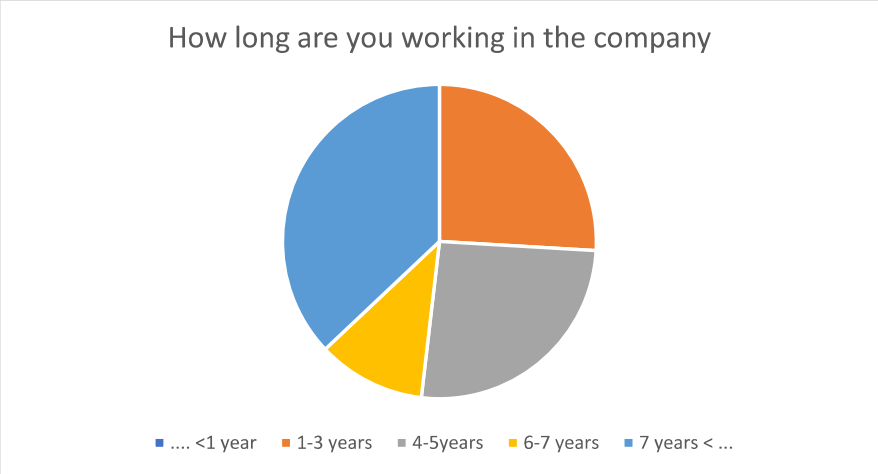


Figure 37:Time period of workers' work in the factory

The third hypothesis may be the fear of losing their job. However, filling in the questionnaire was considered with all security issues. The full explanation of the fact that this questionnaire has only a research aspect was mentioned, but assuming due to the level of education that the majority of workers have based on the chart 38 the given explanations may not have been taken seriously. In addition, in this current situation, due to the economic effects on the whole world, a lot of people are losing their jobs and this might be a reason to deter them of

an honest answer. Based on the chart 38, the majority of workers have school degree. The benefit of knowing workers' education is to know that they have sufficient and up-to-date information about their own health and the effect of long time exposure to different gases created from wood dust.

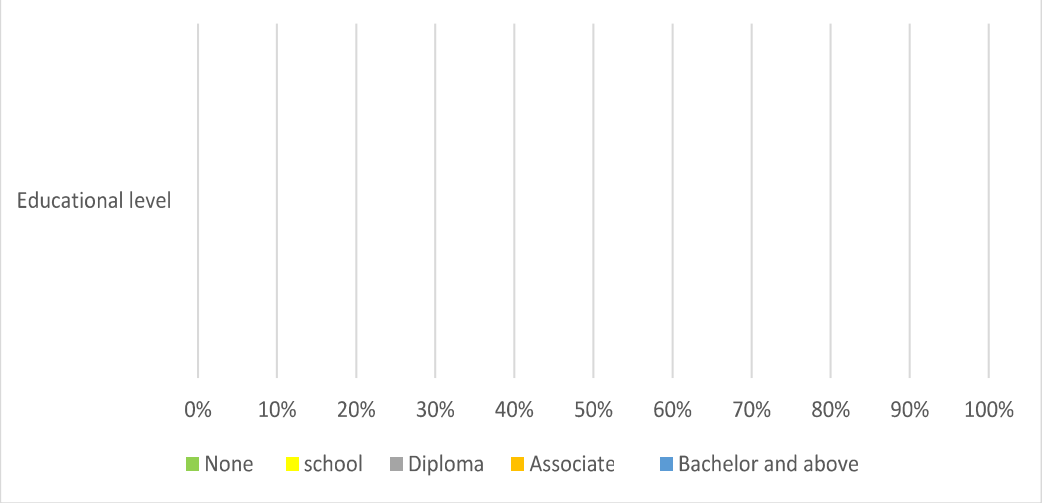


Figure 38: Educational level of workers in the factory

Wood dust has an impact on those who have been exposed to wood dust for a long time and those with an existing heart and lung problems. Also, the health of smokers is at higher risk. Majority of labors mentioned they do not smoke only few people mentioned they smoke but not in their workspace. Another categories of people who are at the risk are elderly people. Wood dust can expand the health problem in this category (‘Department of Australia health,’ n.d.). According to the survey, none of the workers reported a heart or lungs problems. Also, most of the workers are in 20s and 30s (Chart 39). It means they are in less health risk.

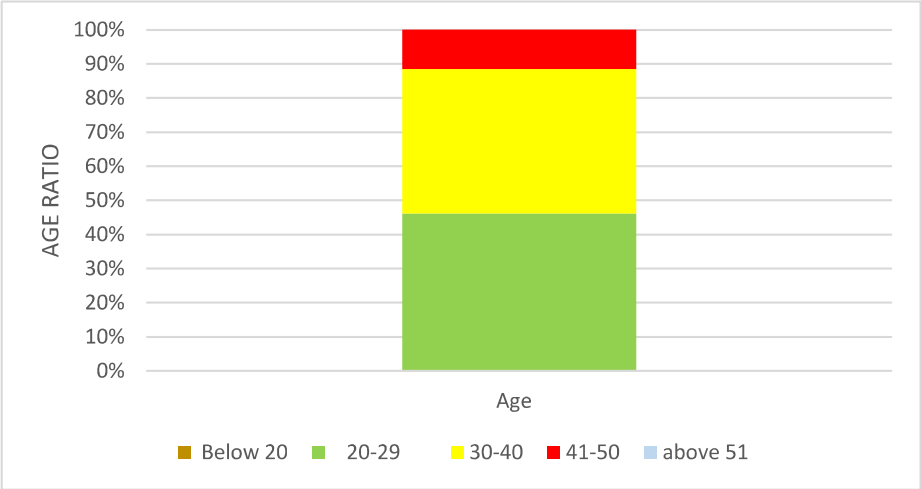


Figure 39: Workers' age

However, majority of the workers are working above 61 hours per week. This proportion is included in the overtime hours. Thus, they are exposed to wood dust for a long time.

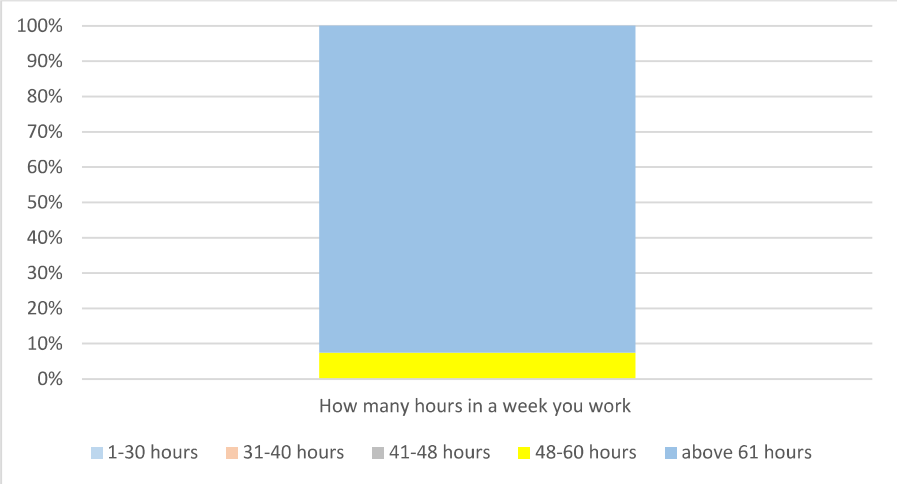


Figure 40: Working hours of labors in the factory

Due to the long exposure of workers to wood dust in their workplace, safety tips are very important for their health. According to the chart 41, all the labors use dust mask during the working hours. However, based on the walking through investigation, I noticed labors use masks

when there is a client (visitors) visits the factory. And they do not use mask regularly. Nevertheless, according to the safety manager statements, using mask during the working hours is obligatory for all the labors and if they do not follow the rules, they get reduction on their salaries.

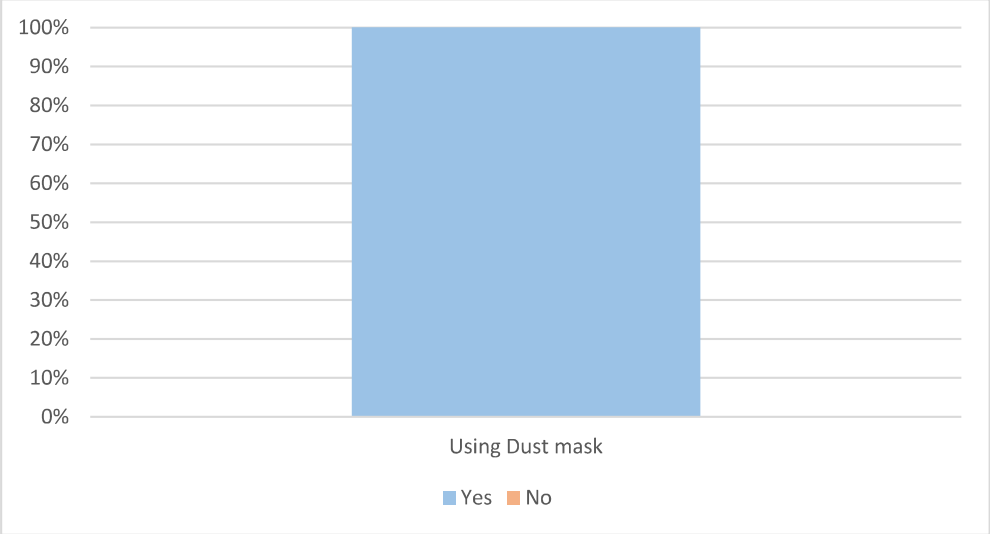


Figure 41:Usage of mask in the workplace

Another safety tip for laborers during the working hours is to use eye protection to prevent the entering of wood dust in their eyes to prevent eyes irritation. Also, high amount of wood dust exposure cause inflammation on mucous membranes of the eyes. According to the survey, more than 70 percentages of laborers using eye protection during working hours and less than 25 percentages of workers never used eye protection. Based on the walking though investigation, I did not see any labors using eye protection during the working hours.

Following chart represents the statements of labors about using eye protection while at work.

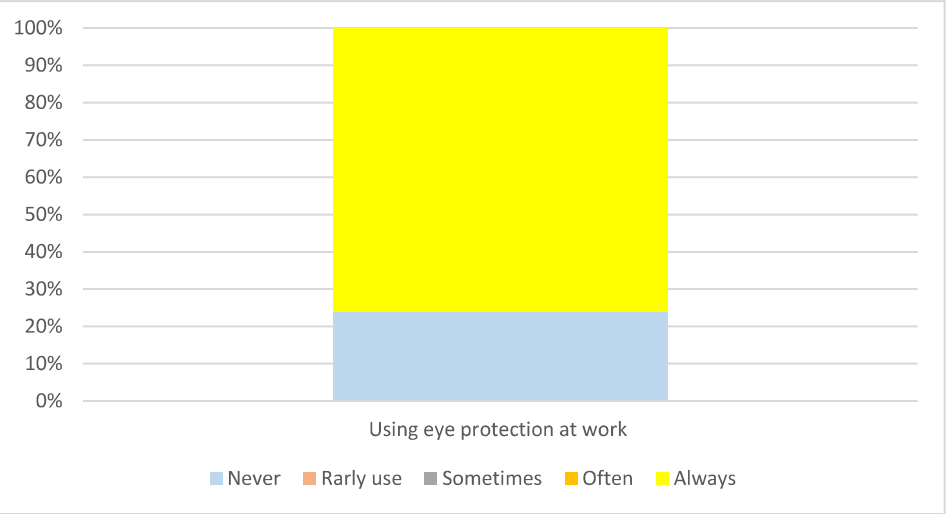


Figure 42:Usage of eye protection at working hours

Before hiring employees, they must have information about their job scope and responsibilities. And after the employer hires them; they usually teach them about their jobs and explain the hazards that may affect their health if they do not follow the instructor rules.. In particular, in the case of certain health hazards such as exposure to wood dust or chemicals employers are responsible for assessing hazards and clearly explaining them to employees. Sometimes, employees do not have sufficient information about the health hazards, and if they face some symptoms like cough, fever, or, some allergies they might consider them as cold or seasonal allergies.

According to the survey questionnaire result, more than 50 percent of workers pretension to have already known about the dangers of wood dust, and 60 percent of workers claim that employers have taught them the health effects of wood dust.

Following chart represent above statements and it compares the proportion of information of workers about wood dust hazards with the information that the employer explained to them. The ratio of their knowledge about wood dust hazards and information that employers described to them is almost in the same range.

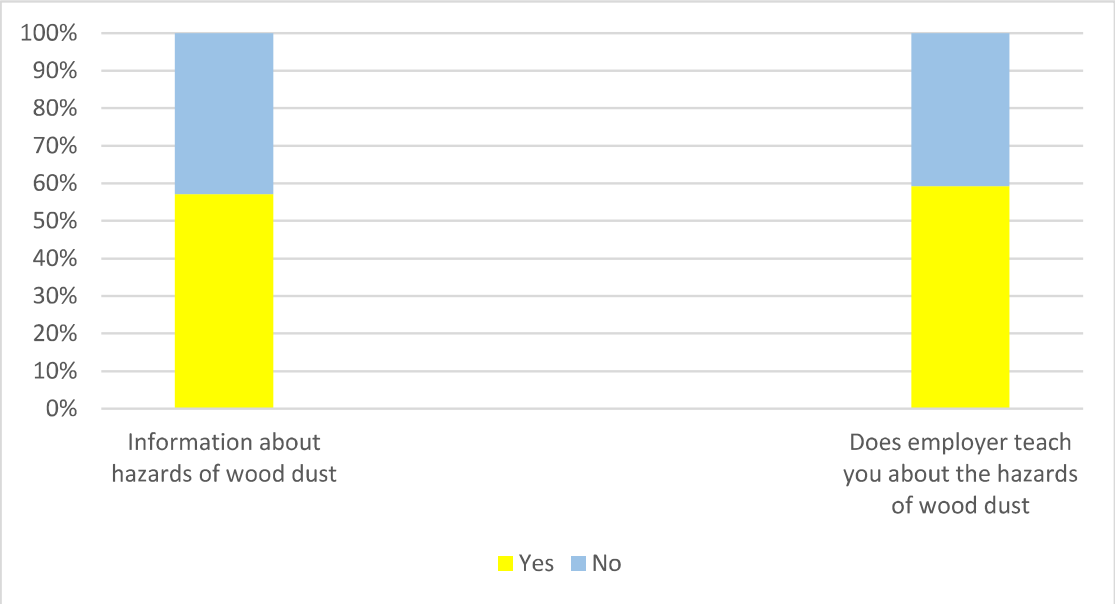


Figure 43: Workers information about wood dust in compare with the information that the employer explained to them

High sensitivity to wood dust may affect people's health more than the people with the less sensitivity. Sensitivity and exposure to wood dust increases health risks. Each type of wood has its own impact on the creation of wood dust. It mostly related to the increase of different gases like ozone, carbon monoxide, carbon dioxide and total volatile organic compounds. Exposure to wood dust can cause serious health problems such as heart diseases and decrease the capacity of lungs. By examining and considering the sensitivity of workers to wood dust, can locate this group of people, in another section in the factory, where wood exposure is less than

the sanding area. Based on the survey questionnaire result, around 55 percentages of workers are not sensitive to wood dust and around 45 percentage of people are sensitive to wood dust. According to the below table represent the statement.

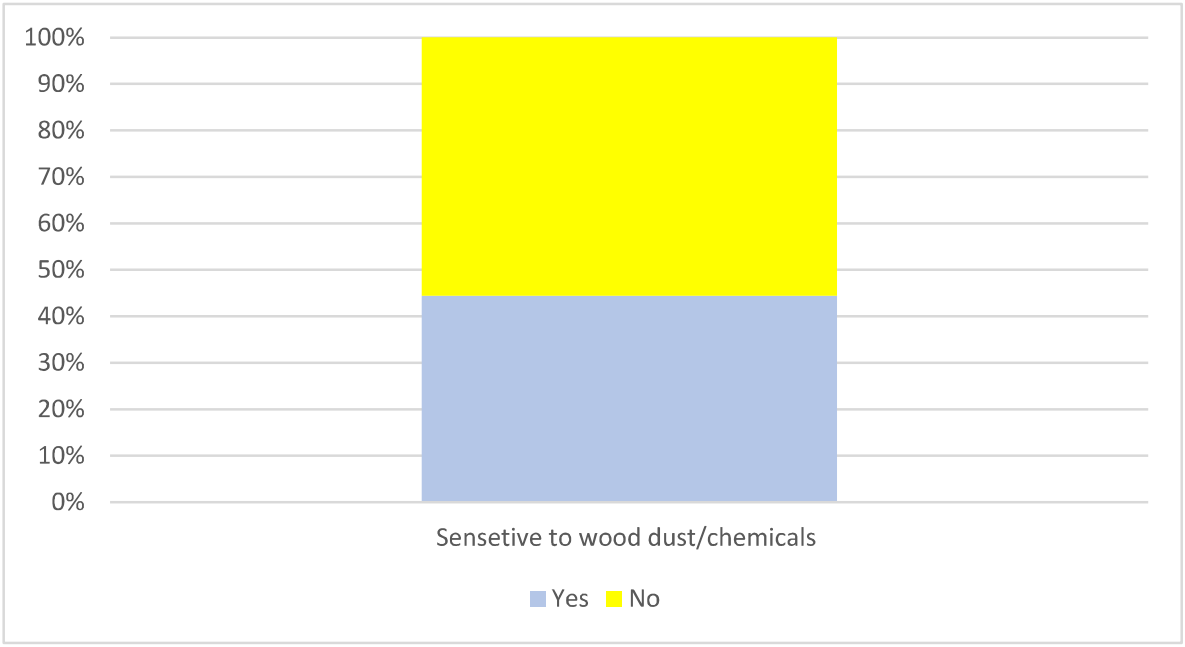


Figure 44:The ratio of workers sensitivity to wood dust

Considering the duration of the years that workers work in the factory, the sensitivity to wood dust increases. And workers may experience different symptoms such like allergy to dust, eczema, respiratory problem, asthmatic problem, nasal cavity, and difficulty in breathing, nasal cavity issues, dermatitis and difficulty in breathing. To find out the health problems of the labors, one of the questions was related to the experience of above symptoms. According to their statements, there are three major health problems they faced with allergy to dust, difficulty in breathing and eyes irritations. The greater ratio of health hazard is related to an allergy to dust, which is clearly the most amounts of particles in the airborne of sanding area in the factory. One

of the most common exposures to wood dust in long time is creation of eye irritation and difficulty in breathing. Difficulty in breathing is the cause of lung problems. The following chart shows the ratio of health problems to exposure to wood dust in sanding area in the factory.

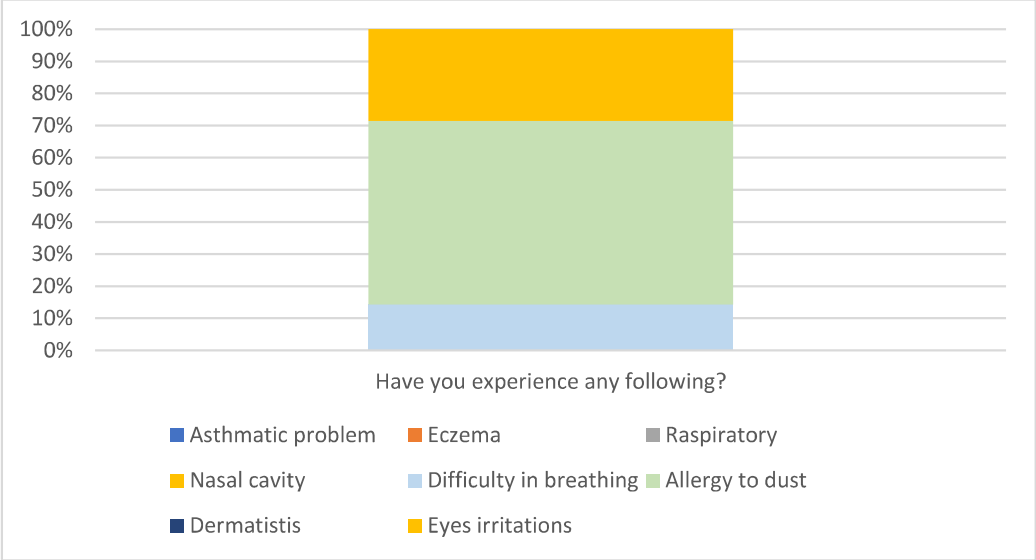


Figure 45: Exposure to wood dust health problem in sanding area

Exposure to wood dust causes some symptoms first and then it turns to diseases. Based on the previous chart, the target of the below chart is to recognize the symptoms that workers experienced over the past year. These symptoms are related to the different increments of gases in the workplace. Sanding variety types of wood create wood dust and each type has its increment of gas emission to the environment. As an example, the symptoms of exposure to carbon monoxide for a long time are shortness of breath, sweating, heart diseases, dizzying, loss weight, chills, etc. and based on the below chart, the highest ratio of these diseases are related to the emission of carbon monoxide. Workers have experienced chills; shortness of breath is the result of carbon monoxide exposure. Also, blurry vision, irregular sweating, tiredness, heart rate

increment, and blood pressure are the reason for exposure to a high amount of carbon dioxide. As per the below chart, people have experienced these symptoms over the past year. Furthermore, exposure to TVOCs for a long time causes headaches, eyes irritation, throat, and nose irritation, skin problems, and shortness of breath. As per the below chart outcome, people had experienced shortness of breath, headache problems over the past year. The below chart present the experience ratio of symptoms over the past year.

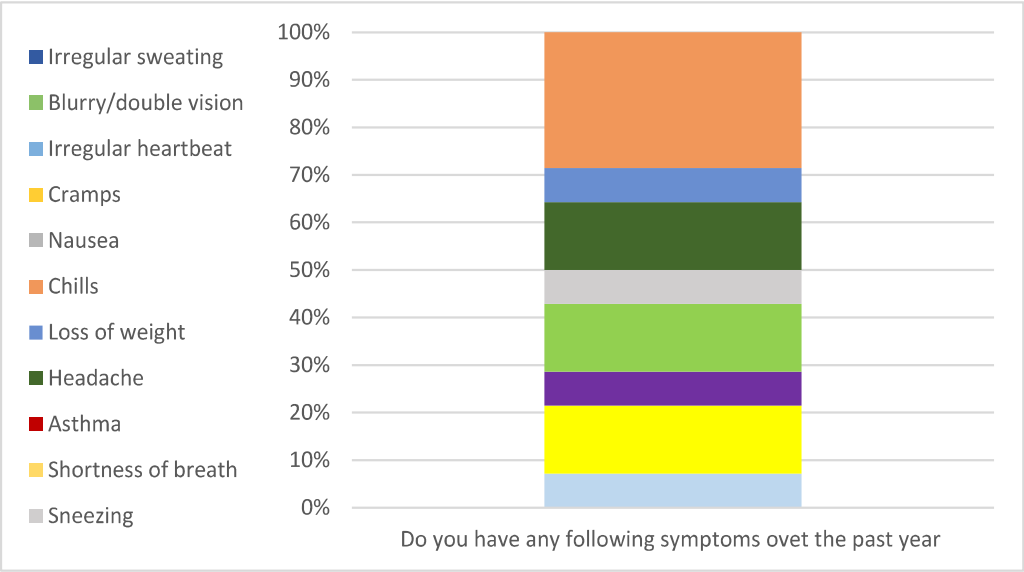


Figure 46: symptoms experienced over the past year

Following the results of the symptoms experienced, workers' sense of health at workplace takes precedence. It is important to know if workers are feeling sick or ill during working hours. Based on the survey result, most of the labors feel fine during the working hours and only 25 percentages of workers rarely feeling ill during the working hours.

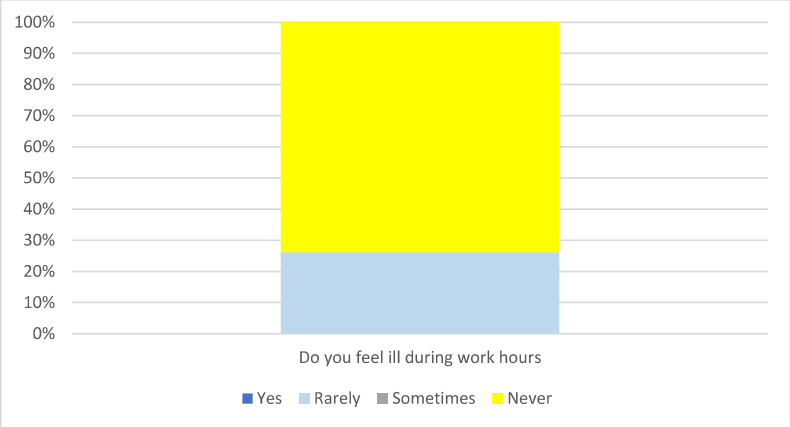


Figure 47: Workers' health feeling during working hours

According to the workers' ill feelings during the working hours, it is important to know whether their sick feeling affects performance during the working hours or not. If their performance is affected by symptoms, they will have serious problems in the near future. Based on the employees' statements, around 75 percentages of the laborers' performances are not affected by their health problem and around 25 percentages of laborers believed sometimes their health problem affected their performance. Below chart represents the survey results.

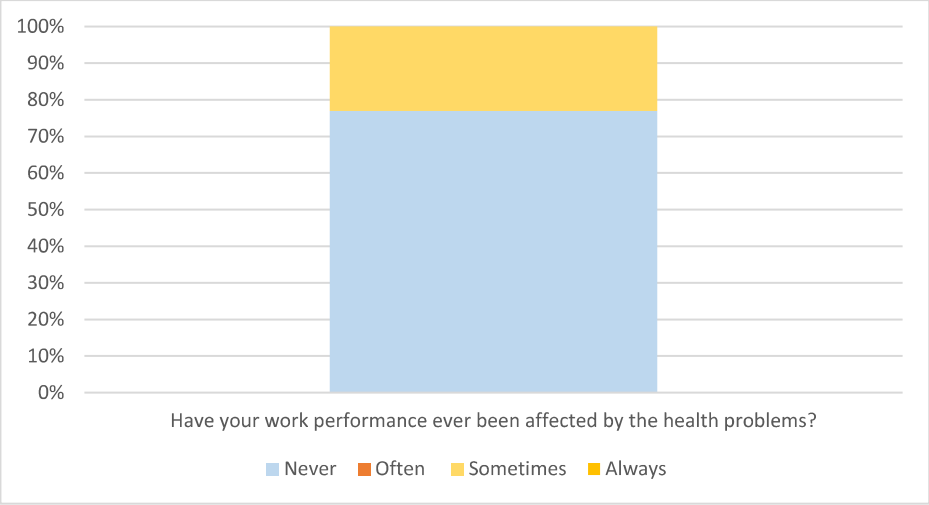


Figure 48:Performance of the labors by the effect of health problems

Another factor that was examined in this questionnaire was in which months the effect of symptoms affect them more. This indicates whether or not the weather conditions have a significant effect on the severity of these symptoms. The summer condition in Dubai is tough. The temperature goes to 45 °C with an average of 90 percentages humidity. During wintertime, the temperature drops to 25 °C with 50 percentages of humidity. Dubai's hot weather starts from the end of March and it continues till October. Based on the survey questionnaire, most of the people around 70 percentages state that the symptoms affect during April till June bothered them more. It shows by starting hot weather or changing the season, the symptoms have more impact on the labors' health condition. Below chart displays the result.

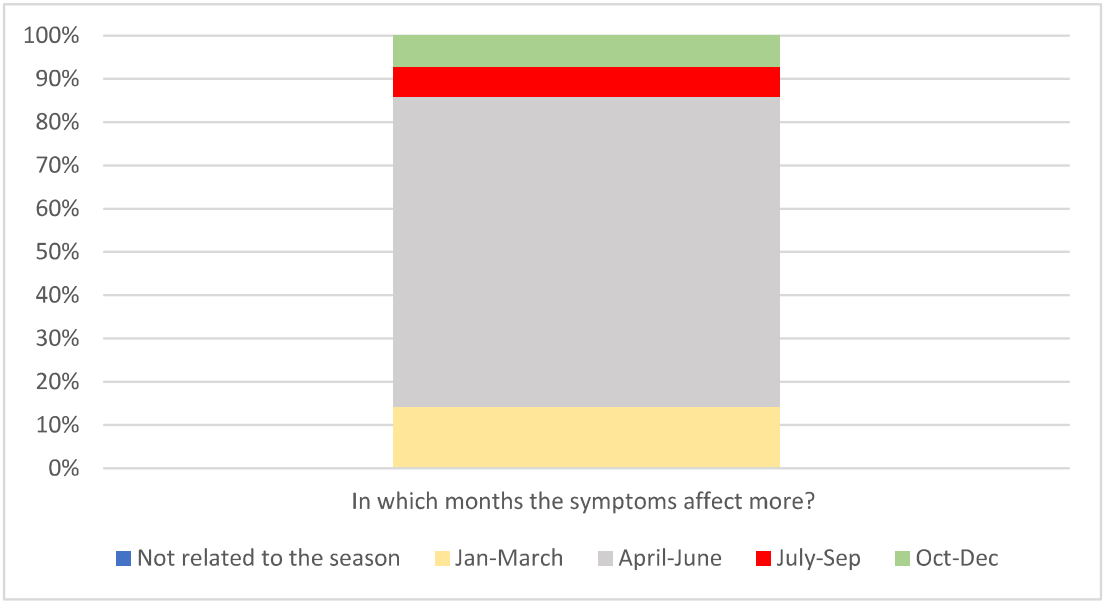


Figure 49:The effect of wood dust symptoms on different months

It is clear that wood dust has an impact on workers' health. Now, the other study that could help to underestimate the source of workers' health problem is to know when the effect of symptoms is higher during the working hours. High amounts of workloads can affect the amount of indoor wood dust emission. However, based on the below chart the ratio of what time in a day (before the break time or after the break time), the effect of wood dust has more impact on their health is almost the same.

The result of this survey indicates that the high effect of symptoms after the break time may be the reason for workloads because employees have a daily schedule to finish their responsibility each day. And the other reason for the high effect of wood dust before the break time can be the overall poor indoor air quality. Below chart shows the result.

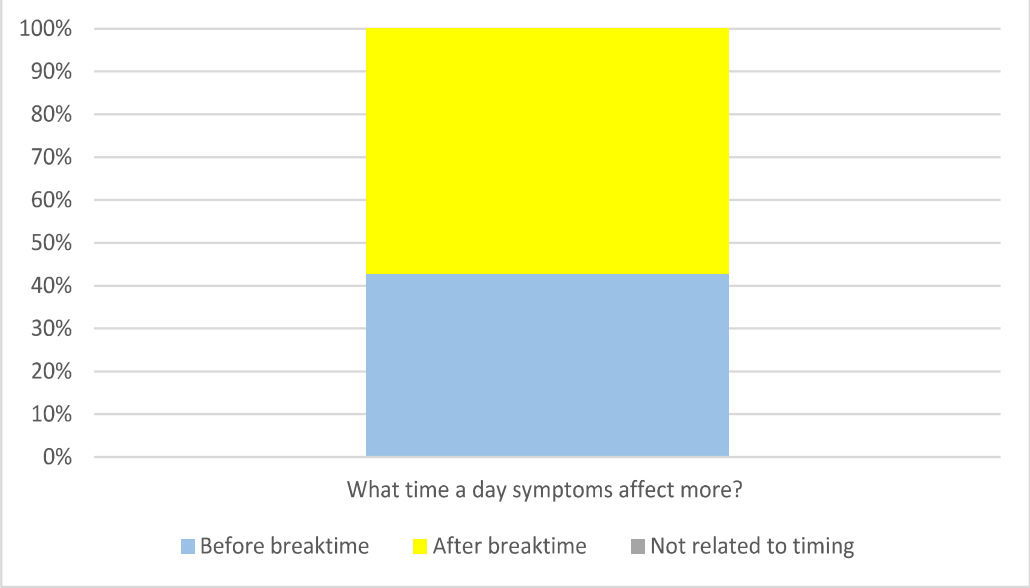


Figure 50:The effect of symptoms by consideration of the time

Another important factor to know is how these symptoms affect workers outside the workplace. The importance of this fact is to realized if the exposure to wood dust have a temporary effect

only during the working hours or this sympotoms became part of their health conditions. Based on the survey outcome more than 80 percentages of people believed their symptms remain the same outside the factory and around 17 % belived they feel better outside the factory.

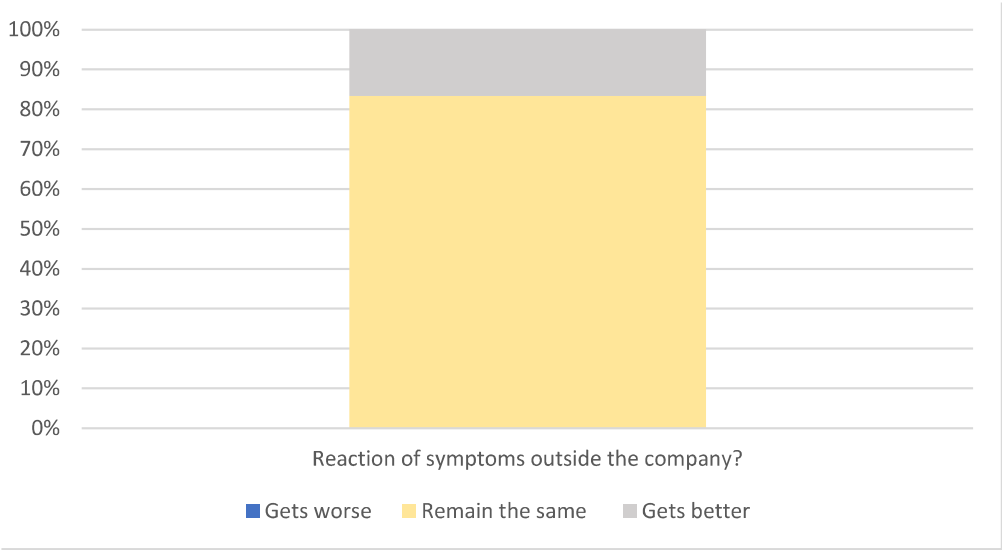


Figure 51:Reaction of symptoms outside the factory

Based on the gathered information of the survey about the reaction of symptoms inside the factory in comparison with outside the factory, it is necessary to comprehend if these symptoms made workers leave the office earlier, or made them stay home. The majority of workers approximately 78 percentages, stated that they never left office because of illness. However, around 10 % expressed that they sometimes left office earlier or stayed home, and around 12 percentages of employees, often affected by symptoms to leave the office earlier. The below chart represents the statement.

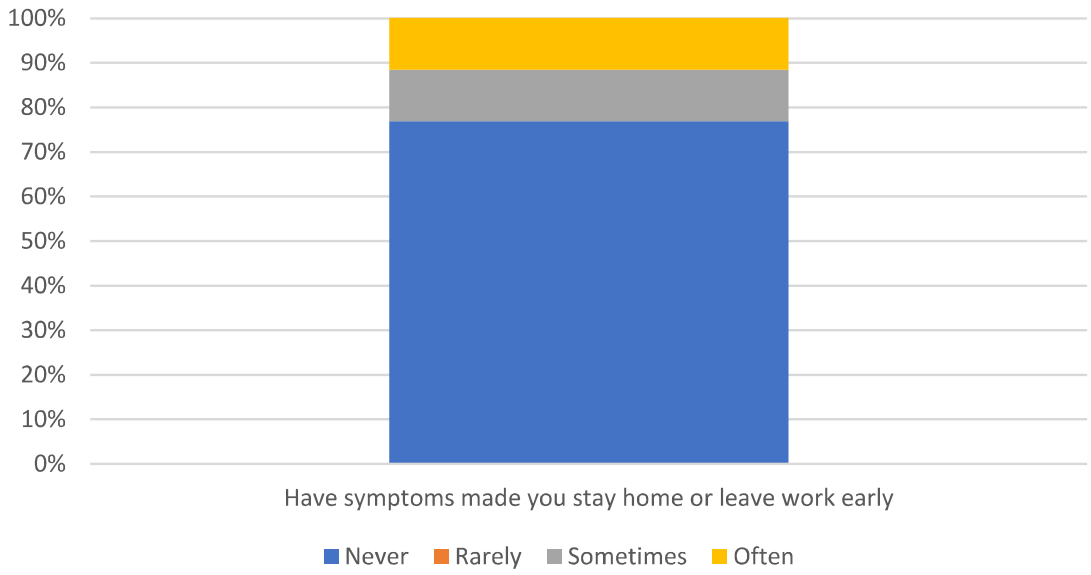


Figure 52:Reaction of symptoms that made workers stay home or leave the office earlier

This survey handed over during April when the weather condition in Dubai was still good and that it was not considered a summer month. According to figure 49, the highest amount of wood dust exposure and its effect is related to April till June. The second season of the high amount of wood dust exposure is related to Jan to March, which is around 12%. The amount of wood dust exposure in the first season is very less in comparison with April to June with around 70 %. To receive more detailed information about the effect of wood dust symptoms, it is necessary to know if the exposure to wood dust affects people's life deeply over a certain month to get sick leave. Based on the below chart, most of the workers around 85 % stated that over the March time, they did not get sick leave and around 15 % of laborers got sick leave because of the effect of wood dust exposure and their symptoms. Below chart shows the ratio of sick leave during March.

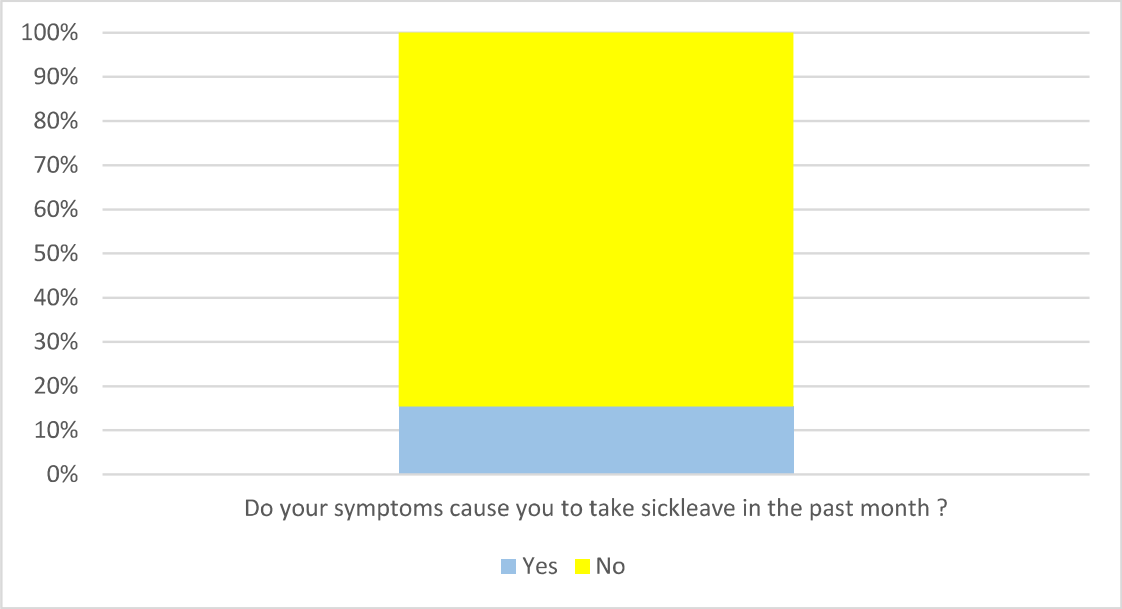


Figure 53: The ratio of sick leave during March

Another reasonable factor of exposure of wood dust is the percentage of cleanliness in the workplace. And how many times per day the workplace gets clean. When the amount of creation of wood dust is high, workplace should get clean regularly. Otherwise, the high amount of wood chips stay on the airborne and it impact workers' health conditions. Knowing the fact that if the workplace is clean and how many times in a day workers clean their workplace can be a great help to proposed solutions to prevent the spread of wood dust in the air.

All the workers expressed that they clean their workplace 1 to 3 times per day, which means they clean their workplace every 3 hours. Chart 54 and 55 represents respectively the cleanliness of the workplace in the point view of labors and how many times per day they clean theirworkplace.

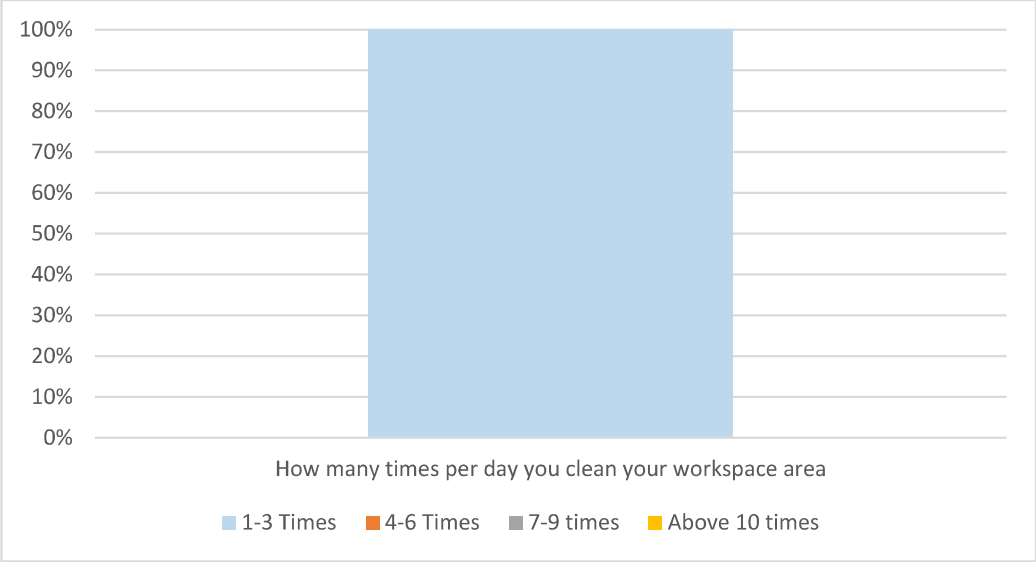


Figure 54: The stated of labors about the cleanliness of their workplace

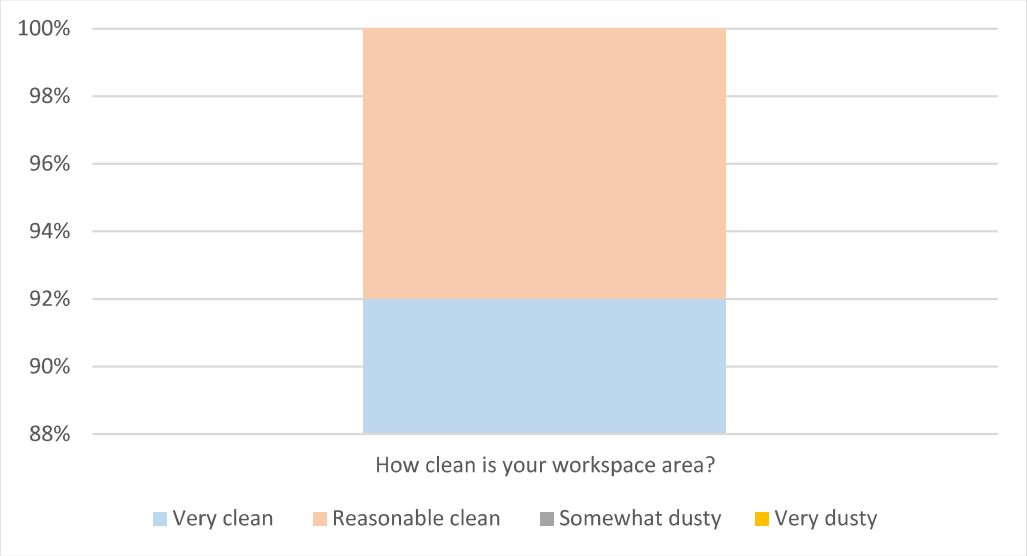


Figure 55: The number of times workers clean their workplace during a day

Chapter 5: Conclusion

Research Summary

Joinery factory has been selected for this research because construction in the UAE is growing quickly and reciprocally. Particularly, demand for joinery works is high. Creating different joinery products needs a lot of effort for the carpenters and laborers including sanding natural wood or wood-related products to build doors, wardrobes, vanity, kitchen cabinets, or any other woodworking products. Therefore, wood dust results from these woodworking activities. A considerable amount of woodworking generates more wood dust, which can affect the health of workers in these sectors. Different kinds of woods affect the number of gas emissions such as carbon monoxide, carbon dioxide, ozone, TVOCs, and more. Long time exposure to wood dust elevates the health risk especially for the people who are in contact with sanding wood, machinery, and assembling a final product. Wood dust causes various symptoms such as irritation of eyes, throat, and skins, sneezing, irregular heartbeat, etc. It is also associated with lung and nasal cancer. Workers in this field have a fundamental role. Thus, their health is an important aspect of each joinery company.

Most studies are generally about indoor air quality in wood processing companies however not many are found in regards to joinery companies. Furthermore, there is no research about the indoor air quality of UAE based joinery or wood processing companies. The findings from this research are beneficial for the joinery industry in UAE.

The following short term conducted research occurred in one joinery factory at the mixed complex area in Dubai. The age of the building is about six years old with fifteen thousand square/m area. It consists of two floors and a front garden yard. Production areas are located on

both floors and there is a separate door for the factory team at the entrance. There are openings on both sides of the ground floor of the factory to ease the loading and unloading of the raw materials. The ground floor is mostly related to the raw material storage and the carpentry section and the first floor is focused on covering the final production line.

The first conducted research was completed as a walkthrough investigation to evaluate and analyze the measurable parameters that affect the indoor air quality of the selected joinery company. The second conducted research was focused on monitoring the chemical indoor air contaminants (Co2, Co, TVOCs, Ozone, and PM) during nineteen consecutive days. Lastly, the third conducted research was a survey questionnaire between labors in selected workstations in the factory, where the number of air contaminants (wood dust) is higher than in other sections.

According to the first walkthrough investigation, some sections in this factory are equipped with suitable types of machinery. Some of the sanding tables are connected to the central vacuum dust collector and a specified company is collecting the dust when the vacuum is filled. Based on the survey questionnaire, they stated that they use masks and eye protection during work time. Unfortunately, however, after observing the workers it seemed that this was not true. Most of the labors do not use facemasks, gloves, and eye protection during the working hours. Besides, they spend all their working hours inside the factory, even during their one-hour break; and they also sleep inside their workstations on the floor. Sleeping in an area containing wood dust can certainly increase the development of health problems. Furthermore, they use dry sweeping to clean their workplace, and dry sweeping can spread even more existing wood dust in the air. Even though there is a curtain wall at the entrance of the sanding area to protect the wood dust from spreading to other sections, the curtain wall is not activated every single day. There are windows on the east and west side of the factory but they are almost always closed during the

entire year. Therefore, natural ventilation is only happening during other entrances such as doors and staircases.

Based on the overall conducted findings and measurements of carbon monoxide, carbon dioxide, ozone, TVOCs, and PM, the emission of these gases has fluctuated in most of the working days whereas the emission rates of other gases in non-working days are less than working days.

Many factors affect the emission of gases such as the usage of different types of machinery, different types of woods, cleaning methods, and more. These result in a high number of particulate matter and indoor air quality. The working capacity can also affect the high amount of gas emissions. Labors have a schedule to finish their work and nonflexible due dates, thus sanding a large number of woods produces more particles in the air. In summary, measurement of different gases was successful except TVOCs due to the calibration of the measurement tool. Completed detailed explanations of the reason for the increase in emissions are available in each section. As a result, the overall measurements of chemical gas emissions are below the standard level except for ozone emission and carbon monoxide. These were higher than the standard level in some days.

The measurement summary of carbon monoxide, carbon dioxide, ozone, and PM is explained in this sequence; Based on the ASHRAE Standard 62.1-2016, the standard level of carbon dioxide concentration in indoors should be below 5000 ppm and the maximum level of carbon dioxide emission in this factory is 2350 ppm. According to the OSHA organization, the standard level of carbon dioxide emission is 50 ppm within 8 working hours. The mid-level of carbon monoxide emission consider between 51-100 ppm (OSHA, 2019). During these nineteen days measurements, the level of carbon monoxide emission was below the standard level except

for two days that the carbon monoxide emission was 57 and 58 ppm during an hour, which is categorized in mid-level emission rate. The average ozone emission in 8 working hours should not exceed more than 0.1 ppm (OSHA, 2019). In this research, the level of ozone emission was below the standard level except for one day, which was 0.4 ppm within one hour. The average standard level of PM 2.5 is 35 mg/m3 in 24 hours and 15 mg/m3 on an annual base. The standard level of PM10 is 150 mg/m3 in 24 hours and an annual based standard level is 50 mg/m3 (EPA, 2020). Based on the gathered information, the maximum PM2.5 level was 12.29 mg/m3 in one day, which is below the standard level. Based on the collective data the reason for the rise of exposure in the joinery factory was found. This measurement happened during the wintertime when the air temperature is pleasant and airflow is adequate. This measurement should also occur during the summertime to achieve a reliable result. Most of the laborers complained about the high level of air temperature and the humid weather condition in summertime. Thus, the explanation below from the questionnaire results shows that their disease symptoms are affected more during summer. The following recommended devices can help to decrease the number of emissions.

According to the overall survey questionnaire results, workers do not have enough information about wood dust and chemical hazards. Also, the employer has not educated them well enough to know how to protect themselves from developing health problems. Considering that this study has been conducted in wintertime thus the best weather condition, the majority of labors stated that the signs of their symptoms are much higher during summer, especially from April to June. With the start of summer, the lack of ventilation systems and low airflow increases air contaminants and development of symptoms from the effect of wood dust on workers greatly.

With consideration of seasonal measurements, the effects of symptoms in comparison with inside the factory versus outside the workplace are the same. Most of the labors are working in this company for a long time and within the same sections at the factory, as well as the majority of them are in their twenties. This should mean that their immune system is usually stronger than mid-age and old people. However, based on the survey outcomes, some of the labors have health problems such as an allergy to dust, irritation of eyes, difficulty in breathing, shortness of breath problem, irregular heartbeat, irregular sweating, chills, headache, blurry in vision, and weight loss.

It is clear that due to the long-time exposure to different gas emissions, these symptoms have turned into a disease. Thus, the quality of the air is not sufficient in this place and consideration must be made to reduce the health risks.

The analysis and evaluation of results investigated at this joinery factory demonstrated the relationship between indoor air quality and the impact on the health and performance of the labors. This investigation must happen in all joinery factories across the UAE regularly to improve and maintain the quality of indoor air in all their sections. The main problem addressed in this research includes a lack of awareness of employers to the poor indoor air quality. Most likely, this is a real picture of most joinery companies in the United Arab Emirates. To get positive results in all joinery companies, it is necessary to conduct other researches and share the approved results with other manufacturers so that others are aware of the benefits of increasing indoor air quality.

The health and workplace satisfaction of the laborers should be of particular importance. To achieve the desired indoor air quality management, certain criteria must be set. According to the gathered information in this study, the author would like to propose the following: Firstly,

acknowledging all aspects of the factory's indoor air quality and its subsequent impact on employees' health and performance encourages a lot to create a healthy indoor atmosphere.

Besides, setting strict policies and having a team to educate and remind them from time to time about the harmful effect of indoor air quality if they do not follow the rules. Secondly, providing high standard and latest types of indoor air tools and machinery with advanced technology to measure the indoor air contaminants, as well as different types of chemical and biological air contaminants that need to be measured to achieve a comprehensive assessment of indoor air quality and the effective relation with the health and performance of the labors. Thirdly, the exact baseline should be specified. The UAE government may establish special preliminaries based on the different weather conditions that exist here in comparison with existing standards from WHO, EPA, ASHRAE, and more. For the construction of new factories in the UAE or similar weather conditions and geographical areas, discussed criteria should be considered. Fourthly, updating production tools with fewer emission rates can be very effective to reduce the airborne particles. Explanation of effective tools for reducing wood dust in the air is given in the recommendations section. To achieve better indoor air quality results, implement alternative tools which reduce wood dust, and then compare the measurements. Lastly, the ventilation system has a great impact on the number of particles in the air. Measuring the ventilation system will provide better results.

Recommendation:

There are a couple of factors that increase the level of wood dust in joinery factories. These factors resulted in the high amount of exposure in the workplace where the labours spend an average of 9 hours per day and long-time exposure to different gases decisively has a direct relation with the health and performance of the labours.

Factors that increase the spread of wood dust in this factory include the irregular maintenance plan, improper usage of power tools, inappropriate cleaning methods, usage of inappropriate hand tools, and failure of production methods, and insufficient training sessions for workers to know about the failure to follow the health tips while at work and control of the environment.

The suggested recommendations to improve the indoor air quality and potential reduction of wood dust exposure at this joinery factory includes the following: first, workplace environmental control, from regular maintenance services to functional cleaning methods are the significant methods of wood dust reduction. Maintenance in the joinery factories plays a vital role to keep the workplace safe and increase the quality of the indoor air. A schedule of a proper maintenance plan can improve indoor air quality. Alternatively, dry sweeping contribute to the high exposure of wood dust emission on airborne. Replacement of cleaning methods from dry sweeping to the latest and newest technology, (industrial vacuum) can effectively decrease the wood dust emission. The second recommendation is to place the vacuum extraction to all hand tools, as the hand tools and power tools categorized in the peak personal contribution of wood dust exposure. Besides, alternative usage of orbit sanders and routers to hand sanders have an influential result in a reduction of wood dust emission. Third, all the used tools should connect to the exhaust ventilation system. The fourth recommendation is to equip all the normal sanding

tables to the downdraft table. Downdraft tables filter the produced wood dust to protect the workers' breathing area. Also, the connectivity of the downdraft table with the vacuum extractor has an impressive impact on the decrement of wood dust emission. The fifth recommendation is to compatible modification of all used hardware with suitable ducting connected to the dust extractor. The sixth recommendation is to consider a daily production plan for workers to prevent high production volumes before the deadline. These functional factors can decrease air pollution in the factory.

Meanwhile, some educational factors help the workers and the employer to have a healthy ambient. The seventh recommendation is to educate all the labours with the training session about the health hazards and the effect of improper usage of facemask and eye protection. This training should be regularly and update the labours to know how to use preventative ways to protect them. The eight recommendations are related to occupational hygiene. All labours asleep over the wood dust on the floor during their break time, which can increase their contact surface with the wood dust and inhaling air particles when they are asleep. Finally, a compulsory full check-up with a doctor regularly can assist the employees to notice their symptoms sooner to prevent critical health risks.

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