Science, Technology & Public Policy
2017; 1(2): 29-35
http://www.sciencepublishinggroup.com/j/stpp
doi: 10.11648/j.stpp.20170102.11

Proposed Design of a Mechanical Ventilation System for an Electronics Company

Teodoro Jimmy Beato

Faculty of the College of Engineering, University of Perpetual Help System – Laguna, Biñan, Philippines

Email address:
jimmy_teodoro@yahoo.com

To cite this article:
Teodoro Jimmy Beato. Proposed Design of a Mechanical Ventilation System for an Electronics Company. *Science, Technology & Public Policy*. Vol. 1, No. 2, 2017, pp. 29-35. doi: 10.11648/j.stpp.20170102.11

Received: March 11, 2017; **Accepted**: May 13, 2017; **Published**: July 31, 2017

Abstract: Proper ventilation system in any establishment must be observed for the convenience and occupational safety of the occupants. In this study, an indoor air quality and carbon dioxide level in the main production area of a semiconductor company was assessed within an eleven-hour observation. Based on data analysis, it was evident that the electronics company did not comply with the indoor air quality standards. Through velocity method, a mechanical ventilation design with specific duct sizes and needed blowers were made. This proposed design can be applied to other type of buildings such commercial or industrial type, schools, etc.

Keywords: Indoor Air Quality, Ambient Air, Industrial Space, Mechanical Ventilation, Velocity Method

1. Introduction

Indoor air quality (IAQ) in the workplace is one of the problems that requires attention these days. This air quality of the indoor environment can profoundly affect the health, comfort, performance and productivity of building occupants.

The quality of indoor air in the workplace is important not only for workers' comfort, but also for their health. The Occupational Safety and Health Administration recognizes that poor indoor air quality (IAQ) can be hazardous to workers' health. [1]

More than 80% of the people in urban regions and about 98% of cities in low and middle income countries have poor air quality according to the World Health Organization. [2]

One of the indicators of poor indoor air quality is Carbon Dioxide (CO_2). CO_2 can be used to indicate the indoor air exchange rate. The lack of air exchange means higher levels of CO_2. High levels of indoor particulates can also be an indication of poor air quality. Due to the lack of fresh air, air circulation, and air filtration, the level of contaminants can be higher in some parts of a semi-enclosed space. [3]

To combat this poor air quality, inspection of the ventilation systems should be conducted at the workplace, look for blocked vents, excessive dust on air vents, intake air supply vents close to loading docks or busy streets, standing water within the HVAC system, recent renovations without appropriate changes to the HVAC system and intake and exhaust vents that are too close together and demand employers to take action on testing and fixing inadequate ventilation systems. The HVAC System (Heating, Ventilating and Air-condition) of a building supplies and removes air either naturally and/or mechanically to and from a space. HVAC systems consist of mechanical parts which should provide air to building occupants at a comfortable temperature and humidity that is free of harmful concentrations of air pollutants. However, HVAC systems can have significant problems such as only a limited amount of fresh outdoor air actually gets into the workplace. Most HVAC systems only allow for 20 per cent outdoor air mixed with 80 per cent re-circulated indoor air in sealed buildings, HVAC systems are limited in controlling contaminants because they don't remove them. Instead, contaminants are mostly spread throughout the workplace for long periods of time, any HVAC systems have fixed settings that don't allow workers to control ventilation rates.

HVAC systems most often consist of mechanical parts which should provide air to building occupants at a comfortable temperature and humidity that is free of harmful concentrations of air pollutants. [4]

The author used mechanical ventilation instead of natural ventilation. It was supported by this statement: Natural ventilation has been shown to maintain pollutant accumulation below current standards governing IAQ but is subject to significant airflow variability. In contrast, the mechanical ventilation was shown to result in lower levels of indoor pollution and provide tight control of pollutant levels. [5]

With this in mind, self-assessment of an indoor air quality was done in an Electronics company located in Tanauan City, Province of Batangas, Philippines. It is a Japanese manufacturing company of electronic devices.

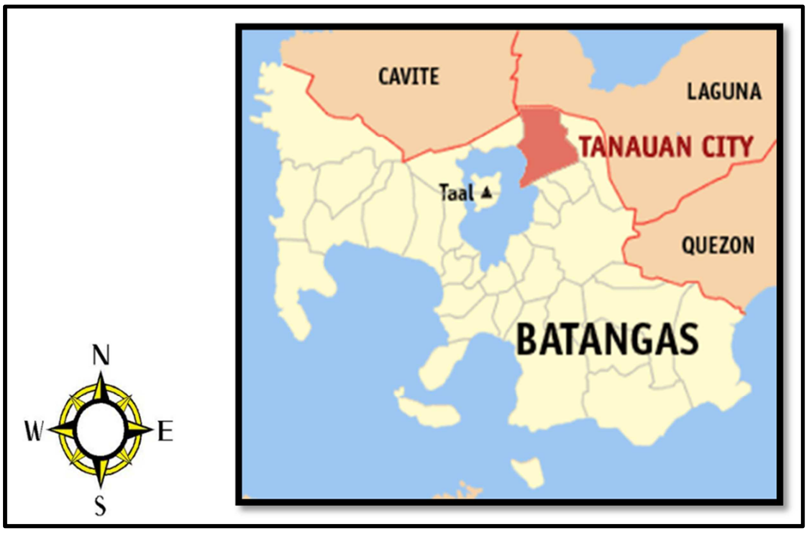

Figure 1. *Site Map, Location of Electronics Company.*

The above figure shows the location of Tanauan City in the province of Batangas. The city share its borders with Calamba City, Laguna to the north, Tagaytay City, Cavite to the northwest, Talisay, Batangas to the west, Santo Tomas, Batangas to the east, and the towns of Balete and Malvar to the south.

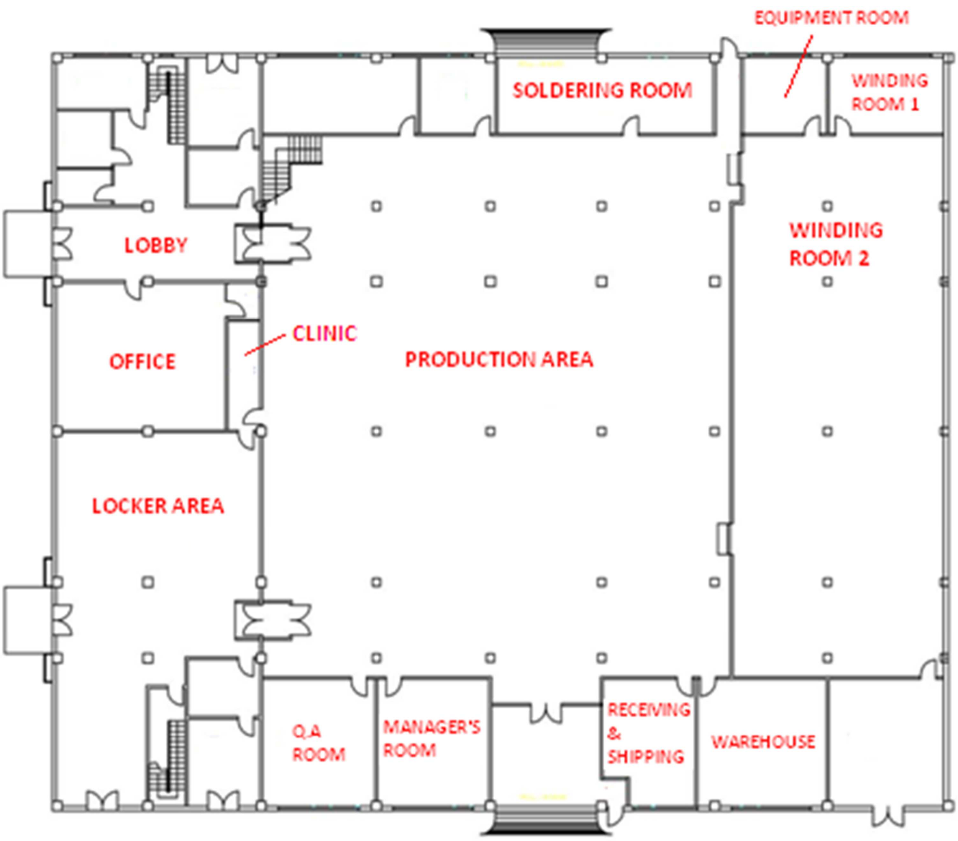

Figure 2. *Floor Layout of an Electronics Company.*

The above figure shows the actual floor layout of the company. As you enter the Winding Room, hotness can be immediately felt due to simultaneous operations of different machines. It can be noted that there was no introduction of fresh air and no exhaust of stale air. By estimation, it was also noted that the height of the ceiling is lower than the usual ceiling elevation. The feedback from the initial observations became a lead to study company's Indoor Air Quality. To broaden the investigation, this study seeks to answer the following objectives such as to: (1) assess the indoor air quality in an electronics company through observation and field measurements of parameters such as temperature, relative humidity, carbon dioxide concentration and air velocity; (2) analyze the results of the assessment through the application of acceptable Indoor Air Quality and Thermal Environmental Conditions for Human Occupancy under the ASHRAE Standards; and (3) design a mechanical ventilation system for the electronics company based on ventilation principles, methods of duct design and fan selection.

The data gathered was then analyzed if it's in compliance with the set standards of ASHRAE 62.1 (Acceptable Indoor Air Quality). Obviously, "requirements" must be met to claim compliance with the standard.

The visualization of the mechanical design will be provided through AUTO-Computer Aided Design. The mechanical ventilation system design will cover the calculation of duct sizes and fan selection based on Trane Air-conditioning Manual.

Theoretical and Conceptual Framework

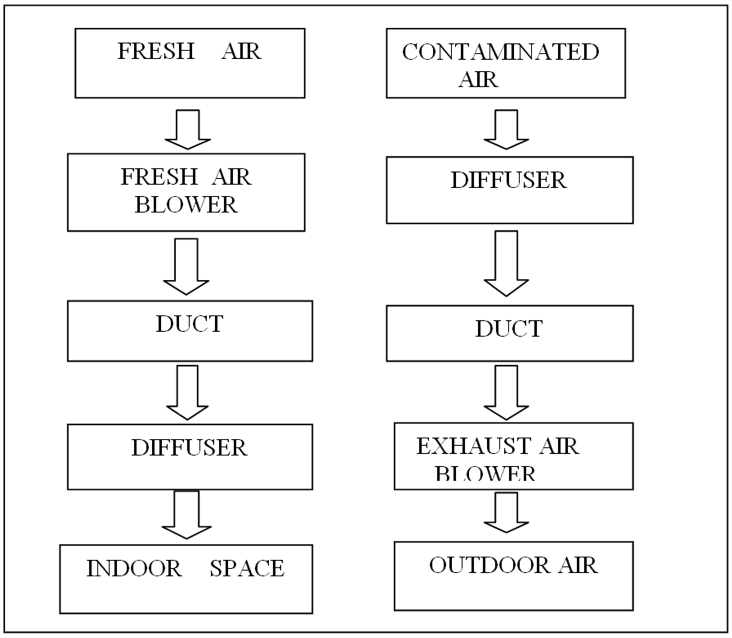

Figure 3. *Block Diagram of Air Ventilation.*

Outdoor or fresh air, as shown in Figure 3, enters the system and is driven by a blower towards the duct then it is diffused (to slow air velocity and enhance its mixing into the surrounding air) at the indoor space where air is being contaminated by occupants of the building or other sources. Afterwards, it is diffused at the duct and drives out through an exhaust air blower towards outdoor air.

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. Understanding and controlling common pollutants indoors can help reduce your risk of indoor health concerns [6]

Indoor air quality and thermal comfort affects working performance and efficiency, particularly for those who work in the office for prolonged periods. Poor air quality even compromises human health of the staff in the office. [7]

Ray & Leung [8] cited WHO 2014 report. Globally, one in eight deaths is caused by air pollution. Over half of those deaths, 4.3 million, result from indoor air pollution. Conversely, improvements to indoor air quality have documented benefits. They also stated that nearly 73% of global deaths from air pollution are in Southeast Asia and the Western Pacific. Radon is a prominent cause of pollution of indoor air; other significant sources of indoor pollution include tobacco smoke and fumes from the combustion of various fuels, as well as asbestos fibers from old insulation and chemicals from furnishings, rugs, and cleaning materials. This article is concerned primarily with outdoor air pollution caused by human activities. [9]

Carbon dioxide concentration is considered to be a primary indicator of "good" indoor air quality. Bad air quality due to concentrations of CO_2 which is too high causes tiredness and lack of concentration and can even bring about illnesses. Therefore should the CO_2 concentration generally not exceed 1,000 ppm. Values of 700 to 1,500 ppm can be viewed as the "reference range"(EPA, 2016).

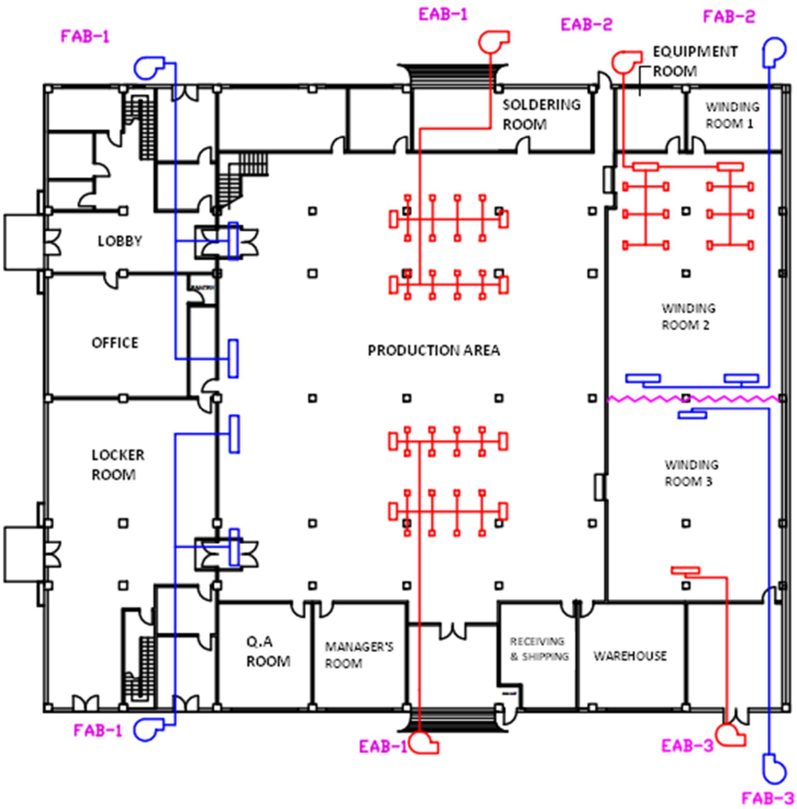

Figure 4. *Initial Duct Layout.*

Figure 4 shows the initial ducting plan for each area where ventilating air will be distributed throughout the system. Ducting sizes vary depending upon the requirement of indoor quality air and space volume of each area.

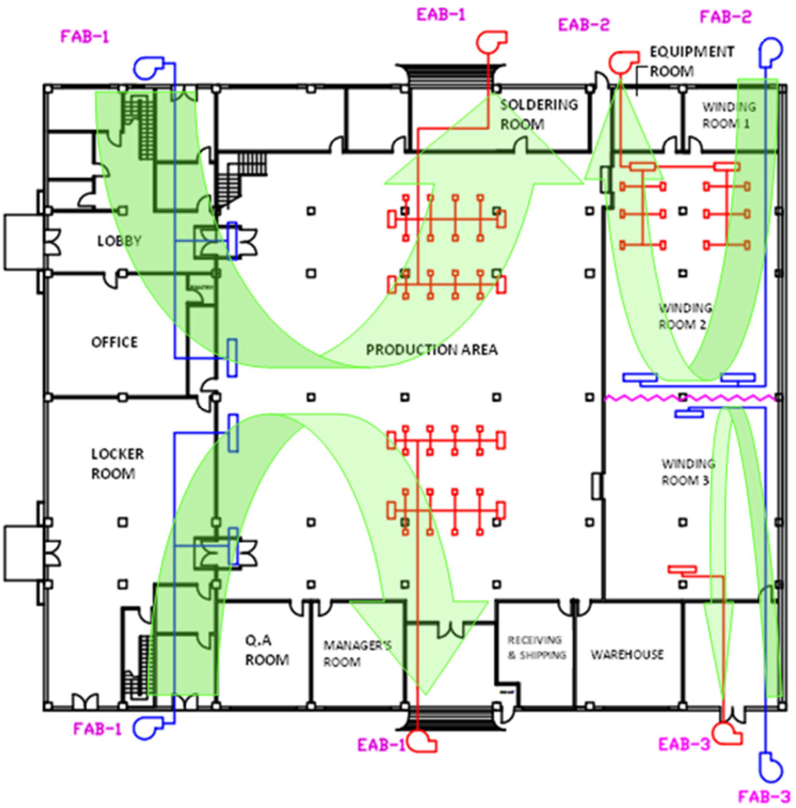

Figure 5. *Desired Air Movement.*

The airflow shown in Figure 5 will be the orientation of the run of air inside the company. The arrow shows the introduction of fresh air that were brought in and where the stale air will be drawn out.

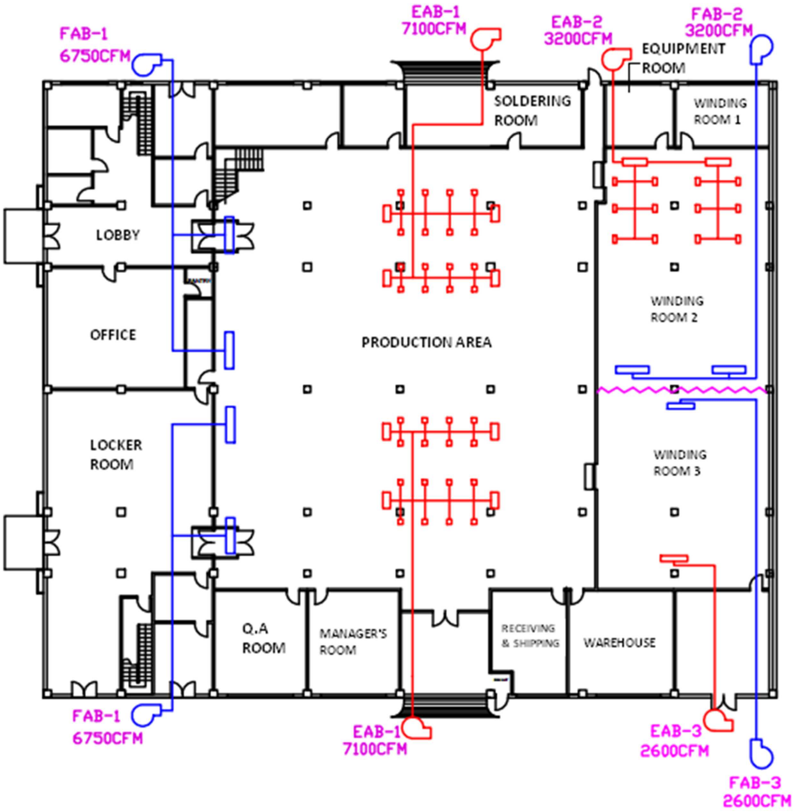

Figure 6. *Final Duct Layout with Fan/Blower Capacity.*

This figure shows the final duct layout with fan/blower capacity to improve the ventilation system of the whole production area. The capacity requirement is expressed in cubic feet per minute (CFM). It is computed based on the amount of indoor air needed and the recommended velocity of air inflow.

2. Method

2.1. Observation

Informal observation was conducted during data collection for validation purposes. In this study, a walkthrough investigation at the semiconductor company was conducted to gather data on CO_2 levels, airflow, dry bulb temperature and relative humidity which will serve as indicators of good indoor air quality within an eleven hour observation. An eleven (11) hour observation was done to gather pertinent data and come up with a design of mechanical ventilation system in each specified area. Air volume was computed at each room with proper air change required in different workplace. Employees working within the area were also considered for in maintaining indoor air quality in which proper air volume for each person was considered. Along with these data and the floor plan, layouts of duct system with the desired air movement were drawn by the use of Auto-CAD software. Negative pressurization was chosen to ensure that the contaminants were properly brought out of the company. Duct design was brought out by using Velocity method.

2.2. Interview

One way of gathering data was by conducting an interview with an authorized personnel of the company regarding the assigned workers for each area of the production department. Through this method the number of persons in each area was taken for they are contributors in the production of CO_2 which was one of important parameters in assessing indoor air quality

2.3. Questionnaires

Other necessary data which were not obtained through observation and interview were done through this method

3. Result

During the survey, it was observed that ten out of fifteen rooms showed non-compliance within the set standard of 5000 ppm CO_2 level [10]. The QA area attained the highest level of CO_2 with the reading of 6257 ppm to 8276 ppm with the maximum number of 23 occupants. The second area that showed the highest CO_2 level is the production area, which holds about 400 persons, displayed 6878 ppm.

Table 1. *CO_2 Reading in each Area.*

Area		Highest CO_2 reading (ppm)	Time	Lowest CO_2 reading (ppm)	Time
1	LOBBY	3505	3:15 PM	648	6:30 PM
2	OFFICE	5196	4:30 PM	4414	6:35 PM
3	PRODUCTION AREA	6878	9:40 PM	3266	8:36 PM
4	CLINIC	6425	2:45 PM	3321	8:42 PM
5	SOLDERING ROOM	2749	1:42 PM	1004	11:35 AM
6	EQUIPMENT RM.	5321	10:05 AM	1859	7:40 PM
7	WINDING RM. 1	5380	11:45 AM	564	10:10 AM
8	WINDING RM. 2	5527	10:20 AM	1665	6:58 PM
9	WINDING RM. 3	5857	10:30 AM	684	7:56 PM
10	WAREHOUSE	6225	10:35 AM	4439	9:07 PM
11	RECEPTION	4399	10:40 AM	2983	2:00 PM
12	MANAGER'S RM.	5984	10:45 AM	3806	9:09 PM
13	Q. A ROOM	8276	5:04 PM	6257	9:11 PM
14	LOCKER ROOM	3068	10:55 AM	788	9:13 PM
15	CANTEEN	1424	11:10 AM	839	5:25 PM

Table 1 shows that the Production Area and the Q. A Room had the highest concentrations of Carbon dioxide. According to ASHRAE Standard 62.1 -2016,"Ventilation for Acceptable Indoor Air Quality", CO_2 concentrations greater than 5000 ppm can pose a health risk. Since carbon dioxide was produced by human respiration, the amount of carbon dioxide can be easily used as an indicator of the adequacy of fresh air ventilation in occupied buildings. The ASHRAE standard requires that sufficient fresh air be provided to keep the level below 1,000 ppm. Buildings with insufficient ventilation will range from 1,000 ppm up.

Table 2. *Air Flow, Dry Bulb Temperature and Relative Humidity in each Area.*

Area		Air flow (cfm/p)	Dry bulb temperature (°C)	Relative humidity%
1	LOBBY	26.91	29.71	64.5
2	OFFICE	2.61	30.23	63.29
3	PRODUCTION AREA	2.4	29.37	48.8
4	CLINIC	2.59	27.84	53.61
5	SOLDERING ROOM	21.6	27.34	51.2
6	EQUIPMENT RM.	3.86	27.79	44.81
7	WINDING RM. 1	4.24	27.56	45.82
8	WINDING RM. 2	20.8	28.28	44.89
9	WINDING RM. 3	28.09	29.64	42.1
10	WAREHOUSE	2.28	28.7	51.03
11	RECEPTION	3.62	28.68	53.34
12	MANAGER'S RM.	2.49	23.31	52.04
13	Q. A ROOM	1.57	28.03	45.84
14	LOCKER ROOM	87.08	28.56	71.33
15	CANTEEN	104.82	29.17	63.28

Table 2 shows the average readings of relative humidity, airflow (cfm/p) or ventilation rate and temperature. As can be seen canteen displayed the highest average ventilation rate and together with the four other areas namely, the lobby, locker room, winding room 2 and 3. The remaining ten areas had a ventilation rate between 1.5 – 4.5 cfm/p which was beyond current standard of 15 – 20 cfm/p.

Along with this are the average measurements of temperature and relative humidity with each area surveyed. The average temperature recorded in most areas except the manager's room was 29°C which was beyond the standard thermal comfort. The average relative humidity ranged between 42% - 72% which can be considered comparable to recommended range of 40% - 60%.

Based from the CO_2 level measurements, some areas which surround the main production area showed high values of CO_2 though were not overly populated. This area generates much CO_2 because of the 3 AHU increasing the pressure within the area causing the contaminants to spreads out to nearby rooms. This was the reason why areas such as QA room, clinic and warehouse displayed high CO_2 levels which is not acceptable specially clinic which is expected to be clean and answers employees' health issues.

Some areas displayed high ventilation rate and correspondently showed low CO_2 levels. This only shows that increase in ventilation rate in these areas lowered CO_2 levels.

4. Discussion

During the survey, it was observed that ten out of fifteen rooms showed non-compliance within the set standard of 5000 ppm CO_2 level as per ASHRAE standard. The QA area attained the highest level of CO_2 with the reading of 6257 ppm to 8276 ppm with the maximum number of 23 occupants. The second area that showed the highest CO_2

level is the production area, which holds about 400 persons, displayed 6878 ppm.

This observation was further strengthened by Maertz (2016). According to him, the Occupational Safety and Health Administration recognized that poor indoor air quality (IAQ) can be hazardous to workers' health. Even Ibrahim (2016) stated that due to the lack of fresh air, air circulation, and air filtration, the level of contaminants can be higher in some parts of a semi-enclosed space

5. Conclusion

Based on the data analysis, it was evident that the electronics company did not comply with the indoor air quality standards. One way of improving indoor air quality and thermal environmental conditions for human occupancy is the use of ventilation system. In designing a mechanical ventilation system, there are a lot of conditions to be considered and a lot of standards to be complied. Careful investigations, observations, analysis and other significant parameters were to be considered to come up with the best design to meet the objectives of the study.

To ease and further improve the design, the interested researchers may use other parameters for additional data that may help build ideas to build better design. Measurements of other pollutants or other indoor air quality indicators such as Oxygen level concentrations will help to come up with significant data to be analyzed and be used for design and meeting the objectives of the study.

Prior to the implementation of the design, data result can be obtained and will be significant to the interested researchers as their basis to further improve the design.

References

[1] Maertz, Wesley J. (2016), Basics of Indoor Air Quality in the Workplace, OSHA.

[2] Chidurala, Veena (2016), *Measurement and Analysis of Indoor Air Quality Conditions* University of North Texas, Denton, Texas, USA.

[3] Ibrahim, Ali (2016), A System for Monitoring and Managing Indoor Air Quality and Environmental Conditions. Boise State University.

[4] The National Institute for Occupational Safety and Health (NIOSH) (2017), *Indoor Environmental Quality.*

[5] Montgomery, James F. et al (2014) *Comparison of the indoor air quality in an office operating with natural or mechanical ventilation using short-term intensive pollutant monitoring*. http://journals.sagepub.com/doi/abs

[6] US Environmental Protection Agency, EPA (2016).

[7] Wang, Fu-Jen et al. (2014) *Improving indoor air and thermal comfort by total heat exchanger for an office building in hot and humid climate*. HVAC & R Research, Oct 2014, Vol. 20 Issue 7, p 731-737.

[8] Ray, Stephen & Leung, Luke (2015). *Improving Indoor Air Quality – Lessons from Two Chinese Case Studies.*

[9] Funk & Wagnalls (2016) New World Encyclopedia, *Air Pollution.*

[10] ANSI/ASHRAE Standard 62.1-2016. Ventilation for Acceptable Indoor Air Quality.