ENVIRONMENTAL CONDITIONS AND THE ASSOCIATED HEALTH EFFECTS AMONGST WORKERS OF ELECTRONIC INDUSTRY.

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ABSTRACT

The ambient environment of electronics manufacturing industry is health hazardous. Present study aims to measure environmental conditions with associated health effects on workers of this industry. Parameters of ambient air (temperature, light-intensity, relative humidity, noise) are measured from seven sections (paint plant,foaming, evaporatorfitting, electrical wiring,gas charging, electrical safety testing, and packaging) of the industry. SPSS, IBM 26 is used for data analysis. Chi-square test of association is applied to questionnaire data to analyze the extensiveness of diseases among employees in the working environment. The obtained results are compared with US-OSHA and NEQS standards. Maximum noise level (97.1dB) is at cabinet preassembly section, and lowest value 87.3 in electrical fitting section. Highest values of temperature are 41.8 in foaming section and lowest values are 35.7 in electrical safety testing, exceedingOSHA limits (20-29℃).Furthermore, highest values of relative humidity are 49.9% in evaporator fitting and lowest value 29 in foaming, paint plant and electrical safety testing. Assessment of health impact shows the N=56 workers reported cough, N=47 reported phlegm, N=38 reported chest pain, N=22 reported wheezing and N=23 reported fever in different timings. Environmental monitoring reveals that some of the metrics high in the interior and outdoor environments are also related to health issues and the industry's atmospheric conditions. Workers are uninformed of the health and safety protocols at the workplace and there is a dire need to give training and awareness regarding health and safety issues.

Keywords –Monitoring Parameters, Human Health Impacts, National Environmental Quality Standards, Noise, Temperature.

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INTRODUCTION

The electronics sector emerged in the latter half of the 20th century and is still quite recent. Across the world, the electronics sector employs millions of people. Southeast Asia has become the primary location for multinational electronics corporations from Europe, Japan, and America to shift their manufacturing because of reduced labor costs, financial incentives, and less environmental regulation .The processes, duties, and physical exposures that employees in the electronics sector must endure, are quite varied. High task variety and a broad range of processes are present (Koh, 2004). Electronic elements, electronics for consumers, cellphone service, defense interactions, computer and auxiliary equipment, industrial electronics, and medical electronics are the eight main industry segments identified by the Electronics Industry Association. (Wexler, A.C., and Loecker, J.D2015). From the final assembly of consumer goods to the creation of extremely specialized electronic components like resistors, electron tubes, LEDs, etc., these sectors of the electronic industry encompass a wide range of operations.

The growing importance of the microelectronics industry is noteworthy. Microelectronics is the production of microchips and microcircuits. The manufacture of semiconductors, integrated circuit (IC) assembly, printed circuit board (PCB) fabrication and assembly, and final product assembly are the main procedures in the microelectronics industry.Though it seems to be fairly similar to other manufacturing sectors, the electronics industry differs from them in a few significant areas.The information regarding the electronics manufacturing industry's effects on the environment and human health was reexamined with the help of available literature, interviews, questionnaires, surveys, lab analyses, and observations. (V.K. Nartey.,2012). In addition, when new items are designed, the industry's technology is still developing quickly. Compared to other industries, the electronics industry replaces and changes its processes and equipment more quickly.

The electronics sector is further distinct in that it has withstood considerable automation. (M. Lehnert *et al* ., 2012). The rapidly changing technology often puts workers exposed to hazardous work environment. Air pollution, poor ventilation and light conditions are dangerous for health of workers.). The pulmonary function of employees is hindered by both high and low relative humidity levels in the workplace. OSHA sets a

threshold of 40–60% for relative humidity. (TED 01-00-015, OSHA Technical Manual Directive Number). Several air contaminants are necessary for air monitoring. The primary air pollutants detected at the monitoring stations are carbon monoxide (CO), sulfur dioxide (SO2), particulate matter (PM10), and nitrogen dioxide (NO2) (S.Z. Azmi., 2010). Employers can determine whether the lighting conditions satisfy the needs for particular tasks or work locations by using lux meters, which offer objective assessments of light intensity.

We took into consideration the OHSA requirements in order to monitor light intensity at various locations inside the electronic manufacturing business. These guidelines offer broad suggestions for ensuring proper lighting conditions that support productivity, safety, and aesthetic appeal.

The air pollution in the area is a result of the industrial activities surrounding the electronics manufacturing industry. Particulate matter, sulfur dioxide, nitrogen dioxide, ozone, carbon monoxide, and sulfur dioxide were the criteria used to measure ambient air quality.For efforts to control workers exposure, proper monitoring is need of the day.

Current investigation was carried out due to the increased prevalence of risks to human health and the environment in the manufacturing electronics sector. Nevertheless, there is a paucity of information indicating the detrimental impacts of the electronic manufacturing sector on the environment and the health of its workforce. This study's goals were to assess the health consequences that employees in the nearby electronic manufacturing sector face as well as to examine the study area's environmental conditions, including the air, noise, temperature, relative humidity, and light intensity.

Objectives of the study: The prime objective of the study is to monitor environmental condition of the manufacturing sector of electronics industry. The second objective is to survey prevalence of various diseases stemming from ambient work environment, amongst workers of electronics industry.

MATERIALS AND METHODS

Study Area: XYZ Electronic manufacturing industry located at Multan Road, Lahore district, Province, Punjab was selected to monitor theenvironmental parameters, e.g. noise, air, relative humidity, temperature and light intensity. The geographical representation of map is given below:

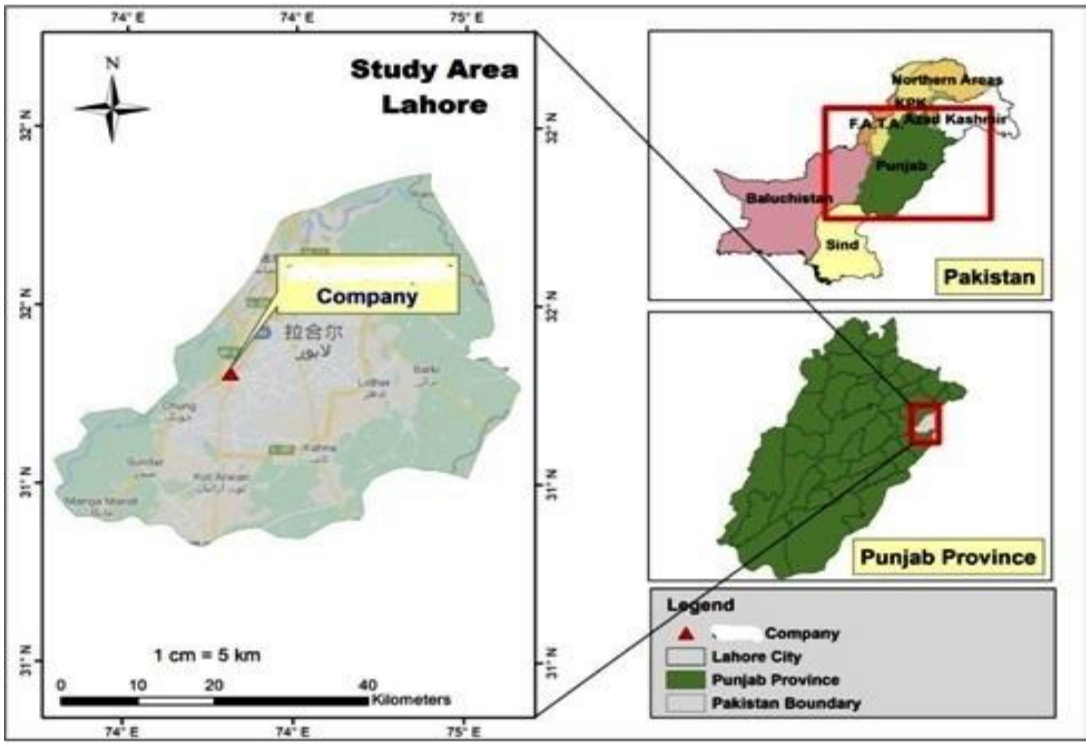

Figure 1 Map of Study Area

Parameters Monitoring: Quality parameters were examined, analyzed, and compared with NEQS to monitor the environment. Temperature, relative humidity, light intensity, noise level, and air quality parameters (carbon monoxide, ozone, sulfur dioxide, nitrogen dioxide, and particle matter were the parameters used to

test the quality of ambient air quality) were all measured. We used thermocouples for temperature, digital hygrometers, for relative humidity, sound meters for monitoring of noise level, lux meter for the measurement of light intensity, and air monitoring stations for the monitoring of ambient air quality. The analysis of these instruments was done through Direct Reading Instruments. Next, the results were compared to NEQS and the fundamental OSHA criteria.

We took three readings from every source and use the following calculation to determine the average: 10.log10 {(logL1/10 + logL2/10 +... + log Ln/10)/n} is the average of L.------Equation 1

The hygrometer was used for assessing the relative humidity in the study area. The relative humidity of the several department. Three distinct locations were used to test these factors. One was located close to the main road. The third one was at the rear of the industry, while the second one was at the warehouse. Except for particle matter, all readings measured were below the NEQs constraints**.**

Questionnairebased interviews: Following verbal permission from the workforce, 50 employees were chosen at random for the survey. Out of fifty employees, all of whom are male. Participants in the study had to have five years of experience working in the electronics manufacturing industry. Every employee verbally consented to take part in the study based on the different stages of employment in the electronics manufacturing sector. Regarding the effects of the electronic manufacturing sector on the health of the interviewees, many questions were posed.

Statistical Analysis: Fordataanalysisofdisease among workers in electronics manufacturing industry, SPSS, 20 software, IBM (Leech *et al* . 2014) version were used for the assessment of diseases. A Chi-square test of association was applied to questionnaire data to analyze the extensiveness of diseases among employees in the working environment of electronics manufacturing industry. There was a 0.05 level of probability.

RESULTS AND DISCUSSION

In Pakistan, the electronic sector is thought to be one of the main causes of public health problems. Ambient air quality was done by Digital Meter for gaseous emissions testing in air and Flue gas Analyzer and noise levels at the proposed industrial site were monitored to evaluate the quality of the air. Temperature was also monitored by thermocouples in different units of industry. Light intensity was also monitored by lux meter and compared with the OSHA LUX standards. Monitoring of light was done by sound level meter

Noise Monitoring: The proposed national environmental quality standard for noise in industrial area is 75 dB (A) for 8 hours working period at day time in a workplace. The resultant values of noise indicated a high level of noise that exceeds the permissible limits set by OSHA i.e., 85Dba. The noise level observed in different units of industry like ABS liner, foaming unit, evaporator fitting, electrical wiring, welding, gas charging and cabinet preassembly. All these units of electrical manufacturing industry show greater values than set values by OSHA standards. All these units have non-compliance status that is highly hazardous to employees working in industry. The various units' noise levels are shown on a graph and listed below (figure 2).The noise level in the several departments was higher than usual, which might have been reduced with good machinery maintenance. Units having a noise level higher than 85 dB (A) should receive additional scrutiny. High temperature in the working environment can cause heat stress.

Table 1 Monitoring of Noise in different sections of electronic manufacturing industry

Sr. no	Unit(s)	Level of Noise Recorded dB(A)	The OSHA Requirement dB(A).	NEQS Requirement dB (A)	Remarks
1	Paint Plant	88	85	75	Failure to Comply
2	Foaming	95	85	75	Failure to Comply
3	Evaporatorfitting	87.3	85	75	Failure to Comply
4	Electrical wiring	91.7	85	75	Failure to Comply
5	Gas Charging	90.3	85	75	Failure to Comply
6	Electrical Safety Testing	95.4	85	75	Failure to Comply
7	Packaging	97.4	85	75	Failure to Comply

The main cause of noise pollution is due to urbanization, increased commercial and to fulfill highly consumer demands. The development of the industrial sector has led to expansion in heavy traffic, which is the biggest source of sound and noise pollution. Noise pollution directly impacts the daily routine of workers which interpose in the proper communication between them. Due to the high level of noise at the workplace one person cannot follow the instructions properly given by the other person. Loud sounds can cause behavioral and emotional stress in the workers which impact their work performance. Continuous exposure to noise among

workers at the work stages can cause hearing loss, even sudden loud sounds can have severe damage to ear drums.(L. Tan *et al* .,2014).

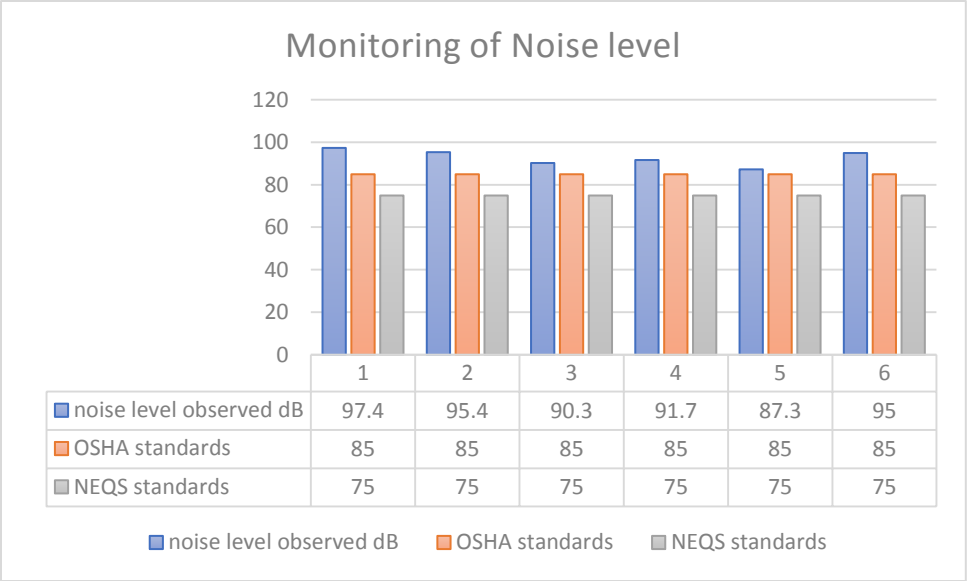

Figure1. Section-wise comparison of measured noise levels.

Temperature monitoring: Electronics that can function dependably in challenging conditions, such as extremely high temperatures, are required by many sectors. To monitor the temperature, we selected Paint plant. Foaming, evaporator fitting, welding, gas charging, electrical safety testing and packaging units of electronics manufacturing industry. The resultant values compared to the OSHA standards (20-29C). All units show high temperature values and non-compliance status. Due to the extremely high temperatures of the card, blow room, ring, simplex, finisher, and comber. The performance of workers might be seriously impacted by high temperatures.

According to OSHA guidelines, the acceptable temperature range is 20 to 29 degrees Celsius (OSHA technical handbook Directive Number: TED 01-00-015). Thermocouples were used to track the temperature in the designated locations. In almost every section, the temperature was higher than acceptable. Consideration must be directed meticulously for keeping temperature within tolerances in the various divisions of the electronic manufacturing sector. The temperature that is tracked in several departments can be observed below (figure 3).

Relative Humidity: The normal range of relative humidity is 40-60 % .The relative humidity in electronics manufacturing in different sections is within the limits of NEQS and OSHA standards limits. To monitor the level of relative humidity, instrument relative humidity meter was used and we selected Paint plant, foaming, evaporator fitting, electrical wiring, welding, gas charging, electrical safety testing and packaging units of electronic manufacturing industry. The resultant values are adequate and below (figure 4) the OSHA standards (40-60%). In this way, relative humidity has no impact on workers' health because the limits are under permissible values.

Table 2. Monitoring of Temperature in different sections of electronic manufacturing industry.

Sr. no	Units	Temperature	The OSHA Requirement℃	The NEQS Requirement℃	Remarks
1	Paint plant	41.2	20-29	25	Exceeds than normal limits
2	Foaming	41.8	20-29	25	Exceeds than normal limits
3	Evaporator fitting	38.7	20-29	25	Exceeds than normal limits
4	Electrical wiring	38.0	20-29	25	Exceeds than normal limits
5	Gas charging	37.5	20-29	25	Exceeds than normal limits
6	Electrical safety testing	35.7	20-29	25	Exceeds than normal limits
7	Packaging	36.0	20-29	25	Exceeds than normal limits

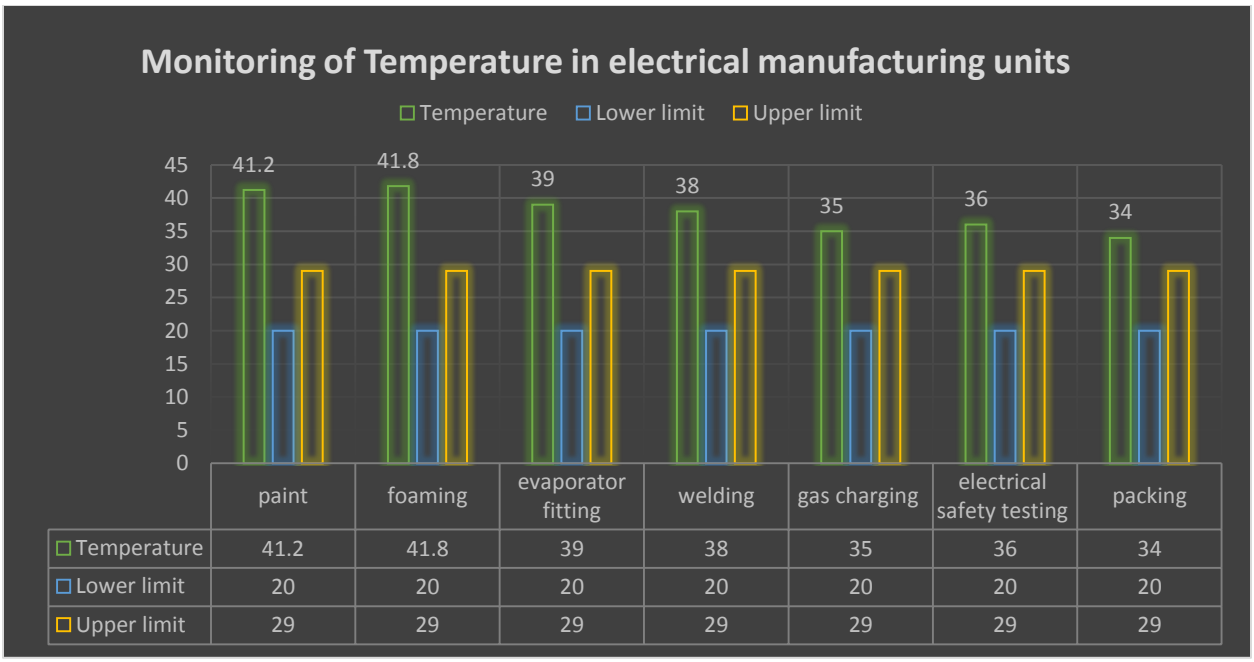

Figure 2. Monitoring of Temperature

Table 3. Monitoring OF RELATIVE HUMIDITY

Sr. no	Units	Relative Humidity (%)	The OSHA Standard (%)	The NEQS Standards	Remarks
1	Paint Plant	29.6	40-60	40-60	Comply
2	Foaming	29	40-60	40-60	Comply
3	Evaporator fitting	49.9	40-60	40-60	Comply
4	Electrical wiring	29	40-60	40-60	Comply
5	GasCharging	30.5	40-60	40-60	Comply
6	ElectricalSafety testing	29.1	40-60	40-60	Comply
7	Packaging	29	40-60	40-60	Comply

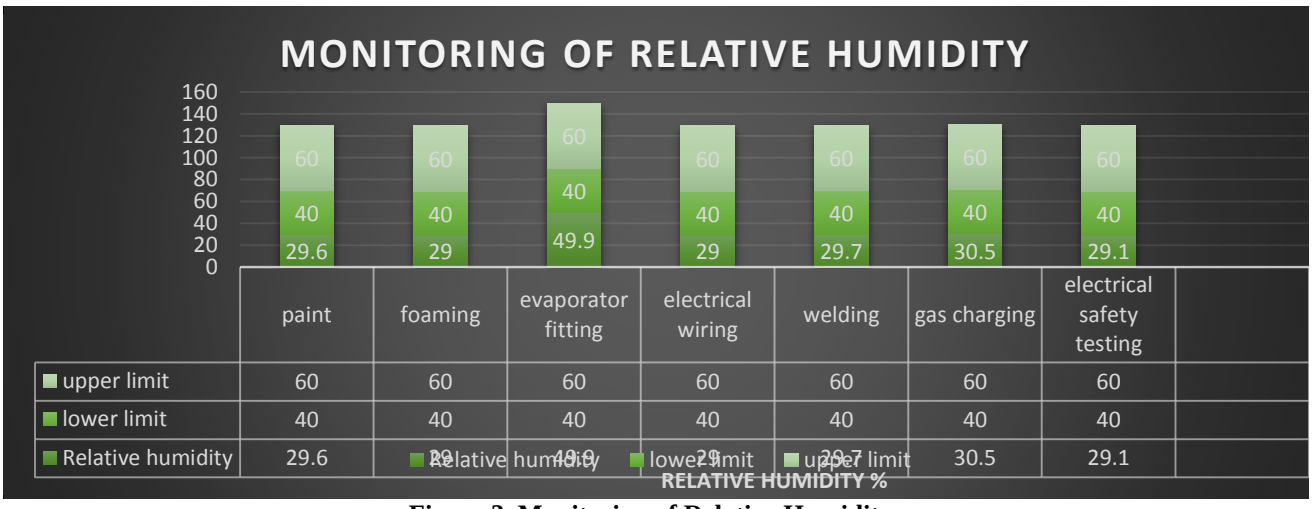

Figure 3. Monitoring of Relative Humidity

Light intensity: Monitor light intensity, we selected workplaces such as Assembly lines and testing stations. Administrative areas, control rooms, inspection areas and microscope workstations. The resultant values are

compared with OSHA LUX standards. LUX is the unit of light intensity. The monitoring was done by Hanna model portable LUX Intensity MeterH197500. All the values of light intensity observed in selected areas of industry are adequate. Therefore, workers do not have any problem regarding light while performing working tasks.
Table 4. Monitoring of light and measurement.

Monitoring of Ambient Air: The manufacturing sector's operational operations are one factor contributing to the area's air pollution. Particulate matter, ozone, sulfur dioxide, nitrogen dioxide, and carbon monoxide were the criteria used to measure the quality of ambient air. 2.5.

Carbon Monoxide: The gas carbon monoxide is colorless and tasteless. It is lighter than air because its density is somewhat lower than air's. In people whose hemoglobin functions as an oxygen transporter, it typically reacts with hemoglobin to generate carboxyl-hemoglobin. It is created anywhere that fossil fuels are burned.

The WHO states that 5 mg/m3 of carbon monoxide in the air and 5 mg/m3 of carbon monoxide in NEQS are the acceptable limits. This gas's level was assessed to be 2.4 mg/m3 close to the main entry wall, 1.6 mg/m3 at the site's warehouse, and 2.3 mg/m3 at the back. Since industry does not utilize fossil fuels, all the levels are below their maximums.

When inhaled, carbon monoxide has the potential to cause rapid death or sickness. If any person inhaled it, it could cause severe headaches, nausea and dizziness. It is a very harmful gas even if workers are exposed to CO for long term, it binds with hemoglobin and many heart issues and hypoxia can be observed due to loss of oxygen which is essential element to humans to survive. (Ioannis *et al* ., 2019).

Workplace	Light intensity observed in areas	OSHA LUX Standards
Assembly lines	350	300-500
Testing station	450	300-500
Administrative areas	400	300-500
Control rooms	500	500-700
Inspection areas	600	500-700
Microscope workstations	1000	1000-2000

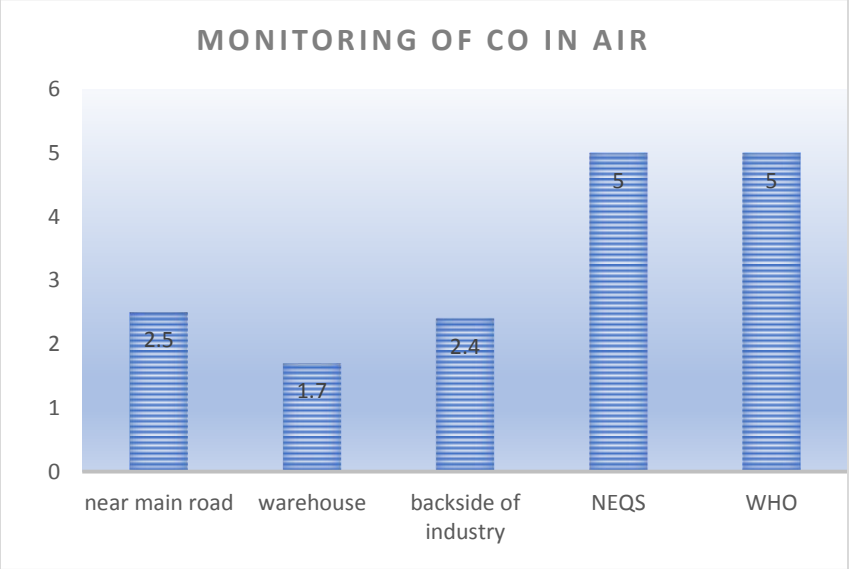

Figure 4. Monitoring of CO in air

Ozone: An inorganic molecule containing three oxygen atoms makes up the gas known as ozone. It has a strong, recognizable smell and is pale yellow in color. Although low ground level is also where it can be found, the high atmosphere is where it is primarily located. Depending on where it is found, ozone is classified as either beneficial or detrimental. It is good for ozone if it is present in the atmosphere since it shields earth's living things from ultraviolet rays. Ground-level ozone is referred to as unpleasant ozone, because it can irritate skin and eyes.
The WHO and NEQS allowable limit for ozone concentration is 130 micro g/m3. The ozone levels were 6 near the front door, 7 in the warehouse, and 10 in the rear. These values did not cause any injury or deterioration of the environment because they were much below the standards.

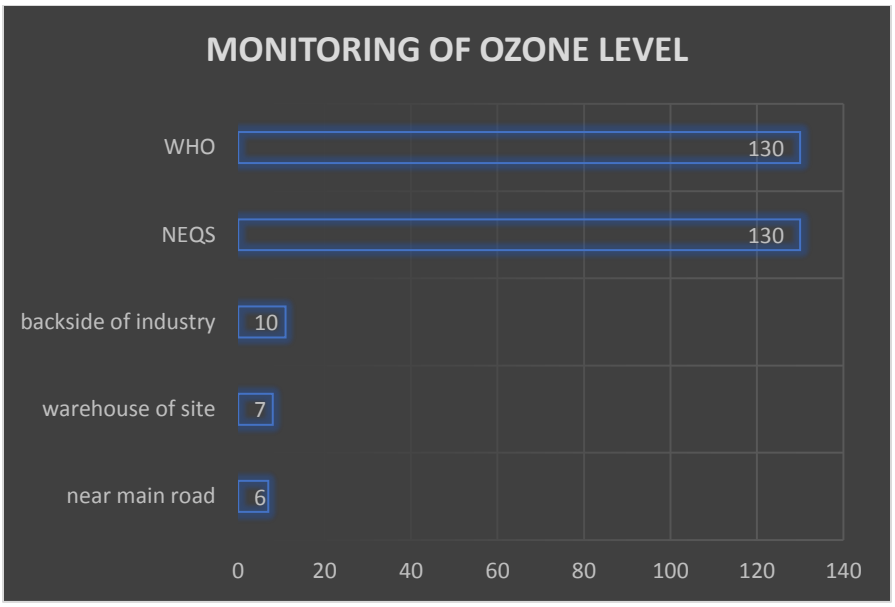

Figure 5. Monitoring of Ozone level in air

Sulphur Dioxide: Sulfur dioxide (SO2) is a colorless, poisonous, non-flammable gas with a strong odor and sour taste. Its thermal dissociation requires a temperature of 2000°C. In industries, it is utilized for a variety of processes such as sulfuric acid (H2SO4).

The WHO sets a standard value of 20 mg/L for SO2, while NEQS provides a value of 120 mg/L. Through investigation and testing, the value of SO2 was determined to be 5.2 mg/L close to the main entrance, 10 mg/L at the warehouse, and 2.7 mg/L at the rear of the industry. The resulting values fall short of the standards' permitted range.

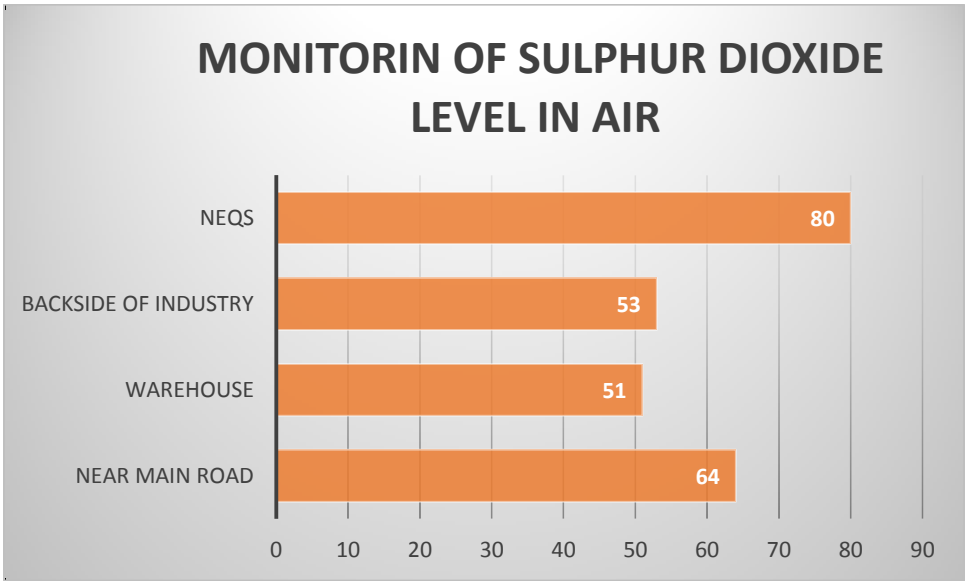

Figure 6. Monitoring of Sulphur Dioxide level in air

Nitrogen Dioxide: Nitrogen dioxide (NO2) A reddish in appearance and easily dissolved in water, NO2 is a well-known, potent, and reactive oxidant. It is the most important gas in the atmosphere. Because NO2 absorbs visible sun radiation, it plays a major role in global climate change. It is emitted into the atmosphere because of both natural and manmade activity. Volcanic eruptions, microbiological decomposition, and lightning are all natural causes.

Conversely, anthropogenic activities comprise electricity generation, combustion of fossil fuels, welding, heating, and the use of combustible engines in

industry and automobiles. (U.S. Environmental Protection Agency, 2010)

The recommended value of NO2 is 80 mg/L, according to NEQS. 40 mg/L is the standard amount that the WHO provides. 64 mg/L is the figure that was found close to the main entrance. The concentration level is 51 mg/L at the warehouse and 53 mg/L at the backside. The values acquired fall short of the NEQS's requirements.

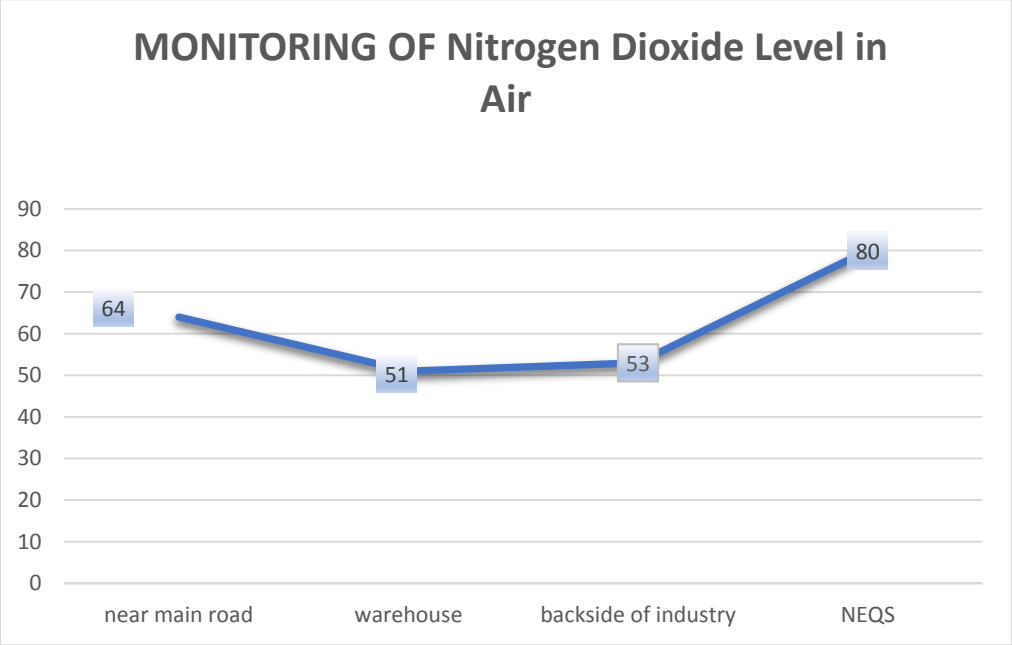

Figure 7. Monitoring of Nitrogen Dioxide level in air

Particulate Matter: According to the results of the ambient air quality monitoring, there are three sections of the site with higher particulate matter concentrations: 166 near the main road, 153 at the site's warehouse, and 165 toward the rear of the industry. The resulting figures show a substantial amount of PM that is over the WHO's and NEQS's acceptable thresholds of 150 and 20.

Forest fires and dust carried by the wind are two other natural activities that release particulate matter into the atmosphere. Particle size affects how long particulate matter hangs suspended in the atmosphere. Polluting substances that have already been released into the environment can also produce particulate particles. (M. Dhimal *et al* ., 2019) Particulate matter is produced because of these pollutants' changes when they are emitted from various activities. VOCs, SOx,NOx, and ammonia are a few examples of recognized particulate matter precursors. The ambient PM levels are lowered in part by the management techniques applied to reduce PM constituents. (Xiaoke, *et al* .,2020)

The smaller particles pose a greater risk to respiration because they can enter the respiratory system more deeply and seriously impair breathing. Pollution with particulate matter (PM) can irritate the lungs. This may result in long-term lung conditions and disrupt normal airway function. On occasion, PM can lead to inflammation of the lung tissue, which can release chemicals that interfere with the heart's ability to operate properly. Blood clots that form as a result of PM can result in a cardiac arrest. (Yu-Fie *et al* ., 2016).

Evaluation of Health Impact: Employees and residents of the planned site's surrounding rural areas were handed the questionnaires. Because a large portion of the workforce at the site and in the surrounding areas had respiratory issues, chest pain, wheezing, phlegm and coughing. The significant amount of particulate matter from operational operations and automobiles was responsible for the poor health of the populace.

The diseases that are observed in workers include cough, phlegm, chest pain, wheezing, and fever. Table 9 shows the number of workers who report pain in the early hours of the day or night. The chi-square test of association was used to get these results. This test aims to ascertain whether a discrepancy between observed and expected data is the result of random variation or a link between the variables. The variables included in the evaluation of worker diseases are age, working months, working hours, working experience, and BMI.

Due to the use of heavy equipment during working activities, the noise level surpasses the standard limits which may cause hearing loss. Unpleasant loud noise can cause great changes in the mood swings or emotional capabilities of a person by creating elements of stress, anxiety and health issues like headaches, migraine and deafness.

Table 5 Monitoring of Particulate Matter level.

Sr. No	Parameters	Units	NEQS	Who Standards	Concentration Near Main Entrance	At Warehouse	At Backside
1	PM 2.5	mg/m^3	150	20	166	153	165

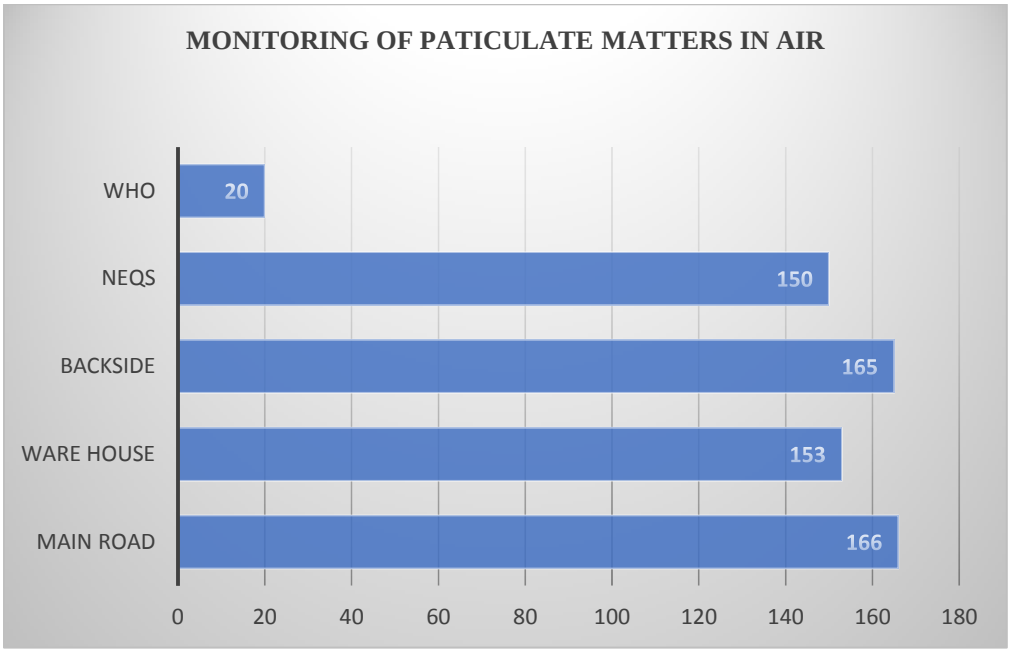

Figure 8 Monitoring of Particulate level Air Quality Levels near Main Road

Table 6. Quality Levels near Main Road.

Sr. No	Parameters	Units	NEQS	Who Standards	Concentration
1	CO	mg/m^3	5	5	2.3
2	O_3	$\mu g/m^3$	130	100	10
3	SO_2	$\mu g/m^3$	120	20	2.7
4	NO_2	$\mu g/m^3$	80	40	53

Table 7. Air quality at warehouse.

Sr. No	PARAMETERS	UNITS	NEQS	WHO Standards	CONCENTRATION
1	CO	mg/m^3	5	5	1.6
2	O_3	$\mu g/m^3$	130	100	7
3	SO_2	$\mu g/m^3$	120	20	10
4	NO_2	$\mu g/m^3$	80	40	51

The next location was close to the site's warehouse. The following values are listed:

Table 8. Air quality at backside of the industry.

Sr. No	Parameters	Units	Neqs	Who Standards	Concentration
1	CO	mg/m^3	5	5	2.4
2	O_3	$\mu g/m^3$	130	100	6
3	SO_2	$\mu g/m^3$	120	20	5.2
4	NO_2	$\mu g/m^3$	80	40	64

The third location was near the backside of the industry.

Excessive exposure to loud noise acoustic and non-acoustic affects both physical and mental health of human beings. High levels of noise can cause Tinnitus, hemostatic distress and overload of allostasis. (Basner *et al* ., 2014)

The impacts of welding fumes, oxides of nitrogen and Sulphur are multifarious as they can cause respiratory diseases, eye irritation, skin rashes and diseases like siderosis. (Chaudhary,2012)

In the electronic manufacturing industry due to the usage of heavy machinery at work stages and electricity generator at the back side of industry, noise was the major problem faced by the workers working in that environment. Meanwhile, welding fumes, lubricants, aerosols, smoke produced by generator, dust particles due to loading and unloading of materials produced poor air quality on site. Furthermore, high temperature, low level of luminance, high level of relative humidity are not suitable for the workers working in indoor and outdoor environments.

Table 9Assessment of Diseases among workers.

Diseases	**No of workers having disease status**		**Pain reported in different timings**		**Prevalence i. >3 months i. >2 year i. > 1 year**			**Chi Square (Test of association)**					
	YES	NO	MO	EV	i.	i.	i.	**Age**	**Working hours**	**Working months**	**Working experience**	**BMI**	
Cough	56	6	42	13	39	13	3	13.52	0.00	16.39	0.00	15.99	0.00
Phlegm	47	15	36	10	28	13	3	6.45	0.00	10.07	0.00	14.63	0.00
	At rest								After rest				
Chest pain	38	24	16	21	26	7	3	20.41	0.00	12.72	0.01	17.57	0.00
Wheezing	22	39	6	16	18	2	2	10.71	0.00	8.33	0.01	11.12	0.00
Fever	23	36	5	15	14	2	2	10.71	0.00	7.33	0.01	10.11	0.00

Conclusion: In the wake of rising vitality of electronic industry, a study was conducted to monitor ambient environmental conditions with their associated health effects in the manufacturing section the industry. Interviews and questionnaires were designed for the industrial personnel and the citizens for the purpose of ease of research. Our study highlights the critical need for monitoring and addressing environmental conditions in the electronics manufacturing industry to safeguard the health and well-being of its workforce. By measuring quality parameters such as temperature, light intensity, relative humidity, and noise levels across various sections of the industry, we identified significant deviations from US-OSHA and NEQS standards, particularly in noise levels and temperature ranges. Results demonstrated that the industrial location had a high PM10 value. The present study findings are noise monitored in selected sections of electronic industry are greater than OSHA and NEQS standards, Temperature monitored in selected sections of electronic industry is not in permissible limits of OSHA and NEQS Standards. The monitoring of relative humidity is within assigned limits of OSHA and NEQS Standards. Monitored light intensity is in good standards assigned by OSHA and NEQS Standards. Due to the dust in the research region, several serious health concerns were found, including respiratory disorders, asthma, cardiac troubles, dizziness, coughing, and diarrhea. The association between these environmental factors and the prevalence of health issues among workers underscores the importance of implementing effective health and safety protocols in the workplace. Our findings reveal a high incidence of respiratory disorders, chest pain, wheezing, coughing up phlegm, and fever among laborers, indicating a pressing need for intervention. Furthermore, the lack of awareness and training regarding health and safety protocols among workers underscores the urgency for educational initiatives and enhanced workplace practices. Addressing these issues will not only improve the health outcomes of employees but also contribute to a more productive and sustainable working environment in the electronics manufacturing industry.

REFERENCES

[1] D. Koh, G. Chan, and E. Yap, "World at Work: The Electronics Industry," *Occupy. Environ. Med.*, vol. 61, no. 2, pp. 180-183, 2004.

[2] Wexler, A.C., and Loecker, J.D. (2015) Reallocation and Technology: Evidence from the US steel Industry, American Economic Review, 105, 131-171

[3] V. K. Nartey, J. N. Nanor, and R. K. Klake, "Effects of Quarry Activities on Some Selected Communities in the Lower Manya Krobo District of the Eastern Region of Ghana," *Atmos. Clim. Sci.*, vol. 2, no. 3, p. 362, 2012.

[4] M. Lehnert *et al* ., "Exposure to Inhalable, Respirable, and Ultrafine Particles in Welding Fume," *Ann. Occup. Hyg.*, vol. 56, pp. 557-567, 2012.

[5] S. Z. Azmi *et al* ., "Trend and Status of Air Quality at Three Different Monitoring Stations in the Klang Valley, Malaysia," *Air Qual. Atmos. Health.*, vol. 3, no. 1, pp. 53-64, 2010.

[6] Leech, N. L., Barrett, K. C., and Morgan, G. A. (2014). *IBM SPSS for intermediatestatistics:Useand interpretation*: Routledge.

[7] L. Tan *et al* ., "Influences on Lumped Passes on Welding Residual Stress of a Thick-Walled Nuclear Rotor Steel Pipe by Multi Pass Narrow Gap Welding," *Nuclear Eng. Des.*, vol. 273, pp. 47-57, 2014.

[8] I. M. Ioannis *et al* ., "Environmental and Health Impacts of Air Pollution: A Review," *Front. Public Health*, vol. 8, p. 14, 2019.

[9] U.S. EPA, "Indoor Air Quality: The Inside Story: A Guide to Indoor Air Quality." [Online]. Available: http://www.epa.gov/iaq/pubs/insidest.html.

[10] X. S. Xiaoke *et al* ., "Research on PM 2.5 Concentration Based on Dissipative Structure Theory: A Case Study of Xi'an, China," *Sci. Rep.*, vol. 10, p. 16435, 2020.

[11] Y.-F. X. Yu-Fei *et al* ., "The Impact of PM 2.5 on the Human Respiratory System," *J. Thorac. Dis.*, vol. 8, no. 1, pp. 69-74, 2016.

[12] M. Basner *et al* ., "Auditory and Non-auditory Effects of Noise on Health," *Lancet*, vol. 383, no. 9925, pp. 1325-1332, 2014.

[13] R. Chaudhary *et al* ., "Combined Study of Welding Work and Ergonomics Risk Analysis Process," *Int. J. Comput. Sci. Commun. Eng.*, 2012.