Thesis

Title:

Evaluation of Occupational Health and Safety and Process Risk Assessment of the Industrial Waste Incinerator Located in Kala Shah Kaku- A Case Study

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Acknowledgement

I would thank Allah whose blessings enabled me to focus all my attention on this work. It is the perseverance, dedication and passion that has made this research possible. Most importantly, the constant support from my supervisors Ms. Sadia Imran and Dr. Samia Saif is one of the pivotal element that kept me on the right track. Their constant feedback and help has proved to be critical in completion of this project. I would specially thank Mr. Abdullah Ansari, the manager of the site, who took time out from his busy schedule to assist me in my visit and help me with the collection of data. It is an effort supported and appreciated by people around me whom I would remain indebted to.

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Terms and Abbreviations

• Carbon monoxide	CO
• Nitrogen oxides	NOx
• Sulphur oxides	SOx
• Tropospheric ozone	O3
• Polychlorinated dibenzo-p- dioxins/ furans	PCDD/Fs
• Particulate matter	PM
• Volatile organic compounds	VOC's
• Polycyclic Aromatic Hydrocarbons	PAHs
• Risk assessment	RA
• Manual materials handling	MMH
• Musculoskeletal disorders	MSDs
• World Health Organization	WHO
• Personal Protective Equipment	PPE
• United States Environmental Protection Agency	USEPA
• Punjab Environmental Quality Standards	PEQS
• Solid waste	SW
• National environmental quality standards	NEQS
• Municipal waste incinerators	MWI's

- Solid waste incinerators SWI’s
- Occupational health and safety OHS

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ABSTRACT

Rapid rise in the population, economic boom, urbanization, industrial growth, and changing socioeconomic conditions have caused an increase in the solid waste (SW) generation. Landfilling, composting, and incineration are the widely practiced methods to handle SW. This study determined the occupational health and safety risks at an industrial waste incineration facility by conducting a thorough Process Risk Assessment at the plant located in Kala Shah Kaku. The air emission levels, waste water and groundwater composition, gaseous emissions, ash and noise levels were also monitored in order to assess the environmental impacts of incineration at the facility. Information regarding the waste incineration was collected with the help of secondary data. Primary data was collected through the survey of the plant. The results indicated that the majority of the health and safety risks at the site range from minor to moderate due to reasonable existing controls and only requires some logical and systematic steps to alleviate those risks. Musculoskeletal issues are a major risk at the site due to manual handling of the waste and require additional mitigation and control measures. All the environmental parameters are within the standard limits and do not pose any harm. This study elaborates the existing as well as the putative risks associated with incineration and provides the basis for risk management decisions and risk communication. It also compares the health and safety status of the site with the standard requirements of International Labor Organization.

1. INTRODUCTION

Rapid rise in the population, economic boom, urbanization, industrial growth, and changing socioeconomic conditions have caused an increase in the solid waste (SW) generation. SW management is a pressing dilemma because of the environmental, public health, and aesthetic concerns associated with its proper disposal. SW management facilities generate a huge amount of GHG's that have a consequential impact on global warming. Contamination of soil and water, generation of unpleasant odor, and spread of diseases are other significant concerns associated with their management. (Awasthi et al., 2019).

According to Environmental protection department of Punjab, solid waste generation in Pakistan is between 0.283 to 0.612 kg/capita/day and the waste generation growth rate is 2.4% per year *(Solid Waste | Environment Protection Department,* 2022.*)*. The solid waste generally consist of biodegradable waste (green waste, paper, food waste etc.), Inert waste (construction and demolition waste, dirt, rocks, debris, etc.), Recyclable material (paper, glass, bottles, cans, metals, certain plastics etc.), Electrical and electronic equipment waste, Composite wastes (waste clothing, tetra packs, waste plastic etc.) and Domestic hazardous waste and toxic waste medication (paints, chemicals, light bulbs, fluorescent tubes, containers, shoe polish, etc.) *(Solid Waste | Environment Protection Department, n.d.)*.

(Source: United Nations Environment Program, report on waste management in Pakistan. UNEP, 2019)

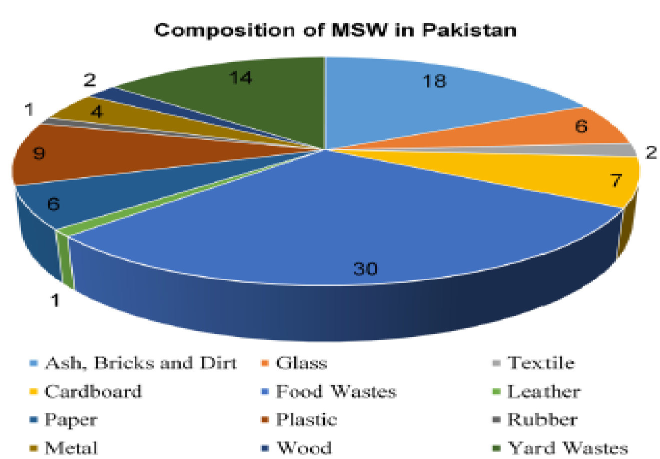


Fig. 1: Classification of MSW generation% in Pakistan. (Pariatamby et al., 2020)

Landfilling, composting, and incineration are the widely practiced methods to handle SW. All the waste that is collected is disposed in open landfills. Closed/lined landfills do not exist in Pakistan. (Pariatamby et al., 2020). According to International Trade Administration, Karachi has three sanitary landfill sites, while Lahore has two. Other major cities are planning to build proper landfill sites. In many areas, solid waste is simply dumped outside the boundaries of the cities. In Sindh, the Sindh Cities Improvement Investment Program (SCIP) is working for the refinement of solid waste management services in 20 secondary cities. In Khyber Pakhtunkhwa, the Water and Sanitation Services Peshawar (WSSP) aims to build a sanitary landfill. Baluchistan has no significant infrastructure for waste management system. Much of Pakistan's solid waste does not reach final disposal sites and is recovered for reuse or recycling, mostly by scavengers, before it ever reaches disposal points. Open dumping is also widely practiced in Pakistan.

Lahore Composting Facility project is the first of its kind in Pakistan. The land for the composting plant is provided within the Mahmood Booti dumpsite. The composting plant is an aerobic windrow composting technology in which the organic waste gets converted into compost in a 70 to 90 days process. This not only reduces the environmental and health hazards due to open dumping but also the methane emissions that are generated during anaerobic decomposition of biodegradable matter are sequestered by this scientifically designed technology.(*ESMAP EECI- Good Practices in Cities.Pdf*, n.d.)

Settlement Area	Waste Quantity					
	Generated		Collected	Transported	Treated	Disposed of
	Daily (kg per capita per day)			Yearly (million metric tons per year)		(% of waste generated)
Large cities (11)	0.55	9.44	80	80	20	80–100[a]
Medium-sized and small cities[b]	0.42	4.44	50–70	50–70	10	90–100
Rural communities	0.33	13.72	20	20	20	80–100
Total		27.58				

Fig 2: Waste generation, Treatment and disposal estimates, Pakistan. (Asian Development Bank, 2022)

The above table depicts the quantity of the waste generated, collected and treated in Pakistan. Most of the waste is disposed of in uncontrolled dumpsites or scattered in the outskirts of rural areas and only a small percentage of waste is treated.

The medical and the industrial waste are considered to be hazardous all over the world. Incineration is the most widely used disposal option for both of the wastes but the type of the waste and their sources are totally different. The types of the hazards associated with the waste, their way of transmission and the diseases that might be caused because of coming in contact with those hazards are quite divergent. Similarly, the hazards and risks associated with waste management of medical and industrial waste will not be similar. Following is a table that depicts the comparison between industrial and medical waste.

Comparative Analysis of Industrial and Medical Waste

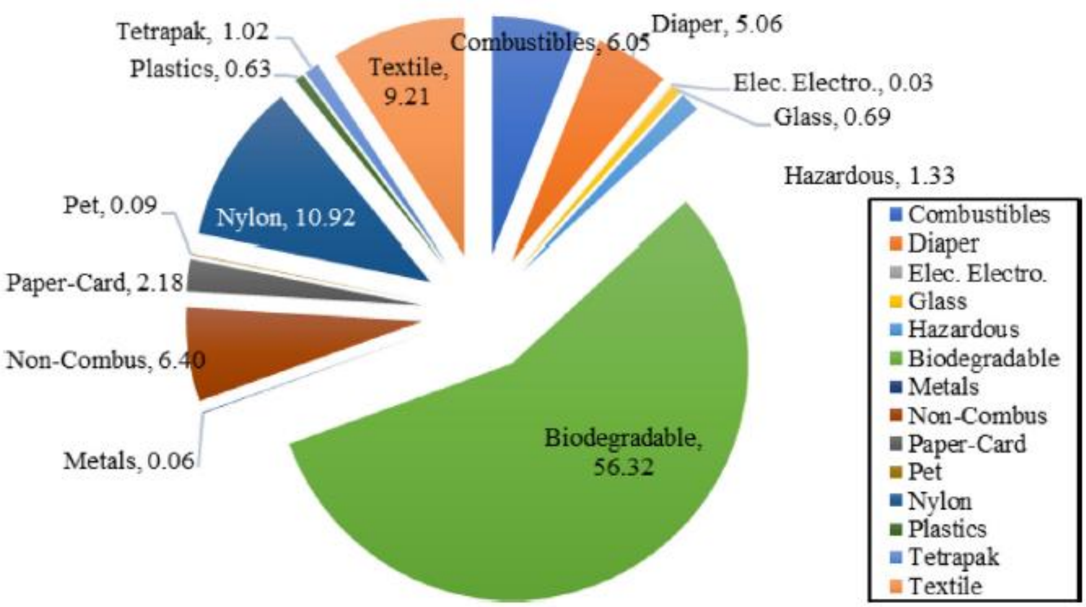
Parameter	Industrial waste	Medical Waste
Type of waste	• Non- Hazardous waste such as carton, plastic, metals, glass etc. • Hazardous waste which can be flammable, corrosive,	• Non-risk waste such as paper, cardboard, packaging, food waste etc. • Risk waste means infectious waste (waste from surgeries, lab

	toxic etc. such as pesticides, paints, industrial solvents, mercury containing batteries.	cultures etc.), pathological waste (tissues, organs, body fluid etc.), sharps (infected needles, syringes, blades etc.), pharmaceutical waste (surplus drugs, discarded gloves, masks, tubes, vials etc.), genotoxic waste (cytotoxic drugs used in cancer treatment) and radioactive waste (waste from in-vitro analysis of body tissues, tumor localization etc.) (EPD, Punjab)
Source	• Industries (textile, paper, plastic, pharmaceutical etc.)	• Hospitals, medical labs and research centers, clinics etc.
Type of treatment practices	• Recycling and recovery • Composting • Pyrolysis • Incineration • Sanitary landfill (Godswill & Twinomuhwezi, 2020)	• Incineration • Steam Autoclave Disinfection • Microwave Disinfection • Mechanical/Chemical Disinfection (EPD, Punjab)
Type of incineration used	• Rotary kiln • Fluidized bed (Nidoni, 2017).	• Rotary kiln • Fluidized bed (Nidoni, 2017).
Rules and Regulations	• No specific rules for industrial waste	• The Punjab hospital waste management Rules, 2014
Types of Hazards	• Toxic chemicals • Flammable waste • Corrosive waste • Sharp materials	• Infectious agents • Genotoxic, radioactive waste • Toxic chemicals and pharmaceuticals.

	(Godswill & Twinomuhwezi, 2020)	• Sharps (Padmanabhan & Barik, 2019)
Types of diseases that might occur	• Gastrointestinal issues • Respiratory issues • Skin issues • Neuromuscular disorders	• Genital infections • Skin infections via pus • Gastro enteric infections • AIDS, anthrax, meningitis, Hepatitis A, B, C, septicemia, bacteremia, candidemia etc. (Padmanabhan & Barik, 2019)
Disease transmission vector	• Battery waters, chemical solvents, metals, glass, acids etc. (Millati et al., 2019)	• Blood, feces, pus, genital fluids, nasal secretions, eye secretions, saliva, vomit etc. (Padmanabhan & Barik, 2019)

Table 1: Comparative Analysis of Medical and Industrial waste

Out of all the waste generated in Pakistan, only hazardous hospital and industrial waste are considered significant and are incinerated in a waste management facility. Waste management companies have been established for the efficient disposal of hazardous and non-hazardous waste from medical and industrial facilities in Pakistan. According to the waste characterization report of Lahore by LWMC, the total hazardous waste coming from all the commercial and institutional areas was 1.33 % of the total mixed waste which include the waste from both the sources i.e. industrial and medical. (Asim et al., 2022). The statistics related particularly to the industrial hazardous waste generation in Pakistan have not been defined yet, however efforts have been made for proper handling and treatment of hazardous waste from industries. (Pariatamby et al.,



2020)

Fig 3: Waste characterization of Lahore with weighted average values. (Asim et al., 2022)

In general, industrial waste can be categorized into two categories, i.e., nonhazardous and hazardous. Nonhazardous industrial waste do not pose a threat to public health or environment and its nature and composition are similar to those of municipal waste for example carton, plastic, metals, glass, rock, and organic waste. This waste is not toxic and can thus be recycled or disposed safely. On the contrary, hazardous waste is a residue from industrial activity that may cause danger to health or environment, either alone or when in contact with other wastes. This waste can be flammable, corrosive, active, and toxic materials and requires a special treatment. Some hazardous wastes may be recycled because they contain important

TABLE 1.11
Characteristic Wastes Produced From Various Industrial Activities.

Industrial Sector	Description	Typical Waste
Mining and quarrying	Extraction, beneficiation, and processing of minerals	Solid rock, slag, phosphogypsum, muds, tailings
Energy	Electricity, gas, steam, and air-conditioning supply	Fly ash, bottom ash, boiler slag, particulates, used oils, sludge
Manufacturing	Chemical	Spent catalyst, chemical solvents, reactive waste, acid, alkali, used oils, particulate waste, ash, sludge
	Food	Plastic, packaging, carton
	Textile	Textile waste, pigments, peroxide, organic stabilizer, alkali, chemical solvents, sludge, heavy metals
	Paper	Wood waste, alkali, chemical solvents, sludge
Construction	Construction, demolition activity	Concrete, cinder blocks, gypsum, masonry, asphalt, wood shingles, slate, metals, glass, and plaster
Waste/water services	Water collection, treatment, and supply	Spent adsorbent, sludge

components, e.g., silica, alumina, iron, and precious metals. (Millati et al., 2019).

Fig.4: Characteristics of waste produced from industrial Activities (Millati et al., 2019)

Chemicals, pharmaceuticals, pesticides, electrical equipment, glass, leather tanning, pulp and paper board, ceramics and cement industries are among the most polluting ones in Pakistan. (Pariatamby et al., 2020)

In common terms, incineration is the destruction of the waste material through controlled burning in a properly managed facility. Major emissions from waste incinerators consist of air pollution control residues and furnace bottom ash, gaseous emission products and cooling water discharges. The substances related to atmospheric emissions from waste incinerators are classified into acidic gases and aerosols, heavy metals, and organic compounds. Air pollution control residues are disposed of to landfill as special waste, whose hazardousness depends on the characteristics of the site and the management practices. The bottom ash is disposed of to landfill as non-special waste, and it can also be reused in building roads or construction materials. Reusing the bottom ash do not pose any major health or environmental threat however risks might be present. Stack emissions consist of many hazardous substances which have the characteristics of environmental persistence, long half lives in the environment, bioaccumulation and bio-amplification, and inherent toxicity and despite of being produced at extremely low levels they have a great impact on the environment and on human health. These harmful substances, when released into the atmosphere become the root cause of the diseases such as lung cancer, heart diseases, respiratory disorders which indirectly leads to short life spans. (Reis, n.d.) (Nidoni, 2017)

Incineration facilities are equipped with heavy machinery that has safety risks, and additional health risks for the workers such as exposure to various waste-derived emissions. Therefore preservation of safety and hygiene, proper equipment and training of the personnel at all waste treatment and management stages is of prime importance.

In order to elevate the health and safety practices and gaining proper management and control, all waste treatment facilities must apply the methodologies of risk assessment and take measures to minimize the safety hazards.

1.1 RISK ASSESSMENT:

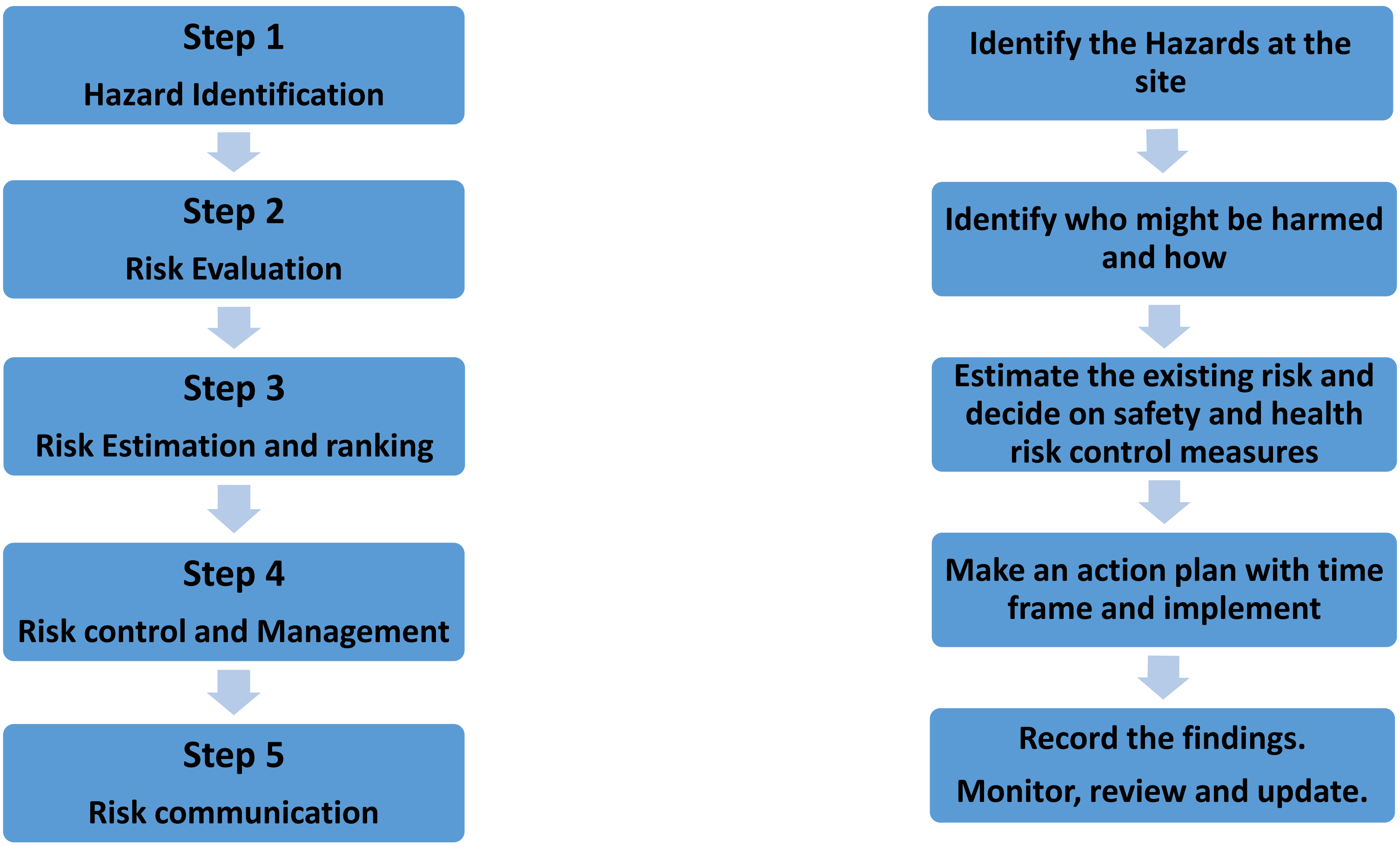
According to US-EPA, "risk assessment is a scientific process of characterization of the nature and magnitude of health risks to humans or other ecological receptors from the chemical contaminants and other stressors present in the environment." The risk due to a contaminant depends on its quantity, exposure and the toxicity. In the context of waste incineration, "a hazard can be defined as a source of potential negative effects on the environment and of subsequent risks to human health or quality of life, directly or indirectly associated with past, current, or future exposure to plant emissions". (Reis, n.d.)

The health of the local workers and the nearby residents can be impacted by the nuisance created by the waste such as unpleasant odors, wind-blown waste, dust, spores, flies, and other pest species attracted to the waste material, transport related emissions such as noise and dust, and a wide range of hazards from the activities of the facilities. (Reis, n.d.)

Risk due to any specific event can be evaluated by multiplying the probability of the event to the frequency of that event (WHO Guidelines):

Risk = Likelihood x Severity

Risk Assessment is a five steps process which are as follows:



1. List the work tasks and identify the hazards (location, people, equipment and substances, activities)
2. Evaluate the risks (Who might be harmed and how?)
3. Estimate the risks (Estimating the existing risk based on current controls and practices)
4. Control and manage risks.
5. Record and review the findings. (*IOSH- Managing Safely.Pdf*, 2012.)

Risk assessment can be done by conducting a survey of the area where the probability of risk is maximum. A checklist is designed in accordance with the area of interest, in order to identify the hazards. A risk matrix is developed that shows the probability and magnitude of the specific risk and categorizes the impacts according to severity.

1.2 INTERNATIONAL LABOR ORGANIZATION

International Labor Organization is a specialized agency of United Nations that aims at bringing together government, employers and workers of 187 member states to set, develop and devise standards, policies and programs in order to promote safe and decent working environment. The three main bodies of ILO include the International labor conference that sets the International labor standards and the broad policies of the ILO, the governing body that takes decisions on ILO policies and develop programs and budget and the International Labor office which governs the overall activities. There are 25 different subjects covered under international labor standards that include child labor, forced labor, social security, employment security etc. Occupational safety and health is one of the major subjects in ILO standards.

Pakistan is one of the member states of ILO. It has a total of 495 legislations for national labor, social security and related human rights out of which 21 are for protection against specific hazards in occupational health and safety which are as follows:

1. The Khyber Pakhtunkhwa Boilers and Pressure Vessels Act, 2016 (Act No. XXXI of 2016).
2. The Baluchistan Boilers and Pressure Vessels Act (Act No. XVI of 2015).
3. The Sindh Environmental Protection Act, 2014 (Act No.VIII of 2014).
4. Khyber Pakhtunkhwa Factories Act, 2013 [Act No. XVI of 2013].
5. Factories (Amendment) Act, 2012 [No. XIV of 2012].
6. Boilers and Pressure Vessels (Amendment) Act, 2009.
7. Hazardous Substances Rules, 2003.
8. Boilers and Pressure Vessels Ordinance (CXXI of 2002).

9. Pakistan Nuclear Regulatory Authority Ordinance, 2001 (No. 3 of 2001).
10. Nuclear Safety and Radiation Protection (Treatment of Food by Ionizing Radiation) Regulations, 1996.
11. Employment of Children Act, 1991 (Act No. V of 1991).
12. Pakistan Nuclear Safety and Radiation Protection Ordinance (No. IV of 1984). -
13. Punjab Weights and Measures (International System) Enforcement Act, 1975 (LII of 1975).
14. Labor Laws (Amendment) Ordinance 1972 (No. 9).
15. Agricultural Pesticides Ordinance, 1971 (II of 1971).
16. The Factories (West Pakistan Amendment) Ordinance, 1966 (W.P. Ord. VI of 1966).
17. Hazardous Occupation Rules, 1963 (No. 1-6 (L-II/64).
18. Factories (North-West Frontier Province Amendment) Act, 1946 (No. 7 of 1947).
19. The Factories (Punjab Amendment) Act, 1940.
20. Factories Act, 1934 (XXV of 1934).
21. Fatal Accidents Act, 1855 (No. 13 of 1855).

According to ILOSTAT data of 2018, Pakistan has about 1136 non- fatal occupational injuries per 100,000 of workers and 40% share of employees work for more than 49 hours per week. The legislations related to the current study include:

- **Hazardous Occupation Rules, 1963 (no.1-6 (L-II/64):**

According to these rules, no child or adolescent must be employed in any work related to hazardous substances. Every worker must be medically examined by a certifying surgeon at intervals of not more than six months and a record must be kept with the manager. Every worker must have a certificate for fitness to work at a hazardous place and he must not be employed if he is not identified to be fit by the examiner. The fees for examination under this rule, must be paid by the employer. (*International Labor Organization, n.d.)*

- **Hazardous Substance Rules, 2003:**

a) According to these rules, the facility must have an Environmental impact assessment consisting of 1) Safety plan that has the analysis of major accident hazards, assessment of nature of adverse impacts, description of safety equipment and systems installed, description of emergency measures to be taken in accidents 2) Waste management plan that ensures that hazardous and non-hazardous waste are not mixed and manages in a way which will protect against adverse impacts.

b) The rules regarding packaging and labelling of hazardous substances suggest that there should be no leakage in the waste, safe transport and storage must be ensured, name and the net contents (volume and weight) of the waste must be mentioned, the warning signs must be posted and the instructions regarding return or disposal of empty container for immediate steps to be taken in case of accident must be present.

c) General safety instructions include proper PPE's for handling must be present, safety instructions must be in local language, no worker below 18years or above 60 years must be employed, Qualified supervisors must be present for proper training of personnel regarding fire-fighting, emergency and safety equipment and eating, drinking and smoking must not permitted in vicinity.

d) Premises should not be in a residential, commercial, congested or office area, should not be close to drinking water sources, should not be in small lanes, should have good ventilation, should have well-maintained electrical installations, should have smooth, crack free floors impermeable to liquids, should have drains which do not connect directly with the sewerage system and should have signs, escape routes, emergency exits etc.

e) The instructions regarding transportation include that the name and address of the person from where hazardous waste is collected and of the person to whom the waste is delivered must be mentioned. The quantity of hazardous waste to be transported and the mode of transportation with full specifications must be properly stated along with the date and time of proposed transportation. *(International Labor Organization, n.d.)*

- **Fatal Accidents Act, 1855 (No.13 of 1855)**

This is an act made to provide compensation to the families in case of loss or death of a person due to wrongful act, neglect etc. The wife, husband, parents and children can claim compensation. Under this Act, suit for compensation can be taken in case of death or other damages that could have caused death. Limitation for such a suit is one year from the date of incident.

The health, safety and welfare of employees at a workplace is very important. There are plenty of factors which must be in appropriate conditions to make a suitable work environment for the workers such as the ventilation systems, temperature, lighting, overall cleanliness, space and seating, proper gateways, walkways and windows, sanitary conveniences, access to drinking water and other facilities for food etc. All of these factors contribute in making a workplace safe or a hazard for the workers. *(International Labor Organization, n.d.)*

A lot of studies have been conducted on the environmental impacts of solid waste incinerators but studies related to health and safety management practices at such facilities are very limited. Therefore, considering the literature, the current study conducted the process risk assessment of the incineration plant, assessed the current health and safety practices at the plant and compared those to the requirements of International Labor Organization. It also evaluated the environmental parameters in order to determine the environmental hazards caused by the facility. The present study proposed management strategies and actions that could eliminate or minimize those risks for the workers. It determined the existing as well as the putative risks associated with incineration and provided the basis for risk management decisions and risk communication.

2. LITERATURE REVIEW

"Incineration refers to the oxidative combustion reaction between the combustible components in the waste and oxygen under high temperatures and aerobic conditions with the release of heat and the conversion to high-temperature combustion flue gas and a stable solid residue." (Awasthi et al., 2019). Incineration greatly reduces the volume. The combustion flue gas can be recycled in the form of energy such as heat whereas the stable residue can be disposed of in landfill or used as building material (Awasthi et al., 2019).

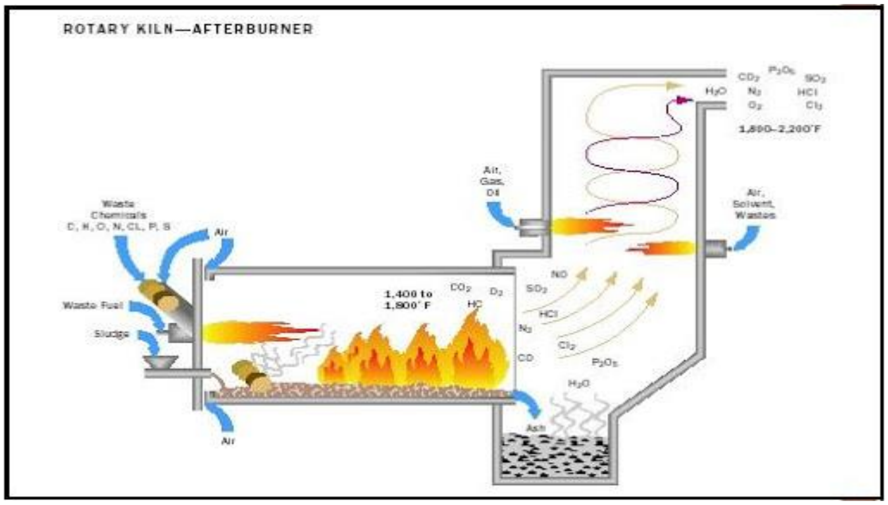


Fig.5 Rotary kiln (Nidoni, 2017)

Out of the three main types of incinerators (rotary kiln, moving grate, fluidized bed), rotary kilns are commonly used for the incineration of hazardous and industrial waste as they ensure continuous mixing of the waste and can handle a variety of wastes due to high operating temperature.

2.1 Working of Incinerator:

It consists of two thermal treatment chambers. The waste is fed into the primary chamber together with inlet of hot exhaust air with oxygen. It is then rotated thoroughly in the kiln where it decomposes thermally by the heat. The secondary chamber also known as the re-combustion chamber is present at the end of the kiln where the remaining waste is completely burnt with the supply of secondary air. Rotary kiln allows thermal destruction of hazardous chemicals and produces low levels of NOx (Nidoni, 2017).

There are certain operational parameters for proper working of an incinerator, which if not adequately met, can have a major impact on the performance of the incinerator. First of all, the temperature has to be from 1000-1200C and waste must be exposed to that temperature for 1-2 seconds in order to minimize emissions. The chimney height should not be less than 50 to 60ft high to ensure proper dispersion of the gases and air flow. The proper agitation of waste along with the adequate air supply is very important homogenized burning and proper conversion of hazardous gases to non-hazardous forms. Next parameter is the residence time of the gas in the secondary chamber which should not be less than 1 sec as it ensures complete combustion of toxic compounds. The pollution abatement equipment need to be adequately installed to comply with the modern emission limits. The ash pit must be made of bricks or concrete blocks. The ash monitoring must be ensured prior to disposal. Ash must be removed from the pit frequently during the process in order to prevent leaching into soil. The SOP's are different for different types of waste so they must be according to the type of the facility and the type of waste being dealt at the site. Different types of waste can cause different type of emissions thus there should be periodic monitoring of each batch of waste. (Nidoni, 2017) (The Incinerator Guidebook: A Practical Guide for Selecting, Purchasing, Installing, Operating, and Maintaining Small-Scale Incinerators in Low-Resource Settings, 2010.)

Emissions once released from the incinerators can no longer be controlled, thus in order to ensure the acceptable levels of emissions and reduce the environmental and health risks, the incineration facilities must be properly designed, operated and adequately monitored. Although exposure to other waste incinerator emissions can also be harmful to health and environment, airborne exposure is more likely. Despite of the fact that toxic releases from latest type of waste incinerators are more limited than those from old ones, the hazardous pollutants are still released into the environment, contributing to the pollution of the surrounding areas. Therefore, information on the substances that have potential harmful impact on the health and environment and are being emitted from the plants is necessary. (Reis, n.d.).

The main sources of exposure to the environment from the incinerators are the atmospheric emissions, ashes and the cooling water. The risks associated with the ashes and cooling water can be minimized if they are properly managed, thus the atmospheric emissions become the primary source of danger and the people's route of exposure. (de Titto & Savino, 2019).

2.2 Volatile organic compounds Pollution

VOCs are categorized according to how easily they can be emitted. The higher the volatility the more easily the compound would be released into the environment. Although many volatile organic compounds are precursors for the production of ozone, they are frequently implicated in accelerating or worsening air pollution. (Zhou et al., 2023)

The light-assisted chemical reaction by volatile organic compounds can also occur in the presence of atmospheric radiation with carbon dioxide, nitric oxide, and with other volatile organic compounds. Continuous climatic warming is caused by the temperature-dependent production of VOCs from various biological and non-biological sources at a pace that is twice as fast as the rise in temperature. (Zhou et al., 2023)

In another study, the cancer risk for benzene exposure was estimated to be 1.26 x 10^{-5} that was greater as compared to the acceptable risk level of 1 x 10^{-6}. (Pudpadee et al., 2017) .

A study of health risk assessment associated with the inhalation of VOCs and heavy metals for workers at waste incinerator site in the South of Thailand concluded that the concentrations of VOCs (benzene, toluene, ethyl benzene, xylenes, and styrene) were high. Evaluation of the carcinogenic and non-carcinogenic effects determined that the cancer risk for benzene exposure was higher than the acceptable risk levels. The main source of exposure of workers to benzene was via inhalation. (Pudpadee et al., 2017). Organic compounds in the incinerator's ambient air are primarily produced in the barrel storage areas as a result of volatilization or degradation of organic compound in the solid or liquid waste, and they are diffused into the air from the containers with insufficient tightness as they have high vapor pressures. (BakoIlu et al., 2004). Benzene is the most common of monocyclic aromatics. It is a carcinogen and is one of the most emitted VOCs at the MWI stack. A study revealed that the urban air concentrations of benzene are often greater than those measured directly at the incinerator stack. (Boudet et al., 1999).

2.2.1. Health impacts of Volatile organic compounds:

VOC's are very harmful due to their mutagenicity, carcinogenicity and reproductive effects. They have been shown to produce testicular toxicity and sterility and exposed male workers in a dose-response relationship. These chemicals are also associated with eyes, nose and throat irritation, dizziness, headaches, allergic skin reactions and nausea. (Shuai et al., 2018).

2.3 Heavy Metal Pollution

Industrial waste contains a lot of heavy metals in different forms. In a study greater concentration of heavy metals was found in the surface soils near MSW incinerator due to the pollution caused by exhaust gas. (Zhong et al., 2020) .Arsenic and cadmium comes from paints, pigments and textile industries. Chromium, copper, nickel, and zinc are usually found in metal plating, electrical equipment etc. whereas mercury usually comes from chemicals and pigments. (Mahurpawar, 2015)

During the incineration of hazardous waste, heavy metals are released from the exhaust gas after going through a number of processes such as evaporation, flue gas entrainment, subsidence of particles on the furnace wall, particle collection in flue gas cleaning systems etc. The physicochemical properties of wastes along with the incineration conditions, influence the distribution of heavy metals. (Li et al., 2018). Another study assessing the distribution and leaching characteristics of heavy metals (As, Cd, Cr, Cu, Pb, Se, Zn, and Hg) in Zhejiang, China concluded that heavy metals (Hg, Cd, As, Pb, and Zn, Se, Cr) were transmitted into the fly ash mainly by condensation, adsorption, evaporation, and entrainment. High chlorine availability in the industrial hazardous waste favors the evaporation of some heavy metals (Cu, Pb and Zn). (Li et al., 2018).

A study conducted in 2013 monitored and compared the heavy metal concentration in brain, bone, kidney, liver and lung of autopsy tissues with 2007 results and found that chromium and manganese concentration was significantly higher in brain and bone tissues. Chromium also showed a significant increase in kidney tissues. (Mari et al., 2014). Although the emissions of metals have been reduced a lot since the discovery of modern procedures to remove dust from stacks and the chlorine emissions have also been lessened due to the sorting and recycling of plastics in municipal wastes but both metals and PCDD/F's are still a public health and environmental concern. (Cunliffe & Williams, 2007)

Belevi et al. conducted research on the factors determining the elemental behavior in municipal solid waste incinerators and suggested that Cr, Mn, Ni, and Ba were transferred to flue gas mainly by entrainment while Cu, Pb, Zn, As, Cd, and Hg were transferred to flue gas by evaporation (Belevi & Moench, 2000).

Chromium VI, nickel, cadmium and mercury are some of the heavy metals that are carcinogenic and are emitted by MWIs. Dioxins, furans and mercury pose threats to environment and humans because of their characteristic of bioaccumulation through the food chain. Nickel, which is a very harmful toxic chemical, is predominantly released from the incinerator stacks. (Boudet et al., 1999).

2.3.1. Health impacts of heavy metals:

Ingesting large amounts of arsenic can cause gastrointestinal symptoms such as severe vomiting, blood and circulation problems, nervous system damage, and eventually death. High blood pressure, heart attacks, and other circulatory diseases have also been associated with arsenic ingestion. Lung cancer is causally linked to occupational arsenic exposure, primarily by inhalation.

Even at very low levels, lead is a highly hazardous toxin. It can have a chronic or acute effect on human health depending on the quantity and exposure. Because of its systemic toxicity, lead can affect various organs in the body, including neurological, cardiovascular, renal, gastro-intestinal, hematological, and reproductive. (Tait et al., 2020)

Inhalation and ingestion are two ways in which humans are exposed to cadmium. Cadmium enters the environment through a number of human-made sources. Wastewater is a major source of cadmium poisoning in the environment, and diffuse pollution is caused by industrial air emissions. The kidney is the principal human organ affected by cadmium exposure, either in general cases or occupational ones.

Excessive copper poisoning can induce temporary gastrointestinal distress, including nausea, vomiting, and abdominal pain. In levels high enough to cause death, liver damage was seen. Copper poisoning can lead to the death of red blood cells, which can lead to anemia. (Mahurpawar, 2015)

Exposure to high levels of mercury can lead to insomnia, neuromuscular disorders, headaches etc. It is also associated with increased heart rates and blood pressure, skin rashes, eye irritations etc.

Excessive amounts of nickel can lead to lung cancer, nose cancer, laryngeal cancer, and prostate cancer etc. Sickness, dizziness, asthma and chronic bronchitis are common issues reported for nickel poisoning. .Nickel fumes irritate the lungs and can lead to pneumonitis. Nickel and its compounds can cause susceptible people to develop a dermatitis known as "nickel itch." (Mahurpawar, 2015)

2.4 Polychlorinated Aromatic Chemical pollution:

Polychlorinated dibenzo-p-dioxins (PCDDs) and polychlorinated dibenzofurans (PCDFs) are simply referred to as dioxins. PCDD/Fs group has more than 200 individual congeners. A study was conducted to assess the PCB accumulation in soil around industrial waste incinerator. PCB accumulation in soil layers depends upon the material being incinerated. The largest PCB accumulation was found to be within the top 0 to 5 cm of the soil layer. (Gabryszewska & Gworek, 2020).

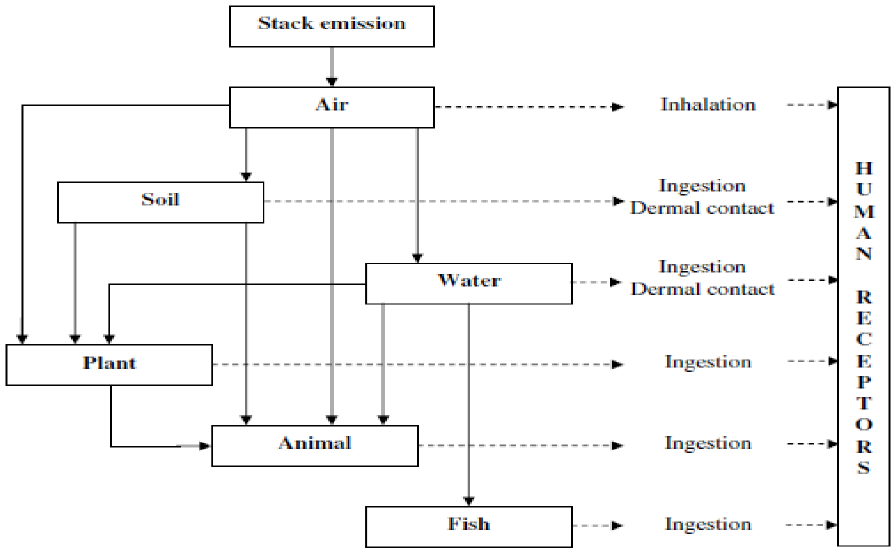
Polychlorinated biphenyls (PCBs) have huge toxicity, bioaccumulation capacity, and persistence. It is observed that PCB's are usually formed in combustion processes in the presence of substances containing chlorine. Park et al. determined the concentrations of Poly chlorinated di-benzo dioxins/furans and Poly chlorinated biphenyls in human serum samples from 26 incinerator workers out of which 10 were industrial waste workers and 16 were municipal solid waste incinerator workers. In comparison to the levels measured in the residents, higher levels of certain PCDD/F congeners, mainly PCDFs, were detected in the serum of industrial incinerator workers. Inhalation and skin contact were main roots of exposure for the industrial incinerator workers in the workplace.(Park et al., 2009).

Dioxins are highly toxic with characteristics of environmental persistence and bio-accumulation (build up in the tissues of living organisms). Dioxins can be produced as a by-product of processes that involve the usage, production or disposal of chlorine or chlorine derived chemicals, or other manufacturing and combustion processes. Research suggests, depending on the temperature profile, dioxins can be regenerated in the post-combustion zone even if they are destroyed earlier in the combustion zone of the incinerators. (Allsopp et al., 2001)

Polychlorinated biphenyls also have huge toxic reproductive, neurological and immunological human health impacts. A study concluded that PCB's were found in the stack gases from the incinerator and were a source of environmental, food and human contamination. (Allsopp et al., 2001).

2.4.1. Health impacts of Poly-chlorinated Chemicals:

Studies have concluded that exposure to dioxins have been associated with suppressed immunity, reproductive toxicity and developmental disorders. It can also cause changes in the levels of hormones, reduced sperm count in males, testicular atrophy and impaired sexual activity. Other impacts include diabetes, skin lesions, weight loss etc. These chemicals are also known to cause weaker immune system, lower birth weights, impaired thyroid and reproductive functioning and delayed cognitive development in children and infants.



(Gabryszewska & Gworek, 2020).

2.5 Soil Contamination:

Incinerator emissions, local climate such precipitation, temperature etc., geological characteristics of the site (soil type, total organic carbon and pH) and the anthropogenic activity intensity in the vicinity of the incinerators determine the soil heavy metal contamination in an area. (Ma et al., 2018).

The pollutants from the incinerator mainly get accumulated in the soil due to particle deposition, vapor diffusion and loss of contaminants through leaching, volatilization etc. Food chain exposure around the incinerators is usually considered to be the major source of human exposure to a wide range of organic airborne emissions. However, if an incinerator is equipped with modern technology then it might not be the main cause of health risks for the surrounding population. (Cangialosi et al., 2008).

Fig.5 Exposure pathways for pollutants from MSWI (Cangialosi et al., 2008)

Heavy metals present in MSW are transferred to fly ash or flue gas via evaporation during the process of combustion and then get released into the atmosphere either from the chimney or as fugitive emissions which then get accumulated in soil by wet and dry deposition. This leads to soil contamination and threatens food safety, posing a health risk to people living in the surrounding area of incinerator. (Ma et al., 2018). The results of another study showed that the soils around a solid waste incinerator were moderately polluted by Cu, Pb, Zn, and Hg and heavily polluted by As and Cd. Human health risks are also associated with Pb and Ni emissions from the incinerator stacks. The land use type also have a crucial influence on the soil heavy metals concentrations (Ma et al., 2018).

2.6 Other Health Related Issues

Apart from the emission related risks at an incinerator, hazards are also associated with mechanical and electrical equipment handling by personnel with no adequate expertise. Multitude health problems in waste management facilities are mainly due to the composition of the treated waste (organic waste, hazardous waste etc.), the chemical nature of the waste (e.g. corrosive, flammable etc.) and the factors which increase the chemical reactivity of the waste.

The health problems in SWM facilities involve pulmonary disorders, gastrointestinal problems such as diarrhea and nausea due to high concentrations of total airborne dust, bacteria, faecal coliform bacteria and fungal spores. Symptoms of organic dust toxic syndrome are also common among the workers at waste management facilities. Such as cough, chest tightness, fever, muscle ache, joint pain, fatigue and headache. Irritation of the skin, eye and mucous membranes of the nose etc. is also common. (*International Hazard Datasheets on Occupation,* 2012.)

2.7 Health and Safety Hazards:

There can be a lot of health and safety related physical or chemical hazards at an incineration facility which require proper control. Thus it is very important to identify and control them.

2.7.1 Chemical Hazards:

Workers can be exposed to the toxic waste components during incinerator operation or maintenance such as entering the unit for inspection, repair or cleaning purposes. Hazards can also be associated with the manual sorting of unseparated waste that may be a cause of exposure to airborne bacteria and endotoxin which are agents of a series of health disorders as well as it might also cause musculoskeletal disorders due to repetitive movements. (Kontogianni & Moussiopoulos, 2017) (Hu & Shy, 2001).

2**.7.2 Physical Hazards:**

The workers at a waste handling facility are mostly involved in heavy lifting, manual handling of containers, repetitive movements, whole body vibration, and exposure to cold environments which increases the risk of musculoskeletal problems. Musculoskeletal are generally defined as inflammation and degeneration affecting the muscles, joints, tendons and ligaments etc. Body parts that are most commonly effected include the lower back, neck, shoulder, arms, and hands. The risk of such issues is related with other health factors as well such as age, obesity, gender, muscle strength etc. Other factors that influence health at a facility include the working hours, work capacity, level of muscular exertion, physical load patterns, division of labor and psychosocial factors. (Punnett & Wegman, 2004)

Apart from that, noise pollution can also be a serious issue at an incineration facility due to operational errors of air blowers, pups or fuel ignition in combustion chambers. According to WHO, Noise pollution from industrial facilities can cause 7 types of health hazards which include hearing impairment, sleep disturbances, cardiovascular issues, communication impairment, negative social behavior, mental health issues and annoyance reaction.

Similarly, operational errors in rotary kilns can lead to excessive heat and pressure build up, resulting in a lot of damage. There can be a lot of other hazards for the workers such as electrocution due to electrical systems, hazards due to equipment handling, burn hazards during ash clean out or during operation, injuries during transfer of waste etc. which require proper control on operations, design, maintenance and construction of incinerator. Thus in order to elevate the health and safety status at the site, a proper risk assessment study must be carried out at the facility. *(Remediation technologies screening matrix and reference guide, n.d.)*

3. IMPLICATIONS OF THE STUDY

Based on the impacts listed from the previous studies above, the main aim of the study was to conduct a thorough process risk assessment of the site, study the current management practices and devise a risk management plan for the workers. It also monitored the air emissions, groundwater, wastewater, noise and ash to assess the likely health risks to the workers during incineration.

Literature on solid waste incinerators mainly focuses on consequences of air emissions, cancer risk assessments, environmental pollution problems etc. occurring due to incineration process and there is very little focus on occupational health and safety management at incineration plants, health and safety related knowledge of the workers and management strategies to reduce the health and safety hazards. Therefore this study is a new addition to the existing body of knowledge.

The study proves to be beneficial for the employees as it assesses their safety behavior and provides management strategies and risk management plan to eliminate or minimize the hazards associated with the whole process of the incineration.

4. RESEARCH OBJECTIVES

Following are the main research objectives of the study:

- Process Risk Assessment of the incineration plant.
- Assessment of the occupational health risks to the workers posed by the process of incineration.
- Monitoring of ambient air, groundwater, waste water, ash and noise at the incineration plant.
- Devising a risk management plan for the workers.

5. RESEARCH QUESTIONS

Following are the research questions of the study:

- What are the occupational health and safety hazards for the workers at the incineration plant located in Kala Shah Kaku?
- What are the risks associated with environmental pollution at the plant and to what extent are the workers affected by it?
- How can we minimize/eliminate the health and safety hazards and risks at the site?

6. STUDY AREA

The Incineration plant at Kala Shah Kaku is privately owned, located on a total area of 11 Kanal (5564.43 sq.m). It is designed on Canadian technology and utilizes natural gas as its fuel. With a total burning capacity of 2000kg/day it is capable to handle variety of materials for combustion at a temperature of 1250 C with almost 80% volume reduction. (*Global Eco Lab*, 2022)

Sr.No.	**Operational Parameters**	**Conditions**
1	Type	Rotary Kiln
2	Fuel	Natural Gas
3	Burning Capacity	2000 kg/Day
4	Temperature	First chamber: 1000 degree Celsius Second chamber: 1250 degree Celsius
5	Operation hours/day	8 hours
6	Moisture Content	500 Liters/day water added during incineration
7	Ash Management	Separate collection of bottom and fly ash
8	Feed Method	Manual Feeding into furnace

Table: Operational Parameters of Kala Shah Kaku Incinerator (*Global Eco Lab*, 2022)

Total number of people on the plant are 11, including 2 managers and 9 workers for handling waste and managing the incineration process.

Wastes from various industries such as beverage industry, textile industry, tobacco industry, pharmaceuticals and paint and coating industries. The major industries sending waste for incineration include Coke, Pepsi, Brighto paints, Abott and the types of waste includes expired or used paints, beverages, textile materials, used oils, sludge, expired cigarettes, expired battery waters, expired pharmaceuticals etc.

Fig 6. Location of the incinerator (Google Maps)

The waste is fed manually into the incinerator. The kiln of the incinerator keeps on rotating slowly to allow proper tumbling and exposure of the solid waste to heat. This ensures the conversion of organic and some of the metal wastes from solids or liquids to hot gases that are passed to the afterburner. Any inorganic materials such as zinc or lead that do not get converted into gases, get collected as ash at the end of the kiln which are taken out into a container manually and further managed. The ash is then used to make bricks, repair the walls of the location or to repair the inner walls of the incinerator. (*Global Eco Lab*, 2022.)

7. RESEARCH METHODOLOGY:

Initially, all the information regarding the industrial waste incineration was collected with the help of secondary data. Primary data was collected by observation method during the survey of the incineration plant and the risks and hazards associated with each process were determined. The main environmental variables that were selected for monitoring were ambient air, noise, groundwater, wastewater, ash and gaseous emissions.

7.1.1 Secondary Data:

A literature review was carried out for secondary data collection regarding the industrial waste incineration and its adverse effects on the surrounding environment. The information was gathered from research papers, books and articles.

7.1.2 Primary Data:

A field survey was done for the collection of primary data. A thorough site visit was conducted in which samples were gathered environmental monitoring was performed for all the relevant parameters. A checklist and questionnaire was designed using the standardized OSHA audits and checklists for the process risk assessment. The main aim was to determine all the occupational hazards and health risks to the workers at each of the processes listed above along with performing the environmental monitoring to assess the severity and extent of these hazards.

The facility was be divided into 5 different processes which are as follows:

- On-site transportation: Transfer of the waste from the vehicle at the main gate to segregation site.
- Segregation: Sorting and separation of waste prior to storage.
- Storage: Storage of waste prior to incineration.
- Incineration: Burning of the waste in controlled conditions.
- On-site Disposal: Collection of ash for final disposal.

For each of these processes, the environmental and the health and safety related risks and hazards were identified separately and assessment of the current control measures was made.

7.1.3 The content of the Occupational health and safety Checklist include the following:

- General health and safety
- All the possible hazards associated with each of the ongoing processes at the plant (On-site transportation, storage, segregation, incineration and On-site disposal**)**

7.1.4 The content of the OHS questionnaire include the following:

- Demographic profile
- Personal health status
- Psychological factors
- Relation with peers
- Awareness about OHS and Emergency preparedness
- Data Monitoring
- Disposal practices.

7.2 Hazard Identification

Identification of risks and hazards is a very important step in risk assessment. This step was carried out in the first field visit to the plant. In this step, maximum possible hazards were identified using the checklist for each of the main processes listed above. After the identification of potential hazards, monitoring of pre-selected environmental variables was accomplished to assess the severity and extent of these hazards.

7.3 Environmental Monitoring

Standard methods were used for the collection of samples. Following environmental variables were monitored:

Sr. No.	Parameter	Standard	Sample Location	Sample Frequency
1	Gaseous emissions	PEQS	Incinerator stack	8 hours monitoring, over a week
2	Ambient air quality and noise	PEQS	• Northern side (Main entrance) • Southern side (Back side of the premises) • Eastern side (Eastern boundary wall) • Western side (Near storage rooms) • Mid-point of the site. (Incinerator location)	8 hours monitoring, over a week
3	Ground water	WHO	Motor/pump installed in the facility.	3 alternative days
4	Waste water	PEQS	Wet scrubber	3 alternative days
5	Ash monitoring	EU sewage sludge directive (86/278/EEC)	Ash pit	1 sample

Table 2: List of Parameters for Environmental Monitoring

7.4 Equipment and Procedure:

7.4.1 HAZ Scanner TM

The Haz-Scanner™ model HIM-6000 air quality monitoring station was used to measure trace levels of criteria air pollutants. It is a portable system that simultaneously measures PM 2.5 and PM 10. The HIM-6000 has up to 12 sensors for toxic gas, sound, radiation, and meteorological air parameters. (Global Eco Lab, 2022.)

7.4.2 Digital sound level meter

Noise can be one of the major problems near incinerators due to the operation of heavy machinery. Sound level was monitored using Noise Level Meter (TES1350a). The instrument has an electric condenser microphone which converts the receiving sounds into electrical signals. It displays these signals in the form of readings on an indicating device in dB (A) or dB (C) according to the requirement. It records the noise level in any area with an accuracy of ±2dB within a range varying from 35dB to 130 dBs. (Global Eco Lab, 2022.)

7.4.3 Atomic Absorption Spectrophotometer

Atomic absorption spectrophotometer with a detector range of 190 -930 nm. Variable slit. Acetylene Air Flame was used. It determines different metals like Chromium, Cadmium, Nickel, Cobalt, Iron, Zinc, Copper, Manganese, and Molybdenum in various types of solutions (Global Eco Lab, 2022.)

7.4.4 Flame Photometer:

This instrument was used to detect potassium, sodium, arsenic etc. in ground water. It measures the emitted light intensity when a metal is introduced into the flame. The wavelength of the color gives information about the element and the color of the flame depicts the amount of element in the sample. (Global Eco Lab, 2022.)

7.4.5 Total Suspended Solids (TSS):

Filtration method was used to calculate TSS in the samples. Filter paper of 0.45mU or 0.43mU were heated for 1 hour in Hot Air Oven at 105^{o}C and then left for about 10 minutes for cooling. Then it was weighed thrice to get a constant weight of the filter paper.

Samples of 25ml, 50ml, 100ml and 500ml were filtered through this filter paper. Then this filter paper was dried in the desiccator and weighed again on the weight balance. TSS was then calculated by following formula: (Global Eco Lab, 2022.)

Total suspended solids = Difference of weight of filter paper x 1000 x 1000/ volume of sample (ml)

7.4.6 Biochemical oxygen demand: (BOD):

BOD of waste water was monitored by taking a 5ml of sample and 300ml distilled water in a bottle. DO was monitored through DO meter. After that bottles were incubated for 5 days in the incubator at 20ºC and then DO was monitored again. (Global Eco Lab, 2022.)

Difference between initial and final DO gave the BOD. BOD was calculated by following formula:

$$BOD = D1 – D2 \times 300 / 5$$

Environmental parameters sampling and monitoring

Environmental sampling and monitoring was performed on-site. The sampling method and locations for all the parameters are shown in the tables below:

Gaseous Emissions Monitoring:

Sample Location: Incinerator stack.

Sr. No.	**Parameters**	**Method**
1	Carbon monoxide	TESTO 350 S
2	Combined oxides of nitrogen (NOx)	TESTO 350 S
3	Sulfur dioxide	TESTO 350 S
4	Smoke	Ringlemann scale

Ambient Air Quality and Noise Monitoring:

Sample Location: Northern, southern, western, eastern sides of the incinerator along with the Mid-point where the incinerator is located. (Spot Testing)

Sr. No.	**Parameters**	**Method**
1	Carbon monoxide	HIM 6000 Air quality monitoring station
2	Sulfur dioxide	HIM 6000 Air quality monitoring station
3	Nitrogen oxide	HIM 6000 Air quality monitoring station
4	Nitrogen dioxide	HIM 6000 Air quality monitoring station
5	Suspended particulate matter	HIM 6000 Air quality monitoring station
6	Particulate matter (PM 10)	HIM 6000 Air quality monitoring station
7	Particulate matter (PM2.5)	HIM 6000 Air quality monitoring station

8	Ozone	HIM 6000 Air quality monitoring station
9	Lead in Particulate matter	Atomic absorption
10	Noise	Digital sound level meter.

Ground Water Monitoring:

Sample location: Grab samples from any pump/motor installed in the facility.

Sr. No.	Parameters	Method
1	PH	PH meter
2	Total dissolved solids	Evaporation
3	Turbidity	Turbidity meter
4	Sulphate	Spectrophotometer
5	Chloride	Digital titrator
8	Total hardness	Digital titrator
9	Potassium	Flame photometer
10	Sodium	Flame photometer
11	Arsenic	Flame photometer
12	Odor	Dilution
13	Fluoride	Spectrophotometer
14	Total colony count	Culture
15	Total coliforms	Culture

Wastewater Monitoring:

Sample location: Grab samples from the wet scrubber.

Sr. No.	Parameters	Method
1	BOD_5	BOD track
2	COD	Spectrophotometer
3	pH value	pH meter
4	Total suspended solids	Filtration
5	Total dissolved solids	Evaporation
6	Chloride	Digital titrator
7	Sulfate	Spectrophotometer

Ash Monitoring

Sample location: One fresh sample from the ash pit.

Sr. no	Parameters	Method
1	Cadmium	Atomic absorption Spectrophotometer
2	Copper	Atomic absorption Spectrophotometer
3	Lead	Atomic absorption Spectrophotometer
4	Mercury	Atomic absorption Spectrophotometer
5	Nickel	Atomic absorption Spectrophotometer
6	Unburned carbon	Atomic absorption Spectrophotometer

7.5 Risk Estimation:

For each identified hazard, the level of risk was estimated using the risk rating formula and the risk matrix below.

Fig 7: Risk matrix(*IOSH- Managing Safely.Pdf*, 2012.)

Following table was used for ranking the severity level of the risks in accordance with their health impact.

Severity Level (Consequences)	Impact on the Health
1 Insignificant	No injury.
2 Minor	Injury needing first Aid.
3 Moderate	Lost time injury.
4 Major	Hospital treatment.

5 Catastrophic	Death or disabling injury.

Table 3: Severity Ranking Table

The likelihood of occurrence for all the risks was calculated using the table below:

Likelihood	Guideline
5 Almost Certain	Likely to occur many times per/ day
4 Certain	Likely to occur few times per/ day
3 Occasionally	Likely to occur one time per/ day
2 Unlikely	Likely to occur every 3 months to 5 months
1 Rare	Likely to occur every year

Table 4: Qualitative Measure of Likelihood

(*IOSH- Managing Safely.Pdf*, 2012.)

After developing these ranking criterions the risk associated with the incineration process were assessed using the formula: (WHO Guidelines):

Risk = Likelihood x Severity

7.6 Risk Evaluation:

Once the risk associated with the activities were assessed using the risk estimation formula, risk was evaluated and categorized into four categories using the risk rating table and the risk matrix.

Categories	Ratings	Descriptor

Acceptable	4 or below	Must be managed by already existing and documented procedures and control measures.
Tolerable (Minor Risks)	5 to 8	Take logical and systematic steps to alleviate the risks. Use engineering controls and techniques of substitution until elimination.
Tolerable (Moderate Risks)	9-14	The activity can only proceed in a case when a standard procedure for the proposed activity has been developed, including the control measures.
Unacceptable	15 and above	Act immediately by implementing mitigation measures or by substituting, or by putting into operation the engineering control measures.

Table 5: Risk Rating Table

(*IOSH- Managing Safely.Pdf*, 2012.)

7.7 Risk Management

Using the risk ratings, and after the categorization of risks, the final step of risk assessment i.e. Risk management was carried out.

According to US-EPA risk management is the process that helps to evaluate how to protect public health. During this stage, control measures were suggested to the facility to minimize or entirely control and eliminate the hazard from occurring in the future. The following table was used for risk management:

List of Hazards	Associated Risks	Mitigation measures	Timeline

Table 6: Risk Management (*IOSH- Managing Safely.Pdf*, 2012.)

8. RESULTS:

The incineration facility located in Kala Shah Kaku had 2 managers and 9 workers. All of them were asked to fill out a questionnaire that had the following components:

8.1 Demographic Profile:

The demographic profile of the respondents was as follows:

Respondents	**Age (years)**	**Weight (Kg)**	**Marital status**	**Designation**
Respondent 1	24	85 Kg	single	Assistant manager
Respondent 2	38	75 Kg	Married	General Manager
Respondent 3	38	110 Kg	Married	Worker (for waste feeding into incinerator)
Respondent 4	45	85 Kg	Married	Worker (for segregation/storage)
Respondent 5	35	70 Kg	Married	Worker (for waste transfer, final disposal of ash)
Respondent 6	40	92 Kg	Married	Worker (for segregation/ storage)
Respondent 7	37	70 Kg	Married	Worker (for waste feeding into incinerator)
Respondent 8	34	78 Kg	Married	Worker (for waste transfer, final disposal of ash)

Respondent 9	38	60 Kg	Married	Worker (for waste feeding into incinerator)
Respondent10	22	82 Kg	Single	Worker (for waste transfer)
Respondent 11	42	97 Kg	Married	Worker (for segregation)

Table 7: Demographic profile of the workers

2 out of 11 respondents were single. None of the respondents were below the age of 18years or above the age of 60 years which is in accordance with the Hazardous occupation rules, 1963 (No. 1-6 (L-II/64) listed in the ILO (international Labor organization) regulations.

8.2 Personal Health Status of the workers:

The following graph represents the status of health issues among workers.

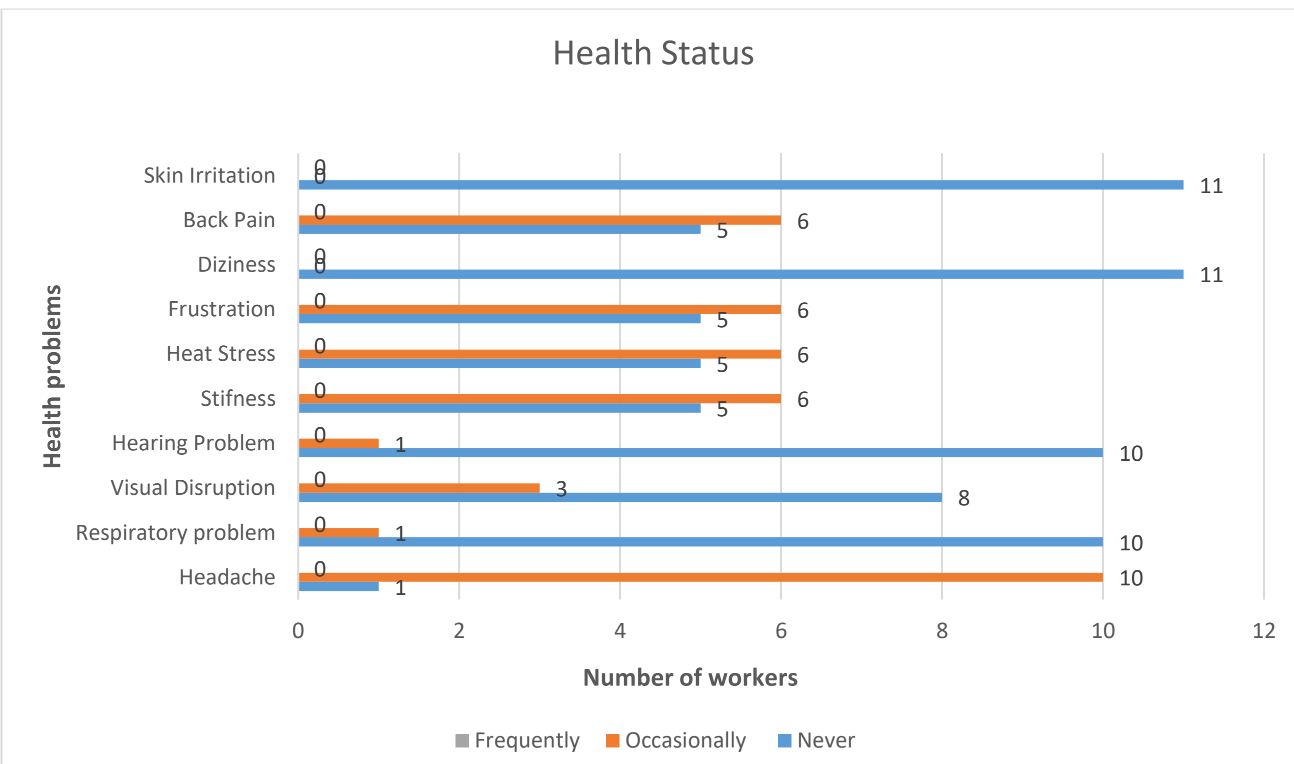


Fig 8: Health status of the workers at the incinerator

None of the workers reported skin irritation and dizziness. Six out of 11 workers reported back pain, stiffness, heat stress and frustration occasionally. Three out of 11 respondents reported visual disruption whereas 10 out of 11 workers reported head ache. Majority of the workers had no hearing or respiratory issues.

None of the workers gets a regular medical examination which is against the Hazardous occupation rule, 1963 in ILO according to which every worker must get medically examined by a certified surgeon at intervals of not more than 6 months and the facility manager must keep the record. Only 2 out of 11 workers reported that they had a medical checkup 4 to 6months earlier.

Only 1 out of 11 workers was immunized against hepatitis A, hepatitis B, polio and tetanus, and none of them reported any chronic disease.

8.3 Psychosocial Hazards:

Psychosocial hazards are the contributing factors that can lead to stress, tension, anxiety or interpersonal problems among the workers in a working environment.

Psychological satisfaction is a very important factor in personal health as low satisfaction level can lead to problems like stress and anxiety which ultimately lead to other health issues. Respondents were asked a certain number of questions that could depict their level of satisfaction from their job.

Working hours reported by the workers were between 8 to 12 hours. Three out of 11 respondents felt that their workload was excessive. All of the respondents were satisfied with their working environment and facilities provided at the plant.

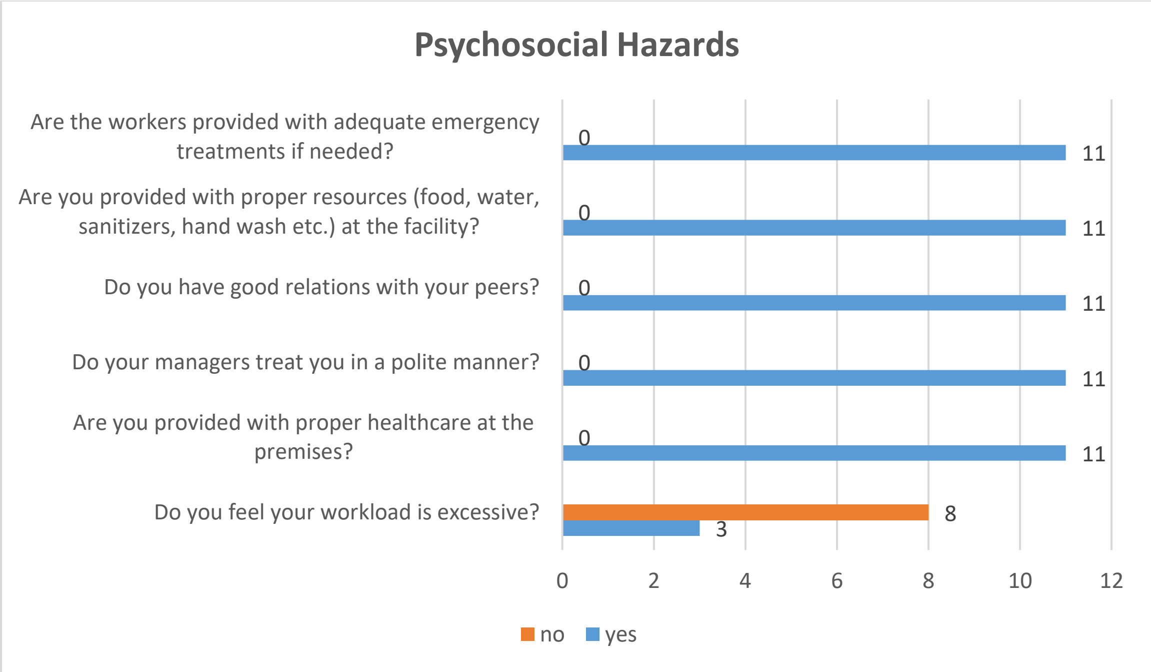


Fig 9: Psychosocial hazards at the site

8.4 OHS measures and Awareness:

All the workers were given emergency, firefighting and first aid training. They were aware about the safety measures and the harmful effects of the chemicals. First aid kits and personal protective equipment were available and workers were aware of their use. The facility had the emergency system shutdown and evacuation plans which were checked during the site inspection. All the requirements of Hazardous substance rule, 2003 ILO guidelines regarding occupational health and safety measures and awareness were met.

8.5 Monitoring Records and Operational Procedures:

Incinerator operation manual, maintenance and repair logs were available at the facility. The waste was properly weighed upon receipt and the all the records were adequately maintained with proper description about the name and address of the person from where hazardous waste was collected as well as the name and address of the person to whom the waste was being delivered along with Quantity of hazardous waste transported. This was in accordance with the Hazardous substance rule. 2003 in ILO guidelines.

8.6 Disposal Practices:

The workers dealing with the removal of ash wore correct PPE's although the ash containers were not covered after adding ash. The final ash was used for making bricks. The waste water at the facility was also incinerated at a quantity of 500litre/day.

9. ENVIRONMENTAL MONITORING:

Environmental monitoring was performed on-site. The results of the monitoring were as follows:

9.1 Gaseous Emissions Monitoring:

For gaseous emissions monitoring, sampling was done from the incinerator stack/chimney and concentrations were monitored on 8 hourly basis, over a week. Average values were calculated individually for all the parameters per day. Although PEQs require 24 hourly monitoring, but since the major focus of the study was not environmental assessment, so values were monitored 8 hourly. Gaseous emissions were found to be within the standard limits. This depicts that the incinerator had no operational errors, the pollution abatement equipment was in good working condition and thus posed no threat to the workers. There were no health risks associated with emissions.

Sr. No.	Parameters	Method	Units	PEQs	Day 1	Day2	Day3	Day 4	Day5	Day 6
1	Carbon monoxide	TESTO 350 S	mg/Nm^3	800.0	248.0	228	192	196	218	250
2	Combined oxides of nitrogen (NOx)	TESTO 350 S	mg/Nm^3	600.0	76.4	82.3	78.2	78.4	77.8	83.5
3	Sulfur dioxide	TESTO 350 S	mg/Nm^3	1700.0	71.5	78	69	74	73	79
4	Smoke	Ringlemann scale	Ringlemann Scale	2.0	1	1	1	1	1	1

Table 8: Gaseous Emissions Monitoring

The graph below depicts the weekly trend of gaseous emissions at the plant. At the end of each day, one average value was calculated out of the 8 hourly values (peak working hours). The values for sulfur dioxide fluctuate between 69 to 79 mg/Nm^3 which is quite below the PEQ limit of 1700 $mg/Nm^{3.}$ Similarly the values for Carbon monoxide ranges from 192 to 250 mg/Nm^3 and for oxides of nitrogen it ranges between 76.4 to 83.5 mg/Nm^3 which are far less than the PEQ limits of 800 mg/Nm^3 and 600 mg/Nm^3 respectively. Minor variations can be seen in the values, which could be due to difference in the type of waste being incinerated, human error during measurement or traffic hours outside the premises etc.

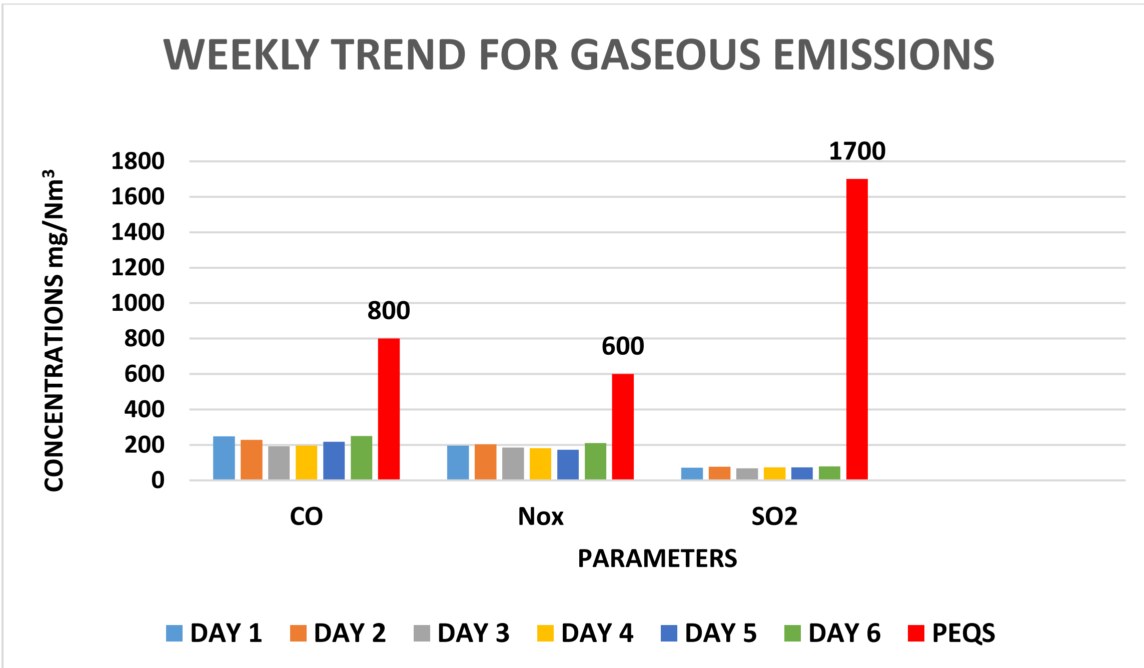


Fig 10: Graph depicting weekly trend for Gaseous emissions monitoring.

9.2 Ambient Air Quality and Noise Monitoring:

Ambient air monitoring was done in the whole facility dividing it into 5 different sides (northern, eastern, western, southern.) with the mid-point being near the incinerator, over a week on an 8-hourly basis. Noise was monitored at the same 5 sides and average value was calculated per day. None of the values exceeded the PEQ limits.

Sr. No.	Parameter	Method	Units	PEQs	DAY 1	DAY 2	DAY 3	DAY 4	DAY 5	DAY 6
1	Carbon monoxide	HIM 6000 Air quality monitoring station	mg/m^3	10	0.25	0.30	0.27	0.38	0.41	0.47
2	Sulfur dioxide	HIM 6000 Air quality monitoring station	$\mu g/m^3$	120	4.41	4.42	3.6	3.89	4.5	4.0
3	Nitrogen oxide	HIM 6000 Air quality monitoring station	$\mu g/m^3$	40	BDL	BDL	BDL	BDL	0.2	BDL
4	Nitrogen dioxide	HIM 6000 Air quality monitoring station	$\mu g/m^3$	80	12	11	14	14	15	15.5

5	Suspended particulate matter	HIM 6000 Air quality monitoring station	μg/m^3	500	281	276	273	269	278	281
6	Particulate matter (PM 10)	HIM 6000 Air quality monitoring station	μg/m^3	150	95	89	77	72	88	96
7	Particulate matter (PM2.5)	HIM 6000 Air quality monitoring station	μg/m^3	35	18	15	12	11	17	19
8	Ozone	HIM 6000 Air quality monitoring station	μg/m^3	180	8.6	7.8	9.6	8.1	11	8.3
9	Lead in Particulate matter	Atomic absorption	μg/m^3	2	BDL	BDL	BDL	BDL	BDL	BDL
10	Noise	Digital sound level meter.	dB	75	45.6	46	44.2	45.8	43.5	43.8

Table 9: Ambient Air and Noise Monitoring

The following graphs depict the weekly trends for air quality parameters. At the end of each day, one average value was calculated individually for all the parameters. The concentration of all the parameters was found to be within the standard limits. Slight variations were observed during the week that could be because of the traffic outside the premises, human errors or other working operations going on near the monitoring site. Moreover the emissions also vary depending upon the type of waste being incinerated. The values for sulfur dioxide fluctuates between 3.6 to 4.5 $\mu g/m^3$ and for nitrogen dioxide between 11 to 15.5 $\mu g/m^3$ which are quite below the PEQ limits of 120 $\mu g/m^3$ and 80 $\mu g/m^3$ respectively. The values for PM2.5 range from 11 to 19 $\mu g/m^3$ which are within the standard limits of air quality. The values for ozone vary from 7.8 to 10 $\mu g/m^3$ which are far less than the standard limit of 180 $\mu g/m^{3.}$

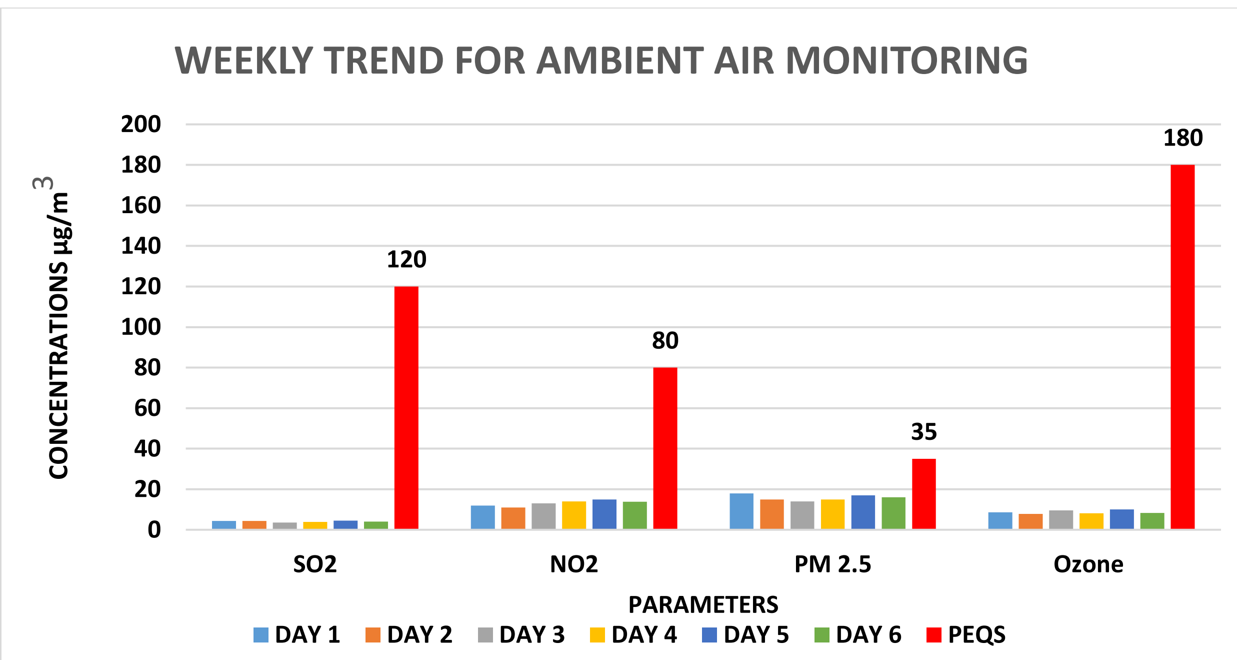


Fig 11A: Graph depicting weekly trend for Ambient Air monitoring

The values for suspended Particulate matter ranges from 269 to 281 µg/m^3 whereas the PEQS limit is 500 µg/m$^{3.}$ Similarly, PM10 values exist between 72 to 96 µg/m^3 below the standard limit of 150 µg/m$^{3.}$

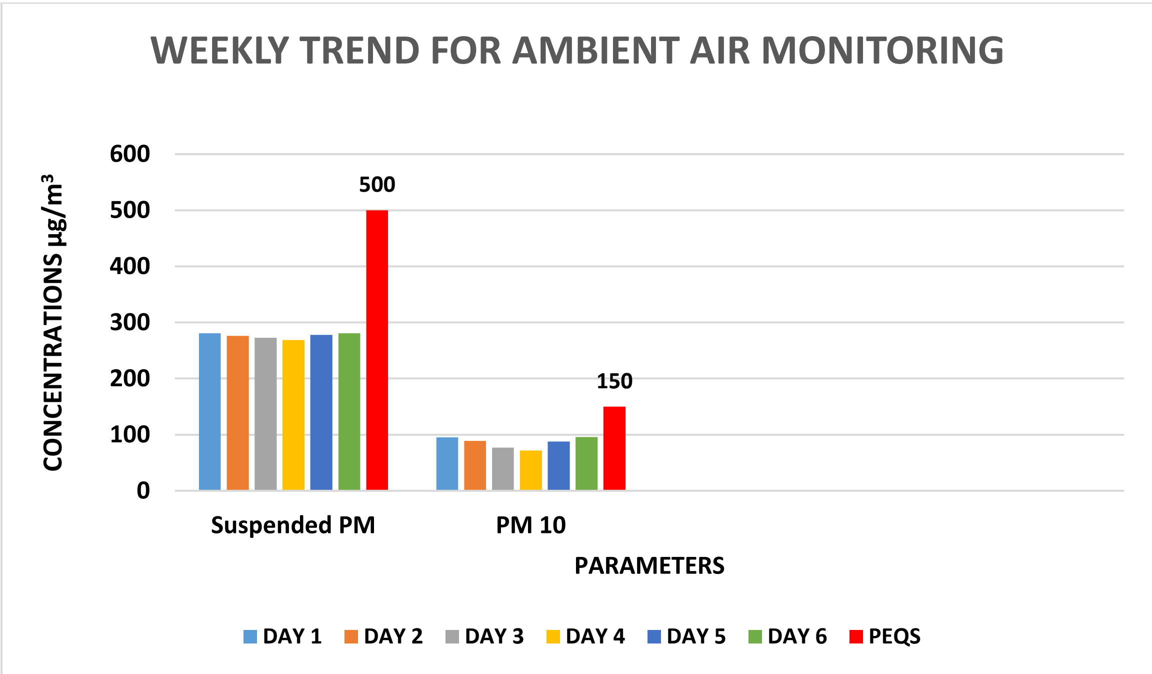


Fig 11B: Graph depicting weekly trend for Ambient Air monitoring

Noise was monitored at the same 5 locations as the ambient air and it was found to be in accordance with the PEQ limits. The noise values fluctuate between 43.5 to 46 dB which are within the PEQ limit of 75dB for industrial area. The slight variation in noise might be due to difference in traffic hours, or ongoing work on site during monitoring.

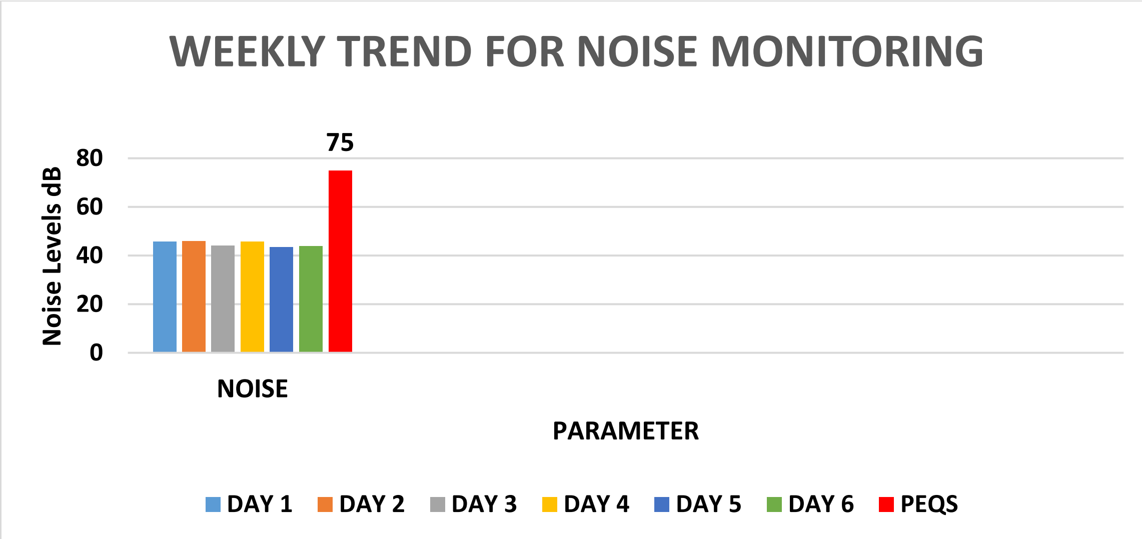


Fig 12: Graph depicting weekly trend for noise monitoring

9.3 Ground Water Monitoring:

Groundwater samples were collected from the pumps installed in the facility. Samples were taken on 3 alternative days to get an estimate of the parameters overall at the site. WHO values were used since no PEQs exist for ground water. All the parameters were found to be within the limits with negligible fluctuations within the values.

Sr. No.	Parameters	Method	Units	WHO guidelines	Sample 1	Sample 2	Sample 3
1	PH	PH meter	---	6.5-8.5	7.1	7.1	7.12
2	Total dissolved solids	Evaporation	mg/L	1000.0	341.0	343.0	345.2
3	Turbidity	Turbidity meter	NTU	5	0.25	0.25	0.283
4	Sulfate	Spectrophotometer	mg/L	250.0	130.0	129.8	130.5

5	Chloride	Digital titrator	mg/L	250.0	228.0	227.7	228.6
8	Total hardness	Digital titrator	mg/L	500.0	94.0	94.3	94.2
9	Potassium	Flame photometer	mg/L	NS	4.7	4.6	4.65
10	Sodium	Flame photometer	mg/L	250.0	98.6	97.8	97.9
11	Arsenic	Flame photometer	mg/L	0.01	0.005	0.005	0.005
12	Odor	Dilution	TON	3	0	0	0
13	Fluoride	Spectrophotometer	mg/L	1.5	0.17	0.17	0.18
14	Total colony count	Culture	cfu/ml	<500	178	176	179
15	Total coliforms	Culture	cfu/100ml	0	0	0	0

Table 10: Groundwater Monitoring

9.4 Wastewater Monitoring:

Similarly, the samples for wastewater were taken from the wet scrubber on 3 alternative days for monitoring, in order to take an estimate for the each parameter at the site overall. Very minor fluctuations were observed in the values. The wastewater concentrations were also within the PEQS limits. Per day incineration capacity of wastewater was kept low (500litre/day) to maintain the incinerator temperature.

Sr. No.	**Parameter**	**Method**	**Units**	**PEQs**	**Sample 1**	**Sample 2**	**Sample 3**

1	BOD5	BOD track	---	80	11	19	17.8
2	COD	Spectrophotometer	mg/L	150	24	33	31.4
3	PH value	PH meter	mg/L	6.0-9.0	7.83	7.91	7.92
4	Total suspended solids	Filtration	mg/L	200	56	44	40
5	Total dissolved solids	Evaporation	mg/L	3500	1780	1458	1410
6	Chloride	Digital titrator	mg/L	1000.0	118.0	134	128
7	Sulfate	Spectrophotometer	mg/L	800.0	89.0	86	82

Table 11: Wastewater Monitoring

9.5 Ash Monitoring

Fresh homogenized ash sample was collected from the ash pit and the concentrations of all the heavy metals were monitored which were found to be within the standard limits. The values were compared to the EU sewage sludge directive (86/278/EEC) as no PEQS exist for ash monitoring and it was only performed to check if any hazards exist due to heavy metals present in the ash. Cadmium and mercury were below detection limit, whereas copper, lead and nickel were 1

Sr. no	Parameters	Method	Units	EU sewage sludge Directive (86/278/ EEC)	Concentrations
1	Cadmium	Atomic absorption	mg/L	40	BDL

2	Copper	Atomic absorption	mg/L	1750	11.4
3	Lead	Atomic absorption	mg/L	1200	25
4	Mercury	Atomic absorption	mg/L	25	BDL
5	Nickel	Atomic absorption	mg/L	400	4.9
6	Unburned carbon	Atomic absorption	%	….	<5

Table 12: Ash Monitoring

10. RISK ASSESSMENT:

A thorough risk assessment of the facility was carried out using an occupational health and safety checklist that was designed specifically for this facility based on previous incinerator audits and standardized environmental health and safety checklists. The checklists were filled during the visit to the facility. The results were as follows:

Occupational Health and Safety Hazard Identification Checklist

General Health and Safety				
Sr. no	**Description**	**Yes**	**No**	**Remarks**
1	Are all areas properly illuminated?			• Incinerator is located in open environment and operated during daytime. • Storage areas have proper heavy duty light bulbs
2	Are warning signs displayed properly?			• Warning signs are placed properly throughout the facility (danger, hazardous chemicals, first aid signs etc.)
3	Work areas clean, sanitary, and orderly. (Garbage disposed of properly, etc.)			• The waste was openly dumped/ placed in the facility causing a bad odor.
4	Are security activities in proper order?			• Security guards available at the main entrance.

				• Gates opened only for working personnel.
5	Are SOP's available?			• The workers are aware of the SOP's and their use.
Personal Protective Equipment				
6	Are PPE's adequately available?			• Workers must have a full covered uniform, especially the ones working near the incinerator. They were wearing their normal clothes with other PPE's.
7	Are PPE's in good condition?			• Other PPE's were available and in good condition.
8	Are PPE's adequately used?			• The safety masks were not worn.
First Aid				
9	Are first aid signs clearly displayed?			• The signs were clearly displayed throughout the facility. • Description in Urdu and English.
10	Are first aid kits and their contents clean orderly and adequately stocked and not expired?			• Yes the first aid kits were available.
Emergency Preparedness				

11	Are emergency contact number available and clearly displayed?			• Emergency contact number not displayed
12	Is the fire-fighting facility adequately available at the facility?			• Fire-fighting equipment available in all the areas
13	Are the workers trained in case of emergencies?			• Workers were trained for all emergencies by the supervisor.
14	Do they have an up to date emergency plan?			• No proper emergency plan available.
Waste Storage and Disposal				
15	Is the waste receipt log available?			• Complete record available with the supervisor.
16	Is the ventilation in the storage rooms appropriate?			• Exhausts available and large airy rooms.
17	Are waste bags/ container adequately available?			• Containers adequately available.
18	Are the waste containers labelled properly?			• The walls where the containers were placed were labelled.
19	Is water supply for cleaning adequately available?			• Adequate water supply available.
20	Is drainage system in proper condition?			• No pollution due to poor drainage observed.

21	Are the Odor causing materials/chemicals properly maintained?			• The facility had an overall bad odor in the storage areas as well.
Psychosocial Hazards				
22	Are workers satisfied with their Workload?			• Few workers felt excessive workload. Which might be the cause of frustration and headaches reported in questionnaires.
23	Is the Managerial behavior proper?			• Friendly and cooperative managers.
24	Do workers have good relation with peers?			• Friendly working environment.
25	Are workers provided with proper facilities (food, water, hand wash, sanitizers etc.)?			• All workers satisfied with the facilities provided.
Incinerator Information				
26	Is the incinerator operation manual available?			• Available with the manager.
27	Incinerator maintenance records			• Available with the manager.
28	Training of personnel working at the plant			• Workers trained by supervisor.
29	Incinerator monitoring			• Done every month.

Incineration is a continuous process that requires accurate operational conditions to work in a proper manner. Different types of waste require different SOP's as each type has specific type of emissions and end products. Any fluctuations or instabilities in the operational conditions and SOP's can lead to different types of risks and hazards at the workplace. Following table depicts the important parameters to be kept in mind regarding the process of incineration: (Nidoni, 2017) (*The Incinerator Guidebook: A Practical Guide for Selecting, Purchasing, Installing, Operating, and Maintaining Small-Scale Incinerators in Low-Resource Settings*, 2010.)

Operational Parameters of an Incinerator

Sr. No.	**Parameters**	**Operating conditions**	**Impact**
1	Temperature	Temperature has to be from 1000-1200C and waste must be exposed to that temperature for 1-2 seconds	Proper temperature is necessary to me maintained in order to minimize emissions.
2	Chimney Height	It should not be less than 50 to 60ft high.	Chimney height is necessary to ensure proper dispersion and air flow.
3	Air control	Total air supply and proper mixing of air and combustion gas must be ensured	This process is necessary to ensure the conversion of hazardous gases to less or non-hazardous forms.
4	Agitation	Proper Agitation and turbulence of the waste in the kiln must be ensured.	This process is very important for a thorough homogenized burning of the waste.
5	Residence Time	Residence time for gas in the secondary chamber should not be less than 1 sec.	This process reduces the toxicity of the fumes emitted.

6	Pollution Abatement Equipment	Proper pollution control equipment such as wet scrubber, electrostatic precipitators, bag house filter etc. must be installed.	The pollution control equipment are necessary for complying with modern emission limits.
7	SOP’s according to the type of waste	SOP’s must be in accordance with the type of the waste being burnt in the incinerator.	Different wastes lead to different emissions, thus appropriate SOPs are necessary for ensuring safety.
8	Emissions Monitoring and controls.	Continuous or periodic monitoring/ for every batch there should be separate monitoring.	Incineration is a batch process which can lead to different emissions during each batch, thus continuous monitoring must be preferred.
9	Ash Disposal	The ash pit must be made of bricks or concrete blocks. The ash monitoring must be ensured prior to disposal. Ash must be removed from the pit frequently during the process.	This is necessary to prevent leaching of harmful substances into the soil.

Table 14: Operational Parameters of an Incinerator

Table 15: Risk Evaluation Table

Hazard category	**List of possible hazards**	**How/when harm could occur**	**Risk of (injury or illness category)**	**Risk to? (Number and type of people exposed)**	**Existing controls**	**Human Factors (Application of controls, fatigue, rushing, vulnerable populations, etc.)**	**Existing Overall Risk**		
							Potential severity	**likelihood**	**Risk Category**
ON-SITE TRANSPORTATION									
Vehicles	Transport	People falling from vehicle or parts of it. Vehicle crashing into other objects. Objects falling from trucks onto staff.	Fall from height. Trip hazard.	workers (including managers)	All operators trained properly. Only trained workers allowed to enter the facility.	Action error/ Mismanagement	moderate (3)	unlikely (2)	Tolerable (6)

Hazard category	**List of possible hazards**	**How/when harm could occur**	**Risk of (injury or illness category)**	**Risk to? (Number and type of people exposed)**	**Existing controls**	**Human Factors**	**Potential severity**	**likelihood**	**Risk Category**
Ergonomics risk.	Quantity of the weight coming at the site	Manually lifting large quantities of the waste can cause musculoskeletal problems	Musculoskeletal issues	workers	Lorries available to transport waste to the storage areas. Physically fit workers trained for carrying.	Repetitive movements or awkward posture.	Major (4)	Certain (4)	Unacceptable (16)
Chemicals	Type of the waste	Hazardous materials can irritate skin or eyes, vapors can cause breathing difficulties.	Skin issues, respiratory problems.	workers	Limited workers allowed to transport. PPE's used properly.	Non-compliance	moderate (3)	occasionally (3)	Tolerable (9)
Ergonomics risk.	Manual handling during unloading	Worker might suffer from back pain during unloading waste	back pain, Stiffness	workers	Manual handling aids available, worker trained in manual handling.	Repetitive movements might cause issues.	moderate (3)	certain (4)	Tolerable (12)

Hazard category	List of possible hazards	How/when harm could occur	Risk of (injury or illness category)	Risk to? (Number and type of people exposed)	Existing controls	Human Factors	Potential severity	likelihood	Risk Category
Struck by object	Heavy weight lifting /lifting operations	Worker might suffer from serious injury if struck by heavy object during lifting.	fracture/injury	workers	Lifting aids available.	Wrong posture can lead to MSD's.	major (4)	occasionally (3)	Tolerable (12)
Slip hazard	Spills and leakage	Workers might slip over the spills or chemical exposure.	Skin issues, respiratory problems, fractures.	Workers including managers.	workers are trained to work, non-slip footwear worn	Accidental spills, mismanagement.	major (4)	unlikely (2)	Tolerable (8)
Stationary objects	Struck by an object/ obstructions	workers might hit into an object during transport	musculoskeletal issues	workers	Area kept clear, trained staff.	mismanagement/ thinking error/shortcuts	moderate (3)	unlikely (2)	Tolerable (6)
Sharp objects	Physical injuries (cuts, rash etc.)	Workers might get exposed to sharp objects in the waste.	minor cuts, bruises etc.	workers	PPE's used, staff trained to work.	Attention diversion/accidental exposure	minor (2)	unlikely (2)	Acceptable (4)

Hazard category	**List of possible hazards**	**How/when harm could occur**	**Risk of (injury or illness category)**	**Risk to? (Number and type of people exposed)**	**Existing controls**	**Human Factors**	**Potential severity**	**likelihood**	**Risk Category**
Slip/trip/fall hazard	Stairs/platforms/walkways	workers might fall or slip from the stairs or platforms	Fractures, physical injury.	Workers including managers.	Walkways are kept clear ensuring no obstruction.	Action error	moderate (3)	unlikely (2)	Tolerable (6)
Extreme weather	Weather and natural hazards	Rains might cause leakage of waste bags.	Exposure to chemicals.	Workers including managers.	Wearing PPE's while handling waste.	accidental leakage	minor (2)	rare (1)	Acceptable (2)
SEGREGATION									
Toxics and irritants	Chemical/ dust/ gases exposure	Workers might get exposed to toxic chemicals and dust during segregation	Skin and eye irritation, respiratory problems.	workers	Workers wear correct PPE's, gloves, masks etc.	Negligence of workers	moderate (3)	unlikely (2)	Tolerable (6)
spills and leakages	leakage of hazardous material	waste bags can leak or hazardous chemicals might get spilled	skin problems, fall or slipping	workers	Workers wear gloves. Spills cleaned immediately	Accidental spillage	minor (2)	unlikely (2)	Acceptable (4)

Hazard category	**List of possible hazards**	**How/when harm could occur**	**Risk of (injury or illness category)**	**Risk to? (Number and type of people exposed)**	**Existing controls**	**Human Factors**	**Potential severity**	**likelihood**	**Risk Category**
Ergonomics risk.	Repetitive movement	workers might experience back pain or muscular pain due to repeated movements	back pain, stiffness	workers	Workers can take break during work.	Wrong posture can lead to MSD's.	moderate (3)	occasionally (3)	Tolerable (9)
confined area	Working in confined space	workers might experience serious health issues if segregation occurs in confined rooms	Lack of oxygen. Exposure to hazardous substances	workers	Working in confined spaces is avoided. Maximum work in open air.	Might have to work in confined area due to weather conditions	major (4)	unlikely (2)	Tolerable (8)
sharp objects	Physical injuries	Workers might get exposed to sharp glass or metals during segregation	Cuts, bruises.	workers	PPE's used, staff trained to work.	Accidental exposure	moderate (3)	Certain (4)	Tolerable (12)
STORAGE									

Hazard category	**List of possible hazards**	**How/when harm could occur**	**Risk of (injury or illness category)**	**Risk to? (Number and type of people exposed)**	**Existing controls**	**Human Factors**	**Potential severity**	**likelihood**	**Risk Category**
Confined area	Working in confined space	Workers might experience serious health issues in confined storage rooms	Lack of oxygen. Exposure to hazardous substances	workers	Storage rooms have exhausts. Minimum number of people enter the rooms.	Physical capability	major (4)	rare (1)	Acceptable (4)
Explosive material	Flammable items	flammable materials might cause explosion	major injuries/ burns	workers	Fire extinguishers available, danger signs labelled, trained workers.	Mismanagement due to negligence.	Catastrophic (5)	rare (1)	Tolerable (5)
Hot/cold environment	working in hot/cold environments	workers might experience inconvenience due to extremely hot or cold weather	heat stress in summers, cold in winters	workers	Adequate ventilation in storage areas.	increased time due to excessive workload	major (4)	unlikely (2)	Tolerable (8)
Ergonomics risk.	Manual handling	Workers might experience back pain or stiffness due to repetitive movements during manual handling.	MSD's	workers	Manual handling aids available, worker trained in manual handling.	Excessive workload, or wrong posture during work.	major (4)	Certain (4)	Unacceptable (16)

Hazard category	List of possible hazards	How/when harm could occur	Risk of (injury or illness category)	Risk to? (Number and type of people exposed)	Existing controls	Human Factors	Potential severity	likelihood	Risk Category
Spills and leakages	Spills and leakage	Hazardous material might get spilled causing exposure of workers to toxic chemical	Skin issues, respiratory issues, slip hazard.	workers	Spills cleaned immediately, PPE's worn to prevent skin exposure	Negligence of workers/ Mismanagement	moderate (3)	occasionally (3)	Tolerable (9)
Electricity	Electrical distribution systems/ sockets, plugs	Workers might experience injuries due to faulty electrical systems	burns, injuries, shocks	workers	Circuits are properly insulated and regularly inspected	Accidental exposure	Catastrophic (5)	unlikely (2)	Tolerable (10)
Biological hazard	Animals/molds/bacteria	Improper cleaning of rooms can lead to animals, molds or bacterial growth.	Skin issues, insect bites etc.	workers	good housekeeping is ensured	Negligence of workers/ non-compliance	minor (2)	unlikely (2)	Acceptable (4)
Workplace	Inaccessibility of storage area	storage area might not be located at an easily accessible place	Fall, struck by objects.	workers	Storage area is at a proper location	Rushing or mismanagement.	moderate (3)	unlikely (2)	Tolerable (6)
INCINERATION									

Hazard category	List of possible hazards	How/when harm could occur	Risk of (injury or illness category)	Risk to? (Number and type of people exposed)	Existing controls	Human Factors	Potential severity	likelihood	Risk Category
Hot surfaces	Thermal stress	Workers might experience excessive heat near incinerator	Heat stress, burns.	workers	PPE's available to prevent from excessive heat	Excessive workload.	major (4)	unlikely (2)	Tolerable (6)
Sharp objects	Physical injuries	Workers might suffer from injuries due to sharp objects in waste	Cuts, bruises.	workers	Gloves, masks, goggles worn.	Negligence of workers.	moderate (3)	unlikely (2)	Tolerable (6)
Fall/trip hazard	Fall from height	Worker feeding the waste into the incinerator might fall	Fractures, physical injury.	workers	Trained staff allowed to feed the waste	Accidental fall	major (4)	occasionally (3)	Tolerable (12)
Chemicals	Exposure to emissions	workers exposed to emissions from chimney	Respiratory problems, other health issues	workers	Emission limits are met	Monitoring negligence	moderate (3)	rare (1)	Acceptable (3)

Hazard category	**List of possible hazards**	**How/when harm could occur**	**Risk of (injury or illness category)**	**Risk to? (Number and type of people exposed)**	**Existing controls**	**Human Factors**	**Potential severity**	**likelihood**	**Risk Category**
Chemicals	Exposure to chemicals	workers exposed to hazardous chemical fumes from incinerator	Respiratory problems, other health issues	workers	PPE's used. Emissions within standard limits.	Monitoring negligence	moderate (3)	rare (1)	Acceptable (3)
Vibration	Hand/arm/Wh ole body vibration	Worker feeding the waste into incinerator experiences whole body vibration	back pain, MSD's	workers	Workers allowed to shift positions.	static work posture/ Fatigue	moderate (3)	Certain (4)	Tolerable (12)
Ergonomic s risk.	Repetitive movements /posture	Worker feeding the waste experiences repetitive movement	MSD's	workers	Workers allowed to shift positions.	static work posture/ Fatigue	moderate (3)	Certain (4)	Tolerable (12)
Noise	Excessive noise	workers working near the incinerator might hear excessive noise	Hearing problems	workers	Noise levels within standard limits	Regular Inspection might be delayed which may cause noise issues	minor (2)	unlikely (2)	Acceptable (4)

Hazard category	List of possible hazards	How/when harm could occur	Risk of (injury or illness category)	Risk to? (Number and type of people exposed)	Existing controls	Human Factors	Potential severity	likelihood	Risk Category
Machinery	Dangerous machinery parts	Workers might suffer injuries due to dangerous incinerator parts	Physical injuries.	workers	PPE's used. Only trained personnel allowed to operate	Negligence	Catastrophic (5)	unlikely (2)	Tolerable (10)
Steam	Pressurized systems	The incinerator parts might explode due to extreme pressure	major injuries, burns	workers	Operational requirements properly met	Operational error	Catastrophic (5)	rare (1)	Tolerable (5)
Fire	Fire and explosions	The incinerator might get on fire and explode	major injuries, burns	workers	Operational requirements properly met	Operational error	Catastrophic (5)	rare (1)	Tolerable (5)
Weather events	Natural hazards	The workers might experience fall or slip hazard due to rain	Physical injuries.	workers	Slip free boots worn by the workers	Accidental fall	moderate (3)	unlikely (2)	Tolerable (6)

Hazard category	List of possible hazards	How/when harm could occur	Risk of (injury or illness category)	Risk to? (Number and type of people exposed)	Existing controls	Human Factors	Potential severity	likelihood	Risk Category
Chemicals	Chemical reactions	There might be an explosion due to certain chemical reactions within the kiln	Major injuries, burns	workers	Operational requirements properly met	Operational error	Catastrophic (5)	rare (1)	Tolerable (5)
Operational	Cracks in incinerator	There might be cracks in the incinerator which may lead to improper burning	Respiratory problems, other health issues	workers	incinerator inspection done regularly	Operational error	moderate (3)	rare (1)	Acceptable (3)
ON-SITE DISPOSAL									
Fall/trip hazard	Pit/dumps	The workers might fall into the pit or dump made for ash causing skin harm.	skin/eye irritation,	workers	Wearing safety shoes with good grip.	Fatigue, accidental fall/ action error	moderate (3)	rare (1)	Acceptable (3)
Chemical/dust	Exposure to ash	The workers can suffer from health issues due ash dust exposure	Respiratory problems, other health issues	workers	PPE's used (masks, gloves, goggles)	Negligence	moderate (3)	occasionally (3)	Tolerable (6)

Hazard category	**List of possible hazards**	**How/when harm could occur**	**Risk of (injury or illness category)**	**Risk to? (Number and type of people exposed)**	**Existing controls**	**Human Factors**	**Potential severity**	**likelihood**	**Risk Category**
Toxic gases	Exposure to gaseous emissions	The workers might get exposed to toxic gases from the freshly burnt waste.	Respiratory problems, other health issues	workers	PPE's used (masks, gloves, goggles)	Non-compliance	moderate (3)	occasionally (3)	Tolerable (6)
Ergonomics risk.	Manual handling of ash	Repetitive movements for ash removal from the pit might cause back pain	MSD's	workers	Working in shifts to avoid over workload.	Long working time/physical capability	moderate (3)	Certain (4)	Tolerable (12)
obstruction	Struck by objects	The workers might hit themselves into the waste containers accidentally	Physical injury.	workers	Staff trained to work professionally	Action error/mistake	minor (2)	unlikely (2)	Acceptable (4)
Hot/cold environment	Hot/cold working environment	Heat stress in summers, cold weather in winters during ash removal	heat stress in summers, cold in winters	workers	Adequate facilities available for workers	Inappropriate working environment	moderate (3)	unlikely (2)	Tolerable (6)

Hazard category	**List of possible hazards**	**How/when harm could occur**	**Risk of (injury or illness category)**	**Risk to? (Number and type of people exposed)**	**Existing controls**	**Human Factors**	**Potential severity**	**likelihood**	**Risk Category**
Hand tools	shovel	Workers might accidentally injure themselves using the hand tools for ash removal	Physical injuries.	workers	Staff trained to work professionally	Divided attention, mistake,	moderate (3)	unlikely (2)	Tolerable (6)
Toxic material	Ash transportation containers	The final ash in the containers which is not covered might cause exposure to toxic materials	Skin problems and irritation.	workers	PPE's used (masks, gloves, goggles)	Non-compliance	moderate (3)	unlikely (2)	Tolerable (6)

Following graph represents the general category of the hazards and the number of risks associated with them throughout the process of incineration.

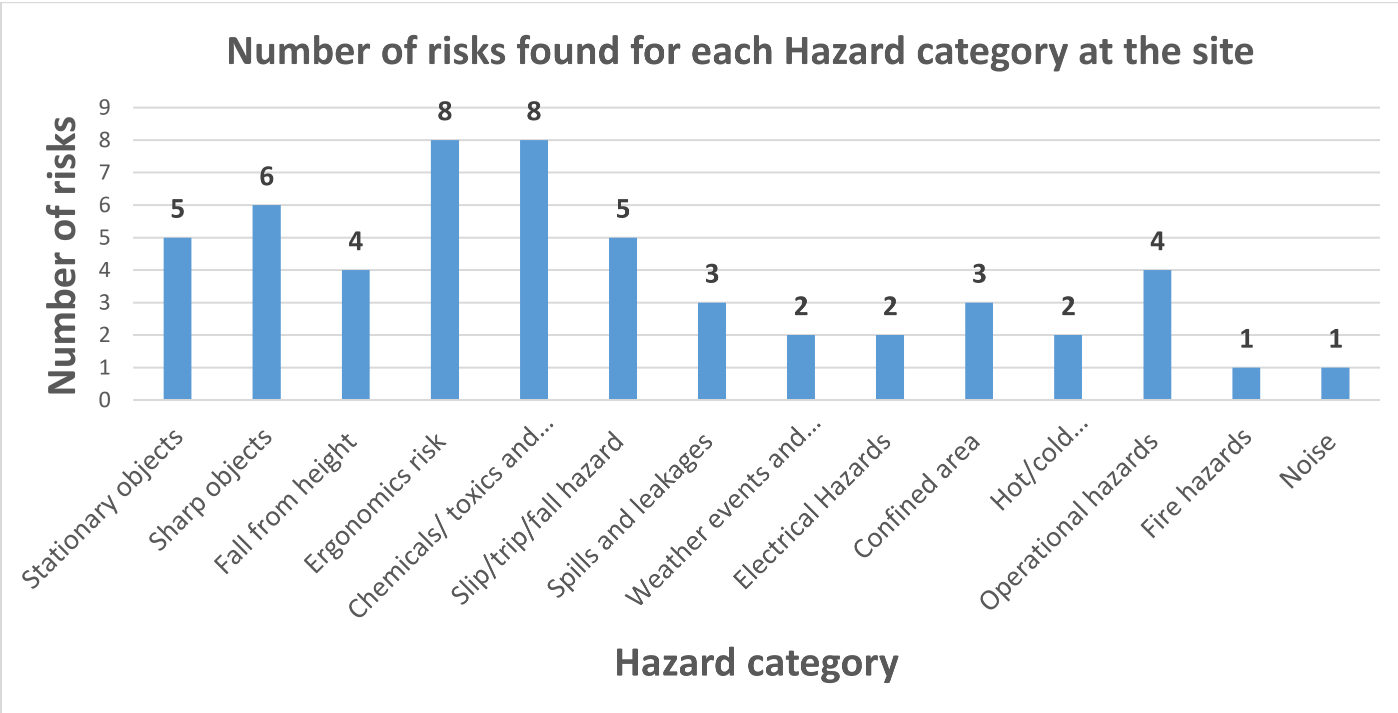


Fig 13: Types of Hazards and Number of Risks Associated at the Site

Maximum possible hazards were identified at all of the processes occurring at the incineration facility. Considering the overall risks, potential severity, likelihood of occurrence of a hazard and existing controls, the risk level for majority of the hazards was found in Tolerable limits in which the activities can be continued following proper standard procedures and engineering controls and techniques which will be recommended later in the study. Only two hazards were found to be unacceptable which were related to musculoskeletal disorders that might occur due to manual handling of heavy waste. Following graph depicts the number of risks at each risk level on the site.

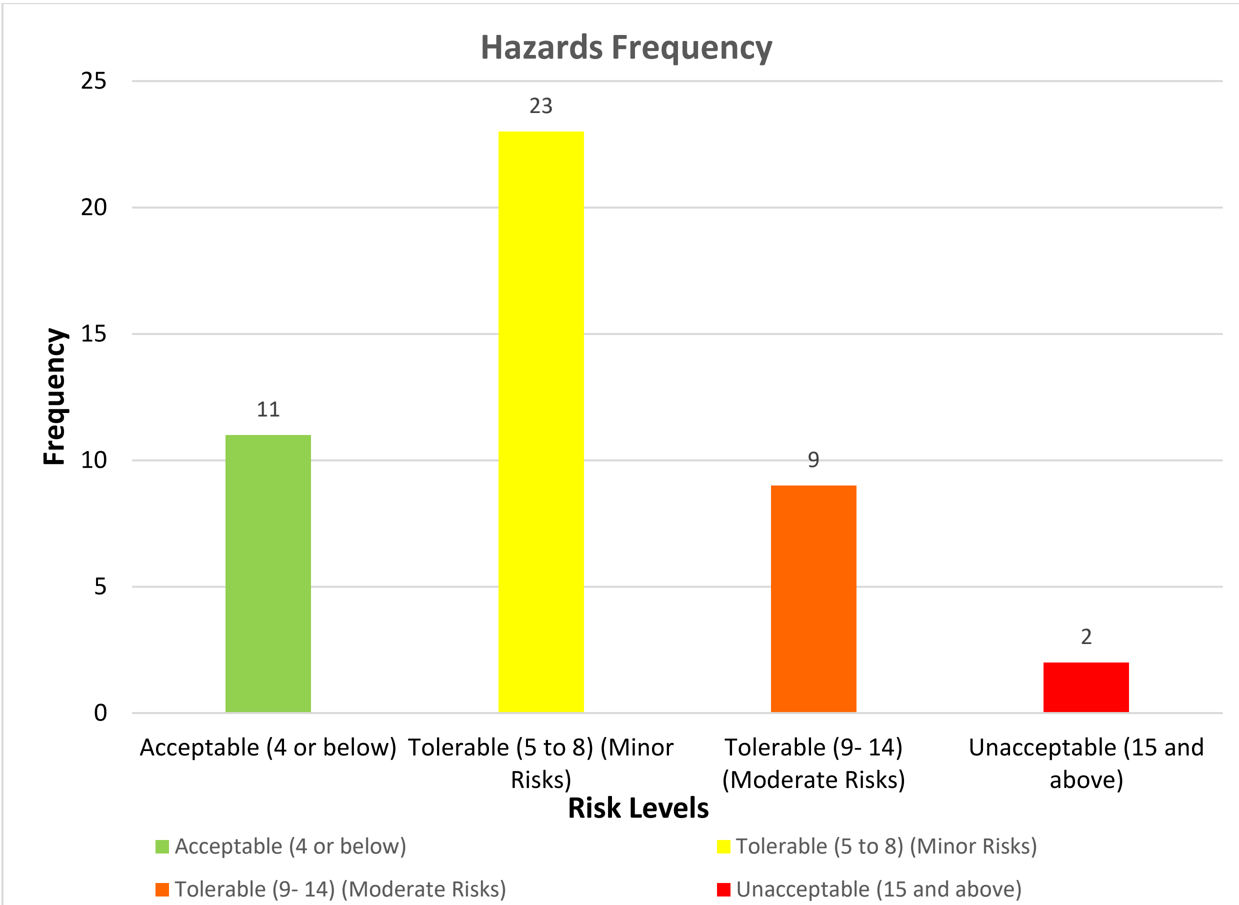


Fig 14: Risk levels at the Site

Requirements of International Labor Organization:

Out of 21 total legislations of Pakistan about Occupational Health and Safety in ILO, 3 were relevant to my area of study which are as follows:

- Hazardous substances rule, 2003.
- Hazardous occupation rules, 1963. (No. 1-6 (L-II/64).
- Fatal Accidents Act, 1855 (No. 13 of 1855).

After a thorough study, a checklist was designed in order to check if the incineration site is meeting the occupational health and safety requirements of International Labor Organization for a workplace dealing with Hazardous substances. Following were the results:

Occupational Health and Safety Requirements of International Labor Organization for a workplace dealing with Hazardous Waste

ILO Required Parameters	Met	Not met	Not adequately met
Hazardous Occupation Rules, 1963 (no.1-6 (L-II/64)			
Regular medical examination (6 months)			
Examination fee paid by employer			
Workers having fitness certificates			
No child or adolescent employed			
Fatal Accidents Act, 1855 (No.13 of 1855)			
Compensation provided to families in case of loss Or damage			
Hazardous Substance Rules, 2003			
Have a license for handling hazardous waste			
Safety plan has analysis of major accident hazards			
Safety plan includes assessment of nature of adverse impacts			
Safety plan has description of safety equipment and systems installed			
Safety plan has description of emergency measures to be taken in accidents			
Waste management ensures hazardous and non-hazardous waste is not mixed			

Hazardous Substance Rules, 2003			
Name of hazardous substances mentioned			
Net contents (volume and weight) stated			
Warning statement and signs (DANGER)			
Proper PPE's for handling.			
Safety instructions in local language.			
No worker below 18years or above 60 years			
Adequate water supply			
Qualified supervisors			
Training to personnel			
Fire-fighting, emergency and safety equipment.			
Eating, drinking and smoking not permitted in vicinity			
Premises should not be in a residential, commercial, congested or office area.			
Premises should not be close to drinking water sources.			
Premises should not be in small lanes			
Premises should have good ventilation			
Premises should have well-maintained electrical installations			

Hazardous Substance Rules, 2003			
Premises should have smooth, crack free floors impermeable to liquids			
Premises should have drains which do not connect directly with the sewerage system.			
Premises should have signs, escape routes, emergency exits etc.			
Name and address of the person from where hazardous waste is collected mentioned			
Name and address of the person to whom the waste is delivered mentioned			
Quantity of hazardous waste to be transported mentioned			
Date and time of proposed transportation.			

11. DISCUSSION:

11.1Environmental Parameters and Impacts:

The environmental parameters monitored at the site were within the standard environmental quality limits. The concentration of gaseous emissions was quite low from the PEQ's. Similar was the case for ambient air and noise which had very low concentration as compared to the standard quality limits. These results indicated that the facility had a proper control over the incinerator operations and the latest technology of the incinerator was preventing air pollution. The ground water and waste water results also indicated no pollution. The heavy metals concentrations in the ash were within the limits and posed no threat. Usually the heavy metal pollution from the incinerators is of great concern due to their carcinogenic, mutagenic and bio accumulative properties. The results of ash monitoring also indicate that the soil near the site is safe from the hazards associated with heavy metal pollution due to leaching or deposition via the ash.

11.2Comparison of Health Status with Environmental Monitoring Results:

All of the environmental monitoring results were validated by the results of the health status of the workers at the facility as majority of the workers did not report any health issue that could have been caused by the gaseous emissions or the heavy metal pollution. Apparently, the workers were found to be safe from environmental emissions, although long term exposure even to minute quantities of the emissions can cause problems. Additional factors like traffic pollution outside the facility, the confounding factors and the combined toxicity effect of all other pollution factors can lead to deterioration in the health of the workers. A Study suggested a similar idea, that the monitoring of ash, air or water contaminants only assesses the external exposure of the people. In order to assess the internal exposure, quantification of compounds in human body needs to be done. Apart from that, incinerator releases consist of hundreds of unknown chemical mixtures of unknown toxicity that usually get ignored in studies. (Allsopp et al., 2001). Thus, this type of research work can be taken up for future studies of the site.

11.3 Risk Evaluation:

During the risk evaluation of the facility two types of failures were kept in mind that include 1) Active failures- these type of errors are made by frontline workers such as machine operators etc. and can have an immediate impact on health and safety in a situation where there is no room for errors. 2) Latent failures- these errors are usually made by managers or decision makers and are the errors in health and safety management systems. Examples of latent failures include inadequate supervision, ineffective training and monitoring, inappropriate design and equipment, improper assigning of tasks and activities etc. These types of failures are more dangerous than active ones and if triggered by certain situations, can cause disastrous impacts. (Großbritannien, 2007). In order to identify the reasons behind these failures, performance influence factors were taken into account. There are three types of performance influence factors which include 1) job factors (system of work, type of task, time, working environment) 2) individual factors (physical condition, stress, fatigue, motivation etc.) 3) organizational factors (work pressure, peer pressure, communication, safety culture etc.). All of these factors influence human performance and human failures due to action errors, decision making failures or non-compliance.

11.4 Comparison of Health Status with Risk Evaluation Results:

The results of health status indicated that half of the workers reported back pain, stiffness and headache at the workplace that might be because of the workload or other ergonomics factors. This result can be linked to the hazards identified at the facility like heavy weight lifting, repetitive movements, improper posture etc. which were focused in the risk assessment section of the study and found to be a major hazard at the facility at all the stages of work that include transportation, segregation, storage, incineration and disposal. The reasons for this can be either the job factors like excessive workload or individual factors like tiredness etc. MSD's occurring at the facility can also be linked with psychological factors as some of the workers felt their workload to be excessive and low job satisfaction can become a cause of experiencing strain or MSD pain while working. In a study higher correlation between physical and psychological job stressors were found which suggested that physical load patterns (repetitiveness, work pace etc.) and psychosocial factors such as job demands, monotony etc. were directly related and psychosocial factors negatively impacted the physiological homeostasis. (Punnett & Wegman, 2004).

While assessing risks associated with lifting, merely weight does not determine the risk for back injury. Other factors that must be taken into account are:

- Frequency of lifting something.
- Bending or twisting while lifting.
- To what height is the object being lifted?
- The origin of the lift.
- At what distance are you holding the object from yourself?
- The time for which you hold the object.

Keeping in view these factors, an object that is safe to lift at one time might be a cause of injury at another.

Apart from that, all other potential hazards at the facility were found to be within the tolerable and acceptable ranges due to the existing control measures, however these can be further reduced by applying some risk control strategies which will be discussed later in the recommendation section.

11.5 Requirements of International Labor Organization

The facility met most of the requirements of international labor Organization although some of them were not adequately met.

Following were the requirements that were in accordance with ILO:

- The facility is registered with Environmental protection Agency (EPA) and has the NOC (No objection certificate) for handling hazardous waste. The renewal of the NOC, if required, is done after the site inspection by EPA.
- None of the workers was below age 18 or above the age of 60 years which is in accordance with the Hazardous substance rules.
- The waste management occurring at the facility was done in a way to ensure that hazardous and non-hazardous waste does not get mixed and there must be minimum impact on environment which is a requirement of Hazardous substance rule.
- All requirements for Packing and Labelling were properly met.
- Warning signs and safety instructions were clearly displayed.
- Eating or drinking within the facility was not allowed.
- All the requirements for premises conditions were met, which includes a proper ventilation system, well maintained electrical facility, smooth crack free floors etc.
- Qualified supervisor was available for training of personnel.
- Transportation requirements of Hazardous substance rule were met which included mentioning of the name and address of the person from where hazardous waste is collected and of the person to

whom the waste is delivered, quantity of hazardous waste to be transported and date and time of proposed transportation.

Following are the requirements that were not met or not adequately met by the site:

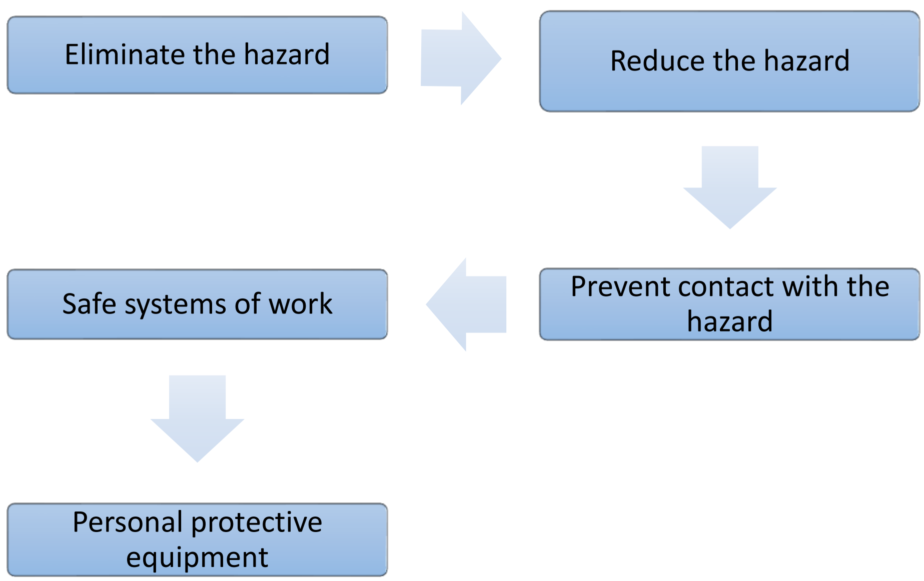
- The medical examination of workers is not carried out regularly which according to Hazardous occupation rules, must be carried out at intervals of not more than 6 months by a certified surgeon.
- The fees of medical examination (if carried out) is not completely paid by the employer which is against the hazardous occupation rules. If the fee is very high then 50% is paid by the employer and the rest has to be paid by the worker.
- None of the workers have certificate for fitness issued by a certified examiner which is a requirement in Hazardous occupation rule.
- No such case has been reported yet but the workers or their families might not be provided with compensation in case of any loss, which is against the fatal accidents Act.
- The premises is located in an area with shops nearby. This is against the Hazardous substance rule, according to which the premises must not be located in a residential, commercial or congested area. Moreover, the floor of the premises was not in proper condition, it was muddy which could become a huge slip hazard in cases of rain.
- The facility does not have a thorough safety plan meeting the requirements of Hazardous substance rule. According to ILO, the safety plan must include analysis of major accident hazards, assessment of nature of adverse impacts, description of safety equipment and systems installed, description of emergency measures to be taken in accidents.

12 RECOMMENDATIONS:

Keeping in view, the current occupational hazards and risks, the facility must adopt a risk control strategy that can be done in three ways:

- Reduce the likelihood of hazard
- Reduce the severity of the hazard
- Reduce the likelihood and severity both.

The risk control hierarchy which a basically a list of options for controlling risks must be kept in mind before making a management plan. (*IOSH- Managing Safely.Pdf*, n.d.)



The best option to control risk, is to eliminate the hazard that is creating the risk at the very first place. For example in case of the incinerator, segregation of the waste can be done in open areas to prevent hazards related to working in confined spaces. If elimination of a hazard is not possible, then reduction is the second best option, such as the load while manual handling can be divided into sections to prevent ergonomics risks. Thirdly, the prevention of people coming into contact with the hazard is another option for controlling risks. Only authorized personnel must be allowed to access hazardous or flammable substances storage sites, which must be kept locked at all times. The dangerous parts of machinery must be in some form of enclosure to prevent contact. Safe systems of work can be provided with the help of a set of procedures that govern the operations being carried out at the plant. There must be complete set of instructions and rules to operate the dangerous machinery, or work in a dangerous workplace. This type of risk control is very much dependent on personal human behavior and people must work in right manner to control risks. For this purpose, the training of the personnel is very important in order to prevent skill based or decision making errors because sometimes the resulting action is not intended. Lastly, is the personal protective equipment that is worn by the workers during work, such as goggles, high visibility clothing, masks, gloves, hard hats and safety boots etc. but this type of risk control is the last in the risk management hierarchy because it depends on the personal behavior of individuals. Such type of errors can be termed as non-compliance errors because the workers might deliberately violate and deviate from the rules and instructions provided. In order to prevent such hazards, the organizational structure must be improved, reporting of violations must be encouraged and awareness must be raised among the workers.

One thing must be kept in mind before applying a risk control strategy that the level of the risk must be proportionated with the cost of risk control measured in time, money and effort. The overall productivity, quality and health and safety can be improved, even by minor changes to tasks and working environment.

- There should be a careful consideration of human factors in order to reduce the number of accidents or occupational ill-health Cases.

- The working environment and the tasks should be well-designed in order to suit the individual capabilities of the workers. This will aid in physical health as well as mental well-being of the workers.
- Proper and effective trainings of workers must be ensured. Routine monitoring and supervision must be provided. This will prevent situational violations that the workers could make under pressure of insufficient staff or workload.
- Practical rules and instructions must exist and workers must be aware of their importance. This will prevent routine violations in which rule- breaking becomes normal amongst the workers.
- Proper training for abnormal and emergency situations must be provided in order to prevent exceptional violations that could be made by the staff in case of emergencies.
- Job redesign such as job rotation can be applied in order to reduce ergonomics risks.
- There is no standard in OSHA which sets limits on the weight lifted by a person at a workplace. However, there is a mathematical model developed by the National Institute for Occupational Safety and Health (NIOSH) which helps predicting the risk of injury based on the weight being lifted. The model establishes a maximum load of 51 pounds (23kgs), which is then adjusted in accordance with how often the person is lifting, the extent of twisting of the back while lifting, the vertical distance, the distance of the load from the body of the person, the distance moved while lifting the load, and how difficult it is to hold onto the load. All these factors must be kept into consideration. (Waters et al., 2021)
- The environmental design parameters, such as lighting, temperature and overall comfort levels etc. can be improved in order to improve alertness of the workers.

- The workforce must be involved and the workers must be encouraged to assess their own work area and discuss the issues observed as the workers are directly involved in work and may have important information regarding associated risks.
- The managers must monitor and assess their health and safety performance on a regular basis either by routine inspection of the premises and equipment or by monitoring evidences of poor health and safety practices.

Based on the risks and hazards identified at the facility and the existing control measures, following are a few recommendations for risk management that will help in improving the occupational health and safety at the plant:

Recommendations for Risk Management at the Site

List of Hazards	**Associated Risks**	**Mitigation Measures**	**Timeline**
Fall from height	Fractures, MSD's	• Minimum load must be placed on the heightened area. (not more than 23kgs) • The worker must be trained to check the cage regularly before use. (Weekly)	Can be taken Immediately
Slip or trip Hazard	Fractures, injuries.	• Floor must be kept dry at all times and must be properly textured to avoid slips. • Staff must ensure good housekeeping standards. • Suitable absorbers must be available for liquid spills. • Spillages must be cleaned immediately • Walkways must be kept clear.	Can be taken immediately.

Struck by objects during transport	Physical injuries.	• Floors must be kept clear. • Trained staff should have access to facility. • Workers working in the vicinity of moving objects must wear high visibility clothing. • Loading and unloading of waste must be done in safe areas only.	1 week.
Working in confined space. (storage areas)	Fire, noxious fumes, low oxygen levels.	• The ventilation exhausts must be checked regularly and properly maintained. • The staff must be aware of the risks and must be trained to use emergency equipment. • Confined space working must be avoided as much as possible.	Can be taken immediately.
Hazardous chemicals	Skins issues, respiratory problems, eye irritations.	• PPE's including rubber gloves must be used. • First aid facilities such as eye wash, bandages, and local anesthetics for skin must be readily available.	1 week

		• Only trained personnel must be allowed to deal with hazardous chemicals.	
Manual handling	Back pain, musculoskeletal disorders.	• Manual handling aids must be in proper conditions. • Workers must be trained regularly for safe manual handling techniques. •	Can be taken immediately.
Fire and Explosions	Burns, injuries.	• Fire exits must be marked and kept clear. • Fire extinguishers must be well located. • Fire detection alarm must be located in required areas. • There should be a proper evacuation procedure displayed with the extinguishers.	2 weeks.
Machinery	Physical injuries/ burns/ stabbing or puncturing of skin etc.	• The condition of the incinerator must be checked weekly. • The area around the incinerator must be kept unobstructed at all times.	1 week.

		• The incinerator must be properly switched off before repairing or maintenance. • It must be ensured that incinerator has no blockages or breakdown before starting it. • Workers must wear a full fire resistant uniform while working near incinerator.	
Lighting (storage areas)	Work errors, accidents	• Stacking of materials in storage areas should be done in a manner to avoid blocking of light or creating shadows. • Floodlighting in the external area should be present. • Lights must be checked regularly and changed when needed.	1 week.
Pressurized system (incinerator)	Burns, injuries, fatalities.	• Highly trained personnel must be allowed to operate or repair the pressure equipment. • There should be a written scheme of examination for	1 month.

		pressure systems made by skilled and competent person. • The workers working near the system must be aware of the prevailing conditions (pressure in the system, temperature, gas or liquid in the system and its properties etc.)	
Hygiene and comfort of staff	Stress, low satisfaction, psychological issues.	• Hot and cold water must be provided to the staff. • There should be a comfortable resting area. • Hand wash, hand sanitizers, food and water must be available adequately.	2 weeks.
Bad odor	Headache, nausea etc.	• Good housekeeping must be ensured. • All areas must be kept clean at all times. • Waste must be covered when placed in containers.	Can be taken immediately.

Working in extremely hot environment.	Heat stress.	• Ensure adequate supply of drinking water. • Reducing time for work in elevated temperatures. • Ensure proper ventilation and fans due reduce heat and humidity.	Can be taken immediately.

13 CONCLUSION:

The incineration plant located in Kala Shah Kaku was found to be working in accordance with the environmental quality standard limits for all the parameters groundwater, wastewater, ash, air, noise, gaseous emissions) without causing any threat to the environment or to the public. Majority of the occupational hazards and risks identified at each of the processes occurring at the plant were within the tolerable range due to reasonable existing controls. Only two were found to be unacceptable, however they can be brought to acceptable levels if the recommended risk management measures are implemented.

14. LIMITATIONS

While evaluating hazards associated with SWIs, although the risk perception of the surrounding community also needs to be considered as they are also indirectly harmed due to waste incineration. But this study was be limited to the immediate vicinity of the incineration plant and the environmental and health risk assessment was carried out for the employees who are working in that area and are at risk of getting affected the most. The study was not focusing on the surrounding area of the incineration plant which can be taken up in future researches conducted in that area.

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Annex 2: WHO guidelines on quality risk management

ANNEXURE 1

Occupational Health and Safety Assessment Questionnaire

DEMOGRAPHIC PROFILE

Name of Respondent:	Gender:	Age:	Marital Status
Designation:			
Body Weight:			

PERSONAL HEALTH STATUS

Do you suffer from any of the following problems? If yes, then how frequently?

Symptoms	Never	Occasionally	Frequently
Headache			
Respiratory Problem			
Visual Disruption			
Hearing Problem			
Stiffness			
Heat Stress			
Frustration			

Dizziness			
Back pain			
Skin Irritation			

Do you have any chronic disease? If yes, what is it?

- Yes
- No

Do you have a medical exam regularly?

- Yes
- No

When did you last have your medical examination?

Are you immunized against hepatitis A, hepatitis B, polio and tetanus?

- Yes
- No

PSYCHOLOGICAL FACTORS

How many hours do you work?

Do you feel your workload is excessive?

- Yes
- No

Are you provided with proper healthcare at the premises?

- Yes
- No

Do your managers treat you in a polite manner?

- Yes
- No

Do you have good relations with your peers?

- Yes
- No

Are you provided with proper resources (food, water, sanitizers, hand wash etc.) at the facility?

- Yes
- No

Are the workers provided with adequate emergency treatments if needed?

- Yes
- No

OHS MEASURES AND AWARENESS

Does the facility have a written EHS program that includes policies and procedures for environmental, .health, safety (EHS) and working conditions?

- Yes
- No

Do you know the contents of occupational health and safety policy?

- Yes
- No

Are you aware of the injury and emergency response procedures?

- Yes
- No

Are employees trained in procedures to be followed in an emergency? (First Aid Training, Firefighting Training etc.)

- Yes
- No

Do you know about the personal protective equipment (PPE)?

- Yes
- No

Do you use the available PPE?

- Yes
- No

Are you aware of the safety measures to avoid the harmful effect of injurious chemicals?

- Yes
- No

Are the housekeeping and storage appropriate at the workplace?

- Yes
- No

Do you have any emergency numbers displayed at the premises?

- Yes
- No

Do you have emergency system shutdown plan?

- Yes
- No

Do you have any emergency evacuation plan?

- Yes
- No

Are first aid signs clearly displayed?

- Yes
- No

Are first aid kits and their contents clean orderly and adequately stocked and not expired?

- Yes
- No

Are skin wipes/ hand washes easily available at the facility?

- Yes
- No

MONITORING RECORDS AND OPERATIONAL PROCEDURES

Is the incineration operational manual available at the facility?

- Yes
- No

How often the monitoring is performed?

Are the incinerator maintenance and repair logs available?

- Yes
- No

Is the waste weighed upon receipt?

- Yes
- No

Are the incineration required temperatures properly met?

- Yes
- No

DISPOSAL PRACTICES

Does the worker removing ash wears the correct PPE?

- Yes
- No

Are the ash containers properly covered?

- Yes
- No

Is the ash pit in proper status?

- Yes
- No

Where is the final ash disposed?

- Landfilled
- Used for bricks
- Other (specify)

Are the correct facilities available for final disposal?

- Yes
- No

How is the waste water disposed?

ANNEXURE 2

International Labor Organization Requirements checklist.

Sr. no.	Questions	Remarks
1	How frequent is your medical examination carried out?	
2	Is your examination fee paid by the employer?	• Yes • No
3	Does your employer provide compensation to families in case of loss?	• Yes • No
4	Do you have any certificate for fitness issued by a certified examiner?	• Yes • No
5	Do you have a license for handling of hazardous substances?	• Yes

	(validity and renewal)	• No
6	**Environmental Impact assessment** 1. Safety plan • Analysis of major accident hazards • Assessment of nature of adverse impacts • Description of safety equipment and systems installed • Description of emergency measures to be taken in accidents 2. Waste management plan • Ensure that hazardous and non-hazardous waste are not mixed. • Management in a way which will protect against adverse impacts.	
7	**Packing and labelling** 1. No leakage 2. Safe transport and storage 3. Name of hazardous substances mentioned 4. Net contents (volume and weight)	

	5. Warning statement and signs (DANGER) 6. Instructions regarding return or disposal of empty container 7. Instructions for immediate steps to be taken in case of accident.	
8	**General safety precautions** 1. Proper PPE's for handling. 2. Safety instructions in local language. 3. No worker below 18years or above 60 years 4. Adequate water supply 5. Qualified supervisors 6. Training to personnel 7. Fire-fighting, emergency and safety equipment. 8. Eating, drinking and smoking not permitted in vicinity	
9	**Premises conditions** 1. Should not be in a residential, commercial, congested or office area.	

	2. Should not be close to drinking water sources. 3. Should not be in small lanes 4. Should have good ventilation 5. Should have well-maintained electrical installations 6. Should have smooth, crack free floors impermeable to liquids 7. Should have drains which do not connect directly with the sewerage system. 8. Should have signs, escape routes, emergency exits etc.	
10	**Transportation** 1. Name and address of the person from where hazardous waste is collected 2. Name and address of the person to whom the waste is delivered. 3. Quantity of hazardous waste to be transported. 4. Mode of transportation with full specifications. 5. Route to be adopted 6. Date and time of proposed transportation.	

ANNEXURE 3

Pictorial Representation of the Facility

Waste Bags received from different industries

Incineration plant

Personal protective equipment (safety masks)

Waste segregated from the bags

Safety Instructions on the wall

Labelled Hazardous Waste

Ash Removal from the pit

Manual waste feeding in the Incinerator

Hazardous Waste Storage Room