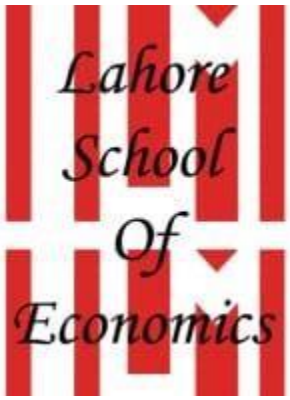
Thesis



Evaluation of Occupational Health and Safety and Process Risk Assessment of the Medical WasteIncinerator Located in Lahore- A Case Study

Submitted to:

Supervisor: Ms. Sadia Imran

Co-supervisor: Dr. Samia Saif

Submitted by: Arusa Maqsood

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 elements that kept me on the right track. Their constant feedback and help have proved to be critical in completion of this project. It is an effort supported and appreciated by people around me whom I would remain indebted to.

Table of Contents

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
• Medical waste	MW
• National environmental quality standards	NEQS
• Medical waste incinerators	MWI’s
• Occupational health and safety	OHS

Table of Figures

List of Tables

Abstract

Rapid increase in the population, economic boom, urbanization, industrial growth, and changing socioeconomic conditions have caused an increase in the medical waste (MW) generation.

MW disposal is a significant concern, especially in underdeveloped and developing countries. Incineration is the viable option for treating such waste in developing countries. A detailed Process Risk Assessment was carried out at the Lahore incinerator plant to evaluate the health and safety hazards associated with medical waste incineration and gauge its impact on the environment. Twenty of the occupational hazards and risks identified at each of the processes occurring at the plant were within the tolerable range and seven were within the acceptable range due to reasonable existing controls. Only two were found to be unacceptable (Ergonomic Hazards: repetitive movements & wrong posture). None of the workers reported skin allergy and burn. 2 out of 10 workers reported watery eyes whereas 3 out of 10 workers reported back pain and 6 out of 10 workers reported headache occasionally. Majority of the workers had reported no visual disruption, dizziness, hearing and respiratory issues. This study also monitored the wastewater and groundwater composition, gaseous emissions, ash, soil and noise level during incineration. All the values/levels were within the safe limits except noise level (near incinerator) 78.3 dB due to the operations occurring in the burning chamber. A thorough walk-through survey and individual interviews were conducted to identify any potential hazards for the workers. Information regarding medical waste incineration was collected with the help of secondary data (available literature). Primary data was collected through the survey of the plant. This study elaborates on incineration's existing and putative risks and provides the basis for risk management decisions and communication. It also compares the health and safety status of the site with the standard requirements of the International Labor Organization and results shown that the incineration facility complied with the ILO's occupational health and safety standards.

1 Chapter:

1.1 Introduction:

Industrial, economic advancement, urban growth, and rise in population have increased per capita waste production. (Ahmed et al., 2023). In 1990, Over 220 million people (13 percent of the earth's population) lived in urban areas. Their daily garbage production was less than 300,000 metric tons then (including broken household objects, ash, scraps, and wrappers). However, over 3 million metric tons of solid waste are generated daily in metropolitan areas, accounting for 49 percent of the world's population by 2000. Day after day, a 5,000-kilometer-long line of garbage trucks would be filled. (Ahmed et al., 2023)

The study found that as China's health care system and economy advanced (such as with rising personal income and the acceptance of universal health care), more people sought medical attention, causing a sharp rise in medical waste (240%) and pollutants (260%), with large hospitals serving as the primary sources. It is predicted that by 2030, the amount of medical waste produced will increase by over 50% compared to 2018, even without the impact of the pandemic. The eastern region has been found to produce more medical waste than the western region, which can be attributed to the higher population and GDP growth in that area. In contrast, the amount of household consumption, which did not vary by area, was the sole factor that affected the amount of medical waste generated per person. Additionally, under intense regulatory pressure in some locations, Hg loading from medical waste is more than twice as high as discharged wastewater. In order to increase efficiency, increase the number of beds in medical institutions rather than building more hospitals, and strengthen basic research on the environmental impact, policymakers should prioritize population-based disposal facilities and promote mobile treatment equipment when planning for the disposal of medical waste in the future..(Wei et al., 2021).

Waste is any liquid, solid or gas that is useless for us and must dispose of. It can be explosive, corrosive, eruptive, catastrophic, carcinogenic, infectious, stinging, sensitizing, and bio accumulative. (Wang & Wang, 2022)

Categorization of Waste:

Waste can be categorized into different categories:

Domestic waste, Industrial waste, Hospital waste, Radioactive waste, E-Waste, etc.

Hospital Waste:

Hospital waste is the kind of waste that is produced during people's or animals' diagnosis, treatment, or immunization. It includes blood-stained bandages, laboratory supplies, paper gloves, medical equipment, needles, tape, etc. (Basak et al., 2019)

Types of Hospital Wastes:

There are two types of hospital waste:

1) Infectious wastes

2) Noninfectious wastes

- **Non-Infectious Hospital Waste**: The two forms of non-infected clinical waste are the kitchen and office waste. We do the same thing at the residence. Healthcare facilities generate 80 to 85 percent of their waste from uninfected sources. Unless effectively separated, not infected waste seems capable of becoming contagious and constitutes a threat to society's environmental well-being. (Bolan et al., 2023)
- **Infectious Hospital Waste**: Surgery residue, animal excrement, including tissues, serum, body fluids, and also microbial cultivation with sanitizing wipes. Pathological waste includes tissues, organs, blood, and body fluids. A variety of everyday items can be infected with blood or bodily fluids. In isolation wards, the waste is thrown away. Health centers create 15 to 20 percent of their trash as hazardous waste. (Rana et al., 2023)

  Infectious waste further classified into medical waste.

  - **Medical waste:** Medical waste is defined as waste produced in hospitals, clinics, and other health care facilities or waste streams polluted by medical procedures that result in human secretion or contact waste, such as blood, body tissue, and fluids. One of the infectious transmission routes for both people and animals can include medical waste. When managed improperly, a considerable portion of medical waste can be biologically harmful and corrosive, which pollutes the air, water, and soil**.** (Bolan et al., 2023). It is considered hazardous and carcinogenic because it contains pathogens. It comprises items created during health care, hospital attention, and scientific analysis. (Wang & Wang, 2022)

Table 1Waste generation rate in selected teaching hospitals of lahore

Sr. No.	Name of Teaching Hospitals	Beds	OPD[1] Visits p.a[3]	A&E[2] patients p.a	@kg/b/d 2.07	Infectious 25%	OPD kg/p 0.075	Infectious 80%	A&E kg/p 2.07	Infectious 25%	General Waste 75%	Total Waste kg/day	Kg/bed/day
1	Jinnah Hospital, Lahore	1500	787,410	269,145	3,105	776	162	129	1,526	382	3506	4793	3.1953333
2	Mian Munshi DHQ 1 Hospital	149	473,474	287,991	308	77	97	78	1,633	408	1476	2039	13.684564
3	Lady Aticheson Hospital	200	142,000	29,037	414	104	29	23	165	41	440	608	3.04
4	Mayo Hospital	2081	1,120,000	333,090	4,308	1,077	230	184	1,889	472	4694	6427	3.088419
5	Services Hospital	1196	1,520,638	329,274	2,476	619	312	250	1,867	467	3320	4656	3.8929766
6	Sir Gunga Ram Hospital	862	611,770	188,880	1,784	446	126	101	1,071	268	2167	2982	3.4593968
7	Punjab Institute of Cardiology	347	251,224	70,709	718	180	52	41	401	100	850	1171	3.3746398
8	The Children Hospital & The Inst. Of Child Health	684	550,000	0	1,416	354	113	90	0	0	1085	1529	2.2353801
9	Lahore General Hospital	1000	891,288	311,023	2,070	518	183	147	1,764	441	2912	4018	4.018
10	Govt. Shahdra Hospital	300	418,167	255,157	621	155	86	69	1,447	362	1568	2154	7.18
11	Govt. Muhammad Nawaz Shareef Hospital	200	845,075	128,682	414	104	174	139	730	182	893	1318	6.59
12	Lady Willingdon Hospital	235	79,908	15,497	486	122	16	13	88	22	434	591	2.5148936
13	Said Mitha Hospital	100	399,558	91,505	207	52	82	66	519	130	561	809	8.09
14	Govt. Kot Khawaja Saeed Teaching Hospital	150	473,474	287,991	311	78	97	78	1,633	408	1477	2041	13.606667
15	Govt. Mozang Teaching Hospital	100	399,558	91,505	207	52	82	66	519	130	561	809	8.09
16	Punjab Institute of Mental Health	1400	129,000	3,417	2,898	725	27	21	19	5	2193	2944	2.1028571
17	Punjab Dental Health	30	125,000	0	62	16	26	21	0	0	52	89	2.9666667
	Total	**10,534**	**9,217,544**	**2,692,903**	**21,805**	**5455**	**1894**	**1516**	**15,271**	**3818**	**28189**	**38978**	**91.129793**
			Total							**Infectious Waste**		**10,789**	
			Total							**General Waste**		**28,189**	

Table 1 : Medical Waste Generation Rate in Pakistan (Arub et al., 2020)

The waste generation rates in these teaching hospitals varied slightly due to differences in patient capacity and available facilities. The combined waste generated across these hospitals amounted to 38,978 kg/day, as indicated in Table 1. The overall waste generation rate averaged at 3.7 kg/bed/day**.**(Arub et al., 2020)

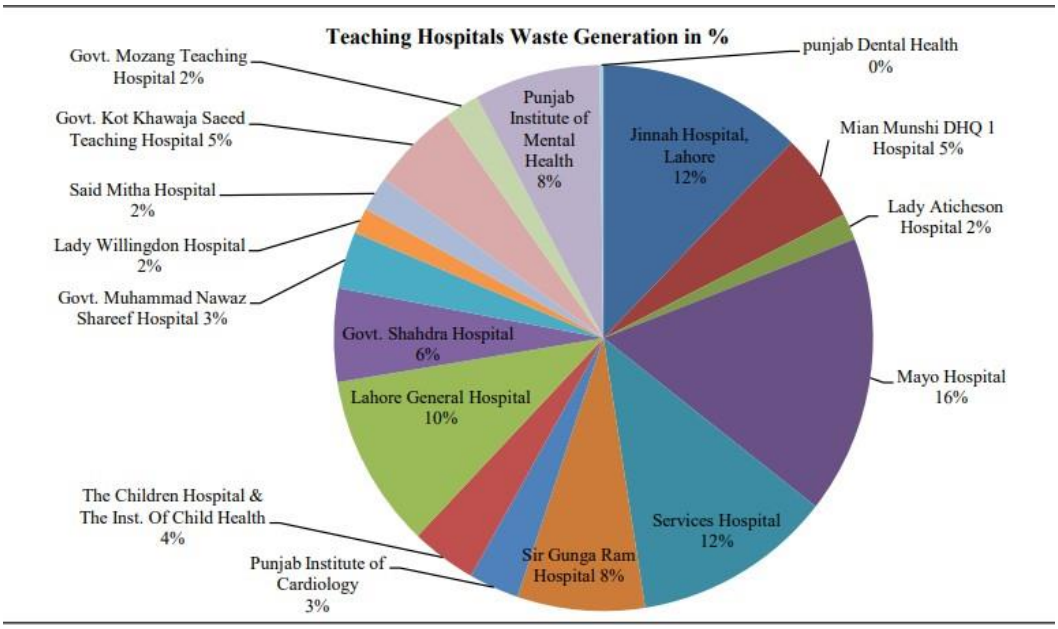


Figure 3. Percentage of waste generation in selected teaching hospitals of Lahore

Figure 1: Percentage of Medical Waste Generation (Arub et al., 2020)

Figure 1 illustrates the proportion of infectious and non-infectious waste among the total waste generated in the teaching hospitals of the Lahore. (Arub et al., 2020)

Table 1. Classification of medical waste [2]

No	Classification	Explanation	Example
1	Infectious Waste	Suspected of containing germs	Materials or equipment that has been in contact with infected patients
2	Pathology	Biological waste in the form of tissue or body fluids	Blood or body parts
3	Sharp Waste	Sharp waste	Syringes, IVs, knives, glass bottles
4	Pharmacy	Waste containing drugs	Expired drugs, drug-contaminated items
5	Genotoxic	Waste that is exposed to genotoxic objects, namely chemicals that can cause genetic mutations	Cancer treatment waste
6	Chemical	Waste contains chemicals	Reagents from the lab, expired disinfectant
7	Metal	Waste containing metal material	Batteries, thermometer, blood pressure measuring device
8	Pressurized Container	High pressure waste	Gas cylinders, cans, aerosols
9	Radioactive	Waste contains radioactive substances	Contaminated lab fluid, glass, packaging, or absorbent paper

Table 2: Classification of Medical Waste (World Health Organization, 2018)

Table 2 shows classification of medical waste with examples.

Various facilities, such as treatment centers, labs, morgue centers, and therapeutic units, including primary care physician and dentist offices, physiotherapists, acupuncturists, drug rehabilitation programs, and gravediggers, contribute to the production of this waste. (Bolan et al., 2023). Medical waste is a waste category requiring special management procedures, particularly collection, storage, separation, and disposal.(Çelik et al., 2023). Since the emergence of the coronavirus, there has been a surge in medical waste output worldwide, posing a severe threat to the environment and public health. This waste includes white gowns, test kits, plastic containers, and syringes. The collection of suspicious patients, extensive patient diagnosis and treatment, and finally, disinfection have produced a considerable amount of infectious medical waste, the majority of which is plastic.(Somani et al., 2020)

1.2 Health and Safety Hazards Due to Improper Medical Waste handling:

Improper management of MW might expose health professionals or the community to dangerous microorganisms. (Mohamed et al., 2023). On a daily basis, the hospital being examined produces approximately 297 kilograms of medical waste. This waste is comprised of plastics (71%), glass (13.9%), papers (3.8%), dressings (5.8%), gloves, masks, sheets, and diapers (0.3%), along with outdated operating room equipment (2%) and blades (0.1%). Labs,

cancer wards, nursing wards, OPD, and the hospital's emergency rooms are the areas that produce the most infectious waste. On average, the hospital generated 3511 kg of general trash per day, of which organics made up

44.3%, diapers 42.8%, demolition materials 2.5%, miscellaneous 1.4%, cardboard 1.4%, papers, cotton 28.2%, glass and 0.7% of iron materials. (Yasin, 2023)

Mishandling and depositing MW in a conventional rubbish storage facility would trigger aquifers and soil degradation, constituting an ecological disaster. HCE sewage is a complex mixture that threatens the planet in soil and water because it is 5–20 times more toxic than sustainable urban wastes. (Patwary et al., 2009) Because of shifts in spatial patterns (urbanization, mechanization, infrastructure advancement, and toxicity), soil pollution has become a vital ecosystem problem in emerging nations during the past couple of decades.
Clinicians in underdeveloped countries like Bangladesh dispose of clinical waste in the same area as common garbage (Sobia et al., 2014)

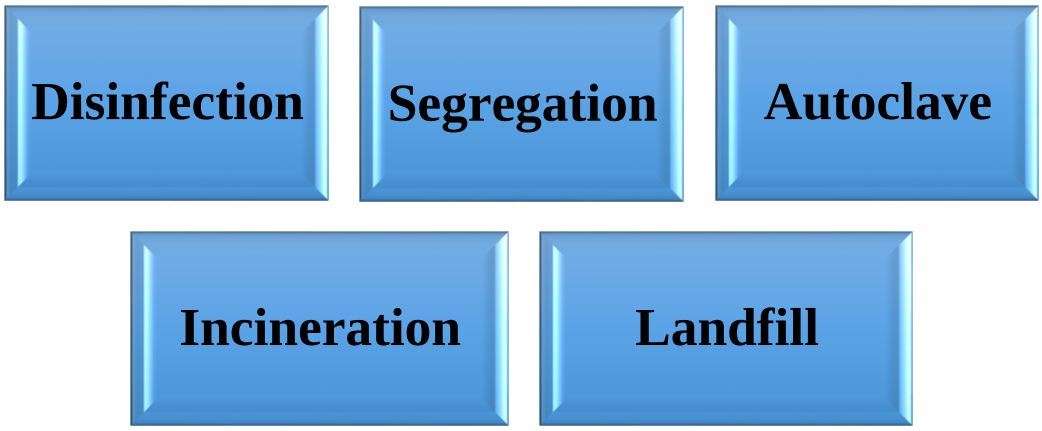
Poisoning of groundwater and soil is a possibility. Agricultural pollution and elevated heavy metal content can arise from toxic waste burial. (Muchuweti et al., 2006). Poisonous pollutants can enter the body via this route exclusively (Khan et al., 2008). Exposure to hazardous substance can negatively impact the immune system, growth during pregnancy, cognitive abilities, and dietary intake and increase the risk of upper stomach cancer. (Ghali et al., 2023)

In underdeveloped countries, healthcare waste is mixed with non-clinical waste, creating severe health hazards (Xie et al., 2009). Significant worries over HIV/AIDS and liver diseases, notable transmission to Hepatitis (HBV), emerged in the 1980s and 1990s. Due to its various consequences for clients, medical personnel, and many more, medical and hospital trash has played a significant role. MW is very toxic, and due to its poisonous nature, it disturbs the eco-equilibrium. The environmental effects of cleaning and disinfection of medical debris persist because these commercial healthcare facilities have established methods to reduce health hazards. (Bokhoree et al., 2014)

The Children's Hospital generates 90% of general and 10% of infectious waste. Plastic and glass are the two most significant components produced in infectious waste. Major components of the general waste from various hospital facilities include organics and diapers. Three main issues that need to be addressed and corrected are more training, insufficient understanding of the makeup of infectious waste, and risks associated with rubbish. The composition and classification of waste are crucial for effectively implementing a waste management system. (Sobia et al., 2014)

1.3 MW Management Techniques:

Many techniques exist to reduce various waste.



(Mohamed et al., 2023)

- S**egregation**: It is beneficial because it inhibits potentially dangerous trash from infecting non-hazardous trash. Therefore, this method will unquestionably reduce the harmful amount of trash. However, sorting the waste into several groups depends on its volume, content, and dumping technique.(Hussain et al., 2020)
- **Separating Different Categories of MW**: Razor blades, infected waste, and hospital debris are separated into different canisters. Inside the medical facility, each form of waste is stored in a sealed, impermeable canister tagged "biohazard." Mass and portability are key factors in determining the capacity of the canisters. Bags of different colors are used to store waste. Yellow plastic bags transport infectious medical waste, which is then cremated. Those who will undergo the sterilized process wrap them in red plastic bags. In steam autoclaving, waste is sterilized by slightly elevated forced air. These pollutants cannot be disposed of using this approach. As a rule, toxic material stored in blue or white opaque bags is sterilized by autoclaving or microwaving, chemically modified and disintegrated, or dumped into landfills after being processed. The hazardous sign is commonly used to mark and recognize dangerous material. Everywhere in the globe, packaging, and labeling have become commonplace. However, there is a difference in the therapeutic methods employed.(Mazzei & Specchia, 2023)
- **Disinfection:** To decrease the severity of specific healthcare by-products, chemical antiseptics, including chlorine dioxide, sodium hypochlorite, or peracetic acid, are occasionally used. Via disintegrating solid refuse, it is possible to sterilize these. However, even though they can be harmful in particular situations, antiseptics are not advised for managing pharmacological, chemical, or contagious waste.(Mazzei & Specchia, 2023)
- **Incineration:** The incineration method involves burning waste at extreme heat in burners to eliminate it. The process eliminates dangerous components, decreases the waste density, and transforms it into safe

ash after being burned (Yoon et al., 2022)

- **Disinfection by Plasma:** Air is used as the base fluid in this method, using a small temperature flame produced by a plasma generator. Although dissipation is minimized, momentum and heat conversion are maximized when hazardous material is mixed and mixed. In addition, heat is generated throughout the process. Such a strategy prevents dioxins and other harmful chemicals from being produced or released into the atmosphere. One of its most significant advantages is that it requires fewer resources than other mineralization techniques (such as burning). (Kumar et al., 2023)

1.4 Techniques Used for Disposal:

Bio-medical waste bins of different colors are used to segregate and manage different types of medical waste generated in healthcare facilities. The color-coding helps in easy identification and separation of various waste categories, which is crucial for proper disposal and minimizing the risk of contamination and infection. (Kumar et al., 2023)

Figure 2::**Segregation of Bio-Medical Waste** (Kumar et al., 2023)

Medical facilities discard waste in various ways, including combusting, sterilizing, autoclaving, encapsulating, retailing, disposing, and using community dumpsters. (Mazzei & Specchia, 2023)

- **Autoclave:**
  Application of steaming disinfects debris in an autoclave, which operates at low temperatures. Centrifugal circulation and suction autoclaves eliminate crevices in different ways. (Kumar et al., 2023)
- **Sterilization**

  Sterilization eradicates all microorganisms in healthcare establishments by mechanical or chemical methods. Most sterilizing treatments used for treatment centers include high-pressure steam, drying process, hydrogen peroxide gas plasma, condensed hydrogen peroxide, and liquid chemicals. "Disinfection" is also referred to as "sterilization" by certain medical practitioners, as well as "slightly

pure" goods in strategic and operational literature. In synthetic sterilization, all microbiological life forms, particularly fungal and bacterial species spores, are killed with certain chemicals . (Rutala & Weber, 2015).

- **Microwave Disinfection:**

  Heat is collected on the object's interface and transmitted to the next phase via conduction in the dry steam sterilizing technique. Sterilization occurs when it meets an appropriate temperature. For example, sterilization at 160°C (320°F) for 2 hours, 170°C (340°F) for 1 hour, or 190°C (375°F) for 6 to 12 minutes is recommended for High-Velocity Heated Air Disinfectant. (Mazzei & Specchia, 2023)

- **Landfill:**

  Waste disposal was first described as a sanitary landfill in 1900 when the word was coined. Waste is disposed of in this way by coating every stack of garbage with dirt every day to preserve pests over and unpleasant odors away. (Hirani et al., 2014). It has been determined that the optimum way for disposing of medical debris is incinerating it (Arshad et al., 2011). Medical waste treatment requires preferential conditions, like burning or dumping toxic waste in landfills. Studies have shown that medical debris is effectively disposed of by incinerating it. (Mazzei & Specchia, 2023)

- **Incineration:**

  One of the most efficient treatment processes (waste-to-energy). It is the best solution for treating such waste, especially pathological-related waste. Additionally, it can eliminate hazardous waste components, reduce waste volume, and only leave ash for disposal, making it the ultimate waste management solution.(Kumar et al., 2023)

Table. 2 The most important technologies of disinfection and treatment of contamination wastes

Disinfection technology	Advantages	Disadvantages	References
Incineration technique	• Simple operation • Reduce waste volume by up to 90% • Complete destruction of COVID-waste	• High investment costs • Energy consumption • Releasing secondary pollutants (dioxin and furans)	Datta et al. 2018; Shah et al. 2020; Wang et al. 2020a
Pyrolysis technique	• Energy-saving • Decomposition of COVID-waste volume • Destruction of toxins such as dioxins and furan	• High investment costs • Energy-intensive • It could not be considered a safe technology	Datta et al. 2018; Wang et al. 2020a
Microwave technique	• Energy can be saved because of low action temperature • It can be considered as a mobile facility in the treatment site	• Narrow disinfection spectrum • Complex impact factors	Datta et al. 2018; Wang et al. 2020a
Autoclave	• It does not release toxic gases	• It is not suitable for all plastic types	Jonathan 2013
Chemical technique	• Stable performance • Rapid action • Broad sterilization spectrum • Controlling virus spread	• Could not reduce the mass and volume of waste • Residual disinfectants	Ilyas et al. 2020; Mallapur 2020; Rowan and Laffey 2020a; Singh et al. 2020a
Vaporized hydrogen peroxide	• After complete disinfection, reuse or reprocessing of protective items is possible	• Causing skin, alveoli, and mucosa health problems	Barcelo 2020; Ilyas et al. 2020; McEvoy and Rowan 2019
Dry heat technique	• Suitable for polymeric material in order to reprocess • Mitigating the threat of supply chain by reusing, for example, N95 masks or PPE	• Decontamination of the trapped virus is unanswered	Ilyas et al. 2020; Price et al. 2020
Ozone	• Oxidative inactivation of the virus	• Lung irritants	Rowan and Laffey 2020b; Silva et al. 2020
ultraviolet light (UV)	• Inactivation of viruses by destroying their nucleic acids	• Low performance because of shadow created by the multifold layers of the FFR's construction	Darnell et al. 2004

Table 3: Important Technologies of Disinfection and Treatment of Contamination Waste (Teymourian et al., 2021)

Table 3 comprehensively compares and analyzes different technologies of disinfection and treatment of

contamination waste, and emphasizes that incineration treatment technology has reduced weight and is harmless.

Incineration demands substantial financial investments in infrastructure and ongoing operational expenses. Therefore, it is imperative to evaluate the availability of the required funds and resources for constructing and sustaining an incineration facility. Nonetheless, if adequate funding and resources are secured, incineration can indeed become a viable waste management option.

Burning waste over extreme heat in burners is an incineration activity. This method removes dangerous components from the waste and its bulk and size, converting them into innocuous dust. Waste that is 60 percent flammable should be burned. Toxic and viral wastes and harsh wastes are suitable for burning. There are several different types of incinerators, each with another purpose. For example, the "drug terminator" is a mobile incinerator to eliminate medicines. A burner that burns toxic and infectious medical waste in tiny medical institutions is called MediBurn. (Cobo et al., 2018)

With the incineration process, you may reduce trash disposal by 50-400 percent. However, despite these benefits, burning has many shortcomings, including massive costs, smoke generation, and environmental issues. For example, due to a) frequent switching and b) less strict pollution controls, hospital boilers have greater levels of aromatics and dioxins than local government boilers. There are several reasons for this, including c) inadequate ignition management (e.g., waste blending and oxygen limits) and Disparities in the content of municipal solid trash vs. waste feed (Shinde & Shejwal, n.d.).

Typically, incinerators are fitted with a stack to prohibit fumes and pollutants from entering the environment. In addition, incinerators generally are spaced 100 meters away from healthcare institutions to limit the influence of fumes. Under the incinerator, the remains are usually collected in a pit. For the treatment of clinical debris, incineration is the best approach. (Solorzano et al., n.d.)

Incinerators are waste-burning furnaces that combust waste. Flue gas treatment is one of the pollution-reducing features of modern incinerators. The trash produced by incinerators included solid and liquid wastes like ground soot and emission reduction device leftovers (if any). Ground-level burial is the norm for solid wastes (typically in landfills or pits). Before release into a sanitary treatment plant, various burning fluid wastes (such as wet scrubber exhaust, burner blow-down, and many more) might be further cleaned. Unfortunately, there needed to be documentation on liquid waste outputs, ignoring the reality that comparatively small incinerators are infrequently used in this country.) Undergrounds that are affected by waste, soot, fluids, and other pathogens might be used as drinkable water if the contaminants are dumped in unlined pits and mismanaged infrastructures. (Shareefdeen, 2012)

When debris is incinerated, they generate soot, gas, and heat. There are two kinds of ash produced by the waste's inorganic components: firm masses and particulates transported by the flue gas. Before they are discharged into the environment, flue gases are always cleaned of gaseous and particulate contaminants.

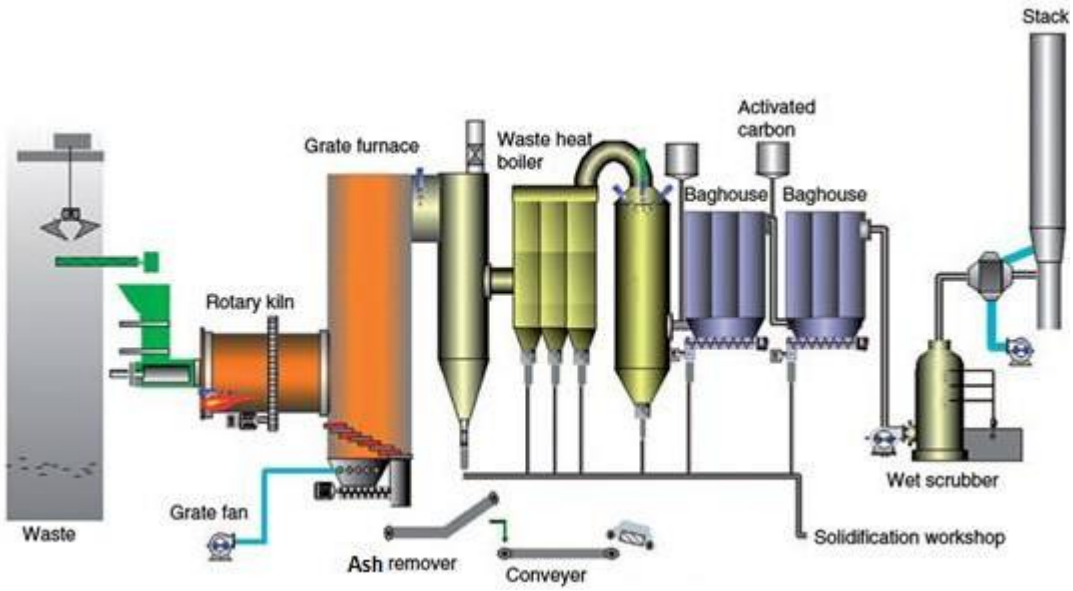


Figure 3: Schematic diagram of the incinerator (X. Jiang et al., 2019)

The incinerator's stack is 60 feet high, with a 60-foot gas diameter. Three inches of pipeline enters the incineration plant. (Sobia et al., 2014). Before burning, waste material was preheated and crushed at 300 degrees Celsius by the waste feeder, which led to a steady combustion process. With its gasifier and SCC temperatures ranging from 700°C and 1050°C, the incinerator was run under a constrained air-burning state. Wet Scrubber employs a liquid to eliminate pollutants from a gas stream. This removal process is accomplished by introducing the gas stream to the scrubbing liquid, enabling the transfer of contaminants into the liquid through mass transfer mechanisms. SCC elevated combustion without the need for additional fuel proved that the distinctive MWI substantially minimized thermal stresses (X. Jiang et al., 2019)

1.5 Risk Assessment

Assessment of risk is a process that consists of the following components:

a) Assessment of future events that might affect persons, the environment, or both.
b) Examining potential risk factors.

According to regulatory requirements, the process of risk evaluation is a vital instrument for maintaining a healthy atmosphere. Need to be considered carefully the possible sources of harm as well as the corresponding safety inspections. 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. Being aware of the risk.
2. Determining who could be subjected to harm and how.
3. Reviewing the risk assessment regularly.
4. Evaluating the hazards and their preventive strategies.
5. Keeping a record of results and putting them into practice.

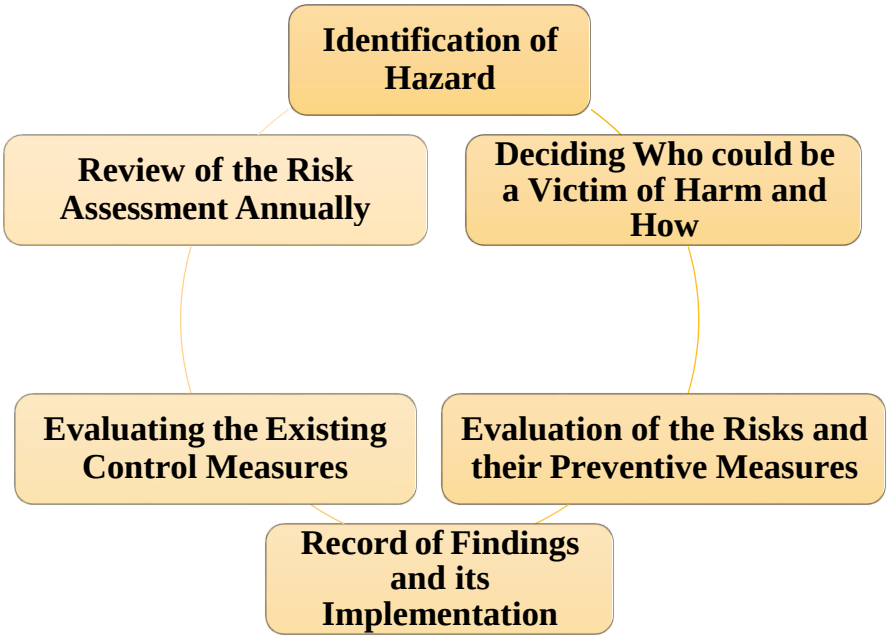


Figure 4: Steps of Risk Assessment (Dewantara et al., 2022)

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. (Dewantara et al., 2022)

OSHA ensures safe and healthful working conditions for workers. (Fakherpour et al., 2023)

This study also covers the Pakistan Environmental Protection Act (PEPA), 1997, Section 18 about Hazardous substance.

The **International Labor Organization** is a specialized division of the United Nations with the mission of bringing together the government, employers, and employees of its 187 member nations in order to establish, develop, and implement standards, policies, and programs to promote safe and decent working conditions. The

International Labor Conference, which establishes international labour standards and the ILO's broad policies,

the governing body, which decides on ILO policies and develops programmers and a budget, and the International Labour Office, which oversees all activities, are the three main bodies of the ILO. (Selberg, 2020)

There are 25 different subjects covered under international labor standards that include child labor, forced labor, social security, employment security etc. Occupational health & safety 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 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. Labour 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. Factories (North-West Frontier Province Amendment) Act, 1946 (No. 7 of 1947).
18. Hazardous Occupation Rules, 1963 (No. 1-6 (L-II/64)
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, it is prohibited for any child or teenager to engage in work involving hazardous

substances. Regularly, not exceeding six months, each worker must undergo a medical assessment conducted

by an authorized doctor, and a documentation of this evaluation must be maintained by the management. All employees must possess a certificate validating their ability to work in risky settings, and if the examining doctor does not consider them fit, employment cannot be granted. This regulation necessitates the employer to bear the expenses linked with the examination.

- **Hazardous Substance Rules, 2003**
  a) According to these requirements, the facility must conduct an environmental impact assessment that includes the following elements:
     i. A safety plan that thoroughly examines the risks of significant accidents, determines the kind of potential negative effects, lists the installed safety systems and equipment, and specifies the emergency actions to be taken in the event of an accident.
     ii. A waste management plan created to ensure that hazardous and non-hazardous trash are handled separately in order to minimize negative consequences.
  b) Specific actions are outlined in the standards for the packaging and labelling of hazardous substances:
     i. Preventing any leaks in waste containment during storage and transportation.
     ii. Ensuring safe means of transportation and storage.
     iii. Naming the waste, describing its net contents (volume and weight), and putting up notices.
     iv. Giving directions on how to properly return or dispose of empty containers and what to do right away in the event of an accident.
  c) General safety instructions cover the following important topics:
     i. Need suitable personal protective equipment (PPE) for handling safety.
     ii. Requiring the local language to be used to provide safety instructions.
     iii. Prohibiting hiring people who are 60 or younger or younger than 18 years old.
     iv. Requiring the presence of certified supervisors who are in charge of instructing staff on emergency response, firefighting techniques, how to use safety equipment, and how to forbid eating, drinking, and smoking nearby.
  d) Regulations pertaining to premises must take the following into account:
     i. Prohibiting the facility's placement in neighborhoods that are residential, commercial, congested, or office space.
     ii. Ensuring a good distance from water sources for drinking and avoiding installation in tight spaces.
     iii. Having sound electrical installations, adequate ventilation, and water-resistant floors free of cracks are all recommended.
     iv. Including drainage systems that are not directly connected to sewer networks, as well as

having obvious signals, exits for emergencies, and escape routes.

e) Transportation instructions mandate the inclusion of specific details:

i. Stating the name and address of both the waste source and destination.
ii. Providing precise quantities of hazardous waste for transportation and specifying the mode of transportation with detailed specifications.
iii. Indicating the proposed date and time of transportation.

- **Fatal Accidents Act, 1855 (No.13 of 1855)**
- This law attempts to provide families with compensation in the event of a person's loss or death brought on by wrongdoing, negligence, or similar situations. Children, spouses, and parents are all entitled for compensation. The Act permits the filing of a claim for compensation in circumstances of both fatal injuries and injuries that could result in fatalities. One year after the incident, these claims must be filed.
- The health, safety, and welfare policies implemented at a company are crucial to the happiness of the workers there. A number of elements work together to create a comfortable working environment, including good ventilation systems, the right temperature, efficient lighting, general cleanliness, enough room and seating, well-designed entrances, walkways, and windows, sufficient sanitary facilities, and accessibility to amenities like drinking water and food. These elements work together to assess whether a workplace is safe for employees or presents risks.
- The primary focus of this study was on the occupational and environmental dangers connected to medical waste incineration processes and activities. It suggested workable management techniques and measures to reduce or get rid of the threats to workers' health and the environment. In order to make informed risk management decisions and to effectively communicate concerns, the research identified both current risks and potential dangers associated with incineration.

1.6 Aim of The Study:

A lot of studies have been conducted on the medical waste incinerators regarding the health risks associated with emissions but there is very limited knowledge on occupational health and safety management at the incineration facilities, health and safety related knowledge of the workers and management strategies to reduce health and safety hazards.

The main aim of the study was to conduct a thorough process risk assessment of the occupational health and safety management at the plant and compare it with the current health and safety practices under Occupational Safety and Health Administration **(OSHA),** Pakistan Environmental Quality Standards **(PEQS),** and the

requirements of International Labor Organization **(ILO).**

1.7 Research Objectives:

Following are the main research objectives of the study:

- Evaluation of 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, soil, ash and noise at the incineration plant.
- Devising a risk management plan for the workers.

1.8 Research Questions:

The following are the subsidiary questions to achieve the main objective of the study:

Q1-What are the occupational health and safety hazards at the incinerator site? How can they affect the worker's health and how can they have impacts on the worker's health?

Q2- What are the possible ways to minimize/eliminate the health and safety hazards and risks at the site?

Q3- What are the risks associated with environmental parameters at the plant and to what extent are the workers affected by it?

Study Area:

The incinerator (Model: ATI-750, Made in France) is located on Ferozepur Road Lahore, Pakistan. Total area is 4 Kanal which includes two installed incinerators, waste storage facility (Yellow Room), administrative office building and few plants within the premises, approx. 0.5 km away from the main building of the hospital. The nearest human settlement is almost 2 km away from the plant. This unit was installed in 2013 and became operational on January 15, 2015.

Operational Parameters:

Sr. No.	Operational Parameters	Conditions
1	Fuel	Natural Gas
2	Temperature	First Chamber: 800-900Degree Celsius Second Chamber: 1100-1250 Degree Celsius
3	Operation Hours/Day	12 hours
4	Ash Management	Collection of bottom ash (manually) and send it to Lakhodair.

5	Feed Method	Automatic Feeding through hydraulic chambers.

6	Burning Capacity	1000kg/Day
7	Chimney Height	60 feet

Table 4:Operation Parameters of Medical Waste Incinerator, Lahore (LWMC, 2018)

This unit receives 1000 kg of waste on daily basis and utilize natural gas as a fuel. Soil is loamy with a moderate texture in the vicinity.The incinerator (Model: ATI-750) is installed in Hall No. 1. In contrast, a small old incinerator (out of order and not working for the last few years) is installed in Hall No. 2. There are 5 people working at this site in the day shift (labor) and 4 in the night shift (labor). From past few years, waste from different hospitals came there for incineration but now only waste of this hospital is incinerated in this incinerator. A truck loaded with ash is delivered to the Lakhodair Landfill site for disposal once a week.

Figure 5 Location of site area – hospital

Figure 6 Location of site area – Hospital on map of Pakistan

This incinerator is located on Ferozepur Road, Lahore. This Map shows the exact location of the incinerator site.

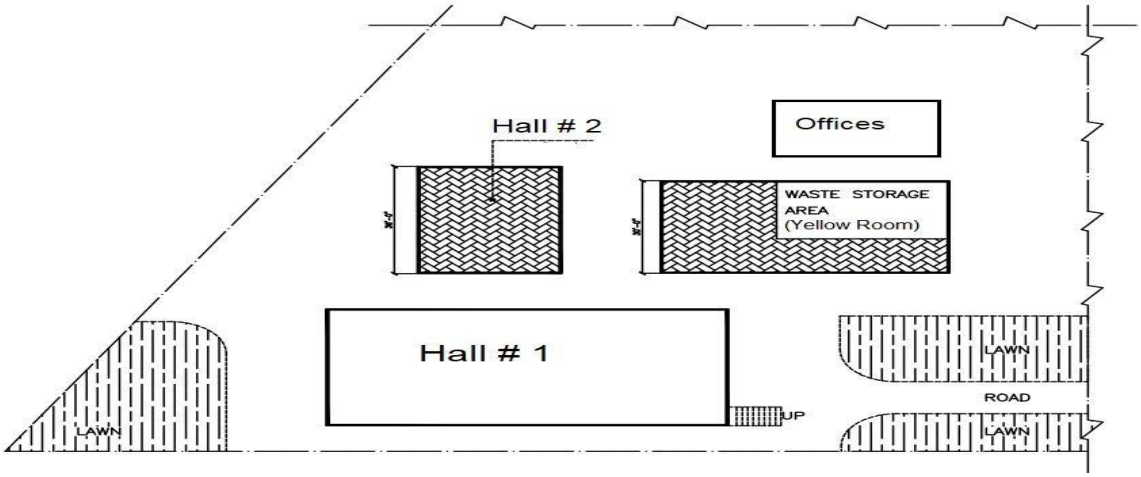


Figure 7 Layout of the medical waste incinerator

- Figure 7 shows layout diagram of incinerator site. Total Area is 4 Kanal which includes two installed incinerators, waste storage facility (Yellow Room), administrative office building and few plants (lawn area) within the premises. All the hazardous waste and materials are stored properly in a designated area known as YELLOW room under control conditions.

2 Chapter 2:

2.1 Literature Review:

Incinerators are one the effective means of managing the medical waste. But the usage of an incinerator can result in several environmental and human health issues. Burning solid and liquid hazardous waste pollutants produces nitrogen oxides and Sulphur oxides. Burning & irritation in the eyes and lungs are early complications. During chlorine-based plastic waste, dioxins, recognized as human carcinogenic, can be generated. Medical waste contains a large amount of plastic (Domingo et al., 2001).

Incinerator's boiler **emissions** harm the air, water, and soil (which include disinfectants and contaminants). As a response to such pollutants, trash employees, the broader population, and the ecology could be affected by heavy compounds. Moreover, contagious dangers might prevail because of inefficiency, notably in the working environment, for example, incinerators or garbage processor controllers.. (Batterman, 2004).

2.1.1 Heavy Metal Pollution:

Mercury, nickel and cadmium are **heavy metals** classified as carcinogens that are emitted by the incinerators. A larger quantity of Cr and zinc (Zn) in medical wastes come from syringes' disposal. High chlorine availability in the medical waste favors the evaporation of heavy metals and it causes neurological, hematological and reproductive issues, sickness, dizziness, chronic bronchitis. (Zhou et al., 2022)

The presence of chlorine in the feeding waste has been shown to increase **PCDD/Fs** emission levels. Changes in the level of hormones, suppressed immunity, impaired reproductive functioning in males.(W. Jiang et al., 2023)

The impact of **mercury (Hg)** on public health and the environment is a serious concern, as Hg can accumulate in fatty tissues when inhaled. In addition, it causes damage to the nervous, reproductive, and excretory systems. (Hirani et al., 2014)

Dioxins, PAHs, and other hazardous combustible material are emitted by trash incineration plants, causing anxiety among the population (de Titto & Savino, 2019). In addition, many undiscovered compounds with unidentified toxicities were detected in tower vapors and soot, reported (Tait et al., 2020)

In addition to fatigue and spine pain, physical material handling is often connected to **musculoskeletal diseases (MSDs**). MSDs even includes the lower spine, bicep, and shoulder stresses (Masaitis, J., 2011). In addition, occupational variables, such as barriers and flooring (wavy or broken), path length, vibration, and heat, affect the risk of mechanical materials handling, as can the manufacturer's traits (psychological factors such as stress and physical aspects) (Giahi et al., 2014).

2.1.2 Air Pollution

In humans affects various systems as well as body parts by both acute and chronic implications. For example, acute respiratory diseases in children and adults, worsening of pre-existing cardiac and pulmonary problems, and bronchial incidences are all possible side effects (Kampa & Castanas, 2008). Due to the high proportion of PVC-containing plastics in medical debris, dioxins and furans can readily be produced and released into the air via medical waste incineration plants**. Dioxins and furans** are released during the burning of medical waste due to the widespread use of PVC goods). (Tait et al., 2020)

- **Acidic Vapors**

These are created when certain non-metal oxides, such as NOx and SO2, are released, in addition to every heavy metal which might be detected (Honest et al., 2020).

- **Incinerator Fly Ash**

Medical waste **incinerator fly ash** (MWIFA) differs from municipal solid waste incinerator fly ash (MSWIFA) since it contains significant amounts of chlorine, dioxin, carbon components, including heavy metal. Its incorrect management can result in irreparable devastation to the ecosystem and mankind (Liu et al., 2018).

- **Volatile Organic Compounds Pollution**

As a result of volatilization or degradation of organic compounds in solid or liquid waste in the barrel storage areas of the incinerator, organic compounds are primarily produced in the ambient air of the incinerator. When containers are not sealed tight enough, they diffuse into the air. Another study showed that refuse feed hoppers and refuse bunkers were the main sources of VOCs. (Maitre, 2003)

Lacking proper safeguards or energy efficiency devices, MW would produce significant amounts of chlorine-containing wastes such as **PVC** or antiseptics. In addition, dioxins and polyaromatic might be formed by burning MW waste (Ferraz et al., 2000). Due to the combustion process, substantial volumes of heavy metal waste could be emitted in the form of vapors, vapors, and particulate. Large volumes of heavy metal debris can indeed be released during burning in the form of gases, vapors, particulates, and soot.(Peng et al., 2023)

The volume of fluid inside the hospital debris may have been burnt as still the reason for the inadequate ignition. We've encountered yellow pouches packed with urine-soaked synthetic toilet rolls were picked from adjacent residential care homes. B because of this water mass, experts are apprehensive about the possibility of unproductive burning and then an increase in **hazardous pollution**.(Shareefdeen, 2012)

MWI is undeniably hazardous to human health and the ecosystem because of the production sources of **dioxins**. Moreover, they ultimately offer a burden to those who supervise and assist these resources (Ghali et al., 2023)

2.1.3 Biological Health Hazards

Are considered life forms that can damage or impair humans. Fauna, insects, microbes such as bacteria, viruses, fungi, and hazardous flora are all included in this category. For example, hospital trash and experimental centers may contain illness bacteria and viruses, which might impact sanitary landfill site workers. Across the other side, wind and water can disperse chemical hazards and epidemiologic agents into the surroundings. (Riese 2nd et al., 1990). (Ghali et al., 2023)

2.1.4 Noise Pollution:

For health and sanitation consultants, **noise** is a key source of worry. You will likely have noise complaints when you live or work near heavy processes. Mental trauma, partial deafness, permanent deafness, perceptual drowsiness, diffusing impacts, elevated blood pressure, biceps dexterity, cardiac trajectories, sleeping ailments, and work-related deafness are just a few of the physical implications noise has on the human body and mind. Some behavioral effects include mental fogginess, tension, irritation, and impatience. (Sorin et al., 2016).
Blood pressure consequences of **noise stress** were studied. According to the research, employers' blood pressure is elevated when listening to excessive noise (greater than 95 dBA) (Ghali et al., 2023)

2.1.5 Soil Contamination:

Environmental and public health concerns arise from soil contamination caused by medical waste incinerators. The contamination of soil caused by medical waste incinerators poses a significant environmental and public health risk. The environmental and public health impact of medical waste incinerator plants is significant. There is a significant environmental and public health risk associated with soil contamination from medical waste incinerators.(Ghali et al., 2023)
The contamination of soil resulting from medical waste incinerator plants is a serious concern for environmental and public health. Contamination of soil caused by medical waste incinerators is a significant health and environmental concern. There is no doubt that soil contamination from medical waste incinerator plants presents a significant threat to the environment and public health. Medical waste incinerator plants can cause significant environmental and public health concerns. A significant environmental and health concern is soil contamination caused by medical waste incinerators. Incinerator plants for medical waste generate soil contamination which is a significant issue for the environment and public health. (Tait et al., 2020)

3 Chapter 3

3.1 Methodology:

Initially, all the information regarding the medical waste incinerator was collected with the help of secondary data (available literature). We gathered primary data by surveying the medical waste incinerator. Our goal was to identify any potential risks or hazards to the environment and any dangers that workers may face. The main environmental variables selected for the medical waste incinerator were gaseous emissions, noise, groundwater, wastewater, and soil.

3.1.1 Secondary Data Collection:

A literature review was carried out for secondary data collection regarding the medical waste incinerator and its adverse effects on the surrounding ecosystem. Information concerning the impacts of the medical waste incinerator on the environment was collected through research papers, books, articles, and journals.

3.1.2 Primary Data Collection:

A thorough site visit was conducted in which samples were gathered, and Questionnaire & the occupational health and safety inspection checklist were filled out, respectively. The checklist was prepared with the help of a literature review to assess environmental risks and to determine the adverse impacts that may occur due to the incinerator. Environmental monitoring was performed for all the relevant parameters. Noise and air pollution have been monitored on the spot while soil, ash, and water samples have been analyzed in the lab. The facility was be divided into 5 different processes which are as follows:

- Transportation
- Segregation
- Storage
- Incineration
- 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.

A checklist and questionnaire have been designed in conformance with these standard

- Sindh Hospital Waste Management Rules2014.pdf

- Environmental Health and Safety Audit Checklist
- (OHSAS 18001-2007 Requirements Checklist)

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 content of the Occupational health and safety Checklist will include the following:

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

The content of the OHS questionnaire will include the following:

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

3.2 Hazard Identification

A field visit to the site location (incinerator) was carried out to assesses and identify risk and hazards. A checklist has been used to identify potential hazards. Systematic observations of the research region were made. Further environmental variables were also observed to determine the hazards' intensity and scope.

3.3 Environmental Monitoring:

Following environmental variables selected were monitored at the site:

List of Parameters:

Sr. No.	Parameter	Standard	Sample Location	Sample Frequency
1	Soil	PEQS	Samples collected from different sites of lawn near incinerator site.	3 alternative days
2	Gaseous emission and noise	PEQS	1-Outside main gate of the hall no. 1 2-Inside main gate 3-Near incinerator 4-Near offices	8 hours monitoring, over a week
3	Ground water	WHO	Sample taken from tap water, which is placed in lawn area.	3 alternative days

4	Waste water	PEQS	Wet scrubber	3 alternative days
5	Ash	EU. Sewage. Sludge Directive (86/278/EEC)	Ash	1 sample

Table 5 List of parameters

3.3.1 Equipment and Procedures:

- **HAZ Scanner TM:**

The HIM-6000 air quality monitoring station from Haz-ScannerTM measures and records air contaminants at trace levels. The extensible and portable apparatus measures PM 2.5 and PM 10 simultaneously. For harmful gas, sound, radiation, and meteorological air factors, the HIM-6000 has 12 sensors available. In addition, solar power, 5-mile wireless data transmission, and Ethernet/Internet data viewing are available.

- **Digital Sound Level Meter:**

Due to the continual operation of heavy machinery, particularly during the operational period, noise is one of the site's biggest challenges. The Noise Level Meter (TES1350a) was used to measure the sound level. The device is made up of an electric condenser microphone, which turns the sounds it receives into electrical impulses. Depending on the need, it displays these signals as readings on an indicating device in dB (A) or dB (C). It accurately measures the noise level in any location with a tolerance of 2 dB across a range of 35 dB to 130 dB.

- **Atomic Absorption Spectrophotometer:**

Its detection range is between 190 and 930 nm, Variable slit and flame made of acetylene. It is used to identify many metals in solutions, including chrome, cadmium, nickel, cobalt, iron, zinc, copper, manganese, and molybdenum.

- **Flame Photometer:**

This instrument 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.

- **Total Suspended Solids (TSS):**

Filtration method was used to calculate TSS in the samples. Filter paper of 0.45mU or 0.43mU was preheated for 1 hour in Hot Air Oven at 105^{o}C and then let it coolfor 10 minutes in desiccator. Then it was weighed on the

weight balance. This step was repeated three times to get a constant weight of filter paper.

This filter paper was placed in the filtration assembly and sample of 25ml, 50ml, 100ml and 500ml were

filtered through it. Then this filter paper was dried in the desiccator and weighed on the weight balance. TSS was then calculated by following formula:

TSS= Difference of weight x 1000 x 1000/ volume of sample (ml)

- **Biochemical Oxygen demand: (BOD):**

5ml of sample and 300ml distilled water was taken in a bottle. Firstly, DO was monitored through DO meter. After that bottles were incubated for 5 days in the incubator at 20^{o}C. After 5 days' bottles were taken out and DO monitor again.

Difference between initial and final DO represent the BOD. BOD can be calculated by following formula:

BOD = D1 – D2 x 300 / 5

3.3.2 Soil Monitoring:

Sample Location: Samples were collected from lawn area (Near Incinerator) on three alternative days. Soil is loamy with a moderate texture. Following parameters were analyzed in soil samples:

Sr No	Parameter	Reference Method	Instrument/Equipment	Instrument Model
1.	Sulphate	APHA 8051	Spectrophotometer	DR-2800
2.	Sulphide	HACH 8131	Spectrophotometer	DR-2800
3.	Fluoride	APHA 8029	Spectrophotometer	DR-2800
4.	pH	APHA-4500-H+	pH meter	pH-700
5.	Chloride	APHA 8206 & 8207	Digital Titrator	#16900
6.	Sodium	APHA-3500 NaB	Flame Photometer	1381 E
7.	Potassium	APHA-3500 KB	Flame Photometer	1381 E
8.	Calcium	APHA-3500 CaB	Flame Photometer	1381 E
9.	Magnesium	APHA-3500 MgB	Flame Photometer	1381 E
10.	Barium	APHA 8014	Spectrophotometer	DR-2800
11.	Iron	APHA-3111	Atomic Absorption Spectrophotometer	210-VGP
12.	Zinc	APHA-3111	Atomic Absorption Spectrophotometer	210-VGP

Table 6 Quality Parameters of Soil and their Reference Methods

3.3.3 Ground Water Monitoring:

Location: Samples were collected from the tap (near offices) on three alternative days. The depth of the groundwater table was 60 meters in the area. Following parameters were analyzed in water samples:

Sr No	Parameter	Reference Method	Instrument/Equipment	Instrument Model
1.	Ph	APHA-4500-H^+	pH meter	pH-700
2.	Chloride	APHA 8206 & 8209	Digital Titrator	#16900
3.	Turbidity	-	Microprocessor Turbidity Meter	HI-93703
4.	Sulphate	APHA 8029	Spectrophotometer	DR-2800
5.	Sodium	APHA-3500 NaB	Flame Photometer	1381 E
6.	Potassium	APHA-3500 KB	Flame Photometer	1381 E
7.	TDS	APHA-254C	Filtration Assembly	AS-20

Table 7 Quality parameters of ground water and their reference methods

3.3.4 Gaseous Emissions and Noise Monitoring:

Sample Location: Outside main gate of the hall no. 1, Inside main gate, near incinerator, near offices (Spot Testing) Following parameters were analyzed in ambient air and noise monitoring:

Sr No	Parameter		Instrument/Equipment	Instrument Model
1.	Air	CO	HAZ Scanner ™	HIM 6000
		NO2		
		SO2		
		PM10		
		O3		
2.	Noise Level		Sound Level Meter	TES-1350a

Table 8 Air and Noise Monitoring and their Reference Methods

Carbon Monoxide, Nitrogen Dioxide, Sulphur Dioxide, Particulate Matter, and Ozone were measured using the HAZ Scanner TM. A portable incident air monitoring system is called HAZ Scanner TM. At the chosen location, a device with a fully charged battery was installed to track the air quality characteristics. In addition, a suitable impactor was chosen to keep track of PM at the chosen location. The HIM-6000 was turned on by holding the start button for ten seconds. After the HIM-6000 instrument had warmed up for 15 minutes, the "System Ready"

message was displayed on the screen. After that, the instrument began to display parameter values every 20 seconds. Results were reported after scrolling through the sensor menu.

The readings' ppm to g/m3 conversions. Sound Level Meter (TES1350a) was used to measure the volume.

3.3.5 Ash Monitoring:

Location: One fresh sample taken from the ash.

Sr. No	Parameters	Equipment/Method
1	Cadmium	**Atomic Absorption Spectrum (AAS)**
2	Copper	
3	Lead	
4	Mercury	
5	Nickel	
6	Unburned carbon	

Table 9 Ash Monitoring

3.4 Risk Estimation:

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

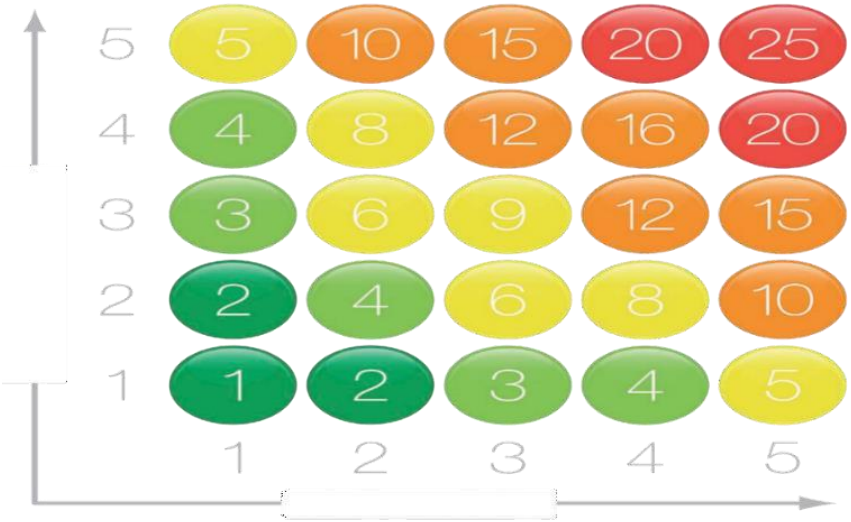


Figure 8 Risk Assessment Matrix (IOSH- Managing Safely.Pdf, 2012.)

3.4.1 Severity Ranking Table:

Following table will be used for tanking the severity level of the risks in accordance with their impact on the environment.

Severity Level (Consequences)	Impact
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 10 Severity *Ranking* (Dewantara et al., 2022)

(IOSH- Managing Safely.Pdf, 2012.)

3.4.2 Qualitative Measure of Likelihood:

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 11 Qualitative Measure of Likelihood

(Dewantara et al., 2022) (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

3.5 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 procedures.
Tolerable (Minor risks)	5-8	Use engineering controls and techniques of substitution until elimination.
Tolerable (Major 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, substituting, or putting the engineering control measures into operation.

Table 12 Risk Ranking Table (Dewantara et al., 2022) (IOSH- Managing Safely.Pdf, 2012.)

3.6 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, certain control measures were suggested to the facility to minimize or in some cases entirely control the hazard from occurring in the future. The following table was used for risk management:

List of Hazards	Associated Risks	Mitigation measures

Table 13 Risk Management (IOSH- Managing Safely.Pdf, 2012.)

4 CHAPTER 4:

4.1 RESULTS:

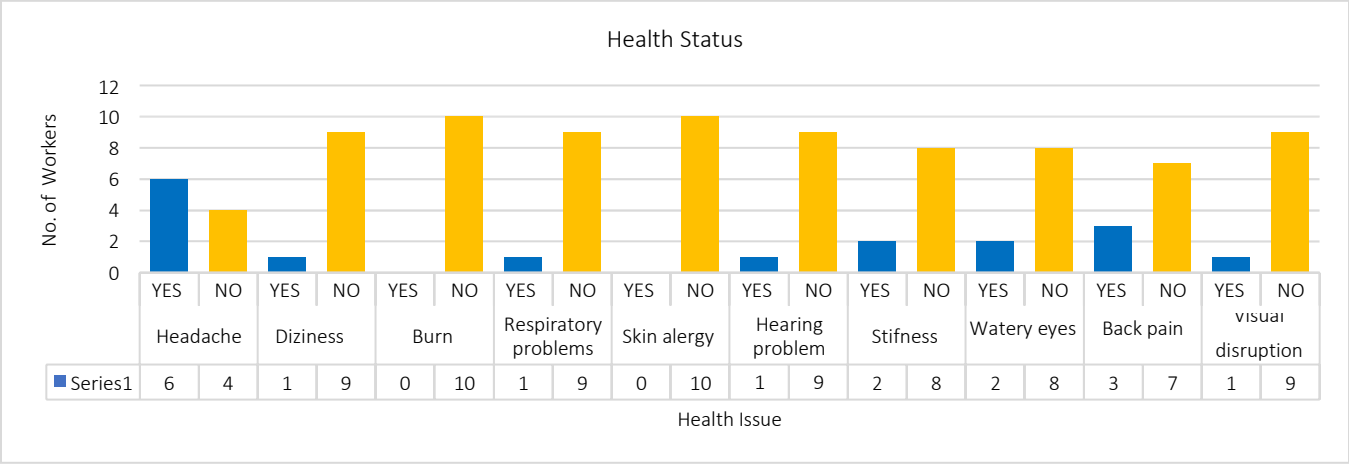
The incineration facility located in Lahore had 1 manager and 9 workers. All of them were asked to fill out a questionnaire that had following components:

4.1.1 Demographic Profiles of Workers:

Respondents	Age (years)	Weight (Kg)	Marital status	Education	Experience (year/years)	Designation
Respondent 1	32	85 Kg	Married	BSc. Environmental Engineering	7	Manager Operations
Respondent 2	38	75 Kg	Married	Primary	10	Worker
Respondent 3	28	65 Kg	Single	Matriculation	6	Worker
Respondent 4	39	80 Kg	Married	Primary	8	Worker
Respondent 5	35	70 Kg	Married	Matriculation	5	Worker
Respondent 6	40	92 Kg	Married	Primary	11	Worker
Respondent 7	27	70 Kg	Married	Matriculation	3	Worker
Respondent 8	34	75 Kg	Married	Intermediate	5	Worker
Respondent 9	22	60 Kg	Married	Matriculation	2	Worker
Respondent10	31	82 Kg	Single	Primary	3	Worker

2 out of 10 respondents were single. All of the participants surveyed were between the ages of 18 and 60, in accordance with the Hazardous Occupation Rules of 1963 (No. 1-6 (L-II/64) listed in the International Labor Organization's regulations.

Personal Health Status of the Workers:



OHS Figure 9 Health status of the workers at the incinerator

None of the workers reported skin allergy and burn. Three out of 10 workers reported back pain occasionally. Two out of 10 respondents reported watery eyes and stiffness whereas six out of 10 workers reported headache. Majority of the workers had no visual disruption and hearing or respiratory issues.

No employee receives a routine medical examination, which is against the ILO's Hazardous Occupation Rule of 1963, which mandates that every employee have a medical examination by an authorized doctor at intervals of not more than six months, and that the facility manager must maintain a record of each examination.

Only 2 out of 10 workers reported that they had a medical checkup 4 to 6 months earlier. Only 3 out of 10 workers were immunized against hepatitis A, hepatitis B, polio and tetanus, and none of them reported any chronic disease.

4.2 Monitoring:

In order to confirm the accuracy of the responses given by the employees during the interview, we monitored various parameters of our surroundings to assess the impact of incineration on the environment and human well-being. Air and noise monitoring was done on the incinerator's site. Additionally, soil, ash, and water samples were taken for laboratory study. For the samples of soil and water, different quality indicators were seen. Therefore, these variables underwent routine analysis, and the results were compared to Punjab Environmental Quality Standards.

4.2.1 Gaseous Emissions Monitoring:

For gaseous emissions monitoring, samples were taken from the incinerator stack or chimney, and concentrations were tracked for a week on an 8-hourly schedule. Each parameter's average value for a given day was calculated separately. The levels of gaseous emissions were discovered to be within the norm. This shows that there were no operational issues with the incinerator, obviating any risk to the workers. Toxic gases at the factory did not pose any health threats.

Sr.	Parameters	Method	Units	PEQs	Day 1	Day 2	Day 3	Day 4	Day 5	Day 6
1	Carbon monoxide	TESTO 350 S	mg/Nm^3	800.0	711.6	712.9	710.9	711.1	711.5	710.9
2	Combined oxides of nitrogen (NOx)	TESTO 350 S	mg/Nm^3	400.0	123.8	120.4	122.2	123.9	124.1	123.9
3	Sulphur dioxide	TESTO 350 S	mg/Nm^3	1700.0	195.6	196.2	195.3	194.7	196.1	195.8

4	Smoke	Ringlemann scale	Ringlemann	2.0	1	1	1	1	0.9	1
5	PM	TESTO 350 S	(µg/ m³)	150	78	80	75	85	79	80

Table 14 Gaseous Emissions

Gaseous emissions were found to be within the standard limits. This depicts that the incinerator had no operational errors and thus posed no threat to the workers. There were no health risks associated with toxic gases at the plant.

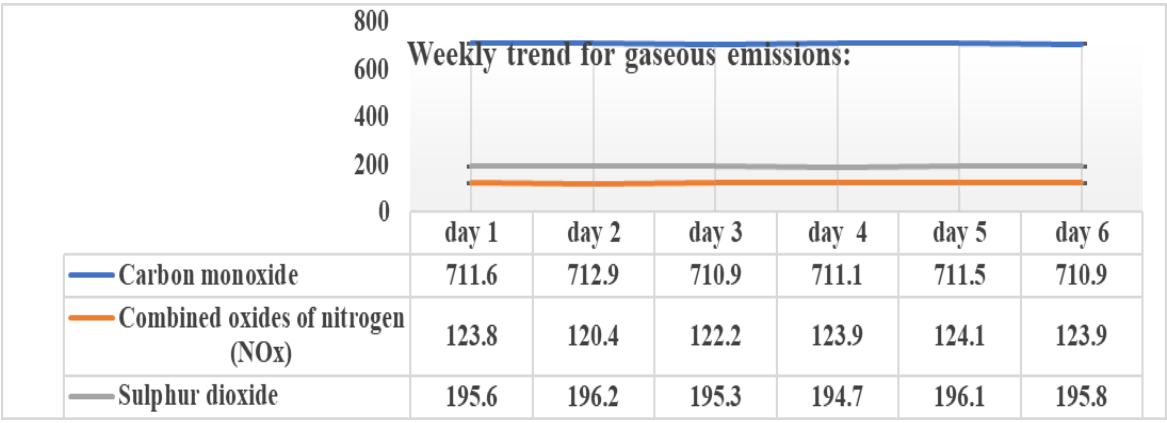


Figure 10 Graph: Representing Gaseous Emissions

This graph shows that all the values are within the safe limit. There were no health risks associated with toxic gases at the plant.

4.2.2 Noise Monitoring:

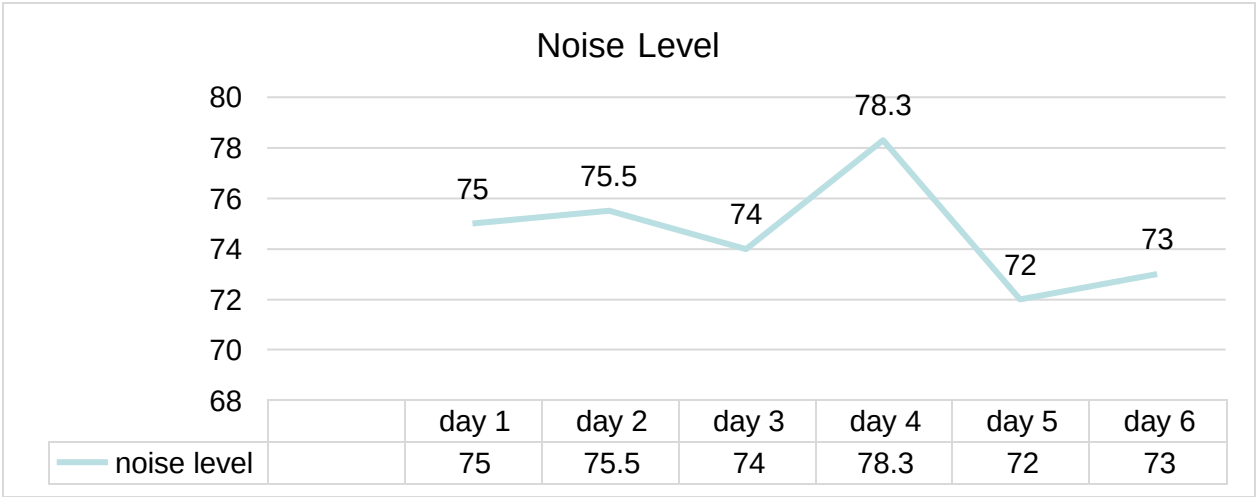


Figure 11 Graphical Noise Monitoring

Findings show that all values are within safe limits except two (days 2 and 4), as mentioned in PEQs. The exceeding values can cause health problems like hearing issues in workers.

4.2.3 Ground Water Monitoring:

Groundwater samples were collected from the tap installed in the facility. Samples were taken on 3 alternative days and monitored.

Sr. no.	Parameters	Method	Unit	WHO Guidelines	Sample 1	Sample 2	Sample 3
1	pH value	pH meter	-	6.5-8.5	7.74	7.43	7.69
2	Total dissolved solids	Evaporation	mg/l	1000	564.0	570.3	560.5
3	Turbidity	Turbidity meter	NTU	5.0	0.05	0.04	0.06
4	Chloride	Digital titrator	mg/l	250	18.0	17.6	18.1
5	Fluoride	Spectrophotometer	mg/l	1.5	0.31	0.35	0.34
6	Nitrite	Spectrophotometer	mg/l	3	0.016	0.014	0.015
7	Copper	AAS	mg/l	2.0	0.013	0.012	0.013

Table 15 Ground Water Analysis:

Findings for all the groundwater parameters are seen to be within safe limits. There were no health risks associated with these parameters at the plant.

4.2.4 Soil Monitoring:

Soil samples were taken at a depth of half a foot on three different days and monitored.

Sr. No.	Parameter	Units	Instrument/Equipment	Standards	Sample 1	Sample 2	Sample 3
1.	**pH**	-	Spectrophotometer	6.5-8.5	8.32	8.33	8.31
2.	**Sulphate**	mg/kg	Spectrophotometer	NS	157	158	156
3.	**Sulfide**	mg/kg	Spectrophotometer	NS	2.100	2.200	2.100
4.	**Chloride**	mg/kg	pH meter	NS	322	323	322
5.	**Fluoride**	mg/kg	Digital Titrator	480	5.2	5.5	5.4

6.	**Sodium**	mg/kg	Flame Photometer	NS	318	317	317
7.	**Potassium**	mg/kg	Flame Photometer	NS	26	24	25
8.	**Calcium**	mg/kg	Flame Photometer	NS	226	228	227
9.	**Magnesium**	mg/kg	Flame Photometer	NS	51	49	50
10.	**Iron**	mg/kg	Spectrophotometer	NS	15	14	15
11.	**Barium**	mg/kg	Atomic absorption Spectrophotometer	9	9	8.7	9
12.	**Zinc**	mg/kg	Atomic absorption Spectrophotometer	16	15.5	15.9	14.9

Table 16 Soil Analysis

Here are the results of the atomic absorption spectroscopy done on the soil sample taken from the incineration premises. The table shows that all minerals and heavy metals were below the detectable level based on the values obtained. There were no health risks associated with these parameters at the plant.

4.2.5 Waste Water Monitoring:

Sr. no.	Parameters	Method	Unit	PEQs	Sample 1	Sample 2	Sample 3
1	pH value	pH meter	-	6-9	7.7	7.4	7.8
2	Total dissolved solids	Evaporation	mg/l	3500	967	964	968
3	Total suspended solids	Filtration	NTU	200	181	180	181
4	COD	Spectrophotometer	mg/l	150	80	79	78
5	BOD	BOD Trak	mg/l	80	55.1	55.7	56
6	Temperature	Thermometer	℃	40	28.0	28.5	28.8
7	Turbidity	Turbidity Meter	NTU	….	96	95	96

Table 17 Waste Water Analysis

Table shows that all the parameters are within permissible limit as per PEQs.There were no health risks associated with these parameters at the plant

4.2.6 Ash Monitoring:

Fresh ash sample was collected from the ash.

Parameter	Units	Standards	Concentration
Cadmium	mg/kg	40	BDL
Copper	mg/kg	1750	184
Lead	mg/kg	1200	82
Mercury	mg/kg	25	BDL
Nickel	mg/kg	400	18.7
Unburned carbon	%	……	<5

Table 18 Ash Analysis

Table shows that the concentrations of all the heavy metals monitored were found to be within the standard limits.

4.3 Psychological Factors:

Psychological contentment is a crucial component of one's health because low levels of satisfaction can result in difficulties like stress and anxiety, which in turn can cause various health problems. Respondents were asked a certain number of questions that could depict their level of satisfaction from their job.

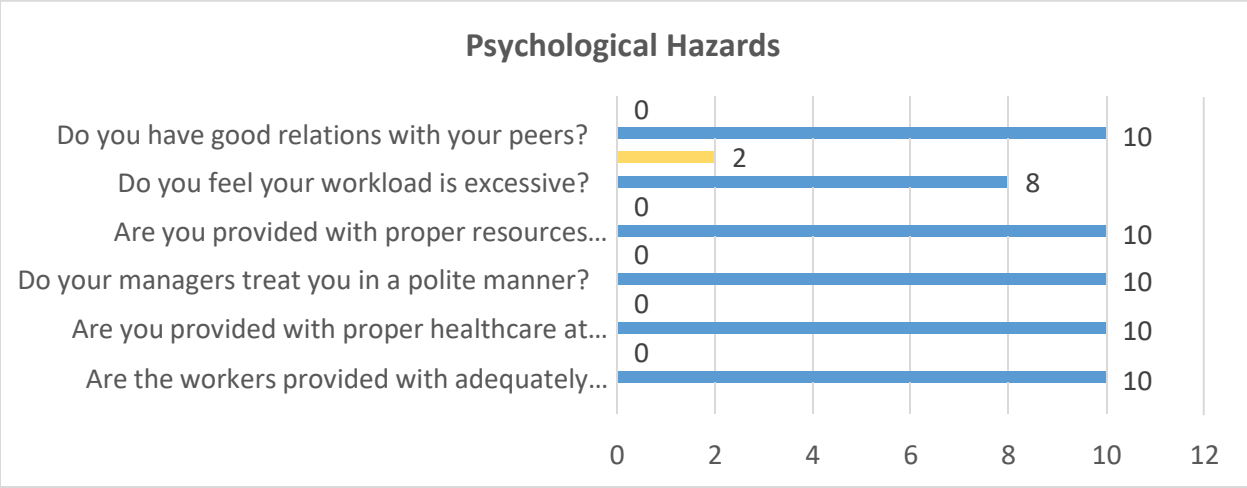


Figure 12 Factors that might be a psychological hazard at the site

Working hours reported by the workers were between 8 to 12 hours. Two out of 10 respondents felt that their workload was excessive. All of the respondents were satisfied with their working environment and facilities provided at the plant.

4.4 OHS Measures and Awareness:

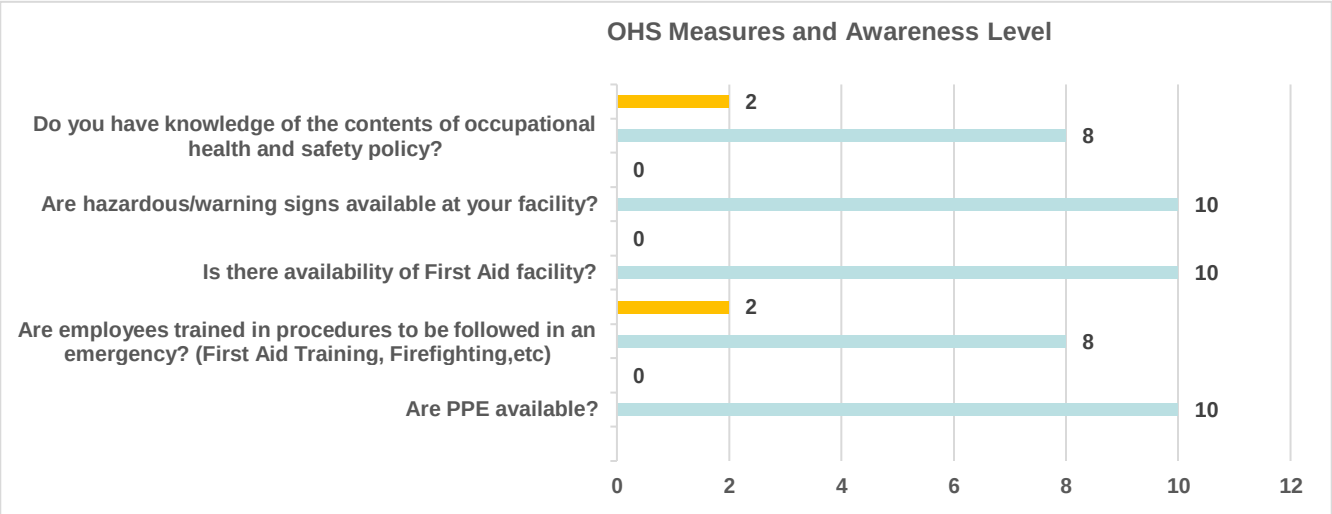


Figure 12 OHS measures and awareness among employees at incinerator site

All the requirements of Hazardous substance rule, 2003 ILO guidelines regarding occupational health and safety measures and awareness were met.

4.5 Monitoring Records and Operational Procedures:

Incinerator operation manual, maintenance and repair logs were available at the facility. The waste was properly weighed and the all the records were adequately maintained. This was in accordance with the Hazardous substance rule. 2003 in ILO guidelines.

4.6 Disposal Practices:

The workers dealing with the removal of ash were wearing gloves, normal masks and safety hats.

4.7 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 checklist was filled during the visit to facility. The results were as follows:

Occupational Health and Safety Hazard Identification Checklist

Sr#	Description	Yes	No	N/A	Remarks
General Workplace Environment & Air Quality					
1.	Is the area adequately lighted.?				• The incinerator is situated in a room that is well-lit (with powerful tube lights and bulbs), with sunlight also coming in. Glare and reflections are minimized.
2.	Are warning signs displayed properly?				• Adequate placement of warning signs, including those for danger, hazards, first aid, chemicals, and other situations. • The "no smoking" "sign" is posted when necessary, and those who violate this rule face consequences.
3.	Are High-noise areas marked with signs requiring the use of hearing protection?				• Yes, there are signs indicating high-noise places that demand the use of hearing protection.
4.	Are the work areas clean, sanitary, and well-organized (Garbage properly disposed of, etc.)?				• Garbage was openly placed far away from the incinerator site. • All the hazardous waste and materials are stored properly in a designated area known as YELLOW room. • Spill incidence are immediately reported.
5.	Are vacuum systems are employed instead of sweeping dust?				• No, there's no need of it.
6.	Are the humidity and temperature levels seem to be within acceptable ranges?				• Yes, and there is no obvious fungal/mold growth or related odors in these areas. • There are no symptoms of mold or moisture damage on the walls, ceilings, or floors. • There are no odor-causing items or harmful compounds in the air intake zones.
Health & Safety					
Sr No.	**Description**	**Yes**	**No**	**N/A**	**Remarks**
1.	Does the facility have a formal EHS program with rules and procedures for environmental health, safety (EHS), and working conditions?				• Yes, EHS program is available. • Necessary health and safety rules are also enforced by the management.

2.	Are routine facility inspections conducted?				• Yes
Electrical Safety					
Sr No.	**Description**	**Yes**	**No**	**N/A**	**Remarks**
1.	Is the risk of electric shock or fire minimized during the installation, construction, maintenance, protection (cover on switchboard), and testing of electrical appliances?				• Yes, even multi-outlet power strips contain circuit breakers and are UL-approved.
2.	Are impediments kept away from switchboards?				• Yes, Unobstructed and labeled circuit breaker panels and emergency shut-offs are used.
3.	Are extension cords and flexible cords used with caution?				• Yes. • Electrical cords should not be run through entrances, beneath carpets. • The use of extension cords as permanent wiring is not recommended
4.	Is the facility's energy use, which is used for a variety of processes, being monitored?				• Yes, the energy consumption is monitored.
5.	Are Splitters used to ensure that electrical outlets are not overburdened with equipment?				• No, splitters are not available
Fire Prevention and Protection					
Sr No.	**Description**	**Yes**	**No**	**N/A**	**Remarks**
1.	Do fire extinguishers have the required mounting, placement, identification, quantity, and type?				• Yes, and even fire extinguishers, fire hydrants and fire alarms are provided at convenient locations within the facility. • These equipment’s are regularly inspected and maintained.
2.	Were stairways, exits, fire equipment, and fire lanes kept clear?				• Yes, fire hazard signs and directions to emergency exit route is displayed at various places at the site.
3.	Are exit lights operational and properly illuminated?				• Yes, exit lights are operational and properly lit.
4.	Are cabinets used for flammable storage labeled?				• Yes, flammable storage cabinets are labeled. “Keep Fire Away."
Environmental Controls					
Sr No.	**Description**	**Yes**	**No**	**N/A**	**Remarks**
1.	Have hazardous compounds been				• Yes, separate waste bins (with

	identified that could cause injury if inhaled, ingested, absorbed via the skin, or come into contact with them?				labels) are placed for different type of wastes - plastic, paper, metal, syringes, glass, and containers etc.
2.	Are records of waste generation and management maintained properly?				• Yes, records of all waste generated is maintained. • Training provided to personnel for identification, segregation, and management of waste. • Non-hazardous non-recyclable wastes are disposed of on designated site. • No waste is dumped at any location outside the proposed project boundary
3.	Does hazardous waste manage properly at the facility?				• All the hazardous waste and materials are stored and managed properly in a designated area. • Spill incidence is immediately reported and cleaned up. • Spill kit is always available at the site.
4.	Is the ventilation system in the work area adequate for the task being done?				• Yes, local exhaust ventilation systems are designed and operating adequately for the application.
Personal Protective Equipment (PPE)					
Sr No.	**Description**	**Yes**	**No**	**N/A**	**Remarks**
1.	If a hazard exists, Is appropriate eye, face, and hand protection accessible and employe?				• Yes, all PPE are accessible. • All workers at the site are provided with personal protective equipment's. • They trained workers on personal safety and disaster management. • They conducted these kind of training sessions twice a year.
2.	If there are any hazards, appropriate hearing and foot protection will be accessible and employed?				• Yes, appropriate hearing and foot protection is accessible and employed.
3.	Are coveralls, aprons, googles, and other protective equipment available and can be used if necessary?				• Yes, the workers which are involved in waste feeding task always wear face covers and googles.
5.	Is PPE stored appropriately and are they in good working order?				• Yes, there are separate cabins for them.
First Aid					

Sr No.	Description	Yes	No	N/A	Remarks
1.	Is there a clear display of first-aid signs?				• Yes, Clear signage posted alerting of possible danger situations.
2.	Are first-aid kits and the items inside them tidy, orderly, stocked, and up to date?				• Yes, first aid kits are in good condition.
3.	Are the kits clearly marked with the phone number and address of the closest first responder and emergency personnel?				• Yes, first Aid kits are always available at the site and staff members trained in first aid administration. • Workers are trained on personal safety and disaster management. Conducted Health and Safety Audits twice a year.
Emergency Response Plan					
Sr No.	**Description**	**Yes**	**No**	**N/A**	**Remarks**
1.	Are there an up-to-date emergency plan at the facility?				• Yes, they have an effective Emergency Response Plan.
2.	Has the emergency plan been practiced and updated?				• Yes, the emergency plan has been practiced and updated.

Table 19 Occupational Health and Safety Hazard Identification Checklist

Table 19 shows that majority of the checklist requirements were fulfilled.

Incineration is a continuous process that needs precise operating circumstances to function properly. Due to the unique emissions and final products that each sort of waste produces, distinct SOPs are required. Workplace risks and hazards can come in many different forms if operational conditions and SOPs fluctuate or become unstable. The following table depicts the crucial considerations for the incineration process:(Nidoni, 2017) (Chu et al., 2023)

4.8 Incinerator Operating Conditions:

Sr. No.	Parameters	Operating Conditions	Functions
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 is 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 20 Incinerator Operating Conditions(Chu et al., 2023)

Table 20 shows the crucial considerations for the incineration process and its impacts.

4.9 Risk Assessment Matrix:

Hazard category	List of possible hazards	How / when harm could occur	Risk of injury / illness	Risk to? (Number and type of people exposed)	Existing controls	Human factors	Potential severity	likelihood	Risk category
Transportation									
Vehicles	Transport	Vehicle crashing into other objects, people falling from vehicle, objects falling from truck onto staff.	Trip hazard. Fall from height.	workers	All operators trained properly.	Action error/ mismanagement.	Moderate (3)	Unlikely (2)	Tolerable (6)
Ergonomics risks	Quantity and loading/unloading of the waste	Manually lifting of heavy or large amount of weight can cause issues.	Musculoskeletal issues	workers	Physically fit workers trained for carrying.	Repetitive movements or wrong posture.	Major (4)	Certain (4)	Unacceptable (16)
Chemicals	Type of the waste	Hazardous material can cause irritation, breathing problems.	Respirator problems, skin issues	workers	PPE'S used properly	Non-compliance	Moderate (3)	Occasionally (3)	Tolerable (9)
Struck by object	Heavy weight lifting	Worker might suffer from heavy injury if struck by heavy object during lifting.	Injury / fracture	workers	Lifting aids available.	wrong posture	Major (4)	Occasionally (3)	Tolerable (12)
Slip hazard	Spills and leakage	Chemical exposure/slip over the spills.	Fracture, skin issue, allergic reaction.	workers	Non-slip footwear worn.	Accidental spills/ Mismanagement.	Major (4)	Unlikely (2)	Tolerable (8)
Stationary objects	Struck by an object	Workers might hit into the object during transport.	Musculoskeletal issues	workers	Working area kept clear, trained staff.	Shortcuts/mismanagement.	Moderate (3)	Unlikely (2)	Tolerable (6)
Segregation									
Toxics and irritants	Chemicals/dust/gasses exposure	Workers might be exposed to toxic chemicals and dust during segregation	Skin and eye irritation, respiratory problems.	workers	Worker's wear PPE'S. (Gloves, masks, etc.)	Negligence of workers	Moderate (3)	Unlikely (2)	Tolerable (6)

Spills and leakage	Leakage of hazardous materials	Waste bags can leak or hazardous chemicals might get spilled	Skin problems, fall or slip	workers	Workers wear gloves, spills cleaned immediately	Accidental spillage	Minor (2)	Unlikely (2)	Acceptable (4)
Ergonomics risks	Repetitive movements	Workers might experience back pain or muscular pain due to repeated movements.	Back pain, stiffness	Workers	Workers can take break during the work.	Wrong posture	Moderate (3)	Occasionally (3)	Tolerable (9)
Sharp objects	Physical injuries	Workers might get exposed to sharp objects (glass, syringes or metal) during segregation	Cuts, bruises	Workers	PPEs used, trained staff.	Accidental exposure	Moderate (3)	Certain (4)	Tolerable (12)
Storage									
Ergonomics risks	Manual handling	Workers might experience back pain or stiffness due to repeated movements during manual handling.	MSD's	Workers	Manual handling aids available, trained staff.	Excessive workload or wrong posture.	Major (4)	Certain (4)	Unacceptable (16)
Spills and leakage	Leakage of hazardous materials	Waste bags can leak or hazardous chemicals might get spilled	Slip hazards, skin issues, respiratory problems	Workers	Spills cleaned immediately; PPE's worn to prevent skin exposure	Mismanagement / negligence of workers	Moderate (3)	Occasionally (3)	Tolerable (9)
Biological hazards	Animals, molds, bacteria	Improper cleaning of rooms can lead to bacteria and other micro-organisms growth.	Skin issues	Workers	Good housekeeping is assured	negligence of workers/ non-compliance	Minor (2)	Unlikely (2)	Acceptable (4)
Incineration									
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 (8)

Sharp objects	Physical injuries	Workers might suffer from injuries due to sharp objects in waste.	Cuts, bruises	Workers	Goggles, gloves, masks.	Negligence of workers	Moderate (3)	Unlikely (2)	Tolerable (6)
Fall / trip hazard	Fall from height	Workers feeding the waste into the incinerator might fall.	Fractures, physical injuries	Workers	Trained staff allowed to feed the waste.	Accidental fall	Major (4)	Occasionally (3)	Tolerable (12)
Chemicals	Exposure to emissions and chemicals.	Workers exposed to emissions from incinerator and chemical fumes from chimney.	Respiratory problems, other health issues.	Workers	Emissions limits within standards, PPEs used.	Monitory negligence.	Moderate (3)	Rare (1)	Acceptable (3)
Vibration	Whole body vibration, arm, hand.	Worker feeding the waste into incinerator experience whole body vibration.	Back pain, MSD's	Workers	Workers should allow to shift positions.	Static work posture / fatigue	Moderate (3)	Certain (4)	Tolerable (12)
Ergonomic risks	Repetitive movement, posture	Worker feeding the waste experience repetitive movements	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 level within standard limits.	Regular inspections might be delayed which may cause noise issue.	Minor (2)	Unlikely (2)	Acceptable (4)
Machinery	Dangerous machinery parts	Workers might suffer injuries due to dangerous machinery parts.	Physical injuries.	Workers	PPE'S uses. Only trained personnel allowed to operate.	Negligence	Catastrophic (5)	Unlikely (2)	Tolerable (12)
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)

Disposal									
Toxic gases	Expose to gaseous emissions	The works might be exposed to toxic gases from freshly burnt waste.	Respiratory problems, other health issues	workers	PPEs used	Non compliance	Moderate (3)	Rare (1)	Acceptable (3)
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)	Rare (1)	Acceptable (3)
Obstruction	Struck by objects	The workers might hit themselves into machinery or waste containers	Physical injury	workers	Staff trained to work professionally	Negligence	Minor (2)	Unlikely (2)	Acceptable (4)
Hot/cold environment	Hot/cold working environment	Heat stress in summers, cold in winters during ash removal	Heat stress in summers, cold in winters	workers	Adequate facilities for workers	Inappropriate working environment	Moderate (3)	Unlikely (2)	Tolerable (6)
Ergonomic Risks	Manual handling of ash	Repetitive movement for ash removal from the pit might cause back pain	MSD's	workers	Working in shifts to avoid over workload	Long working time	Moderate (3)	Certain (4)	Tolerable (12)
Hand tools	Shovel	workers might injure themselves by using hand tools for ash removal.	Physical injuries.	workers	Trained staff.	Divide attention/ mistakenly	Moderate (3)	Unlikely (2)	Tolerable (6)

Table 21 Risk Assessment Matrix

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

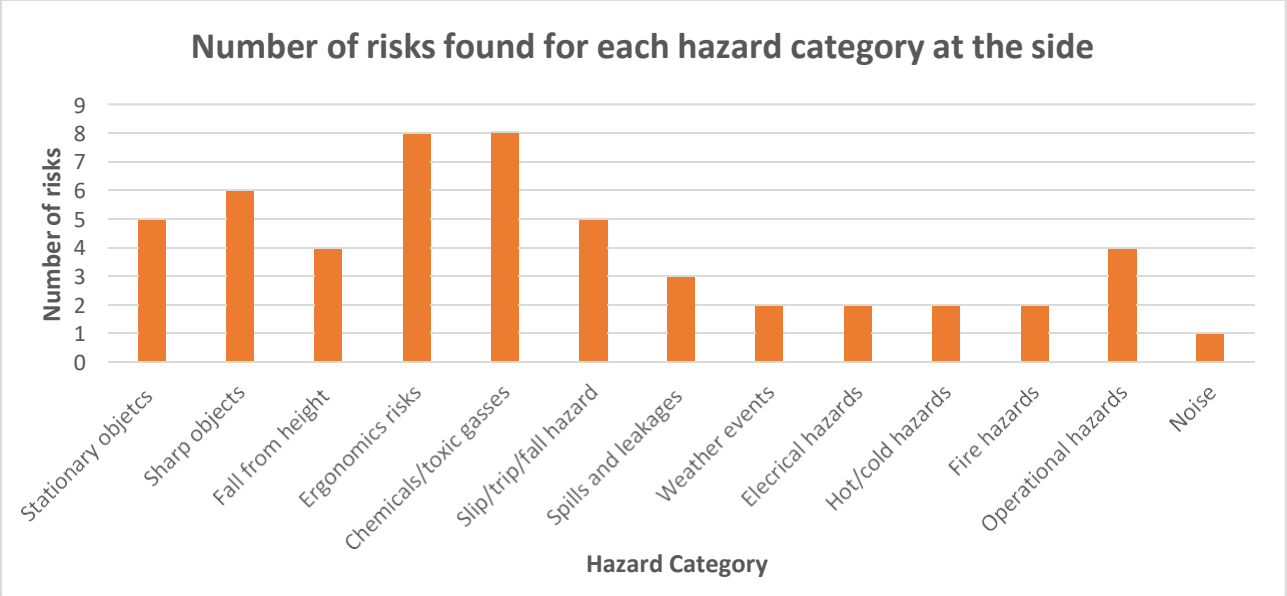


Figure 13 Types of Hazards and Number of Risks Associated at the Site

At every step of the incineration facility's processes, the greatest risks were identified. The risk level for the majority of the hazards was determined to be in TOLERABLE limits, allowing the activities to be continued while adhering to proper standard procedures and engineering controls and techniques that will be recommended later in the study. This was done by taking into account the overall risks, potential severity, likelihood of occurrence of a hazard, and existing controls**.** 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.

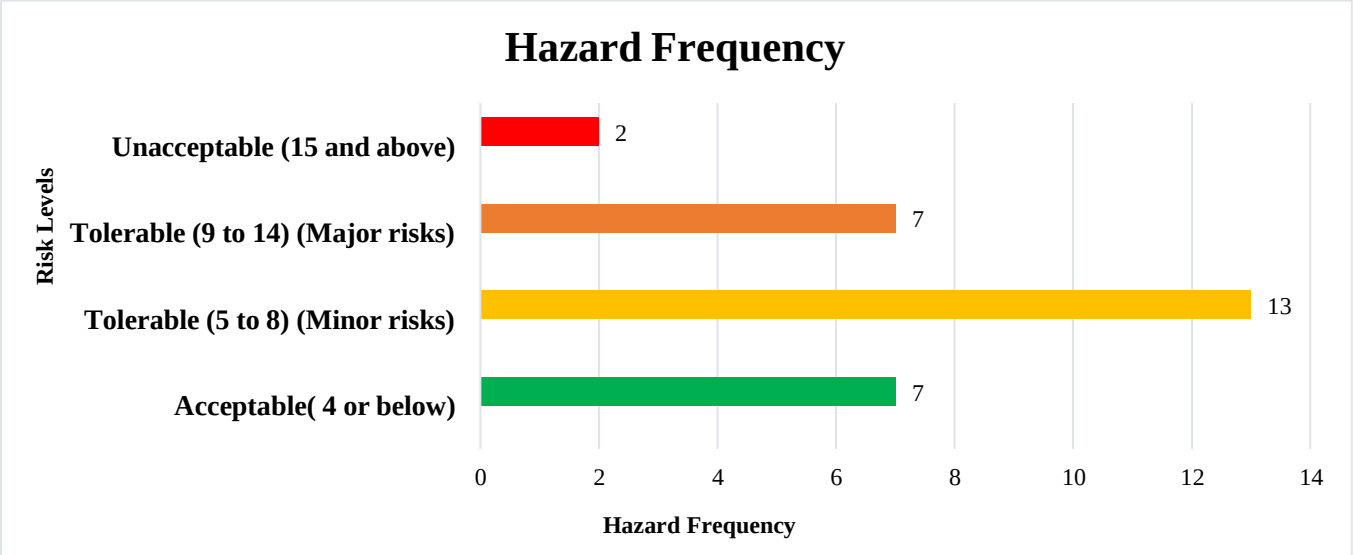


Figure 14 Graphical Hazard Frequency

According to the figure 15, the red line indicates that two hazards were considered unacceptable. The orange line represents seven risks that were deemed tolerable and categorized as Major Risks. The yellow line shows thirteen risks that were also tolerable and categorized as Minor. Finally, the green line indicates that seven risks were acceptable.

4.10 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:

a) Hazardous substance rule,2003.
b) Hazardous occupational rules,1963, (N0. 1-6 (L-11/64)
c) Fatal accidents act, 1855 (No. 13 of 1885)

Following a thorough investigation, a checklist was created to determine if the incineration facility complied with the **ILO's** occupational health and safety standards for a workplace processing Hazardous materials. The results were as follows:

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 occupational Rules, 1963 (no.1-6 (L-II/64)			
After every six months, a routine medical examination should be done.			
Employer pays the examination fee.			
Nobody under the age of 18 is employed.			
Employees with fitness certifications.			
Fatal Accidents Act, 1885 (No.13 of 1855)			
Compensation provided to families in case of loss or damage.			
Hazardous Substance Rules, 2003			
Assessment of the type of negative repercussions is included in the safety plan.			
Major accident risk analysis is included in the safety plan.			
Possess a permit to handle hazardous waste.			
The safety plan outlines the actions that should be taken in the event of an accident.			
The installed safety systems and equipment's are described in the safety plan.			
Waste management prevents the mixing of hazardous and non-hazardous waste.			
Potentially hazardous chemical identified by name.			
Gross components as stated (volume and weight).			
Indicators and a warning phrase (danger).			
Suitable PPE for handling.			
Local language advice for safety and better understanding.			

Neither employees under 18 nor those over 60.			
Sufficient water supply.			
Qualified managers.			
Training sessions for staff.			
Safety, emergency, and fire-fighting gear.			
Eating, drinking, and smoking are not permitted.			
The location of the property shouldn't be near any offices, busy commercial areas, or homes.			
Location or premises shouldn’t be near sources of drinking water.			
Premises should not be in small lanes.			
The space should have adequate ventilation.			
An electrical installation that is well-maintained should be present.			
Premises should have flat, crack-free floors that are impervious to liquids.			
Drains on premises should not be connected to the sewerage system directly.			
Signs, escape routes, emergency exits, etc. should be present on the site.			
Mentioned the person's name and address from whom hazardous waste is collected.			
Should mentioned the person's name and address to whom the waste is being delivered to.			
The proposed transportation's date and time are mentioned.			
Transportable hazardous waste volume was stated.			

Table 22 Occupational health and safety requirements.

Most of the requirements were fulfilled. The facility followed the occupational health and safety standards set by the International Labour Organization for a workplace that handles hazardous materials.

5 Chapter 5

5.1 Discussion:

5.1.1 Environmental Parameters and Impacts:

Hospital waste management in developing countries like Pakistan is vital owing to its contagious and hazardous nature, as it can harm humans and the environment. This work aimed to access the incinerator's impacts on humans and the surrounding. We evaluated the impact of an incinerator site on the environment by conducting on-site air and noise monitoring and collecting water and soil samples for laboratory analysis. We followed established protocols and compared all metrics obtained with the Punjab Environmental Quality Standards.

Additionally, the employer must offer a safe working environment for its workers; as a result, a structured questionnaire survey, site visits, and interviews were carried out to evaluate the hospital's occupational health and safety situation.

In ambient air quality monitoring, four air quality measures, including carbon monoxide, Sulphur dioxide, nitrogen dioxide, and smoke, were observed along with noise. According to Gaseous emission table, all the parameters are within the safe limits as per PEQS. Filters are already installed in the incinerator, so air quality at the incinerator site is found within the PEQS limits. In case of any damage to filters can alter the quality of air, and it can cause severe health issues.

Except for two points all values were found to be within the safe limit or 75 Dba, as shown in Graph when noise was measured at all alternative days. Despite being a substantial health concern for workers, workplace noise frequently causes hearing loss. If control measures are not implemented, it can also lead to insomnia, annoyance, psychiatric disorders, and hypertension. Hearing loss can occur if someone is exposed to noise pollution at levels higher than 75 dB over an extended period. As the noise level and exposure time increase, the risks to do. For their safety, workers should use personal hearing protection against noise. A certain number of minerals and other substances are naturally present in water bodies, but human actions upset the delicate balance of nature. Therefore, samples of the groundwater were taken to determine whether incinerator operations or any leaks are polluting the groundwater.

The groundwater sample were collected from a tap on alternative days placed at the incinerator site. In table all values are within limits. Without adequate treatment and disposal, wastewater harms the ecosystem by altering the pH and other characteristics of the water body, eradicating species, and ruining their habitat. Therefore, all parameters were examined in a laboratory after a wastewater sample was taken from the incineration site. Table shows that every value is within the PEQS range.

Different soil quality characteristics were examined after the soil samples were taken from the top layer. Despite the pH being somewhat alkaline, this was primarily because of basic/alkaline minerals. All other parameters are within limits in table.

Ash samples were collected after the incineration of a regular batch, and Six parameters were analyzed. One sample was collected from the outlet of the Incineration plant, and one sample was collected from the dumping area in the hospital. In table, we can see that all the parameters are within limits. After incineration, they stored ash in the paved area for cooling purposes located behind hall no 1. When the temperature became normal, they sent the ash away. The area is paved, so there is no chance of leaching.

For several years, this hospital received garbage for incineration from four separate hospitals; as a result, the parameters were not within safe limits at that time. But for the last three years, this hospital has solely incinerated its own waste, that's why all the parameters are within acceptable ranges. Every employee has a fundamental right to a safe workplace. As a result, the current research area's occupational health and safety standards were assessed. In addition, we spoke with the workers to get their opinions on how well they understood OHS policies at work. Most employees—75%—completed matriculation, whereas just 25% completed their intermediate education.

Only 14% of employees have been in the hospital for more than five years, compared to 72% employed there for five to ten years. Employees were questioned about their experiences with various health conditions, as shown in the diagram. Out of 10, 2 responders who worked in the loading department (loading waste into the incinerator) reported dyspnea, joint pain, and heat stroke. One of the respondents was diagnosed with arthritis after being questioned about joint pain.

Additionally, two respondents reported having watery eyes and eye inflammation, but when asked to elaborate on what they believed might have contributed to it, they cited smog from the previous year. When asked if they coughed four to six times a day, 1 respondent said yes, but they claimed it was due to seasonal changes. Three employees at the time said they occasionally encountered heat stress, while seven never did.
Employees' understanding of occupational health and safety procedures was tested using the questions. All of the responses were affirmative, suggesting that all necessary measures had been taken to guarantee employees a safe working environment, including providing PPEs, training, a first aid facility, and warning signs.

5.1.2 Risk Evaluation:

A comprehensive survey was conducted to assess the potential risks at the incineration site, followed by an evaluation of a risk assessment checklist. This helped determine if the necessary safety measures were in place and if the items were being stored and used as per protocol. The risks were initially identified in each department, and their likelihood, potential for injury, and frequency were calculated. This approach helped identify the importance of the risks and classify them appropriately at the incinerator site.

5.1.3 Requirements of International labor organization (ILO):

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

Following were the requirements that were in accordance with ILO:

a) The facility has a NOC (non-objection certificate) allowing it to handle hazardous waste and is registered with the EPA. After EPA has inspected the location, the NOC is renewed, if necessary.
b) According to the regulations for handling hazardous substances, none of the workers were under 18 or older than 60.
c) The facility's waste management practices were designed to prevent the mixing of hazardous and non-hazardous waste and to minimize environmental effect, which is a necessity for hazardous substances.
d) All packaging and labeling standards were correctly met.
e) Clear warning signs and safety instructions were displayed.
f) Neither eating nor drinking was permitted inside the hall.
g) Every criterion for the hall's conditions was met, including those for a functional ventilation system, well-maintained electrical equipment, and smooth, crack-free floors, among others.
h) A competent supervisor was on hand to assist with staff training.

5.2 Recommendations:

The facility must implement a risk control strategy that can be done in one of three methods while keeping in mind the current occupational hazards and risks:

a) Reduce the likelihood of hazard
b) Reduce the severity of hazard
c) Reduce the likelihood and severity both.

Before developing a management strategy, it is important to keep in mind the risk control hierarchy, which is essentially a list of choices for managing risks. (IOSH- Managing Safely.Pdf, n.d.)

Figure 15 Risk Control Hierarchy (IOSH- Managing Safely.Pdf, n.d.)

The best option to control risk is to eliminate the hazard creating the risk in the first place. For example, in the case of the incinerator, waste segregation can be done in open areas to prevent hazards related to working in confined spaces. If eliminating a hazard is not possible, then the reduction is the second-best option, such as the load. At the same time, 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. 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 instructions and rules to operate dangerous machinery or work in a dangerous workplace.

This type of risk control is dependent on personal human behavior and people must work in the right manner to control risks. For this purpose, the personnel's training is very important to prevent skill-based or decision-making errors because sometimes the resulting action is not intended. Lastly, is the personal protective equipment's that ate 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 that must be kept in mind before applying a risk control strategy is that the risk level 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: (Guide, 2013)

List of Hazards	Associated Risks	Control Measures/Mitigation Measures
Struck by object/slips and trips	Body injury	• Inspect tools and equipment. • Cover sharp ends
Noise	Hearing loss	• All on-site staff must wear the necessary personal protection equipment (PPE) in places with excessive noise levels that will be prominently designated. • On sources of noise, proper engineering control shall be used.

		• The condition of any used automobiles and other potentially noisy equipment will be checked. Through routine maintenance, noise from automobiles and other types of machinery will be reduced to a minimum.
Energy hazard	Electrical shock, Exposure to hot steam or fire	• Earthing of all electrical equipment's exposed conductive components during installation and creation of an equipotential bonding network. • Apparatus for covering the face. • The project's machinery, vehicles, and generators will all be tuned.
Chemical or toxic substance contact	Skin diseases	• Reduce contact with the chemicals by donning gloves, a mask, or other safety gear. After utilizing chemicals, always wash your hands with soap and warm water. Look into alternatives.
Slip or trip hazard	Fractures, injuries	• Staff must ensure good housekeeping standards. • Floor must be kept dry at all times and must be properly textured to avoid slips. • Spillages must be clean immediately.
Gas inhalation	Respiratory disease	• If necessary, put on the appropriate personal protective equipment to protect against skin, eye, or respiratory exposure to contaminated surfaces or tools. Understand the symptoms of poisoning and how to give first aid. • They will have maintenance so that they cannot be allowed to release any exhaust gases. • Within the workplace, smoking should not permit. • By using filter systems or catalytic converters, exhaust emissions will be greatly reduced. • In order to regulate the air pollutants from the incinerator, air scrubbers will be appropriately maintained. • To guarantee compliance with the PEQS criteria, routine monitoring of ambient air parameters, including PM 10, SO2, CO, and NOx emissions, should be carried out.
Fall from heights	Fracture, MSD’s	• Minimum load must be placed on the heightened area. (Not more than 23kgs) • The workers must be trained to check the cage regularly before use. (weekly)

Table 23 Recommendations for Risk Management at the Site (LWMC, 2018)

5.3 Conclusion:

After an investigation, it was determined that the workers at the incinerator site could perform their duties safely, and all environmental factors are properly controlled. The hospital has also taken necessary measures to minimize its environmental impact.

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.

5.4 LIMITATIONS:

The local community's risk perception must also be considered when assessing the hazards connected with MWIs because they are also indirectly affected by waste incineration. This further brings the limitation of a small sample size for the human health survey. The environmental and health risk assessment was done for the workers who work in that area and are most at risk of being harmed, as this study was only conducted in the immediate neighborhood of the incineration plant. The study did not focus on the area around the incineration plant, which can be addressed in related studies done in the future. The survey questionnaire was filled by interviewing people, and conflict over biased Views and personal issues can be an issue in the study.

6 References

Ahmed, F., Hasan, S., Rana, M., & Sharmin, N. (2023). A conceptual framework for zero waste management in Bangladesh. *International Journal of Environmental Science and Technology*, *20*(2), 1887–1904.

Arshad, N., Nayyar, S., Amin, F., & Mahmood, K. T. (2011). Hospital waste disposal: A review article. *Journal of Pharmaceutical Sciences and Research*, *3*(8), 1412.

Arub, S., Ahmad, S. R., Ashraf, S., Majid, Z., Rahat, S., & Paracha, R. I. (2020). Assessment of waste generation rate in teaching hospitals of metropolitan city of Pakistan. *Civil Engineering Journal*, *6*(9), 1809–1821.

Basak, S. R., Mita, A. F., Ekra, N. J., & Alam, M. J. B. (2019). A study on hospital waste management of Sylhet city in Bangladesh. *International Journal of Engineering Applied Sciences and Technology*, *4*, 36–40.

Batterman, S. (2004). Assessment of small-scale incinerators for health care waste. *Environmental Health Sciences, University of Michigan*.

Bokhoree, C., Beeharry, Y., Makoondlall-Chadee, T., Doobah, T., & Soomary, N. (2014). Assessment of environmental and health risks associated with the management of medical waste in Mauritius. *APCBEE Procedia*, *9*, 36–41.

Bolan, S., Padhye, L. P., Kumar, M., Antoniadis, V., Sridharan, S., Tang, Y., Singh, N., Hewawasam, C., Vithanage, M., & Singh, L. (2023). Review on distribution, fate, and management of potentially toxic elements in incinerated medical wastes. *Environmental Pollution*, 121080.

Çelik, S., Peker, İ., Gök-Kısa, A. C., & Büyüközkan, G. (2023). Multi-criteria evaluation of medical waste management process under intuitionistic fuzzy environment: A case study on hospitals in Turkey. *Socio-Economic Planning Sciences*, *86*, 101499.

Chu, Y. T., Zhou, J., Ren, J., Shen, W., & He, C. (2023). Conversion of medical waste into value-added products using a novel integrated system with tail gas treatment: Process design, optimization, and thermodynamic analysis. *Journal of Hazardous Materials*, *455*, 131551.

Cobo, S., Dominguez-Ramos, A., & Irabien, A. (2018). From linear to circular integrated waste management systems: A review of methodological approaches. *Resources, Conservation and Recycling*, *135*, 279–295.

de Titto, E., & Savino, A. (2019). Environmental and health risks related to waste incineration. *Waste Management & Research*, *37*(10), 976–986.

Dewantara, F., Egidius, E., & Amarilies, H. (2022). *Implementation of Risk Management Based on ISO 31000 as a Risk Prevention Strategy for Diesel Fuel Receiving and Distribution Facilities*. Proceedings of the 1st International Conference on Contemporary Risk Studies, ICONIC-RS 2022, 31 March-1 April 2022, South Jakarta, DKI Jakarta, Indonesia.

Domingo, J., Granero, S., & Schuhmacher, M. (2001). Congener profiles of PCDD/Fs in soil and vegetation samples collected near to a municipal waste incinerator. *Chemosphere*, *43*(4–7), 517–524.

Ferraz, M. A., Cardoso, J. B., & Pontes, S. R. (2000). Concentration of atmospheric pollutants in the gaseous emissions of medical waste incinerators. *Journal of the Air & Waste Management Association*, *50*(1), 131–136.

Ghali, H., Cheikh, A. B., Bhiri, S., Bouzgarrou, L., Rejeb, M. B., Gargouri, I., & Latiri, H. S. (2023). Health and Environmental Impact of Hospital Wastes: Systematic Review. *Dubai Medical Journal*, *6*(2), 67–80.

Giahi, O., Sarabi, M., Khoubi, J., & Darvishi, E. (2014). The effect of ergonomic intervention in reducing musculoskeletal disorders by Snook table method in a steel industry. *Journal of Advances in Environmental Health Research*, *2*(2), 65–71.

Hirani, D. P., Villaitramani, K. R., & Kumbhar, S. J. (2014). Biomedical waste: An introduction to its management. *International Journal of Innovative Research in Advanced Engineering (IJIRAE)*, *1*(8), 82–87.

Honest, A., Manyele, S., Saria, J., & Mbuna, J. (2020). Assessment of air pollutant emissions from healthcare waste incinerators of different design features. *African Journal of Environmental Science and Technology*, *14*(10), 311–328.

Hussain, A., Draz, U., Ali, T., Tariq, S., Irfan, M., Glowacz, A., Antonino Daviu, J. A., Yasin, S., & Rahman, S. (2020). Waste management and prediction of air pollutants using IoT and machine learning approach. *Energies*, *13*(15), 3930.

IOSH- Managing Safely.pdf. (n.d.).

Jiang, W., Peng, Y., Tang, M., Xiong, S., Chen, K., Lu, S., & Wang, F. (2023). PCDD/Fs emissions in a large-scale hazardous waste incinerator under different operation conditions: Effective reduction strategies and an applicable correlation. *Journal of the Energy Institute*, *107*, 101186.

Jiang, X., Li, Y., & Yan, J. (2019). Hazardous waste incineration in a rotary kiln: A review. *Waste Disposal & Sustainable Energy*, *1*, 3–37.

Kampa, M., & Castanas, E. (2008). Human health effects of air pollution. *Environmental Pollution*, *151*(2), 362–367.

Khan, S., Cao, Q., Zheng, Y., Huang, Y., & Zhu, Y. (2008). Health risks of heavy metals in contaminated soils and food crops irrigated with wastewater in Beijing, China. *Environmental Pollution*, *152*(3), 686–692.

Kumar, V., Saikumar, G., Jana, C., Kumar, P., & Kumar, S. B. D. V. (2023). *Biomedical waste management for risk pathogens*.

Liu, F., Liu, H.-Q., Wei, G.-X., Zhang, R., Zeng, T.-T., Liu, G.-S., & Zhou, J.-H. (2018). Characteristics and treatment methods of medical waste incinerator fly ash: A review. *Processes*, *6*(10), 173.

LWMC, L. (2018). *EIA report Report of rehabilitaion and operation of incinerator installed at children's hospital.* LWMC.

Mazzei, H. G., & Specchia, S. (2023). Latest insights on technologies for the treatment of solid medical waste: A review. *Journal of Environmental Chemical Engineering*, 109309.

Mohamed, N. H., Khan, S., & Jagtap, S. (2023). Modernizing Medical Waste Management: Unleashing the Power of the Internet

of Things (IoT). *Sustainability*, *15*(13), 9909.

Muchuweti, M., Birkett, J., Chinyanga, E., Zvauya, R., Scrimshaw, M. D., & Lester, J. (2006). Heavy metal content of vegetables irrigated with mixtures of wastewater and sewage sludge in Zimbabwe: Implications for human health. *Agriculture, Ecosystems & Environment*, *112*(1), 41–48.

Nidoni, P. G. (2017). *INCINERATION PROCESS FOR SOLID WASTE MANAGEMENT AND EFFECTIVE UTILIZATION OF BY PRODUCTS*. *04*(12), 5.

Patwary, M. A., O'Hare, W. T., Street, G., Elahi, K. M., Hossain, S. S., & Sarker, M. H. (2009). Quantitative assessment of medical waste generation in the capital city of Bangladesh. *Waste Management*, *29*(8), 2392–2397.

Peng, Y., Ma, Y., Lin, X., Long, J., & Li, X. (2023). Emission control and phase migration of PCDD/Fs in a rotary kiln incinerator: Hazardous vs medical waste incineration. *Waste Disposal & Sustainable Energy*, 1–12.

Rana, A., Sharma, N., & Hasan, I. (2023). *A review on hospital waste as a potential environmental pollution and their remediation mechanisms*. *2535*(1).

Riese 2nd, D., Settleman, J., Neary, K., & DiMaio, D. (1990). Bovine papillomavirus E2 repressor mutant displays a high-copy-number phenotype and enhanced transforming activity. *Journal of Virology*, *64*(2), 944.

Rutala, W. A., & Weber, D. J. (2015). Disinfection, sterilization, and control of hospital waste. *Mandell, Douglas, and Bennett's Principles and Practice of Infectious Diseases*, 3294.

Selberg, N. (2020). The ILO response to Covid-19: ILO and international labour standards in times of a pandemic. *Italian Labour Law E-Journal*, *13*(1), 161–185.

Shareefdeen, Z. M. (2012). Medical waste management and control. *Journal of Environmental Protection*, *3*(12), 1625.

Shinde, P., & Shejwal, N. (n.d.). A Literature Review on Medical Waste Management. *TECH TONICS*, 8.

Sobia, M., Syeda, A. B., & Muhammad, N. C. (2014). Characterization of hospital waste in Lahore, Pakistan. *Chinese Medical Journal*, *127*(09), 1732–1736.

Solorzano, A. D. B., Wu, M. J. M., & Larios-Francia, R. P. (n.d.). *Environmental Impact of Medical Waste Treatment*.

Somani, M., Srivastava, A. N., Gummadivalli, S. K., & Sharma, A. (2020). Indirect implications of COVID-19 towards sustainable environment: An investigation in Indian context. *Bioresource Technology Reports*, *11*, 100491.

Sorin, S., Toth, L., Călămar, A., Pupăzan, D., & Irimia, A. (2016). SAFETY AND HEALTH AT WORK CONCERNING OCCUPATIONAL EXPOSURE TO NOISE IN STEEL INDUSTRY WORKERS. *International Multidisciplinary Scientific GeoConference: SGEM*, *2*, 547–554.

Tait, P. W., Brew, J., Che, A., Costanzo, A., Danyluk, A., Davis, M., Khalaf, A., McMahon, K., Watson, A., & Rowcliff, K. (2020). The health impacts of waste incineration: A systematic review. *Australian and New Zealand Journal of Public Health*, *44*(1), 40–48.

Teymourian, T., Teymoorian, T., Kowsari, E., & Ramakrishna, S. (2021). Challenges, strategies, and recommendations for the huge surge in plastic and medical waste during the global COVID-19 pandemic with circular economy approach. *Materials Circular Economy*, *3*, 1–14.

Wang, L., & Wang, H. (2022). An integrated qualitative group decision-making method for assessing health-care waste treatment technologies based on linguistic terms with weakened hedges. *Applied Soft Computing*, *117*, 108435.

Waters. (2021). *Waters et al, 2021*.

Wei, Y., Cui, M., Ye, Z., & Guo, Q. (2021). Environmental challenges from the increasing medical waste since SARS outbreak. *Journal of Cleaner Production*, *291*, 125246.

World Health Organization. (2018). *WHO recommendations on intrapartum care for a positive childbirth experience*. World Health Organization.

Xie, R., Li, W., Li, J., Wu, B., & Yi, J. (2009). Emissions investigation for a novel medical waste incinerator. *Journal of Hazardous Materials*, *166*(1), 365–371.

Yasin, A. N. (2023). *Bio-Medical Waste Management–A Short Review*.

Yoon, C.-W., Kim, M.-J., Park, Y.-S., Jeon, T.-W., & Lee, M.-Y. (2022). A review of medical waste management systems in the Republic of Korea for hospital and medical waste generated from the COVID-19 pandemic. *Sustainability*, *14*(6), 3678.

ANNEXURE I

OSHA Questionnaire

DEMOGRAPHIC PROFILE

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

In which unit of the workplace do you work?

- Administration unit
- Manufacturing Unit
- Furnaces
- Burner man
- Surry man
- Vehicle loading and unloading

Working hours per day?

- 6-8
- 8-10
- 10-12
- 12-14

PERSONAL HEALTH STATUS

Are you currently suffering from any of the following chronic diseases?

- Epilepsy
- Arthritis
- Asthma.
- Cancer.
- Cystic fibrosis.
- Heart disease
- Any other
- None

Do you smoke?

- Yes
- No

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

Symptoms	**Never**	**Occasionally**	**Frequently**
Headache			
Respiratory Problem			
Visual Disruption			
Hearing Problem			
Stiffness			
Heat Stress			
Skin Allergy			
Burn			
Dizziness			

Have you ever had to operate with a sharp object?

- Yes
- No

Is whole-body vibration one of your workplace issues?

- Yes
- No

Does the job require heavy weight lifting?

- Yes
- No

Does the job require working at height?

- Yes
- No

Do you face thermally harsh conditions?

- Yes
- No

Is the job required to work in a confined space?

- Yes
- No

Have you ever had any of the following ergonomic issues at work?

Ergonomic problems	**Yes**	**No**
▪ Problems of the body posture?		
• Excessive muscular stretching?		
▪ Repetitive movement?		
▪ Bending, straining, and a bloated posture?		

Have you ever had any of the following accidents at the workplace?

Accidents	**Yes/No**
Fall from height	
Tripping over stairs	
Slips and trips	
Struck by an object	
Physical injuries (cuts, rashes, burns, etc.)	
Electric shock	
fire	
Equipment related accident	
Others (specify):	

OHS MEASURES AND AWARENESS

Do you know the contents of the OHS policy?

- Yes
- No

Do you have any hazardous/warning signs at your place of work?

- Yes
- No

Are the warning/hazard signs positioned at a sufficient distance?

- Yes
- No

What is the language used for these signs?

- English
- Urdu
- Both

Is the industry equipped with First Aid Boxes?

- Yes
- No

Are staff aware of the protocols to follow in the event of an emergency? (For example, first-aid training, firefighting training, and so on)

- Yes
- No

Are you familiar with the term "personal protection equipment" (PPE)?

- Yes
- No

Do you use the available PPE?

- Yes
- No

Do you use hearing protection if needed (noise level above 80 decibels)?

- Yes
- No

CONTROL MEASURES

Are these control measure facilities available at the enterprise?

Control measure/facility	**Yes**	**No**	**Don't know**
Regular environment monitoring			
First aid facilities			
Emergency treatment of workers			
Firefighting facilities			
Transportation in case of any emergency			
Warning signs (Urdu and English)			

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

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

Is the incineration required temperatures properly met?

- Yes
- No

DISPOSAL PRACTICES

Does the worker remove 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

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? (Validity and renewal)	• Yes • 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	**General safety precautions** 1. Proper PPEs 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. Eating, drinking and smoking not permitted in vicinity	
8	**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.	

ANNEXURE 3