# STUDY

# OF

# BIOMEDICAL WASTE GENERATION AND MANAGEMENT

# FOR

# PUBLIC AND PRIVATE SECTOR HOSPITALS

## A Thesis

***Submitted in partial fulfillment of the requirements for the award of the degree of***

**MASTER OF TECHNOLOGY**

**IN**

**CIVIL ENGINEERING**

With specialization in

**ENVIRONMENTAL ENGINEERING**

Under the supervision of

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**JAYPEE UNIVERSITY OF INFORMATION TECHNOLOGY**
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# CERTIFICATE

This is to certify that the work which is being presented in the thesis entitled **"STUDY OF BIOMEDICAL WASTE GENERATION AND MANAGEMENT OF PUBLIC AND PRIVATE SECTOR HOSPITALS"** in the partial fulfillment of the requirements for the award of the degree of Master Of Technology in Civil Engineering with specialization in **"Environmental Engineering"** and submitted in the Department of Civil Engineering, Jaypee University of Information Technology, Waknaghat, India, is an authentic record of work carried out by **Prachi Vasistha** during a period from July 2015 to June 2016 under the supervision of **Dr. Rajiv Ganguly**, Associate Professor, Department of Civil Engineering, Jaypee University of Information Technology and **Dr. Ashok Kumar Gupta**, Professor and Head, Department of Civil Engineering, Jaypee University of Information Technology.

The above statement made is correct to best of our knowledge.

Date: 6 June, 2016

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PRACHI VASISTHA

# ABSTRACT

Waste generated during diagnosis, treatment or immunization of human being or animals is called as 'Biomedical Waste'. In healthcare settings, management of healthcare waste is integral part of infection control and hygiene programs. These settings are a major contributor to community-acquired infection, as they produce large amounts of biomedical waste. Biomedical waste management is the word used for complete scenario comprising of segregation, collection, transportation and finally the disposal of the waste. The Bio Medical Waste Management is a typical process which requires a crucial examination at every point so that the waste is properly disposed off and thereby does not pose a threat to the environment. Biomedical waste can be categorized based on the risk of causing injury and/or infection during handling and disposal. Wastes that require precautions during handling and disposal include sharps (needles or scalpel blades), pathological wastes (anatomical body parts, microbiology cultures and blood samples) and infectious wastes (items contaminated with body fluids and discharges such as dressing, catheters and I.V. lines)

Other wastes which are generated in healthcare settings include radioactive wastes, mercury containing instruments and polyvinyl chloride (PVC) plastics. The management of bio-medical waste is still developing all over the world. There is a lack of appropriate knowledge among the generators, operators, decision-makers and the general community about the safe management of bio-medical waste.

In 1980's in United States a huge chaos was raised by people about hospital waste hovering around and children playing around thus the management of biomedical waste became an issue of concern. The US Medical Waste – Tracking act of 1988 was enacted and enforced on November 1, 1988. A huge outburst against various agencies by public was observed to put pressure on Government of India to enact appropriate laws in country against various practices of disposal of biomedical waste. The Ministry of Environment and Forest of Government of India has enacted Biomedical Waste (Management and Handling) rules which became effective from 20 July 1998, the rules have six schedules which ensure proper management of biomedical waste in the country.

The main reasons for carrying out the study was that the field of BMWM has been explored a lot less as compared to the other fields due to ignorance and confusion about the wastes and the hazardous effects they can produce also the PHA has been performed a lot for the other fields involving risk but has been limited in field of BMW also the quantification technique that has been carried has been a topic of risk analysis in other fields but not in the field of medical waste. The incinerator design has been done so that there is a decrease in the volume of waste and there is a reduction in the quantity of waste to be handled and thereby to ensure safe disposal of the waste produced in the hospital complexes and thereby a complete assurance of environmental safety.

The methodology included Questionnaires to be discussed and filled by the doctors and the nurses in charge at the hospitals and involved in any way in the management and disposal of the bio medical waste. The Questionnaire-1 which contained questions on complete management strategy followed at the hospitals were asked to the persons handling the waste and the results were theoretically composed and compared with the BMWM & handling rules

1998 issued by Government of India. The Questinaire-2 was to be filled by the doctors and the nurses involved in handling and management of BMW and the results were analyzed in a matrix format and quantified for PHA Analysis. The incinerator was designed for the hospitals based on the guidelines and the necessary assumptions were utilized for the design of incinerators.

With this regard the thesis include a complete summary of the BMWM of hospitals in the capital of the state and the neighboring areas within a 100 km radius. The study areas included two hospitals in capital of the state of Himachal Pradesh i.e. the Shimla city, one being a large public sector hospital IGMC Shimla and other being a small but renowned private sector hospital INDUS hospital. The other hospitals considered for study purpose are in the Chandigarh region and includes firstly, MAX Super Specialty hospital, Mohali, which is private Multi specialty hospital providing a large number of treatments in various fields, Secondly, IVY hospital, Mohali, which is also a Private sector hospital and provides health benefits and expert advice in a large no. of medical fields. The third and final hospital is Government Medical College and Hospital in Sector -32 of Chandigarh which is a large government undertaking medical college and hospital.

The management was compared with the BMWM and handling rules as described in Gazette of India and a complete description and analysis was carried out in all the five hospitals undertaken for study purpose according to their will to share the information. The study also includes a Preliminary Hazard Analysis (PHA) of all the hospitals to identify the possible hazards, to rank the matrix involving main categories of waste according to the severity and likelihood in a numerical format, to quantify the calculations and thus rank the wastes involved finally as the most hazardous component and the least hazardous one to compare the results thus obtained further an incinerator design was proposed based on the study of the hospitals that included a primary and a secondary combustion chamber to reduce the quantity of the waste to about 10% of the original and thus render a safe final disposal of the waste. A comparative study has been carried out within the hospitals wether it is in terms of the management of the hospital or PHA Analysis. The results have been included in a quantified format in form of excel sheets and word documents attached in Appendices.

# CONTENTS

# LIST OF ACRONYMS AND ABBREVIATIONS

| | |
|---|---|
| *BMW* | *Bio Medical Waste* |
| *BMWM* | *Bio Medical Waste Management* |
| *BMWM & H* | *Bio Medical Waste Management and Handling* |
| *Cat.* | *Category* |
| *ENT* | *Eyes Nose Throat* |
| *GMCH* | *Government Medical College and Hospital* |
| *GOI* | *Government of India* |
| *HCL* | *Hydrochloric Acid* |
| *ICU* | *Intensive Care Unit* |
| *INCLEN* | *International Clinical Epidemiology Network* |
| *IPD* | *In Patient Department* |
| *LEED* | *Leadership in Energy and Environmental Design* |
| *NABH* | *National Accreditation Board for Hospitals and Healthcare Providers* |
| *NABL* | *National Accreditation Board for Testing and Calibration Laboratories* |
| *OPD* | *Out Patient Department* |
| *OT* | *Operation Theatre* |
| *PCC* | *Primary Combustion Chamber* |
| *PHA* | *Preliminary Hazard Analysis* |
| *PRA* | *Preliminary Risk Analysis* |
| *RHWC* | *Risky Health Care Waste* |
| *RI* | *Risk Index* |
| *RPN* | *Risk Priority Number* |
| *US* | *United States* |

# LIST OF SYMBOLS

| | |
|---|---|
| A | Anatomical Waste |
| I | Infectious Waste |
| P | Pharmaceutical and Chemical Waste |
| S | Sharps |
| °C | Degree Celsius |
| kj/h | Kilo Joule per Hour |
| kg/d | Kilo gram per day |
| kg/month | Kilo gram per month |
| m | Meter |
| $m^2$ | Square meter |
| $m^3$ | Cubic meter |
| L | Length |
| B | Breadth |
| H | Height |
| $H_2O$ | Water |
| $O_2$ | Oxygen |
| $CO_2$ | Carbon Dioxide |
| HCl | Hydro Chloric Acid |
| Qi | Total Heat in from Waste |
| m | Weight of ash |
| Cp | Mean heat capacity of ash |
| dT | Temperature difference |
| Hv | Latent heat of vaporizations of water |
| Qo | Total Heat Out |
| dp | Flow rate of dry products |
| Vm | Volumetric flow rate of moisture |
| Vp | Volumetric flow rate of dry products |
| K | Kelvin |

# LIST OF FIGURES

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# CHAPTER 1
# INTRODUCTION

The chapter includes a detailed description of the relevant information and background details about the Bio-medical waste and its handling and management. It also includes the objectives of the study undertaken, the need of the project, the novelty of the study, limitations of project, outline of the research methodology, and outline of the thesis.

## 1.1 Background and Introduction

Due to rapid advancement in the production and consumption processes, society generate as well as reject solid materials on daily basis from various sectors such as agricultural, commercial, domestic, industrial and institutional. The considerable volume of wastes thus produced and discarded is called solid wastes. Industrial waste, municipal solid waste, agricultural waste etc. are harmful and may pollute the surrounding air, water and soil but their treatment and disposal are less harmful as compared to the effects produced from treatment and disposal of biomedical waste due to production of toxic effluents from the burning of biomedical waste (Levandis et al., 2006); (Soliman & Ahmed,2007). Hospital waste is highly deadly in association to the other wastes. Though, 75-90% of waste produced by health care institutes is non- toxic being generated from administration unit and housekeeping cells, the remaining 10-25% of waste is regarded as 'hazardous' and may create variety of health risks (Srivastav et al., 2012).

Advancement in health care facilities around the globe has led to serious improvement of biomedical waste management in developed countries, however despite strict regulations in Indian context the paradox of the situation is that the healthcare amenities which are foundations for preservation and restoration of public health have caused a huge health risk due to improper management of waste by people in charge and have posed a huge threat to environment. Globally categorized as a serious issue it demands appropriate and necessary steps of management and disposal worldwide. The waste disposal is though associated with government agencies but regulations have to be abided by private healthcare organizations too (Radha et al., 2009).

Earlier, the *BMWM* was the problem of the municipality and the authority would dispose of the waste in the same way as the municipal solid waste was disposed off either by landfill or

by open burning but soon it was realized that the bio-medical waste was hazardous in nature and could not be disposed off as such and demanded a special categorization and special attention for its disposal purpose In 1980's in United States a huge chaos was raised by people about hospital waste hovering around and children playing around thus the management of biomedical waste became an issue of concern. The US Medical Waste – Tracking act of 1988 was enacted and enforced on November 1, 1988 (Dayananda, 2004). A huge outburst against various agencies by public was observed to put pressure on Government of India to enact appropriate laws in country against various practices of disposal of biomedical waste. The infectious diseases such as HIV, Hepatitis (all kinds) and tetanus all are very common in people associated with handling of biomedical waste. In order to prevent such deadly infections and to protect the environment, The Ministry of Environment And Forest formulated and notified biomedical waste (management and handling) rules in 1998 that issues guidelines to all institutes producing Bio- medical waste to ensure safety and soundness in management of waste produced by them (Da Silva et al., 2005).

The rules have six schedules**.** Schedule 1 classifies the biomedical waste into ten categories. (The Gazette Of India, 1998).Schedule 2, describes the color coding scheme and types of containers to be used for collection and storage of biomedical waste. Schedule 3 and 4, recommends that containers should be appropriately labeled with biohazard or cytotoxic symbol to avoid risk. The schedule details have been explained in the detailed in table 1.1 as follows.

**Table 1.1:** Schedule of Biomedical Waste**.**

| | |
|---|---|
| Schedule 1 | Classification of Biomedical waste into different categories. |
| Schedule 2 | Color coding and type of containers for each category of Biomedical Waste. |
| Schedule 3 | Performa of label to be used on container/bag. |
| Schedule 4 | Performa of label for transport of waste container or bag. |
| Schedule 5 | Standards for treatment and disposal of waste. |
| Schedule 6 | Deadlines for creation of waste treatment facility. |

Under schedule 1, the biomedical waste has been classified into ten categories as displayed in Table 1.2 with treatment and disposal options for each category respectively prescribed in schedule 5 (The Gazette Of India,1998).

**Table 1.2:** Categories of Biomedical Waste and methods of their treatment and disposal. [The Gazette of India (1998)]

| Category | Type of Waste | Treatment and Disposal |
|---|---|---|
| 1. | *Anatomical Waste*: human tissues, organs, body parts. | Incineration [a]/ deep burial |
| 2. | *Animal Waste*: tissues, organs, body parts, carcasses, fluid, blood; experimental animals used in investigation, waste generated by veterinary clinics. | Incineration [a]/deep burial |
| 3 | *Microbiology and Biotechnology waste:* wastes from labs, cultures, stocks and specimens of microorganisms, live or attenuated vaccines, cell cultures used in research , contagious agents from research and industrial laboratories, waste from production of biological, toxins, dishes, and instruments used to transfer cultures. | Autoclave/microwave/ Incineration [a] |
| 4 | *Waste sharps:* needles, sharps, scalpel, blades, syringes, glass etc capable of causing puncture and cuts; this contains both used and unused sharps. | Disinfection (chemical treatment)[c], autoclaving microwaving and mutilation/shredding [d] |
| 5 | *Discarded medicines and cytotoxic drugs:* waste consisting outdated infected and discarded drugs and medicines. | Incineration [a]/destruction and drugs disposal in secured landfill |

| | | |
|---|---|---|
| 6 | *Contaminated solid waste:* items infected with blood fluids including cotton dressing, soiled plaster casts, linens. | Incineration [a]/autoclaving/ Microwaving |
| 7 | *Solid waste:* Disposable items other than waste sharps such as tubings, catheters etc. | Disinfection by chemical treatment [c] autoclaving/microwaving and mutilation/shredding[b] |
| 8 | *Liquid waste:* waste generated from labs, washing, cleaning, housekeeping and disinfection activities | Disinfection by chemical treatment[c] and discharge into drains |
| 9 | *Incineration ash:* ash from incinerators for medical waste | Disposal in municipal landfill |
| 10 | *Chemical waste:* chemicals used in production of biological, disinfection etc. | Chemical treatment[c] and discharge into drains for liquid and secured landfill for solids |

[a] There will be no chemical treatment before incineration. Chlorinated plastic shall not be incinerated.

[b] Deep burial can be an option available only in towns with population less than five lakhs and in rural areas.

[c] Chemical treatment using 1% hypochlorite solution or any other equivalent chemical reagent. It must make sure that chemical treatment ensures disinfection.

[d] Mutilation/shredding must be such as to prevent unauthorized reuse.

The Table 1.3 describes the color coding scheme and types of containers to be used for collection and storage of biomedical waste.

**Table 1.3:** Color coding and type of container for biomedical Waste disposal. [The Gazette of India (1998)]

| Color Coding | Type of container and waste category |
|---|---|
| Yellow | Plastic bag<br>*Cat.*1, *Cat.* 2, *Cat.* 3, *Cat.* 6 |
| Red | Disinfected container or plastic bag<br>*Cat.* 3, *Cat.* 6, *Cat.* 7. |
| Blue or white | Plastic bag/ puncture proof *Cat.* 4, *Cat.* 7 |
| Black | Plastic bag<br>*Cat.* 5, *Cat.* 9, *Cat.* 10 (solid) |

Under schedule 3 and 4, it has been prescribed that containers should be appropriately labeled with biohazard or cytotoxic symbol as shown in Figure 1.1 to avoid any risk. In case of transportation of waste offsite, suitable measures should be taken to make containers leak proof to avoid any spillage. [The Gazette of India (1998)]

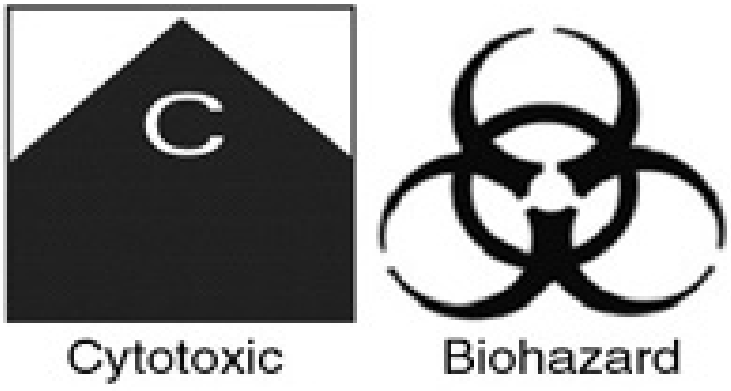


**Figure 1.1:** Biohazard and Cytotoxic Symbol. [www.cpreec.org/pubbook-biomedical.htm**]**

Schedule 6 makes it mandatory for all the hospitals, polyclinics, nursing homes and veterinary institutes, animal house & slaughter house to establish suitable waste managing amenities in the premises.

Before the enactment of Biomedical Waste (management and handling) , it was responsibility of the municipal or government authority to handle all types of waste properly and effectively

but now it has become essential for all health care establishments to manage their waste according to the rules imposed by government ( Patil and Pokhrel, 2005).

Incineration is the most common method used for biomedical waste management and is most suitable for combustible materials but some material cannot be disposed by incineration like body parts and urine bags thus needing other methods for the treatment and incineration. Waste volume is reduced by 10 % of original and also the waste gets decontaminated in incineration process (Ferreira and Veiga, 2003) but ultimately it is the responsibility of the waste generator to take measures to dispose waste safely so that there is no adverse effect on environment. The installation of incinerator in hospitals with more than 50 beds is mandatory under section 15(1) of the Environmental Protection Act, 1996 according to which whoever fails to abide by the orders issued by the government will be punished by "imprisonment for term extending up to 5 years or 1,00,000 Rupees cash , or both and an additional fine may be imposed which could be extended up to 5000 Rupees per day if there is delay or continuance of the negligence after conviction for first such failure or contravention(Yadav,2001).

The topic of *BMWM* has been limited to the southern parts of the country and lot less study has been conducted in the northern region of the country in the state similarly for the *PHA*, a large amount of literature is available in the other fields involving risk analysis but a very limited work is available about *PHA* applied to the *BM* field and almost none is available on quantification of results of *PHA* in the risk involved in *BMWM* field.

The study would reveal the management strategies followed in the entire hospitals wether it be a government hospital or a private sector enterprise. The results have been analyzed thoroughly in accordance with the rules and guidelines issued by the Government of India, also a comparison have been made between them to bring the best management sector. The *PHA* analysis was carried out and the results were quantified to calculate the risk involved with various categories of waste in these hospitals so that care can be taken at all the levels to avoid unnecessary hazards and accidental events.

The study is expected to reveal the best management procedures as well as describe the necessary flaws in the management at all the hospitals enabling the hospitals to remove the necessary cons in the management procedures and ensure that the management is carried to its best possible manner and in accordance with the guidelines being issued by the Government for efficient disposal practices. The *PHA* analysis ensures that all the risk has been accurately identified and calculatively summed up to avoid any unwanted hazardous events in the

hospital premises. It also enables the administration to frame necessary guidelines and follow up actions to be taken in case of emergency or any mishap.

## 1.2 Need of the Project

1.2.1 Past studies have shown research carried out in other parts of the country but very less study has been conducted in northern part of country and almost none in Himachal.

1.2.2 As per the *G.O.I* rules both Public and Private sector hospitals have to follow. legislations for handling B.M waste so a comparative study can been carried out.

1.2.3 The people are unaware of the occupational hazards associated with handling of *B.M* waste and risk potential caused by the inappropriate disposal of biomedical waste.

1.2.4 The hospitals lack necessary risk analysis procedures to determine the risk causing elements and thus follow appropriate risk management and follow up actions during state of emergency.

1.2.5 There is also a lack of proper design and infrastructure of incinerators at the hospital. complexes so an appropriate incinerator design has been proposed which ensures a reduction in the volume of waste and thus its necessary disinfection due to exposure to high heat.

## 1.3 Objective of Research

1.3.1 Biomedical waste management in major hospitals in Shimla city.

a) A very limited literature is available on practices of biomedical waste in Shimla.

b) The waste management of hazardous waste is a sensitive topic and thus requires careful analysis.

c) The biomedical waste management is required to ensure safe and environmentally sound management of waste produced.

d) Improper waste management may lead to microbial ecology change and spread of antibiotic resistance.

1.3.2 Comparison of the two large scale Public Sector and Private sector hospitals.

a) There has never been any comparison between the waste management techniques being followed by a public and private sector hospital.

b) The study describes the difference in techniques of waste management and reveals which sector follows better management techniques.

1.3.3 Risk Assessment according to Preliminary Hazard Analysis (PHA).

a) It reduces the chances of mishap such as fire or loss of life and property due to accidental events, classified according to their severity and ranked.

b) It identifies required hazard control and follow-up actions that may be required for reducing or eliminating a hazard.

1.3.4. Design of an Incinerator for mass burning of bio- medical waste.

a) Incineration is the most widely used, very important and a useful method for disposal of biomedical waste.

b) The process of incineration reduces the waste volume to about 80% of the original. quantity as well as it removes all the organic content by converting it to water vapors and heat and inorganic content to ash.

## 1.4 Limitations of Study on Project Topic

1.4.1 Avery limited study has been done in northern part of country for management of Bio-medical waste and almost negligible study has been conducted on hospitals in the state.

1.4.2 The people are unaware of the hazards associated with handling of *B.M.* waste and potential risk caused by the inappropriate disposal of biomedical waste so *PHA* analysis has been carried out to reveal the potential hazards associated with the *BM* waste.

1.4.3 The quantification in *PHA* has not been formulated in the field of *BMWM* and is a new concept in the field which has been applied in the study.

## 1.5 Overview of Research Methodology

The main tasks completed to meet the objectives are:

- Review of available studies and their suitability for assessment of different hospitals.
- Selection of study sites based on the area location and willingness of the hospitals to share information.
- Developing Questionnaires for the survey to be conducted at various hospitals.
- Conducting the survey to get the results for Questionnaire-1 and Questionnaire-2 and analyzing the results graphically and statistically for Questionnaire-1 and quantatively for Questionnaire-2.
- Inter-comparison and Intra-comparison of the results obtained from the analysis of the Questionnaires.

- Design of the incinerator based on total waste produced in the hospital and necessary guidelines for incinerator design.

## 1.6 Novel Aspects of Research Work

The contributions of this research to the scientific field of air quality include the following:

1. An up-to-date research review on *BMWM* of various private and public sector hospitals in the capital of the state of Himachal Pradesh and nearby area of Chandigarh. has been completed which has never been done so far.
2. In general, qualitative methods have been applied for analysis of *PHA*, any quantification of any kind have not been used for the *PHA* analysis. Thus, this study ensures a new step in the field.

## 1.7 Layout of Thesis

The thesis is divided into nine chapters:

*Chapter one* introduces the problem considered and presents the objectives of the research. The research methodology carried out and the novel aspects of the research study are also mentioned.

*Chapter two* reviews the literature related to the various studies used for *BMWM* of the Hospitals, the *PHA* analysis study procedures and details and the mother paper for the design of incinerator. Some pertinent background details on the management being carried out in the previous years have also been described.

*Chapter three* describes the study sites i.e. Shimla and Chandigarh. The chapter also contains detailed information about all the hospitals in the regions with distinct features that makes them suitable for the study purpose.

*Chapter four* outlines the detailed methodology of the various procedures involved in the entire research work.

*Chapter five* presents the Observations obtained from the application of methodology in the study areas.

*Chapter six* deals with the Results obtained from observations and the suitable discussion of the results. It includes necessary reasons for the results obtained on application of methodology.

*Chapter seven* describes in detail the design of incinerator for the treatment and disposal of *B.M.W.*

*Chapter eight* draws the necessary conclusions from the results and observations obtained during research work.

The thesis also contains references section and appendix section which contain the necessary links of the studies being carried in the field so far and detailed information in form the tables, matrices and necessary excel sheets.

# CHAPTER 2
# LITERATURE REVIEW

## 2.1 Literature Review

Pandit et al., (2007), conducted a study at a 600 bedded teaching hospital (Sher-i-Kashmir Institute of Medical Sciences, Srinagar) to determine the quantity of waste generated and the methods of disposal. Though waste management practice in this hospital was better than other hospitals in the state, yet, all the waste management activities like collection, segregation, transportation, treatment and disposal needed to be done on scientific basis.

Gupta et al., (2008), published a paper providing a description of the rules for biomedical waste (Management and Handling) 1998, and the ongoing waste management practices in one of the established healthcare facility of Lucknow, the Vivekananda Polyclinic. The objective in undertaking this study was to analyze the waste management system, including storage, collection, transportation and disposal, and their compliance with the standards prescribed under the regulatory framework. The analysis consisted of interviews with medical authorities such as doctors, and paramedical staff involved in the management of the biomedical wastes in the Polyclinic. A general survey of the facilities of the Polyclinic was undertaken to discover the effectiveness of the implemented measures. The waste quantification was based on random samples collected from each ward. It was found that, although the Polyclinic in general works by the prescribed regulations for the treatment and disposal of biomedical waste but there is also a need to create awareness among all other stakeholders about the importance of biomedical waste management and related regulations.

Babu et al., (2009), in his study summed up the rules for management and handling of biomedical wastes, defined and categorize biomedical wastes, suggested storage containers including color-coding and treatment options, highlighted the effects of biomedical waste on the environmental components such as air, land and water etc. and disposal of wastes along with regulation and recommendations. Several survey works carried out by various research organizations have been discussed and reviewed in this paper.

Jaiswal et al., (2010), undertook a study at Jindal Institute of Medical Sciences, Hisar, with a 110 bed capacity and evaluated its compliance with Regulatory standards for Bio-medical Waste (Management and Handling) Rules, 1998, under the Environment (Protection Act

1986), Ministry of Environment and Forestry. The study of non infectious and infectious waste generated in different months was performed.

Arshad et al., (2011). Published a review paper which was prepared from the surveys of hospitals and research studies and analyzed the present situation at facility, also medical waste management system was analyzed to understand the various handling and disposal procedures, the knowledge and awareness of individuals involved in handling & disposal, and the potential impacts of the waste stream on both human health and the natural environment. The method adopted for study was literature review and survey method.

Mensudar et al., (2011), in the study a questionnaire survey was carried out to determine the awareness about biomedical waste management policy, practices and to assess the attitude towards it. The objective was to identify the major lacunas and to make recommendations in order to improve the facilities for current requirements. The data collection was done through standard set of questionnaire, which was developed after literature search and review. Thus, the result of the survey enforces the need for strict action to create a better environmental management system for the disposal of biomedical waste in all the hospitals. It should be supported through appropriate education training and the dedication of the healthcare staff, management and healthcare management with an effective policy and legislative framework.

Nema et al., (2011) undertook a study in a nearby hospital in order to get acquainted with the generation of the biomedical waste and their disposal procedures. The study included collection of details about the quantity of different types of waste generated, their treatment, final disposal and various management techniques adopted by the hospital. The methodology followed included asking various questions regarding the issue by the waste management team and the workers involved in managing the waste. This study of the nearby largest hospital of the state in terms of infrastructure and patients inflow has thrown some light on the prevailing status of the waste management strategies in this area.

Shrivastav et al., (2012) conducted a study with the objective of Assessing the current Bio-medical waste management practices such as collection, segregation, transportation, storage, treatment and disposal technologies in tertiary health care center, Assessment of health and practices for the safety of the health care personnel involved in Bio-Medical Waste Management. The methodology consisted study of waste management practices in the Government Hospital during March 2009 – May 2009.The data regarding Bio-Medical Waste Management practices and safety was collected by way of semi- structured interview.

Thirumala S., (2013) conducted a study with the objective to survey of the practice of biomedical waste management such as collection, storage, transportation and disposal along with the calculation of the amount of biomedical waste generated in various hospitals in Davangeree city and to create awareness among the staff and patient about biomedical wastes. Methods of storage and segregation at wards, department, internal transportation, external transportation and final disposal were studied for all 4 hospitals by observation. Informal discussion with various hospital functionaries were carried out. Common regional facility for final disposal of infectious waste was also studied. Wastes generated in four hospitals were weighed during a week for each hospital in three shifts for a period of one month. Interviews with the committee member of hospitals, workers, and training them all segregated wastes according to types of bio medical waste.

Rao et al., (2014), The purpose of this study was to discuss about various kinds of biomedical waste produced in the hospitals, different waste management practices, the hazards of haphazard disposal of biomedical waste and to create awareness among the medical professionals, regarding minimization of the production of biomedical waste and encouragement to follow the best management practices for disposal of hazardous wastes. The methodology of study was to survey the practice of biomedical waste such as collection, storage, transportation and disposal along with the waste generation of biomedical waste in various healthcare units in Eluru city, and create awareness among the patients and workers about biomedical wastes.

Singh et al., (2014), The objective of the study was analyzing the activities that are usually undertaken in health care waste management involving segregation, storage, collection, transportation and disposal of biomedical waste including organizational, planning, administrative, financial, engineering aspects, legal, and human resource development and their management involving interdisciplinary relationship.

Kumar et al., (2014), The objective of the study was to look at the difference in Bio- Medical Waste Management practices if any between the major public and private sector hospitals in Shimla City. The methodology includes Cross sectional study to be conducted in the major public hospitals of Shimla city. The study comprised of cross sectional survey of the personnel handling and monitoring the biomedical waste and observational survey of the hospitals using INCLEN (International Clinical Epidemiology Network) data collection tool.

S.Kucukali.,(2011) developed a fuzzy rating tool for river-type hydropower plant projects. Risk assessment was done based on expert judgments instead of probabilistic reasoning. The

methodology provided a flexible and easily understood way to analyze project risks. The external risks were considered in the model. The eleven risk factors classes were determined based on the interviews with experts, field studies and literature review followed: site geology, land use, environmental issues, grid connection, social acceptance, financial, natural hazards, political/regulatory changes, terrorism, access to infrastructure and revenue. The relative impact of risk factors was determined from the survey results. The survey was conducted for the river-type hydropower projects. The survey results revealed that the site geology and environmental issues were most risky. The new risk assessment method enabled a Risk Index (R) value to be calculated, using a 4-grade Risk evaluation system: low risk was considered having R values between 1.2 and 1.6; medium risk, between 1.6 and 2; high risk, between 2 and 2.4; extreme risk, between 2.4 and 2.8.

Liao et al., (2014), used the failure mode and effects analysis to examined biomedical waste companies through risk assessment. Moreover, it evaluated the supervisors of biomedical waste units in hospitals, and factors relating to the outsourcing risk assessment of biomedical waste in hospitals by referring to waste disposal acts. An expert questionnaire survey was conducted on the personnel involved in waste disposal units in hospitals, in order to identify important factors relating to the outsourcing risk of biomedical waste in hospitals. This study calculated the risk priority number (RPN) and selected items with an RPN value higher than 80 for improvement. These items included availability of freezing devices, availability of containers for sharp items, disposal frequency, disposal volume, disposal method, vehicles meeting the regulations, and declaration of three lists. This study also aimed to identify important selection factors of biomedical waste disposal companies by hospitals in terms of risk. These findings can serve as references for hospitals in the selection of outsourcing companies for biomedical waste disposal.

Carvalho et al., (2002), used the Preliminary Risk Analysis (PRA) to assess practices in the handling of infectious health-care waste. Currently the *PRA* technique is used to recognize and to evaluate the potential for hazard of the activities, wastes and services from facilities and also the industries. The system studied was a health-care establishment which has handling infectious waste. Thirty-six procedures consisting segregation, containment, collection, and storage operations were studied. The severity of the consequences of the risk that could occur from careless management of infectious health-care waste was classified into four categories namely negligible, marginal, critical, and catastrophic. The results obtained in

this study showed that events with critical consequences, about 80%, may occur during the implementation of the inhibition operation, suggesting the need to prioritize this operation.

Xie et al., (2010) studied use of the incinerator rather than a landfill for the disposal of waste which is considered beneficial to reduce the burden on the landfill however the waste with high moisture content is not suitable for burning in direct mass burning incinerator so the a novel integral incinerator was designed by combining a feeder, a rotator grate, a Primary Combustion Chamber (PCC) and a coaxial Secondary Combustion Chamber (SCC) into a unique unit with a capacity of 10 ton/day. Temperature and pollutants concentration in the *SCC* were measured to understand the combustion behavior of volatile organics. Emission concentrations of pollutants before stack were also tested and compared with the China National Incineration Emission Standard.

John et al., (2011), revealed that Incineration is one of the finest methods among various disposal facilities to handle medical waste. Incineration may be defined as the thermal destruction of the waste at elevated temperature say 1200 °C to 1600°C under controlled operational condition. The products of combustion are $CO_2$, $H_20$ and ash as a residue. The unit in which the process takes place is termed as Incinerator. The objective was to design an incinerator according to the design values and criteria's specified nationally and globally.

Sefouhi et.al, (2013), showed that the poor management of wastes exposed health care workers, waste handlers and the community to different risks as: infections, toxic effects and injuries. Risk Management is the identification, assessment, and prioritization of risks. In the hospital of Batna city, a total about 1114 Kg of risky healthcare waste (RHCW) are produced each day. By using Preliminary Hazard Analysis (PHA) which is an assessment tools, the main focus in the paper was to identify and study health risks that may occur due to the existence of hazardous elements in healthcare waste, to identify treatment modalities tailored to each adverse event and to characterize and prioritize these adverse event in terms of occurrence and severity scenario.

## 2.2 Summary of Literature Review

Quite a large amount of study has been done on *BMWM.* It is evident from the literature that a very little study has been done on comparison between major public and private sector hospitals of the cities especially in northern region of the country. The results have been shown in the terms of amount of waste generated in different wards along with the description of the various other procedures like segregation, transportation, storage, treatment and

disposal being carried in the hospital. The practices for segregation, transportation, storage, treatment and disposal of wastes generated at all the major hospitals need to be changed for better management and major improvements need to be done in the system for obtaining better results. There is an utmost need for educating the staff about the possible hazards related with the mismanaged disposal of *BM* waste because of the increasing amount of infections and other fatal diseases being spread these days due to haphazard disposal of *BMW*. Effective steps need to be taken for efficient management of *BMW*. There is a risk associated with the biomedical waste being dealt in the hospitals and other medical institutes. Risk assessment and remediation measures may need to be undertaken at initial level as well as implementation levels to protect workers, patients and doctors related with the Bio Medical Waste Management as well as the environment. Incineration is the main disposal option adopted for the waste disposal. But the design of incinerator varies with the waste characteristics so the incinerator type and capacity varies with the characteristics of waste.

# CHAPTER 3

# STUDY LOCATIONS

The areas that were chosen for the study purpose was Shimla and another area within 100 km of the main study area i.e. Chandigarh. In Shimla, the two main hospitals that were chosen were IGMC Hospital which is a large Public sector hospital and INDUS Hospital which is a Private sector organization, similarly in Chandigarh the hospitals that were taken for study purpose were MAX Super Specialty Hospital and IVY Hospital both of which are large Private Sector hospitals. The reasons for choosing the hospitals were that the hospitals were well known in the area and were ready to share their information and contribute to the study purpose. Further details of the study areas have been described in details below.

## 3.1 Shimla

In the light of above facts and figures the study is intended to take place at the capital of the state Himachal Pradesh. The city of Shimla is located at 31°6'12" north latitude and 77°10'20"east longitude. The city is 2,206 m above the mean sea level. It covers an area of 9.2 km from east to west. The nearest river is Sutlej. The population of the city is found to be 1, 71,817 (National census 2011). The place is well connected through roads, railways and airways. The view of the city is visible in Plate 3.1 below.

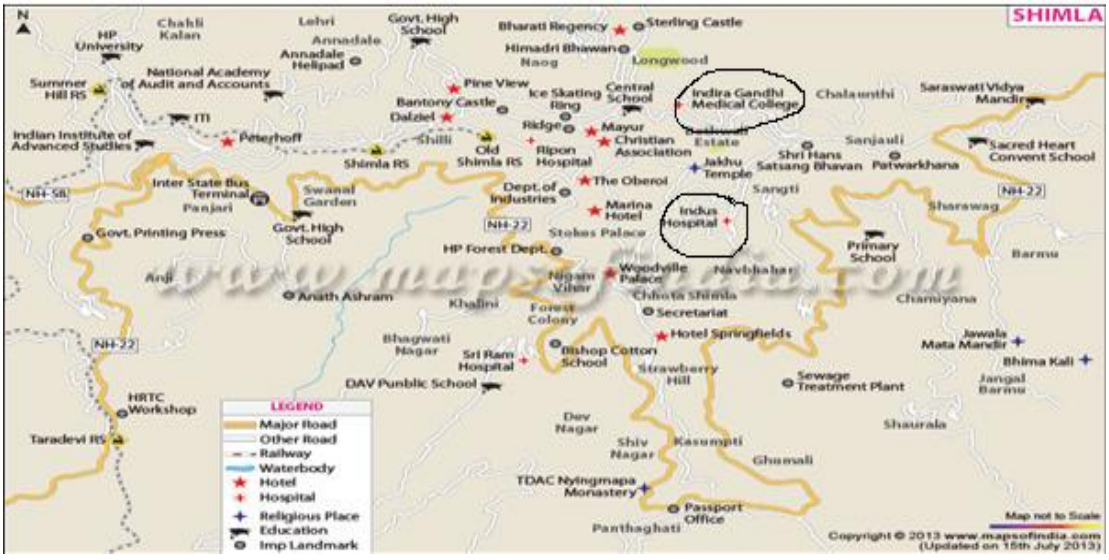


**Plate3.1:** A view of the Shimla City. [www.mapsofindia.com]

### 3.1.1 IGMC Hospital

The public sector hospital is a multistoried building with 33 departments. The biomedical waste management in the hospital premises is looked after by a team of 3 main doctors, personnel in charge of infectious waste along with other workers for waste collection and disposal. The main method of treatment followed at the hospital is allopathic. The annual statistics show that the total number of patients admitted were 31,872 out of which 31,771 patients were discharged. The total number of patient treatment days observed were 2, 44,503. The average length of stay for patient was reported to be 8 days. The instruments used for the diagnosis are reused after sterilization. The average inpatients are 669 with average bed occupancy of 84. IGMC Hospital Shimla has been shown below in Plate 3.1.


**Plate 3.2:** A view of the IGMC Shimla. [www.panoramio.com]

### 3.1.2 INDUS Hospital

The private sector hospital is a 6 storied building with 8 departments comprising of department of surgery, medicine, ayurveda, radio diagnosis and imaging, pediatrics, and adolescent medicine, gynecology and maternity, orthopedic surgery, dentistry and oral health, and department of physiotherapy. The biomedical waste management is managed by team of 2 main members one a head of the nurses training department along with an administrative head and other workers to collect and dispose the waste from hospital wards. The hospital premises is a small area but the hospital wards are well equipped with attached washrooms and intercom facilities in general wards and ventilators, defibrillators, piped oxygen, central

suction and compressed air in the intensive care units. The hospital is looked after by 19 doctors and is open for 24 hours with assigned house physician on duty round the clock. INDUS Hospital Shimla has been shown in Plate 3.3 below.

**Plate 3.3:** A view of the Indus Hospital, Shimla. [indushospital.org]

## 3.2 Chandigarh

Chandigarh is a city and a Union territory in the northern part of India that serves as a capital of the state of Punjab and Haryana. As a Union territory the city is ruled directly by the Union Government of India and is not part of either state.

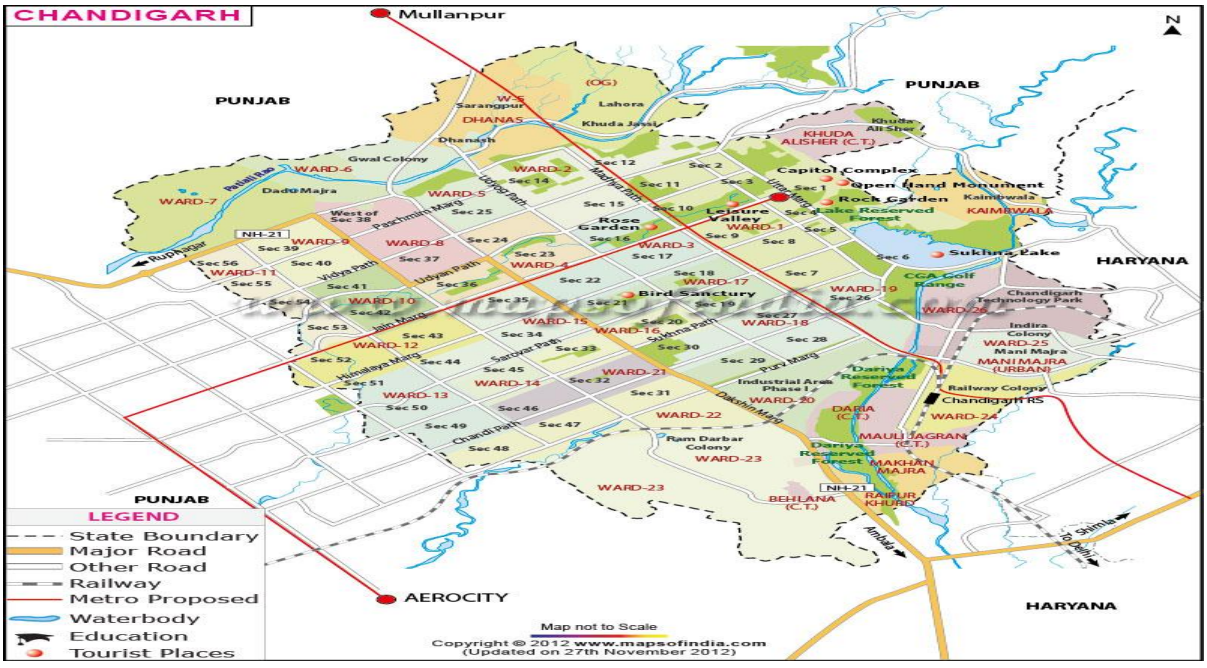


**Plate 3.4:** A view of the Chandigarh City. [www.maps ofindia.com]

The Metropolitan of Chandigarh- Mohali-Panchkula collectively forms a Tri- City with a combined population of over 2 Million. The city experiences extreme climate and uneven distribution of rainfall. It covers an area of approximately 114 Km. It shares a border with the states of Haryana and Punjab. The exact cartographic co-ordinates of Chandigarh are 30.74 °N76.79°E. It has an average elevation of 321 m (1053ft.). The view of the city is visible in Plate 3.4 above.

### 3.2.1 MAX Super Specialty Hospital

Max Healthcare commenced its operations in 2001 and is India's first provider of comprehensive seamlessly integrated world class healthcare services. It has 11 facilities in North India in over 32 disciplines. The total bed strength in the hospital is 200 and aims to bring comfort and convenience to the patients. The hospital uses most technically advanced equipments to achieve excellence in research and treatment. The hospital also has state- of art diagnosis system to understand health problems better and chose right treatment for patients. The hospitals have been renowned with various accreditations such as *NABH, NABL* and *LEED* which makes hospital a highest level quality service provider. The various services provided in the hospital includes Obstetrics, Child Birth, Joint Replacement, Orthopedics, Gynecology, *OPD* facility, Dermatology, Plastic Surgery, Aviation Medicine, Nuclear Medicine, Ophthalmology, Urology, Sexology, Thoracic Surgery etc. MAX Hospital Mohali has been shown in Plate 3.5 below.


**Plate 3.5:** A View of MAX Hospital, Mohali. [www.yespunjab.com]

### 3.2.2 IVY Hospital

IVY Group is one of the largest tertiary care healthcare delivery networks operating in Punjab. The total bed capacity of the hospital is 205 beds and comprise of over 25+ super specialty departments, 125+ consultants, 1500 Paramedical and Nursing Staff, 3000+ Complex Surgeries and more than 1.25 Lakh patients are treated annually. The hospital provide expertise in Heart, Brain, Cancer, Bones and Joints, Kidney and Bladder, Stomach, Liver and Digestive System, Women Health, Child Care, Diabetes, Lungs, Internal Medicine, Psychiatrist, General Surgery, Skin, ENT. The Hospital got its NABH accreditation on 12 December, 2011 which makes it a place of quality treatment. It provides free medical treatment and also treatment at subsidized rates to people below poverty line and people with yellow cards. Medical checkup camps are organized every year along with awareness talks at schools and institutions, free consultation camps in areas where the medical facilities are very less or the income of people are quite low as a part of Social Responsibility. IVY Hospital, Mohali has been shown in Plate 3.6 below.

**Plate 3.6:** A View of IVY Hospital, Mohali**.** [www.pbbase.com]

# CHAPTER 4
# METHODOLOGY

The methodology for the study comprised of different parts. The first part involves the Bio Medical Waste Management for which Questionnaire session was conducted to get the required details for analysis. The second part was Preliminary Hazard Analysis for which another Questionnaire session was conducted which was to be filled by the doctors and nurses involved in Bio Medical Waste handling and the results were further used for matrix filling and analysis. The third part was incinerator design for which necessary assumptions were made according to the guidelines provided for the incinerator design and necessary data obtained from Questionnaire analysis.

## 4.1 Survey and Questionnaire Session

The survey involved critically examining the quantification of waste, segregation, collection, transportation, final treatment and disposal as well as the occupational safety of the person in charge, the degree of intensity with which the various guidelines are being followed in the institutions and the rules and regulations being imposed by the administrative staff for maintaining a healthy and safe environment around. It also focused upon the potential problems faced by the workers and the staff during disposal and at the disposal sites.

A questionnaire session was framed with the purpose of obtaining knowledge about the present waste generation and management strategy being followed in the hospitals and determining the various factors which restrict the proper management and disposal of waste being generated in various units at the hospital. The prepared questionnaire has been attached in the Appendix A under the heading **'A.1 Questionnaire – 1 for study of Bio Medical waste management of Hospitals'**. The questionnaire was prepared with reference to literature review done so far and additional questions were also considered in order to have a complete insight of the hospital's waste management strategies. The questions were verbally asked to the people involved in handling, management and disposal of waste and the data was recorded in form of tables or theory for further analysis. The questions that were listed in the questionnaire were related to the various aspects of waste management such as the procedure which is being applied for the waste handling and collection, handling procedure for the various categories of the waste such as sharps, anatomical waste, pathological waste and

infectious waste etc., various kinds of containers or bags which are used for the different categories of wastes, details of management strategy or team monitoring and supervising waste management plans etc.

## 4.2 Risk Assessment using Preliminary Hazard Analysis (PHA)

A *PHA* was conducted to identify potential hazards and prioritize them according to the likelihood of an accident or injury being caused by the hazard; and the severity of the injury, illness, or property damage that could result if the hazard caused an accident. This tool analysis is based on applying prior experience or knowledge of hazard to identify future hazards, hazardous situation and then risk assessment of Risky Health Care Waste (RHCW). The procedure generally applied for the carrying out of PHA has also been describes as follows:

**1. PHA prerequisites:**

a) Establish *PHA* team.

b) Define and describe the system to be analyzed

c) Collect risk information from previous and similar system (e.g., from accident data bases).

**2. Hazard identification:**

All hazards and possible accidental events must be identified. It is important to consider all parts of the system, operational modes, maintenance operations, safety systems, and so on. All findings shall be recorded. No hazards are too insignificant to be recorded.

**3. Consequence and frequency estimation:**

The risk related to an accidental event is a function of the frequency of the event and the severity of its potential consequences. To determine the risk, we have to estimate the frequency and the severity of each accidental event.

**4. Risk ranking and follow-up actions:**

The risk is established as a combination of a given event/consequence and a severity of the same event/consequence. This will enable a ranking of the events/consequences in a risk matrix.

For the *PHA* again a questionnaire session was conducted among the Doctors and Nurses at the hospitals. The Questionnaire comprised of simple ranking of various waste types namely Infectious Waste, Sharps, Human Anatomical Waste and Pharmaceutical & Chemical Waste. The concerned personnel were asked to rank these wastes on a scale from 1-5 according to

their observation and experience both for severity and likelihood respectively where 1 was the least ranking both for severity and likelihood. In case of severity the table 4.2 i.e. Severity of Consequence Criteria below describes the meaning of each consequence and its ranking. In case of Likelihood the ranking was described as *very unlikely* as *1* for the likelihood of occurrence to be least and increased to *very likely* with ranking as *5*. At least 15 doctors and nurses were approached for the purpose at each hospital. The rankings were then used for analysis numerically using matrix as shown in Table 4.1.below.

| | | **Hazard Severity** | | | | |
|---|---|---|---|---|---|---|
| | | No Effect 1 | Minor 2 | Major 3 | Hazardous 4 | Catastrophic 5 |
| **Likelihood Of Occurrence** | *Very likely (5)* | Low | Medium | High | High | High |
| | *likely (4)* | Low | Medium | Medium | High | High |
| | *Possible (3)* | Low | Low | Medium | Medium | High |
| | *Unlikely (2)* | Low | Low | Low | Medium | Medium |
| | *Very Unlikely (1)* | Low | Low | Low | Low | Medium |
| Low Risk | | Medium Risk | | | High Risk | |

**Figure 4.1:** A Matrix for Risk Ranking

**Table 4.1:** Severity of Consequence Criteria

| | |
|---|---|
| No effect (1) | Has no effect on health |
| Minor (2) | Minor injury |
| Major (3) | Major injury |
| Hazardous(4) | Serious or fatal injury |
| Catastrophic(5) | Death |

The table which was used for the ranking by the doctors as well as the detailed description matrix which has been used for the purpose of analysis has been attached in the Appendix A under heading **'A.2 Questionnaire- 2 for Risk Ranking '**. The rankings that were provided by the doctors to each of the waste class mentioned in the table in questionnaire were subjected to necessary calculations as shown in the sheets attached in the **Appendix B** to get suitable values for likelihood of each waste type, Severity for each waste and Risk for each waste type.

## 4.3 Design of an Incinerator

The above data from Questionnaire-1 and Questionnaire-2 was analyzed and it was observed that the hospital waste management lacked an appropriate incineration facility in the campus. The waste was either sent to an offsite incineration plant or burnt in a share-in facility. Considering the above facts it was felt that there is a need for design of incinerator facility for the hospitals.

For the design of an incinerator following methodology was followed and the necessary details and assumptions were considered from the past studies. The general methodology and necessary steps in general have been listed below but the detailed design has been presented in later chapter.

**a) Design of Primary Combustion Chamber:**

For designing the primary chamber, initially volume of the chamber is to be found out. For finding out the volume 100kg of waste is dumped as a heap and the volume of the heap is considered.

**b) Heat and Material Balance Sample Calculation:**

1) Assumptions.
2) Calculation of Material Input.
3) Calculation of Heat Input of Wastes (kj/h).
4) Determination of Stoichiometric Oxygen for Wastes.
5) Determination of Air for Waste Based on 150% Excess.
6) Material Balance:
   a) Dry Products from waste.
   b) Moisture.
   c) Ash Output.
   d) *HCl* formed from Wastes.

7) Heat Balance.
   a) Total Heat in From Waste.
   b) Total Heat out Based on Equilibrium Temperature of 1100°C.
8) Required Auxiliary Fuel to Achieve 1100°C.
9) Products of Combustion from Auxiliary Fuel.
10) Secondary Chamber Volume Required Achieving One Second Residence Time at 1000°C
11) Residual Oxygen in the Flue Gas.

# CHAPTER 5
# OBSERVATIONS

The Questionnaire -1 comprised of questions about the Bio Medical Waste Management and generation in the hospitals. The information was collected verbally by interview sessions from the in charges at the hospitals about the *BMWM* and in tabular format in from of data sheets for waste generation in hospitals.

## 5.1 Bio Medical Waste Management

The *BMWM* was studied for different hospitals in terms of waste generation, segregation, collection, transportation and finally disposal. The observations were then described theoretically in case of management of the waste in reference to Schedules of *BMWM* and Handling Rules 1998.

### 5.1.1 IGMC Hospital, Shimla

The collection of the waste at the public sector hospital is done by workers assigned to particular wards. The workers remove the filled bag and replace it with the new clean bags. The workers use assigned gloves, boots and masks as they know the risk associated with handling of biomedical waste. The frequency of collection depends upon the amount of waste to be handled which varies from ward to ward. The wards such as Minor Operation Theatre. and Causality, Cardio- Thoracic where the waste production is high due to high rate of cases per day the cycle occurs 3 times a day, once at 7.30 am in the morning, secondly at 1.30 pm in the evening and thirdly at 6.30 pm in the evening. The bags are removed when 80% of bag gets filled. For general waste the municipality is responsible and frequency of removal is once a day. From the general wards and *O.P.D.* where the waste production is less the waste is removed at 7.30 am in the morning and 6.30 pm in the evening.

Waste is segregated at the point of generation in the hospital according to the waste characteristics. The appropriately color coded high- density polyethylene bags are used according to schedule 2 of Biomedical Waste (Management and Handling) Rules 1998 the general waste is collected in black polythene bags or black bin, the infectious waste are collected in red bags, the sharps in puncture proof blue bags and the anatomical waste are collected in yellow bags.

No prescribed routes are followed for transportation at the hospital; waste is collected and directly taken to the incineration plant on campus for the further treatment.

The hospital uses on site incineration plant for treatment of Bio- medical waste. The other treatments technologies that are being used are as follow:

1. Chemical Treatment. The chlorine solution is used for disinfection of sharps and plastic waste.
2. Thermal Treatment. The autoclave is used for thermal treatment. Autoclaves are used for treatment of culture and stock, sharps, syringes, cathedras, blood and urine bags, surgery waste; laboratory waste (excluding chemicals) etc. incinerator is used for burning of waste.
3. Mechanical treatment. The sharps such as needles are destroyed by needle destroyers and the destroyed needles are then disinfected with 0.5% chlorine solution for 30 minutes to 1 hour. However the final disposal of the waste though is incineration process.

### 5.1.2 INDUS Hospital, Shimla

The collection at the hospital is done by workers assigned for waste collection and disposal. The hospital being a small unit and less visited area, the amount of waste production is less. The cycle of waste removal is once a day at 4.30 pm in the evening.

The hospital has a store room at the ground floor where the waste is collected for disposal and stored. The frequency of removal is 2 days from the store area. The general waste is managed by municipality and removed every day.

The waste is segregated at the point of generation in hospital according to the waste characteristics. The appropriately color coded high- density polyethylene bags are used according to schedule 2 of Biomedical Waste (Management and Handling) Rules 1998 the general waste is collected in black polythene bags or black bin, the infectious waste are collected in red bags, the sharps in puncture proof blue bags and the anatomical waste are collected in yellow bags.

No prescribed routes are followed at the hospital; the waste is stored at a well ventilated store room with fire protection facility where the waste can be easily stored for 48 hours due to general cold climate in the area.

The hospital has a contract with a private organization which manages the incineration of biomedical waste off- site.

An autoclave is used for thermal treatment, treatment of culture and stock, sharps, syringes, cathedras, blood and urine bags, surgery waste, laboratory waste (excluding chemicals) etc. The used syringes are disinfected with chlorine solution before treatment and instruments reused after disinfection and sterilization. The sharps are destroyed by needle destroyers and the destroyed needles are then disinfected with 0.5% chlorine solution for 30 minutes to 1 hour.

### 5.1.3 MAX Super Specialty Hospital, Mohali

The *BMWM* in the MAX Hospital is carried by the Nurses in charge and the workers involved in the management and handling of waste. The waste segregation is done at the point of generation whether it be wards, operation theaters, *OPD'S* or any other sections in the hospitals. For the segregation purpose 4 different kinds of containers/bags were used namely Black, Red, Blue and White. The Red Container was used for Anatomical Waste, Blue Container was used for plastic waste such as gloves, glucose bottles, syringes etc., Black Container was used for general waste and Cytotoxic Waste with Cytotoxic and Biohazard symbol labeled over it, Containers fitted with white transparent plastic lids were used for collection of sharp needles as shown in Plate 5.1 below.

**Plate 5.1:** A View of Containers used at MAX Hospital.

Suitable flexes according to Schedule 1 and 2 are fixed at every point of segregation, storage and disposal which contains information about different categories of waste and appropriate color coding for each one of them. Appropriate Biohazard and Cytotoxic symbols are used on the containers and bags with reference to Schedule-3 of *BMWM* and Handling Rules of 1998 as shown in Plate 5.2 and 5.3 respectively.


**Plate 5.2:** Flexes used at MAX Hospital.

**Plate 5.3:** Cytotoxic symbol used at MAX Hospital.

Every patient ward contains a white colored small sized domestic dustbin for dumping of waste generated in the ward on daily basis as shown in Figure below. The workers involved in cleaning and waste removal in the wards are provided with a " Nurses Trolley" which contains a yellow colored and a blue colored bag for removal of cotton contaminated with pus and blood , dressings etc. and catheters, glucose bottles, sharps etc. respectively as shown in Plate 5.4 and 5.5 below.

**Plate 5.4:** A View of Dustbins in wards at MAX Hospital.

**Plate 5.5:** A View of Nurse's Trolley at MAX Hospital.

In the wards and patient rooms the waste removal and cleaning operations are done thrice a day in morning, afternoon and in the evening whereas the *O.P.D.* and *O.T.* the operations are carried even more frequently. The frequency of removal ranges from thrice a day to every hour depending on the quantity of waste generated as shown in Plate 5.6 below.

**Plate 5.6:** A view of Cleaning Operations at MAX Hospital.

There are separate rooms at every floor called "Dirty Utility Room" where different colored large sized containers are placed and the waste collected from every room and ward is dumped into it every two hours, an Sterilization machine is also installed in this room for sterilization purpose as shown below in Plate 5.7 and 5.8 respectively.

**Plate 5.7:** A View of Dirty Utility Room. at MAX Hospital.

**Plate 5.8:** A View of Sterilization Machine. at MAX Hospital.

The large sized dustbins were emptied in the storage area located at the restricted site in the hospital premises twice a day located using appropriate trolley cases as shown in the Plate 5.9 below.

**Plate 5.9:** A View of large sized dustbin at Hospital.

In the storage area necessary sections are made for each category of waste and a weighing machine is placed at the entrance of the storage area to weigh the bags and record the data in the sheets, the bags are then dumped in these large sized bins as shown respectively in Plate 5.10 and 5.11 below

**Plate 5.10:** Sections made in storage area for bins. at MAX Hospital .

**Plate 5.11:** Weighing machine placed at entrance at MAX Hospital.

The storage area is disinfected with Sodium Hypochlorite solution diluted accordingly for disinfection purpose every Friday. The workers are aware of the occupational hazard associated with it and therefore use necessary gloves, aprons, gum boots, masks etc. as shown below in Plate5.12 and 5.13 respectively.

**Plate 5.12:** Worker wearing protective gears at MAX Hospital.


**Plate 5.13:** Use of Hypochlorite Solution at MAX Hospital.

The storage site is maintained at a temperature of about 18° C to 19° C so that the waste can be stored until disposed off. The waste is transported in the tempos to an off- site incineration plant situated at Baliyali area of Mohali. The time of transportation is between 3.00 pm to 4.00 pm., whereas the general waste is removed by the Municipality in the morning. Appropriate performa for transportation is used on the vehicle as shown below in Plate 5.14 and 5.15 respectively.

**Plate 5.14:** Transportation Vehicle carrying Waste.

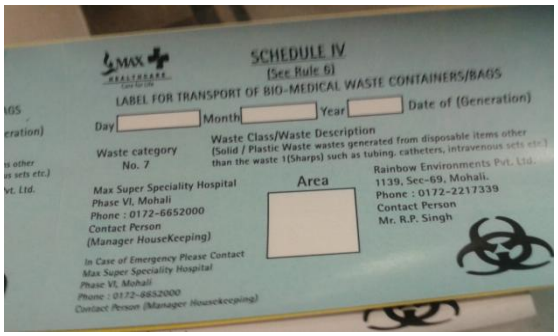


**Plate 5.15:** Label of Transport used on Vehicle.

### 5.1.4 IVY Hospital, Mohali

The Bio-Medical Waste Management at IVY Hospital is carried by Nurses incharge and the workers appointed for handling and waste disposal of waste. The waste segregation is done once at the point of generation and checked once again at an isolated site on the roof top of the

hospital building where a special room is made for its storage to avoid any mismanagement from segregation procedures as shown in the Plate5.16. below.

**Plate 5.16:** Segregation procedure at IVY Hospital.

For the segregation purpose at the point of generation 5 different colored containers or bags are used such as yellow, blue, white, red and green respectively as shown in Plate 5.17 below. Yellow colored bags are used for storing anatomical waste, contaminated cotton. Blue colored bags are used for discarded plastic bottles of glucose, and plastic syringes. White colored containers are used for storing sharps, catheters and tubings etc. Black colored containers are used for storage of cytotoxic waste material and discarded drugs and medicines with appropriate biohazard symbol labeled on it. Green colored bags are used for the storing of general waste. The housekeeping is responsible for waste management and handling procedures.

**Plate 5.17:** Containers kept at IVY Hospital.

The workers use gloves, masks and other protective gears as they are aware of the hazardous nature of the waste and thus follow the instructions from the higher personnel involved in the waste management. The waste is generally stored in the compartments, generally lockable shacks situated in the backside of the hospital until the waste is transported to the disposing site as shown in Plate 5.18 below. The sharps are safely disposed off in the concrete pits made behind these compartments and sealed off when they get filled. These compartments are also color coded cells and the bags of same color are stored into these shacks as shown in fig. below. These compartments are generally cleaned with hypochlorite solution after the waste is removed from them. The general waste is removed by municipality every morning from 7.00 am to 9.00 am.


**Plate 5.18:** A view of Lockable Shacks at the Backyard of IVY Hospital.

The waste removal frequency is twice a day from hospital to these compartments and three times a day from various wards in the hospitals. The bags are weighed before dumping them

into these compartments. For the transportation of waste to the disposal site the tempos are used which carry a Performa of label to be used on them for transportation purpose carrying relevant information about name of the owner, category of waste, date of generation of waste and contact no. of the person incharge, one label is stuck on the vehicle and other is provided to the driver of the vehicle. The waste is taken offsite to Baliyali in Mohali where the wastes are suitably land filled or incinerated.

# CHAPTER 6
# RESULTS AND DISCUSSIONS

The necessary observations were made and these observations were suitably plotted in either a graphical format or in a tabular format to represent the results obtained. The results were then suitably discussed and necessary reasons were discussed for the results so obtained so that the observations could be suitably verified.

## 6.1 Waste generation

The observation table was plotted for waste generation in different wards in the hospitals in Shimla but in case of hospitals in Chandigarh the waste was managed according to the categories and not ward wise so the graphical representation has been done ward wise for hospitals in Shimla and category wise for hospitals in Chandigarh, the variation was observed in terms of quantity of waste.

### 6.1.1 IGMC Hospital, Shimla

The data was analyzed carefully from the record books in each ward and an average quantity of waste was determined for each type of waste produced for each category of waste in each ward

**Table 6.1:** Generation of Biomedical waste in various wards of IGMC Hospital in Kg.

| S.No. | Ward name | Type 1 (yellow bag) | Type 2 (red bag) | Type 3 (blue bag) | Type 4 (black bag) | Total per day | Total per week | Total per year |
|---|---|---|---|---|---|---|---|---|
| 1. | O.P.D Skin | - | 2.50 | 3.00 | 4.00 | 9.50 | 66.5 | 3,467.5 |
| 2. | O.P.D Surgery | 3 | 2.5 | 3.6 | 4.00 | 13.10 | 91.70 | 4,781.5 |
| 3. | Minor O.T. | 7.0 | 4.7 | 1 | 3.5 | 16.20 | 113.4 | 5,913 |
| 4. | O.P.D. E.N.T. | 2.7 | 2.2 | 0.50 | 6.0 | 11.4 | 79.8 | 4,161 |
| 5. | Cardiothoracic | 8.7 | 4.5 | 23.5 | 10.0 | 46.70 | 326.90 | 17,045.5 |
| 6. | Microbiology | 1.0 | 1.50 | 4.5 | 5.7 | 12.7 | 88.9 | 4,635.5 |
| 7. | Causality&O.P.D. | 7.5 | 8.5 | 8.00 | 11.3 | 35.3 | 247.1 | 12,884.5 |

It was observed that the maximum amount of infectious and non- infectious waste generated is in the cardio- thoracic vascular surgery, *O.T.* and *I.C.U.* department which is about 46.70 kg of waste/day followed by causality & *O.P.D.* department which ranges from about 35.3 kg/day and minor *O.T.* about 16.20 kg/day per day. The observations have been tabulated in Table 6.1 regarding the total amount of waste produced in Kg in the various wards of the Hospital according to the different waste containers on per day, per week and annual basis.

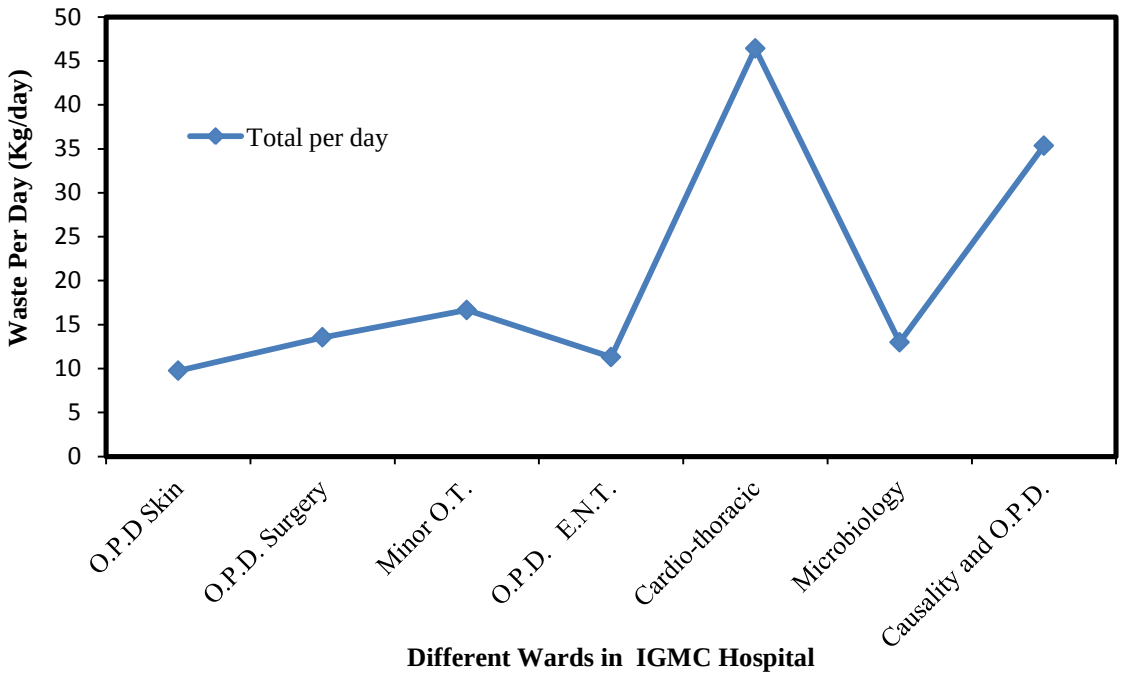


**Figure 6.1:** Total waste produced per day in different wards in IGMC Hospital.

From Figure 6.1, We can conclude that the highest quantity of waste is produced in Cardio-thoracic department of the IGMC hospital due to the hospital being one of the few hospitals in state that offers a large number of facilities alone in the field of cardiology such as pulmonary medicine, open heart surgery, cardiothoracic surgery etc. and only one of its kind to offer treatment related to lung problems also the easy approachability of the hospital campus from around the state is also another factor that contributes to large frequency of patients in this ward. Further, the average stay of people in the cardiac unit is the largest among all the other wards that is 5-7 days so the quantity of waste produced is highest.

The Pie-Chart in Figure 6.2 below clearly describes that the maximum amount of waste percentage per year i.e. 31.79 % is produced in the Cardio Thoracic department of IGMC Hospital which is highest among all the wards.

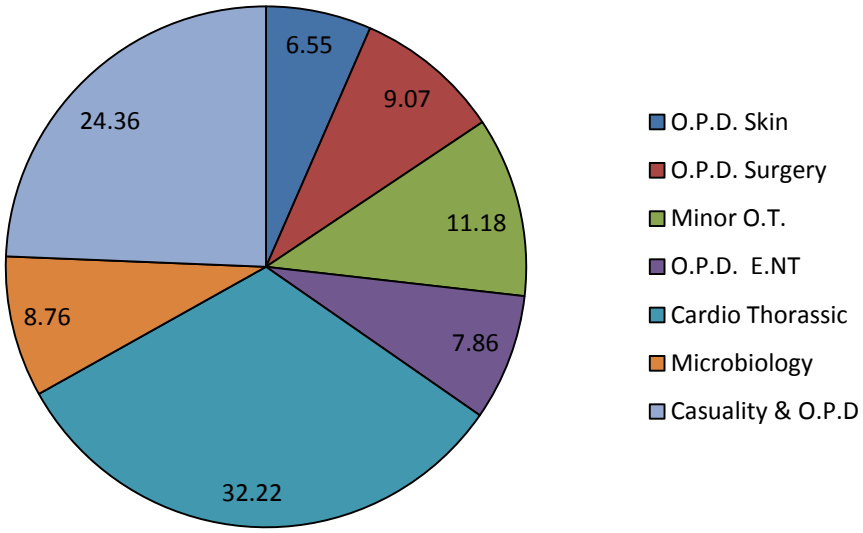


**Figure 6.2:** Ward Wise Percentage Composition of Waste Produced on Yearly basis at IGMC Hospital.

The Category based waste generation in various wards of IGMC Hospital has been shown below depicting waste generation in various categories in a bar chart format.

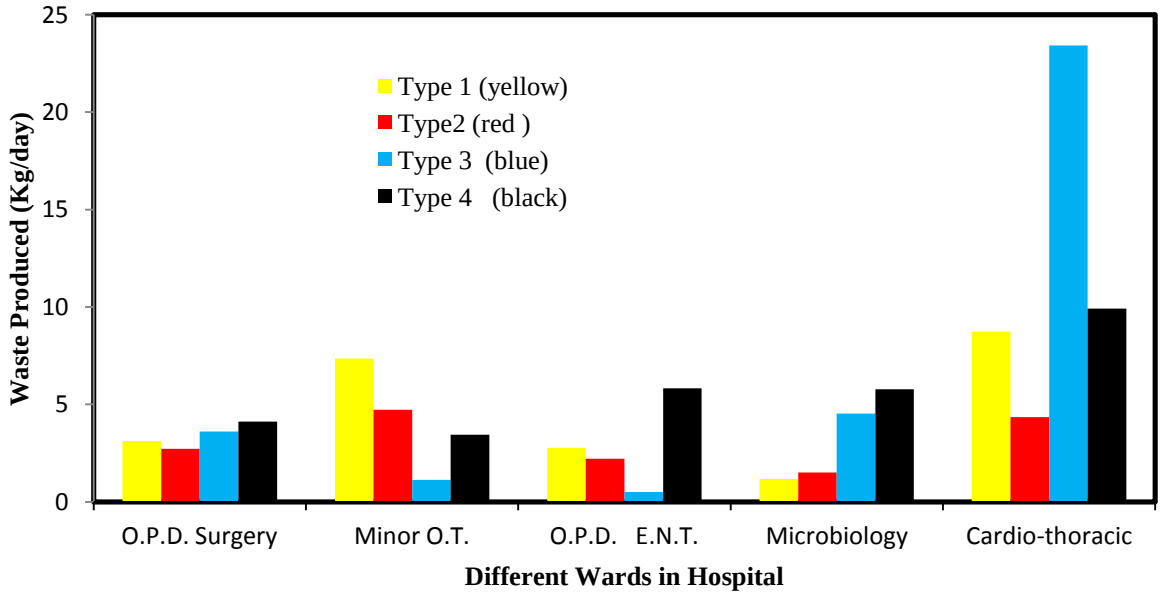


**Figure 6.3:** Variation of Type of waste produced per day in different wards at IGMC hospital.

From Figure 6.3, it can be concluded that the maximum amount of waste is produced is Type-3 in Cardio Thoracic department comprising of Waste sharps, Scalpel, Blades etc. as well as other disposable items such as tubing and catheters etc. due to large number of operational procedures being carried out in the department as the procedures are one of the kind offered in

and around the state there is max amount of waste production in this department also along with it the average stay of the patient is maximum out of all other departments The next department producing high amount of waste is Minor *O.T.* producing Type-3 waste, comprising of Human Anatomical Waste and contaminated solid waste such as linens, beddings and other items contaminated with blood due to minor operational procedures taking place in the department along with regular checkup schedules. The next department producing high quantity of waste is *O.P.D. E.N.T.* department which produces Type-4 waste comprising of used, unused and partially used drugs along with a considerable quantity of plastic wrappers and boxes of medicines, injections etc., and chemical waste used for disinfection due to many outdoor patient treatment procedures being carried out at regular basis along with some minor operational sessions, similar is the case with *O.P.D* Surgery Department. In Microbiology department again the Type-4 waste is produced to max due to disposal of large amount of used and unused chemicals, drugs and other waste items used for culture of stocks and medicines and various testing procedures of body fluids.

### 6.1.2 INDUS Hospital, Shimla

The observation has been tabulated in Table 6.2 regarding the total amount of waste produced in Kg in the various wards of the hospital according to the different waste containers on per day, per week and per year basis.

**Table 6.2:** Generation of Biomedical waste in various wards of INDUS hospital in kg

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| S.No. | Ward name | Type 1 (yellow bag) | Type 2 (red bag) | Type 3 (blue bag) | Total per day | Total per week | Total per year |
|---|---|---|---|---|---|---|---|
| 1. | Female ward | 0.27 | 0.48 | 0.51 | 1.26 | 8.83 | 460 |
| 2. | O.T. Surgery | 0.12 | 0.27 | 0.25 | 0.65 | 4.55 | 237.2 |
| 3. | X-ray | 0.17 | 0.40 | 0.12 | 0.69 | 4.84 | 252 |
| 4. | Microbiology laboratory | 0.15 | 0.40 | 0.12 | 0.66 | 4.64 | 241 |

It was observed that the maximum amount of waste is generated in the female ward which is about 1.26 kg per day followed by X- ray and microbiology/ biotechnology department which

is about 0.69 and 0.66 kg per day respectively. The data has been represented in a graphical format below in Figure 6.4 to show the maximum and the minimum amount of wastes produced in each ward.

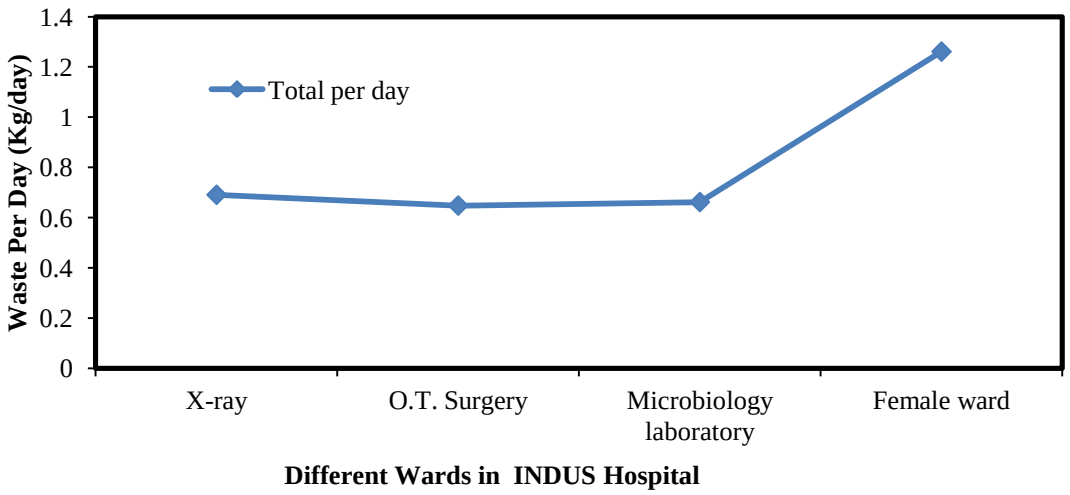


**Figure 6.4:** Total waste produced per day in different wards in INDUS hospital.

From Figure 6.4, We can conclude that the largest quantity of waste is produced in the female ward due to the largest number of inpatients being females and also the duration of stay in female wards as compared to other wards is maximum as the females are provided with antenatal, obstetrical and maternal services by experienced and qualified consultants on regular basis. The gynecology and maternity ward is highly established and famous in and around the place for offering the best care and expertise treatment in the field.

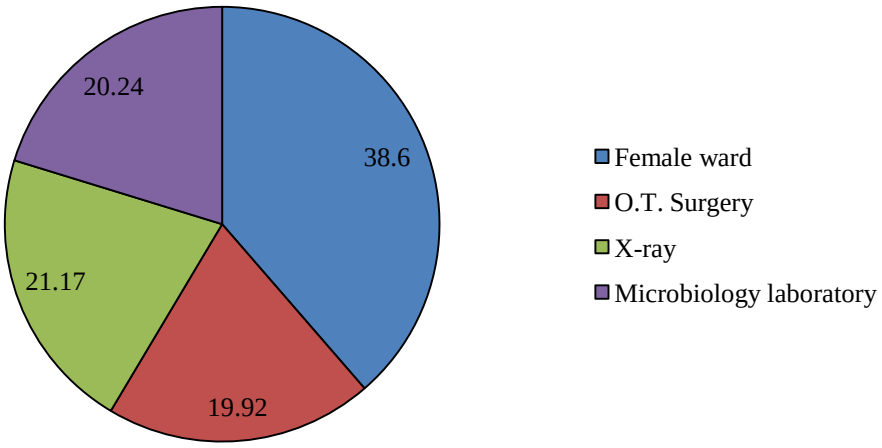


**Figure 6.5:** Ward Wise Percentage Composition of Waste Produced on Yearly basis at INDUS Hospital.

The above Pie-Chart (Figure 6.5), clearly describes that the maximum amount of waste percentage per year i.e. 38.6 % is produced in the Female Ward of INDUS Hospital which is highest among all the wards

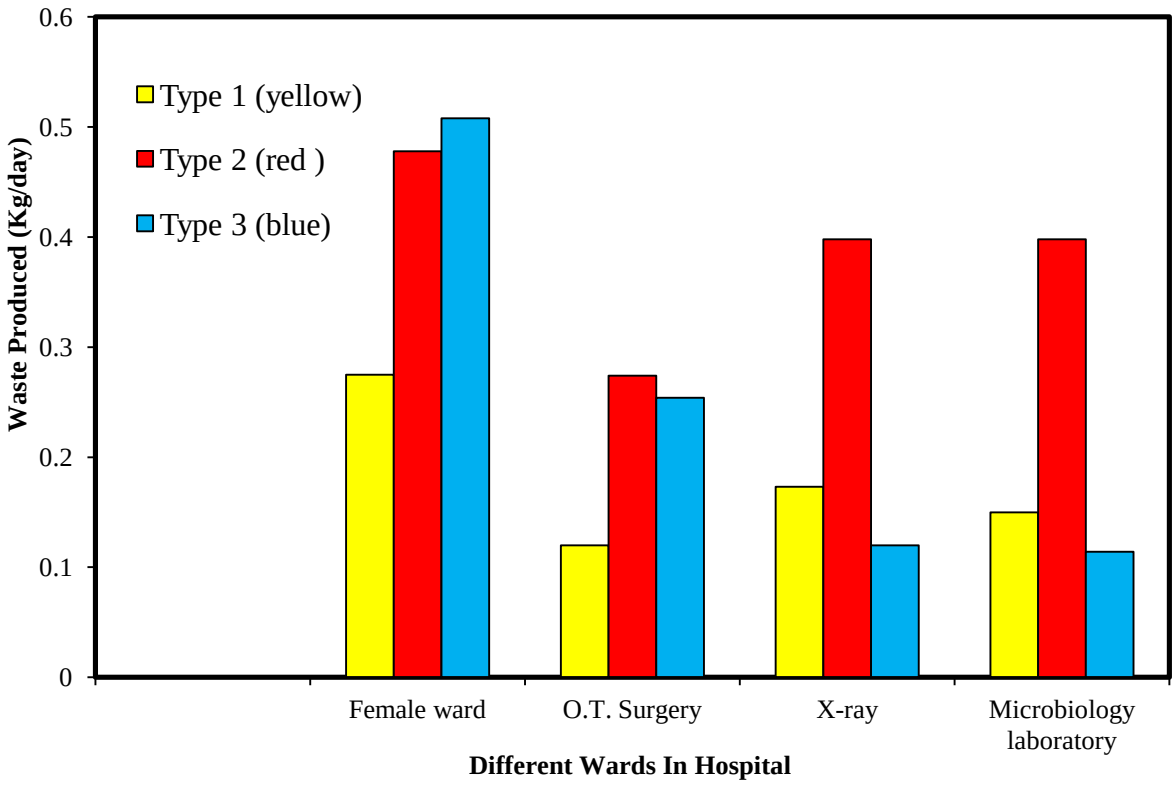


**Figure 6.6:** Variation of Type of waste produced per day in different wards at INDUS hospital.

From Figure 6.6, it can be concluded that the maximum amount of waste of Type-2 is produced in the Female Ward comprising of contaminated Solid Waste consisting of items such as catheters, tubing and cotton dressing, linen, bedding etc. contaminated with blood and other body fluids due to large number of gynecological treatments and small operational procedures being performed in the department.

The next highest waste producing department is X-Ray and Microbiology department producing type-2 waste again comprising of stocks, culture, blades, scalpels, dishes, biological toxins, and specimens of micro-organisms etc. from microbiology lab and cotton dressings, plaster casts, reagents used for preparation of X-ray films all produced during testing procedures.

The *O.T.* and Surgery department again produces Type-2 waste due to large no. of major and minor operational procedures being carried out in the department.

### 6.1.3 MAX Super Specialty Hospital, Mohali

It was observed that the data for waste generation was recorded in terms of number of bags per day and the total amount of waste generated per bag. The record book was studied carefully and suitable calculations were made to determine the average no. of bags per day with average quantity of waste produced per day as shown in table 6.3 below.

**Table 6.3:** Generation of Biomedical waste of various types at MAX Hospital in Kg.

| S.No | Type of waste | Avg. No. of bags for each Category of Waste | Avg. quantity of waste produced in each bag per day (Kg) | Avg. quantity of waste produced in each bag per week (Kg) | Avg. quantity of waste produced in each bag per year (Kg) |
|---|---|---|---|---|---|
| 1. | Type 1 (yellow bag) | 19 | 65.3 | 457.1 | 23,834.5 |
| 2. | Type 3 (blue bag) | 21 | 110 | 770 | 40,150 |
| 3. | Type 4 (black bag) | 5 | 38 | 266 | 13,870 |
| 4. | Type 5 (white bag) | 10 | 41 | 287 | 14,965 |

It was found that the largest amount of waste produced is Type 3(Blue bag) comprising of plastic waste such as tubing, catheters, empty glucose bottles, urine bags, syringes etc... The second largest waste producing category was Type1 (yellow Bag) comprising of anatomical wastes, contaminated cotton swabs, dressing, soiled plaster casts etc.. The third large waste producing category is Type 5(white bag) comprising of sharps, needles, blades, ampoules, lancets, and broken glass bottles etc. The next and last waste category was type 4 ( black bag) comprising of general waste such as paper, empty mineral water bottles, disposable cups and cardboards etc. and also cytotoxic waste such as discarded medicines, vials etc.

The data has been represented in a graphical format below in Figure 6.7 to show the maximum and the minimum amount of wastes produced in each ward.

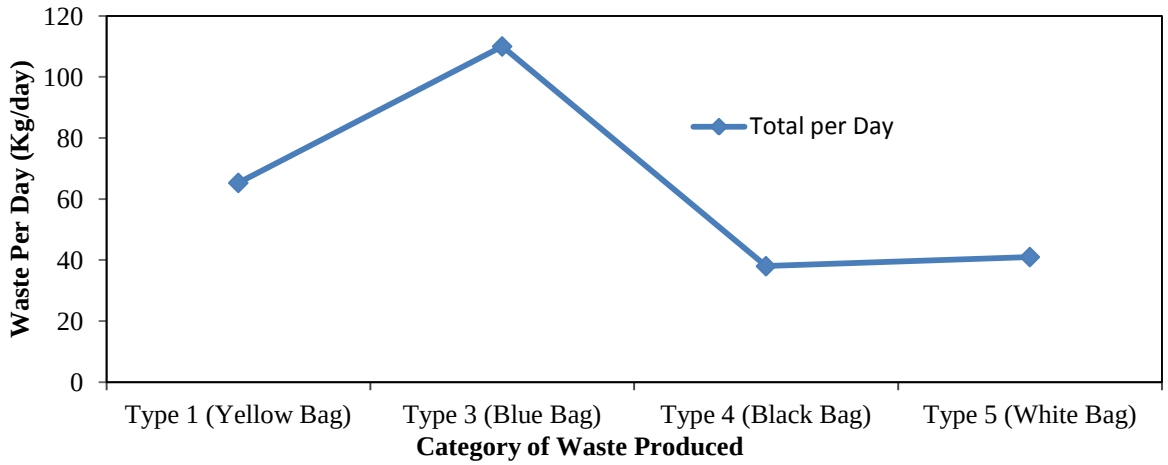


**Figure 6.7:** Total waste produced per day in different wards at MAX Hospital.

It was found that the largest no of bags were produced for type 3 waste category comprising of plastic waste such as tubing, catheters, empty glucose bottles, urine bags, syringes etc. because of the large no. of patient care wards and large no. of inpatients a large quantity of plastic waste is generated due to use of syringes, glucose bottles etc. so the quantity of waste produced is quite large, followed by type 1 waste category comprising of anatomical wastes, contaminated cotton swabs, dressing, soiled plaster casts etc.. The reason for large production of waste of this type is because of large no. of patients for emergency and surgical procedures require a large quantity of cotton and dressing so waste produced is more. The third largest waste producing category was Type 5 comprising waste such as sharps, needles, blades, ampoules, lancets, and broken glass bottles etc. due to the large no. of patients the use of large drugs and medicines in form of injections, syrups etc. per patient is in great quantity and also use of blades and scalpels for small surgical operations a large amount of waste is produced in this section. The next and last waste category was type 4 comprising of general waste such as paper, empty mineral water bottles, disposable cups and cardboards etc. and also cytotoxic waste such as discarded medicines, vials etc. The smaller quantity of general waste is produced in this section due to lesser administrative work in the hospital but also the use of cytotoxic drug is very limited because the drugs are generally limited to cancer care units and isolation units where patients are limited in number and medicines required are also a lot less in quantity.

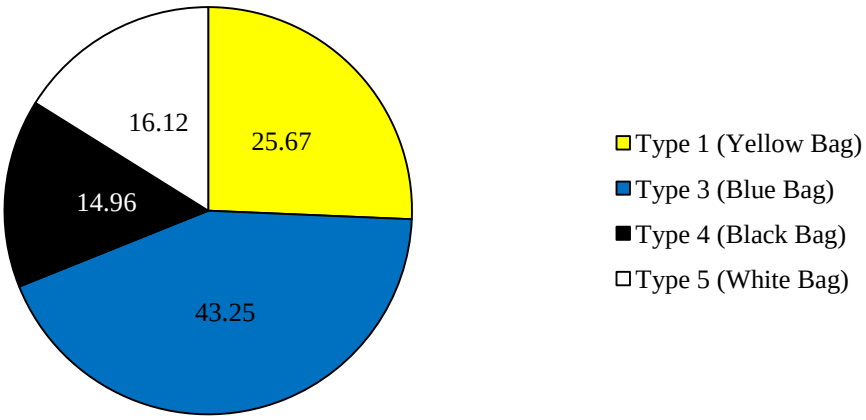


**Figure 6.8:** Percentage Composition of Waste Produced on Yearly basis in MAX Hospital.

The above Pie-Chart (Figure 6.8), clearly describes the waste percentage per year of different type of Wastes.

From figure 6.9 below it was observed that the max waste was producing category was Type 3 (blue bag) comprising of plastic waste such as tubing, catheters, empty glucose bottles, urine bags, syringes etc. followed by type 1 (yellow bag) waste category comprising of anatomical wastes, contaminated cotton swabs, dressing, soiled plaster casts etc.. The third largest waste producing category was Type 5 comprising waste such as sharps, needles, blades, ampoules, lancets, and broken glass bottles etc. The next and last waste category was type 4 comprising of general waste such as paper, empty mineral water bottles, disposable cups and cardboards etc. and also cytotoxic waste such as discarded medicines, vials etc.

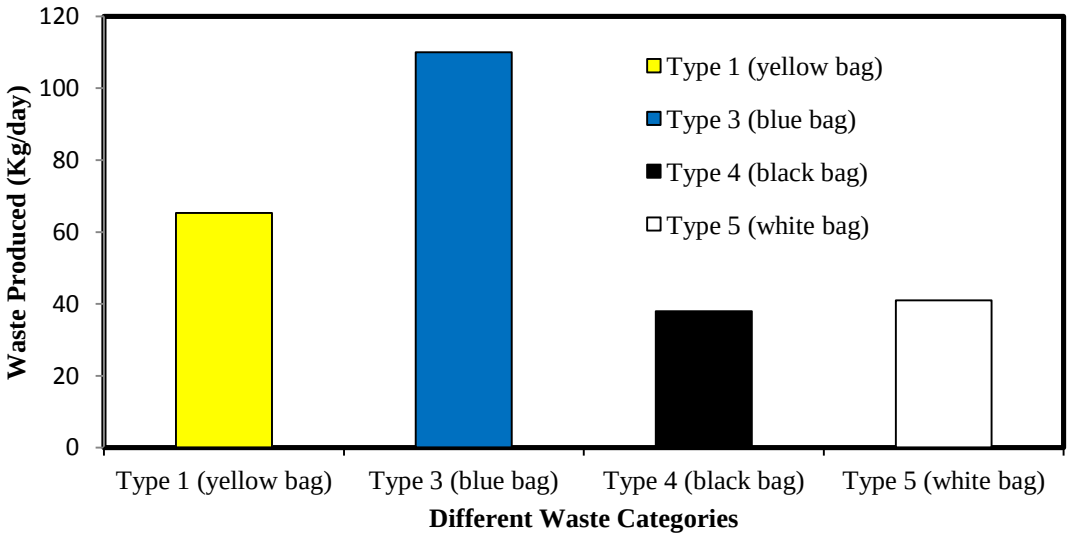


**Figure 6.9:** Variation in Type of waste produced per day at MAX hospital.

### 6.1.3 IVY Hospital, Mohali

It was observed that the data for waste generation was recorded in terms of number of bags per day and the total amount of waste generated per bag. The record book was studied carefully and suitable calculations were made to determine the average no. of bags per day with average quantity of waste produced per day as shown in Table 6.4 below.

**Table 6.4:** Generation of Biomedical waste of various types at IVY Hospital in Kg.

| S.No | Type of waste | Avg. No. of bags for each Category of Waste | Avg. quantity of waste produced in each bag per day (Kg) | Avg. quantity of waste produced in each bag per week (Kg) | Avg. quantity of waste produced in each bag per year (Kg) |
|---|---|---|---|---|---|
| 1. | Type 1 (yellow bag) | 20 | 46.5 | 325.5 | 16,972.5 |
| 2. | Type 3 (blue bag) | 22 | 70.9 | 496.3 | 25,878.5 |
| 3. | Type 4 (black bag) | 4 | 40 | 280 | 14,600 |
| 4. | Type 5 (white bag) | 6 | 12 | 84 | 4,380 |

It was found that the largest no of bags were produced for type 3 waste category comprising of plastic waste such as tubing, catheters, empty glucose bottles, urine bags, syringes etc. because of the large no. of patient care wards and large no. of inpatients a large quantity of plastic waste is generated due to use of syringes, glucose bottles etc. so the quantity of waste produced is quite large, followed by type 1 waste category comprising of anatomical wastes, contaminated cotton swabs, dressing, soiled plaster casts etc.. The reason for large production of waste of this type is because of large no. of patients for emergency and surgical procedures require a large quantity of cotton and dressing so waste produced is more.

The third largest waste producing category was type 4 comprising of general waste such as paper, cardboards, kitchen waste, empty mineral water bottles and also cytotoxic waste such as discarded medicines, vials etc. The larger quantity of general waste is produced in this

section due to more administrative work in the hospital producing large no. of papers, file covers, wrappers etc. and also large and more no of canteens and eating joints producing empty mineral water bottles, disposable cups, wrappers and cardboards etc also the use of cytotoxic drug is large due to a large Cancer Caring Unit which treats a large no. of patients with cytotoxic medicines on daily basis.

Least amount of waste produced is Type 5 comprising waste such as sharps, needles, blades, ampoules, lancets, and broken glass bottles etc. as max quantity of waste is dumped into pits constructed at backyard of the hospital but due to lesser area available but the quantity is generally unmeasured but still some quantity are sent off to the disposal plant and is measured to be lesser in amount.

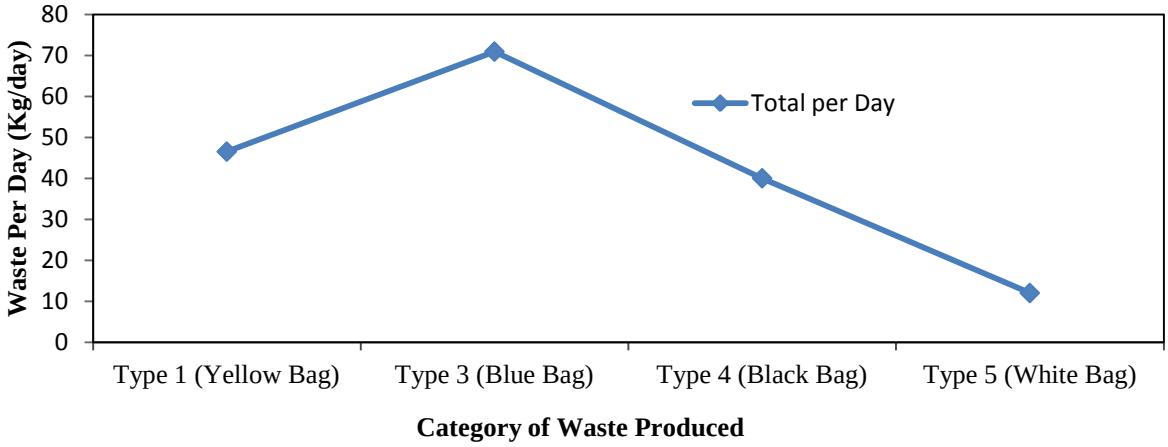


**Figure 6.10:** Total waste produced per day in different wards at IVY Hospital.

The data has been graphically represented in Figure 6.10 above for yearly waste generation of different categories of waste.

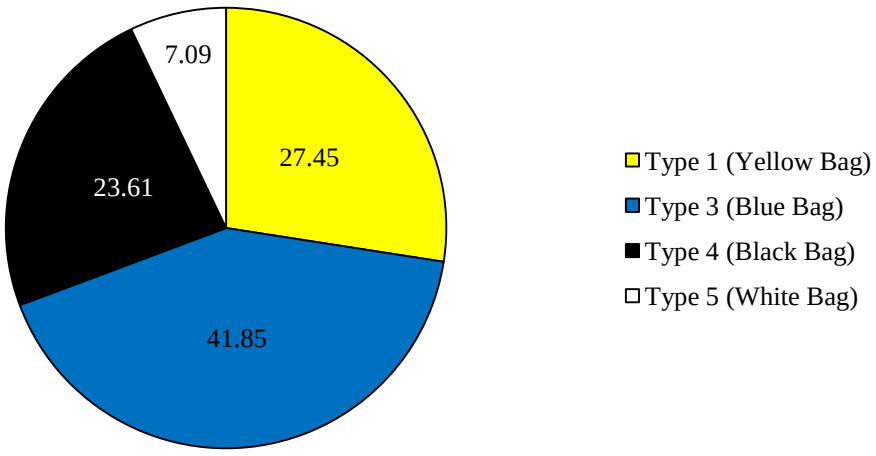


**Figure 6.11:** Percentage Composition of Waste Produced on Yearly basis at IVY Hospital.

The above Pie-Chart (Figure 6.11), clearly describes the waste percentage per year of different type of Wastes

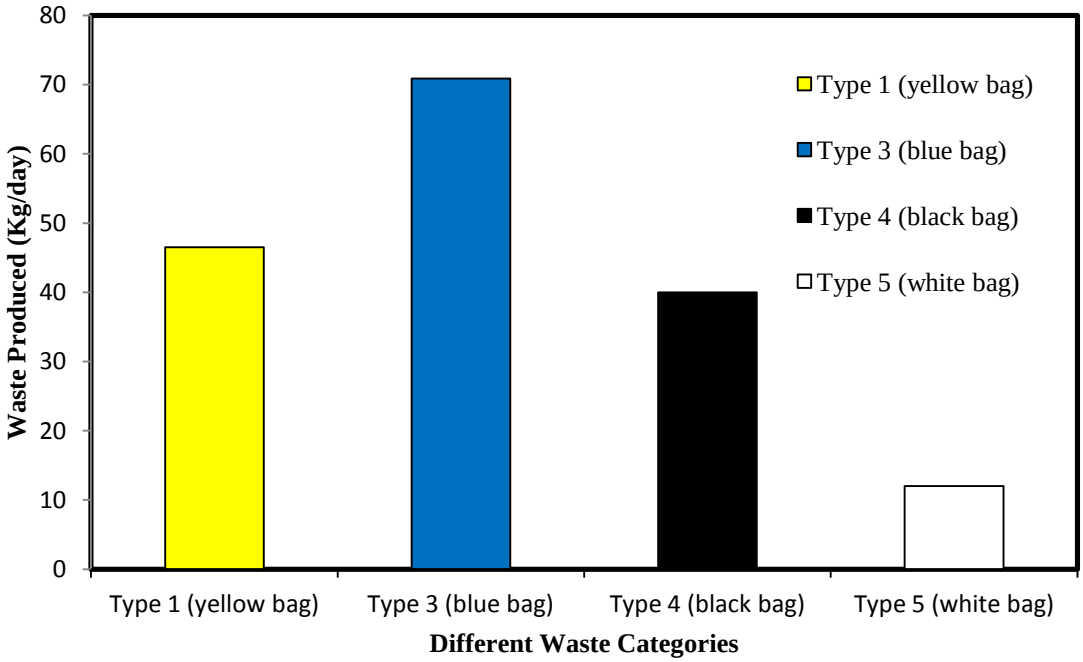


**Figure 6.12:** Variation in Type of waste produced per day in IVY Hospital.

From Figure 6.12 above it was found that the largest no of bags were produced for type 3 (blue bag) waste category comprising of plastic waste such as tubing, catheters, empty glucose bottles, urine bags, syringes etc. followed by type 1(yellow bag) waste category comprising of anatomical wastes, contaminated cotton swabs, dressing, soiled plaster casts etc.. The third largest waste producing category was type 4 comprising of general waste such as paper, cardboards, kitchen waste, empty mineral water bottles and also cytotoxic waste such as discarded medicines, vials etc.. Least amount of waste produced is Type 5 comprising waste such as sharps, needles, blades, ampoules, lancets, and broken glass bottles etc.

## 6.2 Waste Management

The observation table was plotted for waste management in different hospitals undertaken for study purpose. The waste management has been evaluated in compliance to the schedules mentioned in Bio-Medical Waste management and Handling Rules of 1989. The management in all the hospitals was found in compliance to the BMWMH Rules with a certain or little variations which has been shown in Tabular format in Table 6.5 below.

**Table 6.5:** Schedules of biomedical waste and compliance at Hospitals.

| Schedules | IGMC Hospital Shimla | INDUS Hospital Shimla | MAX Hospital Mohali | IVY Hospital Mohali |
|---|---|---|---|---|
| Schedule I | Yes | Yes | Yes | Yes |
| Schedule II | Yes | Yes | Yes | Yes |
| Schedule III | Yes | Yes | Yes | Yes |
| Schedule IV | Yes | Yes | Yes | Yes |
| Schedule V | Yes | Yes | Yes | Yes |
| Schedule VI | Yes | Yes (except Incinerator) | Yes (except Incinerator) | Yes (except Incinerator) |

From the above table it is clear that all the Hospitals followed accurate waste management in accordance with the Schedules mentioned in Bio-Medical Waste Management and Handling Rules issued by Ministry Of Environment and Forest, except for the onsite Incinerator facility which is available at IGMC Hospital in Shimla and not the other three hospitals.

## 6.3 PHA Analysis

The PHA analysis was performed for different hospitals according to the Questionnaire-2 and the observation table for the *PHA* analysis in terms of likelihood and Severity of the waste type such as Sharps, Pharmaceutical and Chemical waste, Infectious Waste and Anatomical Waste were plotted, for each hospital and their variation was observed in terms of the likelihood of the particular waste and its severity.

### 6.3.1 IGMC Hospital, Shimla

An Analysis was done according to Questionnaire-2 which has been attached in Appendix - A under heading A.1 Questionnaire-2 for Risk Ranking. The results were calculated according to the matrix method, in which the results of the Questionnaire -2 filled by hospital staff were taken collectively and necessary calculations were performed that were obtained in terms of likelihood, Severity and Risk Index have been shown Tabular Format in Table 6.6 below.

**Table 6.6:** Likelihood, Severity and Hazard values for different waste types of IGMC Hospital.

| Waste Type | Likelihood Index | Severity Index | Hazard Index |
|---|---|---|---|
| Infectious Waste | 0.93 | 0.89 | 0.83 |
| Sharps | 0.83 | 0.79 | 0.65 |
| Anatomical Waste | 0.76 | 0.67 | 0.51 |
| Pharmaceutical and Chemical Waste | 0.69 | 0.61 | 0.43 |

a) Likelihood Index

It was observed that the maximum amount of likelihood for a hazard was observed for Infectious waste followed by waste Sharps, Pharmaceutical and Chemical waste and lastly Anatomical waste. The Results have been plotted in a tabular format above in Table 6.6.

On observation and discussion with the person in charge it was found that maximum Likelihood was for Infectious waste because a large no. of surgical operations and other procedures are carried in the hospital on daily basis as the hospital involves large no. of medical facilities in different fields so the quantity of infectious waste produced on the daily basis was quite high and so it was more likely that the infections could spread rapidly and lead to a hazard. The second highest likelihood was observed for the waste sharps as being handled in large quantity it had possibility of getting pricked into the hands of person even if precautionary measures like gloves were used so the likelihood of sharps piercing into the hands of person handling this type of waste and leading to injury and infections is high. The third highest likelihood was observed for the anatomical waste because the placenta and other body organs had possibility of spread of infections that might lead to serious diseases. Lastly the least likelihood was observed of Pharmaceutical and Chemical Waste because of the possibility of these harmful chemicals used in testing procedures to spill and cause burns, intoxication or injuries to the person handling the chemicals The detailed description for the analysis for likelihood of the waste types for IGMC Hospital has been attached in the **'Appendix B'** under heading **'B.1 (1) Matrix Method for Calculation of Likelihood Index**

b) Severity Index

It was observed that the maximum amount of severity for a hazard caused by these waste types would be of Sharps followed by Infectious waste, Pharmaceutical and Chemical waste and lastly Anatomical waste. The Results have been plotted in a tabular format above in Table 6.6.

It was observed that the maximum amount of severity for a hazard caused by these waste types would be of Infectious waste followed by Sharps, Anatomical waste and lastly Pharmaceutical and Chemical waste. It was observed that maximum severity was observed in case of Infectious waste, as the consequences associated with waste could be from minor to deadly. It could lead to minor infections such as cholera or typhoid fever but in worse cases may lead to HIV, Poliomyelitis, and Rabies leading to a painful death of the infected person. The second highest severity was for sharps because the consequences associated with sharps were severe it could range from minor infections to even spread of deadly infectious diseases. The third highest severity was observed for anatomical waste as the consequences associated with it could be hazardous. The least severity was observed in case of Pharmaceutical and Chemical Waste as the use of the chemicals on daily basis was large but was limited to a little quantity for every testing procedure so the risk associated was much less. The detailed description for the analysis for Severity of the waste types for IGMC Hospital has been attached in the **'Appendix B'** under sheet heading **'B.1 (2) Calculation of Severity Index for IGMC Hospital, Shimla'**.

c) Hazard Index

On analysis of Index for Severity and Likelihood, calculated above it was observed that the most risky waste type was Infectious waste followed by Sharps, Pharmaceutical and Chemical waste and lastly Anatomical waste. The Results have been plotted in a tabular format above in Table 6.6.

It was observed that the overall risk was maximum in case of Infectious waste because the severity calculated was highest for the Infectious waste and after product of severity and likelihood the overall risk was obtained to be highest. The next highest risk was observed to be associated with waste sharps as the likelihood and severity both were maximum in case of sharps. The third higher risk was associated with Anatomical waste as the likelihood value was less but the severity value was higher for the waste type. The lowest risk was obtained for Pharmaceutical and Chemical Waste because of the lower value of Severity associated with it.

The Matrix method was used for the calculation of Likelihood and Severity of the various waste types but rather simple calculations were applied to the results obtained from Matrix method for Likelihood and Severity. The results of the likelihood for a particular waste type was multiplied with the Severity value for that waste type to obtain the hazard for that waste type.

The detailed description of calculation for Hazard Index of the waste types for IGMC Hospital has been attached in the '**Appendix B'** under sheet heading **'B.4 Hazard Index for IGMC Hospital, Shimla'**.

d) Ranking

The Likelihood and Severity for each waste type was plotted in the Matrix on scale of 0-1 and necessary zone for each waste type was determined as low, medium and high respectively. The necessary markings were made as 'S' for sharps, 'I' for infectious waste, 'P' for pharmaceutical and chemical waste and 'A' for anatomical waste respectively. The Matrix has been shown below in Figure 6.8.

After appropriate depiction of likelihood and severity in the matrix above ranking of the risk was done as low medium and high respectively. It was observed that the Sharps, Infectious Waste and Anatomical Waste lied in the High risk range depicted in red color, only pharmaceutical and chemical waste lied in the medium to high risk range

To verify the results obtained above a check was applied wherein the necessary calculations were performed to verify the likelihood and Severity so obtained with the above Matrix method. The results were found to be correct. The necessary sheets for the verification have been attached in the **'Appendix B'** under sheet heading **B.2 and B.3 Alternative Method for verification of Likelihood Index and Severity Index of IGMC Hospital Shimla'**.

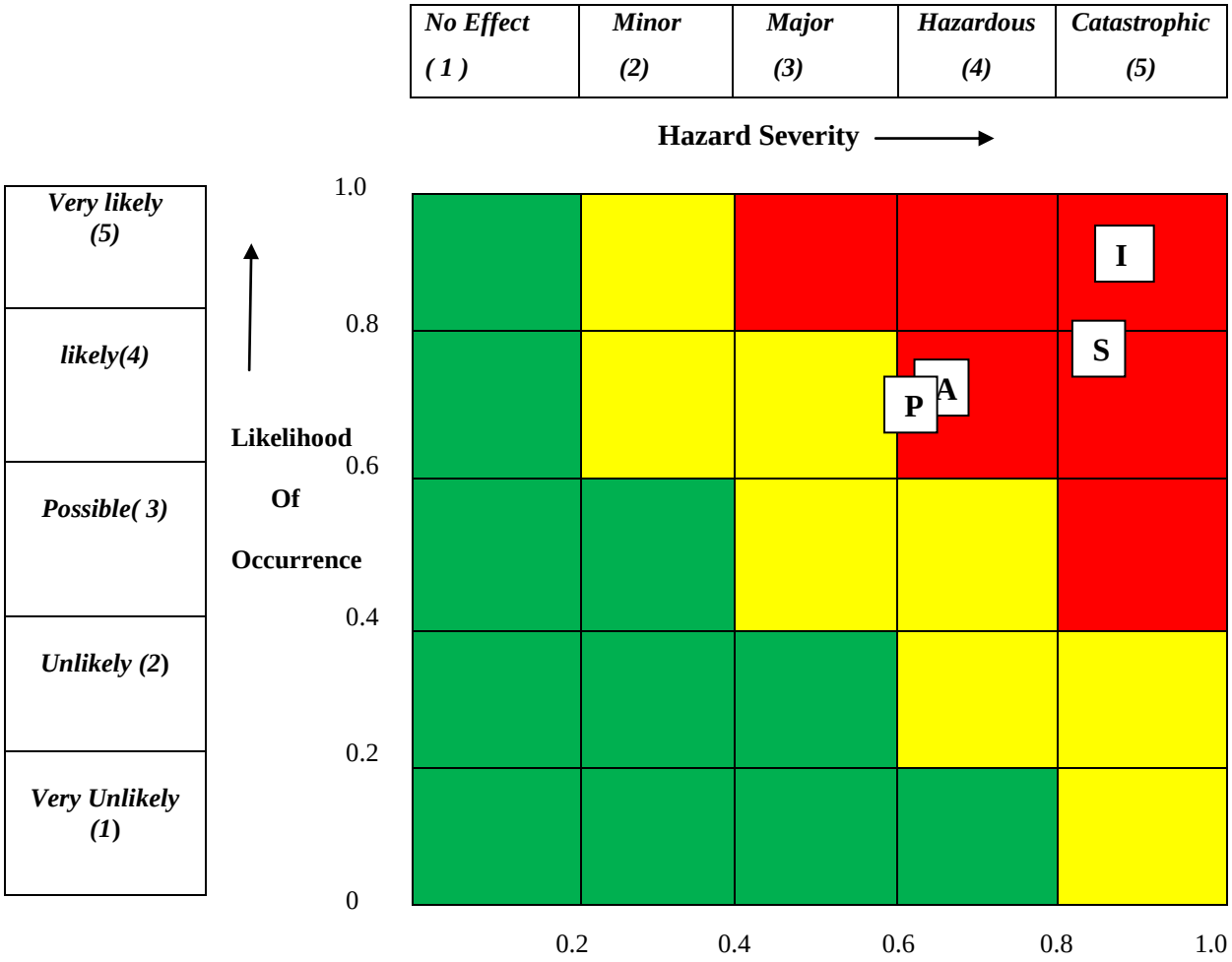


**Figure 6.13:** Matrix for Risk Ranking of different waste type at IGMC Hospital.

### 6.3.2 INDUS Hospital, Shimla

The results were calculated according to the matrix method, in which the results of the Questionnaire -2 filled by hospital staff were taken collectively and necessary calculations were performed and the results were obtained in terms of likelihood, Severity and Risk Index.

**Table 6.7 :** Likelihood, Severity and Risk values for different waste types of IGMC Hospital.

| Waste Type | Likelihood Index | Severity Index | Hazard Index |
|---|---|---|---|
| Sharps | 0.73 | 0.71 | 0.52 |
| Pharmaceutical and Chemical Waste | 0.61 | **0.47** | **0.29** |
| Infectious Waste | 0.56 | **0.63** | **0.35** |
| Anatomical Waste | 0.48 | 0.47 | 0.22 |

The necessary calculations have been shown in Tabular Format in Table 6.7 above.

a) Likelihood Index

On analysis of Questionnaire-2, filled by the doctors and nurses handling and managing the bio medical waste it was observed that the maximum amount of likelihood for a hazard was observed for Sharps followed by Pharmaceutical and Chemical waste, Infectious waste and lastly Anatomical waste. The Results have been plotted in a tabular format above in Table 6.7. On observation and discussion with the person in charge it was found that the waste sharps as being handled in large quantity had possibility of getting pricked into the hands of person handling the waste, even if precautionary measures like gloves were used so the likelihood of sharps piercing into the hands of person handling this type of waste and leading to injury and infections is highest. The second highest likelihood was observed of Pharmaceutical and Chemical Waste because of the possibility of these harmful chemicals used in testing procedures to spill and cause burns, intoxication or injuries to the person handling the chemicals also on discussion it was revealed that testing procedures were carried quite frequently in the hospital so the use of these chemicals was quite high. The third highest likelihood was observed for the Infectious waste comprising of blood from patients, faeces or respiratory tract secretions, but the only infectious components that was observed in the hospital was blood and faeces but that too in small quantity also using appropriate protective gears and precautionary measure only a small possibility was left for these components to cause any infections. Lastly the least likelihood was observed for anatomical waste because of the least no. of operative procedures being carried in the hospital; also the placenta and other body organs were immediately disposed of into containers after necessary disinfection procedures. The detailed description for the analysis for likelihood of the waste types for Indus Hospital has been attached in the **'Appendix B'** under sheet heading **'B.5 (1) Matrix Method for calculation of Likelihood Index for INDUS Hospital, Shimla.**

b) Severity Index

On analysis of Questionnaire-2, filled by the doctors and nurses handling and managing the bio medical waste it was observed that the maximum amount of severity for a hazard caused by these waste types would be of Sharps followed by Infectious waste, Pharmaceutical and Chemical waste and lastly Anatomical waste. The Results have been plotted in a tabular format above in Table 6.7. It was observed that maximum severity was for sharps because the

consequences associated with sharps were severe and dangerous it could range from minor infections to even death. The second highest severity was observed in case of Infectious waste, although the likelihood of waste was less but the consequences associated with waste could be deadly. The third highest severity was observed for Pharmaceutical and Chemical waste because although the consequences associated with it were hazardous but the use of the chemicals was limited to a little quantity so the risk associated was much less. The least severity was observed in case of anatomical waste as the consequence would be limited to infection which is though dangerous but not deadly. The detailed description for the analysis for Severity of the waste types for Indus Hospital has been attached in the **Appendix B** under sheet heading **B.5 (2) Matrix Method for Calculation of Severity Index for INDUS Hospital, Shimla'**.

c) Hazard Index

On calculation of Risk for different waste types by product of Index for Severity and Likelihood, calculated above it was observed that the most risky waste type was Sharps followed by Infectious waste, Pharmaceutical and Chemical waste and lastly Anatomical waste. The Results have been plotted in a tabular format above in Table 6.7.

On calculation it was observed that the overall risk was max in case of sharps as the likelihood and severity both were maximum in case of sharps. The next highest risk was observed to be associated with Infectious waste because the severity calculated was higher for the Infectious waste and after product of severity and likelihood the overall risk was obtained to be higher for infectious waste. The third higher risk was associated with Pharmaceutical and Chemical waste because though the likelihood value was higher for the waste type but the severity value for infectious waste was much higher, so on multiplying the severity and likelihood values to calculate the risk the overall risk obtained was lower for Pharmaceutical and Chemical Waste than for Infectious Waste. The lowest risk was obtained for Anatomical Waste because of the lower values of Severity and risk associated with it. The detailed description of calculation for Hazard Index of the waste types for Indus Hospital has been attached in the '**Appendix B'** under sheet heading **'B.8 Hazard Index for INDUS Hospital, Shimla'**.

d) Ranking

The Likelihood and Severity for each waste type was plotted in the Matrix on scale of 0-1 and necessary zone for each waste type was determined as low, medium and high respectively.

The necessary markings were made as ‘S’ for sharps, ‘I’ for infectious waste, ‘P’ for pharmaceutical and chemical waste and ‘A’ for anatomical waste respectively. The Matrix has been shown below in Figure 6.14.

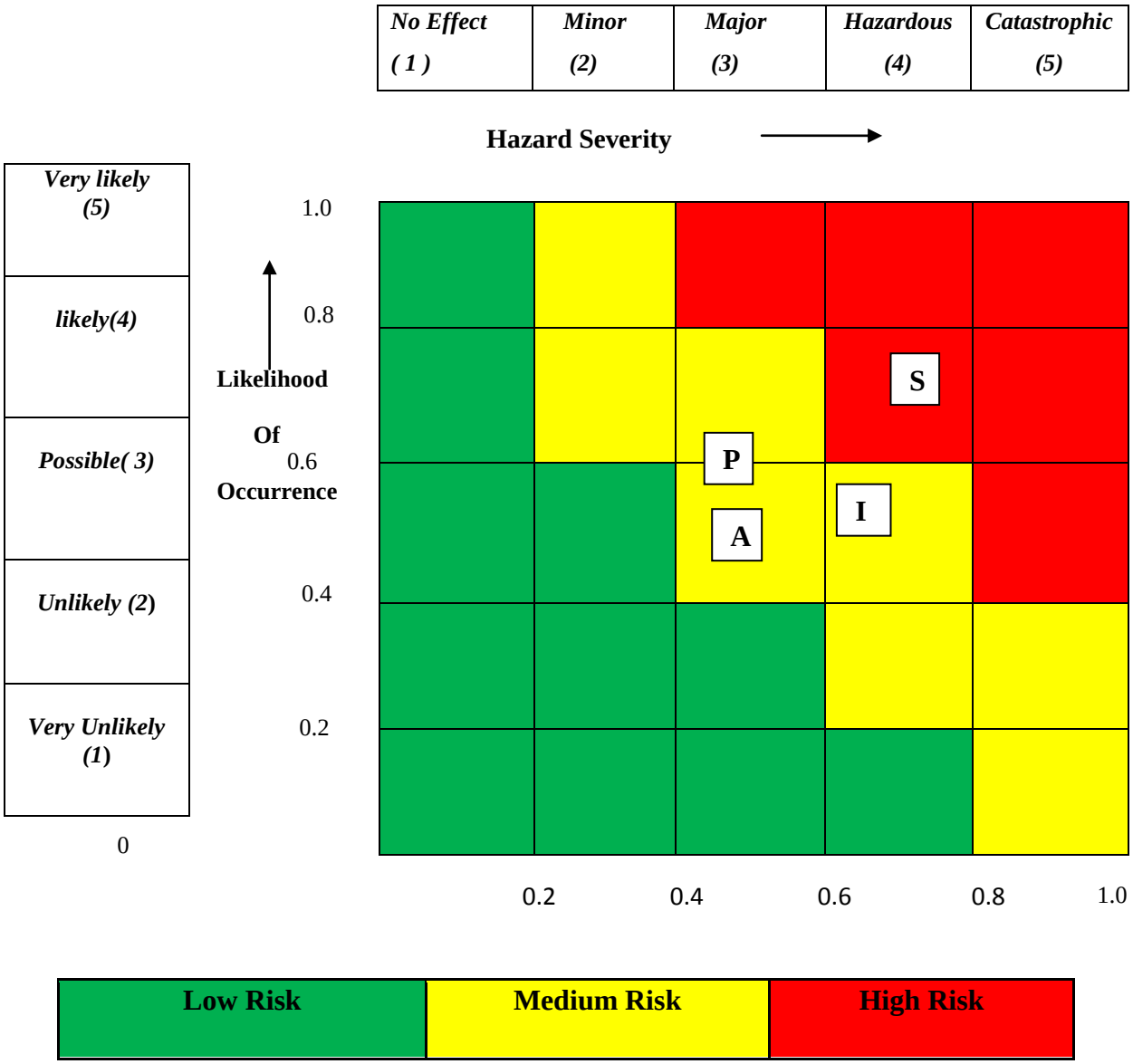


**Figure 6.14:** Matrix for Risk Ranking of different waste type at INDUS Hospital.

After appropriate depiction of likelihood and severity in the matrix above ranking of the risk was done as low medium and high respectively. It was observed that the Sharps lied in the High risk range depicted in red color, the Infectious Waste, Anatomical Waste as well as pharmaceutical and chemical waste lied in the medium risk range depicted by yellow color in the matrix for risk ranking.To verify the results obtained above alternative method was applied in which necessary calculations were performed to verify the likelihood and Severity

so obtained with the Matrix method above. The results were found to be correct. The necessary sheets for the verification has been attached in the **'Appendix B'** under sheet heading **'B.6 and B.7 Alternative Method for verification of Likelihood Index and Severity Index of INDUS Hospital Shimla'**.

### 6.3.3 MAX Super Specialty Hospital, Mohali

The results were calculated according to the matrix method, in which the results of the Questionnaire -2 filled by hospital staff were taken collectively and necessary calculations were performed and the results were obtained in terms of likelihood, Severity and Risk Index. The necessary results have been tabulated below in Table 6.8.

**Table 6.8 :** Likelihood, Severity and Risk values for different waste types of Max Hospital.

| Waste Type | Likelihood Index | Severity Index | Hazard Index |
|---|---|---|---|
| Infectious Waste | 0.75 | 0.79 | 0.59 |
| Sharps | 0.73 | 0.77 | 0.57 |
| Pharmaceutical and Chemical Waste | 0.63 | 0.65 | 0.41 |
| Anatomical Waste | 0.57 | 0.63 | 0.36 |

a) Likelihood Index

On analysis of Questionnaire-2, filled by the doctors and nurses handling and managing the bio medical waste it was observed that the maximum amount of likelihood for a hazard was observed for Infectious waste followed by Sharps, Pharmaceutical and Chemical waste, and lastly Anatomical waste. The Results have been plotted in a tabular format above in Table 6.8. On observation and discussion with the person in charge it was found that maximum Likelihood was for Infectious waste because a large no. of surgical operations and other procedures are carried in the hospital on daily basis as the hospital is a multispecialty Hospital so the quantity of infectious waste produced on the daily basis was quite high and so it was more likely that the infections could spread rapidly and lead to a hazard. The second highest

likelihood was observed for the waste sharps as being handled in large quantity it had possibility of getting pricked into the hands of person even if precautionary measures like gloves were used so the likelihood of sharps piercing into the hands of person handling this type of waste and leading to injury and infections is high. The third highest likelihood was observed for the of Pharmaceutical and Chemical Waste because of the possibility of these harmful chemicals used in testing procedures to spill and cause burns, intoxication or injuries to the person handling the chemicals also on discussion it was revealed that testing procedures were carried quite frequently in the hospital and on a large scale also the labs are quite advanced and modernized so wide variety of chemicals were used and that too quite high in quantity. Lastly the least likelihood was observed for anatomical waste because the placenta and other body organs were immediately disposed of into containers after necessary disinfection procedures and sent to storage area for further transportation to disposal sites also the operative procedures carried for organ removal were quite limited in no so the amount of Anatomical waste produced was low. The detailed description for the analysis for likelihood of the waste types for MAX Hospital has been attached in the '**Appendix B'** under sheet heading **'B.9 (1) Calculation of Likelihood Index for MAX Hospital, Mohali'**.

b) Severity Index

On analysis of Questionnaire-2, filled by the doctors and nurses handling and managing the bio medical Waste. The Results have been plotted in a tabular format above in table 6.8.

It was observed that the maximum amount of severity for a hazard caused by these waste types would be of Infectious waste followed by Sharps, Pharmaceutical and Chemical waste and lastly Anatomical waste. It was observed that maximum severity was observed in case of Infectious waste, as the consequences associated with waste could be from minor to deadly. It could lead to minor infections such as cholera or typhoid fever but in worse cases may lead to HIV, Poliomyelitis, and Rabies leading to a painful death of the infected person. The second highest severity was for sharps because the consequences associated with sharps were severe it could range from minor infections to even spread of deadly infectious diseases. The third highest severity was observed for Pharmaceutical and Chemical waste because although the consequences associated with it were hazardous and the use of the chemicals on daily basis was large but was limited to a little quantity for every testing procedure so the risk associated was much less. The least severity was observed in case of anatomical waste as the consequence would be limited to infection which is though dangerous but not deadly. The

detailed description for the analysis for Severity of the waste types for MAX Hospital has been attached in the **'Appendix B'** under sheet heading **'B.9 (2) Matrix Method for Calculation of Severity Index of MAX Hospital, Mohali'**.

c) Hazard Index

The Matrix method was used for the calculation of Likelihood and Severity of the various waste types but rather simple calculations were applied to the results obtained from Matrix method for Likelihood and Severity. The results of the likelihood for a particular waste type were multiplied with the Severity value for that waste type to obtain the risk for that waste type. On analysis of Index for Severity and Likelihood, calculated above it was observed that the most risky waste type was Infectious waste followed by Sharps, Pharmaceutical and Chemical waste and lastly Anatomical waste. The Results have been plotted in a tabular format above in table 6.8**.**

On calculation it was observed that the overall risk was maximum in case of Infectious waste because the severity calculated was highest for the Infectious waste and after product of severity and likelihood the overall risk was obtained to be highest. The next highest risk was observed to be associated with waste sharps as the likelihood and severity both were maximum in case of sharps. The third higher risk was associated with Pharmaceutical and Chemical waste because the likelihood value and the severity value were higher for the waste type. The lowest risk was obtained for Anatomical Waste because of the lower values of Severity and risk associated with it. The detailed description of calculation for Hazard Index of the waste types for MAX Hospital has been attached in the '**Appendix B'** under sheet heading **'B.12 Hazard Index for MAX Hospital, Mohali'**.

d) Ranking

The Likelihood and Severity for each waste type was plotted in the Matrix on scale of 0-1 and necessary zone for each waste type was determined as low, medium and high respectively. The matrix has been shown below in Figure 6.15.

| Low Risk | Medium Risk | High Risk |
|---|---|---|

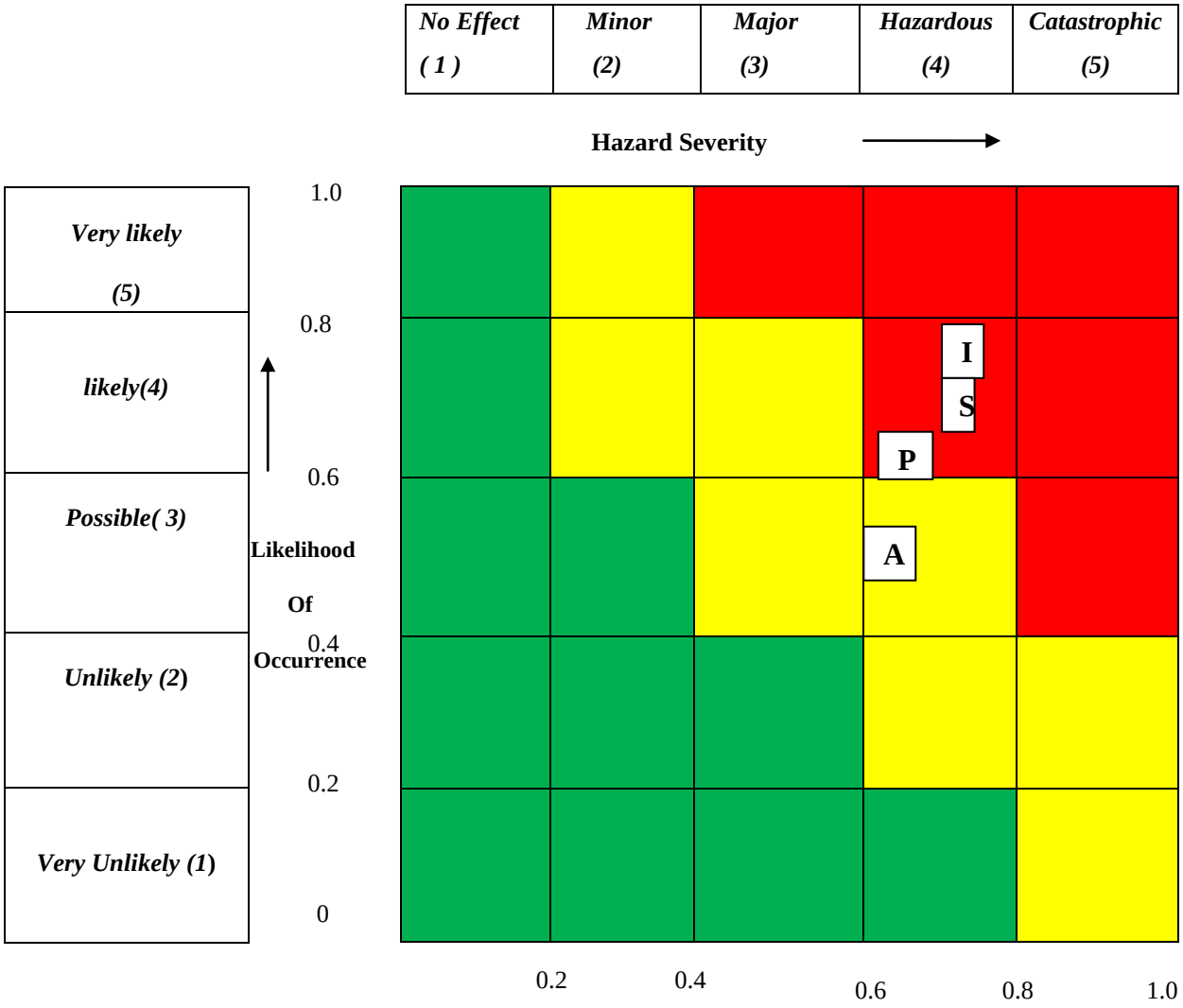


**Figure 6.15:** Matrix for Risk Ranking of different waste type at MAX Hospital.

The necessary markings were made as 'S' for sharps, 'I' for infectious waste, 'P' for pharmaceutical and chemical waste and 'A' for anatomical waste respectively. After appropriate depiction of likelihood and severity in the matrix above ranking of the risk was done as low medium and high respectively. It was observed that the Sharps, Infectious Waste and pharmaceutical and chemical Waste lied in the High risk range depicted in red color, only the Anatomical waste lied in the medium risk range depicted by yellow color in the matrix for risk ranking.

To verify the results obtained above an alternative method were applied in which necessary calculations were performed to verify the likelihood and Severity so obtained with the above Matrix method. The results were found to be correct. The necessary sheets for the checks have

been attached in the '**Appendix B'** under sheet heading **'B.10 and B.11 Alternative method for verification of Likelihood Index and Severity Index for MAX Hospital Mohali**'.

### 6.3.4. IVY Hospital, Mohali

The results were calculated according to the matrix method, in which the results of the Questionnaire -2 filled by hospital staff were taken collectively and necessary calculations were performed and the results were obtained in terms of likelihood, Severity and Risk Index. The necessary results have been tabulated below in Table 6.9

**Table 6.9 :** Likelihood, Severity and Risk values for different waste types of IVY Hospital.

| Waste Type | Likelihood Index | Severity Index | Hazard Index |
|---|---|---|---|
| Sharps | 0.80 | 0.95 | 0.76 |
| Infectious Waste | 0.73 | 0.87 | 0.64 |
| Pharmaceutical and Chemical Waste | 0.67 | 0.76 | 0.51 |
| Anatomical Waste | 0.51 | 0.60 | 0.30 |

a) Likelihood Index

On analysis of Questionnaire-2, filled by the doctors and nurses handling and managing the bio medical waste it was observed that the maximum amount of likelihood for a hazard was observed for Sharps followed by Infectious waste, Pharmaceutical and Chemical waste, and lastly Anatomical waste. The Results have been plotted in a tabular format above in Table 6.9. On observation and discussion with the person in charge it was found that the waste sharps as being handled in large quantity had possibility of getting pricked into the hands of person handling the waste, even if precautionary measures like gloves were used so the likelihood of sharps piercing into the hands of person handling this type of waste and leading to injury and infections is highest. The second highest likelihood was observed for Infectious waste because a large no. of surgical operations and other procedures are carried in the hospital on daily basis as so the quantity of infectious waste produced on the daily basis was quite high and it

was more likely that the infections could spread rapidly and lead to a hazardous consequence. The third highest likelihood was observed for Pharmaceutical and Chemical Waste because of the possibility of these harmful chemicals used in testing procedures to spill and cause burns, intoxication or injuries to the person handling the chemicals also testing procedures were carried quite frequently in the hospital but the quantity of these chemicals used was less for these testing procedures. Lastly the least likelihood was observed for anatomical waste because the placenta and other body organs were immediately disposed of into containers after necessary disinfection procedures and sent to storage area for further transportation to disposal sites also the operative procedures carried for organ removal were quite limited in no so the amount of Anatomical waste produced was low. The detailed description for the analysis for likelihood of the waste types for IVY Hospital has been attached in the **'Appendix B'** under sheet heading **'B.13 (1) Calculation of Likelihood Index for IVY Hospital, Mohali'**.

b) Severity Index

On analysis of Questionnaire-2, filled by the doctors and nurses handling and managing the bio medical waste it was observed that the maximum amount of severity for a hazard caused by these waste types would be of Infectious waste followed by Sharps, Pharmaceutical and Chemical waste and lastly Anatomical waste. The Results have been plotted in a tabular format above in Table 6.9

It was observed that maximum severity was for sharps because the consequences associated with sharps were severe and dangerous it could range from minor infections to even death. The second highest severity was observed in case of Infectious waste, as the consequences associated with waste could be deadly. It could lead to minor infections such as cholera or typhoid fever but in worse cases may lead to HIV, Poliomyelitis, and Rabies leading to a painful death of the infected person. The third highest severity was observed for Pharmaceutical and Chemical waste because although the consequences associated with it were hazardous but the use of the chemicals was limited to a little quantity so the risk associated was much less. The least severity was observed in case of anatomical waste as the consequence would be limited to infection which is though dangerous but not deadly. The detailed description for the analysis for Severity of the waste types for IVY Hospital has been attached in the **'Appendix B'** under sheet heading **'B.13 (2) Matrix Method for Calculation of Severity Index for Max Hospital, Mohali'**.

c) Hazard Index

On analysis of Index for Severity and Likelihood, calculated above it was observed that the most risky waste type was Sharps followed by Infectious waste, Pharmaceutical and Chemical waste and lastly Anatomical waste. The Results have been plotted in a tabular format above in table 6.9

On calculation it was observed that the overall risk was maximum in case of sharps as the likelihood and severity both were maximum in case of sharps. The next highest risk was observed to be associated with Infectious waste because the severity calculated was higher for the Infectious waste and after product of severity and likelihood the overall risk was obtained to be higher for infectious waste. The third high risk was associated with Pharmaceutical and Chemical waste because the likelihood and Severity values was high for the waste type but the overall risk obtained was third highest for Pharmaceutical and Chemical Waste. The lowest risk was obtained for Anatomical Waste because of the lower values of Severity and risk associated with it. The detailed description of calculation for Hazard Index of the waste types for IVY Hospital has been attached in the **'Appendix B'** under sheet heading **'B.16 Hazard Index for IVY Hospital, Mohali'**.

d) Ranking

The Likelihood and Severity for each waste type was plotted in the Matrix on scale of 0-1 and necessary zone for each waste type was determined as low, medium and high respectively. The matrix has been shown below in Figure 6.16.

The necessary markings were made as 'S' for sharps, 'I' for infectious waste, 'P' for pharmaceutical and chemical waste and 'A' for anatomical waste respectively.

It was observed that Sharps, Infectious Waste as well as Pharmaceutical and Chemical Waste all three lied in high range of matrix only Anatomical waste lied in low to medium range of matrix. After appropriate depiction of likelihood and severity in the matrix above ranking of the risk was done as low medium and high respectively. It was observed that the Sharps, Infectious Waste and pharmaceutical and chemical Waste lied in the High risk range depicted in red color, only the Anatomical waste lied in the medium risk range depicted by yellow color in the matrix for risk ranking.

To verify the results obtained above alternative method for verification was applied in which necessary calculations were performed to verify the likelihood and Severity so obtained with

the above Matrix method. The results were found to be correct. The necessary sheet has been attached in the '**Appendix B'** under heading **'B.14 and B.15 Alternative method for verification of Likelihood Index and Severity Index for IVY Hospital Mohali**.

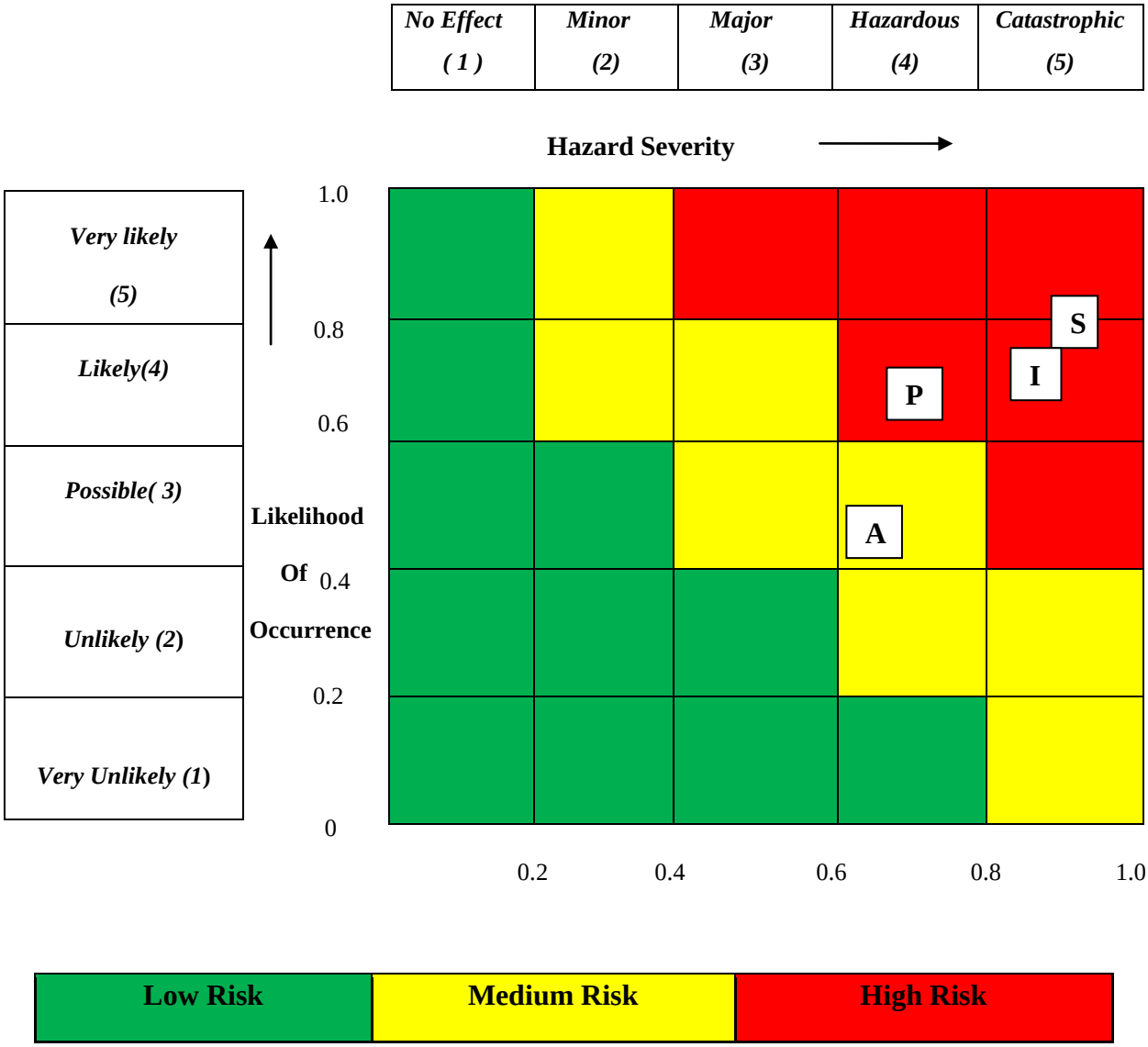


**Figure 6.16:** Matrix for Risk Ranking of different waste type at IVY Hospital.

## 6.4 Inter comparison of PHA Analysis

The inter comparison has been done for the hospitals located in Shimla as well for hospitals located in Chandigarh.

### 6.4.1 IGMC Hospital Shimla and INDUS Hospital Shimla

The PHA Analysis was done for hospitals located in Shimla and the observations and results were compared. Considering the value for Likelihood, Severity and Risk for the hospitals in

Shimla city i.e. the IGMC and INDUS it can be seen that the highest risk at IGMC Hospital was posed by Infectious waste thus demanding maximum care and attention because of the infections that may be caused by the waste kind if not handled properly whereas in case of INDUS Hospital the highest risk posing waste category was Sharps because the sharps can cause the cuts and punctures to persons handling the waste directly and well as the wounds may get contaminated with the pathogens as the needles are used for the patients, therefore are contaminated with their blood thus posing a threat of double risk.

### 6.4.2 MAX Hospital Mohali and IVY Hospital Mohali

In case of the Hospitals at Chandigarh namely the MAX Hospital and the IVY Hospital it was again observed that the maximum risk was posed by Infectious Waste at Max Hospital whereas in Case of IVY Hospital the highest risk posing Category was that of sharps the reason being the same.

## 6.5 Intra comparison of PHA Analysis

On comparing the risk values for all waste types at all the 4 hospitals it could be clearly seen that the highest risk was posed by the Infectious waste at IGMC Hospital with the value of 0.83 followed by sharps at IVY Hospital with a risk value of 0.76. The lowest risk producing category was that of Anatomical Waste at INDUS Hospital due to the least quantity of anatomical parts produced in the hospital therefore posing the least threat. The risk posed by Pharmaceutical & Chemical Waste was variable depending on the number of laboratories and the amount of chemicals being used.

# CHAPTER 7
# DESIGN OF INCINERATOR

## 7.1 Introduction

Sound management of medical waste is very important in today's society to avoid the health risks, improve aesthetic beauty of the society as well as for avoiding any mishap that may result due to the poor management of Bio-Medical Waste. However for promoting efficient Bio-Medical waste management we need to improve the procedures for collection, segregation, storage, transportation and disposal. One of the best methods for detoxification and safe disposal of this kind of waste is Incineration. Incineration is generally defined as the destruction of wastes at relatively high temperatures nearly between 1200 ° C to 1600 ° C but under controlled conditions to detoxify as well as destruct the waste. The products obtained after combustion are mainly $CO_2$, Water and ash. The equipment in which the process is done is called an Incinerator.

Incineration is a very fine technique of Bio-Medical waste disposal and reduces the waste volume and is very useful for combating the problem of landfill in the areas where population is fast growing as the land availability is very low. It is a cleaner and efficient waste disposal technology. The pollutants are reduced to ash which can be contained in a far more efficient way and thereby reduces the load on landfill, but there are still many social, technical and environmental problems associated with incineration.

The basic three types of incinerators available for incineration are:

1. Multiple Chamber (retort and in-line)
2. Controlled Air
3. Rotatory Kiln

Designed Incinerator

The designed incinerator in the project work is a Multiple Chamber Incinerator (controlled air) Incinerator. Combustion of waste in controlled air incinerators occurs in two stages. In the first stage, waste is fed into the primary or lower combustion chamber, which is operated with less than the stoichiometric amount of air required for combustion.

In the second stage, excess air is added to the volatile gases formed in the primary chamber to complete combustion. Because of the low air addition rates in the primary chamber, and corresponding low flue gas velocities (and turbulence), the amount of solids entrained in the

gases leaving the primary chamber is low. Therefore, the majority of controlled air incinerators do not have add-on gas cleaning devices. The line diagram has been displayed below in figure 7.1 to explain the incineration process inside incinerator.

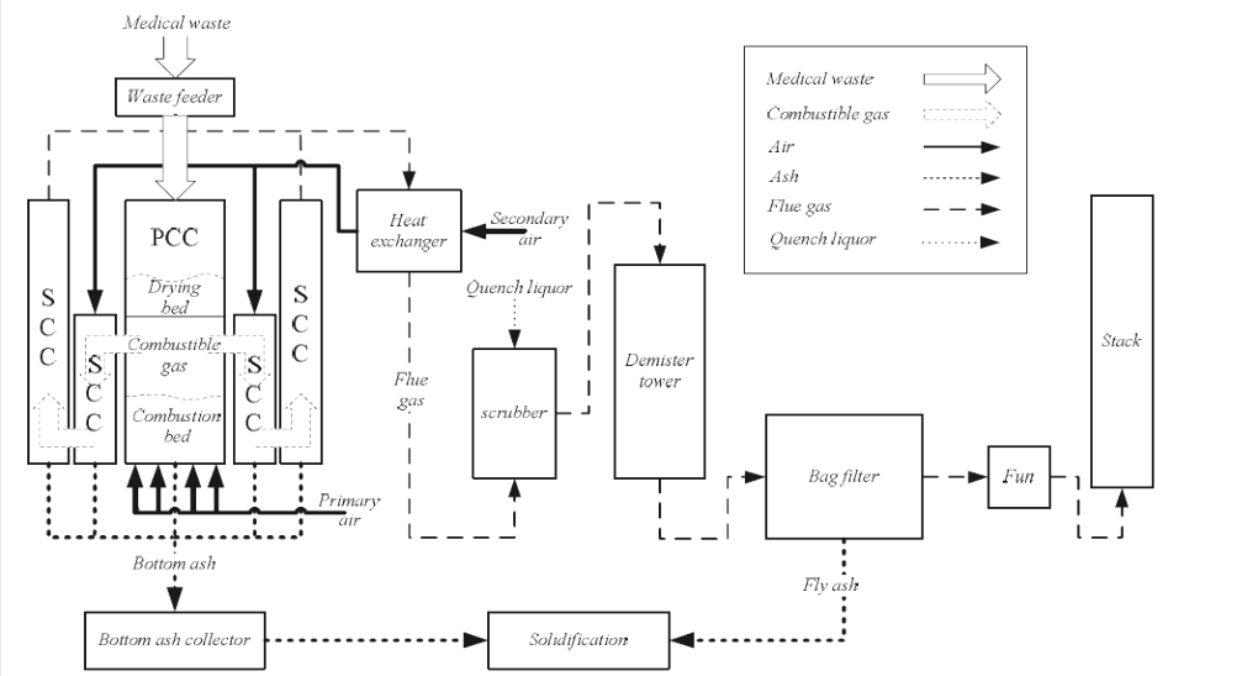


**Figure 7.1:** Schematic diagram of incineration system. [Xie et.al., 2010]

## 7.2 Quantification of Waste

The total quantity of waste generated on per month and per day was quantified to obtain a sample size of waste to be used for designing purpose. The quantification has been shown below in table.

**Table 7.1**: Table for Quantification of Waste for Incinerator Design.

| S.No. | Name of Health Establishment | Quantity of Waste generated/ month | Quantity of Waste generated/ day |
|---|---|---|---|
| 1. | IGMC Hospital, Shimla | 3,012 kg/month | 100.4 kg/day |
| 2. | INDUS Hospital, Shimla | 97.8 kg/month | 3.26 kg/day |
| 3. | MAX Hospital, Mohali | 6,498 kg/month | 216.3 kg/day |
| 4. | IVY Hospital, Mohali | 3,882 kg/month | 129.4 kg/day |

Total Waste generated per month = 13,489.8 kg/month

Total Waste generated per day = 449.36 kg/day

## 7.2 Design of an Incinerator

### 7.2.1 Design of Primary Chamber

For designing of Primary chamber of Multiple Chamber Incinerator under controlled air conditions initially volume of primary chamber is to be determined so 500 kg of waste is dumped and the volume of heap is considered.

Volume of heap = $8m^3$

Assuming suitable depth of 3 m we can find the area of chamber as

Area = Volume/Depth

= 8/3

= 2.66 $m^2$

Assume the ratio of length and breadth as 1.75:1

Therefore L/B = 1.75/1

L = 1.75*B*

Dimensions of Primary Chamber = L*B*H

Area = L*B

2.66 = 1.75 *B***B*

2.66 = 1.75 $B^2$

B = 1.23 m

L = 2.16 m

H = 3 m

### 7.2.2 Heat and Material Balance Sample Calculations

Heat and material balance is an important part of designing of an Incinerator to evaluate the input and output conditions of an Incinerator. It can be used to determine the auxiliary fuel requirements and combustion air requirements or to determine the limitations for Incinerator when charged with known quantity of waste.

Assume Incinerator is to be designed to incinerate 30% of red bags and 70 % of yellow bags (PVC contented 5%) biomedical waste. The waste input is 100 kg of waste per hour, the auxiliary fuel is natural gas, and the waste is ignited and secondary burner is modulated.

The design requirements are as follows:

Secondary Chamber Temperature = 1100 ° C

Flue Gas Residence Time at 1000° C: 1s

Residual oxygen in Flue Gas is 6% minimum.

Step 1: Assumptions

1. The design of Incinerator is based on number of assumptions, the chemical empirical formula, the molecular weight and higher heating values of the components have been taken from specific tables given in design books of Incinerator.
2. According to the site conditions the Input Temperature of the Waste, Fuel ad Air is taken as 15.5 ° C.
3. Air in general contains approximately 23 % oxygen and 77 % Nitrogen by weight.
4. Air contains 0.0132 Kg $H_2O$/Kg dry air at 60% relative humidity and 26.7 dry bulb temperatures.
5. For any ideal gas 1Kg/mole is equal to 22.4 $m^3$ at 0 °C and 101.3 Kpa.
6. Latent heat of vaporization of water at 15.5°C is 2460.3 Kj/Kg.

Step 2: Calculation of Material Input

The table on chemical characteristics of Bio- Medical Waste was considered which shows the chemical characteristics of various kinds of wastes and sound judgment is required to make use of the table for assigning weight percentage for performing calculations.

The red bad contains

Based on an input of 30% of 100 kg/h (i.e., 30 kg/h), the red bag was observed for the kind of waste being input into the bag and the bag was then assumed to have the following composition.

| | | |
|---|---|---|
| Tissue (dry) | $C_5H_{10}O_3$ | = 0.25 * 30 = 7.5 Kg/h |
| Water | $H_2O$ | = 0.1* 30 = 3 Kg/h |
| Ash | - | = 0.05 * 30 = 1.5 Kg/h |
| Swabs | $C_6H_{10}O_5$ | = 0.25 * 30 = 7.5 Kg/h |
| Plastics | $(C_2H_4)$ x | = 0.35 * 30 = 10.5Kg/h |

Total Red Bag = 30.0 kg/h

The yellow bag waste input is 70% of 100 kg/h (i.e. 70 kg/h) and the waste stream was observed and the waste was assumed to have the following composition:

Tissues (Organs) $C_5H_{10}O_3$ = 0.15 * 70 = 10.5 Kg/h

Polyethylene $(C_2H_4)x$ = 0.30 * 70 = 21 Kg/h

Polyvinyl Chloride $(C_2H_3Cl)x$ = 0.20 * 70 = 14 Kg/h

Cellulose $C_6H_{10}O_5$ = 0.35 * 70 = 24.5 Kg/h

Total Red Bag = 70.0 kg/h

Step 3: Calculation of Heat Input of Waste

| | **Compound** | **HHV (Kj/Kg)** | **Input (kg/hr)** | **Total Heat in Kj/h** |
|---|---|---|---|---|
| Tissue | $C_5H_{10}O_3$ | 20,471 | 18 | 3,68,478 |
| Cellulose, Swabs | $C_6H_{10}O_5$ | 18,568 | 32 | 5,94,176 |
| Plastic (Polyethylene - 96%) | $(C_2H_4)_x$ | 46,304 | 31.5 | 14,58,576 |
| PVC 4% | $(C_2H_3Cl)_x$ | 22,630 | 14 | 3,16,820 |
| Ash<br>Moisture | 0<br>$H_2O$ | 0<br>0 | 1.5<br>3 | 0<br>0 |
| **TOTAL** | | | 100 | 27,38,050 |

Step 4: Determination for stochiometric $O_2$ for Waste through equations

1. Tissue $C_5H_{10}O_3 + 6O_2 = 5CO_2 + 5H_2O$

118.1 6(32) 5(44) 5(18)

1.0 1.63 1.86 0.76

Tissue 18 29.34 33.48 13.68

(as fired)

2. Polyethylene $(C_2H_4)x + 3O_2 = 2CO_2 + 2H_2O$

28 3(32) 2(44) 2(18)

1.0 3.43 3.14 1.29

Poly 31.5 108 99 40.6

Ethylene (as fired)

| | | | | | |
|---|---|---|---|---|---|
| 3. PVC | $2(C_2H_3Cl)x$ | $+ 5O_2 =$ | $4CO_2$ | $+ 2H_2O$ | $+ 2HCl$ |
| | 2(62.5) | 5(32) | 4(44) | 2(18) | 2(36.5) |
| PVC | 1.0 | 1.28 | 1.41 | 0.29 | 0.58 |
| (as fired) | 14 | 17.92 | 19.71 | 4.03 | 8.18 |

| | | | | | |
|---|---|---|---|---|---|
| 4. Cellulose | $C_6H_{10}O_5$ | $+ 6O_2 =$ | $6CO_2$ | $+ 5H2O$ | |
| | 162 | 6(32) | 6(44) | 5(18) | |
| | 1.0 | 1.19 | 1.63 | 0.56 | |
| Cellulose | 32 | 38.08 | 52.16 | 17.92 | |
| (as fired) | | | | | |

Hence total Stochiometric $O_2$ required = 193.34 kg/h for burning combustible components of the biomedical waste 95.5kg/h.

Step 5: Determination of Air for Waste Based on 150% Excess

From Step 4 the Stochiometric $O_2$= 193.34 kg/h

Therefore, Stochiometric Air (23% $O_2$) = 193.34*(100/23) = 840.60 kg/h

Total Air required for Waste (150% excess) = (1.5*840.60) + 840.60 = 2101.5 kg/h

Step 6: Material Balance

Total Mass in Waste = 100.0 kg/h

Dry air = 2101.5 kg/h

Moisture in air = 27.73 kg/h (2101.5 x 0.0132) [Step1]

Total Mass In = 2229.23 kg/h

Total Mass Output (assuming complete combustion of waste)

(A) Dry Products from Waste

Air supplied for Waste= 2101.5 kg/h

Lessening Stochiometric air = 840.60 kg/h

Total excess air = 1260.9 kg/h

Add nitrogen from stochiometric air (77%) = 0.77* 840.60 = 647.26 kg/h

Sub Total = 1908.16 kg/h

Add total $CO_2$ from Combustion

$CO_2$formed from $C_5H_{10}O_3$ = 33.48 kg/h

$CO_2$ formed from $(C_2H_4)$ x = 99 kg/h

$CO_2$ formed from ($C_2H_3Cl$) x = 19.71 kg/h

$CO_2$ formed from $C_6H_{10}O_5$ = 52. 16 kg/h

Total Waste Dry products = 2112.51 kg/h

(B) Moisture

$H_2O$ in Waste = 3 kg/h

$H_2O$ from Combustion Reactions = 27.73 kg/h

$H_2O$ in Combustion Air = 80.38 kg/h

Total Moisture =111.11 kg/h

(C) Ash

Ash output = 1.5 kg/h

(D) HCl formed from Waste

HCl formed from ($C_2H_3Cl$) x = 8.18 kg/h

Total Mass Output = 2149.92 kg/h

Step 7: Heat Balance

(A) Total Heat in from Waste = Qi = 27, 38,050 KJ/h [(Step3]

(B) Total Heat is based on Equilibrium temperature of 1100° C

1. )Radiation Loss (5%) of total heat available = 0.05 * 27.38,050

= 1, 36,902.5 kJ/h

2.) Heat to Ash = mCpdT

= (1.5)* (0.831) *(1084.5)

= 1351.83 kJ/h

Where m = weight of ash = 1.5 kg/h

Cp = mean heat capacity of ash = 0.831 kJ/kg. °C (assumed average value)

dT = Temperature difference = (1100-15. 5) °C = 1084. 5°C

Heat required = 1351.83 kj/h

3.) Heat to dry combustion Products = mCpdT

= (2112.51)* (1.086)* (1084.5)

= 24, 88,044.57kJ/h

Where m = weight of combustion products = 2112.51 kg/h

Cp = mean heat capacity of dry products = 1.086 kJ/kg°C (assumed average value)

dT = Temperature difference = (1100-15.5) °C = 1084. 5°C

4.) Heat to moisture = (mCpdT) + (mHv)

(mCpdT)+ (mHv) = (111.11 * 2.347 * 1084. 5) + (111.11 * 2460.3)

= 2, 82,810.67 + 2, 73,363.93

= 5, 56,174.60 kJ/h

Where m = weight of water = 111.11 kg/h

Cp = mean heat capacity of water = 2.347 kJ/kg. °C

dT = (1100-15. 5) °C = 1084. 5°C

Hv = latent heat of vaporizations of water = 2460.3 kJ/kg

Total Heat Out (Qo) = sum of (1,2,3&4) = 31,82,473.5 kJ/h

Net Balance = Qi - Qo

= 27, 38,050 – 31, 82,473.5

= -444,423.5 kJ/h (deficiency)

Auxiliary fuel must be supplied to achieve Design temperature of 1100°C.

Step 8: Required Auxiliary Fuel to Achieve 1100°C

i) Total heat required from fuel = 444,423.5 + 5% radiation loss = 4, 66,644.68 kJ/h

ii) Available heat (net) from natural gas at 1100°C and 20% excess air = 15,805.2 kJ/$m^3$ (assumption)

Natural gas required = 4, 66,644.68 /15,805.2 $m^3$/h = 29.52 $m^3$/h

Step 9: Products of Combustion from Auxiliary Fuel

i) Dry Products from Fuel at 20% Excess Air = 16.0 kg * 29.52 $m^3$ /h $m^3$ fuel = 472.32 kg/h

ii) Moisture From Fuel = (1.59 kg /$m^3$fuel) * 29.52 m $^3$/h = 46.94 kg/h

Step10: Secondary Chamber Volume Required to Achieve One Second Residence Time at 1000 °C

i) Total Dry Products From waste + fuel = 2112.51 kg/h + 472.32 kg/h = 2584.83 kg/h

Assuming dry products have the properties of air and using the ideal gas law, the volumetric flow rate of dry products (dp) at 1000°C (Vp) can be calculated as follows:

Vp = 2584.83 kg dp/h * (22.4 $m^3$)/29 kg dp) * (1273K /273k)* (1 h/3600s)

= 2.59 $m^3$ /s

ii) Total Moisture From waste + fuel = 99.04 kg/h +43.6 kg/h = 142.6 kg/h

Using the ideal gas law, the volumetric flow rate of Moisture at 1000°C (Vm) can be calculated as follows:

Vm = (158. 05 kg $H_2O$/h) * (22.4 $m^3$/18kg H2O) *(1273K/273k) * (1 h/3600s)

= 0.25 $m^3$/s

Total Volumetric Flow Rate = sum of (i & ii)

= 2.59 + 0.25

= 2.84 $m^3$/s

Therefore, the active chamber volume required to achieve one second retention is 2.84 $m^3$ ('dead' areas – with little or no flow should not be included in the retention volume). It should be noted that in sizing the secondary chamber to meet the one second retention time required, the length of chamber should be calculated from the flame front to the location of the temperature sensing device.

K = °C + 273

Step 11: Residual Oxygen in the Flue Gas

Residual $O_2$ (% $O_2$) in Flue gas can be determined by

Excess Air = % $O_2$ / (21% - %$O_2$)

150/100 = % $O_2$ / (21% - %$O_2$)

1.5(21%- %$O_2$) = %$O_2$

0.315 - 1.5 % $O_2$ = % $O_2$

0.315- 1.5 % $O_2$ = % $O_2$

0.315 = 2.5 % $O_2$

% $O_2$ = (0.315/2.5)*100

= (0.315/2.5)*100

= 12.6

# CHAPTER 8
# CONCLUSIONS

The objectives of the present study were i) Biomedical waste generation and management in major hospitals in Shimla city. ii) Comparison of the two large scale Public Sector and Private sector hospitals. iii) Risk Assessment according to Preliminary Hazard Analysis (PHA). iv) Design of an Incinerator for mass burning of bio- medical waste. The Bio- Medical Waste Generation and Management of Public and Private Sector Hospitals were discussed and their comparison was done in this context in terms of waste generation and their management. Further as a part of management risk analysis was done using *PHA*. The Incinerator was also designed as a part of waste management for efficient disposal practice.

Keeping these broad objectives in mind two sets of questionnaires were prepared, the first questionnaire was prepared for determining the waste generation and management practice and the second questionnaire was prepared for risk assessment of Risky Healthcare Wastes. The suitable assumptions and calculations were made to the waste generated in different hospitals for carrying the design of Incinerator. The following conclusions were then drawn for the generation of waste, the waste imposing maximum risk and the hospital showing most efficient waste management.

## 8.1 Waste Generation and Management

For Waste Generation and Management following conclusions were made from the study

8.1.1. The waste generation was determined for both public and private sector hospitals in Shimla city, IGMC and INDUS respectively, it was concluded that the Maximum waste generation was associated with IGMC Hospital because the hospital offers wide range of specializations in various medical fields and large patient inputs.

8.1.2. In case of Private sector hospitals in Chandigarh namely MAX Hospital and IVY Hospital the maximum waste production was recorded in MAX Hospital due to the fact that the hospital is a multi-specialty Hospital and thus offers a wide range of treatment in many sectors of medical field.

8.1.3. The highest waste producing category in both the hospitals was Type-3 (Blue Bag) comprising of tubing, catheters, empty glucose bottles, IV Sets, plastic syringes and urine bags.

8.1.4. The highest waste producing category when compared in all the four hospitals was

Type-3 (Blue Bag) comprising of tubing, catheters, empty glucose bottles, IV Sets, plastic syringes and urine bags.

8.1.5. Though the waste management was carried in each hospital efficiently but the most efficient waste management techniques were observed to be followed at MAX Hospital Mohali right from the point of generation to the point of storage and disposal.

## 8.2 Preliminary Hazard Analysis (PHA)

The Risk analysis was done for the Risky Healthcare Wastes produced in the Hospitals using *P.H.A.* and the following conclusions were made from the study.

8.2.1. In case of PHA Analysis the maximum risk was found to be associated with Infectious Waste at IGMC Hospital, with a high risk value of 0.83 falling in the high risk zone indicated with red color in the risk matrix.

8.2.2. The second highest risk was observed for Sharps at IVY Hospital with a risk value of 0.64 falling in the medium risk zone indicated with yellow color in the risk matrix.

8.2.3. The third highest risk was found to be associated with Anatomical Waste with a risk value of 0.51 falling in the medium risk zone indicated with yellow color in the risk matrix.

8.2.4. The least risk was observed to be for Pharmaceutical & Chemical Waste with a risk value of 0.41 falling in the low risk zone indicated with green color on risk matrix.

## 8.3 Design of an Incinerator

For design of Incinerator and the following conclusions were made from the results obtained

8.3.1. Dimensions of Primary Chamber were drawn to be Length = 2.16 m, Breadth= 1.23 m and Height = 3 m.

8.3.2. From the design the volume of secondary chamber is found to be 2.84 $m^3$ with a detention time of 1sec.

8.3.3. From the heat balance analysis, total heat input is found to be 27, 38,050 kj/hr and total heat output is found to be 31, 82,473.5 kj/hr and therefore a deficiency of 444,423.5 kj/hr incurred and hence this deficiency should nullified by supplying an auxiliary fuel to achieve the design temperature of 1100 ° C.

8.3.4. From the analysis it is found out that an additional amount of 29.52 $m^3$/h natural, gas is required to nullify the deficit and to achieve a design temperature of 1100 $^{o}$C.

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# APPENDIX A

## A.1 Questionnaire - 1 for study of Bio Medical Waste Management of Hospitals.

COMPARISON

OF

BIO-MEDICAL WASTE MANAGEMENT

FOR

PUBLIC AND PRIVATE SECTOR HOSPITALS

QUESTIONNAIRE –1

PROJECT IMPLEMENTATION ORGANIZATIONS

a) IGMC Hospital, Shimla

b) INDUS Hospital, Shimla

c) MAX Super Specialty Hospital, Mohali

d) IVY Hospital, Mohali

e) Government Medical College and Hospital, Sector 32, Chandigarh

1) What is the procedure which is being applied for the waste handling and collection of waste in the various units in the hospitals?

2) What happens to the various categories of the waste such as sharps, anatomical waste, pathological waste and infectious waste etc?

3) What are the various kinds of containers or bags which are used for the different categories of wastes?

4) Where is the main area of storage of waste before disposal?

5) Are proper coats and protective gears such as masks, gloves and boots being used by the workers collecting, segregating, storing and disposing wastes?

6) Do you have a waste management strategy or team monitoring and supervising waste management plans being followed?

7) Are there any rules and regulations being followed in the hospital in accordance with the guidelines issued under biomedical waste (management and handling) rules issued by the government?

Additional Questions Considered

8) Are different kinds of waste collected differently?

9) Is there any segregation procedure at the point of generation of waste or before disposal?

10) Is collected waste stored differently and out of hospital campus?

11) Is the designated place of storage of waste a restricted site?

12) Are any personnel training or instructions being given to the workers handling waste or personnel monitoring and supervising the waste management practices?

13) Are the workers designated for handling the waste restricted to only waste handling purpose or being employed for other patient care works?

**A.2 Questionnaire- 2 for Risk Ranking.**

COMPARISON

OF

BIO-MEDICAL WASTE MANAGEMENT

FOR

PUBLIC AND PRIVATE SECTOR HOSPITALS

QUESTIONNAIRE -2

PERSONNEL MEMORANDUM

NAME ……...

PLACE ……..

DESIGNATION ……

TOTAL SERVICE ……

PROJECT IMPLEMENTATION ORGANIZATIONS

a) IGMC Hospital, Shimla

b) INDUS Hospital, Shimla

c) MAX Super Specialty Hospital, Mohali

d) IVY Hospital, Mohali

e) Government Medical College and Hospital, Sector 32, Chandigarh

Matrix Evaluation for Risk ranking and follow up actions For Different Categories of Waste.

| | | **Hazard Severity** | | | | |
|---|---|---|---|---|---|---|
| | | **No Effect 1** | **Minor 2** | **Major 3** | **Hazardous 4** | **Catastrophic 5** |
| **Likelihood Of Occurrence** | ***Very Unlikely(A) 1*** | **Low** | **Low** | **Low** | **Low** | **Medium** |
| | ***Unlikely(B) 2*** | **Low** | **Low** | **Low** | **Medium** | **Medium** |
| | ***Possible(C) 3*** | **Low** | **Low** | **Medium** | **Medium** | **High** |
| | ***Likely (D) 4*** | **Low** | **Medium** | **Medium** | **High** | **High** |
| | ***Very Likely (E) 5*** | **Low** | **Medium** | **High** | **High** | **High** |

Severity of Consequence Criteria

| | |
|---|---|
| No effect | Has no effect on health |
| Minor | Minor injury |
| Major | Major injury |
| Hazardous | Serious or fatal injury |
| Catastrophic | Death |

Preliminary Hazard Analysis Applied For Risky Healthcare Waste in Hospitals.

| **HCRW** | **Potential hazards Elements** | **Probable Causes** | **Accidental events** | **Likelihood** | **Severity** |
|---|---|---|---|---|---|
| Infectious waste | Blood from patients Contaminated. Feces from patients infected. Respiratory tract secretions from patients infected. | Contact Inhalation | Infection (HIV, viral hepatitis, brucellosis, Typhoid fever, enteritis, cholera, TB, anthrax, rabies, poliomyelitis, etc.). | | |
| Human anatomical waste | Tissue waste Removed organs Amputated body parts Placentas, etc… | Contact | Infection | | |
| Sharps | Needles, Broken glassware, Ampoules, Scalpel blades, Lancets, Vials without content | Punctures and Cuts Infect the wounds | Injury Infection | | |
| Pharmaceutical & chemical waste | Chemical or pharmaceutical substance(flammable, corrosive, toxic) | Contact Absorption Inhalation Ingestion | Intoxication, Injuries and burns | | |

Signature …….

Date …….

# APPENDIX B

## B.1 Matrix Method for Calculation of Likelihood Index and Severity Index of IGMC Hospital Shimla.

Maximum Sample Size (N) = 15 persons

Maximum Ranking for Matrix (A) = 5

Percentage Calculation = [sum of rankings/ {max. sample size (N)*max. ranking (A)}]*100

1. Calculation for Likelihood Index.

| No. of Persons | A | B | C | D | E | F | G | H | I | J | K | L | M | N | O | Total | Percentage Calculation |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Infectious Waste | 5 | 4 | 5 | 5 | 4 | 5 | 5 | 4 | 5 | 5 | 4 | 5 | 5 | 5 | 4 | 70 | 93.33 |
| Anatomical Waste | 4 | 4 | 3 | 5 | 3 | 4 | 4 | 3 | 3 | 4 | 4 | 4 | 5 | 3 | 4 | 57 | 76.00 |
| Sharps | 5 | 5 | 4 | 5 | 5 | 4 | 4 | 4 | 4 | 4 | 3 | 3 | 3 | 4 | 5 | 62 | 82.67 |
| Pharm. & Chemical Waste | 3 | 3 | 3 | 3 | 3 | 5 | 3 | 3 | 3 | 5 | 4 | 4 | 4 | 3 | 3 | 52 | 69.33 |

2. Calculation for Severity Index.

| No. of Persons | A | B | C | D | E | F | G | H | I | J | K | L | M | N | O | Total | Percentage Calculation |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Infectious Waste | 4 | 4 | 5 | 5 | 5 | 4 | 4 | 4 | 4 | 4 | 5 | 4 | 5 | 5 | 5 | 67 | 89.33 |
| Anatomical Waste | 4 | 3 | 3 | 5 | 4 | 3 | 3 | 4 | 3 | 3 | 4 | 4 | 2 | 2 | 3 | 50 | 66.67 |
| Sharps | 4 | 4 | 5 | 5 | 4 | 4 | 5 | 5 | 5 | 2 | 4 | 4 | 1 | 5 | 4 | 59 | 78.67 |
| Pharm. & Chemical Waste | 3 | 3 | 3 | 3 | 4 | 5 | 3 | 2 | 2 | 1 | 4 | 4 | 3 | 3 | 3 | 46 | 61.33 |

**B.2 Alternative method for verification of Likelihood Index of IGMC Hospital Shimla.**

Highest grading (A) = 5

Sample size (N) = 15

Likelihood count (a) = 1, 2, 3, 4, 5….

No of persons referring to particular count (n) = n

Likelihood Index (LI) = ∑an/AN

1. Likelihood Index for Infectious Waste

| Likelihood count (a) | No of persons referring to particular count (n) | a*n |
|---|---|---|
| 1 | 0 | 0 |
| 2 | 0 | 0 |
| 3 | 0 | 0 |
| 4 | 5 | 20 |
| 5 | 10 | 50 |
| | ∑an | 70 |
| | L.I. | 0.93 |

2. Likelihood Index for Anatomical Waste

| Likelihood count (a) | No of persons referring to particular count (n) | a*n |
|---|---|---|
| 1 | 0 | 0 |
| 2 | 0 | 0 |
| 3 | 5 | 15 |
| 4 | 8 | 32 |
| 5 | 2 | 10 |
| | ∑an | 57 |
| | L.I. | 0.76 |

3. Likelihood Index for Sharps.

| Likelihood count (a) | No of persons referring to particular count (n) | a*n |
|---|---|---|
| 1 | 0 | 0 |
| 2 | 0 | 0 |
| 3 | 3 | 9 |
| 4 | 7 | 28 |
| 5 | 5 | 25 |
| | ∑an | 62 |
| | L.I. | 0.83 |

4. Likelihood Index for pharmaceutical and chemical waste.

| Likelihood count (a) | No of persons referring to particular count (n) | a*n |
|---|---|---|
| 1 | 0 | 0 |
| 2 | 0 | 0 |
| 3 | 10 | 30 |
| 4 | 3 | 12 |
| 5 | 2 | 10 |
| | ∑an | 52 |
| | L.I. | 0.69 |

**B.3 Alternative method for verification of Severity Index of IGMC Hospital Shimla.**

Highest grading (A) = 5

Sample size (N) = 15

Severity count (a) = 1, 2, 3, 4, 5….

No of persons referring to particular count (n) = n

Severity Index (S.I.) = ∑an/AN

1. Severity Index for Infectious Waste.

| Severity count (a) | No of persons referring to particular count (n) | a*n |
|---|---|---|
| 1 | 0 | 0 |
| 2 | 0 | 0 |
| 3 | 0 | 0 |
| 4 | 8 | 32 |
| 5 | 7 | 35 |
| | ∑an | 67 |
| | S.I. | 0.89 |

2. Severity Index for Anatomical Waste

| Severity count (a) | No of persons referring to particular count (n) | a*n |
|---|---|---|
| 1 | 0 | 0 |
| 2 | 2 | 4 |
| 3 | 7 | 21 |
| 4 | 5 | 20 |
| 5 | 1 | 5 |
| | ∑an | 50 |
| | S.I. | 0.67 |

3. Severity Index for Sharps.

| Severity count (a) | No of persons referring to particular count (n) | a*n |
|---|---|---|
| 1 | 1 | 1 |
| 2 | 1 | 2 |
| 3 | 1 | 3 |
| 4 | 7 | 28 |
| 5 | 5 | 25 |
| | ∑an | 59 |
| | S.I. | 0.79 |

4. Severity Index for Pharmaceutical and Chemical Waste.

| Severity count (a) | No of persons referring to particular count (n) | a*n |
|---|---|---|
| 1 | 1 | 1 |
| 2 | 2 | 4 |
| 3 | 8 | 24 |
| 4 | 3 | 12 |
| 5 | 1 | 5 |
| | ∑an | 46 |
| | S.I. | 0.61 |

**B.4 Hazard Index of IGMC Hospital Shimla.**

Hazard Index = Likelihood For the particular waste * Severity for particular waste.

H.I. = S.I.*L.I.

1. Hazard Index for Infectious Waste.

| | |
|---|---|
| S.I. | 0.89 |
| L.I. | 0.93 |
| H.I. | 0.83 |

2. Hazard Index for Anatomical Waste.

| | |
|---|---|
| S.I. | 0.67 |
| L.I. | 0.76 |
| H.I. | 0.51 |

3. Hazard Index for Sharps.

| | |
|---|---|
| S.I. | 0.79 |
| L.I. | 0.83 |
| H.I. | 0.65 |

4. Hazard Index for Pharmaceutical and Chemical Waste.

| | |
|---|---|
| S.I. | 0.61 |
| L.I. | 0.69 |
| H.I. | 0.43 |

**B.5 Matrix Method for Calculation of Likelihood Index and Severity Index of INDUS Hospital Shimla.**

Maximum Sample Size (N) = 15 persons

Maximum Ranking for Matrix (A) = 5

Percentage Calculation = [sum of rankings/ {max. sample size (N)*max. ranking (A)}]*100

1. Calculation for Likelihood Index

| No. of Persons | A | B | C | D | E | F | G | H | I | J | K | L | M | N | O | Total | Percentage Calculation |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Infectious Waste | 1 | 1 | 1 | 2 | 2 | 2 | 3 | 3 | 3 | 3 | 4 | 4 | 4 | 5 | 4 | 41 | 56.00 |
| Anatomical Waste | 2 | 1 | 1 | 3 | 3 | 1 | 4 | 3 | 2 | 3 | 2 | 3 | 3 | 3 | 2 | 34 | 48.00 |
| Sharps | 1 | 1 | 3 | 5 | 1 | 3 | 5 | 5 | 5 | 5 | 4 | 4 | 3 | 5 | 5 | 54 | 73.33 |
| Pharm. and Chemical Waste | 3 | 1 | 1 | 1 | 5 | 3 | 5 | 4 | 3 | 3 | 5 | 2 | 2 | 3 | 5 | 43 | 61.33 |

2. Calculation for Severity Index

| No. of Persons | A | B | C | D | E | F | G | H | I | J | K | L | M | N | O | Total | Percentage Calculation |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Infectious Waste | 2 | 3 | 3 | 1 | 2 | 4 | 4 | 3 | 3 | 3 | 3 | 4 | 4 | 4 | 3 | 44 | 61.33 |
| Anatomical Waste | 1 | 1 | 1 | 4 | 3 | 3 | 2 | 2 | 2 | 4 | 2 | 3 | 3 | 2 | 2 | 34 | 46.67 |
| Sharps | 2 | 3 | 2 | 2 | 4 | 4 | 4 | 3 | 3 | 4 | 5 | 5 | 3 | 4 | 5 | 51 | 70.67 |
| Pharm. & Chemical Waste | 1 | 2 | 2 | 4 | 3 | 2 | 3 | 2 | 2 | 2 | 3 | 1 | 2 | 2 | 4 | 34 | 46.67 |

**B.6 Alternative method for verification of Likelihood Index of INDUS Hospital Shimla.**

Highest grading (A) = 5

Sample size (N) = 15

Likelihood count (a) = 1, 2, 3, 4, 5….

No of persons referring to particular count (n) = n

Likelihood Index (LI) = ∑an/AN

1. Likelihood Index for Infectious Waste

| Likelihood count (a) | No of persons referring to particular count (n) | a*n |
|---|---|---|
| 1 | 3 | 3 |
| 2 | 3 | 6 |
| 3 | 4 | 12 |
| 4 | 4 | 16 |
| 5 | 1 | 5 |
| | ∑an | 42 |
| | L.I. | 0.56 |

2. Likelihood Index for Anatomical Waste

| Likelihood count (a) | No of persons referring to particular count (n) | a*n |
|---|---|---|
| 1 | 3 | 3 |
| 2 | 4 | 8 |
| 3 | 7 | 21 |
| 4 | 1 | 4 |
| 5 | 0 | 0 |
| | ∑an | 36 |
| | L.I. | 0.48 |

3. Likelihood Index for Sharps.

| Likelihood count (a) | No of persons referring to particular count (n) | a*n |
|---|---|---|
| 1 | 3 | 3 |
| 2 | 0 | 0 |
| 3 | 3 | 9 |
| 4 | 2 | 8 |
| 5 | 7 | 35 |
| | ∑an | 55 |
| | L.I. | 0.73 |

4. Likelihood Index for pharmaceutical and chemical waste.

| Likelihood count (a) | No of persons referring to particular count (n) | a*n |
|---|---|---|
| 1 | 3 | 3 |
| 2 | 2 | 4 |
| 3 | 5 | 15 |
| 4 | 1 | 4 |
| 5 | 4 | 20 |
| | ∑an | 46 |
| | L.I. | 0.61 |

**B.7 Alternative method for verification of Severity Index of INDUS Hospital Shimla.**

Highest grading (A) = 5

Sample size (N) = 15

Severity count (a) = 1, 2, 3, 4, 5….

No of persons referring to particular count (n) = n

Severity Index (S.I.) = ∑an/AN

1. Severity Index for Infectious Waste.

| Severity count (a) | No of persons referring to particular count (n) | a*n |
|---|---|---|
| 1 | 1 | 1 |
| 2 | 2 | 4 |
| 3 | 7 | 21 |
| 4 | 4 | 16 |
| 5 | 1 | 5 |
| | ∑an | 47 |
| | S.I. | 0.63 |

2. Severity Index for Anatomical Waste.

| Severity count (a) | No of persons referring to particular count (n) | a*n |
|---|---|---|
| 1 | 3 | 3 |
| 2 | 6 | 12 |
| 3 | 4 | 12 |
| 4 | 2 | 8 |
| 5 | 0 | 0 |
| | ∑an | 35 |
| | S.I. | 0.47 |

3. Severity Index for Sharps.

| Severity count (a) | No of persons referring to particular count (n) | a*n |
|---|---|---|
| 1 | 0 | 0 |
| 2 | 3 | 6 |
| 3 | 4 | 12 |
| 4 | 5 | 20 |
| 5 | 3 | 15 |
| | ∑an | 53 |
| | S.I. | 0.71 |

4. Severity Index for pharmaceutical and chemical waste.

| Severity count (a) | No of persons referring to particular count (n) | a*n |
|---|---|---|
| 1 | 2 | 2 |
| 2 | 8 | 16 |
| 3 | 3 | 9 |
| 4 | 2 | 8 |
| 5 | 0 | 0 |
| | ∑an | 35 |
| | S.I. | 0.47 |

**B.8 Hazard Index of INDUS Hospital, Shimla.**

Hazard Index = Likelihood For the particular waste * Severity for particular waste.

H.I. = S.I.*L.I.

1. Hazard Index for Infectious Waste.

| | |
|---|---|
| S.I. | 0.63 |
| L.I. | 0.56 |
| H.I. | 0.35 |

2. Hazard Index for Anatomical Waste.

| | |
|---|---|
| S.I. | 0.47 |
| L.I. | 0.48 |
| H.I. | 0.22 |

3. Hazard Index for Sharps.

| | |
|---|---|
| S.I. | 0.71 |
| L.I. | 0.73 |
| H.I. | 0.52 |

4. Hazard Index for Pharmaceutical and Chemical Waste.

| | |
|---|---|
| S.I. | 0.47 |
| L.I. | 0.61 |
| H.I. | 0.29 |

**B.9 Matrix Method for Calculation of Likelihood Index and Severity Index of MAX Hospital Mohali.**

Maximum Sample Size (N) = 15 persons

Maximum Ranking for Matrix (A) = 5

Percentage Calculation = [sum of rankings/ {max. sample size (N)*max. ranking (A)}]*100

1. Calculation of Likelihood Index

| No. of Persons | A | B | C | D | E | F | G | H | I | J | K | L | M | N | O | Total | Percentage Calculation |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Infectious Waste | 4 | 4 | 4 | 3 | 3 | 3 | 4 | 3 | 5 | 3 | 4 | 4 | 4 | 3 | 5 | 56 | 74.67 |
| Anatomical Waste | 2 | 3 | 4 | 2 | 3 | 2 | 4 | 1 | 2 | 2 | 5 | 4 | 3 | 2 | 4 | 43 | 57.33 |
| Sharps | 4 | 4 | 3 | 4 | 3 | 3 | 3 | 3 | 3 | 4 | 4 | 5 | 4 | 5 | 3 | 55 | 73.33 |
| Pharm. & Chemical Waste | 2 | 4 | 3 | 3 | 3 | 5 | 3 | 2 | 3 | 3 | 3 | 3 | 3 | 3 | 4 | 47 | 62.67 |

2. Calculation of Severity Index

| No. of Persons | A | B | C | D | E | F | G | H | I | J | K | L | M | N | O | Total | Percentage Calculation |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Infectious Waste | 4 | 4 | 4 | 4 | 5 | 3 | 4 | 3 | 4 | 5 | 3 | 5 | 4 | 4 | 3 | 59 | 78.67 |
| Anatomical Waste | 4 | 3 | 4 | 4 | 3 | 4 | 4 | 3 | 2 | 2 | 4 | 3 | 3 | 2 | 2 | 47 | 62.67 |
| Sharp Waste | 3 | 3 | 4 | 4 | 4 | 5 | 3 | 3 | 4 | 4 | 4 | 5 | 5 | 2 | 5 | 58 | 77.33 |
| Pharm. & Chemical Waste | 4 | 4 | 4 | 4 | 4 | 4 | 3 | 3 | 3 | 3 | 3 | 3 | 3 | 2 | 2 | 49 | 65.33 |

**B.10 Alternative method for verification of Likelihood Index of MAX Hospital, Mohali.**

Highest grading (A) = 5

Sample size (N) = 15

Likelihood count (a) = 1, 2, 3, 4, 5

No of persons referring to particular count (n) = n

Likelihood Index (LI) = ∑an/AN

1. Likelihood Index for Infectious Waste.

| Likelihood count (a) | No of persons referring to particular count (n) | a*n |
|---|---|---|
| 1 | 0 | 0 |
| 2 | 0 | 0 |
| 3 | 6 | 18 |
| 4 | 7 | 28 |
| 5 | 2 | 10 |
| | ∑an | 56 |
| | L.I. | 0.75 |

2. Likelihood Index for Anatomical Waste.

| Likelihood count (a) | No of persons referring to particular count (n) | a*n |
|---|---|---|
| 1 | 1 | 1 |
| 2 | 6 | 12 |
| 3 | 3 | 9 |
| 4 | 4 | 16 |
| 5 | 1 | 5 |
| | ∑an | 43 |
| | L.I. | 0.57 |

3. Likelihood Index for Sharps.

| Likelihood count (a) | No of persons referring to particular count (n) | a*n |
|---|---|---|
| 1 | 0 | 0 |
| 2 | 0 | 0 |
| 3 | 7 | 21 |
| 4 | 6 | 24 |
| 5 | 2 | 10 |
| | ∑an | 55 |
| | L.I. | 0.73 |

4. Likelihood Index for pharmaceutical and chemical waste.

| Likelihood count (a) | No of persons referring to particular count (n) | a*n |
|---|---|---|
| 1 | 0 | 0 |
| 2 | 2 | 4 |
| 3 | 10 | 30 |
| 4 | 2 | 8 |
| 5 | 1 | 5 |
| | ∑an | 47 |
| | L.I. | 0.63 |

**B.11 Alternative method for verification of Severity Index of MAX Hospital, Mohali.**

Highest grading (A) = 5

Sample size (N) = 15

Severity count (a) = 1, 2, 3, 4, 5….

No of persons referring to particular count (n) = n

Severity Index (S.I.) = ∑an/AN

1. Severity Index for Infectious Waste.

| Severity count (a) | No of persons referring to particular count (n) | a*n |
|---|---|---|
| 1 | 0 | 0 |
| 2 | 0 | 0 |
| 3 | 4 | 12 |
| 4 | 8 | 32 |
| 5 | 3 | 15 |
| | ∑an | 59 |
| | S.I. | 0.79 |

2. Severity Index for Anatomical Waste.

| Severity count (a) | No of persons referring to particular count (n) | a*n |
|---|---|---|
| 1 | 0 | 0 |
| 2 | 4 | 8 |
| 3 | 5 | 15 |
| 4 | 6 | 24 |
| 5 | 0 | 0 |
| | ∑an | 47 |
| | S.I. | 0.63 |

3. Severity Index for Sharps.

| Severity count (a) | No of persons referring to particular count (n) | a*n |
|---|---|---|
| 1 | 0 | 0 |
| 2 | 1 | 2 |
| 3 | 4 | 12 |
| 4 | 6 | 24 |
| 5 | 4 | 20 |
| | ∑an | 58 |
| | S.I. | 0.77 |

4. Severity Index for pharmaceutical and chemical waste.

| Severity count (a) | No of persons referring to particular count (n) | a*n |
|---|---|---|
| 1 | 0 | 0 |
| 2 | 2 | 4 |
| 3 | 7 | 21 |
| 4 | 6 | 24 |
| 5 | 0 | 0 |
| | ∑an | 49 |
| | S.I. | 0.65 |

**B.12 Hazard Index of MAX Hospital, Mohali.**

Hazard Index = Likelihood For the particular waste * Severity for particular waste.

H.I. = S.I.*L.I.

1. Hazard Index for Infectious Waste.

| | |
|---|---|
| S.I. | 0.79 |
| L.I. | 0.75 |
| H.I. | 0.59 |

2. Hazard Index for Anatomical Waste.

| | |
|---|---|
| S.I. | 0.63 |
| L.I. | 0.57 |
| H.I. | 0.36 |

3. Hazard Index for Sharps.

| | |
|---|---|
| S.I. | 0.77 |
| L.I. | 0.73 |
| H.I. | 0.57 |

4. Hazard Index for Pharmaceutical and Chemical Waste.

| | |
|---|---|
| S.I. | 0.65 |
| L.I. | 0.63 |
| H.I. | 0.41 |

**B.13 Matrix Method for Calculation of Likelihood Index and Severity Index of IVY Hospital, Mohali.**

Maximum Sample Size (N) = 15 persons

Maximum Ranking for Matrix (A) = 5

Percentage Calculation = [sum of rankings/ {max. sample size (N)*max. ranking (A)}]*100

1. Calculation of Likelihood Index

| No. of Persons | A | B | C | D | E | F | G | H | I | J | K | L | M | N | O | Total | Percentage Calculation |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Infectious Waste | 3 | 4 | 4 | 3 | 2 | 4 | 2 | 4 | 3 | 5 | 5 | 4 | 3 | 5 | 4 | 55 | 73.33 |
| Anatomical Waste | 2 | 3 | 2 | 2 | 1 | 3 | 1 | 3 | 2 | 3 | 5 | 2 | 3 | 2 | 4 | 38 | 50.67 |
| Sharps | 4 | 4 | 4 | 4 | 3 | 4 | 3 | 4 | 4 | 4 | 4 | 5 | 4 | 5 | 4 | 60 | 80.00 |
| Pharm. and Chemical Waste | 5 | 4 | 4 | 4 | 2 | 4 | 4 | 3 | 4 | 3 | 3 | 3 | 2 | 4 | 5 | 54 | 72.00 |

2. Calculation of Severity Index

| No. of Persons | A | B | C | D | E | F | G | H | I | J | K | L | M | N | O | Total | Percentage Calculation |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Infectious Waste | 4 | 4 | 4 | 4 | 5 | 5 | 4 | 4 | 5 | 4 | 5 | 4 | 4 | 4 | 5 | 65 | 86.67 |
| Anatomical Waste | 3 | 3 | 3 | 3 | 5 | 2 | 2 | 2 | 3 | 2 | 4 | 2 | 4 | 3 | 4 | 45 | 60.00 |
| Sharps | 5 | 5 | 5 | 5 | 5 | 5 | 5 | 5 | 4 | 5 | 4 | 4 | 5 | 5 | 4 | 71 | 94.67 |
| Pharm. & Chemical Waste | 4 | 4 | 4 | 4 | 4 | 4 | 4 | 4 | 4 | 3 | 3 | 3 | 2 | 5 | 5 | 57 | 76.00 |

**B.14 Alternative method for verification of Likelihood Index of IVY Hospital, Mohali.**

Highest grading (A) = 5

Sample size (N) = 15

Likelihood count (a) = 1, 2, 3, 4, 5….

No of persons referring to particular count (n) = n

Likelihood Index (LI) = ∑an/AN

1. Likelihood Index for Infectious Waste.

| Likelihood count (a) | No of persons referring to particular count (n) | a*n |
|---|---|---|
| 1 | 0 | 0 |
| 2 | 2 | 4 |
| 3 | 4 | 12 |
| 4 | 6 | 24 |
| 5 | 3 | 15 |
| | ∑an | 55 |
| | L.I. | 0.73 |

2. Likelihood Index for Anatomical Waste.

| Likelihood count (a) | No of persons referring to particular count (n) | a*n |
|---|---|---|
| 1 | 2 | 2 |
| 2 | 6 | 12 |
| 3 | 5 | 15 |
| 4 | 1 | 4 |
| 5 | 1 | 5 |
| | ∑an | 38 |
| | L.I. | 0.51 |

3. Likelihood Index for Sharps.

| Likelihood count (a) | No of persons referring to particular count (n) | a*n |
|---|---|---|
| 1 | 0 | 0 |
| 2 | 0 | 0 |
| 3 | 2 | 6 |
| 4 | 11 | 44 |
| 5 | 2 | 10 |
| | ∑an | 60 |
| | L.I. | 0.80 |

4. Likelihood Index for pharmaceutical and chemical waste.

| Likelihood count (a) | No of persons referring to particular count (n) | a*n |
|---|---|---|
| 1 | 0 | 0 |
| 2 | 2 | 4 |
| 3 | 4 | 12 |
| 4 | 6 | 24 |
| 5 | 2 | 10 |
| | ∑an | 50 |
| | L.I. | 0.67 |

**B.15 Alternative method for verification of Severity Index of IVY Hospital, Mohali.**

Highest grading (A) = 5

Sample size (N) = 15

Severity count (a) = 1, 2, 3, 4, 5….

No of persons referring to particular count (n) = n

Severity Index (S.I.) = ∑an/AN

1. Severity Index for Infectious Waste.

| Severity count (a) | No of persons referring to particular count (n) | a*n |
|---|---|---|
| 1 | 0 | 0 |
| 2 | 0 | 0 |
| 3 | 0 | 0 |
| 4 | 10 | 40 |
| 5 | 5 | 25 |
| | ∑an | 65 |
| | S.I. | 0.87 |

2. Severity Index for Anatomical Waste.

| Severity count (a) | No of persons referring to particular count (n) | a*n |
|---|---|---|
| 1 | 0 | 0 |
| 2 | 5 | 10 |
| 3 | 6 | 18 |
| 4 | 3 | 12 |
| 5 | 1 | 5 |
| | ∑an | 45 |
| | S.I. | 0.60 |

3. Severity Index for Sharps.

| Severity count (a) | No of persons referring to particular count (n) | a*n |
|---|---|---|
| 1 | 0 | 0 |
| 2 | 0 | 0 |
| 3 | 0 | 0 |
| 4 | 4 | 16 |
| 5 | 11 | 55 |
| | ∑an | 71 |
| | S.I. | 0.95 |

4. Severity Index for pharmaceutical and chemical waste.

| Severity count (a) | No of persons referring to particular count (n) | a*n |
|---|---|---|
| 1 | 0 | 0 |
| 2 | 1 | 2 |
| 3 | 3 | 9 |
| 4 | 9 | 36 |
| 5 | 2 | 10 |
| | ∑an | 57 |
| | S.I. | 0.76 |

**B.16 Hazard Index of IVY Hospital, Mohali.**

Hazard Index = Likelihood For the particular waste * Severity for particular waste.

H.I. = S.I.*L.I.

1. Hazard Index for Infectious Waste.

| | |
|---|---|
| S.I. | 0.87 |
| L.I. | 0.73 |
| H.I. | 0.64 |

2. Hazard Index for Anatomical Waste.

| | |
|---|---|
| S.I. | 0.60 |
| L.I. | 0.51 |
| H.I. | 0.30 |

3. Hazard Index for Sharps.

| | |
|---|---|
| S.I. | 0.95 |
| L.I. | 0.80 |
| H.I. | 0.76 |

4. Hazard Index for Pharmaceutical and Chemical Waste.

| | |
|---|---|
| S.I. | 0.76 |
| L.I. | 0.67 |
| H.I. | 0.51 |