Kurdistan Engineers Union/KEU,
Sulaymaniyah Branch

# Research on Medical Waste Treatment Design

Prepared by Mohammed Ali Karim,

Mechanical Engineer, ID No. 1013

Email: mohammad.ali.sul@gmail.com

Mobile phone: 07701539771

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## 1. Preamble:

Medical waste, which includes hazardous materials produced by healthcare facilities like hospitals, clinics, and laboratories, must be managed and disposed of properly to prevent environmental contamination and protect public health. Unfortunately, many regions lack specialized medical waste treatment industries, leading to tons of hazardous waste being generated daily and improperly disposed of, posing risks to water resources, air quality, and public health. Engineers are working to provide reliable and eco-friendly solutions for medical waste disposal, urging local authorities to prioritize waste management plant implementation. While successful medical waste treatment systems exist in many countries, it is crucial for regions like the KRG area to establish sustainable waste management systems to safeguard public health and the environment. Despite the inevitability of waste generation in healthcare facilities, the lack of awareness regarding proper disposal practices highlights the urgent need for improved waste management strategies to address the health risks associated with medical waste exposure.

Medical waste is a hazardous type of waste produced by hospitals, clinics, health centers, and laboratories. It is crucial to handle and dispose of medical waste properly to prevent environmental and sanitary contamination, as well as public health risks. In many regions, including the one we live in, there is a lack of specialized and reliable medical waste treatment facilities. This results in numerous healthcare establishments, such as hospitals, clinics, laboratories, and blood banks, producing tons of hazardous waste daily, which often ends up polluting water sources, sewers, and the air. Engineers are working towards providing effective and environmentally friendly solutions for medical waste disposal to address this pressing issue. While many countries have successfully implemented medical waste treatment systems, it is essential for cities in the region to establish sustainable waste management practices to protect public health and the environment. The generation of medical waste is inevitable in healthcare facilities, but there is a lack of awareness regarding its hazards and proper disposal methods. Public interest in the health risks associated with medical waste exposure is growing, emphasizing the need for improved waste management practices in healthcare settings.

## 2. Categorization of Medical Waste

The World Health Organization (WHO) estimates that about 15 to 20% of medical waste falls under the category of hazardous materials due to their infectivity (table 1), Figure 1), toxicity, and in some cases, radioactivity. However, the management practices for medical waste vary between countries due to the lack of clear and definitive categorization. Medical waste, also known as hazardous medical waste (HMW), encompasses infectious, toxic, or otherwise dangerous waste generated by medical institutions during healthcare procedures. On the other hand, non-hazardous medical waste (NHMW) includes regular non-infectious waste fractions like municipal solid waste. HMW is typically contaminated with pathogens, posing a risk of infections and diseases if mishandled or improperly disposed of. Moreover, inadequate management of HMW can lead to environmental contamination, polluting land, water, plants, animals, and air, thus facilitating the spread of diseases.

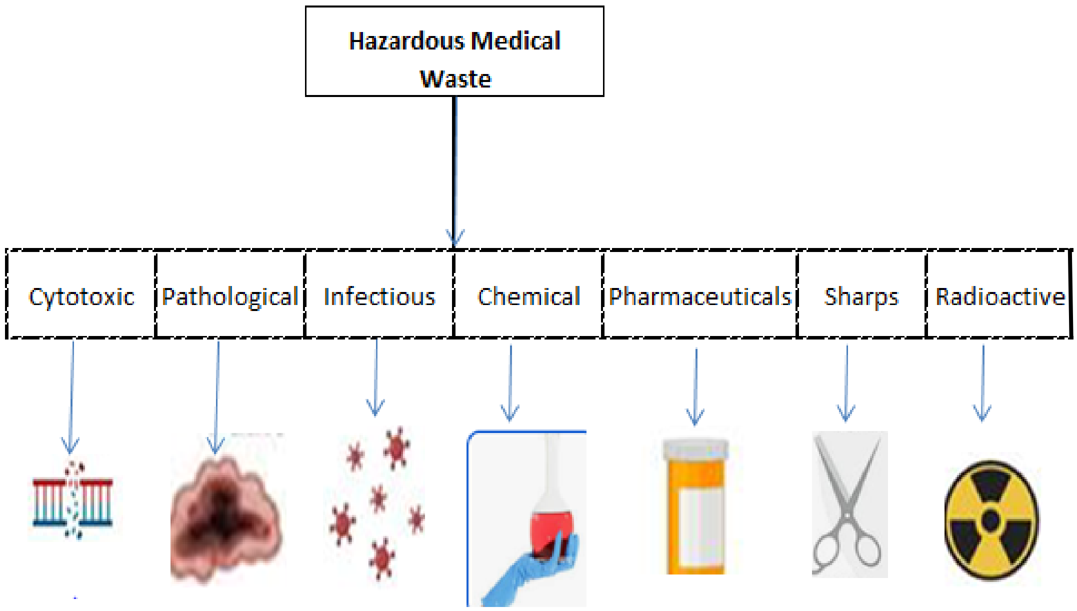


Figure 1 : different types of hazardous and medical waste

Table 1. Healthcare waste categorization according to WHO and the EU

| | Category (Examples) | (WHO) World Health Organization | EU | Source |
|---|---|---|---|---|
| Hazardous | Sharps | Sharps | Sharps | Hospitals, clinics, laboratories, blood banks, nursing homes, veterinary clinics and labs |
| | Organic matter, including body parts and blood | Pathological | Human tissue, body parts, organs, and blood preserves and bags | Hospitals, clinics, labs, mortuary and autopsy facilities, veterinary clinics and labs |
| | Waste with restrictions in collection and disposal due to infectivity | Infectious | Human and Animal Infectious | Hospitals, clinics, and laboratories |
| | Waste with no restrictions or special requirements for collection and disposal due to infectivity (e.g., plasters, casts, dressings, bed sheets, disposable clothing, etc.) | Infectious | Infectious | Hospitals, clinics, and laboratories |
| | Dangerous chemical materials and substances | Chemical | Chemical | Hospitals, clinics, and laboratories |
| | Other chemicals | Chemical | Chemical/ Unused hazardous medicines | Hospitals, clinics, and laboratories |
| | Cytotoxic and cytostatic Medicines | Cytotoxic | Discarded unused medicines | Hospitals and laboratories |
| | Other chemicals | Pharmaceutical | Unused non-hazardous medicines | Hospitals, clinics, and laboratories |
| Nonhazardous | Other chemicals (non-hazardous), Dental clinics (care centres) amalgam waste | Amalgam (tooth filling) waste from dental clinics/centres | Amalgam waste from dental clinics/centres | Dental care centres and clinics |

## 3. Medical waste management practices.

Improper management of medical waste (MW) is a significant issue in various countries and regions. This study aims to evaluate the practices related to the collection, segregation, treatment, and recycling of MW, as well as disposal methods and compliance with regulations in Health-care Facilities (HCFs) and WHO guidelines in Iraq. In addition to the mentioned aspects, HCFs are also responsible for managing leftover medicines and tools from patients. This research necessitates a comprehensive survey, structured questionnaires, on-site interviews, data collection, and observations in collaboration with relevant government agencies. Statistical analysis software may be required for data analysis and scaling. It is crucial to establish a collaborative approach among all stakeholders to implement a safe and effective medical waste management strategy, involving voluntary individuals, NGOs, and other relevant parties. This cooperation should not only focus on legislation and policy development but also on monitoring and enforcement measures.

## 4. Universal regulations for the management of hospital wastages.

Managing hospital waste, especially those with potential infectious and environmental contamination risks, presents a significant challenge in the realms of public health and environmental sustainability. The adoption of the country Convention on Persistent Organic Pollutants (POPs) plays a vital role in combating pollution stemming from persistent chemicals, as mandated in various countries. This global agreement, mirrored in the European context by Regulation (EC) No. 850/2004, concentrates on curtailing the presence of POPs, including dioxins and furans commonly generated by medical waste incinerators. Various studies point out that inadequate handling of infectious hospital waste not only compromises patient care but also poses serious occupational, public, and environmental health hazards. To address these concerns, innovative treatment methods like autoclaving, microwave treatment, and frictional heat treatment have emerged to sanitize medical waste while curbing harmful emissions. Stringent regulations dictate that small and medium-sized incinerators must adhere to emission standards, limiting dioxins and furans to below 0.1 ng TEQ/$m^3$ (Toxic Equivalency Quantity) to safeguard environmental integrity and mitigate health risks associated with exposure to these hazardous substances

## 5. Aims of compliance to international regulations for hospital waste management

The key objectives are:

• Measures for preventing infections: guidelines are in place to stop infections from spreading by managing infectious medical waste safely. This involves correctly sorting, packaging, and handling waste to lessen the chances of contamination.

• Prioritizing the safety of healthcare workers: the rules lay down steps and guidelines to safeguard the well-being of healthcare professionals who come into contact with hospital waste regularly. This involves providing personal protective gear and training on the proper management of waste.

• Focusing on environmental conservation: regulations also concentrate on averting environmental harm caused by medical waste. This includes guaranteeing that waste is treated appropriately to lessen any adverse effects on the environment.

• Optimizing resource use: the provisions aim to enhance the effectiveness of hospital waste **management, for instance**, by sterilizing waste to make it safe for disposal with general municipal waste.

## 6. Methodology(Mode):

The study is directed on determining the understanding of health care workers on MWM and also assesses the current waste management practice of the HCFs. These facilities include general, and specialist hospitals, private hospitals, clinics, and health-care centers located in the towns and villages, The criteria for selecting the HCFs are to be based on their prominence in the society and the willingness of the heads of each facility to provide information. Consents were taken from the heads and structured questionnaires on related issues were administered to the health- care workers. The study employed parametric and non-parametric analysis

| **Generated waste in each HCFs category (kg/day)** | | | | | |
|---|---|---|---|---|---|
| Medical Waste (MW) component | Public Hospitals | Private hospitals | Professional Clinics | Health care centers | Community based Private first aid centers |
| Sharps and needles | 100 | 200 | 20 | 300 | 100 |
| Swabs and absorbents | 100 | 200 | 50 | 80 | 60 |
| Used beddings, IV drips and pharmaceutical products | 200 | 300 | 0 | 50 | 50 |
| Infectious waste | 50 | 150 | 60 | 50 | 40 |
| Plastics, nylon, paper | 200 | 300 | 200 | 90 | 50 |
| Soft tissues | 60 | 100 | 40 | 70 | 80 |
| Leftover Food | 300 | 100 | 0 | 10 | 0 |
| Total | 1010 | 1350 | 370 | 650 | 380 |
| Average generation rate (kg/day) or tons/day | 3760 kg/day ~ 4 tons/day | | | | |

- Table 2. Daily average waste generation and characterization based on assumptions not real.

Technique in this method of data analysis. The survey involves the use of structured questionnaires administered to health-care workers, in-depth interviews and on-site observations which may last for five several months. The main items of the

questionnaire are focused on medical waste segregation, collection, treatment, recycling process, waste disposal and waste management practices. The study also captures health workers understanding on the current MWM. The research instrument will be divided into two parts. First part deals with personal information of the respondent and the type of health-care facility that is currently being considered.
In second part, respondents stated their experiences on the waste management practice in their various health-care facilities. Respondents are Doctors, Nurses, Pharmacists, Attendants and other medical experts. It is proposed That Names of health-care facilities assessed are not mentioned in this report for the purpose of confidentiality. each HCF's administrator before each survey was carried out.

## 7. Data Analysis

Qualitative and quantitative data collected through questionnaire and observation are compiled and analyzed by using percentages and proportions as well as Statistical Department Findings were then combined and presented as a whole assessment. Responses are coded using a linkert scaling * procedure. Procedure combines descriptive analysis and bivariate regression estimation in arriving at the results obtained. The asymmetric distribution of the responses and the asymptotic significance of the hypotheses were verified for statistical significance and distributional effect using chi-square normal distribution test. The variables of analysis were first subjected to descriptive analysis involving frequency distribution and percentages. The regression estimates were utilized to determine nature and direction of the relationship among the dependent and independent variables. Three hypotheses were made prior to conduct the study. The first one was that majority of the HCFs may lack proper arrangement for handling and treatment of medical waste. The second was that, there is inadequate awareness of waste recycling process among medical workers and the third being that, there exist low adoption of MWM practices in most of the local health-care facilities in the study area the study may be taken.

### 7.2 Descriptive analysis

Table 2 shows the nature and average daily amount of medical waste (MW) generated for all HCFs measured at ~4 tons per day solid and soft.

## 8. Design of Treatment Processes

When a waste engineer designs a treatment process, he or she is establishing the sequence of chemical and physical operations needed to produce the desired effect. The design also includes instructions for operating conditions of the , machines, equipment and quantities and flow rates or throughput rates. For instance, emissions rates , size, temperature; electrical loads, target pH, residence time of materials in vessels are all written down as instructions to guide the construction and operation of the treatment process.

**8.1 Aims**

What is your goal? You might think your goal is to convert hazardous medical waste to general innocuous waste through decontamination/inactivation. And that is part of it. But there are other goals and constraints that must be considered. The process designer can never satisfy all needs and desires.

Possible goals:

- efficiency in Disinfection/inactivation;
- Preservation of environment;
- Safeguarding the well being of human including workers;
- efficiency in volume and mass reduction;
- Risk assessment of operations ;
- Amount and verity of secondary wastes produced;
- Demand for Utility services (steam, water, electric power) and their accessibility;
- Required space;
- Location of the treatment site
- Distance to the disposal facility and transportation options;
- Capital costs;
- Operating costs;
- Public acceptability;
- Regulation that must be compiled with.

**9.Emission factors**

The energy sector plays a vital role in the overall health of a nation or local economy and will continue to do so for the long term. Emissions factors are the main tool used to create air quality inventories at different levels of government. They help link the amount of pollutants released to specific activities. Typically, these variables are represented by the ratio of pollutant weight to a specific unit of weight, volume, distance, or time related to the source of the pollutant (e.g., kilograms of particulate matter released per megagram of fuel consumed).

The general relevant equation is:

Emissions (E) = A x EF x (1-ER/100): or

Emissions = Activity rate x Emission factor x overall emission reduction efficiency %(1-ER/100)

Release to Air

Category 1, the default emission factor of 3,500 µg TEQ/t of waste burned was derived from a flue gas flow rate of about 10,000 $Nm^3/t$ MSW.

Category 2, it is assumed that the specific flue gas volume is 7,000 $Nm^3$/t MSW, due to better combustion controls and lower excess air and the concentration is reduced to 50 ng TEQ/$Nm^3$ (at 11% O2).

Category 3, the combustion efficiency and the efficiency of APC systems are further improved (e.g., ESP and multiple scrubbers, spray-dryer and bag house or similar combinations) . Emission arte 5 ng TEQ/$Nm^3$ (at 11% O2).

Category 4 incinerators are the current state-of-the-art in MSW incineration and are equipped with advanced APC technology Thus, only 5,000 $Nm^3$/t MSW and a concentration of less than 0.1 ng TEQ/$Nm^3$ (at 11% O2).

Releases to water:

may occur when wet scrubbers are employed for the removal of particulate matter or to cool down ashes. In such cases, the amount of PCDD/PCDF released through this vector, can best be estimated using the default emission factors given for residue. Normally, concentrations are in the range of a few pg TEQ/L and the highest PCDD/PCDF concentration.

Note: PCDD/PCDF refers to Dioxins and Furan

Release to Land

No release to land is expected unless untreated residue is directly placed onto or mixed with soil. The concentration released in such cases will be covered under “Release in Residues”.

Release in Products

The process has no product, thus no release to product occurs.

Release in Residues

PCDD/PCDF concentrations in fly ash are substantial, while the total mass generated per ton of MSW is typically around 4-9%. PCDD/PCDF concentrations in the bottom ash are rather low, however, the amount of bottom ash generated per ton of MSW is around 19-30% (UNEP 2011b). Fly ash and bottom ash also contain unburned carbon from 1% (class 4) up to 30% (class 1.

In class 2 the concentration is assumed to be 30,000 ng TEQ/kg in fly ash and 100 ng TEQ/kg in bottom ash due to greatly improved combustion efficiency resulting in a much lower LOI of the ash.

For class 3, these values are assumed to be lower due to further improvements.

For class 4, high combustion efficiency, and very high collection efficiency, especially of the very small fly ash particles, are assumed. These small particles supply a large adsorption surface for

PCDD/PCDF and therefore the overall concentration does not decrease further. Thus, the value for the fly ash is set at lower concentration for the bottom ash as drops to 5 ng TEQ/kg.

## 10. Medical Waste Management Process

Medical waste management is a series of steps where the MW generated is handled from the generation point until it can be disposed of safely. The steps of the MW management process are shown in Figure 2a and 2b. The success of the waste management process is demonstrated in limiting the waste going for disposal and achieving a circular economy, where the materials used within the medical system are maximally utilised, reaching almost zero waste.

a) Chart Flow Diagrams

On such below diagram figure 2a each major operating step is represented by a block. Lines connect the blocks to indicate the major flows of material between blocks. These are great for high level communication and letting people (including regulators) know what you are intending to do in your process. No instrumentation is included and no utilities (e.g. gas, water, steam). More on block flow diagrams.

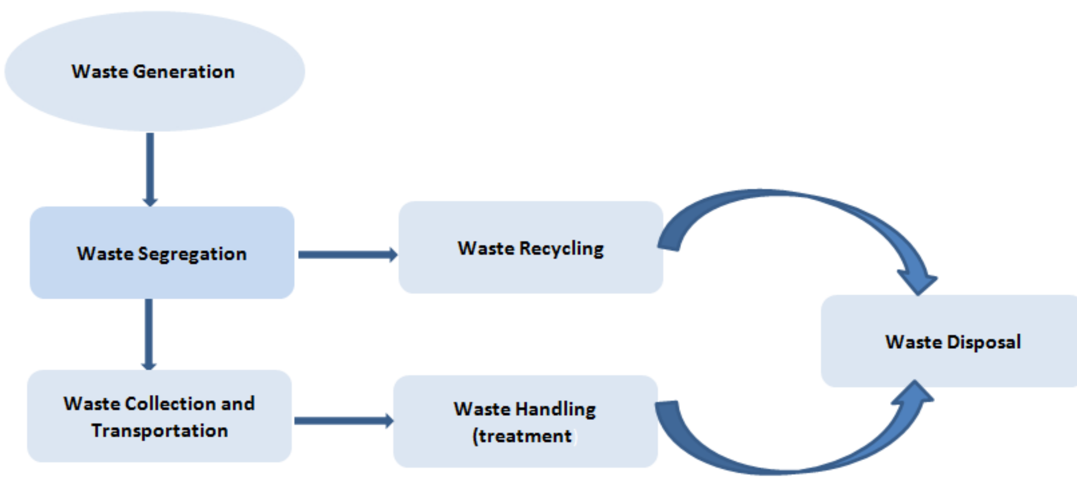


**Figure 2a Chart Flow Diagram**

a) The Process flow diagram as illustrated below:

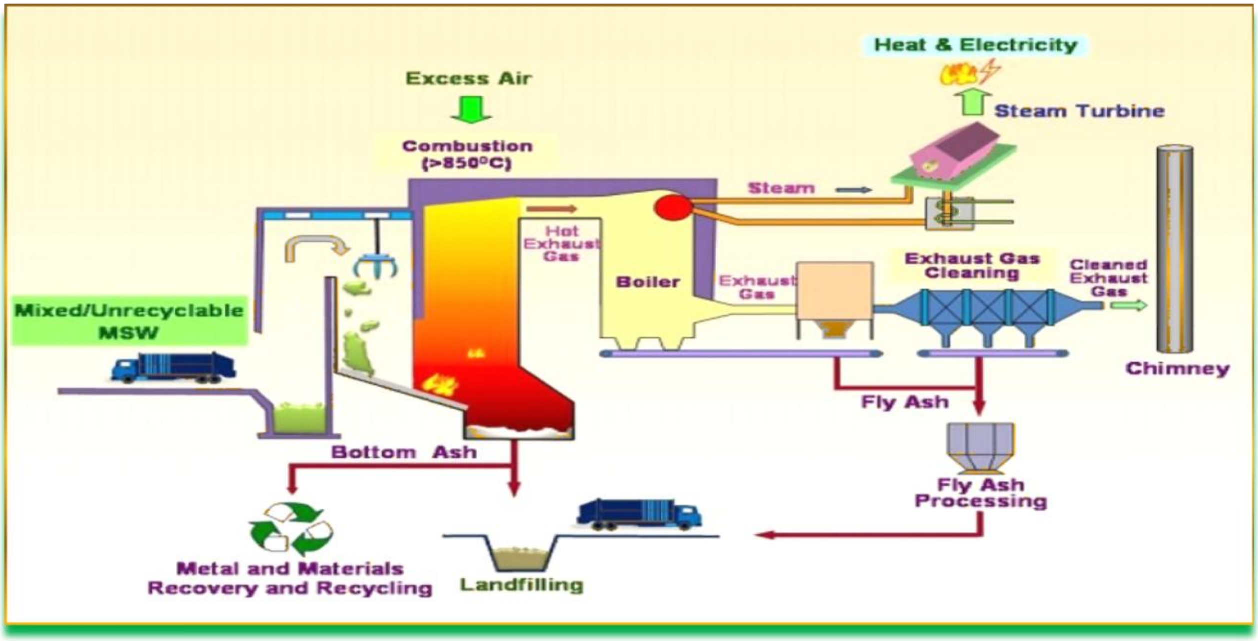


Figure 2b

## 11. Burning or Incinerations

Non-incineration technologies are preferable to incineration, however INCINERATORS EMIT TOXIC AIR POLLUTANTS Medical waste incinerators emit dioxins, furans and heavy metals including lead, mercury and cadmium, fine dust particles, hydrogen chloride, sulphur dioxide, carbon monoxide, nitrogen oxides, PICs (Products of Incomplete Combustion) and many other pollutants into the atmosphere. These compounds have serious negative impacts on the health of incineration plant personnel, the public and the environment. The International Agency for Research on Cancer (IARC) has classified the most toxic dioxin - 2,3,7,8 TCDD as a group 1 human carcinogen while some other dioxins are considered possible carcinogenic substances for human beings.

INCINERATION ASH IS POTENTIALLY HAZARDOUS As a rule, no additional equipment incorporated into an incineration plant with gaseous emission treatment devices will reduce the quantity of dioxins emitted, but, as already stated, will simply transform them into another waste phase. In an incinerator using the Best Available Technology (BAT) the content of dioxins in gaseous emissions was only 2% of the total dioxin content established in all incinerator wastes. During the flue gas treatment process harmful substances concentrate and are deposited in filter cakes, activated charcoal and in the flue gas treatment process wastewater. This waste is usually classified as dangerous and has to be treated accordingly. Residual waste from both incineration plants and from non-incineration medical waste treatment technologies has to be disposed of in landfills properly.

INCINERATORS ARE EXPENSIVE:
The costs of building and operating an incinerator or a selected non-incineration technology may differ in various countries. This can be because of different legislation – waste categorization, different costs for hazardous and municipal wastes, the technology availability and other factors. Generally however, different non-incineration technologies are less expensive than medical waste incinerators. As an illustration, the costs of building an incineration plant in the USA are 3 to 4 times higher than those of processing the same quantity of waste in an autoclave. Also the costs of operating non-incineration technology are usually lower than those of an incineration plant operation.

INCINERATORS MUST MEET NEW EMISSION LIMITS According to the European Union Directive No. 2000/76/EC on waste incineration, medical waste incinerators must meet the emission limit set at 0.1 ng TEQ/m3 for dioxins and furans.

Medical waste categories A waste analysis is an important step in selecting the non-incineration technology that best meets the needs of the facility. Furthermore, a waste stream analysis is a basis for identifying waste minimisation options and establishing the degree of segregation. A waste audit is a powerful tool for analysing the hospital waste stream. Medical waste can be defined as waste generated as a result of diagnosis, treatment, and immunization of humans or animals. It is useful to categorize the overall waste stream into the following four categories:

1. Municipal solid waste includes recyclable or compostable materials.
2. Infectious waste is generally defined as waste that is capable of producing infectious disease. Other terms used include biohazardous waste, biomedical waste, or “red bag” waste. Infectious waste must be treated and decontaminated before landfilling (Directive 99/31/EC).
3. Hazardous waste is defined as waste that may cause or significantly contribute to mortality or serious illness or pose a substantial hazard to human health and the environment if improperly managed or disposed of.
4. Low-level radioactive waste is waste that exhibits radiologic characteristics such as radioactive decay.

Incineration of municipal solid waste (MSW) started in the 1870s in England as disposal route for residential waste which guaranteed complete disinfection and allowed safe disposal of the inertised residues.

**12. Mass and Energy Stability**

Or material and energy balances. The word "balance" is widespread in process engineering and it is similar to the balance seen in accounting. It means keeping track of stuff. In - out = accumulation. In the long run, accumulation is zero, so what goes in comes out. The process might change the nature of the stuff. Chemical, physical processes can change things, and indeed this is “why” you are running the process. But, you can do balances on:

- Energy in = energy out
- Total mass in = out
- Each element. For instance, carbon in = carbon out

## 12.Piping and Instrumentation Diagrams

Piping and instrumentation diagrams (P&IDs) show even more detail and form the basis for the control system philosophy. They are useful in developing cost estimates and in facilitating physical layout and pipe design. Although still schematic (not scaled) they show all equipment (with number) and all valves. The type and schematic location of instruments is specified and pipe diameters are shown. Insulation type and thickness is shown as is materials of construction. A common instrumentation code is: P = pressure I = indicator T= Temperature C = controller F = Flow S = switch L = Level E = element T = transmitter G = gage.

### 12.b Limitations

The process design is often constrained by government permits or regulations. Other major factors include demand/desired throughput capacity, availability of power, steam, data lines availability of water/drains/sewage, and whether a building exists that can house your new process.

### 12.c Information

Accurate data can help you improve and optimize your treatment process, and it can be invaluable in helping you come up with new processes or additions to your existing process.

That's one reason we encourage waste managers to keep good records on how much waste you make (by category), how fast you make it, and how fast you can get rid of it. Think like an accountant.

## 13. Engineering Data on Medical Waste.

Engineers consider factors such as expected:

- Effectiveness

  Does the process render the waste acceptable for disposal in a landfill? These include sanitary landfills and low-level radioactive waste landfills.

  How much  production of secondary and waste volume of waste will be produced and shrink respectively . - Disposal costs scale with volume and sometimes mass.

- Costs

  Capital cost - including cost of installation, additional building costs (if any), instrumentation (for controlling and monitoring the process), and a contingency cost.

Overall cost analysis requires taking time into account, and will require an estimate of equipment life, future replacement and maintenance costs, and the cost of capital.

- Capacity

  Will your process be able to take in waste at a sufficient rate? Is there a cushion in case the needed rate is higher than you expect?

  Does the facility have adequate utilities (e.g. water, electric power).

- Reliability

  What are the costs and threats of equipment failure? Do you need a back-up or contingency process?

- Safety

  How dangerous will the treatment equipment and process be, and can you mitigate the risk? Heated machinery poses risks to employees. So do certain chemicals.

- Regulatory considerations

What treatment processes will be easier to get approved? Which ones will require less communication with regulators in the future? Which processes can be considered Best Available Control Technologies?

Engineers have developed heuristics to help with selection and sequencing of unit operations. Sometimes the designers will have existing equipment to work with and will be tasked with figuring out what to do with that equipment and what new additional treatment elements to add. Designers usually produce a process flowsheet with schematic pictures of process equipment and lines showing transfer routes (pipes or otherwise). A mass and energy balance sheet will probably be attached. These are valuable for determining the needed size of the equipment and for communicating to regulators and stakeholders how the treatment process will operate.

**13.1 Process Equipment and machines**

Equipment is often subject to codes and standards. These rules are set by government agencies, insurance companies, and professional organizations. Even when there is no law about your equipment, you should follow industry standards to avoid liability risk in case things go wrong. Equipment manufacturers sell set "off-the-shelf" (means ready- made machines and equipment) with set capacities and sizes. Often these are listed on the manufacturer's website and prices are fixed. Pumps, filters, incinerators, boilers, and agitators for mixing are in that category.

**14. Treatment and Handling Options**

Currently, available treatment technologies rely on two basic approaches to sterilization. Infectious organisms can be killed by subjecting them to excessive heat, or by bringing them into contact with chemical agents.

The most popular options include:

- heat:
  - steam autoclaves
  - microwave systems
  - dry heat and hot air systems
  - plasma arc
- chemical agents:
  - chlorine compounds (including hypochlorite, chlorine dioxide)
  - ozone
  - alkali
  - other disinfectants.

Some systems use combinations of these treatments. Incinerators, for example, use both heat and a chemical reaction (oxidation by atmospheric oxygen). Another example is a system that operates at a relatively moderate temperature, which would otherwise leave the waste intact, but that uses alkali to liquefy the waste.

There is an additional important consideration relevant to the treatment of infectious waste. Whatever the lethal agent is, it can only be effective if it is applied in sufficient strength throughout the entire bulk of the waste. Either the treatment must be applied for a time sufficient to allow the agent to penetrate to the interior of the waste mass, or the waste must be shredded or ground up to bring the interior to the surface.

Shredding or grinding the waste also has the advantage that it renders any recognizable body parts unrecognizable, as required in some states before disposal. It can also help reduce the volume of the waste. The disadvantage of including a shredding or grinding system is the cost and the additional maintenance required. Breaking up the waste before it has been rendered uninfectious also involves the risk of disseminating the pathogens, so shredding or grinding operations must be carried out in equipment specifically designed for medical waste processing.

The following lists a few of the most significant points of comparison among the available treatment options. A more extensive discussion can be found in Health Care Without Harm publication "Non-incineration medical waste treatment technologies."

## 14.1 Incineration

Incineration is unquestionably effective but is associated with serious air quality concerns. Because atmospheric oxygen is used as the reagent, a large volume of air must constantly pass through the system. Unless the exhaust air passes through a control device, all substances that are volatile at the operating temperature of the system will be emitted with the exhaust stream. Incinerators emit dioxin, mercury, other heavy metals that can impact human health.

The burning of large quantities of fuel entails the generation of excessive greenhouse gases (primarily carbon dioxide) relative to the amount of waste material destroyed.

## 14.2 Thermal treatment

In contrast to incineration, some thermal treatment methods can use the high water content of medical waste to advantage. Water can provide an effective heat transfer medium, to help distribute heat throughout the mass of the waste.

One problem with water as a heat transfer medium is that the temperature at which water boils at normal atmospheric pressure is not sufficiently high to kill some of the hardier microorganisms (spore-forming species, for example). One common solution is to carry out the treatment in a pressure chamber. As the pressure is raised, the boiling point of water increases. At a pressure twice as high as normal atmospheric pressure, the boiling point of water increases by about 20C, to 120C), which is sufficient to kill most organisms of concern. Systems using steam under pressure are called autoclaves and are among the most common alternatives to incineration for medical waste treatment.

Another thermal treatment system that takes advantage of the properties of water uses microwaves as the energy source. In a microwave system, the waste is subjected to high-intensity radio waves, tuned to a frequency that is readily absorbed by water molecules. It is an efficient way to deliver the energy where it is most needed for sterilization purposes. The other side of that coin is that microwave heating will be inefficient if the waste is too dry. Microwaves will penetrate bulk materials to some extent, but the heating will proceed more efficiently if the waste is shredded and mixed in the chamber during the process (for much the same reason that many kitchen microwave ovens use a rotating platform).

An advantage to both autoclaves and microwave systems is the fact that air does not have to move through the systems while they operate. Emission of volatiles only occurs during loading and unloading and can be minimized with proper design and operation.

## 14.3 Chemical treatment

The obvious disadvantage of chemical treatment systems is that they consume chemicals. In addition, even if they are effective in rendering the waste noninfectious, the products of the chemical reactions they undergo are present in the waste, and may pose problems of their own.

## 14.4 Disposal options

After it has been rendered noninfectious, most medical waste can be disposed of as if it were ordinary solid waste. However, some important exceptions differ by an own country and entity.

- Waste that must be managed as hazardous waste must be disposed of in compliance with RCRA regulations

## 15. Progressive Solutions

### 15.1 All-in-One Option for Medical Waste Processing Facilities

The one-stop solution for medical waste treatment plants, including medical waste autoclave(steam sterilizers) , shredder, steam boiler, sewage water treatment system, air collection and deodorization (removing odor in the atmosphere)  of system as well as quick-assembled factories are best choices for the region. Such project need more deep research and proposals, colleting clear data to determine sizes and capacity of the project t, most needy areas,  that could be implanted over several phases not at whole which it can be easier to hand by the government.

Medical Waste Autoclave System (MWC Series) is applied for medical waste treatment plants with medium to large capacity. The treatment capacity of a single autoclave is from 100kg to over 1 ton per hour, and a free combination of autoclaves and the full automatization of the plant are available as per clients demands.

Medical Waste Autoclave System (MWC Series) is a high vacuum, high temperature and pressure autoclave system applied generally for commercial centralized medical waste treatment plants, which provide collection, processing and disposal services of medical waste generated from hospitals and healthcare institutes.

Auto clave system

Shredder and crusher all in one machine

### 15.2 An innovative waste treatment solution: MagnetGAS Treatment System..

A cutting-edge (innovative) revolutionary solution treats all types of medical waste and eliminates the emission problem of dioxin and furan in traditional medical waste incineration or pyrolyzing. The MagnetGas Treatment System turns all organic wastes into white ashes, is compliance with strictest the emission standards, and reaching the goals of zero waste and carbon reduction. This system (MagnetGas Treatment System) More environmentally friendly than non-incineration technologies, MagnetGas Treatment System disposes all kind of medical waste, while normal non-incineration technologies can only treat infectious, sharps, and part of pathological wastes. MagnetGas Treatment System is jointly developed in Canada, USA and China. The system treats all categories of medical waste including chemical waste and pharmaceutical waste, generates almost no dioxins or furans and is compliance with worldwide strictest emission standards. It is worth mentioning Furan is listed as a possible human carcinogen.

**MagnetGas Treatment System**

### 15.3 Resolution to manage waste in international airports.

There are plant pests, diseases, and other contaminants risks of introduction waste originates from countries with different policies and regulations. For these reasons, this airport and port, and vertinary clinic wastes are generally handled separately and processed safely by independent waste autoclaves or waste treatment systems. Giant autoclave and waste treatment systems are ideally applied for international airports and ports waste.

### 15.4 Universal Autoclave with Shredder

Integrated Autoclave with Shredder (MWI series) is designed for on-site treatment in hospitals as well as for small to medium sized medical waste disposal plants. The whole treatment process is automatic, and all process such as shredding and sterilization are completed in one closed vessel, minimizing the environmental impact. Such system could be implemented to hospitals separately.

## 15. 5 Shredder System

Dedicated designed for processing medical waste. Double-shaft shredder with specific wear-resistant blades destroy soft materials as well as hard materials in medical wastes. A Gient shredder system is mainly composed of shredder, control cabinet, automatic bin dumper, hopper and optional conveyor

No doubt that some studies have been conducted on waste generation, segregation and disposal, but little attention has been given to awareness of potential risks associated with medical waste and the need of personnel protection in rural and semi-urban settings. Presently, a gap exists in knowledge and practice among health personnel which requires being bridged not only for the study area but also in the entire counyt. it is believed that poverty as a basic factor that inhibited the success of any country' s efforts in the area of environmentally sound management of hazardous waste.

## 16. Developing a Medical Waste Management Plan.

### Process Validation

Once the treatment process is up and operating, you should test it to make sure it operates as intended before you start running it on a regular basis. Validating the process can give you peace of mind as well as being a great way to encourage any regulators to give you needed permits. The validation establishes that the process achieves some benchmark:

- Destruction of microorganisms (to some level)
- Destruction of target contaminants or compounds
- Operating temperatures and pressures required to get to those destruction levels.

### Engineering Philosophy

As Engineering rules mentioned by professional experts say "design is a series of steps blended together." means there are many factors and mental processes required and design is **almost always iterative**.

The first step is a solution space. You can develop a flow sheet for each process. The flow sheet identifies major equipment and material flows. There are two types of flow sheets: block flow diagrams and process flow diagrams.

"Design is conceiving and giving form to artifacts that solve problems"

## 17. Conclusion:

To summarize, this study has discussed the significance of sustainable Medical waste handling, emphasizing the need for separate management from regular Municipal Waste treatment. It is important for Medical Waste Treatment units to be centralized in a limited geographical area rather than scattered, as this allows for the consolidation of professional skills, advanced machinery, technology, software, information, and international standards. Engineers play a crucial role in designing, implementing, and operating such infrastructures. Additionally, the proper management of Medical Waste Treatment is essential for safeguarding the environment and enhancing public health and the well-being of people. By implementing sustainable waste management techniques, we can reduce the negative impacts of waste and help create a cleaner and healthier environment. It is important for all individuals to take ownership of their garbage and actively work towards decreasing, reusing, and recycling it. By collaborating and educating ourselves, we can strive towards a sustainable future and build a better world for both current and future generations. Let's all pledge to create a beneficial influence on our environment by practicing responsible waste management. Engineers can have a crucial impact on initiating in-depth research and discovering effective engineering solutions for issues and limitations that impede the development of communities and countries.

| **18.Key words & Explanations** | |
|---|---|
| ESP | An electrostatic precipitator (ESP) is a piece of equipment that is used to capture dust particles that are formed or liberated by various industrial processes. The purpose of an ESP is to avoid these particulates being expelled into the atmosphere where they can cause pollution |
| TEQ | Toxic equivalency Quantity |
| Flue gas | (sometimes called exhaust gas or stack gas) is the gas that emanates from combustion plants and which contains the reaction products of fuel and combustion air and residual substances |
| MSW | Municipal solid waste |
| PCDD/PCDF | Dioxins and Furan |
| APC | Air Pollution Control |
| * linkert scaling | A Likert scale is a psychometric scale named after its inventor, American social psychologist Rensis Likert,[2] which is commonly used in research questionnaires. https://en.wikipedia.org/wiki/Likert_scale |
| BAT | Best Available Technology |
| Filter cake | A filter cake is formed by the substances that are retained on a filter. Filter aids, such as diatomaceous earth or activated carbon are usually used to form the filter cake |
| Pathogen | What is a pathogen? A pathogen is defined as an organism causing disease to its host |
| Reagent | a substance used as in detecting or measuring a component, in preparing a product, because of its chemical or biological activity. |
| RCRA | A RCRA characteristic hazardous waste is a solid waste that exhibits at least one of four characteristics; ignitability, corrosivity , reactivity and toxicity |
| POP | Persistent Organic Pollutants: |

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Thanks.