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SMART HEALTHCARE ENGINEERING

Hazardous waste treatments

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CONTENT

- Thermal processes
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- Irradiative processes
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What this presentation is about?

- ✓ Before medical waste is disposed of, it must be considered safe.
- ✓ There are several treatment technologies available today that sterilize medical waste before it is disposed of to make it less hazardous.
- ✓ Treatment of medical waste helps ensure infectious waste, potentially infectious agents or toxic items, do not seep into the soil or nearby water sources at landfills and create a risk to the environment and the general public.

A. THERMAL PROCESSES

❑ Thermal processes **utilize heat** (thermal energy) **to destroy pathogens** in the waste.
❑ **Depending on the temperature** used for:

❖ **low heat processes** that take place in
✓ a **moist/wet environment**, using **steam/vapour** (autoclave, microwaves) or in
✓ a **dry heat environment** using **hot air** (convection, conduction, infrared heat).

The **temperature is from 100° to 180°C**. Low-heat thermal processes use thermal energy at high temperatures enough to destroy microorganisms but are not sufficient to cause combustion or pyrolysis of the waste.

❖ **high heat processes** through incineration (combustion, pyrolysis and/or gasification).

The **temperature is higher, from 200° to over 1000°C.**

- **Autoclaves** have been used for over a century **to sterilize medical instruments** and in the last several decades, they **have been adapted for the treatment of healthcare/medical waste.**

Autoclaves for thermal medical waste treatment and **instruments disinfection** compare with **a steam equipment in Romania used in First World War**

- **A waste autoclave uses heat, steam and pressure.**

- Waste management companies also use this equipment **to treat biohazardous or infectious wastes prior to their final disposal destination.**
- **Pressurized steam** is one of the most efficient and effective methods of treating medical waste.

- **Autoclave is metal vessel designed to withstand to high pressures, with a sealed door and an arrangement of pipes and valves through which steam is introduced into and removed from the vessel.**

- Some autoclaves are designed with a steam jacket surrounding the vessel and steam is introduced into both the outside jacket and the inside chamber. **Heating the outside jacket reduces condensation on the inside chamber wall and allows the use of steam at lower temperatures.**

Advantages and disadvantages of the process are presented below

❖ Low operation costs ❖ Adequacy for biological testing ❖ Less hazardous residues	❖ No change in waste characteristics ❖ Inapplicable for all types of waste ❖ Unknown air emissions

- **Autoclaves are generally not used for large anatomical remains** (body parts) since it is **difficult to determine beforehand the time and temperature parameters needed.**

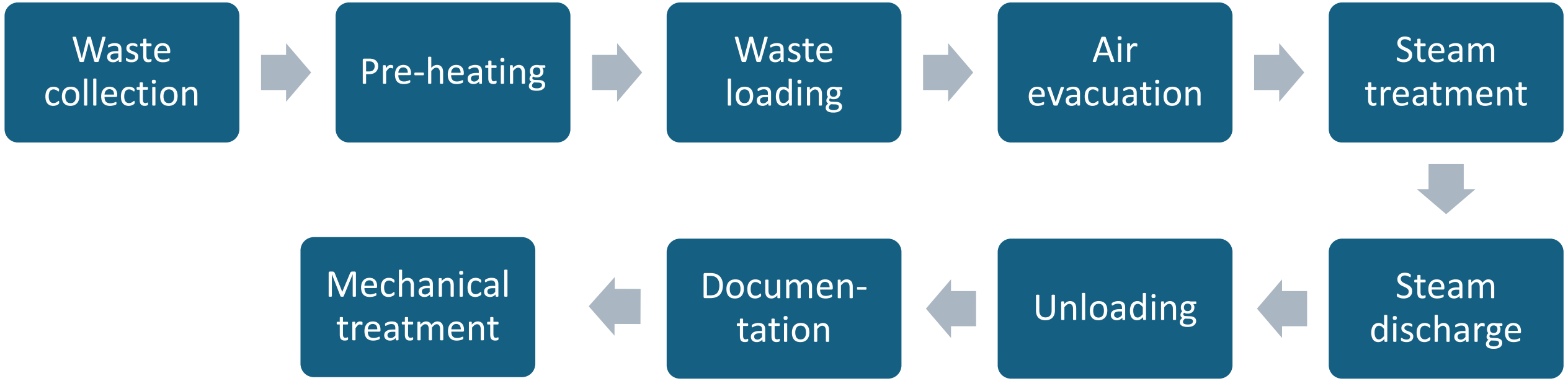
- Removal of air from the autoclave is essential to ensure penetration of heat into the waste.
- **Waste treatment autoclaves must treat the air that is removed at the start of the process to prevent the release of pathogenic aerosols.**
- This is usually done by **treating the air with steam or passing it through a HEPA filter** before being released.
- **Steam is lighter than air.**
- **Hence, steam is introduced under pressure into the chamber forcing the air downward into an outlet port at the bottom of the chamber.**

Types of waste possible to be treated

➢ Materials contaminated with blood and body fluids, sharps, isolation and surgery waste, laboratory waste, gauze, bandages, gowns and bedding.	➢ Chemical waste, volatile and semi-volatile organic compounds, chemotherapeutic waste, mercury, other hazardous chemical waste and radiological waste.

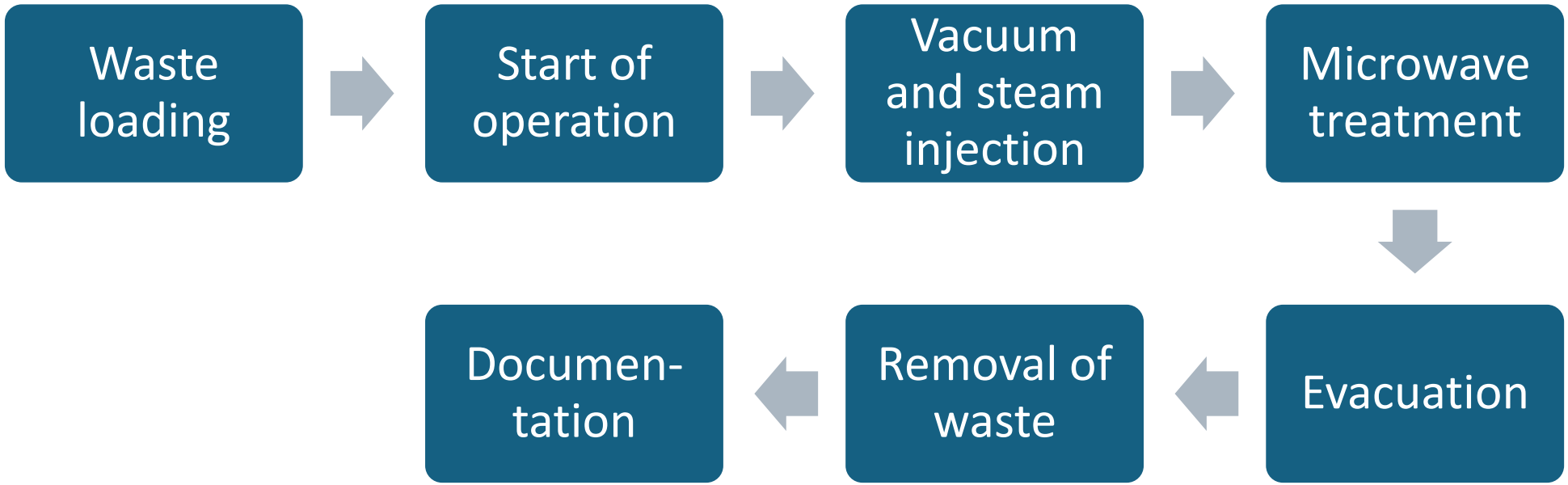
- **With sufficient time and temperature, it is technically possible to treat small quantities of human tissue, but ethical, legal, cultural, religious and other considerations may preclude their treatment.**

Typical operations for an autoclave



- **Microwave technologies** are also a **moist low-heat thermal process** (**hot water and steam generated by the microwave energy).**
- **Works only when there is water in the waste**, because **the radiation directly works on the water, not on the solid components of the waste.**
- For this reason, **treatment units are often supplied with a humidifier.**
- **Mechanical treatment** is often positioned upstream of the microwave to make sure that the waste pieces are small.
- **Smaller pieces enhance the heat to penetrate where infectious microbes are**.
- The entire process takes place **within a single vessel**.

- **Treatment of medical waste through exposure to microwaves is less expensive than incineration although it will not chemically alter hazardous materials that way incineration can.**



Typical operations for a microwave system

- **Dry heat technologies use hot air**, with **no addition of steam**, and operate **below combustion temperatures.** In dry heat systems, the waste is heated by **conduction (materials in contact), convection (circulating flow in liquids and gases), and/or thermal radiation (through electromagnetic waves by objects due to their temperature) using infrared or resistance heaters.**

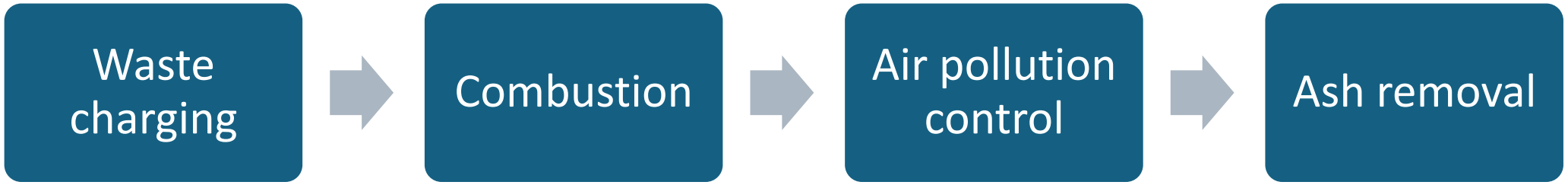
- In **high-heat thermal processes** the **temperature level is from 200°C to over 1000°C,** resulting **chemical and physical changes in the waste through combustion, pyrolysis, or gasification.**

- **Incineration** is a **combustion process that reduces organic and combustible waste to inorganic, incombustible solid residues and gaseous combustion by-products (carbon dioxide, oxygen and water vapor).**

- An **incinerator** should have a **primary combustion chamber** (or furnace or kiln), **a secondary chamber** (or afterburning chamber or post-combustion chamber), **air pollution control devices** (or flue gas cleaning system or emission controls) to meet national and international standards for pollutant emissions, **a wastewater treatment system** if a wet system is used for flue gas cleaning, and **a chimney that is 2.5 times the height of the highest nearby structure.**

- **The exhaust gases** from waste incineration facilities may contain **many potentially harmful substances, including particulate matter, oxides of nitrogen, oxides of sulphur, carbon monoxide, dioxins and furans, metals, such as lead and mercury, acid gases, volatile chlorinated organic compounds, and polycyclic aromatic compounds.**

Typical operations for an incinerator



- **Co-incineration means the burning of medical waste with other types of waste.**
- The **temperature must be over 850 °C, and a precise control and monitoring of the air and the residues.**

Type of medical waste treated through incineration

➢ Cultures and stocks, sharps, materials contaminated with blood and body fluids, isolation and surgery waste, laboratory waste, and 'soft' waste (including gauze, bandages, drapes, gowns and bedding) from patient care. Incinerators specially designed for pathological waste are used to burn cadavers, large anatomical remains (body parts, organs, tissues and animal carcasses). ➢ High temperature (>1200°C) incinerators specially designed for hazardous chemical waste and equipped with high-efficiency air pollution control devices are used to treat laboratory chemical waste, thermally stable pharmaceutical waste, halogenated waste including plastic PVC materials, and chemotherapeutic (cytotoxic) waste.	➢ Pressurized gas containers; large amounts of reactive chemical waste; silver salts and photographic or radiographic waste; waste containing mercury, cadmium and other heavy metals, such as broken thermometers, used batteries and lead-lined wooden panels; sealed ampoules or vials that can burst; and radioactive materials.

- **Pyrolysis** is the **thermal degradation of materials through the application of heat in the absence of oxygen (or with a limited supply).**
- It is difficult to have a completely oxygen-free atmosphere, so some oxidation takes place.
- In the case of healthcare waste treatment, **plasma pyrolysis refers to the use of a highly ionized gas (plasma) to convert electric energy to heat at temperatures around 1650°C and higher.**
- **Gasification** involves the **addition of small, controlled amounts of oxygen, steam as gasification agent.**
- Gasification still generates **by-products, which may contain high levels of toxic contaminants.**
- **Gasification is the transformation of any material containing carbon.**

Differences between incineration, pyrolysis and gasification

	Pyrolysis	Gasification	Incineration
Atmosphere	Inert/nitrogen	Gasification agent: O_2, H_2O	Air
Reaction temperature (°C)	250 – 700	500 – 1600	800 – 1450
Pressure (bar)	1	1 - 45	1
Stochiometric ratio	0	< 1	> 1
Products from the process			
Gas phase	H_2, CO, C_xH_y, H_2O, N_2	H_2, CO, CO_2, CH_4	CO_2, H_2O, O_2
Solid phase	Ash, coke	H_2O, N_2	NO_2
Liquid phase	Pyrolysis oil, water	Slag, ash	Slag, ash

B. CHEMICAL PROCESSES

- Chemical treatment processes use **chemical disinfectants to destroy pathogens in the waste.**
- The microbial inactivation efficacy depends on the **type of chemical disinfectant**, **its concentration**, **the ability to expose all surfaces**, **and contact time**, **but can also be affected by, among others like temperature, pH, water hardness, and amount of organic load in the waste.**
- The most common technologies are **chlorine-based chemical treatment systems using either dissolved chlorine dioxide or sodium hypochlorite (bleach).**
- **Ozone gas treatment** has also been developed (Dr. Negrin Hospital having a good experience).

- A special case of a chemical process is the **alkaline hydrolysis system that uses heated alkali to digest tissues, pathological waste, anatomical parts or contaminated animal carcasses in heated stainless-steel tanks.**
- **Volume reduction** depends on the type of shredding, grinding or mixing used by the system.
- The chemical treatment system usually resulted in **disinfection rather than sterilization**.
- **The speed and efficiency** of chemical disinfection will depend on **operational conditions**, including the **type of chemical disinfectant used**, **its concentration, the contact time between the disinfectant and the waste, the extent of contact, the organic load of the waste, operating temperature, and factors that may affect the efficacy of the disinfectant such as humidity and pH.**
- The obvious **disadvantage** of chemical treatment systems is **that they consume chemicals.**
- However, chemical treatment systems are convenient, and may be suitable in some situations, particularly when small quantities of waste are involved.

- One of the most common constituents of chemical treatment systems is **chlorine,** either in the form of sodium hypochlorite solution (common bleach), or as the more powerful (and correspondingly more hazardous) gas, **chlorine dioxide.**
- These compounds are relatively cheap and effective.
- **While reacting with organic compounds**, they tend to **form unacceptable byproducts such as chloroform and other persistent toxins.**
- The original "oxidizer" is atmospheric oxygen.
- **Ordinary oxygen is not harmful**, because it is in fact essential for the survival of many organisms, including most of the pathogens in medical waste.
- When used in a medical waste treatment system, **ozone acts as an effective sterilizer**, **without the tendency to generate the types of by-products found with chlorine compounds**.
- The major problem encountered with ozone systems is the need to avoid exposure to anyone in the vicinity of the treatment system, since **ozone is highly injurious to lungs.**

- **Alkaline agents** are also used in medical waste treatment, **either in highly corrosive form (sodium hydroxide, or lye), or in a somewhat milder form (calcium oxide, or quicklime).**

- **Alkali tends to hydrolyse (decompose) proteins,** among other effects.

- Apart from the cost of the reagents, **the major disadvantage is the risk of contact, since alkaline solutions damage skin and lungs.**

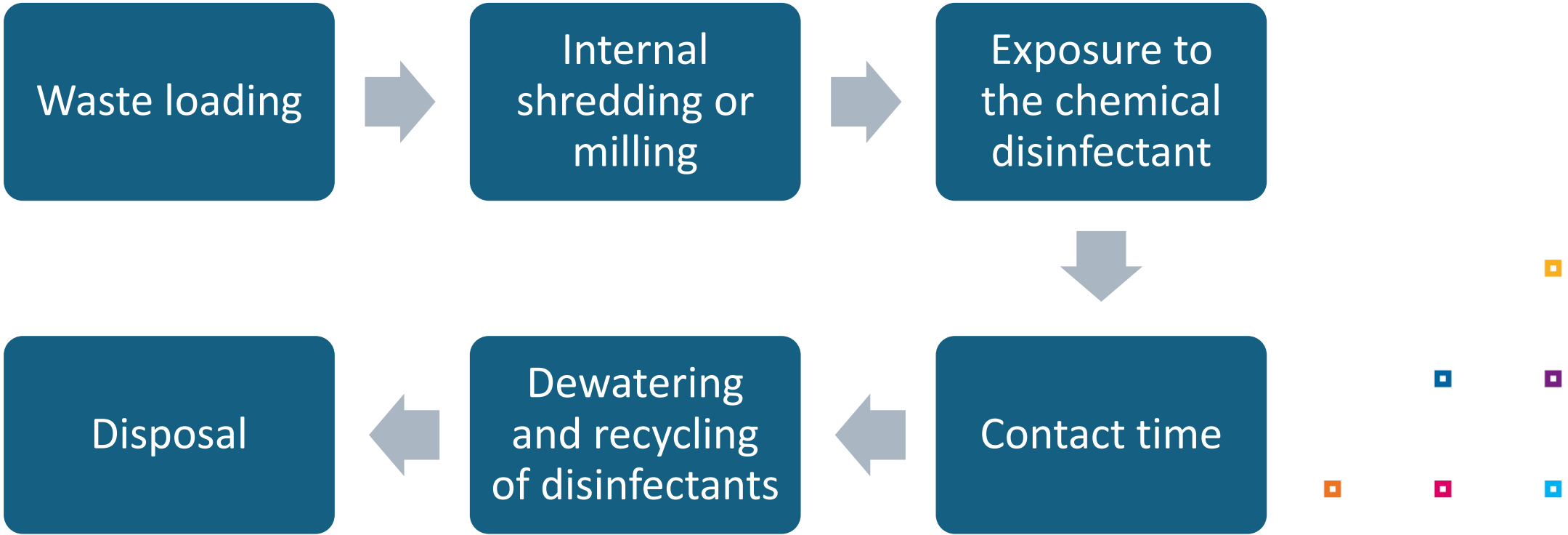
- However, **when oxygen (O_2) is converted to ozone (O_3), a much stronger oxidizer, it becomes toxic to most life forms**.

- Ozone can readily be generated by passing an electric arc through ordinary oxygen gas.

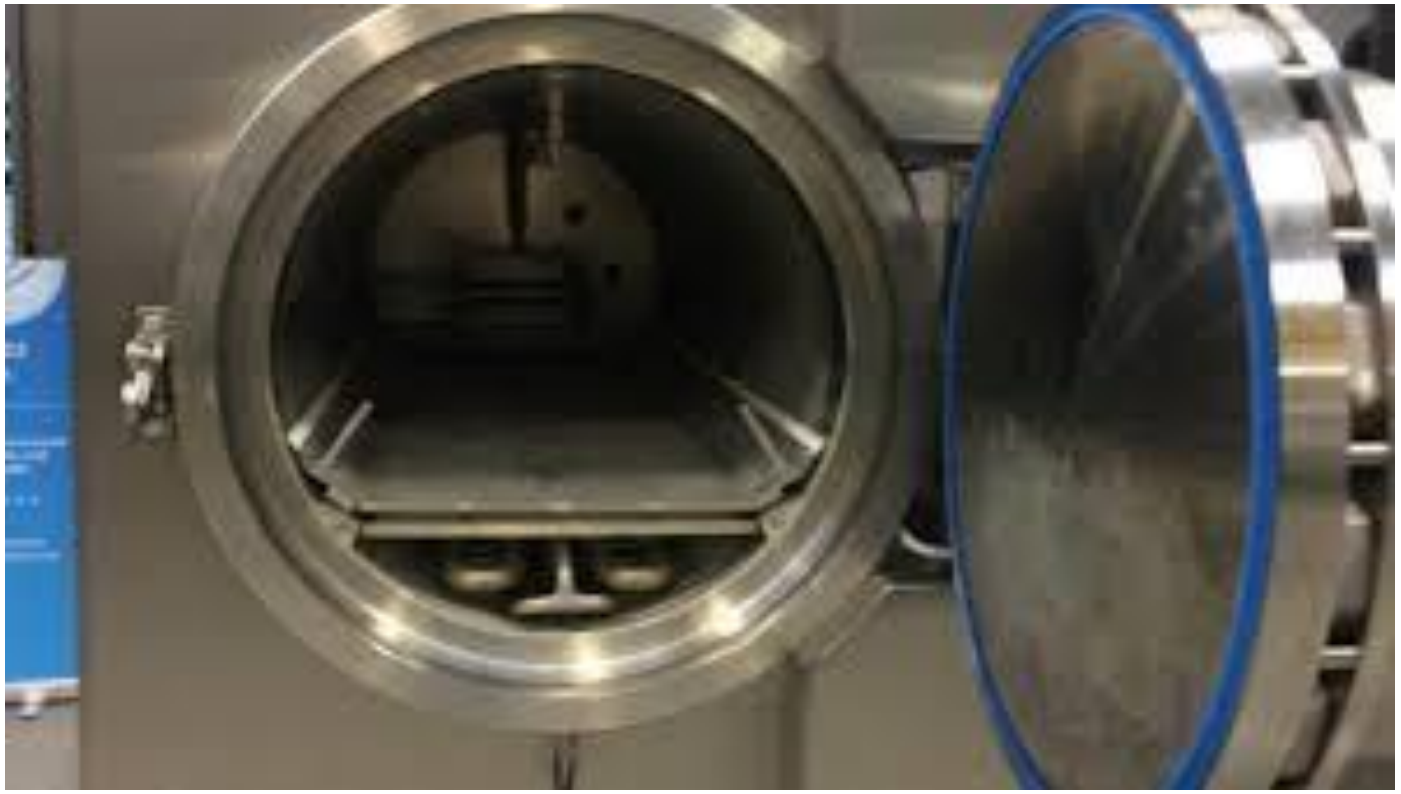
Types of waste treated:

- liquid waste such as **blood, urine, stools or hospital sewage.**
- **infectious healthcare wastes**, including microbiological cultures and sharps, have also been disinfected chemically but using the proper concentration and ensuring contact of the disinfectant with contaminated surfaces are important.

Typical operations in chemical operations systems



Alkaline hydrolysis



Alkaline hydrolysis or alkaline digestion is a process that **converts animal carcasses, human body parts and tissues into a decontaminated aqueous solution**. Alkaline hydrolysis converts fats in human or animal parts into soaps. **Tissues, organs and body parts are decomposed into peptides, amino acids, soaps, salts, sugars, and ammonia.**

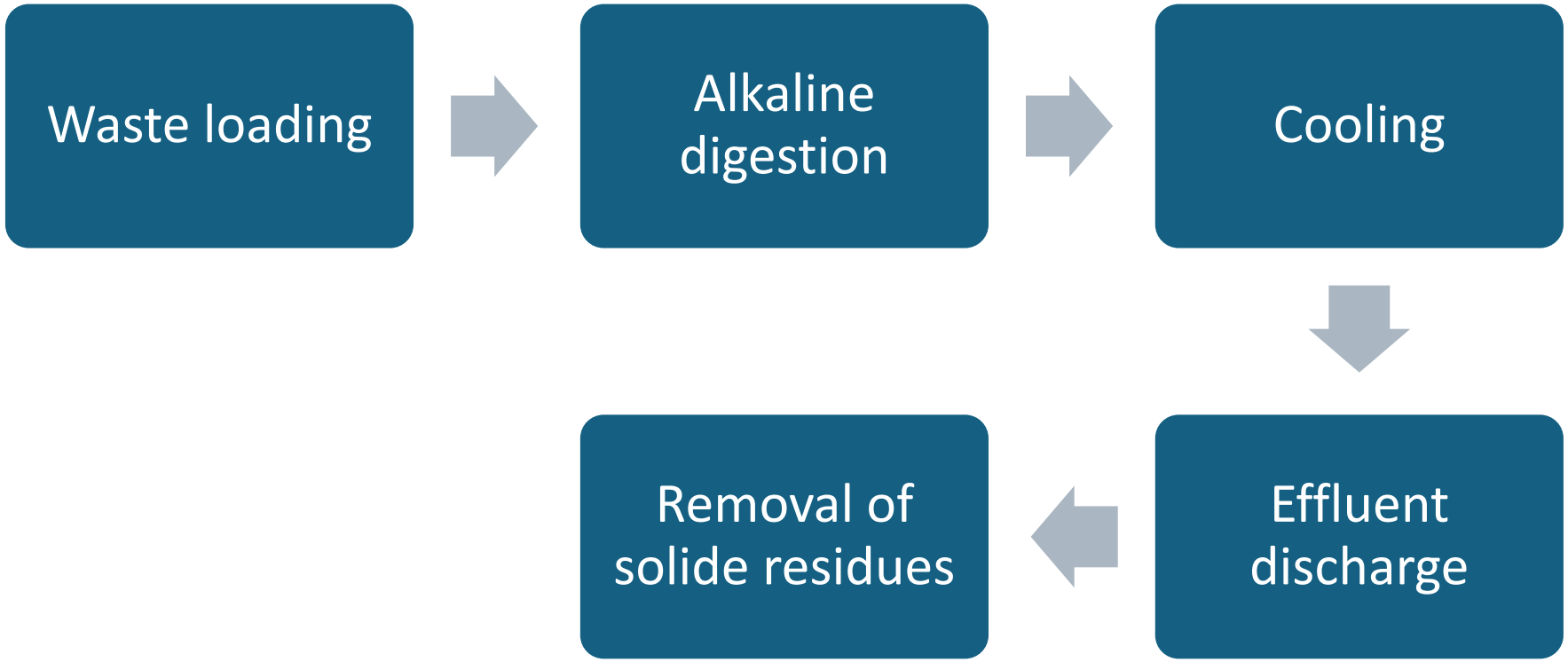
- To understanding the process, **imagine an ice cube melting in a glass of water. Surrounded by a warmer liquid, the solid ice gradually disappears**.
- It is a reasonable metaphor for alkaline hydrolysis.
- Like ice, the human body needs certain things to decompose rapidly.
- **Green cremation involves the placement of the body inside a tank with water and lye.**
- Under a higher temperature and sometimes with pressure, the soft tissues of the body melt.
- **Eventually, bone is the only solid left.**

- **Chlorine dioxide, ClO_2, is an alternative to hypochlorite.**
- **Internal shredding of solid healthcare waste** before or during disinfection is necessary to ensure **good contact between the disinfectant and contaminated waste surfaces**.

Types of wastes for alkaline hydrolysis

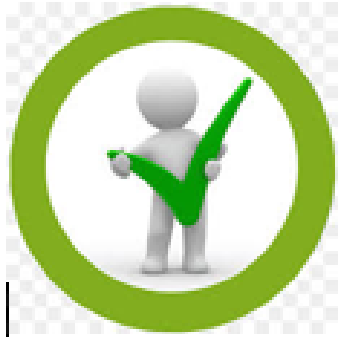
➢ Pathological waste, organs, tissues, cadavers, anatomical parts and contaminated animal carcasses. However, it can also treat biological stocks, cultures, liquid blood, body fluids, and other types of infectious waste, chemotherapeutic agents	➢ Wastes containing aluminum, tin, zinc, magnesium, copper or galvanized iron (as these metals could react to form hydrogen gas), as well as concentrated acids, flammable liquids and organohalogen compounds (especially trichloroethylene), nitromethane and other similar nitro compounds.

Typical operations for alkaline hydrolysis



- **Encapsulation** is a chemical process that **solidifies sharps, blood, or other body fluids within a solid matrix prior to disposal.**
- **Also means coating the waste with inert materials.**
- **Even concrete can be used to dispose of small quantities of pharmaceutical waste in remote areas.**
- The process uses either cubic boxes made of high-density polyethylene or metallic drums, which are **three-quarters filled** with sharps, chemical or pharmaceutical residues, or incinerator ash.
- The containers or boxes are then **filled up with a medium such as plastic foam, bituminous sand, lime, cement, or clay.**
- **Once the medium has dried, the containers are sealed and disposed of in a sanitary landfill or waste burial pit.**

Advantages and disadvantages of the encapsulation

	
❖ Simple, inexpensive and safe. ❖ A solution that can be envisaged for sharps and pharmaceutical wastes. ❖ The risks for scavengers are reduced.	❖ To be regarded as a temporary solution. ❖ The quantities of waste treated are small. ❖ The weight and volume of the waste is increased.

C. IRRADIATIVE PROCESSES

- Some types of radiation have been shown to destroy pathogens.
- Since ionizing radiation using electron beams, Cobalt-60, Cesium-137, X-ray are used for sterilization of medical instruments, the concept has been tested for healthcare waste.
- In the 1990s, **electron beam treatment was successfully demonstrated for healthcare waste treatment**.
- Microbial inactivation efficacy depends on the **dose absorbed by the mass of waste**. **UV-C (germicidal UV) irradiation has also been used but as a supplementary technology for healthcare waste treatment.**
- Values considering: **25-50 kGy for complete disinfection, 5-10 kGy for microbial reduction.**

D. BIOLOGICAL PROCESSES

- Biological processes refer specifically to the **natural degradation of organic matter.**
- Some biological treatment systems employ **enzymes to speed up the destruction of organic waste containing pathogens.**
- **Composting and vermiculture are biological processes and have been used successfully** to decompose hospital kitchen waste, as well as other organic digestible waste and placenta waste.
- The **natural decomposition of pathological waste through burial is another example of a biological process.**

E. MECHANICAL PROCESSES

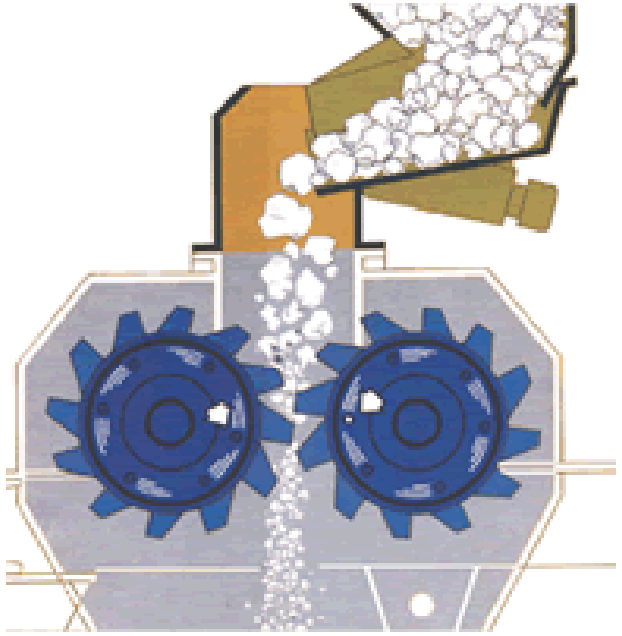
- Mechanical processes encompass **shredding, grinding, mixing, and compaction**.
- In general, these processes are used to supplement the abovementioned technologies for the purpose of **improving the rate of heat transfer, the penetration of steam, or contact with a chemical disinfectant**.
- Mechanical processes are also used **to reduce the volume of treated waste**, render treated waste unrecognizable, or remove physical hazards in the case of treated sharps waste.
- Unless shredders, mixers and other mechanical devices are an integral part of a closed treatment system, they should not be used before the incoming healthcare waste is disinfected.
- Otherwise, workers are at risk of being exposed to pathogens in aerosols released to the environment by mechanical destruction of untreated waste.
- If mechanical processes are part of a closed system, the technology should be designed in such a way that the air in and from the mechanical process is disinfected before being released to the workspace or outside environment.

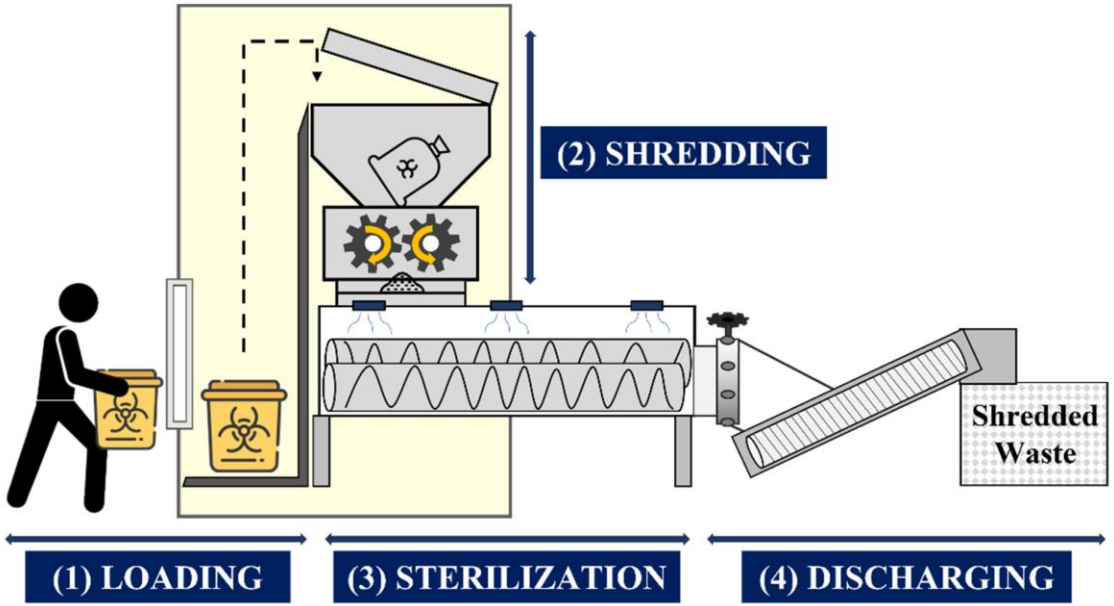
- Shredders are the equipment which cut the waste into small pieces.

- This technique requires competent staff for operating and maintaining the device, since some of these rotary devices are industrial models.

- They are often built into closed chemical or thermal disinfection systems.
- However, grain mills can be converted into simple shredders, but due to the risk for staff while the shredder is running, only disinfected waste should be treated in these devices.

- Shredding, which in certain circumstances provides a means of recycling plastics and needles, should be considered whenever needles and syringes are available in large quantities, this involves a centralized system for collecting and transporting wastes from the various facilities.





Shredders and integrating mechanical process into a medical waste processing stream

Advantages and disadvantages of the shredders

❖ Makes the waste unrecognizable. ❖ Prevents the re-use of needles and syringes. ❖ Reduces volume. ❖ Facilitates the recycling of plastics. ❖ Enhances the effectiveness of chemical or thermal treatment in closed and integrated systems.	❖ Requires electricity. ❖ Some facilities are very expensive. ❖ The shredder can be damaged by large pieces of metal. ❖ The waste is not disinfected. ❖ The staff are exposed to air-borne pathogens when untreated waste is shredded.

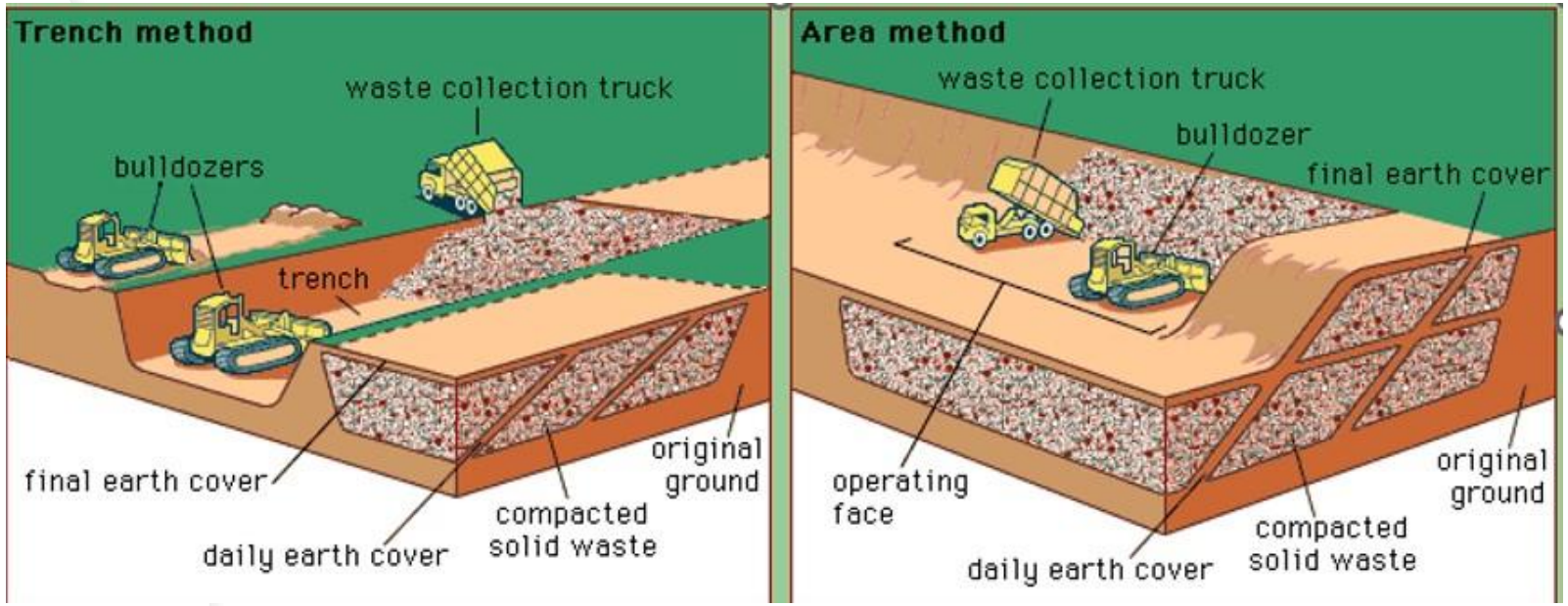
F. BURIAL IN SANITARY LANDFILLS, TRENCHES, PITS

- The disposal of untreated health-care waste in an uncontrolled dump is not recommended and must only be used as a last resort.
- It can be disposed of in a sanitary landfill, subject to certain precautions**: it is important that health-care waste be covered rapidly.**
- One technique is to dig a trench down to the level where old municipal refuse (over three months old) has been buried and to immediately bury health-care waste that is discarded at this level under a 2-metre layer of fresh municipal refuse.

- The following are the essential factors that must be taken into consideration in the design and use of a sanitary landfill:

- access must be restricted and controlled;
- competent staff must be available;
- the discarding areas must be planned;
- the bottom of the landfill must be waterproofed;
- the water table must be more than 2 meters below the bottom of the landfill;
- there must be no drinking water sources or wells in the vicinity of the site;
- chemicals must not be disposed of on these sites;
- the waste must be covered daily and vectors (insects, rodents, etc.) must be controlled;
- the landfill must be equipped with a final cover to prevent rainwater infiltration;
- leachates must be collected and treated.

Sanitary landfilling



Advantages and disadvantages of sanitary landfill and trench method

❖ Simple and inexpensive operating costs. ❖ Can be carried out using the existing municipal waste management system. ❖ Scavengers cannot access health-care waste if the landfill is well managed	❖ The health-care wastes are not treated and remain hazardous. ❖ The landfill must be secure, fenced in, and guarded. ❖ Scavengers and animals need to be controlled. ❖ A high degree of coordination is needed between collectors and landfill operators. ❖ Makes health workers less aware of the need to sort the various types of waste. ❖ Transport to the landfill can be a lengthy and costly operation. ❖ Risk of water pollution.

Advantages and disadvantages of separate pit on the hospital site

❖ Simple and relatively inexpensive to build and manage. ❖ Dangerous substances are not transported outside the hospital. ❖ Control is facilitated	❖ The health-care waste is not treated and remains hazardous. ❖ Risk of water pollution. ❖ Problem of odour. ❖ Vectors (insects, rodents, etc.) need to be controlled. ❖ Space is needed around the hospital.

LIFE IS VERY IMPORTANT FOR EVERYONE.

THAT IS WHY KEEPING A CLEAN ENVIRONMENT, UNCONTAMINATED WATER AND SOIL IS OUR DUTY.

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Thank you!

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