Hazardous Waste Treatment

There are various alternative waste treatment technologies, for example, physical treatment, chemical treatment, biological treatment, incineration, and solidification or stabilisation treatment.

These processes are used to recycle and reuse waste materials, reduce the volume and toxicity of a waste stream, or produce a final residual material that is suitable for disposal. The selection of the most effective technology depends upon the wastes being treated.

Physical Treatment of Hazardous Waste:

This includes processes that separate components of a waste stream or change the physical form of the waste without altering the chemical structure of the constituent materials. Physical treatment techniques are often used to separate the materials within the waste stream so that they can be reused or detoxified by chemical or biological treatment or destroyed by high-temperature incineration.

These processes are very useful for separating hazardous materials from an otherwise non-hazardous waste stream so that they may be treated in a more concentrated form, separating various hazardous components for different treatment processes, and preparing a waste stream for ultimate destruction in a biological or thermal treatment process.

Physical treatment processes are important to most integrated waste treatment systems regardless of the nature of the waste materials or the ultimate technologies used for treatment or destruction.

The physical processes that are commonly used in waste treatment operations are as follows:

1. Screening is a process for removing particles from waste streams, and it is used to protect downstream pre-treatment processes.
2. Sedimentation is a process for removing suspended solid particles from a waste stream. Sedimentation is usually accomplished by providing sufficient time and space in special tanks or holding ponds for settling. Chemical coagulating agents are often added to encourage the settling of fine particles.
3. Flotation is a process for removing solids from liquids by floating the particles to the surface by using tiny air bubbles. Flotation is useful for removing particles too small to be removed by sedimentation.
4. Filtration is a process for separating liquids and solids by using various types of porous materials. There are many types of filters designed to achieve various levels of separation.
5. Centrifugation is a process for separating solid and liquid components of a waste stream by rapidly rotating a mixture of solids and liquids inside a vessel. Centrifugation is most often used to dewater sludges.

6. Dialysis is a process for separating components in a liquid stream by using a membrane. Components of a liquid stream will diffuse through the membrane if a stream with a greater concentration of the component is on the other side of the membrane. Dialysis is used to extract pure process solutions from mixed waste streams.
7. Electrodialysis is an extension of dialysis. This process is used to separate the components of an ionic solution by applying an electric current to the solution, which causes ions to move through the dialysis membrane. It is very effective for extracting acids and metal salts from solutions.
8. Reverse osmosis separates components in a liquid stream by applying external pressure to one side of a membrane so that solvent will flow in the opposite direction.
9. Ultrafiltration is similar to reverse osmosis, but the separation begins at higher molecular weights. The result is that dissolved components with low molecular weights will pass through the membrane with the bulk liquid while the higher-molecular-weight components become concentrated through the loss of solvent. Ultrafiltration systems can handle much more corrosive fluids than reverse-osmosis units.
10. Distillation is a process for separating liquids with different boiling points. The mixed-liquid stream is exposed to increasing amounts of heat, and the various components of the mixture are vapourised and recovered. The vapour may be recovered and re-boiled several times to effect a complete separation of components.
11. Solvent extraction is a process for separating liquids by mixing the stream with a solvent which is immiscible with part of the waste but which will extract certain components of the waste stream. The extracted components are then removed from the immiscible solvent for reuse or disposal.
12. Evaporation is a process for concentrating non-volatile solids in a solution by boiling off the liquid portion of the waste stream. Evaporation units are often operated under some degree of vacuum to lower the heat required to boil the solution.
13. Adsorption is a process for removing low concentrations of organic materials on the surface of a porous material, usually activated carbon. The carbon is replaced and regenerated with heat or a suitable solvent when its capacity to attract organic substances is reduced.

Chemical Treatment of Hazardous Waste:

Chemical treatment processes alter the chemical structure of the constituents of the waste to produce either an innocuous or a less hazardous material. Chemical processes are attractive because they produce minimal air emissions, they can often be carried out on the site of the waste generator, and some processes can be designed and constructed as mobile units.

The five chemical treatment operations commonly used in treating wastes are as follows:

1. Neutralisation is a process for reducing the acidity or alkalinity of a waste stream by mixing acids and bases to produce a neutral solution. This has proven to be a viable waste management process.
2. Precipitation is a process for removing soluble compounds contained in a waste stream. A specific chemical is added to produce a precipitate. This type of treatment is applicable to streams containing heavy metals.
3. Ion exchange is used to remove from solution ions derived from inorganic materials. The solution is passed over a resin bed, which exchanges ions for the inorganic substances to be removed. When the bed loses its capacity to remove the component, it can be regenerated with a caustic solution.
4. De-chlorination is a process for stripping chlorine atoms from chlorinated compounds such as polychlorinated biphenyls (PCBs). One of the processes uses a metallic sodium reagent to break the chlorine bond.
5. Oxidation-reduction is a process for detoxifying toxic wastes in which the chemical bonds are broken by the passage of electronics from one reactant to another.

Biological Treatment of Hazardous Waste:

Biological waste treatment is a generic term applied to processes that use micro-organisms to decompose organic wastes either into water, carbon dioxide, and simple inorganic substances, or into simpler organic substances, such as aldehydes and acids.
Typically, the micro-organisms used in a biological process are present in the incoming waste. In some instances, micro-organisms that were developed to attack specific compounds are injected into a waste stream.
The purpose of a biological treatment system is to control the environment for micro-organisms so that their growth and activity are enhanced, and to provide a means for maintaining high concentrations of the micro-organisms in contact with the wastes.
Since biological treatment systems do not alter or destroy inorganic substances, and high concentrations of such materials can severely inhibit decomposition activity, chemical or physical treatment may be required to extract inorganic materials from a waste stream prior to biological treatment.
There are five principal types of conventional biological treatment. Treatment with activated sludge involves exposing waste to a biological sludge that is continuously extracted from the clarified waste stream and recycled.
In the aerated lagoon method, waste is agitated with air in large enclosures to increase oxygen-dependent biological oxidation. In treatment using trickling filters, wastes are allowed to trickle through a bed of rocks coated with micro-organisms that alter the waste components by using them as food.

Waste stabilisation ponds are ponds in which wastes are allowed to decompose over long periods of time, aeration is provided only by wind action. Anaerobic digestion is a method for decomposing organic matter by using anaerobic organisms in closed vessels in the absence of air; methane may be produced in the process.

Incineration and Pyrolysis of Hazardous Waste:

Incineration and pyrolysis techniques reduce the volume or toxicity of organic wastes by exposing them to high temperatures. When organic chemical wastes are subjected to temperatures of 800-3000°F (430-1700°C), they break down into simpler and less toxic forms. If the wastes are heated in the presence of oxygen, combustion occurs, and the process is known as incineration. Incineration systems are designed to accept specific types of materials; they vary according to feed mechanisms, operating temperatures, equipment design, and other parameters. The main products from complete incineration include water, carbon dioxide, ash, and certain acids and oxides, depending upon the waste in question.

If the wastes are exposed to high temperatures in an oxygen-starved environment, the process is known as pyrolysis. The products of this process are simpler organic compounds, which may be recovered or incinerated, and a char or ash.

Hazardous waste incineration and pyrolysis systems include single-chamber liquid systems, rotary kilns, and fluidised-bed incineration systems. In a single-chamber liquid system a brick-lined combustion chamber contains liquids that are burned in suspension; in addition to being the primary parts of an incineration system, these units are used as afterburners for rotary kilns. A rotary kiln is a versatile large refractory-lined cylinder capable of burning virtually any liquid or solid organic waste, the unit is rotated to improve turbulence in the combustion zone. Fluidised-bed incineration uses a stationary vessel within which solid and liquid wastes are injected into a heated, extremely agitated bed of inert granular material; the process promotes rapid heat exchange and can be designed to scrub off the gases.

Solidification and Stabilisation of Hazardous Waste:

Solidification and stabilisation are treatment systems designed to accomplish one or more of the following —improve handling and the physical characteristic of the waste; decrease the surface area across which transfer or loss of contained pollutants can occur; and limit the solubility of, or detoxify, any hazardous constituents contained in the wastes.

In solidification these results are obtained primarily, but not exclusively, via the production of a monolithic block of treated waste with high structural integrity. Stabilisation techniques limit the solubility or detoxify waste contaminants even though the physical characteristics of the waste may not be changed. Stabilisation usually involves the addition of materials that ensure that the hazardous constituents are maintained in their least soluble or least toxic form.

Disposal of Hazardous Waste:

Ultimately, after all treatment is completed, there remains an inorganic valueless residue that must be disposed of safely.

There are five options for disposing of hazardous waste as follows:

(i) Underground injection wells are steel and concrete-encased shafts placed deep below the surface of the earth into which hazardous wastes are deposited by force and under pressure. Some liquid waste streams are commonly disposed of in underground injection wells.

(ii) Surface impoundment involves natural or engineered depressions or diked areas that can be used to treat, store, or dispose of hazardous waste. Surface impoundments are often referred to as pits, ponds, lagoons, and basins.

(iii) Landfills are disposal facilities where hazardous waste is placed in or on land. Properly designed and operated landfills are lined to prevent leakage and contain systems to collect potentially contaminated surface water run-off. Most landfills isolate wastes in discrete cells or trenches, thereby preventing potential contact of incompatible wastes.

(iv) Land treatment is a disposal process in which hazardous waste is applied onto or incorporated into the soil surface. Natural microbes in the soil break down or immobilise the hazardous constituents. Land treatment facilities are also known as land application or land farming facilities.

(v) Waste piles are non-containerised accumulations of solid, non-flowing hazardous waste. While some are used for final disposal, many waste piles are used for temporary storage until the waste is transferred to its final disposal site.

Of the hazardous waste disposed of on land, nearly 60% is disposed of in underground injection wells, approximately 35% in surface impoundments, 5% in landfills; and less than 1% in waste piles or by land application.