



Hazardous Waste Management

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Introduction

Hazardous waste has been defined differently at different places based on its identification. The commonly defined definition says “any waste that has the potential threat to public health or environment”.

Hazardous waste refers to any liquid, solid or gaseous material that poses threat to health of any living organism including humans & environment due to improper handling, treatment, storage, transportation or management. It is a special type of waste that cannot be disposed off like other by-products. Many a times these wastes are generated from non-specific sources or discarded chemical products.

The hazardous characteristics of these waste material make it highly dangerous to people at large. It could be ignitable under particular temperature and pressure; reactive and can cause explosion, vapours, fumes or gases when compressed, heated or mixed with water; toxic when inhaled, ingested or absorbed by the skin; corrosive having high or low pH.

Classification of Hazardous Waste

Hazardous wastes are classified in different categories on the basis of origin, nature and characteristic:

1. Universal wastes

Wastes generated commonly in large quantity but are of less hazardous in nature to people at large comes under category of universal wastes. For eg. pesticides, tube lights, bulbs, batteries, mercury generated equipment, etc. It has been seen that universal wastes are normally controlled by lenient controlling mechanism but need to be disposed of properly. These wastes are classified in 9 categories namely; explosives, gases, flammable liquids, flammable solids or substances, oxidizing substances and organic peroxides, toxic and infectious substances, radioactive, corrosive substances, & miscellaneous dangerous substances and articles.

2. Household hazardous waste

The wastes generated from residential household falls in this category. Many wastes included in this category also falls in other categories hence overlap with each other. Some of the household hazards include paints and solvents, automotive wastes, pesticides, gas cylinder, cleaning agents, electronics, batteries, ammunition, asbestos, radioactive waste, smoke, etc.

3. Listed Wastes

There are four categories of listed waste depending on specific source, non-specific source and chemical products used in commercial set-ups. They are named as F-list, K-list, P-list and the U-list.

The F-list includes any wastes that are produced from manufacturing and industrial processes but have a nonspecific source. Of the F-list wastes, depending on the operations that produce the wastes, they can be divided into seven groups consisting of dioxin-bearing wastes, wood-preserving wastes, chlorinated aliphatic hydrocarbons production, solvent wastes, petroleum refinery wastewater treatment sludges, multisource leachate, electroplating and other metal finishing wastes.

The K-list wastes are waste produced during production and treatment process in industries having specific sources. It is generally wastewater and sludge that become distinguishable as hazardous wastes. The common industries that produce K-list wastes include iron and steel production, petroleum refining, inorganic pigment manufacturing, explosives manufacturing, inorganic chemicals manufacturing, ink formulation, veterinary pharmaceuticals manufacturing, coking, wood preservation, primary aluminium production, organic chemicals manufacturing, pesticides manufacturing, secondary lead processing. These wastes are generally characterized if they are toxic, ignitable, corrosive, reactive or acute hazardous waste.

P-list and U-list wastes are specific commercial chemical products that meet certain criteria and are disposed of, but unused.

4. Characteristic Wastes

Characteristic wastes are listed on the basis of characteristics they display. Normally they are ignitable, corrosive, reactive, & toxic

5. Mixed Wastes

Mixed waste includes wastes that contain radioactive components along with hazardous waste. Their treatment and disposal are different from other hazardous waste since it involves hazardous and radioactive materials.

Effects of Waste

The hazardous waste generated at different levels contribute tremendously to the health and wellbeing of mankind and environment. If this waste is not managed and disposed of properly, it may result in long-term harm to water, air & soil along with harm to living organism and human health.

The industrial sector produces different byproducts depending on their operations that generate hazardous waste. Besides, solvents used in industrial applications are very useful but also have risk to health and environmental. Electronic wastes, batteries, pesticides & insecticides, medicinal waste, & cleaning agents, etc. all have some chemicals or material that directly impact the mother nature.

The benzene used for petroleum refining is not only flammable but also has carcinogen. The same way chemicals used for dry cleaning, in pesticides/ insecticides, cleansers, or metals used in electronic gadgets, not only damage nervous system, liver, respiratory system, irritation on skin and eyes but also harm brain, kidneys, bones, cognitive and physiological functions. Through direct or indirect exposure, these harmful wastes accumulate in the human body and lead to various health issues including cancer. Certain hazardous wastes release toxic gases and these Volatile Organic Compounds also contribute in air pollution, harm living beings and pose respiratory problems to humans.

The medical waste and expired medicines have another challenge affecting aquatic animals and street animals. The herbicides and pesticides used to kill unwanted vegetation and pests not only impact them but are also toxic to wildlife, beneficial insects and humans. Furthermore, their residues seep into ground, remain in soil and water for prolonged periods, and bring harmful chemicals into the food chain. Over the time, this degrades the soil quality, make it less fertile and impact the broader ecosystem in long run.

It also contaminates the underground water tables and surface water causing threat to aquatic life and can enter the human food chain by consuming other affected aquatic organisms. Moreover, contaminated water sources can render water unsafe for drinking and agriculture, leading to various health issues in humans and animals.

Some chemicals released from hazardous wastes get accumulate in smaller organisms and on consumption by larger ones, these chemicals become more concentrated in the bodies of top predators in a process called biomagnification. It also carries significant risks to other animals and humans that consume them.

Improper disposal sites and spills also destruct the natural environment and habitat, change the pH level of water bodies, making it unsuitable for native plants and animals affecting biodiversity and disrupting the local ecosystems.

The risks generated for non-degradable wastes continue for generations, affecting present and future wildlife populations and potentially lead to prolonged health risks for humans and living organisms.

Handling of Waste

Hazardous waste handling is an important aspect for all the producers and users to avoid any mishappening including long term ill effects. Following some common steps in the process can save the environment and people at large.

- The foremost step is to accurately classify the waste stream and determine whether the waste is hazardous or not.
- Depending on the type of hazardous waste, i.e. solid or liquid, the storage facilities must be used in designated areas. It must be stored in a sturdy, leak-proof container that is kept closed when not in use. Containers having liquid waste must have a curbed and impermeable surface to contain.
- The containers having hazardous waste must be properly labelled including, a clear description of the waste owner details, contents, its physical characteristics and the date when the waste is placed in the container. Careful coding is of utmost importance for safe handling along with details of type and quantity.
- Proper transportation and disposal of waste at hazardous waste facility is another very important aspect of handling waste.
- A proper plan should be prepared and known to all to handle any emergency situation caused by mishandling or mistreatment of the waste.
- Proper training regarding nature of hazardous waste and appropriate safety procedures, must be provided to waste handlers and emergency responders along with hazardous waste handling, storing, or otherwise managing hazardous waste.
- The details of hazardous waste generated and disposed of should be recorded for future reference.

Management of Hazardous Waste

Proper hazardous waste management includes different stages. The most crucial steps include reduction of waste generation, safe storing, recycling, transportation, treatment of waste, proper disposal and making people aware about the same.

1. Source Reduction

The fact that waste reduction is better than its management is a known factor and should be part of planning before setting up any new project. Manufacturers can reduce the volume of waste produced or its toxicity by optimizing industrial processes. In many instances, supporting or encouraging greener alternatives can significantly reduce waste. This lessens the environmental burden and is an effective way to improve profits and competitiveness.

By following simple approaches, we may minimise the generation of hazardous waste like improved process technology, modifying & optimizing production process, improved plant operations, redesigning of final products, segregation of waste and hazardous waste, alternate use of waste products, reprocessing of waste to generate energy or other useful product.

2. Recycling and Recovery

Through recycling and recovery techniques, the potential of repurposing waste or extracting valuable components from the waste can be done and after treating them properly these solvents can be reused. It would help in reducing the requirement of virgin material and is also cost effective. For eg. the oil can be recovered through process of re-refining or distillation; used acid can be treated through acid regeneration & filtration through Ion exchange; waste metals can be treated through ion exchange, electrodialysis, reverse osmosis, membrane filtration, solvent stripping and precipitation; solvents can be recovered through distillation, filtration, evaporation, centrifugation and stripping.

3. Treatment

All the harmful wastes must be treated in transforming hazardous waste into harmless form or less harmful to the environment or lives. The risks associated with disposal or further handling of hazardous waste can be significantly reduced by following various treatment procedures altering its chemical or physical properties. Normally, a combination of the techniques is used, to establish the most cost-effective and environmentally acceptable solution.

For instance, neutralizing acidic or alkaline wastes can ensure they don't threaten soil or water systems. Similarly, detoxifying certain compounds can render them harmless, ensuring they don't present health risks upon disposal. On the basis of procedure adopted, the treatments are classified as below:

- a. **Physical Treatment** is the first step to separate liquid and solid waste commonly used in all the industries. Various physical treatment methods include screening, filtration, sedimentation, centrifugation, evaporation, distillation, reverse osmosis, and others.
- b. Through **chemical treatment**, various hazardous wastes are converted into less hazardous substances that are acceptable by the environment. Neutralization, precipitation, oxidation and reduction, coagulation and flocculation, solubility, colour change, disinfection, are some of the chemical treatment processes normally followed by hazardous set-ups.
- c. **Biological treatment** is one of the most efficient and cost-effective way of treating hazardous substances through biological agents. But it has one limiting factor also that the bio-agents need an ideal condition for its growth. Some of the biological treatment processes are bacterial culture, composting method, aerobic/anaerobic reactor, wetland technology, & bioremediation.
- d. **Thermal Treatment:** It has been seen that the most hazardous wastes have components like metals, carbon, hydrogen, nitrogen, oxygen, halogens and sulphur. Through thermal destruction of hazardous waste technology like incineration, the waste is destroyed or reduced to CO₂, H₂O and other inorganic substances that are useful or harmless to environment. But the generation of emission during treatment that is secondary pollutant limits its implementation.

4. Containment

Containment of hazardous waste is an important aspect of waste management to ensure that waste does not leach into soil or groundwater or move through air. It is required to ensure the non-movement of waste into surrounding environment through engineered containment structure.

5. Disposal

The two predominant methods of hazardous waste disposal include landfills and incineration. It has been seen that despite of many initiatives, some hazardous wastes were disposed of in regular landfills resulting in seeping of hazardous material into the ground and contamination of ground water. Hazardous waste may be seized in a defined hazardous waste landfill or permanent disposal facility with impermeable cover. To ensure safe disposal and avoid seeping of hazardous substances, a barrier must be installed along the foundation of the landfill to contain the hazardous substances. Landfills for hazardous waste must have low permeability soil linear and/or synthetic linear to prevent seepage of leachate to underground strata. A separate drainage layer for leachate collection with leak detection system must be taken care of.

Though the landfill options are quite risky and generally have the fear of subsurface pollution, it is recommended to properly segregate the waste before disposal and only solid wastes are landfilled. The liquid waste should be solidified before disposal.

Another method is incineration of non-recycled and untreated dangerous waste at high temperature and under controlled conditions to ensure minimum release of harmful emissions. Through incineration, not only quantity of hazardous waste is reduced, besides the energy could also be generated from the gases released during the process. In terms of controlling air pollution, starved air incineration is an improved version of the traditional incinerators. Using this technology, the combustion rate of waste could be controlled reducing harmful polluting byproducts produced in the process. This is an ultimate option with every industry. In India, there are seven major incineration sites located in Rajasthan, AP, Maharashtra, Gujarat, TN, West Bengal and MP. In some of the states, this hazardous waste is also proposed to be used for providing supplementary fuel in cement kilns. *some of the States, the incinerable hazardous wastes is proposed to be used as supplementary fuel in cement kilns*

There is plasma technology also through which all waste is put into electrical arc and ultra heat is generated at more than 3000 degree centigrade temperature. Through this process the waste melts into molten slag and when cooled, solidifies into rock like material. Though this process is very expensive but is preferred for the destruction of concentrated organic waste types, pesticides and organic pollutants.

6. Transportation

Proper transportation of hazardous waste is another challenge that needs to be addressed with caution. To protect health of living beings and environment, the movement of hazardous materials from their generation point to treatment, recycling, or disposal facilities has to be done with due care. Properly labelled specialized vehicles designed to contain spills or leaks along with trained drivers and supporting staff having complete knowledge of handling emergencies should be deputed for this purpose. The waste must be transported to facilities specifically designed to safely handle, treat, or dispose of such waste. The emergency response plan including protocol to ensure swift containment of any leakage or spill must be ready to minimize environmental damage and risk to health. Complete tracking of waste transportation including its documentation is a must for clear chain of custody.

7. Regulations

Creation of robust regulatory system and its proper implementation is must in handling, transportation and disposing of the hazardous waste to protect the people, environment, ecosystem and living organisms from potential harm. Improper waste management can pose threat to people at large across the globe. Proper compliance of rules and regulation can help us in saving the mother earth.

8. Public Awareness

Informing and educating business houses and the general populace about the risks and management strategies associated with hazardous waste can lead to more responsible behaviors. Public awareness campaigns can inspire industries to adopt greener practices, households to dispose of hazardous materials correctly, and communities to advocate for safer, more sustainable waste management solutions. Knowledge empowers individuals and organizations alike to make choices that benefit them for long run.

Conclusion

Hazardous waste has a long-lasting environmental impact. If not handled properly, hazardous waste may contaminate the air, water and soil affecting the whole ecological system. The proper management and disposal of waste is critical in preserving the human health, environment, ecological balance and overall well-being of planet. These waste products are a byproduct of development and lifestyle we all follow these days that needs to be addressed urgently. The issue of hazardous waste touches all, from industrial process to household owners. It is not limited to few scientists or policymakers.

Through general awareness, having informed citizens, and advocating for robust waste management practices, we can contribute to a safer, healthier environment for present and future generations. Effective management strategies, ranging from source reduction to stringent regulations, are other weapons against the threats posed by these wastes.

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