Course Learning Outcomes for Unit VI

Upon completion of this unit, students should be able to:

4. Describe properties of various types of hazardous waste.
   4.1 Interpret data and information to calculate a technical result for a hazardous waste condition.
   4.2 Express the technical data results to a specific hazardous waste scenario.

5. Recommend methods for controlling the environmental impact of hazardous waste.
   5.1 Evaluate different operations and technologies that can be employed to treat hazardous wastes containing PCBs.
   5.2 Compare various treatment recommendations for hazardous waste.

Course/Unit Learning Outcomes	Learning Activity
4.1	Unit VI Project
4.2	Unit VI Project
5	Unit Lesson
5.1	Chapter 16 Unit VI Project
5.2	Unit Lesson Chapter 16 Chapter 17 Unit VI Project

Reading Assignment

Chapter 16: Hazardous Waste Treatment

Chapter 17: Land Disposal of Hazardous Waste

Unit Lesson

The treatment of hazardous wastes requires a thorough understanding of the waste characteristics and the treatment options employed to meet treatment standards. Hazardous wastes treatment generally requires multiple technologies to employ. Not only is it important to select the technologies, but also it is important to align the order of the technologies to achieve the overall treatment objectives. Most of us are familiar with the equipment and technologies integrated into a treatment plan. What is missing is having a good understanding of what happens inside these unit operations. Transforming some of the chemical and physical properties of the waste is one way to treat hazardous waste streams.

One of the technologies used to treat hazardous waste includes the precipitation of small particles from liquid wastes (NALCO Water, n.d.). Chemical precipitation involves a two-step process that involves the process of coagulation (becoming viscous) and flocculation (loose, aggregated). For most scientists, this is a black box when it comes to understanding the science behind the chemicals used to perform these functions. In liquids, larger particles readily settle to the bottom of a vessel because of gravity. As the particles get smaller, the surface area begins to control the settling properties of the solids. Gravity has little impact. The charges on the surface of particles will keep particles in suspension. The charges repel each other keeping the particles in suspension (ChemTreat, n.d.-a). If you take a glass of lake water, solids are distributed throughout the glass. Because it is difficult to see individual particles, these are commonly referred to as colloidal solids and the mixture is known as turbidity.

The strategy of deploying chemical precipitation is to neutralize the surface charges and then to agglomerate the particles into larger groups where gravity will begin to cause the solids to settle out of the liquid. The chemicals responsible for charge neutralization are coagulants. A common coagulant is a co-polymer comprised of melamine and formaldehyde monomers. These react to form a polymer with a molecular weight of 10–20,000 g/g-mole. When the polymer reacts with the charges on the surface of the colloidal solid, the tails of the polymer extend out into the liquid repelling other chemically conditioned solids. The second part of the strategy involves flocculating the charge, neutralizing the solids, and building them into larger particles. These are called flocs and after they are built, gravity causes them to settle to the bottom of the vessel. Flocculant chemistries are generally acrylamide-based, and these can have molecular weights up to 50 million g/g-mole (Accepta, n.d.).

The chemical precipitation process works as follows.

- Coagulants are mixed into hazardous waste waters at a level that accomplishes the neutralization of surface charges. This takes a certain level of mixing to ensure that all solids are chemically conditioned.
- Then at low agitation, the flocculant is added and the floc size begins to grow. With too much agitation, the shearing force breaks the floc apart.
- After the flocculation process is completed, agitation is shut off, and the chemically conditioned solids settle to the bottom of the vessel.
- After being pumped out, the wastewater is filtered, and the solids are pressed to thicken them for further handling and disposal.
- Tech service professionals will start to develop a chemical program by running bench studies to find and select the correct combination of chemicals (Pichtel, 2014).

It is as much art as it is science. Some chemical combinations leave colloidal particles unattached, while others form flocs that are easily broken after pumping them out of the tank—the shear forces destroy the flocs. When the right combination is found, strong flocs form, and thickened solids settled to the bottom.

The key variables in chemical precipitation are knowing the multiple chemistries of the coagulant and flocculant reactants. The various chemistries, charge densities, and molecular weights of the coagulants have different capabilities for neutralizing surface charges. For flocculants, molecular weights are the most important. Some chemistries have a dual role. Mannich polymers have the capability to do both charge neutralization and flocculation (ChemTreat, n.d.-a).

Another technology for treating hazardous wastewater involves the separation of oil from water. Oil-water mixtures are referred to as emulsions (ChemTreat, n.d.-b). Emulsions are found in refineries when American Petroleum Institute (API) separators are cleaned. The bottom sludge layer is processed with a centrifuge and the centrate is an emulsion that is comprised of three phases: oil phase, water phase, and the rag layer. The rag layer is comprised of solids and dirt that need to be separated and sent to a hazardous waste facility for thermal oxidation. The emulsion forms when emulsifiers are present. Soap is an example of an emulsifier. One end of the molecule is water-soluble; the other end of the molecule is oil-soluble. The surfactant bridges the two phases and forms an emulsion. The dirt gets into the API separator and becomes mixed into the emulsion. To break an emulsion, an emulsion-breaker is added to the mixture that works at the oil-water interface and allows the oil to coalesce into the oil phase (ChemTreat, n.d.-b). Embreak 2168 is an example of an emulsion-breaker. The chemistry is an oil-based asphaltene stabilizer. Once the emulsion is broken, each of the phases are separately treated (Chemical Online, 2014).

Activated carbon serves as a medium with a large surface area-to-volume-ratio. A few grams of carbon can have as much surface area as a football field. To this surface, chemicals sorb to the carbon removing them from the wastewater. As the carbon becomes saturated with sorbed organics, an interesting phenomenon occurs. Chemicals are preferentially sorbed ("Sorb," n.d.). When there is a lot of surface area available, many different organics sorb to the carbon. As the sorption sites fill, one chemical is replaced by a more preferential chemical. This sets up a strategy for monitoring the activated carbon process. By monitoring for the weakest sorbed chemical, its presence in the effluent is an indication that the carbon needs to be regenerated. Carbon regeneration occurs at a high temperature in the absence of oxygen. The organic chemicals that are sorbed are destroyed in the regeneration process and the sites are available again. The regeneration process is similar to the way that charcoal is formed from wood. Make-up carbon needs to be added to regenerated activated carbon to account for what is lost (Nowicki, & Nowicki, 2016).

Wastewater treatment works in Ayrshire, Scotland.
(Qualit-E, 2009)

Ion exchange is another sorption technology that involves a resin. Chemicals in a hazardous-waste stream are adsorbed to the column and an ion is released from the column into the waste stream. The ion exchange medium is a polymeric medium that can be formulated to target specific chemical substances. Resins can be strong or weak, and they can be cationic or anionic. Ion exchange operations are considered to be a tertiary treatment that is a final clean-up operation. They work best in dilute wastewaters where the target chemical is at low concentration (Mazille & Spuhler, n.d.). Ion exchange tertiary treatment operation is often the final step to achieve water-quality standards.

Solidification is a process reserved for difficult-to-treat hazardous wastes. Solidification is based on the principle of changing the physical properties of the waste rather than the chemical properties. The treatment process involves mixing a binding and filling agent with the waste and allowing the waste to cure and set up into a solid block. Some of the common binding agents include cement, fly ash, hydraulic lime, and hydrated lime. The binding agent is chosen to prevent hazardous substances from being leached out into the environment. The blocks are buried in a secure landfill (Environmental Protection Agency, Center for Remediation Technology and Tools, 1996). In remote areas where hazardous wastes are dispersed throughout a large area, solidification is done in-situ (in place without excavation). It is always a challenge to mix the chemical into the soil. If areas are inadequately treated, rain will leach into the soil and transmit contaminants into the groundwater. This is one reason why groundwater sampling is always a part of a post-closure plan. It can sometimes take more than one treatment to stabilize the area.

In addition to the above unit operations, it is common to use treatment technologies that are more broad-based. Chemical oxidation treatment is often used to reduce the toxicity of a chemical mixture. Chemicals like ozone or hydrogen peroxide degrade to form the super peroxide radical that is a general oxidant, similar to chlorine. The oxidant chemically reacts with organic substances including toxic mixtures to change the structure of chemical substances to form a less toxic substance. See Table 16.3 in the textbook for commonly used oxidizing and reducing agents (Pichtel, 2014). The chemical oxidation of some hazardous wastewaters transform them enough that they can be biologically treated to further degrade them towards CO2 and water. Chemical oxidation is often an early stage unit operation that transforms hazardous wastes into wastes that can be more easily treated (EMIS, n.d.).

The purpose of the above examples is to demonstrate the importance of knowing the role that chemistry has in the treatment of hazardous wastes. It is evident from the above examples that there are a variety of technologies for treating hazardous wastes. Equipment and unit operations have an important role in processing wastes but this is often in conjunction with the use of chemical agents. The environmental professional needs to understand the characteristics of the wastes that are generated at their facility and the technologies that are required to treat these waste streams. There are multiple sites around the United States that treat hazardous wastes. It is not enough to float a bid specification to hazardous waste sites and to choose the lowest bidder. One approach is to run a pilot at the hazardous waste site. This can either be at lab scale or a small system tied together to form a treatment train. The pilot evaluations can include isolating components that can be reused in commerce (e.g., steam stripping or liquid gas extraction). Based on these lab and pilot tests, the environmental professional will reorder the unit operations to optimize their performance and to meet permit performance criteria.

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Suggested Reading

In order to access the following resource, click the link below.

The following is an excellent resource that discusses treatment technologies for treating hazardous wastes. Not only is it a comprehensive compilation of available technologies, but this resource provides treatment efficiencies for a variety of hazardous waste profiles.

Canadian Council of Ministers of the Environment. (1989). *National guidelines on physical-chemical-biological treatment of hazardous waste* (Report No. CCME-TRE-27F). Retrieved from http://www.ccme.ca/files/Resources/waste/hazardous/pn_1082_e.pdf

The following video gives you in-depth information on various important methods of in-situ biological treatment of contaminated soil according to the Environmental Protection Agency (EPA) to help you to understand the process to treat hazardous wastes.

Clark, G. (2013, October 31). *In-situ biological treatment of contaminated soil* [Video file]. Retrieved from https://www.youtube.com/watch?v=bAwAFu7Mrk4

Click here for the video transcript.

Learning Activities (Nongraded)

Nongraded Learning Activities are provided to aid students in their course of study. You do not have to submit them. If you have questions, contact your instructor for further guidance and information.

Chemistry has an important role in the treatment of hazardous wastes. As the environmental, health and safety (EHS) manager at a small metal cutting operation, wastewater containing metal files are discharged into a holding tank outside of the facility. The plant manager has given you the assignment to find a hazardous waste site where the tank contents can be shipped for treatment. In your journal, list the criteria that the treatment facility must meet to qualify as an acceptable site. In addition, construct 20 audit questions built around the decision criteria that you would use before signing a three-year contract with the facility.