Future Generation of Communication and Internet of Things (FGCIOT)

Journal homepage: http://fgciot.semnaniau.ac.ir/

Research paper

Use of Internet of Things (IoT) in Hazardous Waste Management System

Reza Samieifard*

Energy and Sustainable Development Research Center, Semnan Branch, Islamic Azad University, Semnan, Iran

Article Info

Article History:
Received: 6/2/2022
Revised :6/20/2022
Accepted :7/2/2022

Keywords:
Internet of Things (IoT)
Hazardous waste
Recycling
Recovery
Treatment
Landfilling

*Corresponding Author's Email Address:
r_samifard@yahoo.com

Abstract

Population expansion, urbanization and industrialization of cities on the one hand and the rapid growth of technology, access to new production processes, replacement of synthetic materials instead of natural fibers and synthesis of thousands of types of chemical substances and compounds on the other hand produce solid and liquid hazardous wastes. Hazardous waste is generated at various stages of exploration, transportation, manufacturing, distribution and consumption of the product. At each stage, the hazardous waste management system requires special facilities and equipment, which include land, structures and other belongings that are used to store, recycle, recover, treat or dispose of hazardous waste. In this regard, intelligent management of hazardous waste using up-to-date methods and facilities, including the Internet of Things (IoT), is of great importance. Based on this, hazardous waste management facilities are divided into three general categories: recycling / recovery, treatment and disposal on land, and in each category, different methods have been studied. This paper also describes how to use the IoT at different stages of hazardous waste management. Studies show that the use of IoT can increase the efficiency of all hazardous waste management chains.

Introduction

The category of hazardous waste management facilities is not new. Years before hazardous waste laws were passed in the United States, many hazardous waste producers recognized the urgent need to treat and dispose of such waste. Many hazardous waste producers managed hazardous waste by constructing and operating "on-site facilities". In 1954, for example, Dow Chemical Company built a rotary incinerator with the aim of heat-destroying organic waste left over from large quantities of chemicals. A large number of industrial waste treatment plants were also established to neutralize acids and precipitate metals.

Other producers of hazardous waste transferred their waste to other areas for treatment and disposal due to the lack of a suitable place for storage and processing of hazardous waste or the lack of production of large amounts of hazardous waste that justifies the use of on-site facilities. This type of facility is called an "off-site facility" [1]. In the hazardous waste management industry, the construction and operation of off-site facilities expanded dramatically in the late 1960s. Rollins Environmental Services Company, one of the first companies in the field of off-site installations, started in 1971 in New Jersey and still operates on old sites with modern facilities and equipment.

As hazardous waste generation varies, there are different ways to manage such waste. Today, there are about 50 proven commercial technologies for the treatment and recycling of hazardous waste [2]. A hazardous waste treatment and recycling center may operate with only one or a combination of several technologies. The use of multiple technologies is inevitable when a hazardous waste treatment and recycling center serves several hazardous waste producers.

The most common hazardous waste management facilities (excluding storage facilities) are shown in Figure 1.

Doi:

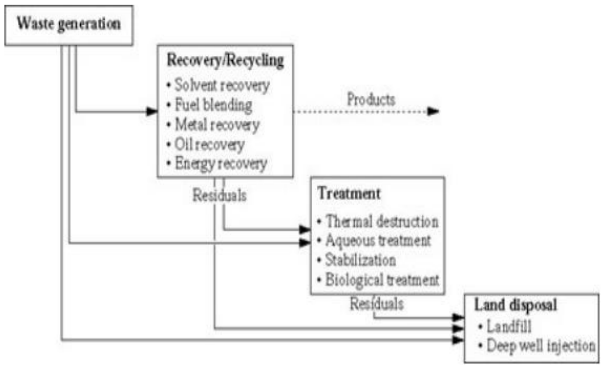

Fig. 1: Facilities for recycling/recovery, treatment and disposal of hazardous waste

As can be seen in the figure 1, hazardous waste management facilities are divided into three main groups, which are:

-Recycling / recovery facilities: Some of these facilities convert waste into marketable materials (such as solvents, oils, acids or metals) and others use the calorific value of waste (such as cement kilns).

-Treatment plants: These plants change the physical or chemical properties of a waste using a wide range of physical, chemical, thermal or biological methods.

-Disposal facilities on the ground: Permanent placement of waste on or below the ground after waste treatment according to the standards is called “Land Disposal Restrictions (LDR)”. Each of the above will be explained below.

1-Recycling / Recovery Facilities

1-1-Solvent Recovery

By separating the contaminants from the contaminated solvents, these facilities regenerate them and convert them into primary or lower quality solvents. This has many applications for the reduction of halogenated solvents. Distillation is one of the processes used by most solvent processors and recycles about 75% of contaminated solvents [3]. Contaminated solvent residues can be in the form of liquid or sludge and should be treated as hazardous waste. Other processes used by solvent processors include filtration, simple evaporation, centrifugation, and stripping.

1-2-Oil Recycling

Most of the used lubricating oils can be recycled to their original quality. The process used for this purpose is called "oil refining". The two methods used in oil recycling are called acid / clay method and intensified distillation method. Because the acid / clay method produces a significant amount of residual oily clay, the intensified distillation method is preferred.

1-3-Acid Recovery

Acid recycling usually involves the separation of unprocessed acid from acidic waste, which is widely used in the steel industry. The method used in the steel industry to reduce acid is to cool sulfuric acid to precipitate ferrous compounds [3]. Alternatively, the acid is reduced by injecting it into a spray fryer. Sour liquid is heated in a spray fryer to form iron oxide and gaseous hydrochloric acid. At the outlet, gaseous hydrochloric acid is separated from other gases to be reused in production lines [3].

1-4-Metal Recycling

Metal recycling is done in two ways: “pyrometallurgical” and “Hydrometallurgical” [4]. In pyrometallurgical method, the difference between the melting point and the boiling point of metals is used to separate them. The required temperature is usually provided by frying or melting. In Hydrometallurgical technology, the metal is separated from the liquid waste (sewage). In this method for separation of metal, processes such as ion exchange, electrodialysis, reverse osmosis, membrane filtration, adsorption, electrowinning, solvent stripping and precipitation are used. It should be noted that to use this method, non-aqueous wastes must first be converted to aqueous solution.

1-5-Mixing with Fuel

In general, waste fuels can be produced in the following two ways:

-Combining different wastes with high calorific value

-Combining different wastes with coal or fuel oils

Wastes, especially oils, need to be pre-treated before being used as fuel compounds. This pre-treatment is to remove sediment and water in this waste. For this purpose, separation and hydration methods are used. The fuel mixing method is a simple and proven technology.

1-6-Waste Co-Incineration in Industrial Furnaces

Manufacturers of cement, pumice and some other products use a special type of rotary kiln. Disposal of hazardous waste by co-incineration in the presence of primary fuels and raw materials in such furnaces has long been common. Cement kilns with high temperature (2600 to 3000 degrees Fahrenheit) and long retention time of materials in these kilns, allow the destruction of the main hazardous organic components of the waste [5]. Therefore, waste is considered as an auxiliary source

for fuel. The waste can be mixed with the fuel on site or the waste can be mixed with the fuel in separate facilities and then fed to the furnace. An example of a solvent and waste oil recycling facility is shown in Figure 2.

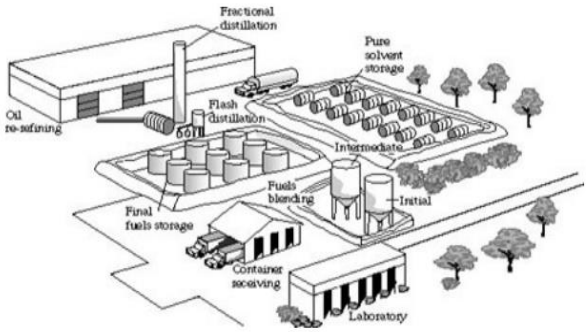

Fig. 2: Liquid organic matter recycling facilities

2-Treatment Plants

2-1-Heat Degradation

When waste is exposed to high temperatures in the presence of oxygen, its organic matter is partially or completely destroyed. The most common method of heat degradation is waste incineration, in which hazardous waste is treated in a closed environment using controlled fuel. Existing federal laws in the United States specify 99.99 percent demolition and disposal efficiencies for waste incinerators [6].

2-2-Aqueous Treatment

In an aqueous treatment system, hazardous components suspended or suspended in water are removed or detoxified. The choice and arrangement of aqueous treatment system units depends on the characteristics of the incoming waste and the required quality of the output. Figure 3 shows the degradation diagram of aqueous waste containing cyanide [7].

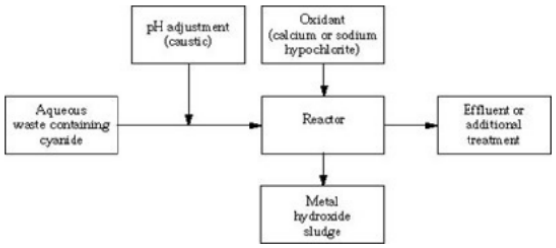

Fig. 3: Diagram of cyanide degradation process

An example of a complete aqueous treatment plant is shown in Figure 4. The process units listed below are capable of treating almost any type of aqueous waste. These process units are:

-Degradation of cyanide
-Chrome reduction
-Two-stage metal sedimentation
-pH adjustment (neutralization)
-Solid filtration
-Biological treatment
-Adsorption by carbon
-Sludge Dewatering

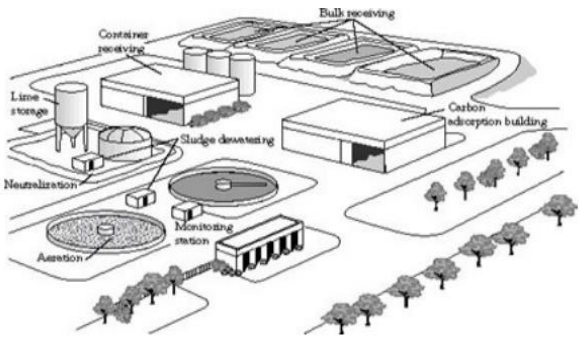

Fig. 4: Complete aqueous treatment plant

2-3-Stabilization

The stabilization process involves mixing certain materials with waste, which is done to improve its physical properties in order to reduce the movement of pollutants in the landfill [7]. Stabilization may reduce the solubility of waste contaminants to zero by chemical modification, or reduce their solubility by chemical bonding.

2-4-Biological Treatment

Biological treatment systems use microorganisms to treat organic waste. In this method, organic matter is either mineralized or converted into lower molecular weight compounds [7]. The primary variables in the biological treatment process are the method of contact of the waste with microorganisms, the moisture of the waste and the method and amount of aeration.

3-Disposal Facilities on the Ground

3-1-Landfilling

Landfilling is the ultimate fate of hazardous waste. In most cases, pre-treatment (such as stabilization) is required before waste disposal in the landfill [8]. Waste disposal in the landfill can be done superficially or in the form of cells in the depths of the earth. A landfill contains several protective elements (such as liners). These elements are designed and implemented in such a way that the production of leachate is minimized and the leachate is properly removed from the site [9]. It should be noted that after the closure of the landfill, it should

be monitored.

3-2-Injection into a Deep Well

This disposal method is done by injecting liquid waste into a deep, porous well containing salt water. Attention to geological layers in this type of disposal operations is of particular importance. Waste wells should be sufficiently spaced from groundwater aquifers and the top layer of the waste injection site should be impermeable. Injection wells include injection pipes. These pipes are formed by a series of concentric sheaths, the space between which is filled with cement and non-corrosive liquids. These shells prevent material from leaking into the structures around the well.

4-Integrated Hazardous Waste Management Facilities

Various studies show that today the hazardous waste management industry is limited to limited but larger companies and the establishment of companies that have the ability to provide complete services of transportation, storage, treatment and disposal of hazardous waste, compared to companies that only they specialize in one of the mentioned services, it is more economical. Therefore, some large commercial facilities use Aqueous treatment, waste incineration, land disposal and other components and form an integrated and comprehensive waste management facility. Figures 5 and 6 show the integrated waste management facilities [10].

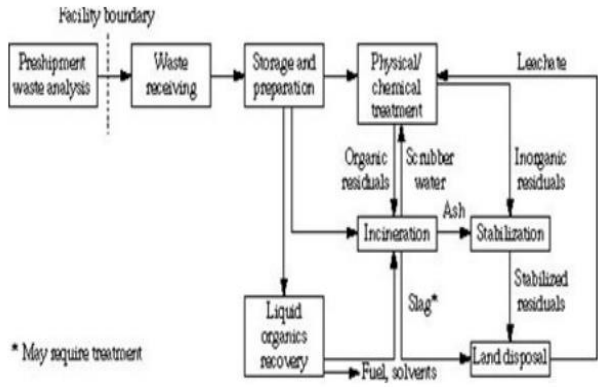

Fig. 5: Waste management chart in hazardous waste management integrated facilities

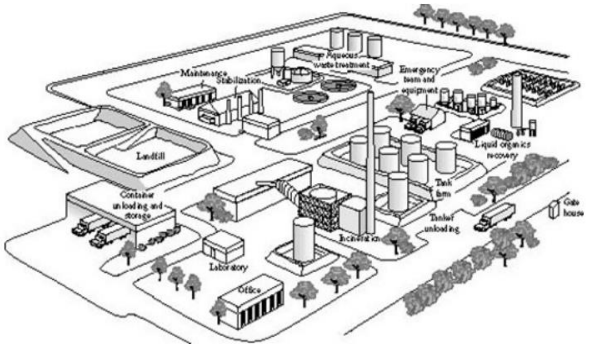

Fig. 6: Hypothetical location of hazardous waste management integrated facilities

5-IoT in hazardous waste management

Hazardous waste management includes processes of waste collection, transportation, processing, disposal, management and monitoring. These processes require time, labor and cost. The Internet of Thing (IoT) can help improve hazardous waste management processes by using the right equipment.

The amount of hazardous waste produced varies at different times. Hazardous waste manufacturers can install a sensor to measure the fullness of the waste storage tank. By sending information about the fullness of the tanks to the collection service, the waste collection vehicle will collect in proportion to the fullness of the storage tanks. How to load and select the optimal route to remove the filled tanks is another category of using the IoT. This method of collection saves fuel consumption as well as manpower costs.

Another challenge in hazardous waste management is how to allocate the collected waste to processing and disposal facilities. As mentioned earlier, there are several ways to process and dispose of hazardous waste. The choice of method depends on various factors such as quantity and quality of hazardous waste, capacity of processing and disposal facilities, distance, labor, cost, etc. The use of the IoT makes it possible to select the appropriate method of processing or disposal by considering the above factors and using the relevant equipment.

Conclusion

Identifying various hazardous waste management facilities and allocating waste to these facilities is one of the most important steps in designing and implementing a hazardous waste management system. Therefore, in this research, various facilities in hazardous waste management were identified and classified. In each category, different methods are presented and its advantages and disadvantages are discussed. Most hazardous wastes are complex in nature, as there are

various factors for allocating hazardous waste to processing and disposal facilities, outdated methods and techniques may not be responsive. In this regard, the use of modern technologies such as the IoT can be helpful. Various studies show that today the construction of hazardous waste management facilities with the approach of using the IoT, which is a combination of different systems and methods, compared to the past methods, which is based on personal experience, is more effective and more productive. Therefore, it can be concluded that from a macro perspective, the establishment of hazardous waste management facilities on the IoT is one of the most important solutions to solve the problem of hazardous waste generation.

Author Contributions

R. Samieifard collected the data and wrote the manuscript.

Conflict of Interest

The author declares that there is no conflict of interests regarding the publication of this manuscript. In addition, the ethical issues, including plagiarism, informed consent, misconduct, data fabrication and/or falsification, double publication and/or submission, and redundancy have been completely observed by the author.

References

[1] Rabbani, M.; Danesh Shahraki, S.; Farrokhi-Asl, H.; Frederick, W.T.; Lim, S. A new multi-objective mathematical model for hazardous waste management considering social and environmental issues. Iran. J. Manag. Stud. 11, 831–865, 2018.

[2] Orloff, K.; Falk, H. An international perspective on hazardous waste practices. Int. J. Hyg. Environ. Health, 206, 291–302, 2003.

[3] Freeman, H. M., ed., "Standard Handbook of Hazardous Waste Treatment and Disposal", McGraw-Hill, New York, 1998.

[4] Freeman, H. M., ed., "Standard Handbook of Hazardous Waste Treatment & Disposal", p. 11. 10, McGraw-Hill, New York, 1998.

[5] ERM, Inc., "Hazardous Waste Management Technologies-An Assessment", report to Pennsylvania Department of Environmental Resources, February 22, 1983.

[6] "Incinerating Hazardous Wastes", edited by H. M. Freeman, Technomic Publishing Co., Lancaster, Pa, 1988.

[7] Clark-McGlennon associates, Inc., "An Introduction to Facilities for Hazardous Waste Management", report to the New England Regional Commission, Boston, November, 1980.

[8] Buckingham, P. L., "Protecting Ground Water With Sitting Criteria", Proceedings of Hazardous Materials Management Conference, Philadelphia, July 14, 1983.

[9] Buckingham, P. L., "Regional Screening Approaches to Selecting Sites for New Secure Landfills", Proceedings of Fourth Annual Madison Conference of Applied Research & Practice on Municipal & Industrial Waste, University of Wisconsin, Madison, September 28-30, 1981.

[10] McCopy and Associates, "Locational Criteria for Sitting TSD Facilities May Have Broad Impact", The Hazardous Waste Consultant, November/December, 1986.