Research Article
Journal of Chemistry Letters
journal homepage: www.jchemlett.com
ISSN (online):2717-1892

Green removal of hospital-medical wastes by designed integrated pyrolysis-incineration system

Ali Khani [a, b,]*, Hamed Rasulzade[b], Nazli Aqapur[b]

[a]Department of Chemistry, Miyaneh Branch, Islamic Azad University, Miyaneh, Iran
[b]Taher shimi-e- Miyaneh Co., Miyaneh, Iran

ARTICLE INFO

Article history:
Received 15 July 2020
Received in revised form 10 September 2020
Accepted 30 September 2020
Available online 1 October 2020

Keywords:
Nosocomial waste
Pyrolysis
Incinerator
Environment
Hydrocarbon

ABSTRACT

The main purpose of the present paper is to introduce the designed integrated pyrolysis-incinerator system for green removing the hospital-medical wastes (nosocomial wastes). The pyrolysis unit and incinerator are two main component of the system. The results showed that the wastes convert to a) valuable products such as hydrocarbons, non-condensable gases, carbon black and scrap metal and glass, b) the safe flue gasses according EU emission limit. In the incinerator section, only drug mixture including solutes, liquids and powders previously dissolved in water burn at temperature of 850-950 ºC. The some physical properties of the obtained hydrocarbons produced from pyrolysis unit such as density (in 15.6 ºC), flash point and pour point are 0.81 g.cm-^{3}, free and <-30 ºC , respectively.

1. Introduction

With the development of global health as a result of improving the economic situation and living standards of people, the growth rate of hospital and medical wastes is accelerating [1]. Therefore, these hazardous and special wastes must be properly managed. For selecting the most efficient treatment method of hospital waste, the composition analysis is generally considered to be the fundamental information. The combustible wastes constituted paper (16.17%), textiles (9.77%), cardboard, wood, and leaves (1.12%), food waste (21.5l %), and plastics (50.45%). The noncombustible waste included 0.40% metal and 0.57% glass [2].
The first and most important step for this purpose is to disinfect and sterilize them. As healthcare institutions search for methods to decrease costs associated with medical waste disposal, many are turning to the use of steam autoclaves [3], because it is more accessible and cheaper than incinerators. However, there are no national standards for challenging medical waste autoclaves and no guidelines for parameters of sterilization for medical waste. On the other, problems such as lack of isolation, steam exudation and high-energy consumption increase the importance of using other methods. Steam did not fully penetrate the load, and bacteria were not killed. Despite assurances from marketers of medical waste autoclaves, institutions considering this method must test autoclaves carefully to ensure safety and compliance with local health regulations. After even sterilizing, when the waste are disposed at dumpsites, they can also cause serious human health, environmental and atmospheric problems [3].
The next general method is to use incinerators. The only purpose of waste combustion systems is to process this waste into safe material while maintaining required legal conditions; for instance, flue gas temperature at the thermoreactor chamber outlet should be at least 1100 ºC (for hazardous wastes). It is worth designing systems that not only handle waste properly, but are also highly effective in using the recovered energy for other purposes. This is of crucial importance especially in the case of medical waste being fuel with high calorific value [4].
There are also many publications, which describe waste-heat management in urban or industrial areas [5]. However, the problems concerning gas emissions such as dioxin to the atmosphere from waste incineration are very important in point of human health and environment [6]. Another method that solves the problem of toxic gases emission is the use of plasma technology in incinerators. In this case, the produced temperature is very high and its technology is relatively complex and expensive.

* Corresponding author. Tel.: +989143238611; e-mail: a.khani59@yahoo.com

Therefore, its use may not be available to everyone. For example, the maximum operation temperatures of the small plasma melter, and the 10 kg.h^{-1} plasma furnace are 1700 °C and 1650 °C, respectively [7].
The main purpose of the present paper is to introduce the designed integrated pyrolysis-incineration system for green removing hospital-medical wastes.

2. Experimental

2.1. Materials

The hospital-medical waste sample obtained from the Takan Co., Tabriz, Iran and analyzed (Table 1). The experiments were repeated three times (standard deviation (σ) = 0.1).

Table 1. The constructive composition of the waste mixtures

Type of Material	Wt%
Plastics	52.0
Textiles (synthetic)	10.9
Wood, paper, etc	8.1
Glass and metals	2.8
Drugs (solution and solid powder)	26.2
Summation	100.0

2.2. Methods

Detection and measurement of hydrocarbons were done by ASTM method in Iranian institute of research and development in chemical industries, Karaj, Iran. Chemical analysis of exhaust (flue) gases was done by gas chromatography with flame-ionization detection (GC-FID). The designed integrated pyrolysis-incineration system was used to remove the hospital-medical wastes. The main parts of the system that were showed in Figure 1, are as following: 1- isolated feeder, 2- shredder, 3- separator column, 4- pyrolysis unit, 5- incinerator, 6- oven and 7- heat exchanger. The pyrolysis unit and incinerator are two main component of the system. The heat source of the system are burners that work with urban gas. The temprature of generated heat in pyrolysis unit and incenerator is 350-450 and 850-950 °C, respectively. The operation steps are as follows: about 100 kg of waste is loaded into the feeder. Then shredder crushes the waste and directs them to the separator column. In this part, waste is divided into three parts based on the physical properties of the material (a- plastics, syntheic textile and wood, b- drugs and c- metals, glass, etc.). The fate of the material is summarized in Figure 1.

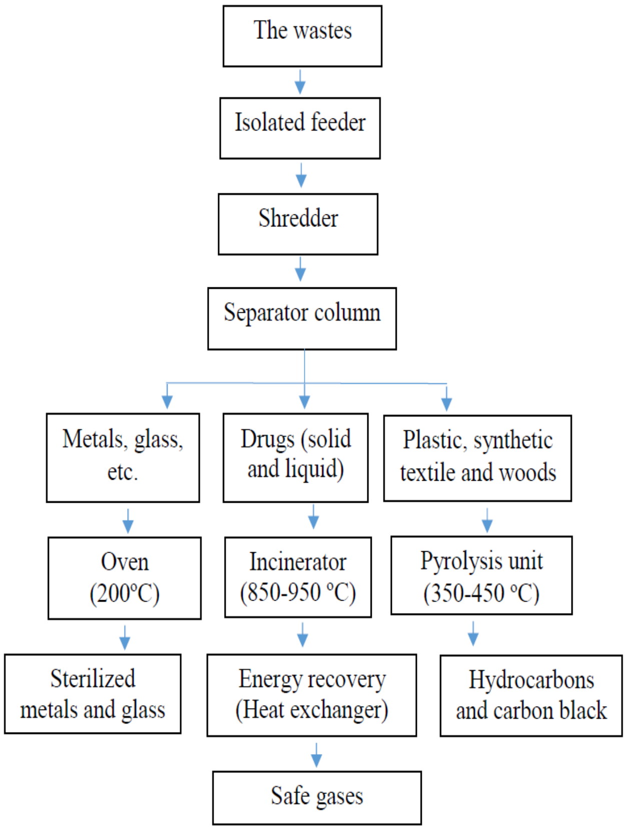

Figure 1. The block diagram of the integrated pyrolysis-incineration system

3. Results and Discussion

3.1. Pyrolysis unit

The plastics, synthetic textile and wood decompose in cylanderical pyrolysis reactor (V=250 L with mechanical stirer) to hydrocarbons vapors and then condence with water coling system. A certain non-condensable gas is burned in the reactor furnace instead of natural gas usage [8]. The composition of the obtained hydrocarbons were summarized in Table 2.

Table 2. Composition of the obtained hydrocarbons

Compound	Vol%
Unsaturated cyclic hydro.	3.9
Paraffines	9.5
Naphthenes	7.1
Olefins	36.1
Aromatics	34.4
Oxygenated compounds	9.0

The some physical properties of the obtained hydrocarbons such as density (in 15.6 °C), flash point and pour point are 0.81 g.cm-3, free and <-30 °C , respectively.

The pyrolysis temperature must be high enough to thermally degrade the polymers (350-450); however, higher temperatures and long gas residence times in the reactor hot zone can volatilize the oil to gas [9]. In this temperature the all microorganism can be degraded in period of few seconds [10]. Another product is carbon black, which was about 45 Wt%.

3.2. The incinerator

Due to the high content of chlorine in plasctics, hospital waste incineration can lead to the formation of Polychlorinated dibenzo-p-dioxins and polychlorinated dibenzo-p-furans (PCDD/Fs) [11]. Several relevant parameters have significant impacts of the emission levels of PCDD/Fs, such temperature, oxygen and chlorine content [12]. In the present system, because plastics and rubbers are separated from the drug mixture before entering the incinerator, the main source of production of these hazardous gases does not enter the incinerator. In the incinerator section, only drug mixture including solutes, liquids and powders previously dissolved in water burn at temperature of 850-950 ^{o}C.

3.3. Microbilogical analysis of the products

Medical waste, which is the contaminated infectious material generated by hospitals or heath care facilities includes syringes, body fluids, blood by products, laboratory samples, bacterial cultures or pharmaceutical wastes. Nosocomial infections caused by the pathogenic bacteria from the hospitals are the leading cause of morbidity and mortality globally and their rate is increasing rapidly worldwide [13]. The results showed that there were no microorganisms in the obtained products. It has been proven that all microorganisms are killed at temperatures below 150 degrees [10]. Therefore, it can be concluded that at temperatures above 200 ^{o}C, no microorganism has a chance to survive.

3.4. Analysis of the flue gas

The analysis results of the flue (stack) gas samples collected with an isostack sampler according to US EPA method 23A [14] showed that not only there are no toxic gases but also the concentration of greenhouse gases is below the emission limit according to EU emission limit.

3.5. The heat exchanger

Exhaust gas is a huge source of energy that if recovered can highly reduce the energy consumption as well as pollution level [15]. The domain of heat recovery from exhaust gases can be classified within several subdomains [16]. Categorization with respect to gas temperature [17] is the simplest one, indeed the systems are divided into three different categories, high temperature systems, medium temperature systems and low temperature system. Shell and tube heat exchangers are used for liquid or vapor to liquid heat recovery [18]. It consists of tubes contained in a shell with baffles to direct the flow of fluid in the shell. Mainly, the low pressure flow circulates through the shell and the higher temperature fluid passes through the tubes. Shell and tube heat exchangers are of three types: fixed bed tube sheet, floating head, and U-tube bundle. In the present work desighned U-tube bundle was used for the energy recovery section. High temperature exhaust gases can play a very large role in the production of thermal NO_X and environmental pollutants. The production of greenhouse gases, which in order to reduce these harmful pollutants can be contacted by a heat recovery device such as U-tube bundle. This reduces the heat energy that is finally released from the chimney. This method is the most effective application to prevent heat loss in the chimney. On the other hand, by recovery the energy, the entry of combustion gases with high temperature is prevented and the ambient temperature does not increase. In fact, the decrease of flue gas temperature can reduce the formation of thermal NO_x, thus effectively inhibit the generation of NO_x.

4. Conclusion

From environmental point of view, the designed integrated pyrolysis-incinerator system was able to successfully remove and recycle the wastes. This technology has advantages over waste incinerators and plasma technology as following: a) because it separates plastic solids, it does not produce toxic gases such as dioxins that produced from this material, b) its technology is not very complicated, c) its construction cost is lower and d) valuable products such as hydrocarbons and carbon black are produced. The results showed that the current system is environmental-friendly in point view of gases emissions and microbiological analysis. Decreasing flue gas temperature can reduce the formation of thermal NO_x and it can also save the thermal energy.

Acknowledgements

The authors would like to express their gratitude to Takan Co., Tabriz, Iran, for the assistance.

References

[1] J. Liu, X. Luo, S. Yao, Q. Li and W. Wang, Influence of flue gas recirculation on the performance of incineratorwaste heat boiler and NOx emission in a 500 t/d waste-to-energy plant, Waste Management 105 (2020) 450-456.

[2] C.-S. Li and F.-T. Jenq, Physical and Chemical Composition of Hospital Waste, Infection Control & Hospital Epidemiology, Volume 14, Issue 3, March 1993, pp. 145-150.

[3] T. Tiller and A. Linscott, Evaluation of a Steam Autoclave for Sterilizing Medical Waste at a University Health Center, American Journal of Infection Control Volume 32, Issue 3, May 2004, Page E9.

[4] J. Bujak, Experimental study of the energy efficiency of an

incinerator for medical waste, Applied Energy 86 (2009) 2386-2393.

[5] K. Holmgren Role of a district-heating network as a user of waste-heat supply from various sources–the case of Göteborg. Appl Energy 2006; 83:1351-67.

[6] A. Porteous, Energy from waste incineration–a state of the art emissions review with an emphasis on public acceptability. Appl Energy 2001; 70: 157-67.

[7] C.-C. Tzeng, Y.-Y. Kuo, T.-F. Huang, D.-L. Lin and Y-J. Yu, Treatment of radioactive wastes by plasma incineration and vitrification for final disposal, Journal of Hazardous Materials 58, 1998. 207-220.

[8] A. Khani, S. Mohammadi and H. Rasoolzadeh, Converting polymeric mixture waste of a car breaker company to hydrocarbon by designed high performance co-pyrolysis system, *Chemical Review and Letters, in press.*

[9] L. Gašparovič, L. Šugár, L. Jelemenský and J. Markoš, Catalytic gasification of pyrolytic oil from tire pyrolysis process. Chem Pap.67 (2013):1504-1513.

[10] W. D. Bigelow and J. R. Esty, The Thermal Death Point in Relation to Time of Typical Thermophilic Organisms, The Journal of Infectious Diseases, 27 (1920) 602-617.

[11] R.S. Bie, S.Y. Li, and H. Wang, Characterization of PCDD/Fs and heavy metals from MSW incineration plant in Harbin. Waste Manage. 27 (2007), 1860-1869.

[12] H.J. Zhang, Y.W. Ni, J.P. Chen and Q. Zhang, Influence of variation in the operating conditions on PCDD/F distribution in a full-scale MSW incinerator. Chemosphere 70 (2008) 721-730.

[13] I.K. Hosein, H.D., L.E. Jenkins and J.T. Magee, Clinical significance of the emergence of bacterial resistance in the hospital environment. J. Appl Microbiol Biotechnol, 2002. 92: p. 90S-97S.

[14] H. Gao, Y. Ni, H. Zhang, L. Zhao, N. Zhang, X. Zhang, Q. Zhang, J. Chen, Stack gas emissions of PCDD/Fs from hospital waste incinerators in China, Chemosphere 77 (2009) 634-639.

[15] B.K. Singh and N. Shrivastava, Exhaust Gas Heat Recovery for C.I Engine-A Review, International journal of engineering sciences and research technology, 3 (2014), 27-32.

[16] H. Jaber, M. Khaled, T. Lemenand and M.Ramadan, Short Review on Heat Recovery from Exhaust Gas, AIP Conference Proceedings 1758, 030045 (2016).

[17] M.F Remeli, L. Kiatbodin, B. Singh, K. Verojporn, A. Date and A. Akbarzadeh, Power generation from waste heat using Heat Pipe and Thermoelectric Generator, Energy Procedia, 75, 645–650 (2015).

[18] H. Hajabdollahia, M. Naderib, and S. Adimic, comparative study on the shell and tube and gasket-plate heat exchangers: The economic viewpoint, Applied Thermal Engineering, 92, 271–282 (2016).

How to Cite This Article

Ali Khani; Hamed Rasulzade; Nazli Aqapur. "Green removal of hospital-medical wastes by designed integrated pyrolysis-incineration system". Journal of Chemistry Letters, 1, 3, 2020, 89-92. doi: 10.22034/jchemlett.2020.120303