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Contributions to Optimize the Thermodynamic Process of Medical Waste Incinerators and Technical Valorization of Resulted Ash

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Abstract

The world today is in continuous crises due to wars and epidemics, which led to a low economic situation with high fuel prices. For this reason, the purpose of the research was to find alternatives to natural gas or fossil fuels or reduce its use, to reduce costs with a decrease in environmental pollution, A mobile medical incinerator working with palm waste fuel is designed in the primary combustion chamber and diesel fuel in the secondary combustion chamber, a capacity of 33.33 kg / hour, the input energy represented by the calorific value of medical waste while the output energy represented the energy of the resulting dry gases (combustion gases and air), water vapor, and the resulting ash , the difference between the energy input and output is the fuel that is supplied to the incinerator to raise the temperatures of the two combustion chambers. In the first stage, palm trees waste fuel was used at 45% of the total fuel, and diesel fuel was used for the secondary combustion stage by an amount of 45% of the total fuel and 10% diesel fuel is used to start the combustion of wood and waste.

Use EES software to get all design parameters with more accurate results. Medical waste is treated in Iraq through medical incinerators, which is the most common method where tens of tons of medical waste are burned daily. Medical waste has increased, especially in the time of the Corona pandemic.

These medical incinerators produce bottom ash (BA) at a rate of 10-30% and fly ash at a rate of 3-5% of the total waste weight before incineration contains heavy metals. The ash is treated in special landfills and mixed with cement so that it does not penetrate into the soil and groundwater and fly in the air. That is why we burned medical waste with palm trees waste to reduce the proportion of heavy metals in ash and to dispose of palm waste at the same time, and reduce greenhouse gases and environmental pollution and reduce the concentrations of some heavy metals in ash such as copper, zinc, Ti and others, which makes it easy to treat and recycle, reducing the area of landfills. Only Basra province in Iraq owns 2476063 palm trees. Palm tree waste is estimated at about 25 kg per palm, this trees waste is either incinerated or buried and requires costs.

This study is also concerned with the treatment and recycling of bottom and fly ash. Samples were taken from the incinerators of the Medical City Hospital complex in Baghdad. These samples were examined at the Ministry of Science and Technology by X-Ray Fluorescence to determine which elements in the ash contained high concentrations of heavy metals and other elements. Which negatively affects the soil, the environment and the human being if it is not treated properly. After grinding and mixing it with an asphalt mixture (base layer) according to the Marshall method in different proportions instead of the filler used in the mixture in proportions of 25%, 50%. 75% and fly ash were mixed in the same proportions. The experimental tests were related to: bulk density (g/cm3), stability (kN), flow (mm), and Air voids (%). It was found that 25% for each of the fly and bottom ash were within the specifications. 90 samples of materials were tested in National Center for Building Laboratories in Baghdad.

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CHAPTER 1

Introduction

1.1 General

The traditional methods used to dispose of medical waste (MW) resulting from hospitals and treatment centers is incineration. It is still used in many countries of the world after managing MW properly. The process of disposing of MW by high temperatures in incineration or other methods is called heat treatment. Incineration destroys organic waste at very high temperatures, up to 900 degrees Celsius or higher, through decomposition and thermal oxidation[1]. It involves converting medical waste into ash that collects at the bottom of the incinerator and into gases with fly ash accompanied by a high temperature that can be used. In recent years, MW has experienced increasing volumes in Europe and poses major problems if it is not managed in an organized and correct manner, as well as environmental problems that lead to local pollution and emissions of gases harmful to the environment and humans that affect the process of global warming [2].

Due to technological development, population increase and per capita economic income increase, healthcare waste has started to increase in quantity and variety around the world [3] [4]. Hospitals, health care facilities and large health institutions are generating general waste and hazardous[5]. Most of the waste generated in health facilities, 80-85%, is non-hazardous and comparable to domestic waste, separated and treated along with municipal waste , while infectious waste is specifically treated by incineration on site or sent to the place of incineration.[6].

1.2 Medical incinerators

Previously, medical incinerators were simple, consisting of a combustion chamber equipped with a burner, added air, and low temperatures, and did not contain control devices and filters to prevent fly ash into the atmosphere and incomplete combustion, which caused many problems due to emissions from burning medical and laboratory waste, which contained high concentrations of metals. Heavy such as chromium, cadmium, lead, chlorine, mercury and other materials [7]. Incinerators are one of the most prevalent methods in the third world countries for the treatment of medical waste, most countries in the world, including the European Union, use incineration to treat waste by burning the waste with the help of the burner and air at high temperatures to get rid of the organic compounds present in the waste and turn it into inorganic materials.

At the present time, medical incinerators have developed, making them a source of energy and using the best technologies to get rid of the emitted gases [8].

CHAPTER 2

Literature Review

2.1 Thermal Treatment Approaches of waste that produce energy

Some waste needs to treat at a high temperature, like medical infectious waste. Thermal treatments used for converting the waste into energy. There are three popular approaches to process waste in high temperatures and reuse their energy as Incineration by incinerators, Pyrolysis, and Gasification.

2.1.1 Treatment of medical waste by incinerators

2.1.2 Treatment of medical waste by pyrolysis

2.1.3 Treatment of medical waste by gasification

2.2 Medical incinerator operations diagram

The incinerators are effective in eliminating the MW with large volume and in rapid disposal to any waste. Figure 2.5 describes the incineration process architecture. The main input to the incinerators is the waste, air (O2) and fuel. The summary of incinerating the MW process starts by weighting, separating and categorizing the waste before delivering it to the incinerator which can be done either manually or by automatic electrical belt move towards the primary combustion chamber (Pcch). the chamber contains one or two burners that work either on diesel or natural gas. Additionally, there is an air supply that helps to reach complete combustion in each chamber. As a result of complete combustion, a blend of gases and fly ashes is generated. The fly ashes and the emitted gasses move to the secondary combustion chamber (Scch) with a temperature range between (900-1200) °C by burner and air supply to complete the incineration and reduce pollution for environment. it is possible to take advantage of the heat of the emitted gases in heating water or generating electricity as shown in the next chapter of this research. As a result, 20-30 % of original waste weight remains as bottom ashes after incineration. Consequently, after cooling the bottom ash, it sent to landfill sites and usually mixed with general waste without treatment. That can affect land and groundwater if not bounded with limitations obliged by international agreement.

To conclude the output, after performing the incineration process, the output of the process is divided into three main outputs including bottom ash, fly ash and gas emission. Bottom and fly ash can be treated and reused in different fields like mixing the ash with cement or asphalt as shown in the last chapter of this research.

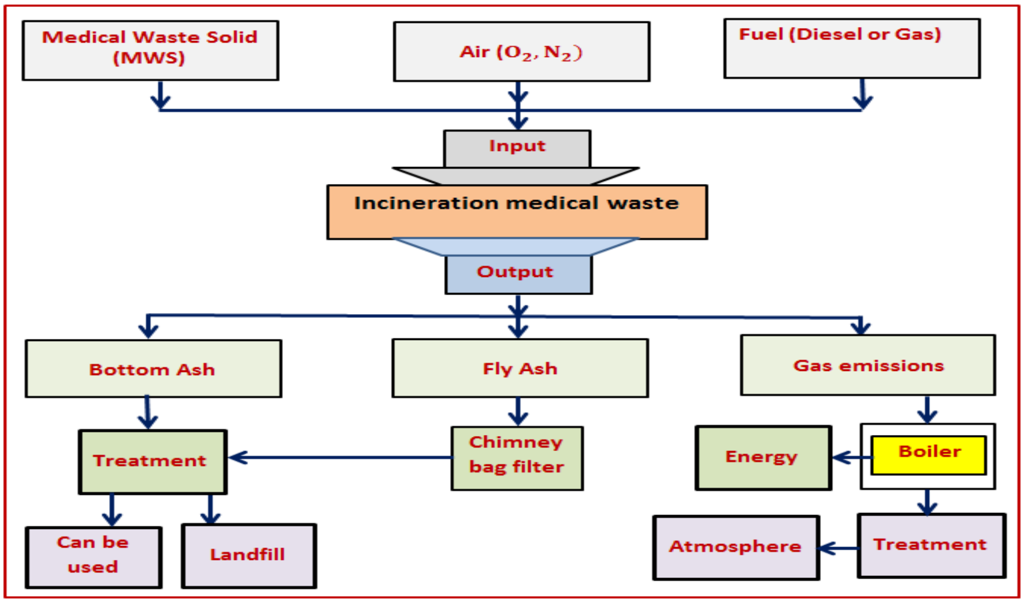

Figure 2.5 Waste burning operations in medical incinerators

2.2.1 Advantages of medical waste incinerators

- One of the most important benefits that medical incinerators have in treating waste from other methods is to reduce the volume of waste to 90-95% [32] [33][34].
- Reducing the weight of medical waste to 70% of the total weight of waste entering incineration[6][35].
- Medical waste incineration works to remove toxins, total disinfection and eliminate pathogens[36].
- Rapid performance in disposal of MW in a short time [37].
- Ease of operation, that is, any operator can take experience and quickly.
- Aids in the combustion of medical waste provide air and fuel to operate the burner.
- In the year 2019 and the emergence of the Corona virus (Covid-2019) and its transformations, all methods of treatment stopped except incineration, as it proved its high and rapid effectiveness in getting rid of huge quantities of medical and other waste[38].
- Energy recovery It is possible to take advantage of the emitted gases to generate electricity, heat water, or otherwise, which reduces its cost [15] [9][10].
- The cost is low compared to other treatment methods.
- Provide less space for landfill sites, especially in countries or regions with high population density[15].
- Recycling the ash produced from incinerators in cement or using it in roads by mixing it with asphalt, as shown in this research[39][40][41].
- Low maintenance.

2.2.2 Disadvantages of medical waste incinerators

- Medical incinerators produce gases emitted from the combustion of medical waste containing chlorine and produce emissions of dioxin and other materials, especially incinerators that operate at temperatures below 800 degrees Celsius and do not contain control devices that negatively affect the environment and humans if the medical waste management is not treated properly[1].

- It produces two types of FA and BA, most of the medical incinerators in Iraq do not contain filter bags to collect the fly ash, it goes out accompanied with gases into the atmosphere and contains heavy metals, acids, organic materials and a high percentage of chlorides, dioxins and carbon components, and these negatively affect the soil and the environment[42].
- the bottom ash that is produced at the end of combustion and is at the bottom of the incinerator contains heavy metals such as copper, lead, cadmium, mercury, Ag, Mo, Ni, Zn, Sb, Ba. It negatively affects the environment, humans, soil and groundwater if not treated[43].

2.2.3 Types of incinerators

Medical incinerators are used to treat MW that cannot be recovered and recycled, meaning it cannot be used, but after incineration and at high temperatures it is possible to benefit from the ashes resulting from these wastes as shown in our experience in the last chapter because it contains high percentages of heavy metals.

Medical incinerators vary according to function, size, quality, efficacy and internal composition.

2.2.3.A A one- or two-combustion chamber incinerator

2.2.3.B Controlled - air or Pyrolytic incinerators, two combustion chambers.

2.2.3.C Excess air incinerators

2.2.3.D Rotary kiln incinerators

2.2.3.E Mobile medical waste incinerators

CHAPTER 3

Experimental setup of a medical waste incinerator system and calculation of waste energy from combustion

3.1.1 The main parts of a medical incinerator used in the experiment to calculate the energy produced by combustion

All modern and old medical incinerators contain main parts and are included in the design of any MWI. Medical incinerators are used all over the world, especially in the year of the Corona Covid-19 pandemic, to disinfect and kill pathogens and reduce the volume of MW to 90% and its weight to 75%, which leads to easy handling of the waste residue from incineration, which is the ash.

3.1.1.A The primary combustion chamber (Pcch)

3.1.1.B The secondary combustion chamber (Scch)

3.1.1.C Flue stack

3.1.1.D Fuel tank

3.1.1.E Control panel

3.2 Thermal processes inside a medical waste incinerator

The method of combustion varies from one state to another. Solids, liquids and gases that mainly contain carbon and hydrogen differ in the manner of their combustion from one state to another.

Medical waste is solid materials, and most of these wastes contain fixed carbon and volatile materials during the combustion process. This process goes through stages

3.2.1 Drying

3.2.2 Pyrolysis (thermal decomposition)

3.2.3 Combustion.

The incinerator used in this study consists of two chs that operate by adding batch air with a capacity of 100 kg per hour, medical waste with yellow bags and used diesel fuel Figure 3.13.

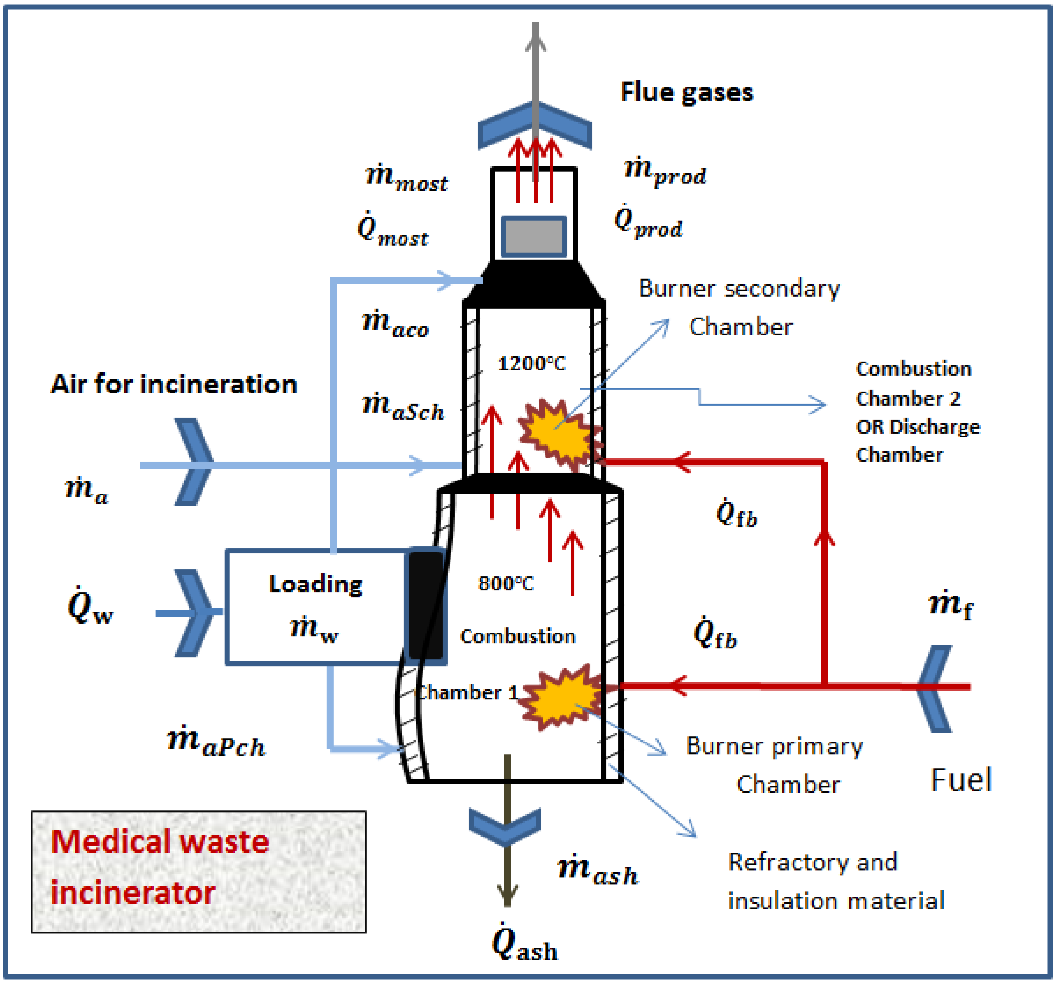

Figure 3.13 System medical waste incinerators and the heat generated from incineration waste[33].

3.3 Calculating the energy generated from a medical waste incinerator using the EES program software

The energy generated by the combustion of MW depends on the energy added by the burners, the intake air, the amount of excess air, the temperature in the Scch, waste type, waste quantity, incinerator type, incinerator operator, all factors affecting the waste energy and the efficiency of the incinerator. In order to find and know the wasted energy, a balance must be made on the incinerator in terms of the incoming and outgoing masses, whether they are solid or gas, and the incoming and outgoing energy from combustion.

The program software (EES) makes it easy to find most of the parameters in an easy way without referring to equations and finding calculations, from which we can compare the amount of excess air with the efficiency of the incinerator, the energy generated by the incinerators, the change in the amount of fuel consumption and its impact on efficiency, as well as the possibility of changing the masses and quantities of waste according to the capacity of the incinerator and finding the air necessary for the combustion of these Completely burning waste and optimum fuel consumption for burners with the highest efficiency

3.3.1 Heat and Material Balance

3.3.1.A Heating values of material input

The material flow per hours into the incinerator is 100 kg/h. Based on an input waste yellow bags waste is assumed to have the following composition, according to the table(3.7) to consist of cellulose swabs C6H10O5,dry tissueC5H10O3 , plastic polyethylene (disposable gown, mask, gloves, top, over shoes) (C2H4) x, PVC 4% (C2H3CL) x , moisture from waste and ash (kg/h) [33].represents A, B, C, D, E and F (kg/h) respectively. Incinerator has a central control unit in which the operating conditions for the temperature and burners are displayed.

Figure 3.14 The shape of incinerator and biomedical waste[33].

Table 3.7 Higher heating values and total heat of the combustible medical waste[33].

Chemical Composition	Chemical Composition	Molecular Weight	Fraction assume	Waste Input (kg/h)	Calorific Value (MJ/kg)	Total Heat in MJ/h
Swabs Cellulose	$C_6H_{10}O_5$	162.1	20	A	23.860	A* 23,860
Tissue	$C_5H_{10}O_3$	118.1	8	B	25.220	B* 25,220
polyethene Plastic	$(C_2H_4)x$	28.1	45	C	37.820	C* 37,820
PVC 4%	$(C_2H_3Cl)x$	62.5	4	D	38.154	D*22,630
Ash≤25%	-	-	13	E	0	0
Moisture H_2O ≤30%	H_2O	18.0	10	F	0	0
Total heat generation from yellow waste bag			A+B+C+D+E+F= 100 (kg/h)		A*23,860+B*25,220+C * 37,820+ D*22,630	
Diesel	$C_{12}\ H_{23}$	167.31	-	$\dot{m}_{diesel}$	45.5	$\dot{m}_{diesel}$*45.5

3.3.1.B Determination of stoichiometric oxygen for combustible medical wastes and combustion air rates

The total theoretical amount of oxygen required to burn the waste determined by the chemical equilibrium equations of the biomedical waste's components from laboratory analysis, the theoretical oxygen to burn the medical waste's combustible component (100 kg/h). We can calculate the total requirements for the theoretical amount of oxygen required to burn (oxidize) the waste [33].

Table 3.8 Material chemical composition[33].

Material	Chemical Composition
Cellulose, Swab.	$C_6H_{10}O_5 + 6O_2 = 6CO_2 + 5H_2O$ 162.1 6(32) 6(44) 5(18) 1.0 1.19 1.63 0.56 A A*1.19 A*1.63 A*0.56
Tissue	$C_5H_{10}O_3 + 6O_2 = 5CO_2 + 5H_2O$ 118.1 6(32) 5(44) 5(18) 1.0 1.63 1.84 0.76 B B*1.63 B*1.84 B*0.76
Polyethylene (as fired)	$(C_2H_4)_x + 3O_2 = 2CO_2 + 2H_2O$ 28.1 3(32) 2(44) 2(18) 1.0 3.43 3.14 1.29 C C*3.43 C*3.14 C*1.29
PVC	$2(C_2H_3CL)_x + 5O_2 = 4CO_2 + 2H_2O + 2HCl$ 2(62.5) 5(32) 4(44) 2(18) 2(36.5) 1.0 1.28 1.41 0.29 0.58 D D*1.28 D*1.41 D*0.29 D*0.58
Diesel	$4C_{12}H_{23} + 71O_2 = 48CO_2 + 46H_2O$ 4 (167.31) 71(32) 48(44) 46(18) 1.0 3.39 3.16 1.24 $\dot{m}_{dis}$ $\dot{m}_{dis}$*3.39 $\dot{m}_{dis}$*3.16 $\dot{m}_{dis}$*1.24

3.3.1.C Material balance for combustion chambers

Calculating the mass entering the incinerator from the mass of waste, dry air and the mass of moisture in the air during one hour.

The masses entering the incinerator represent the masses of waste; swabs C6H10O5, tissue C5H10O3, Cellulose, plastic polyethylene (disposable gown, mask, gloves, overhead, over shoes) (C2H4) x, PVC 4% (C2H3CL) x, which we have imposed with the values A, B, C, D (kg / h) from Table 3.7 and the dry air.

3.3.1.D Arithmetic balancing of the incinerator energy.

3.3.1.D.1 Calculation of the energy entering the incinerator

The total input energy of the incinerator is represented by the calorific value of all waste and the energy generated by the burners of the Pcch and Scch that control the temperatures of the combustion chambers

Total heat generation from the yellow waste bag (Q_w) MJ/h) from table 3.7.

Figure 3.16 Characteristics of the burner used in the two combustion chambers[33].

$$\dot{Q}_{in} = \dot{Q}_{t\_W} + \dot{Q}_{burner} \qquad (17)$$

3.3.1.D.2 Calculation of the energy output of combustion

3.3.1.E Efficiency of the Machine

The efficiency of the burning process lies in the occurrence of a case of complete combustion of waste, that is, the conversion of organic materials in the incinerator to neutral gases such as carbon dioxide gas, water vapour, sulphur oxides and nitrogen, and the factors that join this case;

3.3.2 Applying the EES software program and finding all the parameters

The program is applied by entering basic data, for example, the quantities of waste masses by substituting values kg/h

A = tissues = 8, B= swabs cellulose = 20, C= plastic polyethylene = 45, D= PVC = 4, E= ash = 13, F= waste moisture= 10.

And the introduction of the spent fuel mass for an hour kg /h

$\dot{m}_{diesel}$ =20 = (burner 1+ burner 2)

and the temperature of the secondary combustion chamber because the first degree is considered constant, which is the temperature of the waste before combustion, and it is usually between 20-40

T1= 20 ºC, T2= 1200 ºC

All parameters will appear in the program as shown in table 3.9

Table 3.9 All parameters will appear in the program EES.

When T_1=20,T_2=1200, A=8 kg/h , B=20 kg/h, C=45 kg/h, D=4 kg/h, E=13 kg/h, F=10 kg/h					
$\dot{m}_{diesel}1$	10 kg/h	$\dot{m}_{H2O\_waste}$	10 kg/h	$\dot{m}_{in}$	2262
$\dot{m}_{diesel}2$	10 kg/h	$\dot{m}_{H2O\_rec}$	76.49 kg/h	$\dot{m}_{out}$	2262
$\dot{m}_{tot\_diesel}$	20 kg/h	$\dot{m}_{H2O\_total}$	114.7 kg/h	$\dot{m}_{net}$	0
$\dot{m}_{W}$	100 kg/h	$\dot{m}_{CO2\_tiss}$	14.72 kg/h	$\dot{Q}_{t\_W}$	2913 MJ/h
$\dot{m}_{O2\_poli}$	154.4 kg/h	$\dot{m}_{CO2\_poli}$	141.3 kg/h	$\dot{Q}_{in\_waste}$	2913 MJ/h
$\dot{m}_{O2\_tiss}$	13.04 kg/h	$\dot{m}_{CO2\_cell}$	32.6 kg/h	$\dot{Q}_{loss}$	191.2 MJ/h
$\dot{m}_{O2\_cell}$	23.8 kg/h	$\dot{m}_{CO2\_pvc}$	5.64 kg/h	$\dot{Q}_{ash}$	12.75 MJ/h
$\dot{m}_{O2\_pvc}$	5.12 kg/h	$\dot{m}_{CO2\_diesel}$	63.2 kg/h	$\dot{Q}_{dry\_g}$	2732 MJ/h
$\dot{m}_{O2\_diesel}$	67.8 kg/h	$\dot{m}_{CO2\_rec}$	194.3 kg/h	$\dot{Q}_{H2O}$	599.2 MJ/h
$\dot{m}_{O2\_req}$	196.3 kg/h	$\dot{m}_{HCl\_rec}$	2.32 kg/h	$\dot{Q}_{diesel}$	910 MJ/h
$\dot{m}_{H2O\_tiss}$	6.08 kg/h	$\dot{m}_{a\_sto}$	853.5 kg/h	$\dot{Q}_{in}$	3823 MJ/h
$\dot{m}_{H2O\_poli}$	58.05 kg/h	$\dot{m}_{a\_Pch}$	1110 kg/h	$\dot{Q}_{out}$	3535 MJ/h
$\dot{m}_{H2O\_cell}$	11.2 kg/h	$\dot{m}_{a\_Sch}$	2134 kg/h	$\dot{Q}_{net}$	288 MJ/h
$\dot{m}_{H2O\_pvc}$	1.16 kg/h	$\dot{m}_{N2}$	675.2 kg/h	η_{inc}	0.924
$\dot{m}_{O2\_diesel}$	20 kg/h	$\dot{m}_{ash}$	13 kg/h		
$\dot{m}_{a\_H2O}$	28.17 kg/h	$\dot{m}_{dry\_total}$	2132 kg/h		

3.4 Mobile incinerator design for waste disposal of highly transmissible diseases

In Iraq, especially health care centers and centers for treating corona patients, they do not have medical incinerators, and if they exist, they are old. Biomedical waste is collected from health centers and transported to other hospitals have an incinerator. Therefore, using the mobile incinerator lies in controlling the proper management and treatment of waste [11][12].

Biomedical waste is the waste generated from health care and hospitals through treatment, diagnosis and human protection in research [14], and it has other names, clinical waste and hospital waste. It is solid or liquid waste resulting from diagnosing and treating patients with infectious diseases and viruses [14]. According to the World Health Organization instructions, do not burn medical waste with high humidity of more than 30%, non-combustible materials of more than 40%, compressed gas containers, materials containing PVC cadmium and mercury such as batteries and pressure devices [15]. Health care centres produce medical waste, including waste containing viruses and microbes resulting from the diagnosis of patients. These wastes are packed in yellow bags and then transferred to the medical incinerators of the hospitals.

This waste contains [Cellulose swabs C6H10O5, tissue C5H10O3, plastic polyethene (disposable gown, mask, gloves, overhead, overshoes) (C2H4) x, PVC 4% (C2H3Cl) x, glass SiO2, sharp Fe, and the moisture (kg / h)] and to eliminate the transmission of viruses to working people and other areas, we designed a mobile incinerator in the program EES to control the dimensions of the design and the size of the incinerator capacity according to the amount of waste generated from the centres. For example, the Al-Shifa Center for the treatment of corona virus patients in Baghdad, which is affiliated with the Medical City, contains 250 beds and contains a very old incinerator, the year of manufacture 1982. The incinerator's capacity cannot bear the amount of waste generated because of its old.

3.4.1 Design of the Primary combustion chamber

Coronavirus medical waste is characterized by a low density, such as masks, etc. Therefore, a few densities and others were considered. 80 (kg/m3), Needles and anything sharp and glass were treated as ashes, but the moisture of the waste, the liquid materials, was represented by water. The primary combustion chamber is dimensionally designed on the default shape and mass of the thrust feed to the incinerator [17] (Equation 25). Waste generated from Corona Virus treatment centers is 100 kg, and this waste is incinerated for 4 hours ($\dot{m}_w$=100/4=25) kg/h

To design the volume of the Pcch, the volume of the chamber is equal to the mass of waste divided by the density of the MW.

$$\dot{V}_{Pcch} = \frac{m_w}{\rho_w} \qquad (25)$$

Where; is the volume of the Pcch m^3, m denotes the waste mass (kg) and depicts the density of 80 kg/m^3.

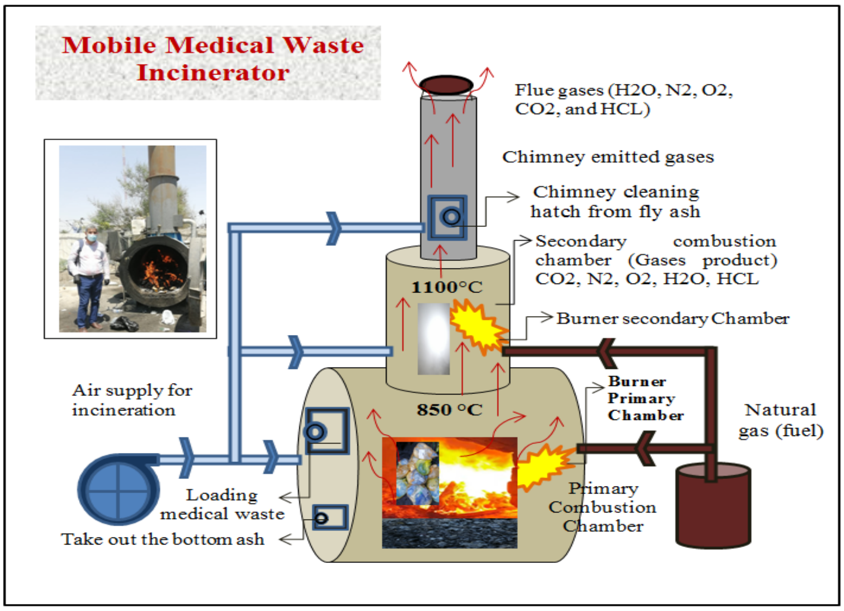

Figure 3.21 Scheme of a mobile medical waste incinerator

Waste entering incineration (A, B, C, D, E, F, Z) kg/h from and sequentially [swabs (cellulose $C_6H_{10}O_5$) tissue $C_5H_{10}O_3$, plastic polyethene (disposable gown, mask, gloves, overhead, overshoes) (C_2H_4) x, PVC 4% (C_2H_3Cl) x, ash, moisture and glass SiO_2, sharp Fe, (kg / h)].

CHAPTER 4

Recycling of Ash from Burning Medical Waste in Asphalt

4.1 General

The world has witnessed rapid development in technology with the increase in the world population. In previous and current years, the spread of the COVID-19 virus has increased the amount of MW. This waste, if not properly treated and managed, causes major problems[2]. One such method is incineration in medical incinerators. Due to the fast processing performance, high efficiency, low cost, easy operation, reducing the waste volume to 95% and weight 70%, as well as detoxification, comprehensive disinfection, and resource and energy recovery[6][32][33][35][36]. These incinerators produce two types: gases resulting from the combustion of MW with the help of air and burners [1] and ash are two types. Fly ash accompanied by combustion gases can be collected through filter bags[79] and is 3-5% of the total weight of the waste. And bottom ash that is produced at the end of combustion and is at the bottom of the incinerator and is extracted automatically or manually after it cools [93] and is about 20-30% and contains heavy metals Cu, Pb, Cd, Hg, Ag, Mo, Ni, Zn, Sb, Ba. As for fly ash, it contains heavy metals, acids, organic materials, and a high percentage of chlorides, dioxins, and carbon components, and these negatively affect the soil and the environment [42][43]. This ash is treated by burying it in private landfills, but what happens is it is buried in public landfills, and this affects the environment, groundwater and soil, and it can be benefited from by recycling and using it in building materials or cement [39][40][41]. In this chapter, bottom ash and fly ash were used and mixed with asphalt mixture in specified proportions instead of filler as a method of treatment and recovery and utilization. Figure 4.1 shows a summary of the process of this research and study. And the details are below.

4.2 Bottom and fly ash samples from medical incinerators

The second part of our experiment is the treatment of bottom and fly ash from medicinal incinerators and their use in road construction.

Only hospitals, health centers and government laboratories across Iraq in 18 governorates produce medical waste weighing 3,448,457 kilograms annually, according to Iraqi Ministry of Health statistics, remedial Department of 2019. In addition to hospitals, health centers and private laboratories, as well as medical waste began to increase due to the COVID-19 pandemic and its transformations 2020 and 2021, as well as due to the increase in the number of hospitals and the increase in population density.[106]

Figure 4.1 The stages of converting medical waste into bottom ash and mixing it with the asphalt mixture[106]

4.3 Marshall Specimen's preparation

The sample mold is a cylinder with a height of 63.5 mm and a diameter of 102 mm. It is heated to 120-150 degrees Celsius. A piece of non-absorbent paper with the diameter of the cylinder is placed at the bottom of the mold. The heated asphalt mixture (reference mixture) with a weight of 1210 g is placed in the mold and a piece of non-absorbent paper is placed on top. Twenty-seven samples were tested, including the source mixture and the additions made to the mixture of bottom and fly ash [106].

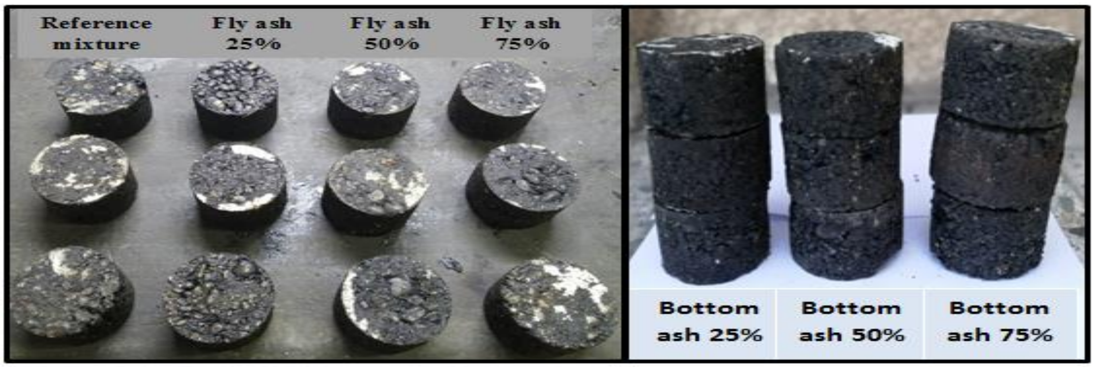

Figure 4.14 Marshall Specimen with the addition of fly ash and bottom ash [106]

CHAPTER 5

A mobile medical waste incinerator that runs on wood and diesel fuels to reduce environmental pollution and heavy metal concentrations in the resulting ash

5.1 Introduction

Scientific The purpose of designing a mobile incinerator is to prevent the transmission of the dangerous virus or any epidemic from the endemic areas to the non-endemic areas where it is eliminated in the same hospitals. Because most hospitals or primary health care unit in Iraq to treat patients with this epidemic have recently been established and do not have medical incinerators, while waste is transferred to other hospitals for the purpose of incineration, and this helps in the rapid transmission of infection. This incinerator works on wood and diesel fuel, in order to reduce the amount of diesel fuel and pollution first, and to reduce the percentage of heavy metals in the bottom ash resulting from burning waste, secondly, that is, treating it at the same time so that it does not affect the groundwater, soil and air when it is buried. Third, the disposal of wood waste.

Figure 5.7 Burning medical waste and palm waste in the medical incinerator

CHAPTER 6

Conclusion

6.1 Conclusion

COVID-2019 and its transformations 2020 2021 is a very dangerous disease that infected millions of people in the world, so the main purpose of designing a mobile incinerator was to reduce the transmission of the virus from zone to another zone through medical waste, workers and drivers. And when the pandemic appeared, in Iraq centers dedicated to treating this disease have been built with an average of 50-100 beds in all governorates, But the biomedical waste produced by these centres is transferred to other areas that contain medical incinerators, which facilitates the transmission of the virus to these areas and infects many people. The mobile incinerator was designed on the basis of the input masses represented by medical waste and energy represented by the calorific value of each type of waste. These wastes are burned in a primary combustion chamber to produce combustion gases and transferred to the secondary combustion chamber to complete the combustion of the volatile with the combustion gases. The combustion process takes place with the help of air and fuel in both chambers.

The results were good using EES software program at Polytechnic University in Bucharest, where all design equations were entered to facilitate the process of changing the input and finding the results.

Incinerators have many benefits with some disadvantage, one of these negatives is the bottom and fly ash, which annually produces thousands of tons of waste incineration, i.e., 30% of the weight of waste before burning. This ash affects the environment, humans, soil and water because of its containment It contains heavy metals, so it is treated by placing it in forms made of cement and then burying it in the soil. In this experiment, the ashes were mixed after the examination (XFR) in proportions with filler used in the asphalt plant, and the four tests (stability (kN), flow (mm), bulk density (g/cm3) and air void %)

When adding 25% of bottom ash and fly ash, the stability was good in both case

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