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Overview of Medical Waste Incineration Systems

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Abstract: Medical wastes are wastes released during healthcare. The institutions with the highest medical waste generation are hospitals. However, medical wastes are generated at many points, such as health cabins, pharmacies and infirmary facilities that employ more than 50 workers. Although 75-90% of these wastes fall under the general waste category, the rest fall into hazardous waste. Medical wastes are beginning to form in large volumes today due to the developing technology, increasing welfare level and widespread health services. Especially, the increase in the use of disposable devices and consumables used to provide hygiene are the most important factors that increase the formation of medical waste. In addition to being infected, medical wastes contain hazardous chemicals, drugs, toxins, radioactive substances, etc. Medical wastes are in hazardous / risky waste group that threatens human and environmental health. The separation, temporary storage, transportation and disposal of medical wastes in hospitals is critical for the environment and human health. In this study, investigation of waste incineration processes, one of the methods of disposal of medical wastes threatening the environment and human health, and examination of emissions released after incineration will be carried out.
Keywords: *Medical Waste, Waste Disposal, Waste Incineration Systems.*

INTRODUCTION

With the rapid population growth, industrial activities, increase in welfare level and developing technology, the consumption diversity of mankind has increased. One of the biggest problems caused by diversified and increased consumption is waste. Due to the increasing population density in large cities, cities are expanding and the formation of large waste storage areas has started to be a big problem in city administrations. In this respect, waste disposal is a very important and critical issue all over the world and has become a topic that is constantly studied with new methods and technologies [1]. In addition to domestic wastes, which are the easiest and relatively low cost of disposal: disposal of hazardous wastes such as medical wastes and chemical wastes continues to be an environmental and economical issue [2].

The importance of medical sciences has been better understood over the past year due to the covid-19 virus, which has shaken the world. The one-time equipment (mask, gloves, device, etc.) used in these days, which focused on how sensitive the epidemic diseases are in the recent period, has increased its waste. Due to the current epidemic of medical wastes, the issue of waste management and disposal has gained a great importance not only from health institutions but from every home and workplace. Medical waste is the general name for wastes consisting of infectious, pathological and cutting-piercing wastes that occur during operations in health units [3]. Although medical wastes make up a small portion of the wastes produced in a society, medical waste management has been accepted as an important issue all over the world [4].

This study will examine the advantages and disadvantages of medical waste incineration plants, one of the medical waste disposal methods whose importance has been understood recently, compared to other methods of disposal, process investigations, waste incineration and waste disposal methods.

Medical Waste Production and Classification of Medical Waste

Today, despite the importance given to waste reduction practices such as zero waste and back projects, the rate of increase in the amount of waste could not be reduced to the desired levels. In the absence of projects implemented for waste reduction, municipal waste is expected to increase 2-fold

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over the next 20 years [5]. Waste reduction methods; It can be achieved with three different approaches: avoiding waste generation, reducing at source and reusing the product [6]. Institutions and organizations that cause medical waste as a result of their activities (hospitals, clinics, maternity centers, health centers, medical centers, dispensaries, health centers, outpatient centers, morgues, autopsy centers, animal hospitals, blood units, dialysis centers, medical research centers) They will have taken the biggest step in reducing medical waste that will occur by applying waste reduction methods. With the covid-19 virus recently taking over the world, the huge hospitals that countries have set up to combat epidemic diseases are expected to be a new source of medical waste. Therefore, the separation process should be carried out in the institutions where the production of medical waste is very intense, and the process of making it ready for disposal should be evaluated within the institution. The wastes generated in hospitals are generally collected in three groups: infected and biohazardous wastes, uninfected solid wastes (domestic wastes) and hazardous wastes. Infected and biohazardous wastes have a high probability of carrying pathogens, and domestic wastes have a low probability of carrying pathogens. While 70-75% of the medical wastes can be mixed with domestic wastes, 10-25% of them enter the hazardous waste part containing health risks [3, 7]. Table 1 shows the classification of wastes originating from an institution or organization providing health services.

Hazards Caused by Medical Wastes

Medical wastes must be disposed of in accordance with the standards in order to prevent illnesses or injuries caused by medical wastes. Medical wastes; it may contain infectious pathogens, change the hereditary structure, contain toxic or dangerous chemical or pharmaceutical substances, be radioactive, dangerous because it may contain cutting piercing instruments. Through medical waste, many infectious diseases that can endanger public health, such as Covid-19, SARS, cholera, plague, tuberculosis and hepatitis (HBV, HCV), AIDS (HIV), are easily transmitted. Doctors within the risk group that will be affected by medical waste; nurses; assistant medical staff; patients; patient visitors; Workers of waste collection, transportation, separation and disposal can be listed as major groups [8, 9].

Table 1 Classification of Wastes from Health Services [10]

Waste Type	Subgroup	Explanation
Municipal waste	General Waste	Office, warehouse, kitchen etc. wastes from.
	Packaging Waste	Paper, cardboard, plastic, glass, metal etc. produced from offices. recyclable materials.
Medical Wastes	Infectious Wastes	Microbiological laboratory waste; blood, blood products and objects contaminated with them; used surgical surgery clothes; dialysis waste; quarantine wastes; bacteria and virus air filters; infectious organ parts, blood and everything contaminated with these substances.
	Pathological Wastes	Tissues, organs, placenta, blood etc. produced from surgical operations. Wastes.
	Sharp Objects	Needles, syringes, broken glass, knives, and other items that can cause cuts or punctures.
Hazardous Wastes		Hazardous chemicals, cytotoxic and cytotoxic medicine, amalgam waste, gynetoxic and cytotoxic waste, pharmaceutical waste, heavy metal waste, pressure vessels.
Radioactive Waste		Turkey atomic energy is collected by the council of law and removed.

Medical wastes, which can cause harm to the environment and human health, must be disposed of as specified in national and international standards. Medical wastes According to the studies of the World Health Organization, disposal methods; It has been determined as inceneration (burning), sterilization and embedding (permanent storage). In this study, the disposal systems of medical wastes will be examined. The advantages and disadvantages of medical waste incineration plants compared to other disposal methods, process investigations, wastes generated as a result of incineration and disposal methods of wastes will be examined.

LITERATURE RESEARCH

Medical waste incineration systems are systems that burn organic and combustible wastes at high temperatures and turn them into inorganic, non-combustible materials. The most important feature of these systems is the volume and weight which is the result of incineration. These systems can also destroy pathogens and dangerous organic materials and bring them into ash form. Medical waste incineration systems are systems that perform both the treatment and disposal of waste at the same time. The oxygen requirement to be used in the systems is provided from the ambient air [8, 11]. However, the major disadvantages of these systems are that the incineration systems emit traces of undesired pollutants such as polychlorinated dioxins, furans (PCDD and PCDF) and heavy metals, which may be produced by qualified personnel. Especially these pollutants emitted from the waste incinerators of hospitals are of great importance with their proximity to city centers [12].

Medical Waste Incineration Systems

Medical waste incineration systems are generally designed in combination with technologies such as waste supply system, incineration system, flue gas treatment system and ash treatment system. In Figure 1, the overall composition of the equipment composition and pollution control measures of waste incineration plants are given.

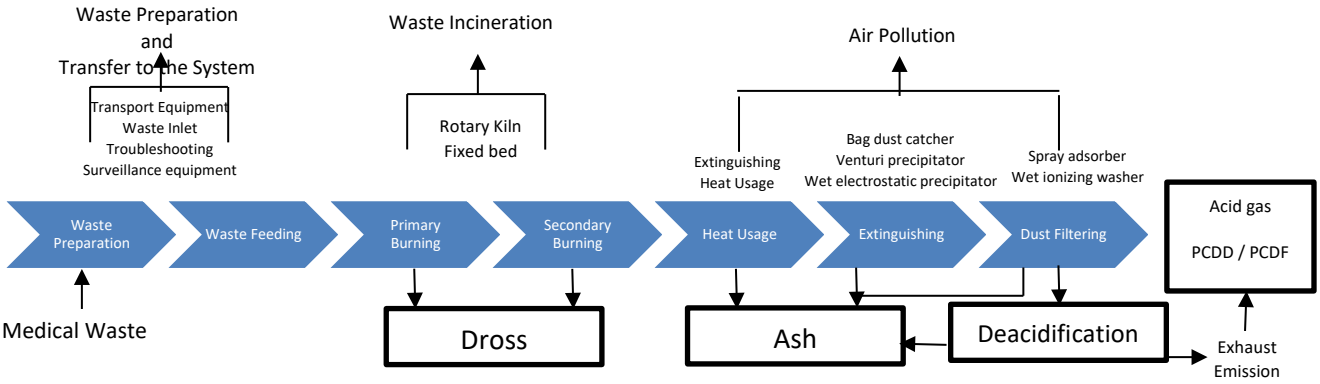

Figure 1 Hardware composition of medical waste incinerators and pollution control measures [13]

Medical waste incineration plants are divided into three categories in terms of waste incineration capacity. These; They are small (less than or equal to 90 kg / h), medium (from 90 to 225 kg / h) and large (greater than 225 kg / h) capacity [14]. In terms of incineration systems, Lee and Huffman have divided medical waste incineration systems into two types:

1) Modular combustion furnaces (Modular combustion furnaces airless combustion furnaces and air inlet combustion furnaces)

2) Rotary kilns

Modular Combustion Systems

Airless Burning

Airless combustion systems are systems in which combustion is performed if there is less air in the environment than stoichiometric calculations. Airless combustion ovens consist of primary combustion and secondary combustion chambers. In primary incinerators, less air and oxygen is provided than needed to incinerate organic and combustible waste. In case of ignition of the system, a smoke (exhaust gas) rich in organic substances occurs in the furnace. With the air to be given into the furnace, a spontaneous combustion takes place in the environment. The flue gas is burned in the secondary combustion chamber, where 100-140% of the stoichiometric air requirement is injected.

Inside the combustion system, there is a burner device that allows the fuel to be burned completely by mixing it with air in an appropriate ratio. Approximately 40-60% air of the stoichiometric requirement is injected into the device. The exhaust gas, which is carried to the secondary combustion chamber with the help of a fan, provides a continuous combustion process with the help of a burner. At this stage of the combustion process, since the combustion process takes place with very little

stoichiometric ratios, the heat intensity in the combustion process increases in the correct proportion with the increase in the amount of oxygen supplied to the environment. It shows that the temperature intensity in these systems is adjusted with the air given to the environment.

Airless combustion systems: From discrete systems where waste input, combustion and ash removal are manual; they can be from semi-continuous systems where one-day waste can be converted into the system, but without ash removal system, or continuous systems with automatic incineration and ash removal systems, where waste is loaded into the system by a waste loading staff. In Figure 2, the general scheme of a controlled waste airless waste incineration system is given [15, 16].

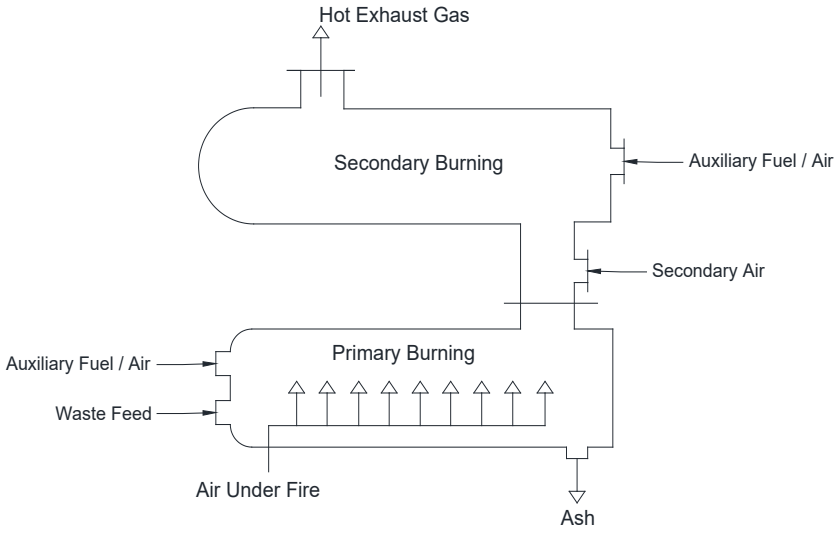

Figure 2 Controlled airless incinerator

Excess Air Intake Incineration Systems

These systems are systems that provide combustion with an air flow that is much more than stoichiometric calculations (60-200 % excess air) in the primary and secondary parts. In pneumatic incinerators, waste is burned in the primary compartment and the secondary compartment, residence time, temperature and additional fuel are provided for the combustion of unburned organics. These systems have a compact design with multiple compartments, and the waste is exposed to flame at 1.800-3.000 ^{0}F temperature levels. These compartments are positioned to direct the off-gases generated during combustion along turns in lateral and vertical directions. With each turn, ash (soot) falls from the flue gas stream. These systems result in loading and burning waste at the beginning of the day and ending the combustion at the end of 24 hours and ash discharge. Figure 3 shows a schematic representation of the incinerator with excess air flow [12, 15].

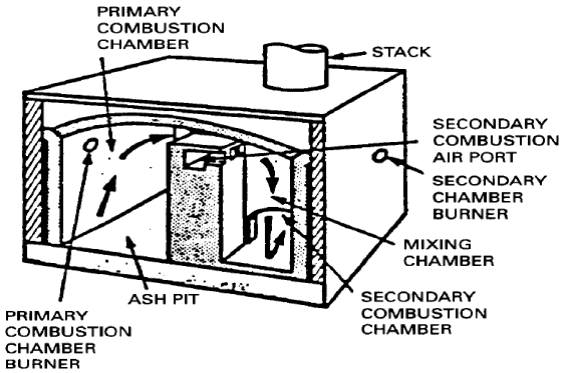

Figure 3 Excess air incinerator

Rotary Kilns

It is a system where the combustion process of the wastes on the refractory lined cylinder rotating on the horizontal axis on the floor of the rotary kiln systems takes place. During the rise of the waste gases formed during the combustion process, a secondary combustion is ensured with air at a level exceeding the stoichiometric calculations given to the environment. The hourly increase in the amount of ash coming out of the furnace is a function of the cylinder rotation speed, rotation slope and burning rate in the system. While the rotation speed ensures the contact of the wastes in the furnace with oxygen and increases the combustion, it increases the particle load in the outlet gas formed in the environment. Particle growth is undesirable as it increases the load of dust removal systems. The roller rotation speed is in the range of 1-3 rpm. The combustion temperature in the system varies between 1.300-2.400 ^{0}F [12, 17].

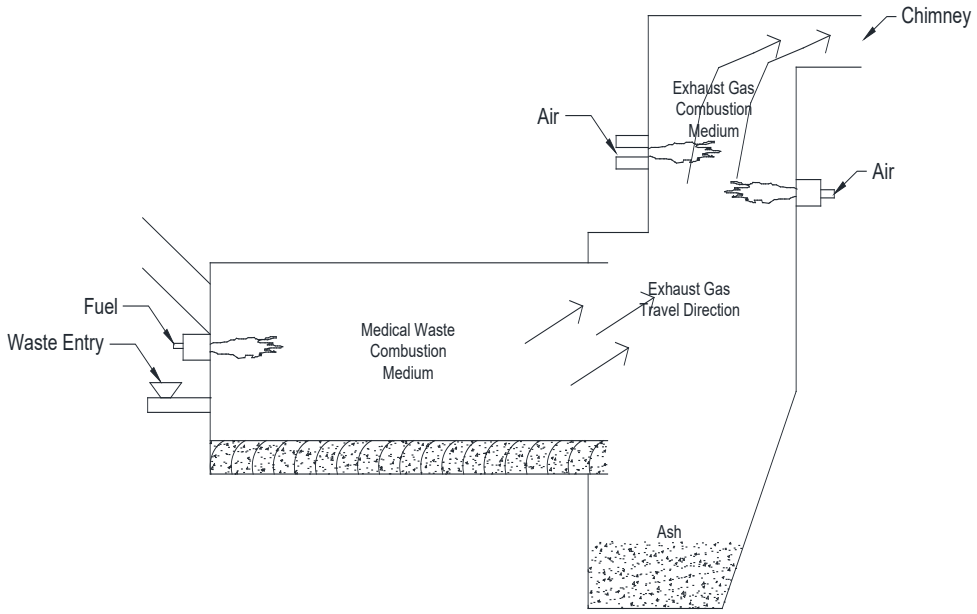

Figure 4. Rotary Kiln Schematic View

Advantages and Disadvantages of Medical Waste Incineration Systems

As in every waste disposal system, waste incineration method from medical waste disposal systems has advantages and disadvantages compared to other systems. One of the most important advantages of waste incineration systems is the mass and volume reduction of waste. While the mass decrease in the wastes entering the system is at the level of 75%, the volume decrease can be at the level of 90%. Bacteria, viruses, parasites in medical wastes are exposed to high heat in the combustion plants of organisms that can cause infection. Another advantage of these facilities is to eliminate the toxicity in medical waste by burning at high temperatures and eliminating the possibility of spreading. It is also possible to recover energy by transporting the high temperature generated during combustion to other industries. The biggest disadvantage of combustion systems is cost. It can cost 10 times more than other medical waste disposal methods. Waste incineration systems; It should be a well-managed organization with advanced technology, qualified personnel and a good business. An improper operation can produce serious environmental pollution (CO, HCl, NO_2, SO_2, PM, PAH, PCDD/F). The elimination of solid residues (ash) and heavy metal emissions, which are the final products of combustion, is also an important problem. It is not easy to adopt a waste incineration plant in public. The community in the region where the facility is located does not want a combustion facility near their habitat [17, 18].

RESULTS

Medical waste incinerators are not well designed and start-up and emit poisonous air pollutants from furnaces as a result of incineration. These pollutants are; particulate matter, acid gases, trace elements, incomplete combustion products, polyaromatic hydrocarbons, dioxins and furans (PCDD/F) [19, 20].

Acid Gases

Inorganic acidic gases formed during the combustion process as a result of chlorine, fluorine, bromine, sulfur and nitrogen components in the wastes of incinerators. It contains hydrogen chloride, hydrogen fluoride, hydrogen bromide, sulfur oxides (SO_x) and nitrogen oxides (NO_x). HCl from chlorine in plastics (PVC) such as syringes; The NOX bond structure made by nitrogen and oxygen at high temperatures and CO and CO_2 gases formed by the burning of cotton and latex gloves show the reasons for the formation of inorganic acid gases. The conversion of the sulfur released as a result of combustion into H_2S or SO_2 gas occurs in trace amounts [14, 21, 22].

Toxic and Carcinogenic Metals

Heavy metals are a type of pollution that may arise as a result of combustion of any waste material entering the incinerator. Even if most of the heavy metals released as a result of the combustion accumulate in the ash that is formed, a larger part is released from the chimney into the atmosphere. It is known that most heavy metals occur at low concentrations. However, in heavy metals where permanent and bioaccumulation is possible, they are released into the atmosphere after combustion. The most common heavy metals encountered in medical waste incineration plants are cadmium, lead, mercury, chromium and arsenic. In some studies, more than 20 types of heavy metals were found [14, 23, 24].

Missing Combustion Products

Flammable material, combustible substance and ignition temperature are required for a combustion event to occur. If the fuel burns completely in a combustion event, the carbon in the fuel is carbon dioxide; hydrogen to water vapour; sulphur turns into sulphur dioxide. In case of incomplete combustion, carbon remains as carbon monoxide. When the fuels do not burn with pure oxygen, nitrogen in the air participates in the combustion and NOx is formed. CO, HC, NO_x, SO_2, SO_3, H_2S, PM occur as a result of incomplete combustion [25].

PCDD / PCDF

PCDD / Fs released as a result of human activities are often called dioxins and furans. They are formed as a result of combustion of organic substances in the presence of chlorine and metals. They are extremely potent toxic components and are effective at low doses in humans and animals. They can spread globally due to accumulation in animals with bioaccumulation. PCDD / Fs are carcinogenic and affect the development, reproduction and immune system [26].

Over 80 % of the PCDD / F load released in medical waste incineration is adsorbed on fly ash. As a result of the combustion process, the mixtures of 75 PCDD and 135 PCDF congeners are exposed. The most toxic and human cancer-causing congener is 2,3,7,8-tetrachlorodibenzo-pdioxine (TCDD) [26-28]. The mechanisms involved in PCDD/F emissions from incinerators can be explained by three theories: PCDD/Fs are already present in incoming waste and are completely destroyed or converted during combustion, PCDD/Fs may occur during combustion, or some heterogeneous flue gas fly ash environment. It can be formed by the de novo mechanism in the low temperature post-combustion zone of incinerators by catalytic reactions [14, 29, 30].

Polycyclic Aromatic Hydrocarbons (PAHs)

PAHs are mainly semi-volatile organic compounds with two to eight rings formed during incomplete combustion from natural and anthropogenic sources. PAHs are environmental contaminants, most of which are shown to be carcinogenic and mutagenic. Research on PAH emissions, motor vehicle exhausts in urban and rural areas [31, 32], smoking tobacco products [33-35], showed that the exhaust gases of industrial processes and incinerators are sources of PAH [16, 36-38]. The waste composition, temperature, and excess air during the combustion process determine the amount of PAH emitted by a particular facility. High PAH emissions were observed when starting the incinerator. During combustion, PAH formation mechanisms are divided into two processes: pyrolysis and pyrosynthesis. Organic compounds are broken into partially smaller and unstable pieces when heated (pyrolysis). These fractions lead to more stable PAH formation, mainly through reactive free radicals, recombination reactions (pyrosynthesis) [14].

Pollution Control Equipment in Medical Waste Incineration Plants

In the medical waste incineration plants, toxic air pollutants and ash are released as a result of the combustion process. Various treatment technologies have been integrated in combustion systems to prevent direct emissions of these emissions into the environment.

Pollutants emitted from combustion systems as a result of researches to prevent air pollution include particulate matter, sulfur oxides, nitrogen oxides, carbon monoxide, hydrogen chloride, heavy metals, volatile organic compounds and dioxins. Particularly toxic substances are particulate matter, heavy metals and dioxins. Control systems used in incinerators are generally cloth filters, wet washers (venturi, spray towers, packet bed washers) and dry washers (adsorption systems) [39]. The most common system used for the treatment of waste gas, respectively; gas cooling unit (lowers the high temperature gas to ambient temperature), venturi scrubber (PM removal), package adsorption tower (deacidification) and demister (visible vapor cloud removal). These units may vary. Wet electrostatic precipitators, ionizing wet washers and cloth filters are also used for PM removal. However, the researches have performed better than other applications of the venturi washer. Researches show that PAH and PCDD / F treatment, one of the waste incineration systems, is not sufficient even in new systems [16, 39-41]. Detoxification must be carried out before the fly ash is finally disposed of with regular storage. Mixing the ash with cement and curing the resulting mixture will be a suitable option to prevent future pollution in case of stabilization of heavy metals [42, 43].

Good Incıneratıon Practice

Complete combustion must take place in order to completely eliminate the living organisms in the waste and to ensure minimum emission to the environment. Thus, both the termination of microorganism activities and the formation of incomplete combustion emissions will be prevented. For this, waste, gases and ashes must be exposed to sufficiently high temperatures. Researches conducted; adding waste in the initial period when the incinerator and the associated channel is cold; The incinerator shows that not bringing to the full operating temperature before feeding each waste batch and adding high moisture waste, which can cause a rapid drop in the incinerator temperature, expose excessive emission loads and prevents good combustion [12].

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