SOLID WASTE TREATMENT TECHNOLOGIES

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Abstract: Environmental pollution is the major problem associated with rapid industrialization, urbanization and rise in living standards of people. Increasing of the amount of solid waste and the pressure what it has on the environment, impose the need to introduce advanced approach to effectively managing of solid waste. This advanced approach includes technologies for solid waste treatment, that fall into the category of "Renewable". This paper put emphasis on technologies for material and energy utilization of solid waste, such as: composting, gasification, pyrolysis and incineration. These kinds of technologies allow obtaining volume reduction, material and energy recovery.

Keywords: COMPOSTING, GASIFICATION, PYROLYSIS, INCINERATION, ENERGY RECOVERY

1. *Introduction*

Waste is defined as an unusable or unwanted substance or material. It can be in solid, liquid or gaseous form. Solid waste is a term usually used to describe non-liquid materials arising from domestic, trade, commercial, agricultural and industrial activities, and from public services [1].

The components that constitute the solid waste are paper, textile, lather, food waste, yard waste, rubber, metals, plastic and glass [2]. The most dangerous solid waste is the waste that does not or it needs a long time to degenerate. Some types of solid waste and the time it takes to degenerate are shown in Table 1 [3,4].

Table 1*- The type of solid waste generated and the approximate time it takes to degenerate*

Type of waste	Time it takes to degenerate
Organic waste such as vegetable and fruit	A week or two
Paper	10-30 days
Cotton cloth	2-5 months
Wood	10-15 years
Woolen items	1 year
Tin, aluminum and other metal items such as cans	100-500 years
Plastic bags	Million years
Glass bottles	Undetermined

Increasing of the amount of solid waste and the pressure what it has on the environment, impose the need to introduce *advanced approach to effectively managing of solid waste.*

According to European Legislation, the *advanced* approach to waste management based on principle “waste hierarchy”. Here, the order of the priorities of solid waste management is introduce, (Fig.1) [5].

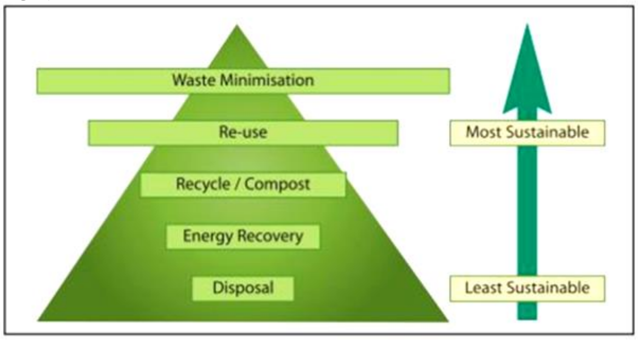

Fig.1 *Hierarchy of the priorities in the waste management sector*

Advanced solid waste management involves several activities at a higher level of final disposal of the waste management hierarchy. The aim of the waste hierarchy is to extract the maximum practical benefits from products and to generate the minimum amount of waste.

Waste minimization is the process of reducing the amount of waste produced by a person or a society. Re-use, it means use an item more than once. This includes conventional reuse where the item is used again for the same function and new-life reuse where it is used for a new function. For example, solid waste concrete can be crumbled and used as a base for roads; inert material may be used as a layer that covers the dumped waste on landfill at the end of the day.

Recycling and composting are processes of material waste recovery. Recycling means obtaining substances from waste (secondary raw materials) and their utilization as a substitution of the primary raw materials. Composting is biochemical decomposition of organic substances found in the waste.

Energy recovery technologies allow to obtained volume reduction and energy recovery. Waste disposal is proper disposition of a discarded or discharged material in accordance with local environmental guidelines or laws.

2. *Material and energy recovery technologies*

2.1. Composting

Composting is nature's process of recycling decomposed organic materials into a rich soil known as compost. The basic process of composting is shown at Fig.2 [6].

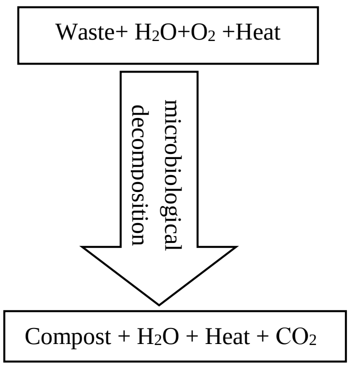

Fig.2 *Process of composting*

With composting process organic materials are reduce. This reduction occurs because of CO_2, H_2O and other gases are release into the atmosphere. The product of the end, compost, is composition of microorganisms, products of decomposition and organic matter that these organisms could not decompose. Compost is excellent fertilizer for gardening and horticultural plants. At the end of the process, the amount of composting pile is reduced for 20-60%, moisture content is smaller than 40% and weight is reduced for 50%. PH value of compost is 7 and the ratio carbon/nitrogen should be smaller than 80:1. Under natural conditions, the decomposition process can last from several months to a year or even more, depending on climatic conditions.

Based on a study of the composting process, the following factors are important [7]:

-The size of the particles of the organic material;
-aeration;
-porosity;
-moisture content;
-pH value of the material;
-nutritive and
-the ratio of carbon and nitrogen C/N.

Microbiological activity takes place on the surface of the particles of the composting material. With cutting on smaller parts, the surface of organic material can be enhanced. The increased surface allows microorganisms to decompose material faster and generate more heat. A good particle size would be 1.25-4 cm.

Aeration is achieved by enriching the compost pile with fresh air, where oxygen is missing. Quick aerobic decomposition occurs only if there is sufficient amount of oxygen. Therefore, at the beginning of the process, the composting pile should be regularly mixed to satisfy quantity of fresh air. In the first weeks of composting, the needs of oxygen are greatest.

Porosity refers to the space between particles in the compost. If the material is not saturated with water, these spaces are partly filled with air which supplies the microorganisms with oxygen. Otherwise, saturated composting pile with water reducing air space, and it comes to slowing down the process of composting.

The moisture content of 40-60% provides adequate moisture without aeration inhibiting. If the moisture content is below 40%, bacterial activity will be slowed down, and completely broken if it falls below 15-20%. On the other hand, if the moisture content is above 60%, the volume of air is reduced creating an unpleasant smell and the process of decomposition slows down.

Heat is developed as a result of the activities of microorganisms for decomposition of organic material. There is a relationship between temperature and oxygen consummation. Higher temperature means greater consummation of oxygen, thus faster decomposition of the material is possible. The temperature of the pile between 32 and 60°C, indicate a rapid process of composting. Temperatures above 60°C reduces the activity of many microorganisms. Thus, the optimal range for composting is 32 and 60 °C. The temperature of composting pile, increase to 55-60°C, gradually, and remains so weeks, then, the temperature falls to 38°C or to temperature of surrounding air.

The optimal pH value for microbial activity is between 6.5 and 7.5. The release of organic acids may temporarily or locally to reduce the pH, thus the acidity of material increase. On the other side, the production of ammonia from nitrogen compounds can increase the pH, thus the alkalinity of the material increase. But regardless, the pH measurement of the organic material at the beginning of the process, the pH value of the compost at the end of the process will be 7, neutral.

Carbon and nitrogen are constituents of organic waste, which can easily disrupt the process of composting if that are in insufficient or excessive quantities or if the ratio C/N is inappropriate. Microorganisms use carbon as an energy source, and nitrogen for the synthesis of proteins. The ratio of these two elements should be approximately 30 parts carbon, 1 part nitrogen, depending by the weight. C/N ratio in a range of 25:1 to 40:1 results in efficient process [8, 1].

2.2 Gasification

Gasification is defined as a thermal reaction with insufficient oxygen present for reaction of all hydrocarbons (compounds of carbon, hydrogen and oxygen molecules) to CO_2 and H_2O. This is a partial oxidation process which produces a composite gas comprised primarily of hydrogen (H_2) and carbon monoxide (CO). The oxidant may be air, pure oxygen and/or steam. The gasification conditions are between 700-1600°C. Steam is injected into gasification reactor to promote CO and H_2 [9]. Fig.3 illustrates a typical conventional gasification process.

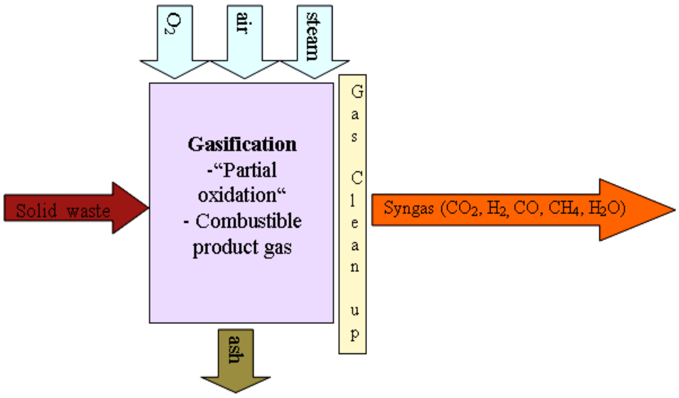

Fig 3*. A schematic diagram of gasification process*

The main reactions taking place during gasification are:

Oxidation: $C + O_2 \rightarrow CO_2$ (exothermic)

Water evaporation reaction: $C + H_2O \rightarrow CO + H_2$ (endothermic)

$CO + H_2O \rightarrow CO_2 + H_2$ (exothermic)

$C + CO_2 \rightarrow 2CO$

CH_4 formation reaction: $C + 2H_2 \rightarrow CH_4$ (exothermic)

Thus, CO, H_2 and CH_4 are the basic components of the gasification process producing the gaseous mixture. The resulting gas mixture is called syngas. Heating values of syngas are generally around 4-10 MJ/m^3 [10].

The raw syngas exits the reactor and is cleaned up of carry-over particulate matter from the reactor, sulfur, chlorides/acid gases. Syngas is sent to the power generation plant to produce energy, such steam and electricity for use in the process and energy. The export energy is converted to electricity and sold to the grid [11].

2.3 Pyrolysis

Pyrolysis is the thermal degradation of carbon-based materials through the use of an indirect, external source of heat, typically at temperatures of 450 to 750°C, in the absence or almost complete absence of free oxygen to produce a carbonaceous char, oils and combustible gases. This drives off the volatile portions of the organic materials, resulting in a syngas composed primarily of H_2, CO, CO_2, CH_4 and complex hydrocarbons [12, 13].

The reactions taking place initially are decomposition ones, where organic components of low volatility are converted into other more volatile ones [14].

$$CxHy \rightarrow CcHd + CmHn$$

Moreover, at the early stages of pyrolysis process, reactions occurring include condensation, hydrogen removal and ring formation reactions that lead to the formation of solid residue from organic substances of low volatility:

$$CxHy \rightarrow CpHq + H_2 + \text{coke}$$

In the case of existence of oxygen, CO and CO_2 are produced or the interaction with water is possible. The produced coke can be vaporized into O_2 and CO_2.

The pyrolysis process is shown in Fig.4. The products obtained from the pyrolysis process are solid residues and synthetic gas "syngas". The majority of the organic substances in waste are subjected to pyrolysis by 75 – 90 % into volatile substances and by 10–25% to solid residue (coke). The syngas cleanup step is designed to remove carry-over particulate matter from the reactor, sulfur, chlorides/acid gases (such as hydrochloric acid), and trace metals such as mercury [15].

Syngas is used in the power generation plant to produce energy, such as steam and electricity, for use in the process and export energy. The export energy is typically converted into electricity and supplied/sold to the grid. Synthetic gas typically has energy value between 10 and 20 MJ/Nm^3. If it is necessary, the cooling part synthetic gas can be collected as condensate to be used as a liquid fuel [16].

The bottoms from the reactor are ash, carbon char, and metals. The carbon char and metals have use as recyclables in industry. However, the ash from the pyrolysis process is usually disposed of in a landfill [11].

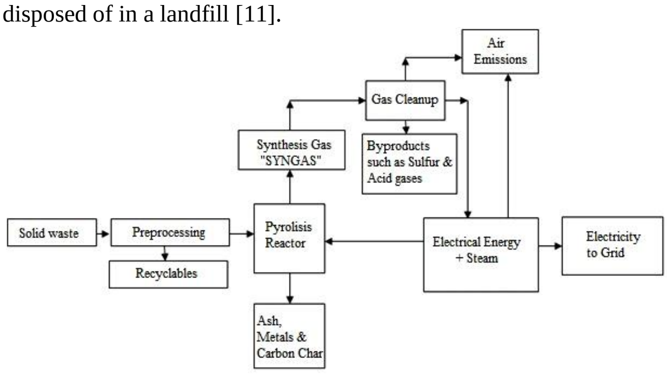

Fig.4 *A schematic diagram of pyrolysis process*

2.4 Incineration

The incineration is process of combustion of solid waste chemical elements (carbon, hydrogen, sulfur) in an oxygen-rich environment, at temperature higher than 850°C and producing combustion gases, especially CO, CO_2, NO_x, H_2O, SO_2, ash, and heat. The inorganic content of the waste is converted to ash. Fig.5 illustrates a incineration process [16,11].

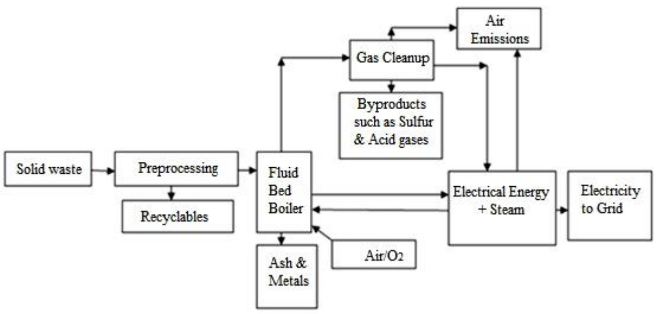

Fig.5 *A schematic diagram of incineration process*

High-pressure steam produced in the fluid bed boiler is sent to the power plant for energy generation. Hot exhaust gases from the fluid bed boiler are sent for gas cleanup and heat recovery sent to the power plant for generation of energy.

The main elementary reactions of solid wastes in the combustion process at the incinerator are the follow ones [12]:

$$C + O_2 \rightarrow CO_2 \qquad 2H_2 + O_2 \rightarrow 2H_2O \qquad S + O_2 \rightarrow SO_2$$

In the case of lack of oxygen, the reactions are characterized as incomplete combustion ones, where the produced CO_2 reacts with C that has not been consumed yet and is converted to CO at higher temperatures.

$$C + CO_2 \rightarrow 2CO$$

The object of this thermal treatment method is the reduction of the volume of the treated waste with simultaneous utilization of the contained energy. The recovered energy could be used for: heating, steam production, electric energy production. The net energy that can be produced per ton of solid waste is about 0.7 MW/h of electricity and 2 MW/h of district heating.

Incineration is a process that can be used to treat different types of waste including municipal solid waste and industrial solid waste. The method could be applied for the treatment of mixed solid waste as well as for the treatment of pre-selected waste.

3. Conclusion

As result of all it was presented in this paper, we can conclude that:

- Composting, gasification, pyrolysis and incineration are waste minimization technologies.
- Thermal waste treatment technologies allow to obtained volume reduction and energy recovery. The energy produce by solid waste treatment contribute for the use of less fossil fuels and can help meet renewable energy targets as a consequence of global warning problem.
- With thermal treatment technologies the hazard components of solid waste are converted in non- hazard, what makes these technologies environmentally friendly.
- Composting is a natural process and this makes it an ecological technology for treatment of decomposable wastes. This process reduce the amount of waste going to landfills and provide a useful soil conditioner.

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