AN OPPORTUNITY TO REDUCE GREENHOUSE GASES BY TURNING MUNICIPAL SOLID WASTE TO ENERGY

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ABSTRACT. This article presents existing technologies for the treatment of municipal solid waste (MSW), and offers a comparison between them. A technology suitable to convert MSW into energy without the need for pre-treatment or long-distance transportation is proposed. For every 100 t of MSW, the plant generates 11 100 kWh of electricity and 99.7 MWh of heat with a supply temperature of 75°C to be used for district heating purposes. The technology makes it possible to use the energy for the needs of the community that generates the waste. The presented technology is suitable for communities with a population of 30 to 70 thousand inhabitants.

Key words: environmental protection, incineration, packed bed, gas cleaning

ВЪЗМОЖНОСТ ЗА НАМАЛЯВАНЕ НА ЕМИСИИТЕ НА ПАРНИКОВИ ГАЗОВЕ ЧРЕЗ ПРЕВРЪЩАНЕ НА ТВЪРДИТЕ БИТОВИ ОТПАДЪЦИ В ЕНЕРГИЯ

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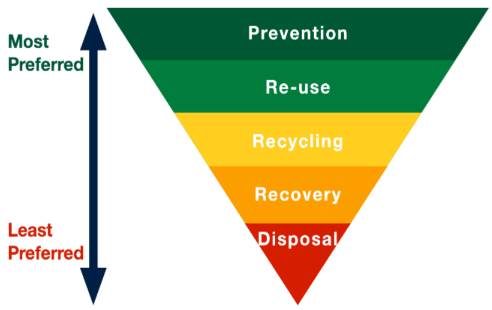
РЕЗЮМЕ. В тази статия са представени съществуващите технологии за третиране на твърди битови отпадъци (ТБО) и е направено сравнение между тях. Предложена е технология, подходяща за превръщане на ТБО в енергия, без да е необходимо предварително третиране или транспортиране на големи разстояния. За всеки 100 t ТБО инсталацията произвежда 11 100 kWh електроенергия и 99,7 MWh топлинна енергия с температура на подаване 75 °C, която се използва за целите на централното отопление. Технологията дава възможност енергията да се използва за нуждите на общността, която генерира отпадъците. Представената технология е подходяща за общини с население от 30 до 70 хил. жители.

Ключови думи: опазване на околната среда, изгаряне, колони с пълнеж, пречистване на газове

Introduction

The EU policy expressed in Directive 2018/850 on the landfill of waste contributes to increasing resource efficiency within the EU and reducing the negative environmental and health impact. The hierarchical order of priorities for the utilisation of MSW is given below.



What is required for the development of a new technology

As society develops and cities grow, the amount of MSW generated has dramatically increased. The amount of waste generated per person per year in the European Union member states is more than 500 kg per capita per year.

Over the years, various waste treatment methods have been used:

- Disposal in open landfills;
- Disposal in covered landfills;
- Incineration in large factories – incinerators.

I would like to try briefly to describe the methods used:

Disposal in open landfills

Environmental pollution resulting from gases generated by anaerobic decomposition of biological components is significant. It should be taken into account that the territories thus used cannot be employed for other purposes.

Disposal in covered landfills

The specific feature is that in the process of the construction of covered landfills, pipes are placed in the construction so that the gases generated by anaerobic decay are collected and discharged. Gases generated from the decaying contain the following components (Assamoi, 2012): methane 55% and CO_2 45%. The collected gases are used to generate thermal and electrical energy.

Unfortunately, according to data from B. Assamoi (2012), 25% of the produced landfill gas is lost due to leakages in the landfill systems. This causes significant damage to the environment.

It should be noted that the territories of the covered landfills can be reclaimed and used for other purposes.

Incineration in large factories – incinerators

From an environmental point of view, the use of incineration plants for waste treatment is the best solution in terms of recovering the calorific value of waste through the heat from their incineration; in terms of reduction of the quantity of waste for landfill; and also in terms of emissions of harmful gases, as mentioned above.

The energy generated from incineration is used to produce electricity and heat. The generated ash and cinder are used in the road construction for roadbeds, and also as a substitute of inert material. Combustion gases are purified in large industrial facilities and the discharged gases thereof meet the highest environmental requirements.

Figure 1 shows the distribution of the technologies used in some European Union member stated in 2015. The figure shows that some countries such as Germany, Belgium, and Sweden have solved their landfill problems with household waste, while others like Romania, Bulgaria, and Greece must work hard to solve the challenges of municipal waste.

All that has been said and shown so far make it clear that the incineration of waste is a preferred method for efficient MSW processing. It is an issue that so far only technologies and plants for processing large quantities of waste have been developed, and this is associated with significant transport costs.

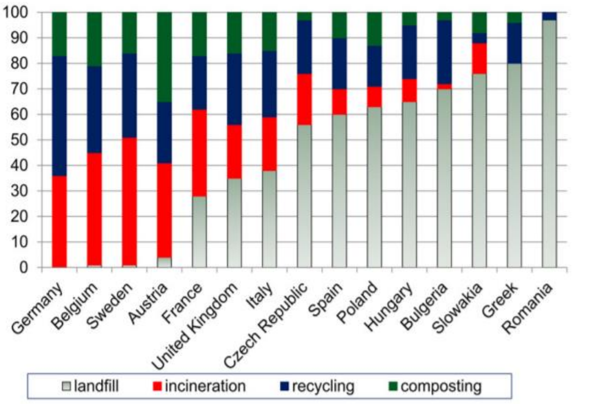


Fig.1. Municipal **Solid Waste treatment in selected EU countries (in %)** (after M. Nellesa 2016)

Presentation of technology and operation processes

Figure 2 shows the process flowchart of the proposed technology (Kolev and Lyutskanova 2006).

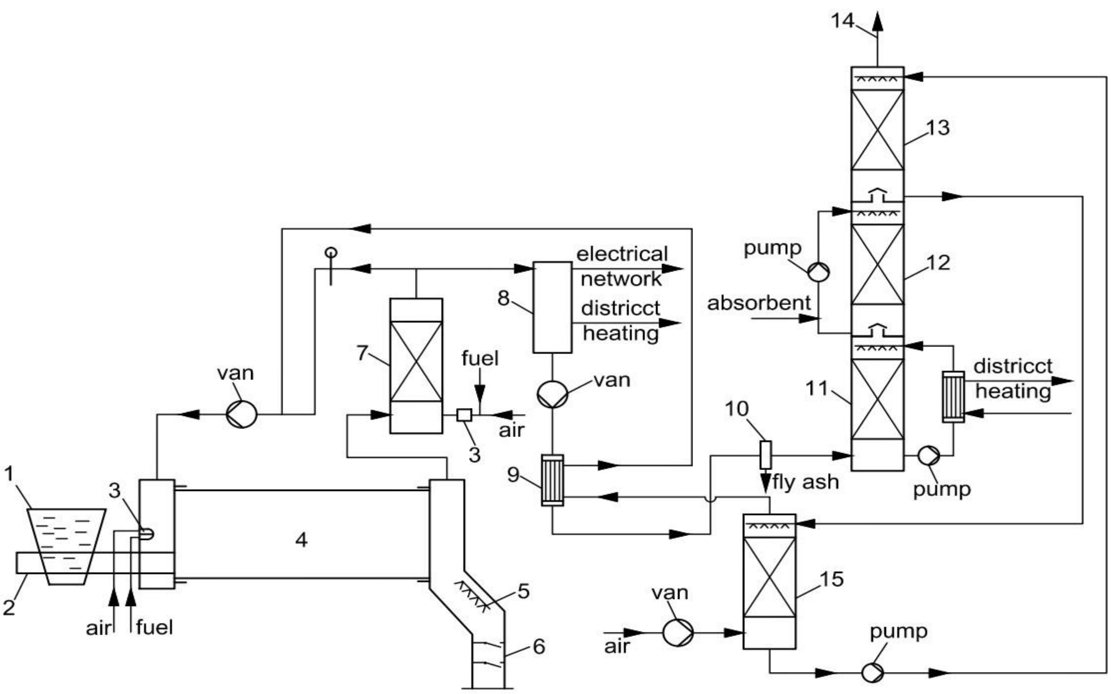


Fig. 2. Installation for incineration of MSW

Operation Processes

The arriving truck discharges the waste into a receiving bunker through a large-size mesh sieve. Thus, large-size waste is separated. After the bunker, the waste passes along a separation line where the following steps takes place: the bags are broken open, then waste passes through a scale and magnetic separator, and from there it is delivered into a shredder. The purpose of the shredder is to homogenise the waste and cut it to pieces of similar size. Having thus been separated, it is delivered into a day bunker or into a line stand-by bunker. The stand-by bunker has a capacity to take waste for 15 days, which makes it possible to store waste in case of a sharp increase in the amount of household waste - for example, during the New Year holidays.

From the daily bunker, the waste is delivered to the rotating combustion chamber (rotary kiln). The downtime therein is around 30 minutes. The length of the rotary kiln is 15 m. The temperature maintained in the combustion chamber is about 850° C. On the initial start of the plant, a liquid or gaseous fuel burner shall also be used to provide the required temperature. During the process, when the temperature in the combustion chamber starts decreasing, the burner is automatically turned on to maintain it. The bottom ashes generated from the incineration are removed from the combustion chamber, being pre-cooled with water. The device does not allow uncontrolled air entering into the process when removing the ash. The flue gases generated are supplied to a post combustor where a burner maintains a temperature of 1100° C. The post combustor is designed as a packed bed column, which makes it possible to maintain the temperature profile therein constant. The gas downtime in the post combustor is more than 2 seconds. If necessary, a burner can keep the temperature in the post combustor constant.

After the post combustor, the gases are separated into two streams. One stream goes to a recovery unit, where gases are cooled down to 500° C. They are then sent to a recuperation unit, where they heat the air for the incineration process, and ~~they~~ are cooled down to 200° C, the temperature of the wet thermometer is 79.1° C. Next, they pass through a bag filter to separate the ash carried over with the gases. Thus cooled and mechanically purified gases are delivered into a contact economiser (Kolev, 2003) - direct water heat exchanger, where they indirectly heat the district heating water up to 75° C. Then, they enter an absorber for their chemical treatment. After the absorber, the gases enter a second economiser. There, they heat the water, which in turn heats and humidifies the air for the incineration process. Flue gases leave the plant through a flue duct fully meeting the highest environmental requirements.

The second stream of gases is mixed with the heated and humidified air and at a temperature of about 700° C is delivered to the entry of the rotary kiln.

The recovery unit is a Rankine cycle turbine, where electricity and heat are generated in the form of hot water for district heating purposes.

The technology is designed for processing of 50 to 100 t/day of MSW. The inability to work with larger quantities of waste is related to the increase in the diameter of the rotating furnace, which causes worse performance of the combustion process. If necessary, several process lines may be used simultaneously.

Table 1 provide specifications of the waste to be processed.

Table 1. *Integrated specifications of MSW*

Characteristic	Values
bulk weight	300 kg/м^3
total humidity	30%
caloric content	4.6 MJ/ kg
PH value	7
organic substances	35%
inorganic substances	65%

Table 2 shows the quantities of the specified utilities saved from the incineration of 100 t of domestic waste, as well as the emissions of CO_2 during the year-round operation of the installation.

Table 2. *Quantities of fuels replaced by 100 t of MSW*

	MJ/kg	Quantities of fuels replaced by 100t of MSW	CO_2 tons per 365 days
wood	10.8	42304 kg	**278**
wood briquettes	19.6	23404 kg	**10 670**
wooden pellet	19.6	23404 kg	**10 085**
coal briquettes	10.5	44000 kg	**86 620**
light boiler fuel	41.8	11000 kg	**72 575**

The energy obtained from the incineration of 100 tons of MSW is given in Table 3

Table 3. *Energy recuperation after the incineration of 100 t MSW*

electricity – to the electricity grid	kWh	**11 100**
generated heat to be supplied to the district heating network	MWh	**99,7**

In addition to the benefits, incineration plants also cause some problems that need to be addressed. Below are the main contaminants from the incineration of MSW and the methods by which the proposed technology resolves them:

NOx - The presence of nitrogen oxides in combustion gases is due to the following endothermic reaction between nitrogen and air oxygen:

$$N_2 + O_2 = 2NO \quad (1)$$

When the temperature decreases, nitrogen oxide is converted into a nitrous trioxide by the reaction

$$2NO + \frac{1}{2}O_2 = 2N_2O_3 \quad (2)$$

as well as in various other extremely harmful nitrogen oxides. In the presence of water vapor in the atmosphere, these oxides are converted into nitrous acid and nitric acid.

Reaction 1 is balanced and at high temperature is shifted to nitric oxide. The reverse reaction of nitric oxide decomposition is very slow, so once formed it does not decompose to nitrogen and oxygen within the foreseeable time. For this reason, the only reasonable measure to avoid its generation is to conduct the incineration process at a lower flame temperature. Moisturising the combustion air leads to a significant decrease in the temperature in the flame.

Furans - MSW contains chlorine-containing waste, such as PVC. When it is incinerated at low temperatures, furans are produces – compounds which are harmful to human health. For this reason, the incineration of the waste is carried out at temperatures above 850° C. In addition, the gases resulting from the incineration must stay at this temperature for more than 2 seconds. The new technology provides an after-burner in the combustion chamber, where the combustion gas temperature is maintained at 1100° C. This is done using an additional burner. In this additional chamber, the gases are retained for more than 2 seconds. It is essential for furans that they can be synthesised back if they are not cooled down quickly. The new technology uses an indirect heat exchanger to quickly reduce the temperature of combustion gases from 500 to 200° C, while at the same time heating the combustion air.

SO2, chlorides and fluorides - the generated combustion gases undergo treatment in an absorber with a solution of Na_2CO_3. The pH of the solution is monitored during the process. When the absorbent is exhausted, pH decreases and, accordingly, the absorbent is replaced. The absorbent changing intervals cannot be predicted in advance. Below are also shown the reactions that take place therein:

$$Na_2CO_3 + HCl = 2NaCl + CO_2 + H_2O \quad (3)$$

$$Na_2CO_3 + HF = 2NaF + CO_2 + H_2O \quad (4)$$

$$Na_2CO_3 + SO_2 = NaSO_3 + CO_2 \quad (5)$$

$$NaSO_3 + \frac{1}{2}O_2 = Na_2SO_4 \quad (6)$$

The resulting solution contains salts that can be used during the winter months to deal with icy pathways.

Dust – the present technology provides a multi-stage dust purification: 1. bottom ashes are discharged after the rotary kiln; 2. flying ashes are discharged from the bag filters; 3. wet cleaning is carried out in a contact economiser, lead powder is exported together with condensed water vapour.

Conclusion

From the presentation so far, it is clear that the new technology solves the addressed issues, namely:

1. To process domestic waste / MSW up to 100 t/day;
2. To recover the resulting heat in several steps;
   - generation of electricity more than 8% from the energy carried by MSW (Turboden ORC);
   - production of hot water for district heating purposes more than 78% from the energy carried by MSW;
   - heating of air used for the combustion;
3. Not to pollute the environment – the level of combustion gases treatment meets the best European practices;
4. To reduce distances from the origin to the processing and use of waste, i.e. to reduce its transport.

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