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An Eco-Incinerator Plant Using Modern Waste Disposal Methods

Abstract

Threats associated with municipal waste are a problem applicable to residents of every city. The amount of waste keeps growing each year. In highly developed countries, the largest percentage of waste comprises cardboard and waste paper. In Poland, a very significant percentage of waste is constituted by plastics. Thanks to European Union funds, it is possible to implement such projects as the construction of the Thermal Waste Processing Plant in Krakow. The operation of this facility allows for a significant reduction in the volume of waste deposited on landfills, which is not recyclable concurrently generating green energy for the city. The aim of the research was to determine the impact of modern techniques of municipal waste disposal on the ecological safety of city dwellers and the natural environment.

Keywords: incinerator plant, green energy, waste treatment

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Ekospalarnia wykorzystująca nowoczesne metody utylizacji odpadów

Abstrakt

Zagrożenia związane z odpadami komunalnymi to problem mieszkańców każdego miasta. Z roku na rok ich ilość wzrasta. W państwach wysoko rozwiniętych największy procent odpadów stanowią tektury i makulatura. W Polsce bardzo znaczący procent odpadów to tworzywa sztuczne. Dzięki funduszom z Unii Europejskiej możliwa jest realizacja takich projektów, jak budowa Zakładu Termicznego Przetwarzania Odpadów w Krakowie. Działalność tej placówki pozwala na znaczne zmniejszenie objętości składowanych odpadów, które nie podlegają recyklingowi, przy jednoczesnym wytworzeniu zielonej energii dla miasta. Celem badań było określenie wpływu nowoczesnych technik utylizacji odpadów komunalnych na bezpieczeństwo ekologiczne mieszkańców miast i środowiska naturalnego.

Słowa kluczowe: spalarnia, zielona energia, przetwarzanie odpadów

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Екоспалювальна установка з використанням сучасних методів утилізації відходів

Анотація

Загрози, спричинені комунальними відходами, є проблемою для жителів кожного міста.

Їх кількість з року на рік зростає. У високо розвинених країнах найвищий відсоток відходів становить картон і макулатура. У Польщі значним відсотком відходів є пластмас. Завдяки дофінансуванню з Європейського Союзу, існує можливість реалізувати такі проекти, як будівництво установки тепловиої переробки відходів у Кракові. Діяльність такої установки сприяє значному зменшенню кількостіі складованих відходів, які не підлягають вторинній переробці, продукуючи водночас зелену енергію для міста. Метою дослідження було визначення впливу сучасних технологій утилізації побутових відходів на екологічну безпеку міських мешканців та природнє середовище.

Ключові слова: спалювальна установка, зелена енергія, переробка відходів

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Introduction

An inevitable phenomenon arising from economic development of man is the generation of waste [6]. In Europe, every human being produces ca. 350 kg of rubbish in a year; however, in Poland it is estimated at approx. 1000 kg [2, 14]. Overfilled landfills are waiting for a healing solution. This is a new law on waste, which introduces high standards in the field of waste segregation and recycling of secondary raw materials [3, 4, 7]. Thanks to this law, the major part of waste will go to the Regional Municipal Waste Treatment

Plant (RIPOK). EU directives and Polish law impose on citizens the segregation of waste generated in households. This allows preventing the creation of wild waste dumps [5, 9]. Also promoted is selective waste collection, which significantly facilitates the recovery of recyclable materials. The positive impact of constructing an ecological waste incineration plants has been proven, which in the past aroused opposition of local residents [8, 12]. For the planned investment it is extremely important to develop a forecast of waste accumulation for the period during which the designed object is to operate [13]. The value of the accumulation is usually determined by the client, i.e. an enterprise that deals with the waste disposal in a given area [1, 10]. Thanks to European Union funds it is possible to implement projects such as the Thermal Waste Treatment Plant in Krakow, the activity of which will allow a significant reduction in the volume of deposited waste, while generating green energy for the city.

Department of Thermal Processing of Waste in Krakow

The plant meets BAT requirements (Best Available Techniques), which guarantee the highest standards of environmental protection. This makes it possible to meet the most stringent standards. The plant is a safe facility for the environment and people and it remains under constant monitoring.

Figure 1 shows the incineration plant in Krakow.

Fig. 1. Department of Thermal Processing of Waste in Krakow

Source: [11]

The plant ensures the recovery of energy contained in municipal waste, and produces both electricity and heat. Energy obtained from the incineration of municipal waste is considered largely as renewable energy, called also the "green energy". The plant in Krakow is tasked with burning 220 thousand tonnes of municipal waste during the year. As a result of the transformation of this amount of waste, approximately 65 thousand MWh of electricity Energy and ca. 280,000 MWh of thermal energy will be produced. The generated thermal energy meets 10% of the city's annual heating needs for Krakow housing. Given the energy generation by the incinerator, it was necessary to build ca. 3.65 kilometres of a heating network. Also built was a 110 kV medium voltage transformer station, as well as ca. 537 meters of 110 kV line between the plant and high voltage transformer station. In order to prevent the introduction to thermal processing of objects that may cause disturbances in the operation of the installation, it has been additionally equipped with sensors for detecting radioactive materials. The scintillation sensors are mounted on weighbridges before the entrance to the incineration plant. The plant has two independent technological lines, with each of them allowing for disposal of 14.1 tonnes of municipal waste per hour. All vehicles bringing waste to the plant are weighed on entry and exit. The scales are furnished with a computer registration system connected to the central control room. Data from the scales are entered into the plant's system and analysed on a regular basis. The dispatching centre is shown in Fig. 2

Fig. 2. Dispatching centre

Source: [11]

Unloading and storage of waste

Waste brought to the incineration plant is unloaded in the unloading hall to the bunker, which is a reinforced concrete waste tank with a capacity of storing waste for at least 5 days. In order to homogenize the mass of waste and thus increase the combustion efficiency, the bunker mixes garbage by two gantries. A suction system was used in the unloading hall and also in the bunker. The installed system enables avoiding odour and dust emissions. The air sucked into the bunker is then used for the combustion process. The unloading of waste to the bunker is shown in Figure 3.

Fig. 3. Unloading of waste to the bunker
Source: [11]

A fire protection system was installed at the node for the acceptance and preparation of waste for combustion. Its composition includes, among others, thermal imaging cameras to monitor waste contained in the bunker. There are also two water plots that are operated in the event of a fire by the crane operator. In addition, the bunker has a drainage and sewage disposal system from stored waste. The mixed waste in the bunker is fed by the gantry to hoppers located on the upper edge of the bunker. Overhead cranes are equipped with grippers that allow easy and effective mixing of garbage in the bunker and their transport to the hopper. The waste in the funnel falls under its own weight to the loading shaft. The shaft is a temporary waste warehouse, which then feeds the grate. Fig. 4 shows a waste bunker and a crane furnished with a gripper that loads waste into two hoppers visible on the right. The position of the crane operator is shown in Fig. 5.

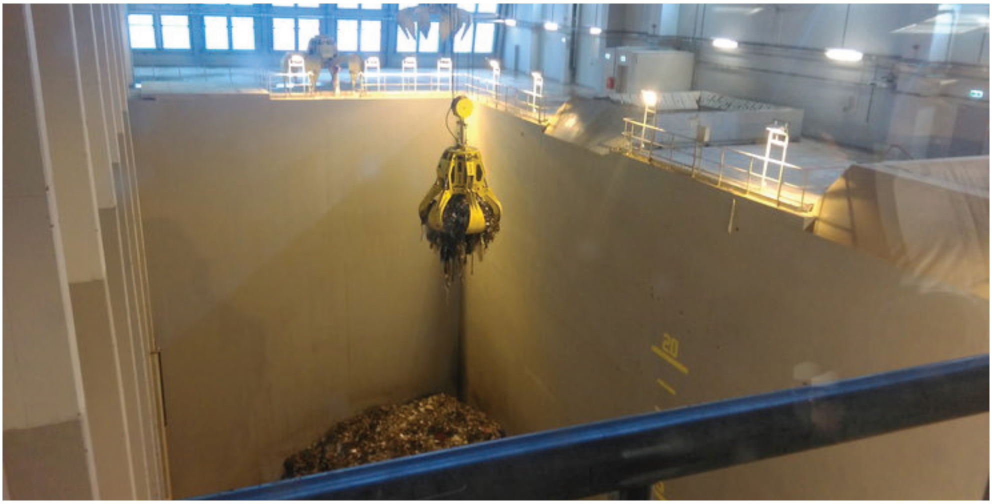

Fig. 4. Waste bunker with a visible industrial crane

Source: [11]

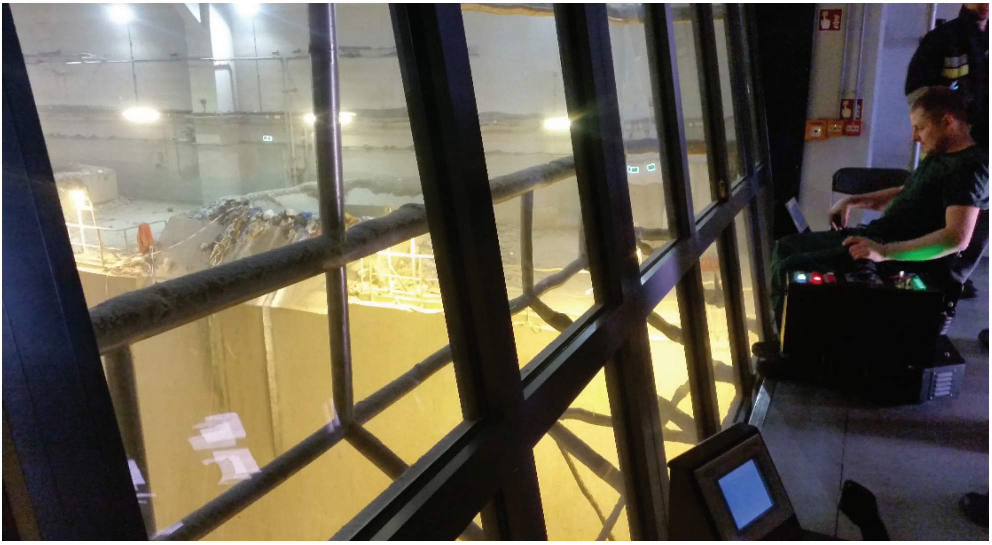

Fig. 5. Station of the industrial crane operator

Source: [11]

Loading shaft is placed high enough so that the waste column in it ensures the required tightness between the charging funnel and the combustion chamber. This solution does not allow flames from the combustion chamber to back up. To protect its lower part against overheating, the chamber was equipped with a water jacket. The installation has also been equipped with a hydraulic piston feeder, which is located at the end of the shaft, to ensure proper dosing and spreading the trash on the grate.

Thermal treatment of waste

Waste is burned on the grate with hydraulic drive, air-cooled. The grate is divided into three sections. The first two were designed as a reciprocating grate with a slope of 10°, while the third section is designated as a reciprocal grate. Each grid section consists of several rows of movable and fixed grates, alternating on a grid. The shape of the used grates and the air circulation in the combustion chamber ensure almost complete burnout of waste that moves on the grate. The air is sucked into the combustion chamber from the waste bunker and from the unloading hall, as well as from the secondary air. Secondary air goes into the combustion chamber through nozzles, which are arranged in the walls of the furnace chamber. When the temperature in the post-combustion chamber falls below 850°C, the start-up burners are automatically initiated. Temperature drops in the chamber may be caused by fluctuations in the calorific value of the garbage. Start-up and boost burners are supplied with fuel oil and are used to start and shut down the installation. The burners are also switched on in threatening situations in the event of unreliability of the waste incineration process. During the thermal treatment of waste ash and slag are produced. This waste is directed by ashes hoppers, which are located below each grate zone, as well as the slag dropping shaft, where the slag goes to the so-called slag trap with a water seal. In the slag relief system, water provides protection from the inflow of "false" air to the combustion chamber, as well as against an uncontrolled escape of flue gas. Ashes and slag after cooling are transported via a conveyor to the slag indexing node, which is situated in the building of the economy of process residues. The thermal treatment process of waste takes place on a grid according to the following phases:

1. Drying – in the initial zone once waste gets on the grate, it is heated to a temperature above 100°C as a result of radiation or convection, which leads to the evaporation of moisture.

2. Degassing – as a result of further heating to temperatures above 250°C volatile components such as moisture and carbonization gases are released from the waste.
3. Combustion – total incineration of waste is achieved in the third part of the grate at a temperature over 850°C. In this zone, the roasting loss is below 0.5% of the total mass fraction.
4. Gasification – in this process volatile products are oxidized by molecular oxygen. A minor part of this process takes place on the grate. The major part of the waste, which undergoes oxidation at 1000°C, takes place in the upper zone of the furnace chamber.
5. Afterburning – the main task is to minimize some unburned amounts of CO in the exhaust. For complete combustion, secondary air is supplied in this zone. The exhaust gases stay in this zone for a minimum of two seconds at a temperature of not less than 850°C. [10]

Energy recovery system

The main device in the system that participates in energy recovery is the waste heat boiler. This boiler has a natural exhaust gas circuit in which heat exchange takes place. The flue gas from the furnace is cooled down to 180°C, and the heat recovered in this way is then used to transform the water flowing through the boiler to superheated steam. Overheated water vapour, which has a temperature of 415°C and pressure of 40 bar, is directed to the node of transformation and energy output. Through the waste heat boiler, the heated steam is fed to turbine blades. There it expands and then goes into the state of a condensate. In the turbine driven generator, electricity is produced, which is consumed for own needs of the plant and supplied to the power grid. Electricity is supplied to the station through a block transformer system and a 110 kV switching station. In the period in which the demand for thermal energy is higher, the turbine operates in a mode in which electricity and heat energy are produced, which then supplies the municipal heating network. The main source of heat for heat exchangers in which the heated water is located is the turbine bleed steam. Water from heat exchangers is supplied to the municipal heating network, at 135°C, respectively, in winter and in summer, at a temperature of 70°C.

The technology used in the plant is characterized by very low energy consumption as well as high efficiency of energy processing and production.

Applied exhaust gas cleaning methods

During the incineration of municipal waste, waste gases are formed, which primarily consist of carbon dioxide, carbon monoxide, water vapour, nitrogen oxides, sulphur dioxide and partially burnt or unburnt hydrocarbons. These impurities occur in both dust and gas. Gases from waste incineration pass successively through a waste heat boiler; smoke purification installations; exhaust fan and a chimney that discharges exhaust gases into the atmosphere. To meet the applicable emission standards, use is made of primary methods of emission reduction to air. These include design solutions that already reduce the amount of pollutants generated at the stage of waste incineration. Such solutions ensure a favourable composition of raw exhaust gases prior to purification. Solutions used in the plant include, among others, proper design of the furnace chamber and grate, primary and secondary air heating, as well as its feeding in the appropriate combustion zones. The entire exhaust gas treatment system in the Eco-incinerator starts already in the combustion chamber just before the waste heat boiler. The flue is subjected here to a reduction in the concentration of nitrogen oxides (NOx). The reduction takes place as a result of a selective non-catalytic compression of nitrogen oxides, where a 25% urea solution is injected into the hot combustion chamber. The urea injection is made with the use of pressurized air and is implemented by appropriately spaced nozzles. The exhaust gases that come from the thermal waste treatment process are directed to the exhaust gas treatment system through a flue gas duct that is connected to a semi-dry reactor. At the top of the reactor, the dispersion gas system leads the exhaust gas towards the lime spray devices. The flue gas contains impurities such as HCl, SO_2 and HF, which are absorbed by intense contact with sprayed drops of milk lime. In a semi-dry reactor where absorption takes place; the exhaust gas is also cooled from 180°C to around 140°C. After passing through the semi-dry absorber, the exhaust gases are directed through a channel to which activated carbon is then introduced, which is responsible for the reduction of heavy metals as well as a decrease in the concentration of dioxins and furans. The duct runs flue gas to the bag filter station, where the dust concentration is reduced as a result of passing through it. The purification station containing bag filters, apart from dust reduction, is also the second stage of so-called exhaust purification second degree absorber. The passage of exhaust gases through bag filters causes the formation of the so-called filter cake. It is a layer of dust that contains unreacted absorbents, partial reaction products, active carbon and fly ash. When passing through these layers of dust and gases, absorption of residual SO_2 and reduction of heavy metals and dioxins and furans takes place. Extracted steam is discharged to the atmosphere using exhaust fans. It passes through separate chimney routes having a height of 70 m and a diameter of 1.6 m at the outlet for each technological line. Chimney lines in the Eco-incinerator are in one outer cladding. The temperature of the steam that is at the outlet of the chimney is formed at about 140°C.

Post-process waste

The residue left from incineration of municipal waste comprises slag and furnace ash, metal scrap, fly ash and boiler dust, as well as solid residues from flue gas cleaning. The essential part of the waste incineration process is slag, which slides through the reception gaps at the end of the post-combustion grate. Some part of the fine and not fully burned material permeates into the primary air ducts, from where it is removed along with the slag. As slag has a very high temperature, it should be cooled in a bathtub filled with water. This water circulates in a refrigeration cycle. First, heavy metals are removed from the slag, where it is sorted on sieves by grain size. The residues from the waste incineration process account for about 30% of the input stream to the Eco-incinerator. An external entity that holds the relevant permits and also acts on the basis of applicable law is responsible for the collection and proper management of the waste. Hazardous slag and ash are managed by their valorisation in the slag indexation node. Slag mainly consists of non-flammable substances, such as water-insoluble iron and aluminium oxides and silicates. The first stage of the slag indexation process is preliminary seasoning. It takes place on a tight and hardened base in a warehouse inside the building, which serves as its drainage and stabilization. After a period of two weeks, slag undergoes treatment during which appropriate size fractions and heavy and non-ferrous metals are separated with the use of a magnetic and inductive separator. Separated fractions are then transferred to the slag storage units. Slag remaining from the valorisation process is subjected to laboratory tests to determine its further use, e.g. in construction. Thicker slag can be used for road construction, while finer slag, along with fly ash, is kept in landfills. In order for the slag to be used, for example as a building material, it must obtain the appropriate technical approvals. The maximum installation capacity is about 70,000 tonnes per year. The building of the process residue management is equipped with ventilation, which generates a negative pressure in the building. This application prevents dust from spreading during the slag treatment process, and also maintains proper working conditions. The building is also furnished with a filter bag.

By means of bench extracts, the dust is sucked into the bag filter and then goes to the ash silo located in the stabilization and solidification node. For three silos in the junction, pneumatic and fly ash and boiler dust as well as solid residues from flue gas cleaning are transported, where they undergo solidification and stabilization processes. After the contamination to the stabilization and solidification node has been hit, its primary purpose is to transform waste inside it from hazardous to non-hazardous or neutral waste. Waste conversion is achieved by its mixing with appropriate additives and hydraulic binders. This process includes two steps, the main goal of which is to reduce the solubility of ingredients. Hydraulic binders include, among others, cement that binds toxic compounds. The products of the stabilization and solidification process, such as fly ash, boiler dust, as well as solid residues from the flue gas cleaning, meet conditions that allow the waste to be deposited on a landfill.

Process control

All parameters are continuously measured in the incinerator, and are used to control the process of thermal waste treatment. The parameters are measured in the combustion chamber where oxygen concentration, temperature and flue gas parameters are measured (including moisture content, O_2 concentration, pressure, temperature), as well as the concentration of pollutants that are emitted to the atmosphere. In line with binding regulations the installation is equipped with continuous exhaust monitoring, which is based on reference methods. The monitoring is connected with the plant automation systems and enables the authorized institution to view the process data. The central control room monitors the entire process through the central control system. The central dispatching centre is located in the main building, which receives data from the quality control system for waste delivered to the waste incineration plant. The laboratory is equipped with the necessary equipment to perform tests, which allows monitoring of selected plant installations according to reference methods, which are included in the relevant binding regulations and standards.

Summary and Conclusions

Systematic economic development causes an increasing consumption of various material goods. As a result of the consumption of these goods, an increasing amount of municipal waste is generated. The increase of social awareness and ecological movements have resulted in the introduction of stricter standards that apply to waste management in all European Union member states. The standards introduced are aimed at stopping and reversing the trend of increasing the amount of waste. The technology of thermal treatment of municipal waste is the most mature and pro-ecological solution to waste problems. This is confirmed by many years of experience of European countries, where the system of thermal treatment of municipal waste, in which energy recovery was applied, forms the basis of the entire waste management structure. This is confirmed by the fact that there are ca. 500 incinerator plants operating in European countries, and new ones are still being built. The operation of a thermal waste treatment installation does not significantly affect people living in the area or the environment, because odours, noise and air pollution are reduced to a minimum. This is possible thanks to compliance with emission standards and other acceptable regulations set by applicable law. Despite the high costs of construction and operation, indubitable advantages of installations for the thermal treatment of municipal waste include, among: limiting the amount of legal landfills, as well as preventing the establishment of wild landfills that pose a threat to the natural environment, because contaminants from them permeate into the soil, ground and surface water,

- the use of energy (electric and thermal), generated during the incineration of waste,
- the possibility of re-use of slags and ashes in the construction industry, allowing savings of natural resources, reduction of long runs of lorries used for waste disposal, which has a positive impact on traffic and exhaust gases (traffic jams, lower emissions),
- elimination of dioxin contamination through the use of the latest technologies and filters,
- new work places.

Thanks to the use of the latest technological solutions (BAT – Best Available Techniques) it is possible to meet the most stringent emission standards. Waste incineration is the only and most effective treatment for non-recyclable waste, which is ecological as well. The aim of the fire-extinguishing plant in Krakow is to reduce the volume of waste deposited by 90%. According to experts, the commissioning of a municipal waste thermal treatment installation is currently the only and effective way for its full neutralisation. The visualization of the incineration plant in Kraków, reminiscent of stripes of multi-coloured vegetation, blends well with the surroundings.

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