Development of innovative methods of thermal waste processing in modular waste burners with a high degree capture of harmful emissions

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Abstract. Innovative methods have been developed for the thermal processing of solid waste in modular waste incineration plants with mechanical furnaces of boilers from 1.16 MW with gas afterburning over the layer and with a high degree of capture of harmful emissions in compact emulsifiers and activated carbon filters.

1. Introduction

More than 13 million m³ of municipal solid waste (MSW) is accumulated in Kazakhstan annually, of which more than 2 million m³ in the city of Almaty and its suburbs alone. The analysis carried out over the past 5 years indicates a tendency for an annual increase of solid waste at disposal facilities by an average of 10 - 12%. Solid waste management (SWM) is one of the main points in the concept of transition to a green economy [1]. In particular, the government has been tasked with increasing the share of solid waste processing to 40% by 2030.

Each year significant areas of land, often valuable farmland, are allocated to landfills for solid waste-as of 2019 the allotted land for landfills in the country exceeds 1200 hectares. At the same time more than 90% of landfills do not have a hydraulic protection system, and less than half of the landfills have a sanitary protection zone. In general, the analysis carried out in the regions of the Republic of Kazakhstan showed that the system for sorting and processing of secondary resources and solid waste works inefficiently. Technical support and preparatory work among the population for the collection of solid waste is low, so up to 50% of all annual paper resources and up to 20% of ferrous and non-ferrous metals and other valuable components go to landfills. The norms for solid waste accumulation from housing, public facilities, trade (wholesale markets) and cultural institutions, educational institutions and schools have been exceeded. A separate problem is the transportation of solid waste to waste transfer stations and beyond.

In most developed countries, environmental issues relating to the protection of the environment from garbage are high priority. Garbage is a source of various kinds of pollution and offers an environment for bacteria to thrive, resulting in diseases among the population. Meanwhile transportation using garbage trucks with large capacities, using railway platforms, river and sea
barges, is developing. Sanitary, environmental, and techno-economic effective methods for the disposal of solid waste are also being developed [2, 3, 4].

To a greater extent utilization methods should be applied with the maximum use of all the useful properties of the waste by processing parts of solid waste into organic fertilizer and biofuel. To a lesser extent liquidation methods should be used that do not provide for the use of the beneficial properties of waste: landfill, dumping into mines, quarries, removal to the sea and burning of waste without using the produced heat [4].

According to the technological essence, the methods of garbage neutralization can be divided into the following types:

- biological - liquidation and disposal with the processing of solid waste by microorganisms [5,6];
- thermal - burning without and with using heat, pyrolysis to produce combustible gas [7-12, 21-24];
- chemical - hydrolysis [13];
- mechanical - pressing and manufacturing of various blocks using binders and additives [14, 15, 16].

2. Analysis of recent research, publications and unsolved parts of the issue

Currently, there are more than 2500 waste-to-energy plants in the world, most of them in developed countries across Europe, as well as the US and Australia.

Examples are the most efficient and environmentally friendly waste-to-energy plants in Germany, Italy, Austria, and France (one of the plants operates within the city centre of Vienna) [10, 17, 18]. In France, the utilization of household waste at 34 enterprises with the generation of heat and electricity on their basis allows for energy savings in terms of the oil equivalent of more than 300 thousand tons per year. In Germany, more than 33% of the more than 25 million tons per year of household waste incinerated at 42 plants is used to generate electricity and steam. More than 70% of household waste is used in Denmark, more than 80% in Sweden and half of this is used as fuel. According to the estimates of Swedish scientists, burning 5 tons of household waste gives the same amount of energy as burning 1 ton of fuel oil or 2 tons of coal. At the same time, 1 ton of fuel oil costs 1,400 SEK and preparation for burning 1 ton of household waste costs 160 SEK, i.e. almost nine times cheaper. Recalculation of the cost in preparation for the incineration of solid waste in Kazakhstan and comparison with the cost of fuel oil in tenge will be almost the same ratio.

In Italy, waste-to-energy plants successfully operate in Modena with an electric capacity of 19 MW, in Bologna 37 MW, in Ferrara 70 MW, in Ravenna 28 MW, in Forli and in Rimini Coriano of up to 80 MW. At the same time, the cleaning and capture systems are under constant and continuous control of Italian supervisory authorities. Moreover, from the chimneys of the indicated plants there are practically no emissions visible from the unaided eye or smoke of a bluish and dark color.

Starting from 2017, about 200 waste-to-energy plants are commissioned in the Russian Federation. The expanded production of powerful boilers at the Machine-Building Factory of Podolsk with a coating of steel all-welded screens with a special composition to increase the service life during the combustion of solid waste was operationally launched [11, 19]. The widespread and successful use of furnaces for the incineration of household waste and efficient generation of electricity in the Scandinavian countries, the USA and the UK should also be noted. In New Jersey (USA) a plant was put into operation back in 1988, designed to recycle 106 thousand tons per year of waste with a design heat capacity of combustion of 12.3 MJ / kg (with a base of 10.5 MJ / kg). The installation provided district heating for a population of 550 thousand people. The area occupied by the station was 10 ha. It should be noted that the power plant consists of two independent technological units, each of which is designed to burn 180 tons of waste per day. There is experience in the successful operation (since 1976) of the Bernard Road power plant in Sheffield (England). At this station, 102 thousand tons of household waste are burned annually. A boiler with a thermal capacity of 24.4 MW, a steam capacity of 32 t / h with a pressure of 1 MPa (10 kg / cm²) provides heat to the area with a population of 100 thousand people. Significant successes in the design and development of solid waste incineration technology used to obtain heat and electricity were achieved in Switzerland [20].
Of certain interest is an incinerator steam boiler (Russian Federation) E-6.5-1.4-225 "O" (KE-6.5-14-225 SHW) with a steam capacity of 6.5 t / h designed for burning unsorted solid household waste (SHW) with a steam capacity of 3 tons / hour. The boiler produces superheated steam to meet the technological needs of the enterprise or for the purposes of heat supply, ventilation and hot water supply.

3. Purpose of the study and the main results of the development
An experimental verification of joint-combined burning of solid waste in a burning layer of coal was carried out on a KST-1 [21,22] (solid fuel steel boiler with heat capacity of 1 Gcal) boiler with a mechanical furnace with fire-bars for drop grate (figure 1) and showed low calorific value of unsorted solid waste (up to 1800 kcal / kg) and unpreparedness of solid waste for burning in such a wet form.

![Figure 1. Mechanical furnace with fire-bars for drop grate.](image)

The thermal power of the boiler decreased by 25–40% without the subsequent addition of coal. The duration of the experimental combustion was 4-5 hours. Also on the KST-1 boiler, substandard cardboard and paper were burned for 2.5–3.5 hours. The experiments on burning solid waste led to the conclusion that it is necessary to increase the combustion mirror and to partially modify the grate. Previous experiments and developments of the authors formed the basis for the developed working drawings of the KST-1.16 hot-water boiler with mechanical cast-iron fire-bars for drop grate, complete with the working documentation of a mobile modular boiler house with an automatic heating system up to 2.32 MW with a chimney. A draft design of a feeder hopper with a dispenser for feeding solid waste into the furnace of the KST-1.16 boiler was developed, with a preliminary design of an emulsifier with a capture coefficient of up to 99.7% of solid fractions when burning solid waste.

Initial data has been prepared for the development of technical documentation using modern 3D design software products to prepare the production of the first samples of modular waste-to-energy plants. The plants are equipped with new mechanical furnaces for hot water and steam boilers with a thermal capacity of 1.16 MW and up to 11.6 MW with afterburning over the bed complete with efficient purification of harmful emissions by compact emulsifiers and filters using activated carbon.
batteries. This is accomplished using automated combustion process control systems and shows potential for application in large cities and regional centers of the Republic of Kazakhstan.

The authors are preparing for experiments in semi-industrial conditions for the experimental burning of solid waste on a layered manual grate with the useful utilisation of heat. New dry systems for collecting solid fractions in the gas duct behind a steel boiler are being prepared for experimental verification.

4. Conclusion
Preliminary heat engineering tests and simulation in the special software have shown the technological possibility of burning low-calorie solid waste in hot-water solid fuel boilers. The developed working drawings for the KST-1,16 steel hot water boiler with a mechanical furnace and swinging grates for solid waste incineration in the layer can be an effective solution to the problem of waste disposal, provided that the equipment is highly environmentally friendly. Now the authors are working on the development and testing of a block-modular boiler house with a set of emulsifiers and an automated control system for the combustion process. New dry systems for capturing solid fractions in the flue behind a steel hot water boiler have been developed and are being prepared for experimental testing.

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