Modern Methods of Utilizing Municipal Solid Waste (MSW)

V I Gel and V A Litvinov
Yaroslav-the-Wise Novgorod State University, 41,ul. B. St. Petersburgskaya, Veliky Novgorod, Russia Federation
E-mail: v-gel@mail.ru

Abstract. The article deals with the handling of municipal solid waste, it is shown that waste disposal at landfills still prevails in Russia, because it is associated with significant difficulties in organizing separate collection. It is shown that in European countries, along with separate collection, sorting and thermal processing of municipal waste are widely used. The operation of the MSW sorting plant in the city of Kostroma showed the possibility of deep sorting with subsequent marketable products receiving. However, the issue of processing glass and the organic part of (food) waste, whose moisture after separation reaches 40%, remains unresolved. The low-temperature combustion of MSW on moving gratings leads to significant emissions of dioxins and furans. In addition, the calorific value of organic waste, due to high humidity, is not sufficient to maintain combustion using air blast; in addition, cleaning a large volume of gases is difficult. The burning of MSW is successfully resolved by the use of oxygen blasting and additives of low-grade solid fuel. It allows achieving a high combustion temperature of the waste (1300°C and above), leading to complete burning of dioxins and furans, as well as significant reduction of exhaust gases volume.

1. Introduction
In the Russian Federation the concept of municipal solid waste (hereinafter – MSW) disposal is currently prevailing. The reason for this approach is simple: if there is a lot of land in the country, why bother building expensive processing or incineration plants, it is much easier and cheaper to take garbage to a landfill. The same concept prevails in some other countries, such as Canada, for example.

Unfortunately, the collection of MSW with its placement at landfills is attractively simple and cheap. Unfortunately, the collection of MSW with its placement at landfills is attractively simple and cheap. Unfortunately, separate waste collection in Russia is in its infancy. Its organization, in addition to large financial investments in increasing the number of containers for separate waste collection and its timely removal, will meet significant difficulties, mainly due to the disinterest of the population to separate waste sorting in their own housing.

In the USSR, in some cities and towns, the population used to separate food waste. But it did not take root in Russia.

2. Objects and methods of research
The thermal processing of MSW has a large number of opponents for two main reasons: the environmental hazard of the emitted harmful gases and the high cost of waste incineration plants.

There are examples of competent burning of MSW. In Austria, a factory with a chimney restaurant has been operating in the center of Vienna since the 1990s. Moreover, sewage treatment plants occupy more than 70% of the territory of the plant. In all European countries, incinerators are located both in capitals and other cities. Today, more than 2500 incinerators operate in the world, which utilize about...
200 thousand tons of MSW and generate 130000 MW/h of electricity. The proportion of such processing in different countries depends on population density and the possibility of exporting waste. The share of thermal processing in different countries is in Japan – 75%; in the USA – 15%; in the Netherlands – 45%; in Luxembourg – 50%; in Germany – 43%; in Belgium – 55%; in Austria – 48%.

In Russia, according to various sources, up to 70 million tons of MSW are generated per year. It should be noted that when burning 1 ton of waste, it is possible to get up to 720 kW/h of electricity and 920 kW/h of heat, i.e. when burning all MSW in Russia for a year, it is possible to receive only electricity up to 59 million MW/h per year and about the same amount of heat in the form of steam and hot water.

The experiments established the relationship between the ability to independently maintain burning depending on the ash content, humidity and the combustible part of the fuel, which the Tanner triangle illustrates (figure 1) [1].

![Figure 1. The Tanner triangle.](image)

Having examined the ratio of characteristics obtained from the Tanner triangle, we can conclude that, taking into account the ignition temperature of 396 °C, the inorganic fraction should not exceed 5%. When inorganic parts are removed from MSW, their primary moisture content can be increased up to 40%, i.e. preliminary heat treatment will be required for further burning.

Based on well-known techniques (heating the blast, enriching the blast with oxygen, adding more high-calorie fuel), burning low-calorie fuels can be intensified.

By the way, Japanese waste incineration plants use both blast heating and oxygen, while German plants additionally use cheap coal.

Low-temperature burning of MSW at landfills and unauthorized dumps leads to the release of TCDD (tetra-chlorodibenzo-p-dioxin), which enters the MSW with household waste and plastics. In the case of low-temperature combustion in incineration plants, gaseous TCDD are reduced completely to dioxins upon cooling. This requires complex multi-stage gas treatment with gas neutralization.

Significantly safer is burning with oxygen, because process temperature can reach 1300 °C. At the same time, due to a decrease in ballast nitrogen in the blast, the volumes of exhaust gases are sharply reduced, which allows reducing the cost of gas cleaning and gas neutralization with lime and activated carbon [1].

Thermal methods of MSW processing currently include incineration, pyrolysis, gasification, plasma gasification, gasification in silicate (slag) melt furnaces.
3. Results and discussion
In research literature [3, 4, 5, 6, 7, 8] the characteristics of the technologies used or recommended for use for processing MSW by thermal methods are given (table 1).

| Table 1. Technologies for MSW processing by thermal methods. |
|-------------------------------------------------------------|
| **Characteristics**                      | **Method** |
| The destruction of the organic part, furans, dioxins | Desctruction 70% (650–1050 °C) | Desctruction 90% (450–900 °C) | Desctruction 90% (800–1150 °C) | Full desctruction (2000 °C) | Full desctruction (1300–1650 °C) |
| Resin and furan formation                      | Much resin and furan 30% of toxic resin | Resin and furan are present 10% of resin | Resin and furan are present 10% of ash | No resin and furan | No resin and furan 0.15% ash per turnover |
| Ash formation                              | Except certain types of inorganic waste | Except certain types of inorganic waste | Except certain types of inorganic waste | Any waste type | Any waste type |
| Recyclable waste types                      | Waste pre-sorting is necessary | Waste pre-sorting is necessary | Waste pre-sorting is necessary | No waste pre-sorting | No waste pre-sorting |
| Recyclable volume                          | Large amount of waste up to 500 t/day | Waste volume in pyrolysis plants up to 30 t/day | Waste up to 250 t / day | Waste up to 110 t / day | Waste up to 330 t / day |
| The level of gas emissions with a conditional capacity of 120 thousand MSW/year | High flue gas emissions up to 60 thousand nm³/h | For comparison, there are no installations for this performance | Flue gas emissions – 50 thousand nm³ / h | No data available | Flue gas emissions – 30 thousand nm³ / h |
| Sensitivity to waste moisture               | Sensitive to waste moisture | Waste humidity of about 20% when removing inorganic parts up to 40% | Waste humidity up to 50% with a low level of inorganic part | Not sensitive to waste moisture | Not sensitive to waste moisture |
| The quality of the resulting synthesis gas  | Generator gas (technical) | Ballasted synthesis gas | Generator gas (technical) | High quality synthesis gas | Generator gas (technical) |
| Output products                            | Heat, electricity | Synthesis gas, liquid fuels, electricity, heat | Heat, electricity | Synthesis gas, liquid fuels, electricity, heat | Synthesis of gas, electricity, heat, fused slags |

* According to the Institute GINTSVETMET

As can be seen from table 1, the best performance is achieved in plasma gasification and in silicate (slag) melt furnaces, in which temperatures are reached above 1300 °C and liquid slags containing no benzene pyrenes are formed, however, the cost of equipment for implementing these technologies is prohibitive. So, for example, a complex with a slag melt furnace for processing solid waste from a city
with a population of 250 thousand inhabitants will cost about 4.0 billion rubles. And if you pre-sort MSW with the extraction of secondary raw materials, then the remaining amount of MSW can be processed in installations of a much smaller scale.

In this regard, the question arises: is it possible to implement fully automatic MSW sorting in the North-West region of Russia? Is a consumer-friendly tariff possible in the locations where a new waste management facility has been created, including a modern waste sorting plant and a landfill for unclaimed waste from this plant?

In Kostroma, such a plant was built, it is successfully operated and the technologies used in it are being improved.

A distinctive feature of the work of this plant is the widespread use of a wide variety of operations: crushing, grinding, magneto-electrodynamic methods of processing MSW entering the plant, multi-stage optical sorting with separation of plastic and paper. In addition, the plant develops technologies for the sale and use of various types of products. For example, the technology of using plastics for the production of sand–polymer pavement tile has been successfully implemented.

The photographs show a type of sand-polymer tile and MSW processing and sorting products in the city of Kostroma (figure 2).

![Figure 2. Products of MSW processing.](image)

Investments in the creation of the enterprise were preceded by seasonal studies of the composition of MSW by manually disassembling representative samples.

It should be noted that the glass as a part of the MSW significantly interferes with further sorting, therefore, a separate collection is organized in the city, and residents are willing to do it.

The work of the Kostroma ETM plant, being a member of the group of companies of the large holding AVENUE, was itself a customer, an investor, a designer (the company possesses the relevant competencies) and a developer, which made it possible, with the involvement of private investment and tax benefits, to create an enterprise in a short time. The cost of the enterprise amounted to more than 1.2 billion rubles. with tax benefits of 64 million rubles [9].

4. Conclusion

Plasma burning or processing in slag melt furnaces together with hazard class 1 waste (for example, medical waste) would drastically reduce the cost of such an enterprise and allowed producing synthesis gas, electricity for own needs and heat for greenhouses. The cost of such a plant for 30,000 tons of waste per year would be substantially reduced, and when using the infrastructure, for example, a plant for processing scrap and copper waste, would be halved. Moreover, the cost would include the costs of creating a waste sorting plant.

It goes without saying that, before deciding to create such a complex, it is necessary to first
investigate the structure of MSW, as well as to study a more thorough sorting of polyvinyl chloride, the main source of dioxin formation, for example, with a PolyMax laser analyzer. The second way – after sorting, the remaining 30% will be buried in landfills created according to the latest norms and rules, where the existing technology of layer-by-layer waste treatment can be applied.

References
[1] Dolgen D, Sarptas H, Alpaslan N and Kucukgul O 2005 Energy Potential of Municipal Solid Wastes Energy Sources 27 1483–92
[2] Samylin A and Yashin M 2009 Sovremennyye konstruktsii gazogeneratornykh ustanovok [Modern design of gas generating units] LesPromInform 1 (59) 78–85 [in Russ.]
[3] Justification for choosing the best way to dispose residential waste from the housing stock in the cities of Russia 2012 (Moscow: Federal Service for Supervision of Natural Resources) p 40 [in Russ.]
[4] Vlasov O A and Mechov V V 2017 Analysis of the operation of waste incinerators Solid household waste 8 38–41 [in Russ.]
[5] Nam-Chol O, Hyo-Song, Yong-Chol S, Yong-Hyok Ri and Yong-Nam K 2018 A feasibility study of energy recovery of RDF from municipal solid waste Energy Sources Part A: Recovery, Utilization and Environmental Effects 40 24 2914–22
[6] Mechjov V V, Vlasov O A and Mechov P V 2012 Thermal Processing of Coals, Domestic and Industrial Wastes with the Production of Electricity and Commodity Products Moscow p 344 [in Russ.]
[7] Glushkov D, Kuznetsov G and Paushkina K 2020 Switching Coal-Fired Thermal Power Plant to Composite Fuel for Recovering Industrial and Municipal Waste: Combustion Characteristics, Emissions and Economic Effect Energies 13 (1) 259
[8] Mahendra Singh and Leena G 2020 Forecasting of waste-to-energy system: A case study of Faridabad India Energy Source Part A: Recovery, Utilization, and Environmental Effects 42 3 319–28
[9] Mal'tseva O N 2017 Automatic waste sorting: Kostroma experience Solid household waste 10 24–9 [in Russ.]