

Cracking of municipal waste in the fuel production

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Abstract

Municipal waste is incinerated for energy purposes or is landfilled. In this article, the results obtained by catalytic cracking of average municipal waste sample are presented with the aim to obtain liquid fuels. The yield of such fuels is determined mainly by plastics content in the waste and in our experiments was between 35 to 50 % wt. from the input waste at the temperatures of 390 – 550 °C.

1. Introduction

With the increasing living standard of the population the amount of wastes is increasing in consumer and also in manufacturing sector. Wastes threaten water, soil and air qualities as well as human health. The European Union pays great attention to the problem of wastes (Directive [2008/98/EC](#) on waste).

According to the origin of the waste, the wastes tend to be divided into municipal, industrial, waste from mining, forestry and agriculture, waste from energy production, sewage sludge from municipal and industrial wastewater treatment plants and radioactive waste. Since the municipal waste is a blend of various materials with changing composition, its processing is more complicated than in the case of industrial and agricultural waste, or waste from mining, for example.

As European society has grown wealthier it has created more and more rubbish. Each year in the European Union alone we throw away 3 billion tonnes of waste - some 90 million tonnes of it hazardous. This amounts to about 6 tonnes of solid waste for every man, woman and child. It is clear that treating and disposing of all this material - without harming the environment - becomes a major problem. Between 1990 and 1995, the amount of waste generated in Europe increased by 10 %. Most of what we throw away is either burnt in incinerators, or dumped into landfill sites (67 %). By 2020, the OECD estimates, we could be generating 45 % more waste than we did in 1995. Obviously we must reverse this trend if we are to avoid being submerged in rubbish.

Protection of human health and friendly approach to the environment are the basic assumptions in the reuse and disposal of wastes. The primary objective was to remove the wastes hygienically, but the wastes began soon to be used as a material and energy source. This is a key trend in the modern waste management together with the waste prevention and the reduction of landfill amounts. Although recycling is preferred, i.e. material utilization of waste, this hierarchy may be changed based on life cycle assessment in favor of energy production - energetic waste utilization (EWU).

EWU is advantageous for several reasons:

- waste is an excellent replacement of non-renewable fossil resources with the calorific value comparable with this of brown coal so it saves these resources;
- waste is the cleanest power source among thermooxidative processes with clean combustion gases;
- it reduces ten times the volume and 60 to 70 % the weight of waste;
- residual materials are further useful or safely storable;
- EWU is environmentally neutral in relation to carbon dioxide resulting from oxidation of organic carbon. Compared to the landfill emissions of greenhouse gases are lower - EWU produces only CO₂, while the landfill CO₂ and methane in a ratio of about 1:1. CH₄ is about 25 times more effective greenhouse gas than CO₂.

Landfill is the simplest and cheapest way of waste management but is not optimal and environmentally-friendly. Waste should be stored in layers using such technologies to avoid damage of the groundwater. In Switzerland, 50 % of municipal waste is recycled and 50 % is incinerated. In Austria, 69 % is recycled, 23 % is burned in incinerators and 18 % is landfilled. In Germany, 51 % is recycled, 25 % burned and 15 % landfilled. In the Czech republic is 18 % recycled, 10 % incinerated and 72 % landfilled.

In the case of municipal waste, the change of management from waste landfill disposal to the energetic waste utilization should be connected with the waste composition study Burnley showed that the composition of municipal waste was depended not only on age and municipal size, but also on socio-economical factors [1]. Pyrolysis of waste plastics is theoretically and technically well managed [2]. Pyrolysis of municipal waste plastics leads to the formation of paraffins and olefins, which can be used as fuel. Products of catalytic cracking are composed mainly of *iso*-alkanes and aromatic compounds that are welcomed components of petrol [3]. The composition of the final pyrolysis product depends on the types of plastics present. The usual components of municipal waste in a group of waste plastics are mainly polyethylene (PE), polypropylene (PP), polystyrene (PS), polyvinyl chloride (PVC), polyethylene terephthalate (PET), polyamide (PA) and polyurethane (PU). PS and PET are leading to the formation of aromatics. In the pyrolysis of PS and PA, the content of sulfur and nitrogen in the product increases [4]. Lin and Sharratt cracked plastics from municipal wastes in the presence of zeolites at 360 °C. The yield of hydrocarbons C₁-C₉ was about 90 % and the remaining 10 % were hydrocarbons with longer chains and cracking residue [5]. An overview of the literature shows that the waste cracking is focused only on the plastics recovered from municipal wastes. The cracking of the municipal wastes as a complex is not processed by this technology. Municipal wastes include besides the plastics also paper, wood, textiles, glass, metals and other components.

The aim of submitted work is to assess the possibility of catalytic cracking of municipal waste as a whole in the preparation of liquid products, usable as fuel or its components in road transport or in cogeneration units.

2. Experimental

Materials

Municipal waste for the testing of catalytic cracking included plastics, paper, wood, textiles, metals, glass, biological wastes and water (moisture of material). Municipal wastes collection came from the city Győr, Hungary. It was adjusted to the size of 5 mm. As the catalyst, natural zeolite with particle size 1-3 mm was used.

Procedures

Cracking of municipal waste was taking off in the three-stage stainless steel reactor with screw mixers with a diameter of 300 mm. The capacity of the reactor was 200 - 350 kg/h of wastes. During the measurements in a continuous reactor semi-continuous mode was kept.

Fig. 2 shows a diagram of a cracking and treatment of liquid condensate. The fraction 150 °C is usually a clear pale yellow in color with a strong odor. Fraction 150-330 °C is again a clear orange liquid with a characteristic odor. It may contain the paraffin deposits, soluble at 40 °C. Individual fractions obtained by the treatment of the liquid condensate were evaluated

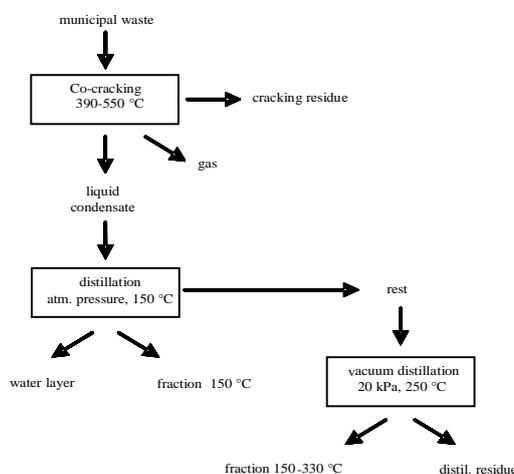


Fig. 2 Scheme of cracking and treatment of liquid condensate obtained from cracking of municipal wastes

by gas chromatography and the acid value (AV), density, viscosity and mass balance were determined.

For analytical evaluation, the GL chromatography device Chrompack CP 9000 with a glass column packed with 10% SE 30 on Chromatone NAW-DMCS 1.8 mx 3 mm, provided with FID was used.

To determine other parameters, the standardized procedures were performed.

3. Results and discussion

According to our measurements, during the catalytic cracking of municipal wastes it is possible to obtain a liquid condensate with a yield of around 35 to 50 wt. % of input material using standard sample of municipal waste. With an increasing proportion of the catalyst and increasing the proportion of the gas phase, the yield of liquid condensate was increased and the amount of the cracking residue was decreased. The highest yield of liquid condensate of 49.3 wt. % was obtained at 5 wt. % catalyst. Further increasing the proportion of catalyst would have been unproductive and impractical. The share of liquid condensate is mainly dependent on the proportion of plastics in municipal wastes stream. Graphic representation of recovery process is shown in Fig. 3. The output of treatment of the liquid condensate is represented by two organic distillate fractions, aqueous fraction and the distillation residue. Tab. 1 contains the material balance of the liquid condensate obtained in the cracking in the presence of a catalyst and without catalyst. Shares of individual fractions are calculated from input material. The first distillate was spontaneously separated into the aqueous layer, consisting of water and short acids C1 and C2, and the organic layer – fraction 150 °C. Acid value of aqueous layer was about 9 mg KOH/g. The least share of water layer also with the lowest acidity was obtained in cracking without catalyst. The highest share of fraction 150 °C was obtained by cracking in the presence of 5 wt. % catalyst. This fraction did not contain

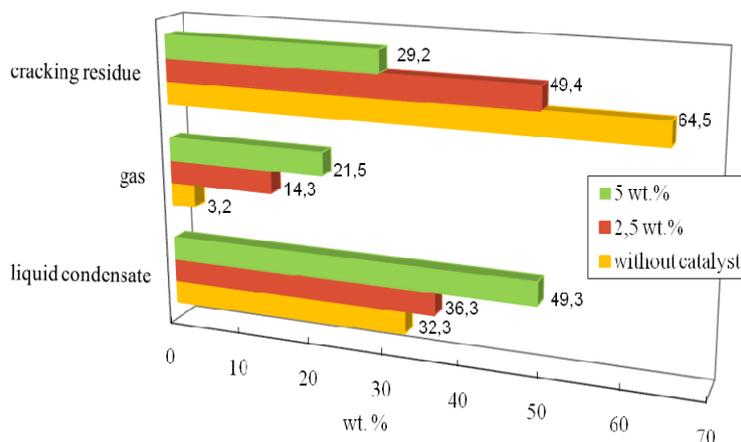


Fig. 3 Yields of liquid condensate, gas and residue from catalytic cracking of municipal wastes

organic acids, the acid value was zero. Densities of the fractions 150 °C in all three measurements corresponded to a density typical for fossil diesel fuels, while their viscosities in comparison with the viscosity of fossil naphtha were significantly lower. The highest yield of fractions 150-330 °C were also obtained by cracking in the presence of 5 wt. % of catalyst.

Tab. 1 Mass balance of treatment liquid condensate obtained from cracking and its properties

	Amount of catalyst (wt. %)		
	0	2.5	5.0
Fraction 150 °C			
yield (wt. %)	8.8	13.9	18.7
density (kg/m ³)	831	823	831
viscosity (mm ² /s)	0.878	0.898	0.818
AV (mg KOH/g)	<0.1	<0.1	<0.1
Fraction 150 -330 °C			
yield (wt. %)	12.3	10.5	21.2
density (kg/m ³)	903	897	914
viscosity (mm ² /s)	1.717	1.397	2.176
AV (mg KOH/g)	11.0	13.6	12.3
Distillation residue			
yield (wt. %)	7.4	6.3	5.1
Water layer			
yield (wt. %)	3.8	5.6	4.3
AV (mg KOH/g)	3.3	9.3	8.9

Acid value of fractions 150-330 °C was slightly higher than that of the fractions 150 °C. The densities of these fractions for all measurements were conversely significantly higher compared with fossil diesel. However, the viscosities of the above fractions were lower than

the viscosity of fossil diesel. Share of distillation residue was decreased with increasing proportion of the catalyst.

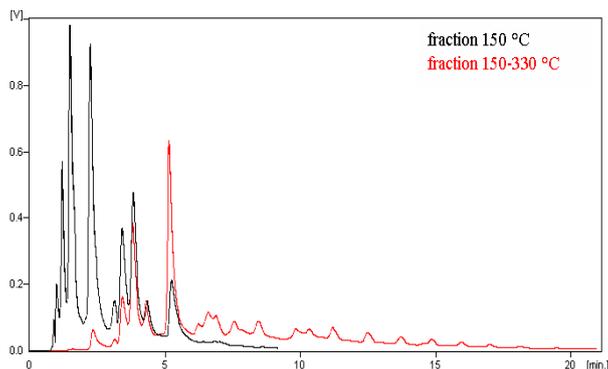


Fig. 4 GLC of fraction 150 °C and fraction 150-330 °C obtained by cracking of municipal wastes in the presence of 2.5 wt.% catalyst

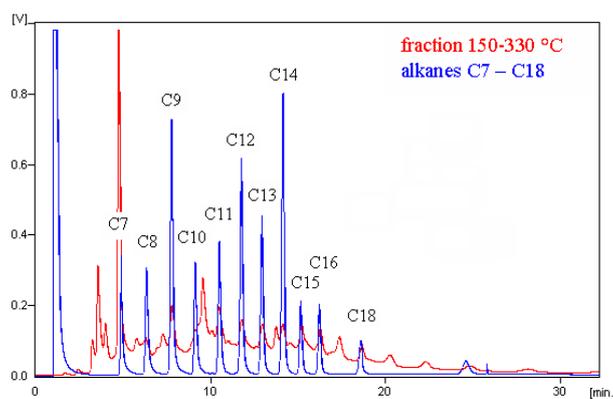


Fig. 5 GLC of fraction 150-330 °C from measurement with 2.5 wt. % catalyst and GLC of n-alkane standard

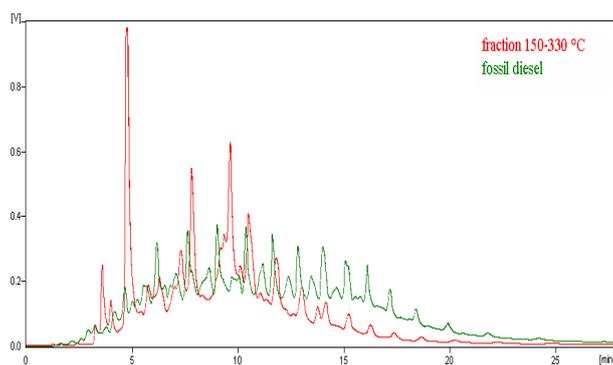


Fig. 6 GLC of fraction 150-330 °C obtained by waste cracking in the presence 5 wt. % of catalyst compared to the GLC of fossil diesel

Fig. 4 shows GL chromatograms of the fraction 150 °C and the fraction 150-330 °C for the measurements with 2.5 wt. % of catalyst. Fig. 5 shows the GL chromatogram of the fractions 150-330 °C for the measurements with 2.5 wt. % of catalyst, together with the

chromatogram of standard mixture of n-alkanes C7 - C18. The figure enables convenient and instructive identification of the peaks in the cracking condensate. Fig. 4 shows that the fraction 150 °C is composed of relatively short hydrocarbon chains with carbon number up to 6 and corresponds with the gasoline fraction, although its density is substantially higher. Fraction 150-330 °C contains mainly hydrocarbon chains C7. Analogous chromatograms could be shown for the distillate fractions for measurements with 5 wt. % and without catalyst, respectively. All chromatograms show that the amount of the catalyst had only a little influence on component share and in all cases the same components were present. Increased densities and viscosities of the fractions 150-330 °C compared with the fractions 150 °C are due to the presence of hydrocarbons with longer chains. Fig. 6 is a chromatogram of the fraction 150- 330 °C for the measurement of 5 wt. % of catalyst, compared with GLC of fossil diesel. From the comparison of both chromatograms it is obvious that the cracking product is a different material compared with fossil diesel. Distillation treatment of the condensate should be carried out in two steps, first step at atmospheric pressure, because of the presence of volatile components, and the second step under reduced pressure, which is intended by the need to reduce the working temperature. High conversion in cracking without a catalyst, as well as small differences in yields for different proportions of the catalyst show that beside a zeolite catalyst, there may be active also another type of catalyst.

The byproducts from the cracking - cracking residue and gaseous phase – can serve as the energy sources. In our case, the higher heating value of the cracking residue was 12 055 MJ/kg. The next study will focus on the problem of chlorine and aromatics content. Aromatics in the condensate can come both from the decomposition of PS and PET, both may be formed by cyclization of primary products from the cracking. Hydrogenation treatment of distilled condensate would solve its acidity and density.

4. Conclusion

Cracking of municipal wastes running in a three-stage reactor with screw mixers at temperatures from 390 to 550 °C gave a liquid condensate with a share from 35 to 50 wt.% of the starting material. In the condensate after its distillation the components C4 - C7 prevailed in it, typical for gasoline, but with the higher density comparable with the fossil diesel.

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