Mini review

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Study of the pyrolysis process of household polymer waste

Abstract

The research aims to study the functional and monomer composition of the obtained samples of pyrolysis products from the most common household polymer waste to determine the possibility of their use in industrial technologies using chromatography. The analysis of modern methods for recycling household polymer waste allows us to establish that one of the promising methods is their thermochemical decomposition (destruction) by pyrolysis. It has been shown that in the process of pyrolysis of a mixture of polymer waste, plastic waste decomposes into liquid and gaseous fractions with the release of a solid residue, the amount of which depends on the degree of contamination of the waste and the type of plastic. It has been established that the main part of plastic waste includes products of thermal destruction of polyethene, polypropylene and polyethene terephthalate and they are 90-95% represented by unbranched alkanes and alkenes.

Keywords: pyrolysis, household polymer waste, products, chromatography, research

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Abbreviations: MSW, Municipal solid waste; HPO, household polymer waste

Introduction

Household polymer waste (HPO) belongs to the category of municipal solid waste (MSW). There are two main methods of elimination: passive - disposal at landfills; and active - burning. The most widespread method is landfill burial (98%).[1] Despite the relative simplicity of this method, it has the following disadvantages: irretrievable loss of waste fractions, removal of large areas of land from circulation for a long period, and significant costs for carrying out the necessary sanitary and epidemiological protective measures. The greatest disadvantage of solid waste disposal at landfills is associated with the existence of a real danger of contamination of drinking water aquifers. These polygons fill up quickly due to the large volume and low density of contained waste. The looseness and low compressibility of plastic waste lead to frequent landfill fires.

Of the active methods of solid waste elimination, the fire (flame) combustion method is mainly used.[2,3] Combustion is carried out in furnaces and furnaces of various designs. In this case, a distinction is made between layered combustion of unsorted waste in the furnaces of boilers of waste incineration plants and chamber combustion of specially prepared (enriched) waste, which has a relatively stable fractional composition, in the furnaces of energy boilers or cement kilns.[4,5] In practice, it has been established that during flame combustion, fine dust (25-50 kg/t of waste) and gases containing carbon dioxide, nitrogen oxides, sulfur, hydrogen chloride and hydrogen fluoride, organic compounds (aldehydes and phenols), extremely toxic, are released into the atmosphere. organochlorine compounds (dioxin and furan), as well as heavy metal compounds.[6,7]

The analysis of modern methods of recycling HPO allows us to establish that one of the promising methods is their thermochemical decomposition (destruction) by pyrolysis.[8,9] This method is carried out in special reactors and is more environmentally friendly and energy-efficient. It is characterized by a high intensity of thermochemical transformation and an optimally structured relationship between controlled energy product flows throughout the entire technological cycle, which ensures extremely high energy efficiency values (86%).[10,11]

The research aims to study the functional and monomer composition of the obtained samples of pyrolysis products from the most common HPOs to determine the possibility of their use in industrial technologies using chromatography.

Material and methods

Household polymer waste was used in the form of a mixture of waste plastic bags, polypropylene disposable tableware and polyethene terephthalate bottles in the proportion of 30:30:40% wt., respectively. The HPO pyrolysis technique included adding 100 g of BPO and placing it in a Wurtz flask, pre-weighed on a technical balance – Figure 1.

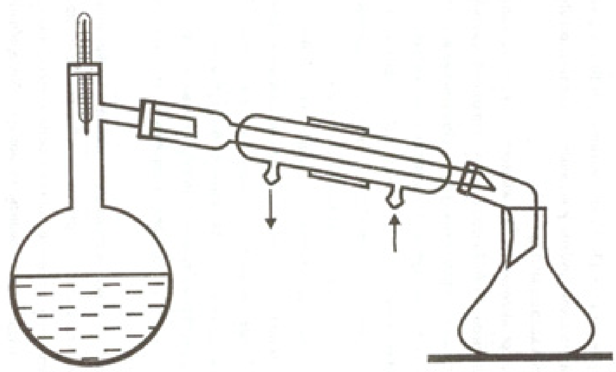

Figure 1 The BPO pyrolysis installation included a Wurtz flask.

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A water cooler and a receiver (also pre-weighed on a technical balance) are connected to the Wurtz flask. Then the BPO is heated to a temperature of at least 350 °C. Low molecular weight liquid hydrocarbon products are collected in a receiver during the process of thermal condensation in a water refrigerator. The thermal condensation temperature is controlled by a thermometer. After the appearance of the first drops of condensate, reduce the heating speed. The heating of the flask is adjusted so that the pyrolysis rate does not exceed 1 drop per second. The experiment was continued at a temperature in the heating mantle not higher than 350 °C until the end of the process of separation of low molecular weight liquid hydrocarbon products, which can be judged by the cessation of condensate formation.

The liquid products of HPO pyrolysis composition were determined by the standard gas-liquid chromatography method on a Shimadzu chromatograph (Japan). Evaporator temperature – 240 °C; detector temperature – 250 °C; speed of carrier gas (hydrogen) – 1.0 ml/min., flow division – 1:60. Fatty acids were identified by comparing their retention times with the retention times of reference samples.

Results and discussion

Results should be clear and concise and also separate from the Discussion part. Each Table and Figure must be found below their respective paragraphs from the Results part. It has been shown that during the pyrolysis of HPO, plastic waste decomposes into liquid and gaseous fractions with the release of a solid residue, the amount of which depends on the degree of contamination of the waste and the type of plastic. The finished products of HPO pyrolysis were a semi-liquid product with an admixture of a white paraffin-like substance, and the residue after exiting the reactor was a solid grey mass.

Table 1 presents the results of the chromatographic analysis of liquid products of HPO pyrolysis by main groups of substances.

Table 1 Explanation of the chromatographic analysis of liquid products of HPO pyrolysis by main groups of substances

Peak	Area	Area %	Height	Height, %	Name
1	46946	2.35	40655	3.12	1-Propene, 2-methyl-
2	365703	18.29	359853	27.6	Pentane
3	32651	1.63	33947	2.6	2-Butene, 2-methyl-
4	28383	1.42	16183	1.24	2-Methyl-1-butene
5	67109	3.36	56923	4.37	Pentane, 2-methyl-
6	338720	16.94	284324	21.81	1 -Pentene, 2-methyl-
7	36348	1.82	32949	2.53	Hexane
8	44160	2.21	36995	2.84	Cyclopropane, 1,1,2-trimethyl-
9	16410	0.82	11797	0.9	Cyclopentane, methyl-
10	24168	1.21	17311	1.33	1,3-Pentadiene, 2-methyl-, (E)-
11	14903	0.75	11139	0.85	2,4-Hexadiene
12	36411	1.82	27419	2.1	1 -Pentene, 2,4-dimethyl-
13	17271	0.86	9742	0.75	Cyclopentene, 1-methyl-
14	45611	2.28	32679	2.51	2,4-Dimethyl 1,4-pentadiene
15	76531	3.83	44772	3.43	Benzene
16	38271	1.91	23978	1.84	1-Heptene
17	32100	1.61	19975	1.53	Heptane
18	37718	1.89	16449	1.26	1,3-Pentadiene, 2,4-dimethyl-
19	58207	2.91	24479	1.88	Heptane, 4-methyl-
20	578202	28.92	175813	13.48	2,4-Dimethyl-1 -heptene
21	40809	2.04	12554	0.96	Cyclohexane, 1,3,5-trimethyl-, (1 .alpha, 5 beta)-

The analysis of the results of Table 1 shows that the largest part of the liquid products of HPO pyrolysis is occupied by the pentane fraction, which accounts for about 18.3% wt., also a significant part of the products is made up of unsaturated hydrocarbons 2-methylpentene-2 and 2,4-dimethylheptene-1. Thus, the main part of plastic waste includes products of thermal destruction of polyethene, polypropylene and polyethylene terephthalate and they are mostly represented by unbranched alkanes and alkenes.

Conclusion

Thus, in the process of pyrolysis of a mixture of polymer waste, plastic waste decomposes into liquid and gaseous fractions with the release of a solid residue, the amount of which depends on the degree of contamination of the waste and the type of plastic. It has been established that the main part of plastic waste includes products of thermal destruction of polyethene, polypropylene and polyethylene terephthalate and they are 90-95% represented by unbranched alkanes and alkenes.

In general, the liquid fraction containing light and heavy hydrocarbons can be used to produce liquid fuels and wax, the latter being used, for example, in the manufacture of cables and capacitors. The solid residue can be used in construction as a good waterproofing agent; after mixing it with sand and crushed stone, obtaining a high-strength paving slab coating is possible.

One of the important areas of application of semi-liquid products of pyrolysis of plastic waste may be their use as raw materials followed by hydrodealkylation to obtain diesel fuel components with high cetane numbers and ultra-low sulfur and aromatic hydrocarbons content.

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None.

Conflicts of interest

Declare if any conflict of interest exists.

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