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Evaluation of the emission of petroleum products during the disposal of contaminated polyethylene cans

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Abstract. During the maintenance of private vehicles, a stream of consumer waste is generated in the form of containers with engine oil residues. When choosing methods for handling such waste, it is necessary to have quantitative indicators of the tare weight and the volume of engine oil remaining after use. Containers contaminated with motor oils during disposal, neutralization and disposal due to the emission of oil residues create increased risks of man-made impact on environmental objects. The purpose of the study is to determine the volume of motor oil remaining after emptying under various conditions. Viscosity, temperature, runoff angle of engine oil was taken into account as changing conditions. Laboratory studies made it possible to establish that when disposing containers made of HDPE (from 1 to 30 liters), in which engine oil was placed, the waste may contain from 1.5 to 15% of oil products. The smaller the tare volume, the higher the percentage of oil product residues in relation to the tare weight. It is proposed to use K_1 indicators to assess the emission of oil products from containers during its disposal, which allows quantifying the volume of engine oil that can enter the environment during disposal or disposal.

Keywords: ecology, oil products, motor oil, recycling, low pressure polyethylene, emissions

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Оценка эмиссии нефтепродуктов при утилизации загрязненной тары из полиэтилена

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Аннотация. При техническом обслуживании частных транспортных средств формируется поток отходов потребления в виде тары с остатками моторного масла. При выборе методов обращения с такими отходами необходимо иметь количественные показатели массы тары и объема моторного масла, остающегося после ее использования. Тара, загрязненная моторными маслами, при утилизации, обезвреживании и захоронении за счет эмиссии остатков нефтепродуктов создает повышенные риски техногенного воздействия на объекты окружающей среды. Цель исследования – установить объем моторного масла, остающийся после опорожнения тары, при различных условиях. В качестве изменяющихся условий были приняты во внимание вязкость, температура, угол стекания моторного масла. Лабораторные исследования позволили установить, что при утилизации тары из полиэтилена низкого давления (ПНД) (от 1 до 30 л), в которой размещалось моторное масло, в отходах может содержаться от 1,5 до 15 % нефтепродуктов. Чем меньше объем тары, тем выше процент остатков нефтепродуктов по отношению к массе тары. Предложено для оценки эмиссии нефтепродуктов из тары, при ее утилизации, использовать показатели K_1, позволяющие оценить количественно объем моторного масла, которое может поступить в окружающую среду при утилизации или захоронении.

Ключевые слова: экология, нефтепродукты, моторное масло, утилизация, полиэтилен низкого давления, эмиссия

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Introduction

For transportation and temporary storage of petroleum products used for private consumption, containers made of polymeric materials are used. Of the wide variety of petroleum products used for vehicle maintenance, motor oils can be distinguished. According to the research company Russian Automotive Market Research, motor oil consumption in Russia in 2023 will be 976 million liters, which will require more than 260 million plastic containers. For the production of packaging, high-density polyethylene (HDPE) is used. The commonly used container volume is from 1 to 30 liters. Containers contaminated with motor oils during neutralization and disposal increase risks of man-made environmental impact due to the release of oil residues [1–5]. Motor oils contain a large amount of chemicals having a significant impact on the environment. Motor oils are composed of liquid mixtures of isoparaffin, naphthenic, aromatic and naphthenoaromatic hydrocarbons; oxides and sulfates of Ba, Ca, Mg; heavy metal compounds; polyolefins, diesters; sulfonates; salicylates, etc.

The use of the HDPE waste material resource to obtain secondary granules and other products requires thorough cleaning of waste from various contaminants. The presence of oil products in waste increases the consumption of detergents by several times and forms a secondary waste stream in the form of sludge [6–11]. The developed technologies for using the material resource of consumption waste from HDPE, without preliminary purification, in order to obtain high-performance physical and mechanical characteristics, require quantifying the content of engine oil in the composition of the HDPE waste [12].

In order to assess the risk of possible release of petroleum products from containers into the environment, calculate the amount of detergents used in preparing containers for disposal, and establish the technological parameters of various methods of disposal that are sensitive to the content of engine oil, it is necessary to estimate the volume of engine oil remaining in the container after its use.

The purpose of the study is to establish the volume of engine oil remaining in the container under various conditions.

Materials and methods

To assess the volume of engine oil that can remain in the container after it has been emptied, containers made of HDPE with a capacity of 1, 4, 10, 20, 30 liters were used as objects for research (LLC “TARAPLASTIC” Moscow city). As oil

products, oils 80w-90, 15w-40 and 10w-40 (LLK-International LLC) most widely used in the technical service of vehicles and technological machines, were used. An HDPE sheet was used to determine the thickness of the oil layer. The experiment was carried out at a temperature of 20So and 40So, the oil flow angle was set to 60° and 90° to the horizon, thereby simulating filling from containers. The thickness of the oil layer (h), which is formed by flowing down an inclined surface, was determined by the calculation method based on the ratio $h = V/S$, where V is the volume of oil (the volume used was 0.5 ml), S is the area occupied by this volume running down an inclined surface. The kinematic viscosity of oils at temperatures of +20 °C and +40 °C was determined using a viscometer.

Results and discussion

The physical properties of engine oil and the temperature determine the volume that will remain in the container after it has been emptied. When in contact with the container material, engine oil forms a film, which is due to the lubricity (stickiness) of the engine oil, i.e. the ability to wet surfaces well and form strong adsorbed films on them. The viscosity of the engine oil, the ability to adsorb determine the thickness of the film that is formed on the surface of the container when it is emptied. The volume of engine oil will be determined by the internal area of the container.

Using the data of the container manufacturer, the surface area of the container was determined, see Table 1.

Table 1. **Characteristics of containers for engine oil**

Index	Tara				
Volume, liter	1	4	10	20	30
Length, mm	80	241	233	272	285
Width, mm	83	102	185	272	280
Height, mm	220	306	308	371	527
The area of the inner surface of the container, mm^2	$85 \cdot 10^3$	$259 \cdot 10^3$	$343 \cdot 10^3$	$552 \cdot 10^3$	$755 \cdot 10^3$
Weight of empty containers, gr	70	240	460	805	1100

From the calculation presented in Table 1, it can be concluded that when using containers of a smaller volume, a greater amount of waste is generated by weight, causing a higher level of technogenic load on the environment. The lower this indicator, the lower the energy and material costs for waste disposal.

The thickness of the oil layer (h) formed by flowing down an inclined surface was determined by the calculation method based on the ratio $h = V/S$, where V is the volume of oil (1 ml), S is the area occupied by this volume during flowing. Kinematic viscosity of oils at temperatures +20 °C and +40 °C was determined using a viscometer. The slope angles of the engine oil drain surface are selected in the range of 60–90 degrees (typical for draining from a container). The obtained data is presented in Table 2 and 3.

Table 2. **Estimated value of oil layer thickness at +40 °C, mm**

Oil	Kinematic viscosity, at +40 °C, (C_{st})	Tilt angle 60°	Tilt angle 90°
80w-90	144	0.090	0.072
15w-40	106	0.065	0.034
10w-40	79	0.045	0.022

Table 3. **Estimated value of oil layer thickness at +20 °C, mm**

Oil	Kinematic viscosity, at +40 °C, (C_{st})	Tilt angle 60°	Tilt angle 90°
80w-90	280	0.125	0.093
15w-40	168	0.095	0.055
10w-40	115	0.068	0.038

The thickness of the engine oil layer is influenced by the viscosity of the oil, which in turn depends on the temperature of the oil. Draining the engine oil from the container at a higher temperature reduces the layer of engine oil that is formed on the inside surface of the container.

Using the obtained area of the inner surface of the container (see Table 1) and the size of the layer that is formed under various conditions (see Tables 2 and 3), the estimated amount of engine oil remaining in the container after its emptying was determined. The calculation of the volume of oil remaining in the container at various temperatures is presented in Tables 4 and 5.

Table 4. **The volume of engine oil in the container after emptying at an angle of 60°, ml**

Oil		Tara, liter				
		1	4	10	20	30
80w-90	при +20 °C	10.6	32.4	42.9	69.0	94.4
	при +40 °C	7.7	23.3	30.8	49.7	67.9
15w-40	при +20 °C	8.1	24.6	32.6	52.4	71.7
	при +40 °C	5.5	16.8	22.3	35.9	49.1
10w-40	при +20 °C	5.8	17.6	23.3	37.5	51.3
	при +40 °C	3.8	11.7	15.4	24.8	34.0

Table 5. **The volume of engine oil in the container after emptying at an angle of 90°, ml**

Oil		Tara, liter				
		1	4	10	20	30
80w-90	при +20 °C	7.9	24.0	31.9	51.3	70.2
	при +40 °C	6.1	18.6	24.7	39.7	54.4
15w-40	при +20 °C	4.6	14.2	18.9	30.4	41.5
	при +40 °C	2.8	8.8	11.7	18.8	25.7
10w-40	при +20 °C	3.2	9.8	13.0	20.9	28.7
	при +40 °C	1.9	5.7	7.5	12.1	16.6

Using the obtained data, it is possible to estimate how much engine oil will enter the environment when the used containers are placed at the landfill. When using 1 container of 30 liters, from 94.4 ml to 16.6 ml of engine oil is released into the environment. Using 30 1 liter containers, from 318 ml to 57 ml of engine oil enters the environment resulting in 3.2–3.4 times higher technogenic load.

Using the above data on engine oil residues in containers, it is possible to calculate how much engine oil will go to the MSW landfill or disposal line per one ton of HDPE containers. The data is presented in Table 6.

Table 6. **The volume of engine oil in the container after emptying**

Index	Tara				
Volume, liter	1	4	10	20	30
Weight of empty containers, gr.	70	240	460	805	1100
Number of containers in 1000 kg, pcs	14285	4166	2174	1242	909
The volume of engine oil in containers after emptying at +20°C, at an angle of 60° (per 1000 kg of container), liter	151.4	133.3	93.3	85.7	85.8
The volume of engine oil in a container after emptying at +40°C, at an angle of 90° (per 1000 kg of container), liter	27.1	23.7	16.3	15.0	15.1
Percentage of engine oil residues in containers K_1, %	15.1–2.7	13.3–2.3	9.3–1.6	8.5–1.5	8.5–1.5

Analyzing the above data, we can conclude that when disposing HDPE containers upon usage of motor oil or other petroleum products, they can contain from 1.5 to 15% of petroleum products. It has been established that the smaller the container volume, the higher the percentage of oil product residues in relation to the container weight. This circumstance increases the material costs for the preparation of waste for recycling and requires separate collection of containers of small volume (up to 4 liters) and containers of a larger volume (more than 4 liters) or the development of a recycling technology that allows the use of the material resource of HDPE and engine oil in one technological process. To assess the release of petroleum products from containers during their disposal, it is proposed to use the indicator K1, which determines the amount of release of engine oil, coming with waste containers to the MSW landfill or to the line of preparation for disposal. Due to the fact that the content of engine oil residues in a container depends, to a large extent, on the viscosity of the oil, temperature, the angle of inclination of the runoff surface, the calculation of the *K*1 indicator must be made taking into account the above conditions for each type of engine oil. The general dependencies obtained for engine oil will be typical for other petroleum products.

In the course of the study, it was additionally found that crushed containers contaminated with motor oil, in prescribed quantities, can be successfully used for the production of organo-mineral mixtures used for road construction. Combined use of HDPE and engine oil in asphalt concrete, according to preliminary data, allows to increase the indicators of shear resistance, crack resistance, maintain the bending strength of asphalt concrete at low temperatures. Determining the optimal content of HDPE and motor oil in the composition of asphalt concrete requires additional research. This technology makes it possible to use waste containers contaminated with engine oil without prior cleaning. Due to this, a reduction in material and energy costs will be achieved, which, in general, will make it possible to create a resource-saving technology for the disposal of containers contaminated with engine oil.

Conclusion

The data obtained during the study led to the following conclusions:

1. The amount of oil products release from containers used for temporary storage and transportation of engine oil depends on its volume, ambient temperature, oil viscosity, runoff angle.

2. When disposing of used containers, it is necessary to take into account that depending on the volume of containers, the content of oil products can vary from 1.5 to 15% of the weight of the container being recycled.

3. It is proposed to assess the environmental performance of packaging, using the container indicator *K*1, which allows quantifying the volume of engine oil that can enter the environment during disposal. The quantitative index of the environmental friendliness of the container must be set individually, taking into account the conditions for emptying the container and the physical characteristics of the oil product.

4. The established amount of engine oil, for containers of various volumes, can serve as a guideline for choosing a method or technological processes for its disposal. With such a quite accurate assessment of the material flows generated during the disposal of HDPE containers contaminated with motor oil, it is possible to develop a recycling technology without preliminary cleaning of containers. Such technology can be the combined use of the material resource of HDPE and engine oil in the production of asphalt concrete mixtures.

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