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Research paper

Research on the Impact of Used Automobile Oil Filters on the Soil and Natural Air

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Abstract

The paper presents the results of studies of used automobile oil filters impact on the soil. The migratory properties of petroleum products, which are the used automobile oil part, are investigated in soil. The content of petroleum products and the damage from the placement of used automobile oil filters on the soil are defined.

Keywords: *soil, used automobile oil filter, petroleum products, motorization, engine oil, environment pollution.*

1. Introduction

Global motorization has led not only to natural air pollution by exhaust gases, but also to the formation of a large number of waste elements. In accordance to the existing legislation, most of them are hazardous waste and should be recovered.

Wastes produced during the recovering of motor vehicles are characterized by large heterogeneity in composition, all of them, when used improperly, cause significant damage to the environment. Today, the serious matter is the waste accumulation on the earth surface, as well as the environment pollution that arises during waste storing and piling. The intensive transport growth in Ukraine has led to the hazardous waste accumulation, in particular, used automobile oil filters. No less important reason for the rational handling of used filters is that they contain resource-intensive components, which undoubtedly should be used as secondary raw materials. In modern conditions, Ukraine is still one of the first in the world in terms of energy, water, mineral resources and other resources per GDP unit, while industrial waste per capita exceeds similar indicators in many countries.

The introduction of domestic recovering technologies is necessary. There is a need to compare them with already existing world experience, which would allow to make the maximum use of oil filters components without the environment damage. Recovering and reuse of the used filters components will reduce the natural resource consuming, the negative impact on the environment, as well as to obtain economic benefits from the recovering process implementation in the production [1]. The solution of these issues is relevant both in the territory of the Poltava region and in Ukraine in whole, since at the moment a significant amount of used oil filters are taken away to sanitary fill or uncontrolledly thrown by the owners, creating an ecological danger.

The main places for the occurrence of used oil filters are auto repair shops, as well as car operation enterprises. It is possible to monitor the amount of used filters formation and placement at enterprises, since the data on them are fixed in permits for the waste formation and placement. Accordingly, waste owners pay for the produced waste. However, car owners often replace the oil filter by hand, and throw the used filter together with the waste oil in the garbage. Therefore, a significant part of filters comes to solid waste landfills, unauthorized waste deposits in wood lines, territories near private garage consumer cooperatives, etc.

Automobile oil filters in automobiles serve to clean the oil from harmful impurities, which significantly affect the wear acceleration of engine parts. In the engine operation process, the oil quality becomes worse, and the amount and concentration of pollutants increase significantly. In each used automobile oil filter contains from 200 to 500 grams of used automobile oil. As a result, a great deal of waste oil comes to the environment.

Motor oil is a mixture of high molecular weight petroleum hydrocarbons, which is used to reduce friction between moving surfaces in piston internal combustion engines [2]. Spent lubricants are complex multicomponent systems that are produced during the operation of vehicles. They include: the lubricant basis and additives, the decomposition products of the basic components and additives, as well as foreign impurities. In waste motor oil, more than 140 types of carcinogenic polycyclic hydrocarbons have been identified. The number of these compounds increases as the oil life increases [3].

Therefore, the main component we study is the petroleum product –mixtures of hydrocarbons, their derivatives, as well as other chemicals and additives which are the oil distillation result. Gasoline and mazut, oils and all sorts of lubricants, cooling liquids and solvents are extracted from oil.

Used automobile oil, as waste is classified as hazard class 3 and, when entering the environment, contaminates the soil, surface and groundwater. The dirty soil restoration is the most difficult thing, because it is able to accumulate and fix harmful and toxic substances, its natural recovery is a very slow process. At a high level of pollution there is almost a complete absence of the flora and fauna functional activity, the soil self-cleaning ability.

Synthetic and semisynthetic oil is of particular danger. Therefore, the utilization and recycling problem of automobile oil filters is currently very important.

Waste oils may contain:

- heavy metals (barium, chromium, zinc, etc.);
- wear products;
- residues of additives;
- combustion products (polycyclic aromatic hydrocarbons);
- base oil dehydrated chemicals.

Absolutely all of the above-mentioned substances are very harmful to the environment and the human body. When penetrated in soil or groundwater, waste oil can have a toxic effect on humans and animals [4].

Petroleum products are one of the most widespread and dangerous technology-related pollutants, due to the hydrocarbon ability to form toxic compounds in soils, surface and groundwater. Petroleum products differ considerably in their properties - volatility, viscosity, solubility in water, ability to be absorbed in porous materials (soil).

In soils impregnated with oil, the structure dispergation develops, water permeability decreases, oxygen is displaced, biochemical and microbiological processes are violated, the carbon - nitrogen ratio increases, and the content of the phosphorus and potassium mobile forms decreases. As a result, the water, air and nutrient conditions deteriorate, root nutrition of plants is disturbed, and their growth and development are. deccelarated which causes death. The gradual increase in the concentration of petroleum products on the soil surface, combined with the evaporation and decomposition processes of their volatile fractions, leads to the accumulation of hardly decomposed hydrocarbons, such as solid paraffins, cyclic and aromatic hydrocarbons, resins and asphaltenes that seal the soil pores [5].

Based on the above, the impact study of used automobile oil filters on the environment by identifying the migration properties of petroleum products that are part of the used motor oil and the damage extent from their placement on the soil is essential. The separate collection and disposal issue, with the subsequent removal of resource-intensive components of this waste is an ecological and economic component of economic activity for our country.

2. Main body

When entering the soil, the oil products interpenetrate in the surface. They are absorbed at the expense of capillary forces and can be kept in such a state for a long time, completely depriving the soil of fertility, turning it into a saturated oil sponge. The oil transformation into more toxic compounds that can be adsorbed and accumulated there, is also possible. Contaminated soil can become a source of toxic substances for the human body by trophic chains: soil - plant - food, soil - groundwater - man, soil – natural air - a person that increases the risk of ecologically determined diseases [6].

During the infiltration of petroleum products in the ground there are the violations of its water-air regime, the soil structure changes, the toxic substance transfer, the transformation of the soil carbon-nitrogen balance and migration capabilities of individual trace elements [7]. Due to the high content of petroleum products, the soil may become completely waterproof, airtight and, therefore, temporarily loses fertility [8].

In addition, in soils contaminated with hydrocarbons, we can observe the enhanced reproduction of microorganisms - nitrogen fixing, denitrifying and sulphate reducing bacteria, which use oil as a source of energy and carbon. It leads to mineralization and partial oil oxidation. However, the intensive growth of microorganisms, actively absorbs soluble compounds, greatly impoverishes the soil with nitrogen and phosphorus compounds, which in future may play a limiting factor role in the development of plant groups [9].

Thus, we can conclude that the negative oil impact on the soil is manifested in the following:

- deterioration of the soil nitrogen regime of the;
- violation of the soil filtration regime;
- disturbance of root nutrition of plants;
- migration of toxic substances inside the soil layer.

As consequence, there is a natural soil fertility loss, that results to the rejection of areas from agricultural use.

A plot of 1.86 m^2 was prepared for the experiment. The vegetation layer was removed, but the roots remained for the sake of observing whether the vegetation could sprout in such conditions, 17 used oil filters with a hole down were placed. Engine oil residues contained in the filter came to the investigated area and under the influence of natural conditions penetrated into the soil.

After a while, there were clear spots of waste oil on the soil surface. The vegetation that sprouted between the filters is thin, yellow and almost immediately dried up and completely disappeared.

Studies on the content of petroleum products in the soil have been conducted after a time, due to the penetration of used automobile oil in it. The most available in our case is a method of measuring the mass fraction of petroleum products (non-polar hydrocarbons) by gravimetric method, which is based on the petroleum products extraction from the sample, the extract purification from polar substances, the extractant removal by evaporation and weighing the residue [10].

The results of measurements of the petroleum products mass fraction in baseline samples and contaminated soil samples are calculated and summarized in Table 1.

Table 1: Results of measurement of the mass fraction of petroleum products in contaminated soil

	Baseline sample		Contaminated soil sample	
Number of the cup	1	2	3	4
Weight of the empty cup, g	62,6808	59,3610	54,0594	56,1624
Weight of the cup on load, g	62,6833	59,3640	54,0780	56,1818
Load weight, mg	2,0	2,5	18,1	18,9
Mass fraction of petroleum products, mg/kg	100	125	905	945
Average value, mg / kg	112,5		925,0	
Measurement error, %	± 36 %		± 14,6 %	

As a laboratory study result, a mass fraction of petroleum products contained in the soil, which is 925.0 mg / kg, was determined. This value is 8 times greater than the mass fraction of petroleum products in the baseline sample.

The maximum permissible concentration (MPC) of petroleum products in soils is not established in any country of the world, since it depends on many factors: type, composition and properties of soils, climatic conditions, composition of petroleum products, vegetation, etc. Therefore, the norms of the petroleum products content in soils are developed specifically for each case in accordance with the nature of regional environment pollution, the territory industrialization degree, its physical and geographical location [11]

At present, specialists do not have approved methods for determining the content of oil and its transformation products, norms of permissible content of oil and petroleum products for different types of soils [12]. Some experts propose to accept the following gradation degrees of soil contamination by oil and oil products: uncontaminated soils - up to 1.5 g / kg; mild contamination- from 1.5 to 5.0 g / kg; average contamination - from 5.0 to 13.0 g / kg; acute pollution - from 13.0 to 25.0 g / kg; very acute pollution - more than 25.0 g / kg. It is believed that mild contamination can be eliminated in the process of soil self-purification in the next 2-3 years, the average - within 4-5 years. The beginning of serious environmental losses is the soil pollution by oil in concentrations exceeding 13 g / kg, since at these concentrations the migration of petroleum products to groundwater begins, the ecological balance in the soil biocenosis is significantly disturbed. Recently, Ukraini-

an scientists have proposed methods for quantifying the soil pollution level with petroleum products and categorizing them according to an integral indicator of the pollution intensity, which helps to assess their pollution risk [13].

According to this method, the content of petroleum products in soils is regulated by the sanitary condition nomenclature, that is, they are not classified as priority environmental pollutants that are capable of sustainable accumulation. The content of petroleum products in soils is regulated by the temporarily permissible concentration (TPC), TPCn= 4000 mg / kg. The soil pollution level by petroleum products is determined by the degree of their TPC excess (Table 2).

Table 2: Indicators of soil contamination by petroleum products, mg / kg

Pollution level	Oil and petroleum products
The first (admissible)	< TPC
The second(mild)	1000–2000
The third(average)	2 000–3 000
The forth(acute)	3 000–5 000
The fifth (very acute)	> 5 000

Taking into account that the aforementioned mass fraction of petroleum products in the soil was 925 mg / kg - almost the second (mild) contamination level, we have such results in a short period of time, namely 6 months. Due to the rather small amount of used automobile oil filters installed on the study site, the results are impressive.

The predominance of certain processes of petroleum products transformation, migration and accumulation to a large extent depends on the climatic conditions and the properties of the soils in which these pollutants enter. It was established that petroleum products that penetrated in the soil, fall into the soil vertically under the gravity influence [14]. At the same time, they propagate in a horizontal plane, penetrating into the pores between the soil particles.

The rate of oil impregnation depends on its properties, the soil nature, as well as the quantitative ratios of oil, air and water Soils contaminated with oil and oil products include soils where the concentration of pollutants affects the soil system ecological balance; leads to changes in morphological, physico-chemical and chemical characteristics of soil horizons and soil water-physical properties; violates the relationship between the individual fractions of the soil organic matter. The permissible concentration level of oil and petroleum products in soils will vary depending on the soil-climatic zone, type of soil, composition and properties of oil and petroleum products. On average, the lower limit of pollutant concentrations in contaminated soil varies from 0.1 to 1.0 g / kg [15].

The vertical migration of petroleum hydrocarbons depends on three main factors: the pollutant properties (density, viscosity), environmental conditions (temperature) and soil properties. Among the latter, the decisive values are humidity, density and granulometric composition. In dry soil, the migration processes practically do not depend on its density in the range from 1.0-1.4 g / cm3, but cease in moist compacted soils. Soils have a certain oil capacity, and the danger of hydrocarbon vertical migration becomes real, starting at a load of about 10 l / m2 and the physical sand content in the soil more than 50%.

The main processes that determine the migration of hydrocarbons, is the sorption and the soil permeability. The oil filtration rate in soils depends to a great extent on moisture: in dry soils, filtration develops much more slowly than in the wet ones.

The study of the migratory properties of petroleum products shows that it is necessary to examine their penetration in the horizontal plane and into the soil depths. The long-term interaction of used automobile oil filters with the environment, as a result of atmospheric factors, leads to the casing destruction. Therefore, there is a constant decomposition process of its dangerous components and the oil leakage in the environment.

The investigation of oil products penetration into the horizontal plane has been carried out. The results of measurements of the petroleum products mass fraction are summarized in Table 3.

Table 3: Results of measurement of the mass fraction of petroleum products in the horizontal plane

	1 sample		2 sample		3 sample	
Number of the cup	1	2	3	4	5	6
Weight of the empty cup, g	83,800	79,165	78,597	77,375	58,778	59,360
Weight of the cup on load, g	83,802	79,167	78,599	77,376	58,780	59,362
Load weight, mg	1,5	1,4	17,	1,4	1,5	1,6
Mass fraction of petroleum products, mg/kg	75	70	85	70	75	80
Average value, mg / kg	72,5		77,5		77,5	
Measurement error, %	± 45 %		± 44 %		± 44 %	

The obtained data allow us to conclude that distribution of petroleum products in a horizontal plane develops uniformly.

Investigation of petroleum products penetration into the soil showed the following results (Table 4).

Table 4: Results of the petroleum products mass fraction measurement into the soil depth

	Sample on depth of 5 cm		Sample on depth of 15 cm		Sample on depth of 25 cm	
Number of the cup	1	2	3	4	5	6
Weight of the empty cup, g	63,853	66,371	67,196	66,327	58,315	56,526
Weight of the cup on load, g	63,857	66,374	67,199	66,330	58,316	56,527
Load weight, mg	2,8	2,8	1,9	2,3	0,8	0,9
Mass fraction of petroleum products, mg/kg	140	140	95	115	40	45
Average value, mg / kg	140		105		42,5	
Measurement error, %	± 30,5 %		± 38 %		± 53 %	

We see that with increasing depth there is a decrease in the mass fraction of petroleum products, but quite significant penetration develops.

In recent years, snow cover is increasingly used as a monitoring object, as an atmospheric pollution integral indicator in areas which are characterized by the stable snow cover for a long time. Snow acts as a natural concentrator of airborne pollutants. The content of pollutants in it is 2-3 times higher in comparison with natural air [16], which allows to determine their concentration by relatively simple methods with a high degree of reliability.

By the spring migration cycle, pollutants are preserved in the snow cover. During the spring flood, these substances enter the natural environment, contaminating it. Consequently, a chemical analysis of the snow will allow predicting the composition of future migrants in various natural landscapes. Snow as an object of monitoring is irreplaceable in determining the pollution sources, as well as in determining the area of influence of these pollutants.

According to standard methods for determining the pollutants in the atmosphere, sampling of snow is carried out at the beginning of its melting, roughly in late March - early April. The obtained results of the melt water chemical composition characterize the total content of pollutants in the snow cover accumulated during the winter season. Undoubtedly, the process study of chemicals accumulation during the winter months is of great interest.

This study purpose was to examine the accumulation of petroleum products that evaporate into the atmosphere in the snow cover. The snow cover sampling was carried out using regulatory documents [17-18].

The snow cover sampling was carried out during the period of its maximum accumulation, shortly before the period of snow melt (end of February - March 2016), by the method of "envelope" (samples are taken with snow collectors of a chemically stable polymeric material), herewith debris from the surface (leaves, branches etc.) are removed, the presence of soil particles is excluded.

From selected samples a collective sample, weighing not less than 2 kg, is placed in a container of chemically stable polymer material (for example, in a plastic bag) and is marked.

The petroleum products content is determined by the weight method, which consists in the multiple extraction of petroleum products from water with chloroform and in their next chromatographic separation from all other impurities. The results of measurements and calculations are summarized in Table 5.

Table 5: The content of petroleum products in the snow cover

	The content of petroleum products, mg/dm^3
Baseline sample (conditionally clean snow)	0,078
Snow sample at a height of 50 cm above the contamination source	0,088
Snow sample at a height of 5 cm above the contamination source	1,559

The artificial soil contamination by used automotbile oil filters showed a negative impact on vegetation, and laboratory studies determined the mass fraction of petroleum products in the soil, which was 925 mg / kg, indicating a significant pollution level.

Over time, the concentration of used motor oil is reduced due to the petroleum products migration properties, as is evidenced by the petroleum products mass fraction at depth of 15 and 25 cm, and the study of the pollutants accumulation in the snow cover showed a background concentration excess even at an elevation of 50 cm above the pollution source.

The negative impact of used oil filters on the environment has been determined and confirmed. It demonstrates an environmental hazard high level in case of such waste misuse. Therefore, it is necessary to collect and utilize them.

The damage extent from the placement of used automobile oil filters on the ground is determined in accordance with the Order "On Approval of the Methodology for Determining the Extent of Pollution and Land Resources Littering Damage due to Violations of Environmental Law" [19] by the formula:

$$P_ш = A \cdot Г_{оз} \cdot П_д \cdot K_з \cdot K_н \cdot K_{ег} \quad (1)$$

If the pollutant content is determined by the instrumental and laboratory control results, Kz is determined by the formula (2):

$$K_з = (C_{зр} \cdot Г_п)/(T_{зш} \cdot I_п \cdot K_{роз}) \quad (2)$$

After determining all the necessary indicators we have the following values (table 6):

Table 6: Indicators for calculating the extent of damage from land contamination

Indicators	Indicator symbol	Indicator value
Contaminated site area, m^2	$П_д$	1,86
Depth of pollutant impregnation, m	$Г_п$	0,1
Pollutant		Petroleum products (nonpolar hydrocarbonic)
Relative pollutant density, t / m^3	$Щ_{зр}$	0,73
Pollutant concentration (mass fraction) according to the instrumental and laboratory control results, mg / kg	$C_{зр}$	925,0
Dimensional unit for calculating the earth pollution factor, m	$T_{зш}$	0,2
Cost Charge Index	$I_п$	0,1
Estimated coefficient, mg / kg	$K_{роз}$	1000000
Specific costs for the elimination of the pollution consequences.	A	0,5
Normative monetary land plot value (indexed), UAH / m2	$Г_{оз}$	2,8543×0,95 = 2,712
Land contamination coefficient	$K_з$	1,0
Pollutant danger coefficient	$K_н$	4
Coefficient of ecological and economic value of lands	$K_{ег}$	1

So, the extent of the damage from the experimental site contamination is:

$P_ш = 0,5 \cdot 2,712 \cdot 1,86 \cdot 1 \cdot 4 \cdot 1 = 10,09$ грн.

According to the traffic police administration of the MIA of Ukraine in Poltava, as of 01.01.2018, 58534 units of motor vehicles belonging to individuals were registered. The analysis of the conditions for the use of passenger cars by individuals showed that 57% of these cars are over 15 years old, about 50% are operated by regular owners at non-daily use, and the remaining 50% of cars are operated by the same owners daily with an average mileage of 100 km. After 5 years of operation cars are usually sold to other owners and are in operation until 15 years with an average annual mileage of about 15 thousand kilometers. Replacement of the 5-wheel tire kit is carried out, on average, 1 time every 4 years, replacement of the battery - 1 time for 3-4 years, used automobile oil filter - 2 times a year. Therefore, we have about 117068 used automobile oil filters annually [20].

If they are put into a single layer of 1 filter height, and with a notional volume of 0,001 m3, which one filter occupies, then every year it is necessary to allocate a plot with an area of 117.07 m^2 plot, accordingly the damage extent will be:

$P_ш = 0,5 \cdot 2,712 \cdot 117,07 \cdot 1 \cdot 4 \cdot 1 = 934,99$ UAH.

And if we make calculations for all Ukraine [19], we have the following:

$P_ш = 0,5 \cdot 2,712 \cdot 17135,62 \cdot 1 \cdot 4 \cdot 1 = 92943,6$ UAH.

The part of used motor oils includes other dangerous substances, which, at further calculations, can increase the damage extent by a factor of dozens or even hundreds.

Investigation of oil products penetration in the horizontal plane, to the deep into the soil and the use of snow cover as an integral indicator of atmospheric pollution made it possible to determine the pollution degree and the extent of damage from the placement of used automobile oil filters on the soil.

The artificially created soil contamination by used automobile oil filters showed a negative impact on vegetation, and laboratory studies determined the mass fraction of petroleum products contained in the soil. Over time, the concentration of waste engine oil is reduced due to the migration properties of petroleum

products, and the accumulation of pollutants in the snow cover above the pollution source shows a background concentration excess.

3. Conclusions

The increase in the number of motor transport in Ukraine requires the scrappage sphere development of both motor vehicles and their separate elements removed from operation, including all types of filters. The introduction of a comprehensive approach to the problem of used automobile oil filters utilization is a necessary environmental safety component in the country.

An important scientific-practical task is investigated - the influence of used automobile oil filters on the soil. Oil and petroleum products are among the most dangerous and technogenic pollutants, due to the ability of hydrocarbons to form toxic compounds in soils, surface and underground waters.

Based on the calculations, the dangerous influence of used automobile oil filters, and especially their constituents, on all environmental media has been confirmed. Therefore, there is a need to immediately resolve the problem of handling such a kind of waste, in order to improve the environment state. The most efficient way to handle used automobile oil filters is to collect, reprocess and reuse, since the filter contains a significant amount of valuable raw materials that can be restored and reused in the production process. It is also necessary to introduce effective ways to use spent filters as a resource-intensive waste, which in turn will reduce the use of natural resources and energy sources.

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