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Resource Saving and Eco-Friendly Technology for Disposal of Used Railroad Engine Oils

Yuliia Zelenko[1], Maryna Bezovska[1], Valeriy Kuznetsov[2], Antonina Muntian[1]*

[1]Dnipro National University of Railway Transport named after Academician V. Lazaryan, Ukraine

[2]Railway Institute, Warsaw, Poland

[*]corresponding author's e-mail: vkuznetsov@ikolej.pl

1. Introduction

Waste generation is a significant problem for many sectors of the national economy of Ukraine, in particular for rail transport. The wastes featuring significant amounts are the oil-contaminated ones, among which it is necessary to single out the used engine oils of the engines of traction rolling stock of diesel-electric locomotives and diesel trains.

The waste oils after being discarded today are most often used without regeneration as heating and boiler fuel directly at railway enterprises or transferred for further use or regeneration to other enterprises. For example, waste oils can be used to lubricate forms at ferroconcrete products and construction plants as well as for other purposes instead of the corresponding fresh petroleum products (Chervinskiy et al. 2015, 2016, Pyza et al. 2018, Jacyna et al. 2018, Liu et al. 2019, Ashtiani et al. 2019).

For purification (regeneration) of used oils, most often there are used the simplest physical methods, such as settling, filtration and centrifugation. For settling one uses steel vertical and horizontal oil tanks. Such tanks are manufactured at factories and get on site in the finished form. These tanks are designed for an internal pressure of 0.07 MPa, with a tapered or flat bottom; they are installed above the ground on supports or underground at a depth of not more than 1.2 m from the ground level. In addition to the tanks the railways use different types of containers.

Clarification of oils here takes a sufficiently long period (from a few to six months); the obtained product, after being checked for its compliance with the quality standards, can be reused for the same needs as a fresh one, but its useful life is much less because of the rapid loss by oil of its main operational parameters. Yet this method is the most widespread in the railway enterprises because it does not require large investments, specially trained personnel and high running costs.

Filters and centrifuges are used for fine clarification of used engine diesel oils. The main drawback of filters is their impossibility of removing water from oil. This problem can be solved with the help of separators.

However, all of the above methods only give a slight effect, clarifying the oil, but not removing the main aging products from it.

To obtain a better effect, a combination of different methods with the use of special additives must be applied to make the product complying with DSTU standards by all parameters. Only in this case can we talk about obtaining a completely restored product.

Thus, the simplest methods used today for the recovery of waste oils on the railways do not give a full effect; therefore, it is more rational to use the latest developments that will quickly pay off and give a significant ecological and economic effect.

2. Materials and methods

We have developed and proposed a scheme for the recovery of waste oils of the brand M-14B_2. It is more environmentally friendly unlike the most common and still used scheme of cleaning with sulphuric acid. As the sulfuric acid substituent – alkylbenzene sulfonic acid (ABSA) is a substance of hazard class 3 and sulfuric acid belongs to hazard class 2. In addition, the purified product yield in this scheme is more than 90% while the product yield in case of the sulfate acid purification is about 60%.

The general scheme includes heating the waste oil, mixing it with ABSA and SAS Neonol, centrifuging and doping to bring all of the operational parameters of the oil to the standards specified in the technical specifications and standards. The schematic representation of the regeneration process is shown in Figure 1 (Zelenko & Bezovska 2013, Zelenko et al. 2013). It is worth noting that it was the new combination of reagents that gave a positive result in the course of laboratory studies that made the further development of the scheme possible.

It is proposed to pump the waste oils from the diesel locomotive to the special balance tank and after settling to the first-stage mixer. Next, the oil is heated to the desired temperature in the mixer, then from the special containers there is added the required amount of reagents: ABSA and subsequently neonol. After mixing, the mass is fed through pipeline to the centrifuge and then to the second-stage mixer. Besides, a dosing pump supplies an additive to the same mixer, and the mixing process is in progress.

Subsequently, the finished oil is pumped to a special storage tank or directly into an oil tank car for light petroleum products. If necessary, it is possible to transport the prepared oil to other users by rail or tank-vehicles. Also, the scheme provides for a sludge collecting container for discharging by-products from the first-stage mixer and centrifuge; these products are subsequently processed in a mixture with the process sludge of the enterprise.

As a tank for storing finished products, we propose to use the horizontal tank-cisterns, which are most often used as ready-storage tanks.

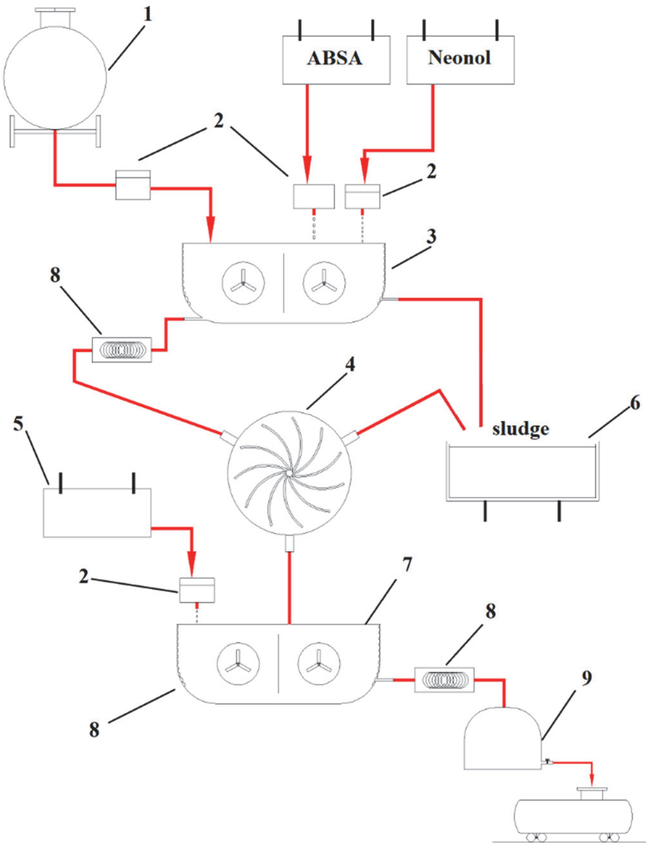

Fig. 1. Scheme for treatment of discarded waste oil; 1 – balance tank, 2 – dosing pumps, 3 – first-stage mixer with heating, 4 – centrifuge, 5 – additive storage tank, 6 – sludge collector, 7 – second-stage mixer, 8 – pumps, 9 – storage tank for restored oil

The main parameters monitored by us at all stages of the research were as follows:

- contamination, (τ cm^{-1}) – determines the degree of oil contamination by various impurities and is an indicator by which diesel oils are most often discarded at railway enterprises,
- pH – determines corrosive aggressiveness of oils,
- open flash point, °C – characterizes the presence of lightly boiling fractions in oils, in particular a significant deviation of this indicator from the norm indicates that the oil is diluted by fuel,
- viscosity at 100°C, mm^2/s – the most important indicator that determines starting and operation characteristics of machines,
- base number, mg KOH/g – an indicator that reflects the ability of oils to neutralize corrosive and aggressive products that are usually formed during its operation,
- water content, % – the appearance of this component contributes to the formation of low-temperature deposits, which impair the functioning of the diesel locomotive system, in particular filtration and subsequent feeding to the surfaces of friction.

3. Results and discussion

Below there are Figures 2-6, which show the main parameters of used and recovered oils compared with the discarding indicators and TU standards (except for water that was absent at all stages of the research). All data were obtained during experimental research at the university laboratory. Also the results were further confirmed at the depot’s chemical engineering laboratory, where the rejected oil was received for testing.

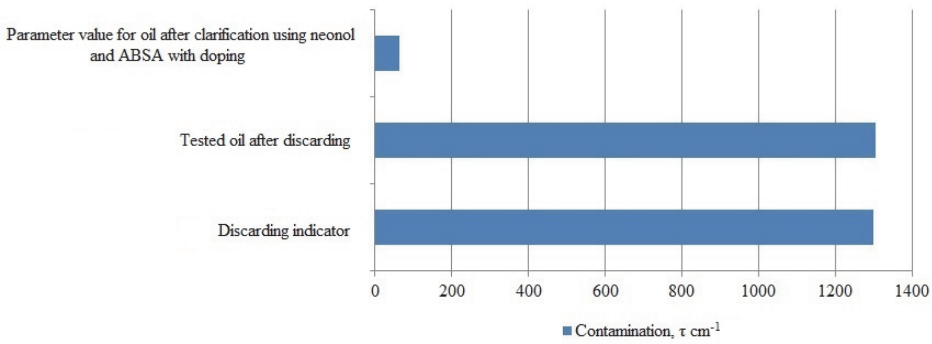

Fig. 2. Contamination

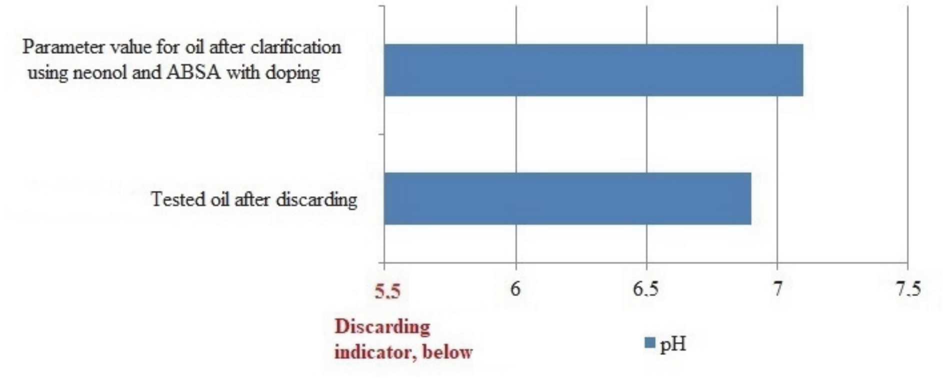

Fig. 3. pH

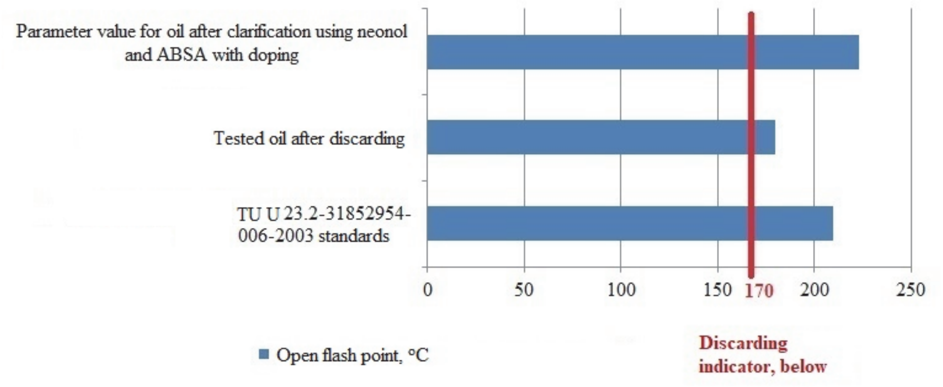

Fig. 4. Open flash point

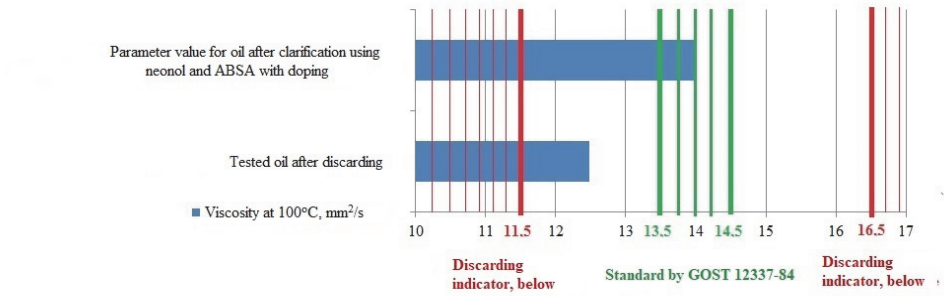

Fig. 5. Viscosity

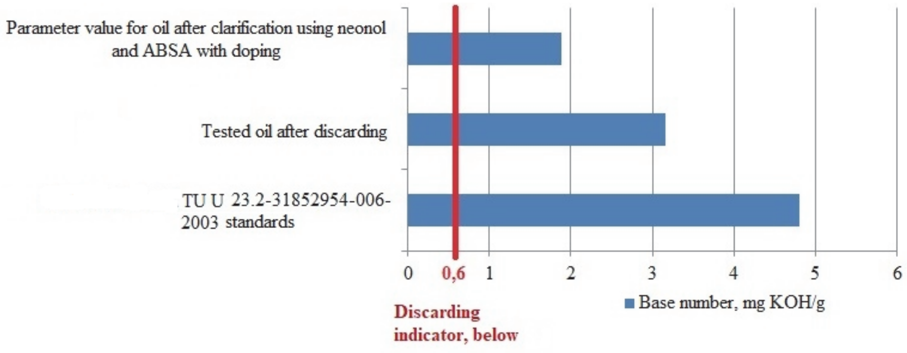

Fig. 6. Base number

We propose two options of implementation of the technological scheme: the first – to obtain small amounts of oil, which will accumulate in a special storage tank in the territory of line units of the railways for their internal needs; the second – for obtaining significant amounts of recovered oil at large oil regeneration stations serving a great number of enterprises. The calculation will be made on the basis of a greater amount of neonol to obtain universal-sized equipment, i.e. 2.7% by weight.

It should be noted that this scheme can also include the processing of oil-containing sludge, which will be processed together with sludge formed after oil purification. In particular, we recommend that these wastes be separated by means of surface-active substances into three fractions – water, hydrocarbons and solid residues; herewith the first two components can be used in production. Thus, the introduction of such a process scheme will solve the problem of utilization of main railway oil waste and the following environmental problems of Railways:

Implementation of this scheme solves the following environmental problems of railways:

- minimization of the amount of used oils – the main waste by volume from the locomotive facilities,
- there is a return of valuable raw materials (oils) to the technological process in the form of recovered engine oil and washing liquid for diesel locomotive systems,
- the amount of oil sludge will be significantly reduced,
- recovered oils and washing liquids do not have the degree of toxicity as that of the used oils, and therefore do not pose a threat to the environment.

When developing the general scheme for restoring the operational quality of the used engine oils, we proceeded from the results of the performed laboratory tests on different purification methods and an optimized variant of the chosen technology, namely, the temperature conditions, the number of reagents and the time of their contact with the oil.

Comparing the main operating parameters of the recovered M-14B_2 oil after using the scheme with neonol and ABSA and the methods proposed by different manufacturers, we can see that the parameters of oil recovered under the proposed scheme are not worse, and in some cases even exceed the parameters of existing plants. In particular, the kinematic viscosity of the oils after clarification in existing plants is up to 13 mm^2/s at 100°C (based on the published data of the oil-purifying equipment developers), while after using our technology it is 14 mm^2/s.

Considerable attention was also paid to the ecologo-toxicological side of this issue. After all, used petroleum products are toxic waste, which have a low biodegradation degree (10-30%). The toxicity of petroleum products is determined by the combination of hydrocarbons that are part of their composition. In particular, arenes are the strongest carcinogens in the composition of petroleum products, and olefins, sulphur compounds, nitrogen and oxygen also have a significant toxic effect. The used petroleum products have particularly negative effects on human central nervous and cardiovascular system, endocrine system, reduce haematological parameters, cause damage to the liver and thyroid gland (Davydova & Tagasov 2002, Evdokimov 2010, Fuks et al. 2004, Markisova et al. 2013, Miao Yu 2012, Ryabtsev 2010, Stan et al. 2018).

Excessive damage is caused by petroleum products on the environment and especially on water resources. Thus, according to experts, one litre of waste oil can pollute about seven million litres of groundwater.

It should be noted that the main compounds that form the negative toxicological profile of oily waste (including waste oils) are benz(α)pyrene, furans, dioxins, polychlorinated biphenyls, and others. The main recommendation of the international community for the composition of oils from this point of view is the absence of heavy metals and chlorinated compounds in them. That is why we checked the fresh, used and recovered M-14B_2 oils according to the proposed scheme for the content of benz(α)pyrene, heavy metals (lead, nickel, cuprum, cobalt, chromium, zinc) and chloride ions.

4. Conclusion

Based on the results obtained, we propose to apply the developed scheme of cleaning the M-14B_2 oil. At the laboratory the following advantages of the scheme were confirmed: the purification efficiency – more than 95% and the maximum yield of the purified oil – 90%. After the recovery process, such oil can be recommended for reuse directly at the establishment where it was formed.

After comparing the environmental indicators of fresh, discarded and recovered oils M-14B_2 we found that chloride ions are absent at all stages; also, when working with the oils of both brands there appears a benz(α)pyrene, which completely disappears from the oils after processing them according to the proposed schemes; a significant reduction in the amount of toxic elements (lead by 82.61%, nickel by 84.62%, copper by 85.29%, zinc by 87.50%) after the treatment of oils according to the proposed schemes confirms the safety of recovered oils and the ecological compatibility of the schemes (Zelenko & Bezovska 2019, Zelenko et al. 2014, 2016).

It should be noted that the presence of heavy metals in waste oils says not only about their environmental hazard, but also indicates the unsatisfactory operation of diesels, because according to the recommendations of the Organisation for Cooperation between Railways (Recommendations) after exceeding certain concentrations of metals in oils, it can be concluded that diesel is in an emergency condition and needs repairing.

After conducting technical and economic assessment of the process scheme components, calculations of fees for waste placement, ecological and economic efficiency of the proposed environmental measures, we determined the magnitude of the conditional environmental effect, which was more than 70 thousand UAH with an accumulation of about 30 tons of waste oil per year (the case of one railroad linear unit). According to our calculations, on condition of annual savings of 300 thousand UAH on average for the purchase of new oil, this scheme will have a positive effect already in 4 years and 11 months after the introduction.

Thus, the implementation of the proposed scheme will return valuable raw materials (oil) to the process cycle, will create almost non-waste production of recovered oils, as well as promote the creation of a non-waste production-territorial complex on the basis of the linear unit of the railway, which will give an opportunity to obtain significant economic effect.

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Abstract

The article deals with the problems of handling used motor oils on the railways of Ukraine. At the moment, this waste is transferred to other enterprises for disposal. But, based on international experience, it is advisable to be regenerated directly at the enterprise where it is formed. The purpose of this work is to develop a modern scheme for oil waste disposal. In this regard, various indicators were investigated, reflecting both the operational suitability of oils and their toxicological parameters. As a result, we proposed a scheme and selected special equipment for handling the used engine oils, which allows to reduce the technogenic load associated with their accumulation, handling and minimization, contributes to the return of oil to the technological process. The calculated value of the conditional environmental effect and the approximate payback period allowed us to draw conclusions about the undoubted environmental and economic effect of implementing the proposed scheme.

Keywords:
waste, engine oils, railway enterprises, restoration, treatment scheme