Study of Treatment Efficiency of Wastewater Collected from the Surface of Roads by Natural Zeolite

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Abstract. One of the main tasks of raising the technical level of highways, safety and environmental performance is timely and targeted collection and removal of water from the surface of roads and subsequent cleaning of pollution. In modern technologies of water purification processes of water filtering and filtering materials occupy the dominant position. The progressive environmental degradation of water bodies requires constant updating of filter elements, which include higher technological and environmental requirements. The new generation of modern filter materials include zeolites. In order to use the sorbents for the removal of oil, they are to be hydrophobic and, at the same time, absorbing oil well. As a result of comparative evaluation of sorption purification of waste water from the surface of roads, using zeolite and gravel mixture there was determined the efficiency of using alternative materials. The introduction of new methods of treatment using natural zeolites solves the problem of raising the technical level of highways, traffic safety and environmental performance.

1. Introduction

One of the main tasks of raising the technical level of highways, safety and environmental performance is timely and targeted collection and removal of water from the surface of roads and subsequent cleaning of pollution.

If there are regulations available on the design of roads, grounding of the purpose of flowsheets for removal and cleaning of the runoff from roads is not paid due attention [1].

The system of surface water drainage from the road consists of several buildings and planning activities intended for interception and diversion of water from the road. The system includes: planning of the roadway and roadsides, culverts, side, interception and other ditches.

The issues concerning the application of sewage treatment plants need to be addressed on the basis of a set of indicators of construction conditions, and the selected drainage system, reliability of connection of treatment plants with it and the efficiency of functioning of both the drainage and water treatment structures [2].
Given the factors that influence the formation of surface waste water, nature and degree of contamination of mineral and organic components of various origins, the priority indexes that one should be guided with in choosing the technological scheme of runoff treatment collected from roads, necessary and sufficient are such composite indexes of water quality as the content of suspended solids and oil products. More viscous oil products adsorb on the adsorbent surface much more effectively compared with the lighter ones [3].

The specific polluting components in the composition of runoff from roads that have to be removed during the cleaning process (such as detergents, salt of heavy metals, nutrients) are, as a rule, the result of man-made pollution or poor sanitary condition of the surface watershed. They should therefore be included in the list of priority indexes only according to the field research after studying the reasons that precondition their presence.

Concentrations of contaminants in the surface runoff collected from roads, that are disposed to treatment plants or into the water bodies, are recommended to be taken according to field and laboratory investigations. However, determination of average values of indexes is performed by means of statistical processing of data of chemical analysis, assuming normal (or log-normal) distribution of random changes in quality of the water.

Diversion of the runoff from roads into water bodies should be in accordance with the regulations, as well as the specific conditions of its formation: sporadic atmospheric precipitation, intensity of snowmelt, abrupt changes in the cost and concentration of waste.

Typical solutions for organization of drainage, which represent strictly regulated uniform structures and sizes of both road edge and angle shoots for all types of roads and conditions of use do not meet the requirements of regulatory support of transport and operational performance of modern multi-speed roads [4].

In modern technologies of water purification processes of water filtering and filtering materials occupy the dominant position. The progressive environmental degradation of water bodies requires constant updating of filter elements, which include higher technological and environmental requirements. The new generation of modern filter materials include zeolites. In order to use the sorbents for the removal of oil, they are to be hydrophobic and, at the same time, absorbing oil well [5].

2. The use of zeolites for cleaning the surface run-off

The use of zeolites for cleaning the surface runoff is regulated by technical specifications TU 14.5-00292540.001-2001.

The urgency of solving problems related to improving the efficiency of wastewater treatment on the areas adjacent to roads determines the topicality of the subject [6].

The objective of the work is comparative evaluation of the effectiveness of adsorption treatment of surface wastewater from oil using zeolite and gravel.

Experimental studies were conducted in the laboratory, using model surface waste water - oil emulsions (OP). Model surface wastewater was prepared by emulsification of diesel fuel in distilled water while stirring with a mechanical stirrer (3 thousand rpm) during 6-7 minutes. In the model wastewater they created the concentration of OP, typical for rain washouts on highways that are formed during the first 10-20 minutes of the rain (10.5 mm of rainfall), when the concentration of pollutants has the highest value, and the runoff from rain should be subjected to purification in full.

Effectiveness of adsorption purification from OP was examined, using 5 options of adsorbents. As adsorbents for cleaning the model runoff they used 4 zeolite fractions (≤1, 1-3, 3-5, ≥5 mm) and gravel mixture (3-5 mm), which is used in the known method of processing washouts from roads.

100 cm³ of resultant emulsion of OP was placed in conical flasks of 250 cm³ in volume, and then 10 g of sorbent of one option was placed in each flask (each option was repeated 2 times). The mixture was stirred for a given time period, using a shuttel apparatus, then filtered through a paper filter "White Ribbon", in the filtrate there were discovered residual amounts of OP. The cleaning effect was calculated, using the following formula:

\[ E = \frac{(C_{\text{init}} - C_{\text{fin}})}{C_{\text{init}}} \times 100, \]  

(1)
where $E$ - efficiency of cleaning, %; $C_{fin}$ - concentration of OP in the water after cleaning; $C_{init}$ - concentration of NP in the water before cleaning.

The concentration of OP was determined by the gravimetric method using the procedures recommended by current regulations. The gravimetric method is based on extraction of OP from water by chloroform, evaporation and removing the solvent, dissolving the residue in hexane, separation of polar compounds on a column with aluminum oxide, removing the solvent and gravimetric measurement of the residue mass [6].

OP concentrations in wastewater in the dynamics of treatment by different sorbents is shown in figure 1.

![Figure 1](image)

**Figure 1.** Effect of duration of adsorption treatment of waste water for OP content in the surface wastewater.

Apparently, the dynamics of OP content while processing using gravel mixture is described by the linear dependence, while the dynamics of OP content in wastewater while processing using zeolite is more complex. The speed of cleaning increases with decreasing of zeolite fractions size, which is characteristic for sorption methods of treatment (table 1).

**Table 1.** Speed of surface wastewater cleaning from OP in the dynamics of processing.

| Adsorbent, fraction | Speed of OP removal (mg/g·hour) during the duration of treatment, min. |
|---------------------|------------------------------------------------------------------------|
|                     | 10                                                                     |
|                     | 30 (within the interval of 10-30 min. of treatment)                    |
| Zeolite:            |                                                                        |
| ≤ 1 mm              | 12,5                                                                   |
| 1-3 mm              | 7,8                                                                    |
| 3-5 mm              | 4,7                                                                    |
| ≥5 mm               | 3,7                                                                    |
| Gravel mixture      |                                                                        |
| 3-5 mm              | 0,7                                                                    |


The highest rate of treatment (12.5 mg/m·h) is determined for the smallest fraction of zeolite (≤1 mm) during the first 10 minutes of processing. It is possible that the rate of OP removal by this fraction used to be higher, and the complete removal of OP was reached before the first sampling - 10 min. In the dynamics of processing the speed of OP removal by zeolites of all fractions was steadily decreasing, which is typical for the sorption mechanism of cleaning and the rate of OP removal by gravel mixture in 30 minutes time even slightly increased compared with the first 10 minutes.

The dependence of the rate of OP removal within the first 10 minutes of wastewater contact with zeolites upon the fraction size of zeolites is shown in figure 2.

![Figure 2. The dependence of the rate of OP removal within the first 10 minutes of wastewater contact with zeolite upon the zeolite fraction size.](image)

The dependence of the effect of sewage treatment by various sorbents upon the duration of treatment is shown in figure 3.

![Figure 3. Dependence of the effect of sewage treatment by different sorbents upon the duration of treatment.](image)
Apparently, for zeolites the dependence of cleaning effect is described by typical absorption curves: the dependence of the first order transforms into the dependences of zero order. For zeolite fractions of 2-3 mm in size they conducted more detailed studies of the effectiveness of OP removal in the dynamics of processing (figure 4).

The data obtained confirmed the adsorption mechanism of OP removal [7, 8].

![Figure 4. Effectiveness of OP removal in the dynamics of processing for zeolite fractions of 2-3 mm in size.](image)

3. Conclusions
As a result of comparative evaluation of sorption purification of waste water from the surface of roads, using zeolite and gravel mixture there was determined the efficiency of using alternative materials. The introduction of new methods of treatment using natural zeolites solves the problem of raising the technical level of highways, traffic safety and environmental performance [9, 10].

4. References
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