Purification of Sewage Contaminated by Oil Products Using Mesoporous Coal

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Abstract. The sorption properties of mesoporous coals (pore size of ~ 4 nm, the specific surface area of 25 to 150 m²/g) of Georgian hard coal deposit have been studied and the efficacy of their usage for the treatment of sewage water polluted by oil products has been established. Purification rate depends on coal mass loaded in filter, grain size, initial concentration of oil products, the water acidity, etc.

1. Introduction
At present, protection of the environment from waters contaminated by oil and oil-processing numerous products is one of the main tasks. To purify these waters, different methods have been used – from mechanical to biological. The easiest and most effective is leaking filtration in adsorbent layer. Any porous material can be used as adsorbent, among them are coals.

2. Research
The percolating filtration in the adsorbent layer is the most common and efficient method for purification of the sewage, contaminated by the oil products. Any porous material, including coals, may be used as an adsorbent. In the course of the study of Tkibuli- Shaori deposit coal (Georgia), as a gas collector, it has been established that it is characterized by a developed system of mesopores (transient, capillary) and by a high adsorptivity with regards to the gases. These properties have provoked the presented investigations, in particular, the study of their sorption ability regarding the oil products and for preparation of a low-cost adsorbent for sewage purification [1,2].

The study of the sorption properties of the coal, crushed and classified by coarseness (-5+3,-3+2mm; -2+1mm) regarding to the oil products has shown that the class of (-2+1) mm is more active, which has a larger specific surface.

The degree of the purification of oil emulsion containing water is twofold greater at the material of (-3+2) mm size than in the case of the coal of (-5+3) mm coalescence. The following factors affect the purification degree: height of the coal layer, filtration rate, initial concentration of the products and medium temperature [3].

The adsorbent, obtained from Tkibuli Coals, is low in price, the destruction of oil products is not necessary, it may be utilized as a fuel and does not serve as the source of secondary contamination in contrast to the filters of other inert materials. Its use may be profitable for small and medium industrial entities, such as automobile service centres, transport agencies, petrol filling stations, petroleum storage depots of small volume, in which the daily flow rate of sewage is low, but they are characterized by the sewage contaminated by the oil products in large quantities [4].
3. Results and Discussions
The sample for research was taken from the layer of the deposit, which is formed by the following coals: semi-glittering Clarain and Durain-Clarain, with a middle layers of semi dull Clarain-Durain. The structure of these coals is a Clarain tape, the main mass is uniform. Individual elements are kept quite well. Their characteristics are given in Table 1.

Table 1. The Main Characteristics of Coal as Adsorbent

| Ash concentration, [%] | Mass share of volatile substances, [%] | Porosity, [%] | Pores volume, [cm³/g] | Pores radius, Å |
|------------------------|---------------------------------------|-------------|---------------------|-----------------|
| 24.65                  | 35.09                                 | 12.09       | 0.056               | 2.5÷300, 400    |

To identify the possibility of usage of coal as a filter, the experiments have been carried out on emulsified oil-containing waters (waste waters of one auto repair enterprise), feeding of which occurred on a coal layer loaded in adsorbent column from top to bottom. To select the optimal conditions for waste waters’ purification, different factors of influence on waters’ purification quality have been studied, namely grain sizes of loading filter, thickness of the coal layer and filtration velocity, variability of oil product’s initial concentration, medium pH and temperature. The results of the purification of the oil product from contaminated waters by up to 5 mm granulated and classified coal on the same velocity layer are shown in Table 2.

Table 2. Influence of Coal Size on the quality of waste water purification

| Coal size, [mm] | Filtration velocity, [l/min] | Mass share of oil products, mg/l | Purification quality, [%] |
|----------------|-----------------------------|-----------------------------------|--------------------------|
| -5+3           | 2.01                        | Before purification: 264          | After purification: 154  |
| -3+2           | 1.2                         |                                    | 65                       |
| -2+1           | 0.55264                     |                                    | 32                       |

According to the data of Table 2, the most active class is -2+1 mm, then class -3+2 mm, and -5+3 mm that is natural – more coal grinding quality means more space of its surface, and accordingly – more adhesive and adsorption ability towards the oil. To identify other parameters of purification, the experiments have been conducted on last two classes of coal. Dependence of the quality of waste waters’ purification from emulsified oils on coal layer height and filtration velocity is shown in Figure 1 and Figure 2.

In the experiments, diapason of coal layer’s height variability is 0.5 – 1 m, and filtration velocity is 0.5 – 10 m/min.

According to the charts (Figure 1 and 2), the higher the coal layer height, the lower the waste waters filtration velocity and the higher the water purification quality. The optimal values of these parameters are: layer thickness 0.9 – 1 m and filtration velocity < 0.5 m/h.

Depending on the thickness of the coal layer the degree of the purification of emulsified oil-containing water varies from 34% to 98-99%. At the height less than 0.75 mm, the oil concentration in water is still high and above this value the initial concentration of the contaminant gas has negligible effect on the purification degree.
Medium pH and temperature also have an effect on the purification characteristics (Tables 3, 4).

**Table 3. Medium pH influence on waters purification quality**

| No. | pH  | Initial concentration of oil product, [mg/l] | Residual concentration of oil product, [mg/l] | Water purification quality [%] |
|-----|-----|---------------------------------------------|-----------------------------------------------|--------------------------------|
| 1   | 3.0 | 823                                         | 80.1                                          | 90.27                          |
| 2   | 5.0 | 823                                         | 56.1                                          | 93.18                          |
| 3   | 8.7 | 823                                         | 67.0                                          | 91.86                          |

Comment: - water under purification contaminated with oil emulsion had pH 8.7.

From three discussed cases, the best result is received in regard to pH5. It seems that slight acidity causes the coagulation of contaminative substances (oil drops coalescence) that improves purification
quality. Waste water temperature in °C; initial concentration of the oil product in mg/l; residual concentration of oil product in mg/l; water purification quality in percentage. The Table data show that the reduction of temperature increases adsorption of oil products on coal grains’ surface. Water purification quality increases from 93.20 % (20 °C) to 96.96 % (5 °C), and residual concentration of oil products decreases 2, 3 times. Water is better purified in the conditions of the temperature less than 5°C.

Table 4. Temperature influence on water purification quality

| No | Waste water temperature [°C] | Initial concentration of oil product, [mg/l] | Residual concentration of oil product, [mg/l] | Water purification quality, [%] |
|----|-------------------------------|---------------------------------------------|---------------------------------------------|------------------------------|
| 1  | 5                             | 677                                         | 20.6                                        | 96.96                        |
| 2  | 15                            | 677                                         | 35.6                                        | 94.74                        |
| 3  | 20                            | 677                                         | 46.196                                      | 93.20                        |

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Thus, on Tkibuli coals, the optimal parameters of oil product-containing waters’ purification are: the size of coal filter grains -2 +1 mm, coal layer height of 0.9 – 1.0 m, filtration velocity - 0, 5 m/h, medium temperature < 20°C. The purification results of different concentration -contaminated waste waters conducted the in the mentioned above conditions are shown in Table 5.

The possible constructional execution of the sewage purification from the oil products at coal is the following: column–adsorber by water feeding from the sewage collector or pressure filter. But for every specific case of contamination, the optimal rate of the filter and height of loaded coal layer must be selected. Coal consumption depends on the quality of waters’ contamination.

Table 5. The results of purification of emulsified oils-contaminated waters

| Height of coal loading, [m] | Duration of filter operation, [min] | Concentration of oil-emulsion waste water, [mg/l] | Purification quality, [%] |
|---------------------------|-----------------------------------|-----------------------------------------------|------------------------|
|                           |                                   | Influent waste water | Purified waste water   |                        |
| 0.5                       | 30                                | 201                                        | 29.0                   | 83                     |
| 0.75                      | 60                                | 201                                        | 11.3                   | 94                     |
| 1.0                       | 90                                | 201                                        | 4.8                    | 97                     |
| 0.5                       | 30                                | 41                                         | 18                     | 56                     |
| 0.75                      | 60                                | 41                                         | 3.4                    | 91                     |
| 1.0                       | 90                                | 41                                         | 0.3                    | 99                     |
| 0.5                       | 30                                | 28                                         | 12                     | 57                     |
| 0.75                      | 60                                | 28                                         | 5.0                    | 82                     |
| 1.0                       | 90                                | 28                                         | 0.3                    | 98                     |

4. Conclusions
In optimal conditions (sorbent grain size -2 +1 mm, height of the coal layer 0.9-1.0 m, filtration rate of 20-25 cm/min) the purification rate of oil polluted water ranges from 91 to 99% depending on the oil
initial concentration. Oil mass fraction in treated water is equal to its maximum allowable concentration (0.3 mg/l), [5].

"Mesoporous" coal is a cheap sorbent and does not require regeneration. Its utilization as a fuel is not a problem.

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