Treatment and disposal of surface wastewater and Sludge

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Abstract. The main sources of surface wastewater pollution are products of soil washout, destruction of asphalt and so on. Surface wastewater pollutes water bodies with suspended, surface-active substances, oil products, organic impurities, heavy metal ions and other pollutants. Precipitation leads to pollution and siltation of watercourse channels, disrupts the vital activity of living organisms, microorganisms, and has a negative effect on the biocenosis and self-cleaning ability of water bodies. The aim of the study was to develop a technology for treating surface wastewater from coal industry enterprises using a new water filtering facility, a clarifier reactor. The composition of the enterprise’s surface wastewater was studied. A draft of a new wastewater treatment plant and a clarifier reactor were developed. The quality of the treated water corresponded to the requirements. As a result of theoretical and experimental studies, a technology for the storm sewage treatment of industrial enterprises was developed, which allows them to be dumped into open water bodies or used for disposal in industrial water supply enterprises.

1. Introduction
Rain and melt water are discharged from the territories of enterprises as a result of intense precipitation and snowmelt. Therefore, surface wastewater contaminated with suspended solids, oil products and other impurities enters water bodies, which adversely affects the ecosystem of water bodies. The pollution of surface wastewater with oil products is typical and the most dangerous for water bodies, as a rule, they are sorbed on suspended solids.

There is a problem of organizing surface wastewater disposal systems, which are in poor condition, since they have practically not developed at industrial enterprises. Rain and melt water occur on the territory of industrial enterprises, which complicates the movement of vehicles, causes flooding of buildings, and this leads to the equipment damage and the destruction of building structures. Also, insufficiently fast and incomplete diversion of surface water leads to the level of groundwater increase, premature deterioration of the road surface and deterioration of a site’s sanitary condition. Flooding of the territories leads to disastrous consequences with an unfavorable terrain [1-4].

Along with the problems of the surface runoff diversion, there is the problem of its purification. Storm water treatment facilities are technically imperfect and do not provide the required quality of treatment, sufficient for discharge of wastewater into water bodies or use in technical water supply at most industrial enterprises.

Pollution, introduced into water bodies by surface wastewater, has a significant impact on their sanitary conditions. The most adverse effect is exerted by suspended solids and petroleum products. At high concentrations of suspended solids, they partially precipitate in the section of surface wastewater discharge and downstream. This leads to siltation of the reservoirs and interferes with the normal
course of biological processes at the reservoir’s bottom. The organic part of dissolved solids is gradually oxidized by oxygen dissolved in water. Floating petroleum products, coming from highways, leads to the formation of an oil film on water bodies’ surface and a decrease in the amount of dissolved oxygen, which has a detrimental effect on the aquatic organisms’ lives.

The heavy residues of oil products settling in reservoirs decompose and pollute water with decay products. Some of them are carried to the surface in the form of gas bubbles, forming an oil slick [5]. Prolonged exposure to small concentrations of petroleum products is of particular danger, since the hydrocarbons in their composition can dissolve other pollutants.

Melt water contains dissolved chemicals of anti-icing materials (which include reagents containing sodium chloride, ferrous cyanide, calcium and magnesium salts, etc.), which impact nature on the environment has not been studied in detail yet [6,7].

As a result, that ensuring organized drainage and the required treatment of surface wastewater can be concluded an important task. Even up to 10% of dissolved organic and mineral pollutants remain in wastewater that has gone through all stages of treatment, including biological one. Suitable for using as drinking water, it becomes after repeated dilution with pure natural water. Contaminated surface wastewater introduction into the aquatic environment leads to a decrease in its productivity as a habitat, making it impossible for humans, to use it for domestic, agricultural and industrial processes.

Depending on the requirements, surface wastewater treatment methods are used, based on physical, chemical and physico-chemical processes occurring in treatment plants, or natural biological self-cleaning processes in soil or water bodies.

Precipitation process is probabilistic. At the same time, rainfall is characterized by extreme unsteadiness, both in terms of costs and polluting components, which concentration varies over the widest range during one rain. Therefore, the most important issue of surface wastewater treatment technology is the flow rate averaging and composition of wastewater before being sent for treatment. In this regard, treatment facilities for surface wastewater include facilities for controlling flow and averaging the composition of effluents, as an obligatory element.

In this regard, this research work aimed at studying of surface wastewater quality, development of wastewater management facilities for flow and concentration, as well as their effective treatment, is relevant and timely.

The aim of the study was to develop a technology for treating surface wastewater of coal industry enterprises using a new filter plant - a clarifier reactor.

2. Mathematical and Methods
In order to achieve this goal, the following tasks were solved:

- a qualitative composition analysis of surface wastewater;
- conducting experimental studies on the treatment of surface runoff;
- development of facilities and technologies for surface wastewater treatment.

Experimental studies were carried out in the production conditions of Novosibirsk coal plant. The experimental setup was a model of treatment facilities for storm and melt wastewater of the enterprise. We used natural surface wastewater coming in during the rain period from the on-site storm sewer. The experimental setup is shown in Figure 1.

The installation’s work was carried out as follows: storm water from a well of a storm network was pumped through a pipeline (1) to a storage tank, simulating a storm water storage tank (2). The water temperature was 10–12 °C. Along with the wastewater supply, a solution of aluminum oxychloride with an optimal dose of 10 mg / L was introduced into the sumps. The optimal dose was previously determined by trial coagulation according to standard methods [2]. The water was sedimented under mild conditions for 60–90 minutes. After settling, the hydroxide precipitate was discharged through a pipe (17) and examined for moisture and impurities content. The volume of sediment was up to 10% of the treated water volume. With the help of a booster pump (3) the clarified water from the tank was
piped (4) to a constant-level tank (5), and then with a dosed flow rate to a clarifier reactor (CR) (6) filled with quartz sand. The size of the sand was 0.4–0.8 mm, the loading height was 1 m.

Then clarified water came to a pressure-free quick filter (7) by gravity with a grain size of 1–2 mm from a crushed burnt rock. Then the water came to the charcoal filter (8) with activated carbon loading of the AG-3 grade with 1–2.5 mm grain size. The purified water was discharged through a pipe (9) into the domestic sewage system. An ejection washing of the clarifier reactor load and ordinary water washing of the quick and coal filters were performed after the protective action time of CR weighted contact load expired and the quality of the clarified water deteriorated below the established sanitary limit of 3 mg/l in terms of suspended matter content.

The installation's work was carried out as follows: storm water was pumped through a pipe 1 to a storage tank from a well of a storm network, which simulated a storm water storage tank - 2. Water temperature was 10-12 °. Solution of aluminum oxychloride with an optimal dose of 10 mg/L was introduced into the sumps along with the supply of wastewater. The optimal dose was previously determined by trial coagulation according to standard methods [2].

The experimental water sedimentation took place under mild conditions for 60-90 minutes. After sedimentation, the hydroxide precipitate was discharged through pipe 17 and examined for moisture and impurity content. The volume of sediment was up to 10% of the treated water volume. The clarified water from the sump was piped 4 to a constant-level tank 5 with the help of a booster pump 3, and then with a dosed flow rate to the clarifier reactor (CR) 6 loaded with quartz sand. The sand size was 0.4-0.8 mm; the loading height was 1 m.

Then, the clarified water came to a pressureless quick filter 7 by gravity with loading from crushed burned rock with a grain size of 1-2 mm. Then the water came to the charcoal filter 8 with a load of activated carbon of AG-3 brand with 1 -2.5 mm grain size. The purified water was discharged through a pipe 9 into the domestic sewage system. The ejector washing of the clarifier reactor load and the usual water washing of the quick and charcoal filters were carried out by the content of suspended solids after the protective action time of CR weighted contact load expired and the clarified water quality deteriorated below the established sanitary limit of 3 mg/L.

The clarifier reactor is a fundamentally new facility for pre-treatment of wastewater by filtration according to the operation and design principle (Figure 2).
Figure 2. Scheme of the clarifier reactor.

The principle of the CR operation is based on upward filtration of water through 10% layer of fine-grained loading expanded.

The clarifier reactor operates as follows. Raw water treated with the coagulant is supplied to the air separator 15 through the water supply pipe for treating 3. Flocculant solution is introduced through the pipeline 16, if it is necessary, depending on the quality of the water to be clarified. Water enters the lower part of the housing 1 through a vertical lowering pipe 17. It is evenly distributed over the treating zone area of the device with a distribution cap system 18 and is filtered from bottom to top through the loading layer 2 at a speed that ensures it’s weighing.

Quartz sand or any other fine-grained material that meets the requirements for mechanical strength and chemical resistance is used as contact load 2. In the suspended advanced loading layer, sediment is retained and accumulated.

Part of the sediment flakes is removed from the layer, but is retained by the thin-layer module 12, slides down the inclined walls of its rings and settles on the contact load surface. The result is a high effect of water treatment, increases the performance of the device.

The clarified water is collected by the chute 4 and is discharged by a pipe 5 from the reactor. The contact charge is ejected by means of a water ejector 8 and a water-air ejector 14 after the protective action time of the extended contact charge expires and the quality of the clarified water deteriorates. The supply of source water does not stop for the washing period (10-15 min.), and all water is discharged for treatment to reuse. It contributes to the washing process and reduces its duration. Water-sand pulp is effectively washed during its tangential movement in the separator 13.

The washed grains of the contact charge are deposited in the suspended layer, and the precipitate is discharged with the used wash water through the collecting chute 4 and pipeline 6. The contact load removal into the collecting chute is prevented by a thin-layer module 12. Pulp is discharged from it through the pipe 11, if it is necessary to replace contact weighed load or emptying the device for water treatment.

A large specific surface area of fine-grained loading grains from burnt rocks, CR productivity and the dirt capacity of its filter loading are increased due to the elimination of stagnant zones in the places of grain contact.

The operating filtration rates on CR exceed the recommended BR water filtration rates on quick filters up to 1.5 times. In this case, the contact coagulation process takes place in RO charge, due to the upward filtration of water; therefore, the reagent doses are reduced by up to 50%, compared to fast filters. In the clarifier reactor, an ejection washing of the contaminated charge with the initial water is
provided, which allows achieving an effective washing of its entire volume without the formation of water impurities agglomerates and grains of the lower supporting layers characteristic of contact clarifiers. Ejection flushing allows you to reduce the flow of clean water for flushing more than 2 times compared with flushing quick filters and contact clarifiers.

Thus, CR combines the advantages of granular filters and clarifiers with suspended sediment, has high performance, reliable operation and low operational cost [8].

3. Results
Storm water samples were taken from the end point of the on-site rain network of the Novosibirsk coal plant in order to determine the qualitative composition of the enterprise’s surface wastewater. The average values of wastewater quality indicators for the autumn research period are presented in table 1.

| N  | Indicators         | Units       | MAC    | Result  |
|----|--------------------|-------------|--------|---------|
| 1  | Oil products       | mg / dm³    | 0.05   | 0.382   |
| 2  | Suspended matter   | mg / dm³    | 10     | 110.67  |
| 3  | Hydrogen indicator | pH          | 6.0-9.0| 7.5-8.0 |
| 4  | Ammonium ion       | mg / dm³    | 0.5    | 1.25    |
| 5  | Total nitrogen     | mg / dm³    | 0.4    | 1.5     |
| 7  | Phenol             | mg / dm³    | 0.001  | 0.006   |
| 8  | Iron               | mg / dm³    | 0.1    | 0.51    |
| 9  | Aluminum           | mg / dm³    | 0.04   | 0.89    |
| 10 | Copper             | mg / dm³    | 0.001  | 0.002   |
| 12 | Zinc               | mg / dm³    | 0.01   | 0.014   |
| 13 | Nickel             | mg / dm³    | 0.01   | <0.001  |
| 14 | Chromium           | mg / dm³    | 0.07   | <0.001  |
| 15 | Cadmium            | mg / dm³    | 0.005  | <0.0001 |

Table 1. Surface Wastewater Quality Analysis.
In order to determine the effectiveness of the purification technological scheme (Figure 1), samples were taken during the tests at the following points: a well of a storm network, after a sedimentation tank, after a clarifier reactor, after emergency and charcoal filters. The operational efficiency analysis of the technological scheme was evaluated by the content of petroleum products, suspended solids, iron and phenols. The results of experimental studies are summarized in table 2.

| Indicators                     | Source water | After outcome of the sump | After the clarifier reactor | After the quick filter | After carbon filter |
|--------------------------------|--------------|---------------------------|-----------------------------|------------------------|---------------------|
| Oil products, mg               | 0.382        | 0.362                     | 0.137                       | 0.062                  | 0.01                |
| Suspended matter, mg / dm³     | 110.67       | 45.75                     | 2.9                         | 2.5                    | 1.5                 |
| Iron, mg / dm³                 | 0.51         | 0.098                     | 0.05                        | 0.05                   | 0.05                |
| Phenol, mg / dm³               | 0.006        | 0.0126                    | 0.0123                      | 0.0123                 | 0.001               |

Table 2. Analysis of Treated Surface Wastewater.
The purified water quality met the MPC (Table 1).
Based on the studies, a surface water treatment technology has been developed (Figure 3).
The technological scheme includes sump regulators with integrated grilles and sand traps. Coagulant is introduced into the source water before sedimentation tanks. The settled wastewater is pumped to the clarifier reactors through mixer-air separators after non-flowing sedimentation for one hour. Flocculant solution is introduced into the pipeline in front of the mixers. Aluminum hydroxide flakes and water impurities, sorbed on them, are retained in the contact extended loading of CR. Then the water flows into the quick filters, if necessary, it undergoes sorption treatment on filters loaded with granular activated carbon, and is disinfected with UV radiation.

The quality of treated storm water allows it to be dumped into open water bodies or used for the needs of recycled technical water supply.

Flushing of the clarifier reactor and filters is carried out by daily cleaning of the washing water supplied by the washing pump from one section of the wash water sump and dumping it into another section. The wash water is reused after reagent treatment. Wash water is replenished by discharging the first filtrate from the filters.

The resulting precipitation of storm and wash water is dehydrated and taken out for disposal for the production of building products [9, 10].

4. Conclusion
The results of experimental studies proved the possibility of treating surface wastewater from industrial areas according to the proposed technology to a quality that allows them to be dumped into open water bodies or reused in the enterprise’s technical water supply. A technology for the treatment of surface wastewater from coal industry enterprises using a new filter plant - a clarifier reactor was developed. The sludge is disposed in the building products manufacturing [11-16]. At the same time, along with solving the environmental protection tasks, a directed regulation of the concrete mixtures’ properties and the building products manufacturing with desired properties are carried out.

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