Characteristic Properties of Surface Run-off and Its Disposal from Railway Transport Enterprises

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Abstract. This paper focuses on railway transport enterprises and their classification. It outlines the number of railway stations of the Kuibyshev railway (KZhD) located in various regions of this country. The classification takes into account the region where these railway stations are located, the number of tracks at every particular station, and its land area. The article provides data on the surveyed railway transport enterprises and information on surface wastewater generated on their territory. The researchers analyze surface run-off from various railway industry enterprises, this wastewater composition and the dependence of contamination of surface wastewater discharged by different railway industry enterprises on the form and composition of their watersheds. They come up with recommendations for criteria of surface wastewater disposal from the territories of railway transport enterprises and railway tracks, as well as proposals for the treatment of surface run-off from the enterprises under consideration.

1. Introduction
There are 769 railway stations on the Kuibyshev railway (KZhD), the number of tracks located at these stations varies from 1 to 24, the length of the stations varies from 200 m for small-scale stations up to 4000 m for major station junctions. Besides, every 500 m railway tracks cross watercourses.

2. Research basis
According to their land area, all railway stations of OJSC Russian Railways "KZhD" can be divided into five groups (see Tables 1 & 2). Thus, the researchers examined several similar enterprises that are typical representatives of each group of the railway industry. These enterprises were used for the preparation of initial data and design of surface water treatment facilities from the territory of railway stations, bridge crossings and railway transport facilities [1-8].
Table 1. Classification of KZhD railway stations by regions and republics of their location.

| №   | Name                           | Number of stations, units | Number of tracks, units | Area, m²   | Annual run-off volume, m³/year | Run-off discharge, l/sec |
|------|--------------------------------|---------------------------|-------------------------|-----------|-------------------------------|--------------------------|
|      | Ryazan Region                  |                           |                         |           |                               |                          |
| 1    | Small-scale stations           | 6                         | 1-2                     | 3 000-10 000 | 536-1787                      | 1.87-6.25                |
| 2    | Small stations                 | 3                         | 3-4                     | 10 000-50 000 | 1787-10340                     | 6.25-31.25               |
| 3    | Middle-scale stations          | 1                         | 5-7                     | 50 000-100 000 | 10340-20790                     | 31.25-62.5               |
| 4    | Major stations                 | 1                         | 8-10                    | 100 000-500 000 | 20790-103400                    | 62.5-312.5               |
| 5    | Large stations                 | -                         | More than 10           | from 500 000 to 1 000 000     | 1034009-178750           | 312.5-625                |
| 6    | Railway tracks and watercourses crossings | 103            | 2                      | 300-3 000 | 53.6 – 536                      | 0.18-1.87                |
|      | Tambov Region                  |                           |                         |           |                               |                          |
| 1    | Small-scale stations           | 7                         | 1-2                     | 3 000-10 000 | 536-1787                      | 1.87-6.25                |
| 2    | Small stations                 | 3                         | 3-4                     | 10 000-50 000 | 1787-10340                     | 6.25-31.25               |
| 3    | Middle-scale stations          | 1                         | 5-7                     | 50 000-100 000 | 10340-20790                     | 31.25-62.5               |
| 4    | Major stations                 | 1                         | 8-10                    | 100 000-500 000 | 20790-103400                    | 62.5-312.5               |
| 5    | Large stations                 | -                         | More than 10           | from 500 000 to 1 000 000     | 1034009-178750           | 312.5-625                |
| 6    | Railway tracks and watercourses crossings | 108            | 2                      | 300-3 000 | 53.6 – 536                      | 0.18-1.87                |
|      | Republic of Mordovia           |                           |                         |           |                               |                          |
| 1    | Small-scale stations           | 35                        | 1-2                     | 3 000-10 000 | 536-1787                      | 1.87-6.25                |
| 2    | Small stations                 | 14                        | 3-4                     | 10 000-50 000 | 1787-10340                     | 6.25-31.25               |
| 3    | Middle-scale stations          | 7                         | 5-7                     | 50 000-100 000 | 10340-20790                     | 31.25-62.5               |
| 4    | Major stations                 | 4                         | 8-10                    | 100 000-500 000 | 20790-103400                    | 62.5-312.5               |
| 5    | Large stations                 | 2                         | More than 10           | from 500 000 to 1 000 000     | 1034009-178750           | 312.5-625                |
| 6    | Railway tracks and watercourses crossings | 244            | 2                      | 300-3 000 | 53.6 – 536                      | 0.18-1.87                |
|      | Penza region                   |                           |                         |           |                               |                          |
| 1    | Small-scale stations           | 71                        | 1-2                     | 3 000-10 000 | 536-1787                      | 1.87-6.25                |
| 2    | Small stations                 | 28                        | 3-4                     | 10 000-50 000 | 1787-10340                     | 6.25-31.25               |
| 3    | Middle-scale stations          | 14                        | 5-7                     | 50 000-100 000 | 10340-20790                     | 31.25-62.5               |
| 4    | Major stations                 | 9                         | 8-10                    | 100 000-500 000 | 20790-103400                    | 62.5-312.5               |
| 5    | Large stations                 | 4                         | More than 10           | from 500 000 to 1 000 000     | 1034009-178750           | 312.5-625                |
| 6    | Railway tracks and watercourses crossings | 646            | 2                      | 300-3 000 | 53.6 – 536                      | 0.18-1.87                |
|      | Ulyanovsk region               |                           |                         |           |                               |                          |
| 1    | Small-scale stations           | 54                        | 1-2                     | 3 000-10 000 | 536-1787                      | 1.87-6.25                |
| Region                  | Stations       | Flow Rate (km/h) | Length (km) | Density (km/km²) |
|-------------------------|----------------|-----------------|-------------|------------------|
| Republic of Tatarstan    |                |                 |             |                  |
| Small-scale stations     | 31             | 1-2             | 3 000-10 000 | 536-1787         |
| Small stations           | 12             | 3-4             | 10 000-50 000 | 1787-10340       |
| Middle-scale stations    | 6              | 5-7             | 50 000-100 000 | 10340-20790     |
| Major stations           | 4              | 8-10            | 100 000-500 000 | 20790-103400   |
| Large stations           | 2              | More than 10    | from 500 000 to 1 000 000 | 1034009-178750 |
| Railway tracks and       | 337            | 2               | 300-3 000   | 53.6 – 536       |
| Railway tracks and       |                 |                 |             |                  |
| Large stations           | 2              | More than 10    | from 500 000 to 1 000 000 | 1034009-178750 |
| Railway tracks and       |                 |                 |             |                  |
| Large stations           | 6              | More than 10    | from 500 000 to 1 000 000 | 1034009-178750 |
| Railway tracks and       |                 |                 |             |                  |
| Bashkortostan            |                |                 |             |                  |
| Small-scale stations     | 109            | 1-2             | 3 000-10 000 | 536-1787         |
| Small stations           | 43             | 3-4             | 10 000-50 000 | 1787-10340       |
| Middle-scale stations    | 21             | 5-7             | 50 000-100 000 | 10340-20790     |
| Major stations           | 14             | 8-10            | 100 000-500 000 | 20790-103400   |
| Large stations           | 6              | More than 10    | from 500 000 to 1 000 000 | 1034009-178750 |
| Railway tracks and       | 1023           | 2               | 300-3 000   | 53.6 – 536       |
| Railway tracks and       |                 |                 |             |                  |
| Large stations           | 6              | More than 10    | from 500 000 to 1 000 000 | 1034009-178750 |
| Railway tracks and       |                 |                 |             |                  |
| Bashkortostan            |                |                 |             |                  |
| Small-scale stations     | 9              | 1-2             | 3 000-10 000 | 536-1787         |
| Small stations           | 4              | 3-4             | 10 000-50 000 | 1787-10340       |
| Middle-scale stations    | 2              | 5-7             | 50 000-100 000 | 10340-20790     |
| Major stations           | 1              | 8-10            | 100 000-500 000 | 20790-103400   |
| Large stations           | -              | More than 10    | from 500 000 to 1 000 000 | 1034009-178750 |
| Railway tracks and       | 48             | 2               | 300-3 000   | 53.6 – 536       |
3. Criteria and boundary conditions of the initial data based on the proposed methodology

The first enterprise to be examined was a structural division of the Kuibyshev railway branch of OJSC "Russian Railways", Base No. 47, located in the Samara region (in the Bezenchuk district), with a land area of 22 000 m². It belongs to the category of small stations. The company stores batteries (dry-loaded), floating railway bridges, pontoons, water-powered equipment, etc [9-15].

The investigation of the section of railway tracks located on the territory of Base No 47 was carried out in the following way. At the first stage, a 14-meter-long railway track has a catchment tray that allows collecting surface run-off from the ballast section into the reservoir. The ballast section has a bottom width of 4.7 m. Accordingly, the area of surface run-off from this site is 65.8 m². During rainfall, the researchers calculated the run-off coefficient from the ballast section. They determined the rainfall intensity as 0.23 mm/min. As the experiment lasted for 20 min and the volume of water trapped in the tank in 20 min amounted to 76.2 l, the run-off coefficient turned out to be 0.376. At the second stage, the investigation of the degree of run-off pollution trapped in the reservoir was conducted: the water pollution with oil products amounted to 71.0 per mg/l, suspended solids equaled to 1798.0 mg/l.

Open joint-stock company "Abdulinsky Remputmash plant for repair of track cars and production of spare parts" is located on the territory of the Orenburg region in the city of Abdulino. With its land area being 90 000 m², it is referred to the category of middle-scale stations. The analysis results showed the following concentrations of pollutants in the surface run-off: petroleum products – 65-300 mg/l, suspended substances – 1100-1800 mg/l. The run-off coefficient was determined to be 0.378.
The researchers examined the plant territory and the location of railway tracks and found out that there was one connecting track and seven branches leading to jobbing plants. All these tracks were closely examined. During rainfall, surface wastewater samples were collected from the ballast section of each railway track.

There are three washing and steaming stations (WSS) located on the territory of the Kuibyshev railway. The "Urussu" washing and steaming station is located in the northern part of the urban-type settlement Urussu of the Republic of Tatarstan. With an area being 125,000 m² it is referred to the category of large stations (see Figure 1). The researchers examined the site area (up to 5 m deep) located under the railway tracks, around the reservoir and in wastewater treatment facilities. There are 8 railway tracks, 3 elevated structures, a pit and a carpenter's workshop located on the territory of this station.

![Figure 1. "Urussu" washing and steaming station and its borders.](image)

During rainfall, surface wastewater samples were collected from the ballast section of each railway track. The analysis results showed the following concentrations of pollutants in the surface run-off: petroleum products – 70-480 mg/l, suspended substances – 1100-1900 mg/l. The run-off coefficient was determined to be 0.31.

Table 3 gives the initial data used to determine the criteria and boundary conditions for the development and design of technological schemes for surface wastewater treatment from railway transport enterprises (see Table 3).

| Classification groups (with the Samara region as an example) | Enterprise | Visual inspection | BOD concentration, mg/l | Concentration of suspended substances, mg/l | Concentration of petroleum products, mg/l | Iron concentration, mg/l | Run-off coefficient |
|-------------------------------------------------------------|------------|------------------|-------------------------|------------------------------------------|------------------------------------------|-------------------------|-------------------|
| Bridge crossings, 2271 units                               | Low-polluted | 20               | 402-1861               | Average 1132                             | 220-554                                  | 6.6                     | 0.25              |
| Small-scale stations, 93 units                             | Low-polluted | 20               | 1798.0                 | Average 120                              | 69.0-170                                 | 4.5                     | 0.25              |
The examination of five railway transport enterprises showed the consistency and correctness of the methods for determining the contamination of surface wastewater and the run-off coefficient coming from railway tracks according to the classification of stations by their category.

4. Railway service enterprises: operation schemes of surface wastewater collection, disposal and purification

According to the Water Code, Articles 44-46, discharge of wastewater into a water body and on terrain is prohibited. So, it is necessary to collect wastewater, take it to the place of treatment, then clean and discharge the treated wastewater according to existing legislation (Order of the Civil Code of the Russian Federation on Fisheries No 20 of January 18, 2010. "On approval of water quality standards for water bodies of fisheries significance, including standards for maximum permissible concentrations of harmful substances in the waters of water bodies of fisheries significance").

There is another problem which is the reliability of the upper and lower structure of the railway track for rolling stock, passengers and cargo transportation, which can be provided by timely measures to divert surface, ground and drainage water. It should be noted that drainage systems are assigned a secondary role in the planned financing of OJSC "Russian Railways" programs. Taking into account modern requirements, it is necessary to include water disposal systems for surface run-off into all structures, which positively affect the reliability of the track railway line and reduce the current repairs of railway tracks.

To collect water from railway tracks, various drainage schemes can be used. This is necessary to maintain the reliability of the ballast section. It means that the surface run-off is in this case sent to the drainage trays and becomes organized. Naturally, organized run-off must be treated in accordance with the Water Code. Systems and schemes for water disposal and treatment of surface wastewater from railway transport enterprises depend on the following: 1) the geographical location; 2) climatic conditions; 3) terrain; 4) products, services or orientation of the enterprise; 5) the enterprise area; 6) the volume of wastewater; 7) concentrations and types of pollution, etc. Let's consider two types of treatment facilities, the use of which is most rational on the railroad: 1 – mobile treatment facilities and 2 – local stationary treatment facilities. The use of these facilities also depends on the five categories of railway enterprises area [16-20].
5. Stationary treatment facilities of railway transport enterprises

In this paper, the authors did not consider options for biological treatment of surface wastewater, since the flow of surface wastewater is uneven and sometimes there is a time when there is no flow of wastewater into the flow-equalization basin and, accordingly, to the treatment facilities, which causes the equipment to stop working.

Mobile treatment facilities contain equipment, communications, and tools, and are permanently integrated into a specific technological scheme. They are not located on a certain land plot, regardless of whether they are connected to engineering support networks or not. When considering possible schemes for surface wastewater treatment, the researchers point out such main indicators of pollutants as BOD-full, suspended substances, petroleum products, iron. The above groups of railway stations are considered as a classification.

From bridge crossings, wastewater with a flow rate of 16.2-162 m³/day, in the amount of 5661 pcs and with an area of 300 to 3.000 m² is sent to one or two compact mono-installations located under the bridge beams or on the cones of bridge supporting structures, without additional storage tanks. These installations can have a capacity of 2.5, 5 or 10 m³/day. Installations located on bridges and bridge crossings can operate in a periodic mode ‘winter – summer’, the flotator operates in the secondary clarifier mode, flushing and regeneration is not performed in case that the load is replaced with regularity varying from once a year to once every two to three months. The researchers recommend conducting routine inspection and technical restoration of all mono-installation structures three times a year (spring, summer, and autumn). If the degree of contamination of the coal sorbent with petroleum products is more than 15% by weight, the loading is considered as wastes of Hazard Class V and is taken to the landfill. The structure is filled with a new load. If necessary, wastewater can be sent to filter trenches for further treatment (see Figures 2 & 3).

Figure 2. Location of two mono-compact treatment plants depending on the slope of the railway track.

Figure 3. Location of a single mono-compact treatment plant depending on the slope of the railway track.
6. Conclusions
The research yielded the following conclusions:
- For railway transport enterprises, both mobile and stationary treatment facilities can be used to ensure the treatment of surface wastewater generated on the territory of railway enterprises and sections of track.
- Compact wastewater treatment plants for clarifying surface wastewater with a high content of suspended substances and petroleum products can be used as mobile treatment facilities.

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