Content analysis of salts and suspended substances in snow and thawed water

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Abstract. The research article discusses the chemical composition of the anti-icing reagents, and presents the results of studies to determine the content of suspended solids and salts in the snow at different intervals from the edge of the roadside on the main streets of Izhevsk. The following dependence was revealed – a decrease in the concentration of salts and suspended substances in snow samples with distance from the edge of the roadway. The concentration of salts in the samples at different distances from the edge of the roads reached 5822 mg/l. The concentration of suspended solids in snow samples reached 13470 mg/l. It was found that when taking samples of snow at a distance of 25 meters from the edge of the roadway, there is an excess of the concentrations of salts and suspended solids in the snow, the values of the maximum permissible concentration for admission to surface water bodies.

1. Introduction
Automobile transport is an essential part of the life of a modern human, and traffic safety on the roads is one of the key tasks for road services. To ensure traffic safety during the winter season, the road maintenance service regularly carries out maintenance work on the roadbed, artificial structures and construction elements [1]. In turn, the current regulations in Russian Federation severely restrict the time to eliminate the effects of adverse weather conditions due to decrease a coefficient of adhesion on the road surface, reduce in visibility during precipitation and change in the speed mode of the car traffic.

2. Theoretical basis
During precipitation or during the formation of winter slippery conditions, road maintenance services sprinkle sand-salt (anti-icing) mixture on the roadway to increase the coefficient of adhesion to the road surface. The most used reagents currently are modified calcium chloride, potassium acetate, calcium nitrate, magnesium, carbamide (urea) [1-3]. Analysis of scientific studies of a number of authors [1-7] showed that a certain part of the sand-salt mixture remains in the snow (table 1). It is logical to assume that most of the anti-icing mixture enters into the soil, basins of surface and groundwater bodies, which further threatens the deterioration of many ecosystem components, primarily salinization of the soil and water [1, 2, 4, 8, 9, 10]. Researches show that the concentration of chlorides near the edge of roadway can reach from 150 to 1000 mg/l [1-7, 11] (for comparison: the maximum permissible concentration according to Russian standards for chlorides treated water...
entering the surface water is 300 mg/l \[1\]), and the concentration of suspended substances is from 100 to 600 mg/l \[1-7, 11\] (for comparison: the maximum the concentration of suspended solids in the effluent entering the reservoir is 10 mg/l \[11\]). Accordingly, most of the snow and thawed water located near the roadway must be cleaned before discharge into surface water bodies or, even, into the city sewage system, since the concentrations of certain substances in the melted snow (table 1) are higher for admission to the city drainage system network \[1, 8, 9, 12, 13, 14\]. Therefore, it is necessary to assess the distribution of the concentration of pollutants from the edge of the roadway to determine the actual mass of snow that needs to be cleaned.

### Table 1. The composition of the chemical substances in the melted snow.

| Substance                        | Unit of measurement | min  | max  |
|----------------------------------|---------------------|------|------|
| Dry residue                      | mg/l                | 159.0| 952.0|
| BOD5                             | mgO2/l              | 4.46 | 10.37|
| Ammonia and ammonium salts       | mg/l                | 0.9  | 11.82|
| Oil products and fats            | mg/l                | 3.12 | 57.20|
| Chlorides                        | mg/l                | 21.25| 598.0|
| Sodium                           | mg/l                | 20.71| 589.0|
| Potassium                        | mg/l                | 27.2 | 130.9|
| Manganese                        | mg/l                | 0.21 | 0.91 |
| Iron                             | mg/l                | 0.87 | 2.76 |
| Zinc                             | mg/l                | 0.04 | 0.21 |
| Synthetic surfactants            | mg/l                | 0.63 | 1.62 |

### 3. Materials and methods

To assess changes in the concentration of pollutants in the snow (or rather, suspended solids and salts), a series of experiments were conducted from the roadside territory of individual streets in Izhevsk. Streets with high traffic density (50 years of the VLKSM (sampling place number 1), Kirov st. (Sampling place number 2), Lenin street (sampling place number 3) (figure 1)) were chosen as the object of research by several reasons:

- These streets are connecting for several districts of the city;
- On selected streets, especially in places where samples are taken, there is a significant elevation difference along the traffic profile;
- The previous two reasons are a consequence of the following - these streets are a priority when dealing with winter slippery conditions and the roadbed is sprinkled with sand and salt mixture earlier and more thoroughly than other streets;
- Thawed snow from the streets falls into surface water bodies (the Karlutka river and the Podborenskaya river);
- The presence of drainage system makes it possible to estimate the concentration of pollutants in the snow of the roadside areas, as well as in the melt snow from the surface of the roadway.

The sampling was carried out using the standard envelope method – cutting and scraping from the entire thickness of the snow masses at four points and at the intersection point of the diagonals drawn from these points. Next, the samples were melted at room temperature and mixed.

Sample selection was carried out on the streets from both roadside lanes at a distance of 1 to 25 meters. The results of the analyzes are given in table 2 and in the graphs presented in figure 2 and 3.
Figure 1. Snow sampling sites in the Oktyabrsky and Pervomaisky district of Izhevsk (image used from Google Maps service).

Table 2. The content of suspended substances in the snow at different intervals from the edge of the roadway.

| Sampling point | Right side of the road, m | Left side of the road, m | Concentration, mg/l |
|----------------|---------------------------|--------------------------|---------------------|
|                | 1 | 5 | 10 | 15 | 25 | 1 | 5 | 10 | 15 | 25 |
| №1            | 3503 | 9015 | 13470 | 799,5 | 3627 | 5876 |
| №2            | 6420 | 3211 | 651 | 78 | 74 | 2325 | 1722 | 670 | 125 | 102 |
| №3            | 4221 | 6607 | 1012 | 6903 | 1376 | 834,4 |

Figure 2. The change in the concentration of suspended substances in snow samples depending on the distance from the edge of the roadway (right side).
The change in the concentration of suspended substances in snow samples depending on the distance from the edge of the roadway (left side).

Data analysis table. 2 and the graphs presented in figure 2 and 3 shows that at sampling points No. 2 and 3 there is an almost linear relationship between the content of suspended solids in snow and the increase in distance from the edge of the roadway. Interesting situation is observed at sampling point No. 1 - an increase in the concentration of suspended solids in snow samples with increasing distance from the roadway. These growth may be due to several factors - wind transfer of sand and salt mixture or transfer of a mixture of snow and sand over a long distance during the embankment [1], [2], [5], [13], [14]. A noticeable decrease in the concentration of suspended substances occurs only in the interval of 10–15 m from the edge of the roadbed (at sampling points No. 1 and 2), and in the interval of 15–25 m the decrease in the content of suspended solids in the snow is no longer significant. And from the point of view of cleaning snow and melted water, it can be concluded that it is necessary to clear snow from the roadside at a distance of at least 15 m from the edge of the roadway in each direction of motion. However, in the Russian regulations [1], [2], [5] recommendations are given for cleaning and removal of only boned snow, which in practice is 1.5–3 m from the edge of the roadway.

Table 3. The salt content in the snow at different intervals from the edge of the roadway.

| Sampling point | Right side of the road, m | Left side of the road, m |
|----------------|---------------------------|--------------------------|
|                | 1  | 5  | 10 | 15 | 25 | 1  | 5  | 10 | 15 | 25 |
| №2            | 5822 | 1102 | 785 | 540 | 545 | 5289 | 1078 | 825 | 683 | 345 |
| №3            | 1376 | 834  | 563 | 1412 | 693 | 423   |

The change in the concentration of salt in snow samples depending on the distance from the edge of the roadway (right side).
Analysis of the data presented in the table, 3, and the graphs in figure 4 and 5, also makes it clear that a decrease in salinity is observed up to 15 m from the edge of the roadway. However, even at such a distance, the salt content in the snow is almost twice as high as the current norms [11].

4. Discussion and Conclusions

Regular use of anti-icing agents in the fight against winter slipperiness leads to the accumulation of suspended solids and salts in the snow of the roadside areas to concentrations several times higher than the limits for discharge of melt water into the reservoir.

Analysis of the obtained data on changes in the content of suspended solids and salts in the snow (depending on the distance from the edge of the roadway) shows that a noticeable decrease in the concentration of suspended solids occurs in the interval from 10 to 15 m from the edge of the roadbed, and in the interval from 15 to 25 m decrease in the content of suspended solids and salts in the snow is not significant. Thereby, the authors recommend clearing snow from the roadside at a distance of at least 15 m from the edge of the roadway in each direction of motion.

To clean thawed drains and snow, it is recommended to install a sump-averager, which makes it possible to clean thawed snow without using large areas for sewage treatment plants. At the same time, the degree of purification of melt water makes it possible to discharge it into drainage system and water bodies without causing harm to the environment.

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