Study of snow cover of functional zones of city territory

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Abstract. In cities the surface flow is one of the main sources of pollution for surface waters within urban development. Snow cover is an indicator of the atmospheric air pollution and sanitary state of populated areas. Using the examples of various urban functional zones, the evaluation of the snow cover state in modern conditions has been carried out. The analysis of the meltwater composition has shown that the metal ions are one of the main components of pollutants. In order to decrease the negative influence upon water bodies of surface waters of populated areas, a system of surface flow with compulsory afterpurification should be organized. A version of reconstruction for existing network of surface flow has been considered, with installation of local purification facilities including cartridge filters. A version with gabion structures has been considered for shallow parts of coastal zones. In this case rainwater and meltwater flow through spaces between gabions, without affecting aesthetic appearance of the territory. Seepage waters ensure the supply of groundwater.

1. Introduction
The territory of populated areas constitutes a complex of natural and artificial objects meant for ensuring comfortable living conditions; it includes components of industrial and business objects, vegetation and water bodies.

In some cases water bodies within urban development not only fulfill the role of recreation territory, but also provide the sources of drinking water supply. For a city the importance of such water bodies and waterways is associated with formation of landscape architectural environment, as well as with their exploitation for provision of household water for the population. Besides, the existence of water bodies on the territory of populated areas involves their interaction with engineering infrastructure (crossing of water obstacles, viaducts, separation structures), road transport network (highway and railway bridges, pedestrian overpasses). In the territories of populated areas and adjacent territories the surface flow is nowadays one of the main sources of pollution for surface waters not only within urban development

The condition of urban water bodies is greatly influenced by the condition of water-collecting areas that border upon the water front without embankments, which prevent the disorganized ingress of surface flow into a water body and destruction of its banks in conditions of high-level mechanical stress [1-7].

2. Results and discussion
Modern cities are characterized by increase in areas with watertight coating (street transport networks with asphalt coating, roofs of the buildings), which fact influences the volume of the formed meltwater
and rainwater surface flow [3]. Snow cover is the source of integral accumulation of pollutants that are adsorbed on the surface of snow crystals, as a consequence the meltwater is one of the main characteristic features of the underlying surface pollution. The urban flow structure differs essentially from the natural flow structure, but in all cases the process of flow formation is complicated; it includes many dynamically changing climatic and other natural and anthropogenic factors [8, 9]. The role of each source in pollution of water resources is different. As development widens and purification of industrial and urban waste waters improves, the necessity of surface flow purification is growing in importance, the same is true about other disorganized pollution sources.

One of the city water bodies – the Miass river – flows through the central part of the city, crossing various functional zones, at that the water-front territory is under stress, not only as a recreational area, but also as populated area containing highways with significant transport load.

To determine the influence of territorial areas with disorganized surface flow on the river condition, the analysis of snow cover was carried out measuring the pH values, sedimentary particles and metal content. The samples of snow cover were taken in the beginning, the middle and the end of winter period (December, February, March) at seven points. To systematize the pollution sources for surface waters within the city territory, the position of sampling points was chosen subject to various functional zones: industrial, transportation, populated, and recreational zones. Each zone was characterized by a specific character of its use: the type of development territory, the transport infrastructure, the line of use. One of the main features characterizing the choice of a territory was the organization degree of the surface flow systems.

The content and concentration of heavy metals was measured with the use of a Rigaku Supermini X-ray fluorescent spectrometer after preconcentration of 100 mL samples of meltwater.

The pH values were measured with the use of a Sartorius PP–25 professional pH-meter within one day from the sampling time. The amount of sedimentary particles was measured according to [10].

Modern urban development is characterized by increasing intensity of vehicular traffic within the city boundaries. The frequency of vehicular traffic on the roads significantly influences the condition of surface flow for such territories [11]. The pollutant content in the surface flow for various types of urban development can be found in normative literature [12], if the actual data for the territory are absent.

The acidity value of meltwater (pH) is an important characteristic feature. The pH value of meltwater was determined both after filtering sedimentary particles off and in the presence of suspensions, which made it possible to determine the relative contribution of solid particles into total salt content of meltwater. The pH values in various functional zones are represented in the table.

The analysis of the obtained data enables us to conclude that the meltwater in all control points can be characterized as neutral (the filtered meltwater pH is in the range 5.5 – 6.74; the first portions of the snow cover in the presence of sedimentary particles are characterized by the pH values in the range 7.2 – 7.76). The application of deicing agents and accumulation of pollutants during winter period leads to alkalization of precipitation (the pH values are within the range 8.59 – 7.78).

Winter with little snow led to further alkalization of meltwater, with the highest alkalization in points 4 and 6, characterized by intensive traffic of motor transport. On the one hand, the motor transport emits the fuel combustion products containing oxidized carbon, sulfur, and nitrogen, at the ground level, which leads to acidification of snow cover, but significant amounts of solid particles that accompany deicing and contain calcium, magnesium, and hydrogen carbonate ions promote alkalization of snow cover. In the area of industrial zone with intensive traffic of freight and passenger vehicles the increasing alkalinity of meltwater is probably caused by complex influence of traffic stream and industrial emissions of various plants. It has been noted that in the boundaries of the investigated territories acidification of snow cover does not occur, the acidity index shifts towards alkalinity (the pH values for some areas are 7.9 – 8.6 to the winter end).
Table. The pH values in meltwater.

| Point No. | Location                        | Area characteristics                                                                 | pH value |
|-----------|---------------------------------|--------------------------------------------------------------------------------------|----------|
| 1         | Residential area                | Suburban territory                                                                   | 5.65     |
| 2         | Shore zone of a river           | Central part of the city, trade, business and residential area; highway with intensive traffic | 6.38     |
| 3         | Shore zone of a reservoir (town beach) | Shore zone territory (reservoir weir)                                             | 6.20     |
| 4         | Territory of residential suburban regions | Territory of the reservoir sanitary protection zone | 6.65     |
| 5         | Urban residential area          | Territory of shopping and entertainment center, highway along the river shore        | 5.15     |
| 6         | Park (recreation) zone          | Entrance area with intensive traffic of passenger cars                               | 6.74     |
| 7         | Industrial zone                 | Territory of industrial objects in lower part of landform, highway with intensive traffic | 6.50     |

The presented data are in agreement with the results of the study, in which the acidic and basic properties of snow cover have been analyzed for industrial cities of Chelyabinsk region [13], as well as the studies of element composition of snow cover [14].

It is known that the state of snow cover characterizes the process of accumulation for pollutants during the cold period, therefore the determination of the snow cover chemical composition is of great interest [13,15].

According to the data of the Complex Report of the environmental conditions in Chelyabinsk region in 2016, the Miass river has been observed to contain concentrations in excess of threshold limit value (TLV) for such elements as total iron, zinc, copper, and manganese.

During snow melting the surface flow is characterized by increased content of sedimentation particles, mineral in this case. The flow of such waters into river is instrumental in increasing the suspension content and bed silt, which can be transferred into the water column under specific conditions (wind disturbance, change of pH, mineralization, and water content, or dredging operations, etc.), thus causing secondary water pollution [16, 17]. The suspended particles can absorb a significant part of pollutants that go into water. Shallow depths, specific features of water collection, the presence of suspended particles promote sedimentation of pollutants adsorbed by suspended particles without substantial change in their chemical composition; they are accumulated near bottom, where the process of biochemical oxidation proceed much slower. In [17] the bed silt is characterized as mineral and organic components that behave as "collectors" of heavy metals and produce highly stable compounds with them (iron and manganese oxides). At certain conditions (changing pH, the presence of various complex-forming substances) the desorption processes are not ruled out, and metals in dissolved state go into the water column, as a result, the bed silt turns into the source of secondary water pollution. Besides, the particles entering a water body, are simultaneously precipitated due to gravity and mixed with the main body of water, therefore at some distance from the discharge point the concentration of suspended particles decreases, which leads to increasing the bed silt layer. The disturbance conditions for the bed silt layer and the beginning of movement for the particles on the bottom of water streams are determined by critical values of the flow rate ("nonerosive" rates).

As the Complex Report mentions, the increased concentration of iron and manganese in the Miass river is also possibly due to the sorption-desorption processes on the bed silt when certain conditions change.

The elemental analysis of the meltwater composition shows that the content of heavy metals in the meltwater from the city territory fluctuates both in element composition and concentration. According to the analysis data, the dissolved substances are predominantly represented by compounds of mineral nature (silicon, calcium, magnesium); their content varies from 50% to 60-70 % (m/m) depending on
the functionality of a zone. The presence of such natural elements as sodium and magnesium, as well as their concentration, reflects the purity grade of the meltwater. The residential areas in new suburbs, in spite of quite heavy traffic, are characterized by the highest concentration of sodium and magnesium ions in the meltwater: 40–50% (m/m) compared to 30–40% (m/m) in the areas of industrial zones.

In the meltwater samples such microelements as magnesium, aluminium, calcium, chromium, iron, nickel, copper have been found, as well as the presence of lead in the samples from some parts with intensive traffic. Significant fluctuations of the silicon content (silicic acids) in meltwater from different territories in various time periods can be explained by the fact that the solubility of silicic acid in natural waters depends on a number of factors, primarily on their ionic composition and the pH values. The presence of calcium and magnesium cations that can form sparingly soluble silicates with silicic acid lessens its possible concentration in water.

Excessive chloride content has been registered in the meltwater samples taken in the immediate vicinity of highways, which can be related to the use of deicing salt treatment. It has been noted that the chloride content increase is observed after formation of snow cover and long periods without precipitations, which leads to growth of the fraction of such elements as calcium, aluminium, and magnesium, present in deicing mixtures, from 50 – 55% (m/m) to 70 – 80% (m/m).

It has been found that the fraction of heavy metals – chromium, iron, nickel, copper – increases on the industrial zone territory and the territories adjacent to it (concentration of these elements at the end of winter period in meltwater comes to 10 – 15%).

The snow cover in the residential area near the shopping and entertainment center is highly polluted, both in the content of elements characterizing natural components (sodium and magnesium) and the components of deicing mixtures and heavy metals. At present such areas are located in the territories adjacent to those parts of the shore zone without embankments that should contain the surface flow network. As a result, disorganized surface flow causes erosion of the shore in part, formation of water furrows and leads to pollution of river water.

The most informative complex value is the specific combinatorial index of water pollution (SCIWP), which is a relative ratio of the pollution degree for surface waters. It arbitrarily evaluates the pollution effect fraction added to the total water pollution degree that is due to the simultaneous presence of a number of pollutants. According to the data of the Complex Report of the environmental conditions in Chelyabinsk region in 2016, the Miass river is characterized as "dirty" in terms of SCIWP, at that the average content of total iron is 1.2 TLV, zinc content is 3.1 TLV, copper content is 2.5 TLV, and manganese concentration is 8 TLV. The described analysis of heavy metals in snow cover for the territories that are the sources of disorganized meltwater flow into the river within the city is urgent. The presence of heavy metals in meltwater that joins the river in the city area is conductive to keeping the water quality at the "dirty" level.

In order to reach the necessary quality of surface water at its purification, two treatment methods are the most efficient and widespread: the reagent method and the sorption method. The review of modern methods used for treatment of the surface flow network [18 – 21] allows us to suggest a surface flow purification scheme with the use of cartridge filters, applying sorption filtration techniques: removal of suspended / emulsified particles by filtering material and of dissolved substances by sorption material.

Taking into account the limited areas on the residential territory, as well as the existing surface flow network for purification of surface flow, it is possible to use the cartridge filters in storm water sewage wells, at that their installation can be carried out in operating network, in the wells before the rainwater and meltwater discharge, without cardinal reconstruction of the existing network. It is possible to use a well with a settling section for preliminary treatment, which takes the principal load of suspended particles and oil products. In this case the cartridge filter sorbs metal ions.

For the residential area with lower parts of landform and green recreational zones (public gardens and parks) the problem can be solved by surface flow organization in the shape of "artificial"
landscape: arrangement of gabion-type structures; as a result rainwater and meltwater are going to be partially filtered through a layer of rubble fill, and aesthetic appearance of the territory will not suffer.

3. Conclusion
Anthropogenic activity on water-collecting area leads to additional pollution of water bodies due to disorganized surface flow from various water-collecting surfaces on the city territory. The paper shows the presence of heavy metals in snow cover for all investigated functional zones of urban development: magnesium, aluminium, calcium, chromium, iron, nickel, and copper; besides, in some zones with intensive traffic the presence of lead is observed.

In order to decrease the load on water bodies within urban development it is necessary to take water-protective measures. The main focal point is the organization of the surface flow system with mandatory purification of surface flow. From the economic and operational point of view it is worthwhile to install local underground purification facilities in the residential area territory.

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