Microplastics in the snow cover of the south of Western Siberia

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Abstract. Plastics production is growing all over the world, but the total emission of microplastics is unfortunately not reducing. In the external environment, plastics degrade over time. This leads to the appearance of smaller particles or fibers which are referred to as secondary microplastics at a size of less than 5 mm. Atmospheric transfer is one of the main ways of microplastics entering the environment. The purpose of this study is to identify microplastics in the snow cover of the south of Western Siberia, as well as preliminarily assess the possible sources of their supply. Snow samples are taken during a period of maximum snow accumulation (March, 2020) according to requirements developed by the Norwegian Institute for Air Research. The microparticles are visually evaluated using a digital microscope, Dino-Lite AM211, a fluorescent dye solution, and a Wood lamp. To assess the possible atmospheric distribution and deposition of the particles, an analysis of the synoptic conditions based on data of NCEP/NCAR, ERA5, and HYSPLIT is performed. The microscopic analysis has shown that microplastics (namely, films, fibers, and granules) have been detected in 16 of the 18 snow samples in the city of Barnaul and adjacent territories, as well as fibers and granules have been revealed in 3 snow samples from the Kasmala River basin.

1. Introduction
The production of plastics is growing all over the world including Russia, but the volume of plastic emissions (unprocessed, recycled or buried) unfortunately is not reducing [1, 2]. In the external environment, plastics degrade over time, which leads to the appearance of smaller particles or fibers, which are referred to as secondary microplastics at a size of less than 5 mm [3, 4]. Microplastics can be released to the ambience at all stages of the life cycle of plastic products and have already been detected in almost all environments [5, 6].

Atmospheric transfer is one of the main ways of microplastics entering the environment. At the same time, atmospheric precipitation (in the form of rain and snow) promotes the deposition of microplastics on the underlying surface, and their particles can act as condensation nuclei [4, 7-9]. In
this regard, snow cover is considered as an accumulator of atmospheric scavengings of microplastics, in particular, in urban areas. Weather conditions are not always decisive in the flow of microplastics into the environment, giving way to the influence of local sources of their supply [10].

The microplastics are characterized by only anthropogenic origin and, therefore, they can serve as a reliable marker both for assessing the geochemical situation and for indicating the sources of their emission. It should be noted that research on microplastics both in precipitation and in snow cover including urbanized areas has not been carried out in Russia before the cold season of 2019-2020. In this regard, the purpose of the study is preliminary identification of microplastics in the snow cover (accumulator of atmospheric scavenging during the cold period) of the south of Western Siberia.

2. Data and methods

Snow samples were taken in the south of Western Siberia (Figure 1) both in an anthropogenically loaded territory (the city of Barnaul and adjacent territories) and in a relatively unloaded one (the Kasmala River basin) during the period of maximum snow accumulation (March 1-7, 2020) according to the requirements developed by the Norwegian Institute for Air Research [11].

As soon as the samples arrived at the laboratory, they melted at room temperature in foil-sealed glass containers, and then filtered through fiberglass filters (pore diameter: 0.2 μm). The microparticles were visually evaluated using a digital microscope Dino-Lite AM211. In addition, we used a fluorescent dye (Nile Red) solution that has already been successfully applied to identify microplastics, as well as a Wood lamp (wavelength: 360 nm) [12, 13].

All basic GIS analysis operations and layout originals of maps were performed in ESRI ArcGIS Pro 2.5.0. To assess the possible atmospheric distribution and deposition of particles, an analysis of the synoptic conditions of the cold period of 2019-2020 was carried out in the south of Western Siberia based on data of NCEP/NCAR reanalysis (National Centers for Environmental Prediction and National Center for Atmospheric Research), as well as ERA5 reanalysis (European Centre for Medium-Range Weather Forecasts) and backward trajectory frequencies of air masses (Hybrid Single Particle Lagrangian Integrated Trajectory – HYSPLIT) [14-16].

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**Figure 1.** South of Western Siberia. Kasmala River basin (a) and Barnaul and adjacent territories (b).
3. Results
During visual identification by a digital microscope Dino-Lite AM211, a large number of particles of various shapes and colors were found in the samples (Figure 2 a).

![Figure 2](image_url)

**Figure 2.** Fibers and plant remains from snow cover samples taken in the Kasmala River basin (a - fiberglass filters under normal light, b - fiberglass filters stained with fluorescent dye under normal light, c - fiberglass filters stained with fluorescent dye under ultraviolet light).

At the next stage, the obtained filters were stained with Nile Red fluorescent dye, and their repeated microscopy was carried out with photographic recording of the results both under normal and ultraviolet light. It should be noted that not all particles have reacted with the dye and acquired a glow under ultraviolet light (Figure 2 b and c). The absence of glow in stained particles and fibers indicated that they were not plastic and most likely have a biological origin. The results of the research showed that microplastic fibers were detected in all samples taken in the Kasmala River basin, since they had glow after staining with the dye under ultraviolet light (Figure 2 c).

In the snow samples taken in the city of Barnaul and its surroundings, not only fibers, but also particles and granules of microplastics were identified. The identified microplastic granules had diameters ranging from 100 to 600 μm, while the fibers and films reached a length of 1200 μm. Microplastics were not identified only at two sampling points (no. 12 and no. 13) in the vicinity of Barnaul. To determine the atmospheric supply of microplastic particles and fibers, we analyzed the average wind speeds and directions according to the NCEP/NCAR reanalysis data in the studied region for the period from November 07, 2019 to March 10, 2020, i.e. from the date of setting-up of stable snow cover until the time of sampling. The analysis of wind speeds and directions was carried out for the average heights of the atmospheric boundary layer, i.e. a parameter that was successfully used in determining the regional atmospheric input of microplastics [17]. According to ERA5 data in the cold period of 2019-2020, the boundary layer height in the south of Western Siberia averaged 560 m (Figure 3), which practically corresponds to the height of 925 mb used for the calculation of the average wind speeds and directions (Figure 4).
Figure 3. Atmospheric boundary layer height from November 07, 2019 to March 10, 2020 according to ERA5 data.

Figure 4. Average wind speeds (m/s) and directions (arrows) at the level of 925 mb from November 7, 2019 to March 10, 2020.

During the cold season of 2019-2020 at a height of 925 mb, southwestern air masses with average wind speeds of 8-11 m/s prevailed, i.e. the potential sources of microplastics could be located southwest of the sampling sites. In the next step, we calculated the average monthly partial backward trajectories of air masses movement using the HYSPLIT model for the heights of the boundary layer. By analogy with a previously successfully implemented approach for determining the potential regions which could supply the particles and fibers of microplastics, we used the GDAS meteorological archive as the input parameters for calculating the trajectories, and the computation time was equal to 2 hours (Figure 5).
Figure 5. Sampling points in the city of Barnaul and adjacent territories and backward trajectory frequencies of air masses movement calculated by HYSPLIT.

The results of calculating the backward trajectory frequencies for the city of Barnaul and its surroundings showed that for 16 points where the microplastics were determined the sources of their atmospheric supply were located within a radius of 30 km. Thus, first results on the identification of microplastics in the snow cover of the south of Western Siberia have been obtained, and the potential territories as sources of their atmospheric transfer have been determined. In the future, it is planned to use several cross methods for detecting the microplastics (scanning electron microscopy and energy dispersion X-ray analysis) in parallel. This will increase the accuracy of determination and make it possible to obtain some information about their chemical composition, which will also be used to determine major sources of the microplastics entering the environment.

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