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# The Impact of Urbanization on the Environment in Shymkent: Dynamics of Solid Waste

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**Abstract**: The main goal of the study is to assess the physical and chemical properties of the snow cover, the level of dust pollution of the snow cover and the ground layer of the atmosphere in the technogenic source of pollution of the urban environment – the zone of influence of the solid waste landfill in the city of Shymkent. The study sampled snow and measured the thickness of its cover in areas with undisturbed snow cover and, based on its results, came to the conclusion that the snow cover in the city and its environs is characterized by an increased content of carbon monoxide, nitrate ions, chlorides, which is a consequence of technogenic influence pollution sources. The results of the study of soil samples of soddy-podzolic soil showed: a clear relationship was established, and it was revealed that porous soils with a high content of fractions <0.005 mm have both a large total perimeter and pore area.

Keywords: environmental pollution, ecological situation, monitoring, snow cover, sampler, dust load

## 1. Prerequisites for the publication

The research topic requires study, since one of the main environmental problems of the present time is the deterioration of the urban environment. The concentration of various sources of pollutants in populated areas is extremely high. Cities are hotbeds of environmental pollution, which, due to the high concentration of population, infrastructure, and sources of pollution, form a special technogenic environment, often unfavourable for life. In Shymkent, about 209-230 thousand tons of municipal solid waste (MSW), of which in 2021 62,700 tons were sorted, and more than 41,100 tons were transferred to enterprises for processing municipal solid waste 1). In Shymkent, the use of snow cover as an indicator of air condition is especially relevant, since the period of accumulation of snow cover lasts 5.1 months, from October 26 2022 to March 29 2023 2).

The issue at hand is that in Shymkent, the environmental conditions are shaped by the presence of waste incineration facilities that handle waste, potentially containing dangerous substances that release gases and flammable materials. The issue at hand is substantiated by the observation that during the incineration of waste at a plant, oxygen is consumed. Specifically, one company depletes 1 $m^3$ of oxygen from the atmosphere each year, exacerbating the existing scarcity of oxygen in major urban areas of Kazakhstan. Furthermore, each tonne of incinerated waste pollutes over 20,000,000 $m^3$ of the atmosphere to a hazardous extent 3). Disposal of MSW is solved using such cheap and unsafe methods as burning, drowning in water sources and organizing rubbish dumps. These methods of dealing with MSW negatively affect the ecological situation of urban areas, and also affect the life processes of not only people, but also the fauna and lead to a radical change in the natural flora. MSW contains chemical compounds that, when burned, release chlorinated dioxins and other toxic chemicals that can cause cancer in humans and destroy their hormonal system. The decay period of poisons can last more than 20 years. In Shymkent, the method of recycling industrial waste for further use is a new and not fully developed area. The relevance of the technology lies in the possibility of obtaining cost savings that can be obtained by using recycled materials rather than primary sources.

Research results of the authors Ye. Bitmanov et al. 4) showed the content of heavy metals in the soils of the city of Kokshetau and the ratio of the content of heavy metals in 2020-2021. Exceeding the maximum allowable concentration (MAC) of heavy metals in the city of Kokshetau was noted at the copper glass factory – 2.1 MAC. In the city of Shchuchinsk, in soil samples taken in 2020 in various regions, the content of chromium was in the range of 0.184-0.813 mg/kg, lead – 0.13-1.37 mg/kg, zinc – 0.31-1.56 mg/kg, cadmium – 0.0042-0.1379 mg/kg.

Authors A.Z. Abilmagzhanov et al. [5] presented the results of studies of 10-point and combined samples of municipal solid waste from a landfill in the Ili district of the Almaty region. In 2021, the results of a study of the morphological composition of municipal solid waste showed that it is influenced by the activities of illegal sorters who extract valuable recyclable components. The results of a microbiological study showed the presence of heterotrophic bacteria, actinomycetes, microscopic fungi and bacteria of the *Escherichia coli* group in aqueous extracts.

Research by the authors M.R. Aktayev et al. [6] showed the results of monitoring the waters of the Shagan River in terms of changes in the specific activity of tritium for 2016-2020. According to the results of observations, it was found that the specific activity of $^{3}$H (hydrogen) in surface and ground waters varies in a wide range of values depending on the time of observation. At the site of maximum pollution, the content of $^{3}$H varies from a minimum of 8 Bq/kg in the spring, to a maximum of 370,000 Bq/kg in the summer-autumn period, at the exit points of the river. Shagan outside the polygon, the concentration of $^{3}$H varies from 90 Bq/kg to 12,400 Bq/kg, in the area where the river flows. In the Irtysh, the content of $^{3}$H does not exceed 110 Bq/kg.

In the study, authors A.V. Panitskiy et al. [7] examined the nature of the vertical distribution of the main long-lived technogenic radionuclides $^{137}$Cs (caesium), $^{241}$Am (americium), $^{90}$Sr (strontium), and $^{239+240}$Pu (plutonium) in the soils of the Semipalatinsk Nuclear Test Site. It was a major nuclear testing facility located in Kazakhstan, which was part of the Soviet Union during the Cold War era. During its operation, the Semipalatinsk Test Site was used for conducting over 450 nuclear tests, including both atmospheric and underground explosions. These tests had significant environmental and health consequences for the region, leading to radiation exposure and long-term health problems for nearby populations. In the course of the studies, the authors identified differences in the nature of the depth distribution of the studied radionuclides in the soils of the indicated areas. Based on the data obtained, the authors developed recommendations aimed at optimizing studies of the vertical distribution of radionuclides in the soil cover of the former Semipalatinsk Nuclear Test Site. Researchers have found that when conducting such studies, it is sufficient to classify the soil-to-soil type and limit the studies to a depth of 30 cm.

In the study, authors D. Vinnikov et al. [8] measured the concentration of particulate matter PM2.5 in the city of Almaty, to which people working outdoors are exposed in winter. Twelve non-smoking security guards wore a TSI DustTrak AM520 dust analyser for 8 hours in 12 different areas of the city. The measurements were taken from mid-November 2018 to mid-March 2019. PM2.5 concentrations in different parts of the city were different, but consistently exceeded the MAC values. On one day a person could inhale an average of 120 μg/m$^{3}$ of PM2.5, and on another – 1,500 μg/m$^{3}$.

The aim of this study was to assess the physicochemical properties of the snow cover and the level of pollution of the surface atmosphere in the territory of Shymkent, with a focus on understanding the impact of solid waste landfills and waste processing companies on the environment.

## 2. Materials and methods

During the research, the methods of snow cover sampling and preparation for chemical analysis and analysis of the level of dust pollution were used, the use of which is regulated by ST RK 1517-2006 "Environment protection. Method for determination and calculation of the amount of pollutants emission" [9]; ST RK 1877-2009 "Environment protection. Method for determination and calculation of the amount of pollutants emission" [10]; ST RK ISO 10396-2019 "Stationary source emissions – Sampling for the automated determination of gas emission concentrations for permanently-installed monitoring systems, IDT" [11]; ST RK 3461-2019 "Determination of background levels of pollutants in the components of the natural environment in areas where hazardous production facilities are located" [12]. In the course of the research, gravimetry methods, snow cover indication method, potentiometry, titrometry, gas chromatography, photometry, photocolorimetry, voltammetry, argentometry. Using these methods, a snow survey was carried out, and 5 snow samples were taken in the first half of March 2023, during the expected accumulation of the maximum moisture content of the snow mass. Dust collection in spring-summer time was carried out from April 15 to June 12, 2023.

Also, in the city of Shymkent, a landfill for municipal solid waste (MSW) was investigated, which is accompanied by biogas emissions and the formation of leachate, as a result of which an increased level of pollution of the atmosphere, soil, and groundwater of the territories adjacent to the landfill was noted. Also, industrial wastes that do not meet the requirements are sent to this landfill: their humidity exceeds 85%, the directed wastes are explosive, self-igniting and self-igniting, the level of toxicity of industrial wastes is higher than that of MSW (according to the results of the analysis of water intake), wastes 1-2 are placed hazard class, as well as radioactive substances and biological waste. At several points of the site selected for sampling with undisturbed snow cover, snow cores were cut to the entire depth of the snow cover, while avoiding contamination of the lower part of the core with soil particles and plant inclusions. The sample was transferred to a vessel and delivered to a place where it was melted at room temperature in glass beakers. Then, to separate the solids from the solution, the samples were filtered through a "blue" tape filter paper and the filter was dried at a temperature of 95±5°C. The dried filters were weighed, after which the mass of the solid residue was determined.

A specialist from the testing laboratory took part in the study of snow samples in the presence of a controlled person using video recording. Measurements of the physicochemical composition of snow water and dust load were carried out in the laboratories of the South Kazakhstan State University. For the study, regulatory scientific and technical materials were used on the methodology of snow cover sampling for chemical analysis, regional regulations, environmental requirements Ecological code of the Republic of Kazakhstan [13] of January 2, 2021 No. 400-VI ZRK. The following devices were used to sample the snow cover: a plastic sampler – a snow pipe with an inner diameter of 103 mm and a length of 100 cm, a dust collector for trapping dust in the spring and summer seasons, additional means of inert material, plastic bags, electronic scales with a measurement error of 0.1 g, a measuring ruler of 100 cm, polypropylene vessels for storing and transporting samples. When performing sampling, special clothing, gloves, masks were used.

## 3. Results

The climate of the city of Shymkent is sharply continental, and moderately humid. Winters are cold with frequent and short thaws and dry, hot and long summers. There is little precipitation. The average annual amount is 580 mm, the maximum value is 602 mm, the minimum value is from 7 to 97 mm. The annual precipitation in the north is 150 mm, in the highlands – up to 800 mm [1]. The lowest precipitation was recorded in August, with an average of 7 mm. Most precipitation falls in April, with an average of 97 mm [14]. According to the Shymkent weather station, from October 26 2022 to March 29 2023, on average, from 25 to 158 mm of snow falls [2]. Thus, the climatic conditions of the city of Shymkent are characterized by a moderate-warm climate due to the southern location of the city. The National report on the state of the environment and on the use of natural resources of the Republic of Kazakhstan for 2021 [1] presents data of polluting substances in the city Shymkent in dynamics 2019-2021 (Fig. 1).

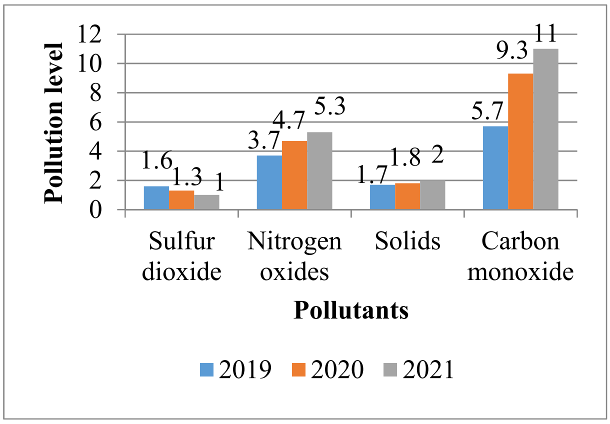

**Fig. 1:** Emissions of main pollutants in Shymkent.

Figure 1 observe a concerning increase in air pollutants from 2019 to 2021, particularly with carbon monoxide levels nearly doubling. Nitrogen oxides showed a slight increase initially, then stabilized, while sulfur dioxide and solids displayed less consistent patterns, with a general increase over the years. The year 2021 marked the highest recorded levels for carbon monoxide and nitrogen oxides, suggesting a deterioration in air quality. Considering Shymkent's moderate-warm climate, these trends underscore potential health risks and environmental challenges, emphasizing the need for targeted environmental policies and actions to manage and mitigate air pollution in the region.

When analysing the emission data for the main pollutants over a two-year period, an increase in the content of nitrogen oxides, particulate matter and carbon monoxide, and a decrease or stabilization of sulphur dioxide in the atmosphere is noted. The number of points at which samples were taken was determined on the spot, based on the required sample volume, the moisture content in it, and the uniform coverage of the selected sampling area [1]. To study the physical and chemical properties of the snow cover, 8 locations of sampling points were selected in the territories adjacent to the container sites:

- No. 1 – 300 m to the west of the solid waste landfill;
- No. 2 – area of the Shymkent airport;
- No. 3 – 18th Microdistrict;
- No. 4 – 3 km west of the solid waste landfill, Akzhar Microdistrict;
- No. 5 – Shymkent treatment facilities of waste processing plants;
- No. 6 – “Student Square”;
- No. 7 – Anarova Str. (railway district);
- No. 8 – Embankment Str. (Badam River); the background is the forest massif of the “Yntymak” Microdistrict (conditionally background territory).

To measure the height of the snow cover, a snow gauge was utilized. Gravimetric studies relied on a drying cabinet for snowmelt water (SMW) samples, specifically the 67/350 model, and laboratory scales (VLR-200 g). To assess suspended solids (dust) during winter, a snow blower was deployed, while a dust collector was employed for spring-summer assessments. Density measurements were conducted using a snow gauge. Potentiometric studies involved an ionomer pH-120 device for pH measurements. Titrimetric studies utilized a chloridometer as the measuring instrument. The concentration of carbon monoxide was determined using a Clarus 690 gas chromatograph, while ammonium nitrogen levels were measured using a photoelectric colorimeter. Photocolorimeters were employed to assess the concentration of nitrate and nitrite ions, whereas a voltammetric analyzer TA-4 was used for nitrite ion concentration determination. Phosphate ion concentration was determined through a spectrophotometer called KFK-

ZOM3. Additionally, physical and mechanical properties of soil samples were studied using a scanning electron microscope (SEM).

The analysed parameters included: the level of the average snow depth, the mass of snow inflow, suspended matter content, density, pH, chloride content, mass concentration of carbon monoxide, ammonium nitrogen, nitrate ions, nitrite ions and phosphate ions. The results of measurements of the snow cover height within the study area showed that the height varied from 15 to 60 cm and averaged 45 cm. The maximum value of snow cover thickness was noted at sampling point No. 7 – 60 cm, which is due to the lack of multi-storey buildings. The minimum value was obtained at sampling point No. 8 – 15 cm (Fig. 2).

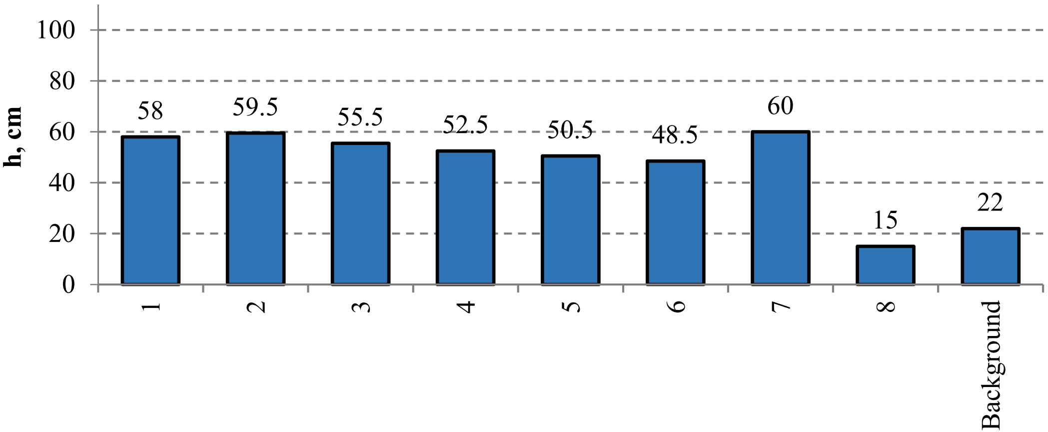

**Fig. 2:** Snow depth in Shymkent.

Source: compiled by the authors.

Despite the fact that the height of the snow cover is often associated with the intensity of spring floods, the amount of snow precipitation in Kazakhstan has little effect on the flood situation on its territory. As a method for determining the content of suspended substances (dust) in the snow cover, the snow cover indication method was used. Snow samples in the area of the solid waste landfill in Shymkent, including a background sample, were taken in accordance with the document regulating the organization and control of air pollution [15]. Snow sampling was carried out in the first 10 days of March 2023. Snow sampling began with the laying of profiles, 5 snow samples weighing 6-10 kg were collected. At each site, height measurements were taken and the characteristics of the snow cover were described. Using a snow sampler, snow samples were taken at 4 points in the corners and one in the centre of the sample area, and then an average sample with a total mass of up to 10 kg was collected using the envelope method.

In the course of snow sample preparation, a separate analysis was carried out of melted snow water and a solid sediment consisting of atmospheric dust that settled on the snow cover. Melt water from each site was filtered, and the residues dried on the filter. The difference in the mass of the paper filter before and after filtration characterizes the mass of dust in the sample. In this way, the quantitative level of dust in snow water samples was determined. The calculation of the dust load was carried out according to the formula:

$$Pn = Po/St, \qquad (1)$$

where $P_n$ – dust load, mg/m$^2$ (days); $P_o$ is the mass of dust in the sample, mg; S is the area of the pit, m$^2$; t is the time from the date of snow cover to the date of sampling, days.

In practice, the following gradation is used in terms of dust load: less than 250 – low degree of pollution; 251-450 – average s; 451-850 – high; over 850 is very high. When conducting snow surveys in the study area, the average level of snow cover depth was determined, and for dust fallout, the dust concentration, mg, and dust load (mass of dust entering the snow cover), $P_n$ in kg/km$^2$ (day) or mg/m$^2$ (day) are the amounts of solid precipitation per unit of time per unit area, as well as the mass of snow inflow, kg/m$^2$ (5 months). The results of calculating the mass of dust input (in water-insoluble form) on the snow cover are shown in Table 1.

Table 1. Calculation data for the mass of snow and dust entering the surface atmosphere (water-insoluble form) of the surveyed area of the territory of Shymkent for March 2023

| No. | Sampling point | Snow receipt, kg/m$^2$ (5 months) | Average snow depth, cm | Dust load | | Degree of pollution |
|---|---|---|---|---|---|---|
| | | | | g/m$^2$ (5 months) | mg/m$^2$ (days) | |
| 1 | Shymkent, 300 m west of the solid waste landfill | 72 | 11 | 2.3 | 15.2 | Low |
| 2 | Shymkent, 600 m west of the landfill | 81 | 12 | 1.2 | 8.3 | Low |
| 3 | Shymkent, 1.5 km west of the landfill | 82 | 13.4 | 1.35 | 9.5 | Low |
| 4 | Shymkent, 3 km west of the solid waste landfill | 74 | 11.6 | 2.25 | 14.5 | Low |
| 5 | Background sample (forest in the Yntymak Microdistrict) | 132 | 27 | 1 | 4.3 | Low |
| 6 | Average (excluding background) | 77.1 | 12.1 | 1.9 | 12 | |

Source: compiled by the authors.

The experimental data indicate that the supply of snow, excluding the background, at individual points varied from 72 to 82 kg/m$^2$ (5 months), the height of the snow cover was from 11 to 13.4 cm. The maximum snow supply was recorded 11 km from the city Shymkent in the Yntymak Microdistrict (background sample). The greatest value of the mass of snow input is associated with the location of this site in the forest area. The mass of dust load on the snow cover ranged from 1.2 to 2.3 g/m$^2$ (5 months) or 8.3-15.2 mg/m$^2$ (day) (Fig. 3).

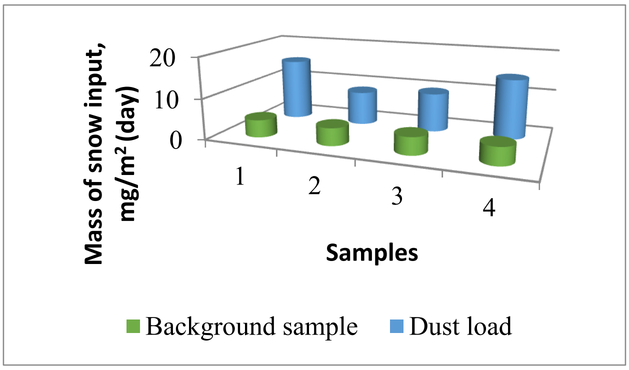

**Fig. 3:** Indicators of the mass of snow and dust inflow (water-insoluble form) to the surveyed area of the territory of Shymkent for March 2023.

Source: compiled by the authors.

The average content of suspended matter (dust) in the samples of melt water from the snow cover of the study area is 12 mg/m$^2$. The maximum amount was found in the sample taken at point No. 1 – 15.2 mg/m$^2$ (day), and the minimum – at sampling point No. 2 and is 8.3 mg/m$^2$ (day). The highest amount of dust load was noted 300 m and 3 km west of the solid waste landfill, and the lowest level was detected in the remaining sampling areas. As a result of the study, indicators were obtained according to which the degree of dust contamination of the snow cover in the area of the solid waste landfill in Shymkent was assessed as low. In 2019-2020, such physical and chemical substances as suspended substances in the water body of the river. Badam was not found. In 2019-2020 in the river. Magnesium and phenols (hazard class 4 substances) were found in Badam [16),17)].

In the course of a study conducted in 2023, the highest value of suspended solids content was noted in sample No. 1 – 15.2 mg/m$^2$ (day), which may be due to the territorial location of sampling points. In the immediate vicinity and along the wind rose is the Akzhar Microdistrict, from which rubbish collection companies, in violation of contractual obligations, stopped exporting solid waste, citing the refusal by the rise in price and the shortage of diesel fuel. The data obtained indicate a significant uneven distribution of suspended solids within the urbanized territory of the city of Shymkent and indicate the local nature of pollution. To study the dust load of the surface atmosphere, 10 dust collectors were installed on the territory of the city of Shymkent. Dust collection was carried out from April 15 to June 12, 2023. Based on the results of air quality monitoring in Shymkent for 2019-2022, an average concentration of suspended solids (dust) was noted – 0.16-0.174 mg/m$^3$ (pollutant content in 2021 exceeded the multiplicity of the average daily value of MAC ($MAC_{s.s.}$) 1.157 [18),19)]. The results of calculating the mass of dust entering the surface atmosphere are shown in Table 2.

Table 2. Data for calculating the mass of dust entering the surface atmosphere in the surveyed area of the territory of Shymkent for April-June 2023.

| No. | Sampling point | Dust load | | Degree of pollution |
|---|---|---|---|---|
| | | g/m$^2$ (5 months) | mg/m$^2$ (day) | |
| 1 | Shymkent, 300 m west of the solid waste landfill | 280.1 | 450 | Average |
| 2 | Shymkent, 600 m west of the landfill | 260.2 | 353.3 | Average |
| 3 | Shymkent, 1.5 km west of the landfill | 265.3 | 356.5 | Average |
| 4 | Shymkent, 3 km west of the landfill | 270.2 | 447.1 | Average |
| 5 | Background sample (forest in the | 251.1 | 342.3 | Average |

| | | | | |
|---|---|---|---|---|
| | Yntymak Microdistrict) | | | |
| | Average value (excluding background) | 260.9 | 350 | |

Source: compiled by the authors.

Experimental data indicate that the mass of dust load on the surface atmosphere ranged from 260.2 to 280.1 g/m$^2$ (5 months) or 353.3-450 mg/m$^2$ (day) (Fig. 4).

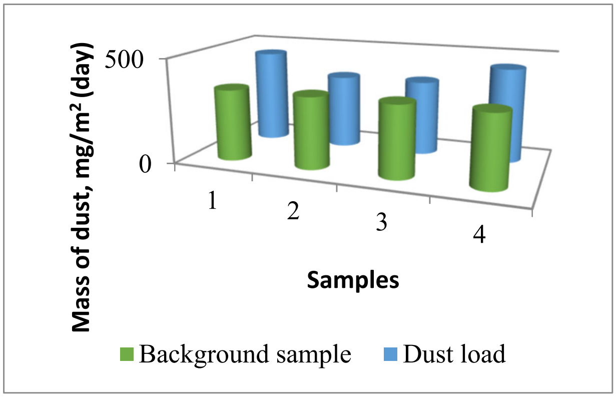

**Fig. 4:** Indicators of the mass of dust entering the surface atmosphere on the surveyed area of the territory of Shymkent for April-June 2023.

Source: compiled by the authors.

The average content of suspended substances (dust) in samples of melt water from the snow cover of the study area is 350 mg/m$^2$. The maximum amount was found in the sample taken at point No. 1 – 450 mg/m$^2$ (day), and the minimum – at sampling point No. 2 and is 353.3 mg/m$^2$ (day). The highest amount of dust load was noted 300 m and 3 km west of the solid waste landfill, and the lowest level was detected in the remaining sampling areas. As a result of the study, indicators were obtained, from which it became known that the degree of dust pollution of the ground atmosphere in the area of the solid waste landfill in Shymkent was assessed as average. During a study conducted in 2023, the highest value of suspended solids was noted in sample No. 1 – 450 mg/m$^2$ (day), which may be due to the territorial location of sampling points. In the immediate vicinity and along the wind rose is the Akzhar Microdistrict, in which the presence of accumulations of MSW that were not removed outside the residential area was noted. The data obtained indicate a significant uneven distribution of suspended substances within the urbanized territory of the city of Shymkent and indicate the local nature of the pollution. The snow density in the study area varied within a narrow range, from 0.22 to 0.29 g/cm$^3$ and averaged 0.26 g/cm$^3$. The data obtained indicate insignificant variability in microclimatic conditions that determine the snowmelt regime (Fig. 5)

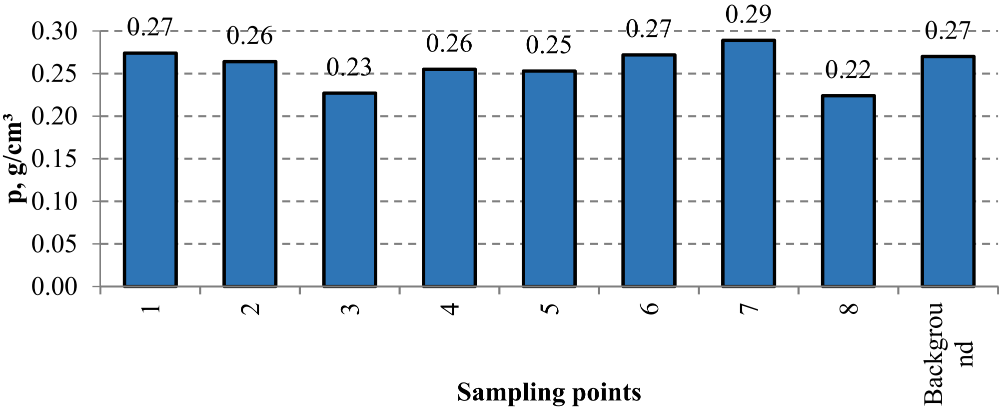

**Fig. 5:** Snow cover density on the territory of Shymkent.

Source: compiled by the authors.

A large accumulation of snow mass is facilitated by the absence of strong thaws and the long duration of occurrence. The density of snow cover often depends on the location. In open areas exposed to wind and solar radiation, the density of snow cover will be higher than in forest, park, and yard areas. In the course of the study, it was found that the average pH value in Shymkent is 6.33±0.1. The highest indicator corresponds to the snow cover at sampling point No. 6 – 6.6±0.1. The smallest indicator corresponds to point No. 8 – 5.78±0.1 (Fig. 6).

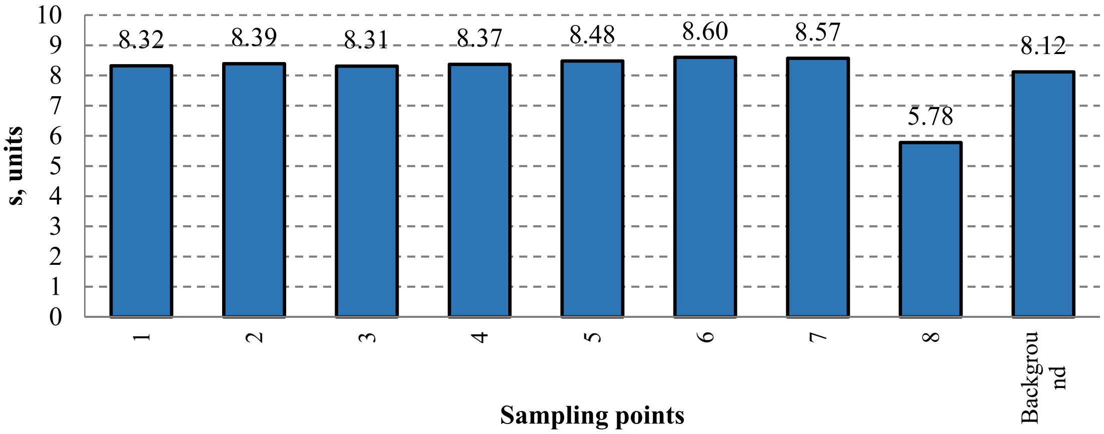

**Fig. 6:** Hydrogen index (pH).

Source: compiled by the authors.

According to informational data on the state of the environment of the Republic of Kazakhstan, regarding the measurement of the level of acidity (pH) during 2019-2022, it was found that the pH of snowmelt waters is in the range of slightly acidic values from 6.4 to 7.9 units [20]. Sample No. 8 corresponds to this range; the rest have an excess. The highest levels of acidity can be traced at sampling points No. 6 and No. 7. Point No. 6 is located 40 m from the highway with busy traffic. Point No. 7 is 30 m from the railway, as well as within a radius of 500 m, there is a large accumulation of landfills. The average value of chloride content in the snow cover of the study area is 23.42±0.13 mg/dm³ (Fig. 7).

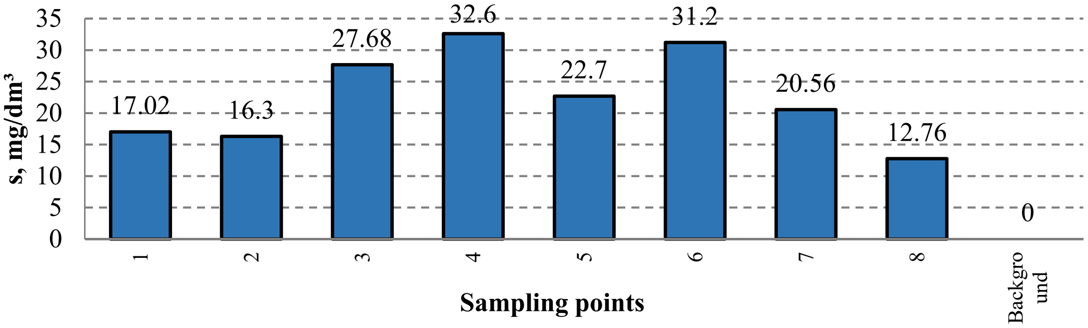

**Fig. 7:** Chloride content.

Source: compiled by the authors.

According to the study, the level of chloride content in the snow cover of the urbanized zone of the city of Shymkent, relative to the background concentration, is higher and corresponds to the range from 12.76±0.15 mg/dm³ at sampling point No. 8, up to 32.6±0.09 mg/dm³ at point No. 4. No chlorides were found in a sample of melt water from the snow cover taken at a point outside the urbanized zone, which indicates the influence of anthropogenic activities on the level of pollution of the snow cover. The chloride content may be determined by the proximity of sampling points to landfills. The average carbon monoxide content in samples of melt water from the snow cover of the study area is 77.5±5 mg/dm³. The maximum amount was found in samples taken at point No. 4 – 301±10 mg/dm³, and the minimum – at sampling point No. 3 and is 18±2 mg/dm³ (Fig. 8).

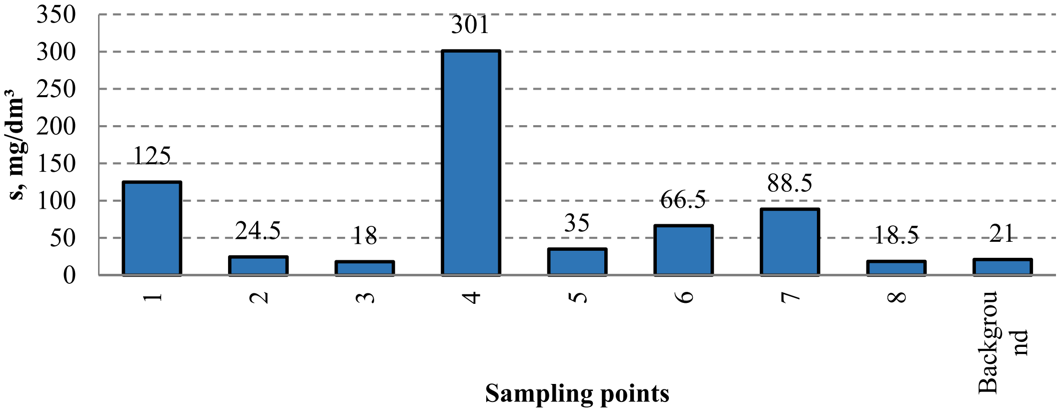

**Fig. 8:** Carbon monoxide content in the territory of Shymkent.

Source: compiled by the authors.

According to studies conducted in 2021, the concentration of carbon monoxide on the territory of the city of Shymkent, on average, was 20 mg/dm$^3$ 1). In the course of a study conducted in 2023, the highest value of carbon monoxide was noted in sample No. 4 – 301±10 mg/dm$^3$, which may be due to the territorial location of the sampling point. In the immediate vicinity and along the wind rose, there is a solid waste landfill, to which industrial explosive and self-igniting waste is sent. The data obtained indicates a significant uneven distribution of carbon monoxide within the urban area of the city of Shymkent and speaks of the local nature of pollution. The average value of the ammonium nitrogen content in the snow cover of the urbanized area of the city of Shymkent for 2023 is 0.67±0.038 mg/dm$^3$. The maximum value is observed at sampling point No. 3 – 0.96±0.048 mg/dm$^3$. Minimum at point No. 8 – 0.4±0.02 mg/dm$^3$ (Fig. 9).

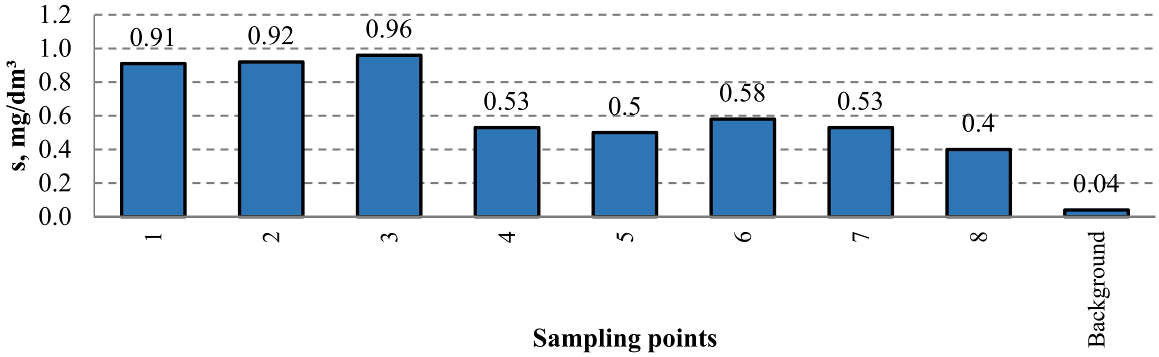

**Fig. 9:** Ammonium nitrogen content.

Source: compiled by the authors.

According to the results of the studies, which corresponds to the research data conducted in 2023, except for the excess at sampling points No. 1 – 0.91±0.045 mg/dm$^3$, No. 2 – 0.92±0.045 mg/dm$^3$ and No. 3 – 0.96±0.048 mg/dm$^3$ 19). According to the study, the background concentration of ammonium nitrogen is 0.04±0.002 mg/dm$^3$. Samples taken in the urbanized area of the city of Shymkent have a significant excess from 10 to 24 times. Ammonium nitrogen is a background component of atmospheric precipitation and appears as a result of human activities. The average value of the content of nitrate ions in the city of Shymkent is 68.81±17 mg/dm$^3$. The maximum indicator can be traced in the snow cover of sampling point No. 7 – 268.37±67 mg/dm$^3$. Minimum at point No. 3 – 1.61±0.4 mg/dm$^3$ (Fig. 10).

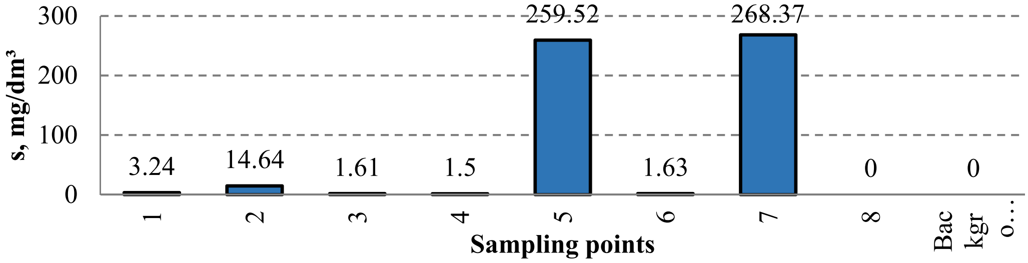

**Fig. 10:** Content of nitrate ions.

Source: compiled by the authors.

According to the results of studies conducted for 2019-2022, the level of nitrate ions during the study period fluctuates in the range of 1.23-2.53 mg/dm$^3$ 19). According to the study, a large excess of the content of nitrate ions can be traced at the sampling points No. 7 – 268.37±67 mg/dm$^3$ and No. 5 – 259.52±65 mg/dm$^3$. Such a large excess at sampling points No. 7 and No. 5 may be due to the proximity (250-280 m) to waste treatment plants. In the snow cover sampled outside the urbanized zone, nitrate ions were not found, which indicates the influence of anthropogenic activity on the level of pollution of the snow cover. The average content of nitrite ions within the study area is 0.03±0.007 mg/dm$^3$. The maximum index is observed in the snow cover sampled at point No. 2 – 0.04±0.01 mg/dm$^3$. Minimum at point No. 6 – 0.02±0.005 mg/dm$^3$ (Fig. 11).

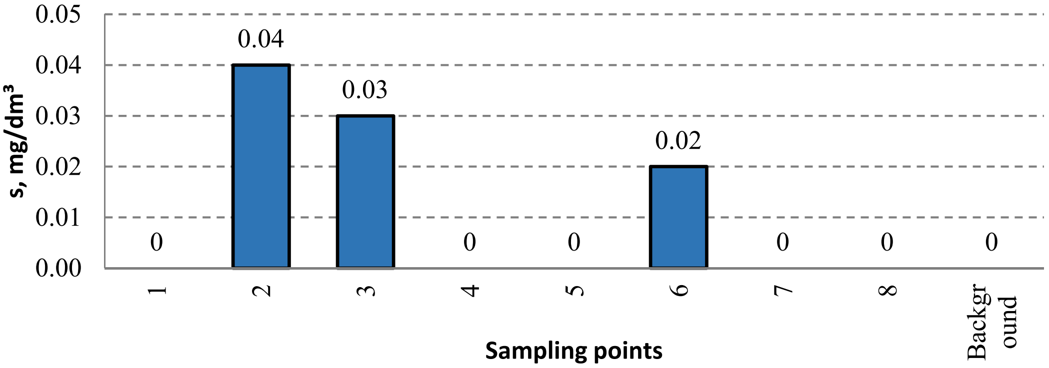

**Fig. 11:** Nitrite ion content.

Source: compiled by the authors.

According to the study on the background concentration, the melted waters of the snow cover have an excess of points No. 2 – 0.04±0.1 mg/dm$^3$, No. 3 – 0.03±0.007 mg/dm$^3$ and No. 6 – 0.02±0.005 mg/dm$^3$. No other points of nitrite ions were found in the snow cover. In the snow cover sampled outside the urbanized zone, nitrite ions were not found, which indicates the influence of anthropogenic activity on the level of pollution of the snow cover. Nitrite ions appear as a result of human activities and are the background components of precipitation. According to the study, phosphate ions were found only in the melt waters of the snow cover of point No. 2 – 0.08±0.0001 mg/dm$^3$ located in the area of Shymkent airport (Fig. 12).

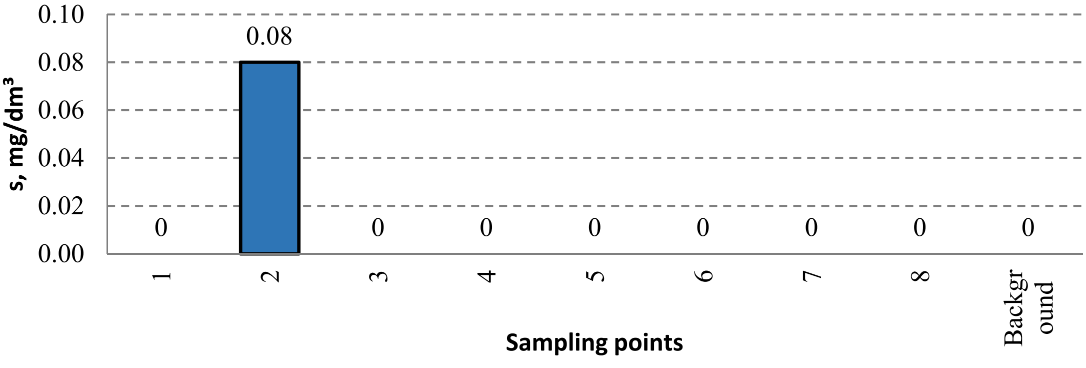

**Fig. 12:** The content of phosphate ions.

Source: compiled by the authors.

At other sampling points, including the point taken outside the urbanized zone, no phosphate ions were found, which indicates the influence of anthropogenic activity on the level of pollution of the snow cover at the sampling point No. 2. Phosphate ions are the background components of precipitation and appear as a result of human anthropogenic activity. Table 3 summarizes the results of the study of the snow cover and the surface layer of the atmosphere in the territory of Shymkent.

Table 3. Results of studies of snow cover in the territory of Shymkent.

| No. | h, cm | SS, mg/m$^2$ (dust) winter period | SS, mg/m$^2$ (dust) summer period | ρ, g/cm$^3$ | pH | Chlorides, mg/dm³ | Carbon monoxide, mg/dm³ | Ammonium nitrogen, mg/dm³ | Nitrate ions, mg/dm³ | Nitrite ions, mg/dm³ | Phosphate ions, mg/dm³ |
|---|---|---|---|---|---|---|---|---|---|---|---|
| 1 | 58 | 15.2 | 450 | 0.274 | 8.32±0.1 | 17.02±0.15 | 125±0.03 | 0.91±0.045 | 3.24±0.8 | n/a | n/a |
| 2 | 59.5 | 8.3 | 353.3 | 0.264 | 8.39±0.1 | 16.3±0.15 | 24.5±0.03 | 0.92±0.046 | 14.64±3.7 | 0.04±0.01 | 0.08±0.001 |
| 3 | 55.5 | 9.5 | 356.5 | 0.227 | 8.31±0.1 | 27.65±0.09 | 18±0.03 | 0.96±0.048 | 1.61±0.4 | 0.03±0.007 | n/a |
| 4 | 52.5 | 14.5 | 447.1 | 0.255 | 8.37±0.1 | 32.6±0.09 | 301±0.02 | 0.53±0.026 | 1.5±0.38 | n/a | n/a |
| 5 | 50.5 | n/a | n/a | 0.253 | 8.48±0.1 | 22.7±0.15 | 35±0.03 | 0.5±0.025 | 259.52±65 | n/a | n/a |
| 6 | 48.5 | n/a | n/a | 0.272 | 8.6±0.1 | 31.2±0.09 | 66.5±0.04 | 0.58±0.029 | 1.63±0.4 | 0.02±0.005 | n/a |
| 7 | 60 | n/a | n/a | 0.289 | 8.57±0.1 | 20.56±0.15 | 88.5±0.05 | 0.53±0.026 | 268.37±67 | n/a | n/a |
| 8 | 15 | n/a | n/a | 0.224 | 5.78±0.1 | 12.76±0.15 | 18.5±0.02 | 0.4±0.02 | n/a | n/a | n/a |
| B | 22 | 4.3 | 342.3 | 0.267 | 8.12±0.1 | n/a | 21±0.03 | 0.04±0.002 | n/a | n/a | n/a |

Note: B – Background; SS – Suspended substances.

Source: compiled by the authors

Based on the results, it was revealed that of all the studied pollutants, the most significant pollutant of the snow cover in terms of content is carbon monoxide (CO) – a colourless, combustible and toxic gas released during the combustion of municipal solid waste, detected at a distance of 3 km west of the solid waste landfill near the Akzhar Microdistrict – 301±0.02 mg/dm³. Soil samples of soddy-podzolic soil 2-5 mm in size were selected for experimental studies, their surface was analysed using a SEM. 18 samples of 9 soils, typical for Shymkent, were selected for experimental studies. Compression studies were carried out on cylindrical samples with a diameter of 20 mm and a height of 50 mm in the direction perpendicular to the layering. Determination of shear strength was carried out according to the scheme of two planar sections of a beam with a cross-section of 1.5-1 cm$^2$ without applying a normal load (Fig. 13).

**Fig. 13:** Layout of sampling sites for SEM studies in Shymkent.

Source: compiled by the authors.

Mathematical and statistical processing of the analysed images of soil samples processed using the Structural Image Analysis (STIMAN) software package was carried out using the least squares method. The main results of the conducted studies are as follows (Table 4).

Table 4. Results of mathematical and statistical processing of soil samples.

| No. p/p | No. of a point | $M_{<0.005}$, in % | P*10$^3$, μm | ln$E_y$, MPa | A*10$^3$ μm$^2$ |
|---|---|---|---|---|---|
| 1 | T1-1 | 28 | 1.7 | -2 | 5.3 |
| 2 | T1-2 | 37 | 2.2 | -2.7 | 4.6 |
| 3 | T2-1 | 44 | 2.2 | -1 | 3.8 |
| 4 | T2-2 | 54 | 2.8 | 0 | 3.7 |
| 5 | T3-1 | 57 | 3.1 | 1.4 | 3 |
| 6 | T3-2 | 55 | 3.3 | 1.4 | 3.3 |
| 7 | T4-1 | 64 | 3.6 | 2.2 | 2.3 |
| 8 | T4-2 | 69 | 4.2 | 2 | 2.3 |
| 9 | T5-1 | 79 | 4.8 | 4 | 1.7 |
| 10 | T5-2 | 87 | 5.2 | 6 | 0.7 |
| 11 | T6-1 | 23 | 2 | -2.7 | 5.7 |
| 12 | T6-2 | 22 | 2.5 | 0 | 5.2 |
| 13 | T7-1 | 51 | 2.6 | 0.2 | 4.7 |
| 14 | T7-2 | 45 | 3.2 | 1.2 | 4 |
| 15 | T8-1 | 46 | 3.5 | 1.7 | 3.1 |
| 16 | T8-2 | 53 | 3.9 | 6 | 3.1 |
| 17 | T9-1 | 54 | 4.1 | 5 | 2.4 |
| 18 | T9-2 | 67 | 4.6 | 5 | 2.1 |

Note: M – % particle content <0.005; P – μm pore perimeter, A – pore area, μm$^2$; E0 – total deformation modulus; Ey – specific deformation modulus.

Source: compiled by the authors.

From Table 4 it follows that the study of the pore space of soil samples or, in general, dispersed materials, in addition to the qualitative characteristics of their spatial microstructural organization, allows one to obtain quantitative relationships between physical and mechanical parameters and morphometric characteristics. As experimental studies have shown, the total porosity is closely correlated with the total pore area measured from the SEM image.

Analysis of snow cover and soil samples revealed relationships between parameters like deformation modulus, pore characteristics, and pollutant levels. Carbon monoxide and dust pollution were highest near the solid waste landfill. The data shows uneven distribution of pollutants in Shymkent, with hotspots near industrial areas and landfills. Overall, the results point to worsening environmental conditions in Shymkent tied to human activities, necessitating a careful examination of mitigation policies and actions to manage the risks.

## 4. Discussion

Analysing the results of the study, the conclusion was made that when burning municipal solid waste, in particular plastic bottles, polyethylene, products based on polyvinyl chloride (PVC) and synthetic materials such as nylon, some acrylics, and polyurethane foams, often used for stuffing sofas, armchairs and mattresses, as well as for the manufacture of rugs on a foam lining, numerous various toxins are formed, which, in combination with other pollutants, is extremely dangerous. Comparing the study with the results of studies of other authors on the chosen topic, it should be noted that researchers from the United States Environmental Protection Agency (ERA) for the protection of the environment. Research Department, U.S. ERA [21)] on Chemical Safety and Pollution Prevention, consists in studying the toxicity of particulate dust and fine dust ($PM_{10}$). It was found that by adsorbing toxic substances on its surface, dispersed dust contributes to the thinning of the mucous membrane of the human upper respiratory tract, the occurrence of skin cancer, and exacerbation of respiratory diseases. It was also noted that fine dust ($PM_{10}$) has an even higher toxicity class, which can stay in the atmosphere in a suspended state for several days and be transported tens or hundreds of kilometres from the source of exposure, posing a serious threat to the health of the lower respiratory tract.

Research R. Sahu and R.D. Gupta [22)] were to analyse the area of snow cover and its relationship with climate variability in the Chandra River basin, Western Himalayas, in the period 2001-2017, using Moderate Data Resolution Imaging Spectroradiometer (MODIS) and ERA5. The assessment of the state of the environment showed that the total average observed snow cover area (SCA) is 84.94% of the basin area for the study period. The maximum average annual SCA was 91.23% in 2009, and the minimum was 76.37% in 2016. There is a strong correlation of annual and seasonal SCA with temperature, indicating that SCA variability is very sensitive to temperature. The work by W. Chen et al. [23)] was to study the radiative forcing of soot in seasonal winter snow based on remote sensing data over Xinjiang, a region in north-western China. Black carbon (BC), which consists of the strongest light-absorbing particles in snow, has been considered as a potential factor accelerating regional climate change and global snowmelt. In the study, the authors used remote sensing observations (Medium Resolution Imaging Spectroradiometer (MODIS)) combined with a snow albedo model – snow, ice, and aerosol radiation (SNICAR) and a radiative transport model (Santa Barbara Atmospheric Radiative Transport (SBDART)) to obtain a radiative forcing (RF) with BC in snow ($R^{BS}$) for the first time in Xinjiang, China.

Research by W. Chen et al. [24)] consisted of studying the concentration and distribution of carbon black sources using the AE-33 model. In the urban area of Shenzhen (southern China), changes in BC concentrations throughout the dry season were assessed and the sources of BC, including fossil fuels (e.g., vehicle emissions) and biomass fuels (e.g., industrial emissions), were assessed. The research by W. Chen et al. [25)] was to investigate the feasibility of using multiscale normalized difference vegetation index data to estimate total suspended solids (TSS) concentrations in surface waters. Watershed degradation puts enormous pressure on water quality, especially in arid and semi-arid regions. TSS provides important information for assessing environmental water quality. The authors suggested that a common remote sensing index (normalized difference vegetation index (NDVI)) could be used to estimate TSS concentrations in water due to the influence of vegetation cover. To test this hypothesis, 65 water samples from the Ebinur Lake watershed in northwest China were collected to investigate the potential relationship between Sentinel-2-based TSS and NDVI concentrations at different scales (100, 200, 300, 400, and 500 m). The authors developed a classical measurement error (CME) model to estimate TSS concentrations. The results showed that TSS concentration was negatively associated with NDVI value at all buffer distances. The average NDVI value at 300 m scale showed the most effective explanation of changes in TSS concentrations ($R_2$=0.83; P-value<0.001), indicating that TSS concentration can be estimated using NDVI.

The research by M. Ahmad et al. [26)] consisted in studying the contrast changes in the snow cover and its sensitivity to the aerosol optical properties (AOPs) in the Hindu Kush-Karakorum Himalayan region. As a result of their research, a tendency was revealed for SCA to increase at a rate of 577.3, 1090.6, and 652.3 km$^2$/year in March, May, and June, respectively, with a decrease in April due to the uneven distribution of SCA during 2005-2015. The results showed a strong positive correlation (R=0.77) between SCA and AOPs, while SCA and TSS were negatively correlated (R=-0.82) during the study period. The work by A.P. Yunus et al. [27)] was to conduct analysis of long-term (2002-2020) trends and peaks in total suspended solids in the Chesapeake Bay using MODIS images. The authors developed a fully automated Google Earth Engine (GEE) for estimating overall TSS in the Chesapeake Bay based on spectroradiometer images Terra with moderate MODIS resolution. A time series analysis was performed that showed a decreasing trend in TSS concentrations between 2002 and 2020, suggesting that the sediment concentration in the bay has been gradually declining over the past two decades. A downward trend was observed in 49 of the 60 bay segments, indicating significant progress in meeting water quality standards in the Chesapeake Bay.

In the work, the authors Y. Du et al. 28) characterized the total amount of suspended matter and management of lakes in East China. In the study, the authors, using empirical methods, developed a robust model (root-mean-square error (RMSE)), bias, nash-sutcliffe efficiency (NSE) and relative error RE were 26.63 mg/L, -4.86 mg/L, 0.47 and 16.47%, respectively, to estimate total TSS in lakes and reservoirs (hereinafter referred to as lakes) across the Eastern Plain Lakes Zone (EPL). The model was based on 700 in-situ TSS samples collected during 2007-2020 and a log-transformed Landsat redband reflectance. Based on the GEE engine, TSS concentrations were mapped in 16,804 lakes between 1984 and 2019. P. Trechera et al. 29) described the phenomenology of urban ultrafine particles (UFP) in Europe and paid particular attention to air quality. Hourly particle number size distribution (PNSD) for 2017-2019 were assessed from 26 sites in Europe and 1 in the US, focusing on 16 urban background and 6 traffic objects within the research infrastructure strengthening air quality monitoring capabilities in European urban and industrial areas (RI-URBANS).

In the work, the authors D. Wu et al. 30) reviewed the causes and effects of long-range dispersion of carbonaceous aerosols from bushfires in Australia in 2019-2020. The authors investigated the atmospheric dynamics and the thermodynamic mechanism of long-range transport of carbonaceous aerosols (CAs) from November 2019 to February 2020. The results show that the emitted CAs had a triple adjective distribution pattern across the Pacific Ocean in the Southern Hemisphere (SH), mainly influenced by westerly winds and anticyclonic systems. In the work, the authors L. Tripathee et al. 31) measured mercury, other trace elements and major ions from wet deposition in Jomsom, a semi-arid mountain valley in the Central Himalayas. Pollutants from South Asia can be transported and deposited by wet/dry deposition in the remote areas of the Himalayas and can pose a serious threat to mountain ecosystems. Therefore, in order to understand the concentrations, fluxes, seasonal variations, and origins of mercury (Hg), major ions and trace elements, during 2012-2013, researchers collected precipitation samples from a region with data gaps, Jomsom, a high semi-arid mountain valley in the central Himalayas.

In the work, the authors A.P.F.V. Furtado et al. 32) appreciated the importance of sanitary, environmental and urban improvements implemented on the watershed. Estimated total phosphorus (TP) and total TSS transported to LP between 2016 and 2017 based on hydrological and water quality monitoring data. In addition, simulations were carried out using the Storm Water Management Model (SWMM) to estimate the TP and TSS loads in hypothetical scenarios. In the work, the authors X. Tan et al. 33) conducted a sequential search for aerosol optical depth and total suspended solids' concentration in the turbid coastal waters of East China. The researchers proposed an algorithm to sequentially determine aerosol optical depth (AOD) and total TSS in turbid coastal water using shortwave infrared and visible light.

In the work, the authors D. Ghaderi and M. Rahbani 34) tracked suspended solids at the mouth of the Tiab River, north of the Persian Gulf, using artificial neural networks (ANNs) and remote sensing. To conduct the study, the authors used combined methods of direct and indirect measurements of suspended sediments. Field measurements were taken during two planned cruises, one in October and one in November 2015. The current velocity and turbidity were recorded using the CM9 device and an optical backscatter sensor. Water samples were taken with a Niskin bottle. The Niskin bottle is an oceanographic bottle designed for collecting water samples at different water depths.

T.N. Do et al. 35) assessed surface water pollution in Hanoi, Vietnam using remote sensing and machine learning algorithms. Researchers have developed a methodology to better track and analyse pollutants in surface waters. The results were compared with field data using regression models. The results show that ML-CB based pollutant predictive estimates provide significant results. The authors proposed an alternative water quality monitoring method for managers and urban planners that could play an important role in the protection and sustainable use of surface water resources in Hanoi and other cities in the Global South.

In the work, the authors M.M. Bolick et al. 36) monitored water quality in urban watersheds and compared machine learning algorithms for predicting dissolved oxygen in urban streams. The authors identified a successful predictive machine learning model with minimal parameters based on the use of simple, low-cost sensors to create a monitoring system for the urban network stream, Hunnicutt Creek, in Clemson, South Carolina, USA. In the work, the authors I. Bashir et al. 37) considered the problems and threats of pollution of aquatic ecosystems. Researchers regularly monitored and controlled the release of pollutants into nearby water bodies. In the work, the authors J. Xu et al. 38) conducted long-term monitoring of changes in particulate matter composition in the Great Lakes using MODIS data. In this study, a semi-analytical algorithm based on Rayleigh-corrected reflectance at 678 nm and 748 nm on MODIS images was used to estimate the ratio of chlorophyll – a TSS, which characterizes particulate composition of the Great Lakes. Long-term spatial and temporal characteristics of total suspended sediment and chlorophyll – a TSS in the Great Lakes region from 2000 to 2020. More than 120,000,000 tons of MSW is in landfills in Kazakhstan. Every year, these wastes increase by 5,000,000 tons. Of these, about 15% of waste goes to the processing and disposal of MSW.

The circular economy (CE) by its very nature involves the circulation of waste in production. Consequently, in the conditions of using waste in a continuous technological and production cycle, there is no need directly for waste disposal facilities (WDF). Indeed, waste disposal activities involve their storage and disposal in appropriate, special facilities. At the same time, storage involves the storage of waste for the purpose of further disposal, neutralization, and burial. Burial, in turn, involves the isolation of waste that is not subject to further disposal. It should be noted that each of these types of waste management, by its nature, does not imply their further use in economic activity. Accordingly, if waste disposal is not envisaged under the conditions of the CE, then there is obviously no need for WDF. As part of the implementation of the transition to CE, it seems necessary to conceptually review the current legislation of Kazakhstan and make appropriate changes, consolidate new categories and legal mechanisms, which is undoubtedly the topic of independent scientific research. A separate issue in the process of this reform of legislation and the transition to a "green" economy is the issue of reforming the institution of waste disposal in Kazakhstan. In particular, the possibility of changing the content of the categories of storage and disposal of waste is allowed. For example, in relation to the storage of waste, it is presumably acceptable to understand this category as the accumulation of waste in the process of waiting for their reuse and processing.

## 5. Conclusions

In the course of the study, an assessment was made of the physicochemical properties of the snow cover and the level of pollution of the surface atmosphere in the territory of Shymkent. Analysis of the results allows to note that the average daily concentrations of suspended solids were characterized by low and medium pollution. In accordance with the gradation of levels of dust pollution of the snow cover, the indicators correspond to the gradation: low – 12 mg/m$^2$ (days) in the zone of influence of the solid waste landfill in Shymkent. In the spring-summer period, an average level of pollution of the surface atmosphere was recorded – 350 mg/m$^2$ (day) in the zone of influence of the MSW landfill in Shymkent. The mass of suspended particles (dust) from 1.2 to 2.3 g/m$^2$·5 (month) or 8.3-15.2 mg/m$^2$ entered the snow cover in winter. In the spring-summer period, the mass of dust load on the surface atmosphere ranged from 260.2 to 280.1 g/m$^2$·5 (months) or 353.3-450 mg/m$^2$ (days). In terms of the magnitude of winter and spring-summer dust load, the most unfavourable are the territories 300 m west of the solid waste landfill and the territory of the Akzhar Microdistrict, which is 3 km west of the solid waste landfill, the Shymkent airport area and the 18th Microdistrict are more favourable. From the results presented in the study, it can be concluded that the most toxic substance is carbon monoxide (carbon monoxide) released during the combustion of rubbish, the second place in terms of the content of pollutants was taken by nitrate ions, and the third place was taken by chlorides.

The ecological situation in Shymkent has developed in such a way that in the summer and winter surface atmospheres of the city, the brightest halos of dust pollution and anomalies of toxic elements are formed under the influence of the zones of MSW landfills and waste processing companies that violate the terms of the agreement on the placement of solid waste at the landfill and regular rubbish removal from residential neighbourhoods. To eliminate such a situation associated with the illegal disposal of MSW of hazard classes 1 and 2 and irregular rubbish collection, it is necessary to introduce an effective system of fines for violating companies in the waste industry. It was revealed that porous soils with a high content of fractions <0.005 mm have both a large total perimeter and pore area. The close correlation dependence as $M_{<0.005}$=f (A, P) does not contradict the existing pattern of porosity growth in more dispersed systems and indicates the complex shape of the microaggregate pores formed in them.

Further air monitoring is required to establish predictive models and quantify population exposures. Detailed epidemiological studies on the health impacts of the observed pollution increases would provide critical data to inform policy decisions and risk management. More work is needed to characterize relationships between pollutants, quantify emission levels, and identify unmonitored contaminants. Research into cleaner production technologies and waste management practices is necessary to develop evidence-based pollution control measures. Broader environmental monitoring and lifecycle analyses of anthropogenic activities would give a comprehensive picture of sustainability challenges.

## References

1) S. Syafrudin, M.A. Budihardjo, N. Yuliastuti, and B.S. Ramadan, "Assessment of greenhouse gases emission from integrated solid waste management in Semarang city, Central Java, Indonesia," *Evergreen*, 8 *(1)* 23-35 (2021). doi.org/10.5109/4372257
2) Climate and average weather year-round in Shymkent. (2023). https://weatherspark.com/y/106909/Average-Weather-in-Shymkent-Kazakhstan-Year-Round
3) A.R. Bizhanova, A.S. Koshkinbayeva, G.A. Zhunisova, D. Belkhozhayeva, and D.S. Baisymakova, "Regulatory Issues of Depollution in Kazakhstan,"

*Evergreen*, 9 *(4)* 903-908 (2022). doi.org/10.5109/6622877

4) Ye. Bitmanov, A. Abzhalelov, and L. Boluspayeva, "The content of heavy metals in the soil of central Kazakhstan," *Reports of the National Academy of Sciences of the Republic of Kazakhstan*, 3 *(343)* 5-14 (2022).
5) A.Z. Abilmagzhanov, N.S. Ivanov, A.E. Nurtazina, and I.E. Adelbayev, "Study of energy characteristics of solid household waste from the Almaty landfill," *Reports of the National Academy of Sciences of the Republic of Kazakhstan*, 5 *(339)* 73-81 (2021).
6) M.R. Aktayev, A.O. Aidarkhanov, A.K. Aidarkhanova, S.S. Pronin, and A.O. Iskenov, "Monitoring of tritium pollution of the Shagan river waters," *NNC RK Bulletin*, 2 25-29 (2021).
7) A.V. Panitskiy, A.E. Kunduzbayeva, and S.A. Baygazy, "Vertical distribution of radionuclides in soils of Semipalatinsk test site," *NNC RK Bulletin*, 3 31-38 (2022).
8) D. Vinnikov, Zh. Tulekov, and A. Raushanova, "Occupational exposure to particulate matter from air pollution in the outdoor workplaces in Almaty during the cold season," *PLoS ONE*, 15 *(1)* e0227447 (2020).
9) ST RK 1517-2006 "Environment protection. Atmosphere. Method for determination and calculation of amount of pollutants emission". https://online.zakon.kz/Document/?doc_id=30421302&pos=6;-106#pos=6;-106
10) ST RK 1877-2009 "Environment protection. Atmosphere. Method for determination and calculation of amount of pollutants emission". https://online.zakon.kz/Document/?doc_id=36980972
11) ST RK ISO 10396-2019 "Stationary source emissions – Sampling for the automated determination of gas emission concentrations for permanently-installed monitoring systems, IDT". https://online.zakon.kz/Document/?doc_id=34379723
12) ST RK 3461-2019 "Determination of background levels of pollutants in the components of the natural environment in areas where hazardous production facilities are located". https://online.zakon.kz/document/?doc_id=35076996#sub_id=0
13) Ecological code of the republic of Kazakhstan. (2021). https://adilet.zan.kz/eng/docs/K2100000400
14) Climate Shymkent. 2023. https://inlnk.ru/0Q2Z3E
15) ST RK 2036-2010 "Environment protection. Emissions. Guide to air pollution control". https://online.zakon.kz/Document/?doc_id=31607259
16) Ministry of Ecology, Geology and of Natural Resources of the Republic of Kazakhstan. (2019). Information bulletin on the state of the environment of the Republic of Kazakhstan for 2019. https://www.kazhydromet.kz/uploads/calendar/67/year_file/60e02bcd6bf98byulleten_2019-god_rus.pdf
17) N. Moldakhanova, S. Alimkulov, and Zh. Smagulov, "Analysis of Changes in the Ecological Space of the Ili River Delta (due to Reduced Flow of the Ili River)," *Evergreen*, 10 *(1)* 29-35 (2023). doi.org/10.5109/6781031
18) Ministry of Ecology, Geology and of Natural Resources of the Republic of Kazakhstan. (2021). Newsletter on the state of the environment in Shymkent and the Turkestan region in 2021. https://www.kazhydromet.kz/uploads/files_calendar/942/file/60d571aabf100inf-byull-obsch-russ-mart-21g.pdf
19) R. Muhammad, and S. Adityosulindro, "Biosorption of Brilliant Green Dye from Synthetic Wastewater by Modified Wild Algae Biomass," *Evergreen*, 9 *(1)* 133-140 (2022). doi.org/10.5109/4774228
20) Ministry of Ecology, Geology and of Natural Resources of the Republic of Kazakhstan. (2022). Information bulletin on the state of the environment of the Republic of Kazakhstan. https://www.kazhydromet.kz/uploads/calendar/116/year_file/63f6efd70fb3fgodovoy-rk-2022-rus.pdf
21) United States Environmental Protection Agency. (2023). National Emissions Inventory (NEI). https://www.epa.gov/air-emissions-inventories/national-emissions-inventory-nei
22) R. Sahu, and R.D. Gupta, "Snow cover area analysis and its relation with climate variability in Chandra basin, Western Himalaya, during 2001-2017 using MODIS and ERA5 data," *Environmental Monitoring and Assessment*, 192 489 (2020).
23) W. Chen, X. Wang, J. Cui, X. Cao, W. Pu, X. Zheng, H. Ran, and J. Ding, "Radiative forcing of black carbon in seasonal snow of wintertime based on remote sensing over Xinjiang, China," *Atmospheric Environment*, 247 *(15)* 118204 (2021).
24) W. Chen, X. Cao, H. Ran, T. Chen, B. Yang, and X. Zheng, "Concentration and source allocation of black carbon by AE-33 model in urban area of Shenzhen, southern China," *Journal of Environmental Health Science and Engineering*, 20 469-483 (2022).
25) W. Chen, J. Wang, X. Cao, H. Ran, D. Teng, J. Chen, X. He, and X. Zheng, "Possibility of using multiscale normalized difference vegetation index data for the assessment of total suspended solids (TSS) concentrations in surface water: A specific case of scale issues in remote sensing," *Environmental Research*, 194 110636 (2021).
26) M. Ahmad, K. Alam, S. Tariq, and T. Blaschke, "Contrasting changes in snow cover and its sensitivity to aerosol optical properties in Hindukush-Karakoram-Himalaya region," *Science of the Total Environment*, 699 *(10)* 134356 (2020).
27) A.P. Yunus, Y. Masago, and Y. Hijioka, "Analysis of long-term (2002-2020) trends and peak events in total suspended solids concentrations in the Chesapeake

Bay using MODIS imagery," *Journal of Environmental Management*, 299 *(1)* 113550 (2021).

28) Y. Du, K. Song, Q. Wang, S. Li, Z. Wen, G. Liu, H. Tao, Y. Shang, J. Hou, L. Lyu, and B. Zhang, "Total suspended solids characterization and management implications for lakes in East China," *Science of the Total Environment*, 806 151374 (2022).
29) P. Trechera, M. Garcia-Marlès, X. Liu, C. Reche, N. Pérez, M. Savadkoohi, D.Beddows, I. Salma, M. Vörösmarty, A. Casans, J.A. Casquero-Vera, C. Hueglin, N. Marchand, B. Chazeau, G. Gille, P. Kalkavouras, N. Mihalopoulos, J. Ondracek, N. Zikova, J.V. Niemi, and X. Querol, "Phenomenology of ultrafine particle concentrations and size distribution across urban Europe," *Environment International*, 172 107744 (2023).
30) D. Wu, X. Niu, Z. Chen, Y. Chen, Y. Xing, X. Cao, J. Liu, X. Wang, W. Pu, "Causes and effects of the long-range dispersion of carbonaceous aerosols from the 2019-2020 Australian wildfires," *Geophysical Research Letters*, 49 *(18)* e2022GL099840 (2022).
31) L. Tripathee, J. Guo, S. Kang, R. Paudyal, C.M. Sharma, J. Huang, P. Chen, P.S. Ghimire, M. Sigdel, M. Sillanpää, "Measurement of mercury, other trace elements and major ions in wet deposition at Jomsom: The semi-arid mountain valley of the Central Himalaya," *Atmospheric Research*, 234 104691 (2020).
32) A. P. F. V. Furtado, R. C. de Almeida Monte-Mor, E. De Agruiar do Couto, "Evaluation of reduction of external load of total phosphorus and total suspended solids for rehabilitation of urban lakes," *Journal of Environmental Management*, 296 113339 (2021).
33) X. Tan, B. Sun, G. Wang, T. Cheng, K. Huang, and F. Shen, "Consecutive retrieval of aerosol optical depth and total suspended solid concentration in turbid coastal water of Eastern China," *Journal of Quantitative Spectroscopy and Radiative Transfer*, 287 108231 (2022).
34) D. Ghaderi, and M. Rahbani, "Tracing suspended matter in Tiab estuary applying ANN and remote sensing," *Regional Studies in Marine Science*, 44 101788 (2021).
35) T.N. Do, D.M.T. Nguyen, J. Ghimire, K.C. Vu, L.P. Do Dang, S.L. Pham, and V.M. Pham, "Assessing surface water pollution in Hanoi, Vietnam, using remote sensing and machine learning algorithms," *Environmental Science and Pollution Research*, 30 82230-82247 (2023).
36) M.M. Bolick, C.J. Post, M.Z. Nased, and E.A. Mikhailova, "Comparison of machine learning algorithms to predict dissolved oxygen in an urban stream. *Environmental Science and Pollution Research*, 30 *(32)* 78075-78096 (2023).
37) I. Bashir, F.A. Lone, R.A. Bhat, S.A. Mir, Z.A. Dar, S.A. Dar, "Concerns and threats of contamination on aquatic ecosystems," in: *Bioremediation and Biotechnology* (pp. 1-26). Cham: Springer, 2020.
38) J. Xu, H. Liu, J. Lin, H. Lyu, X. Dong, Y. Li, H. Guo, and H. Wang, "Long-term monitoring particulate composition change in the Great Lakes using MODIS data," *Water Research*, 222 118932 (2022).