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Effect of Auto Road on Spatial Metal Distribution in Dust and Snow Cover

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ABSTRACT

The present investigation examined the impact of highways on the global dispersion patterns of metallic elements present in dust and snow. A total of 18 mixed snow samples were collected from both sides of the Moscow-Tambo-Astrakhan Caspian Highway by the end of the winter season. The analysis of the samples indicated the presence of 35 distinct chemical elements, where Al, Ba, Ca, Fe, K, Mg, Na, and Zn were identified as the primary contaminants. The primary area of pollution on the windward side originating from the road spans a distance of 20-40 meters, while on the leeward side, it extends to 10 meters. The data presented suggests that the metals found in highways exhibited variability in terms of their solubility in water and concentration. Our findings demonstrate that the predominant wind directions affect the dispersion of pollutants. Furthermore, it was observed that the region with a higher concentration of metal on the side of the road facing the wind had a thickness that was 2-3 times less than that of the opposite side. It is advisable to conduct a subsequent inquiry within the ensuing five years to obtain dependable data regarding the extent of metal pollution.

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INTRODUCTION

Suvetha et al. (2022) and Vlasov et al. (2023) posit that road dust comprised of solid particles that are generated through mechanical processes, including but not limited to soil erosion and deflation, transportation infrastructure and vehicle wear, trash crushing, de-icing agent (DIA) residues, and atmospheric particulates. Studies conducted by Huo et al. (2023) and Han et al. (2023) identified automobile-generated road dust as a significant contributor to particulate matter (PM) in urban environments. Oyewumi et al. (2022) and Jalali et al. (2022) reported that the existence of traffic dust poses a challenge to the surveillance of the environment and geochemistry of major urban centers across the globe.

Dust serves as a crucial environmental indicator for the presence of metal contamination resulting from atmospheric deposition. Air pollution can originate from diverse stationary and mobile sources, including but not limited to vehicular traffic, industrial operations, power generation facilities, residential combustion of fossil fuels, waste disposal through incineration, construction and demolition activities, and the re-suspension of soil that is contaminated (Krasovitov et al., 2021; Xu-Yang et al., 2022; and Pozhitkov et al., 2021). The studies conducted by Gonçalves et al. (2021) and Hernández- Terrones et al. (2021) are relevant to

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the topic at hand. The chemical composition of highway dust is intricate and results from the interplay of various solid, liquid, and gaseous constituents originating from diverse sources and activities. The prevalence of automobiles in contemporary society has resulted in an increase in the presence of dust on highways. Additionally, Forastiere et al. (2021), Yu et al. (2022), and Le Vern et al. (2022) suggested that road surfaces and controllable automobile emissions may be blamed for the buildup of dust.

Per the findings of to Chang et al. (2023) and Alshetty and Nagenda (2022), the re-suspension of road dust in the atmosphere results in the emission of significant amounts of trace metals. This is due to the fact that road dust is not persistent and can be easily re-suspended in the air. According to Sun et al. (2020) and Zhou et al. (2023), road dust is a multifaceted combination of particles and contaminants that originate from diverse urban and industrial sources and procedures. The composition of road dust renders it a viable indicator of the extent and distribution of metallic contamination in the surface ecosystem. Per the to recent studies conducted by Aguilar et al. (2021) and Švédová et al. (2020), road dust has been found to contain a diverse range of contaminants, including dead skin, pollen, hair, textile, paper fibers, soil minerals, cosmic dust particles, and various metals that are present in the surrounding environment. Empirical evidence has demonstrated that metallic residues present in road dust originate from urban areas, industrial facilities, and transportation sources. Airborne dust comprises of soil particles that remain suspended in the atmosphere in regions with sparse vegetation, and arid soil that are susceptible to erosion, and high-velocity winds.

The presence of road dust in urban areas is indicative of the level of pollution, as the particles it contains are known to harbor various contaminants such as heavy metals and metalloids (Alshetty and Nagenda, 2022). Road dust has the potential to cause secondary pollution in the surrounding air and ground adjacent to roadways. According to Zong et al. (2023) and Islam et al. (2023), air pollution exacerbates particulate deposition in urban areas, leading to a decline in air quality and visibility. According to Yao et al. (2022) and Dimitropoulou et al. (2022), naturally occurring aerosols in the lower troposphere that contribute to cooling comprised of more than 50% dust particles. The study conducted by Hill et al. (2023) revealed that the interaction between airborne dust and liquid or ice clouds can significantly alter their physical characteristics, including their appearance, longevity, and precipitation patterns. The health of individuals is increasingly vulnerable to particulate matter present in the atmosphere, such as dust originating from geologic sources. In recent years, there has been a surge in interest regarding the impact of dust on human health due to the strong correlations that have been observed between this type of pollution and respiratory disorders. Studies by Onishi et al. (2022), Al-Jashami and Khudair (2022), and Jasim et al. (2022) are just few that have documented this phenomenon.

Although the metal concentrations in soils adjacent to roads were found to be higher than their respective natural background levels, they were generally observed to be below the "critical trigger concentrations" for contaminated soils, as reported by Mabood et al. (2021); and Dytow and Górka-Kostrubiec (2021). The further the distance from the road, the greater the decrease in the concentration of metallic components in the soil. The studies conducted by Koju et al. (2022) and Sarhan et al. (2021) have revealed that the levels of heavy metals concentrations in plant exhibit a negative correlation with their proximity to major roads. Specifically, as the distance between the plants and the road increases, the concentration of heavy metals in the plant decreases.

Despite the existence of several studies on the correlation between dust, metal concentration in dust, and proximity, further investigation is required to gain a comprehensive comprehension of the primary metals present in road dust and their connection with distance. The article discusses the findings of research that examined the concentration of metals present in the spring snow cover at varying distances from the roadside.

MATERIALS AND METHODS

Gritchino, near Kashira, was chosen as the test site for a number of different reasons, such as traffic intensity along the Caspian Highway (Moscow-Tambov-Astrakhan) (Figure 1), . With the intensity of traffic on the road increasing more than five (5) times since its completion in 1983, the number of cars on it had climbed to more than thirty thousand in 2020. (Pospelov et al., 2021; Kirilina et al., 2022). It is located at 54° 36' 15" North and 38° 6' 20" East. It has a mild continental climate with warm summers and chilly winters, with prominent west-southern winds (Vasil'ev, 2021; Sidorenkov, 2021). According to Kashira meteorological monitoring stations, the dominant wind direction during the winter of 2021–2022 was southwest as shown in (Figure 3). The testsite is flanked with arable land on both sides of the route, with the average February temperature of -10°C. The test location is located on a modest slope of a hill with a western aspect (Figure 2).

Snow samples were collected at a distance of 30–190 m from both sides of the Caspian Highway (Moscow–Tambo–Astrakhan) at the end of winter 2021–2022. (22.02.2022). The position of the sample spots was calculated using UAV parameters obtained throughout the sampling campaign, with an error of less than 10 cm. A total of 18 mixed samples (three samples were mixed at each test point) were collected using a snow collection tube 1 m long and 10 cm in diameter, as illustrated in Figure 1. Each sample's snow depth was measured. The samples were subsequently taken to Moscow's V.V. Dokuchaev Soil Science Institute for processing and

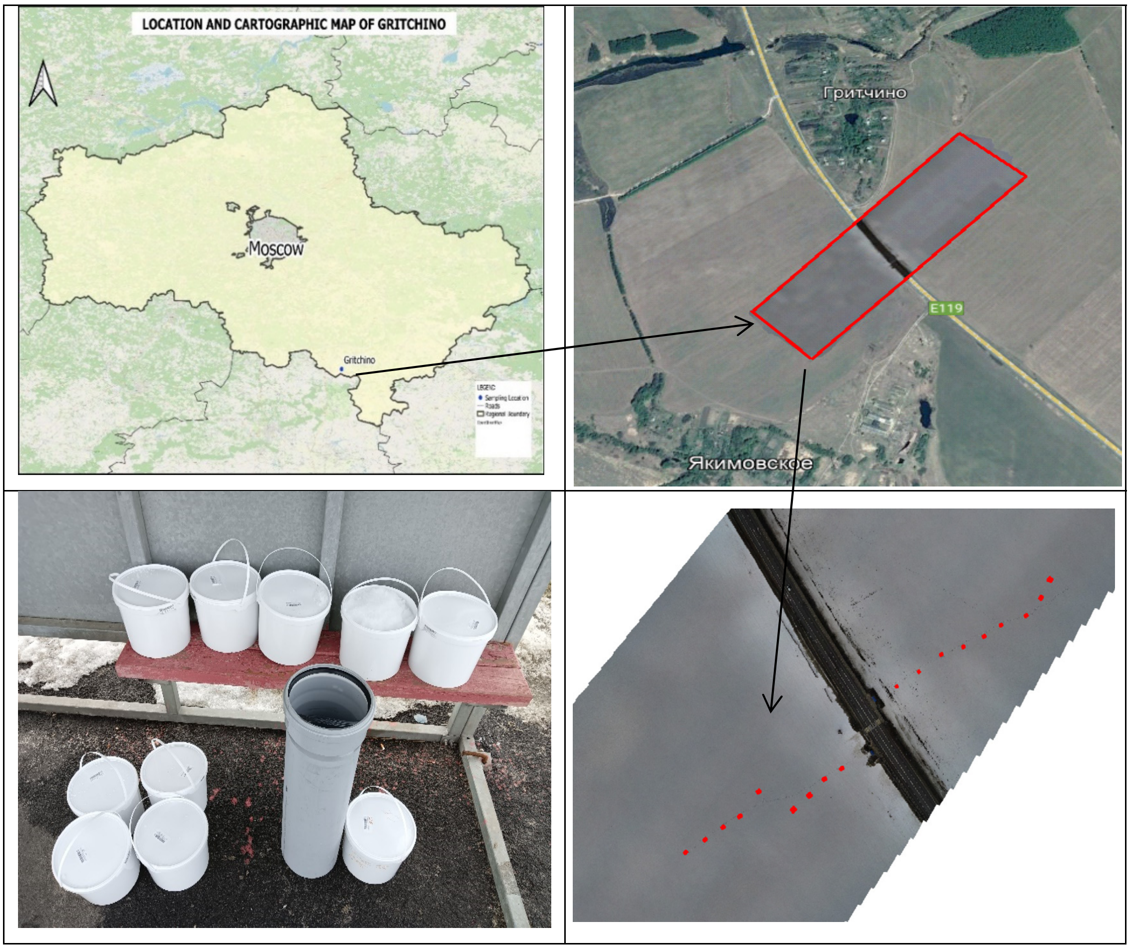

Fig. 1. Location of the study area (based on UAV data), test points (in red), and collected samples in sealed buckets

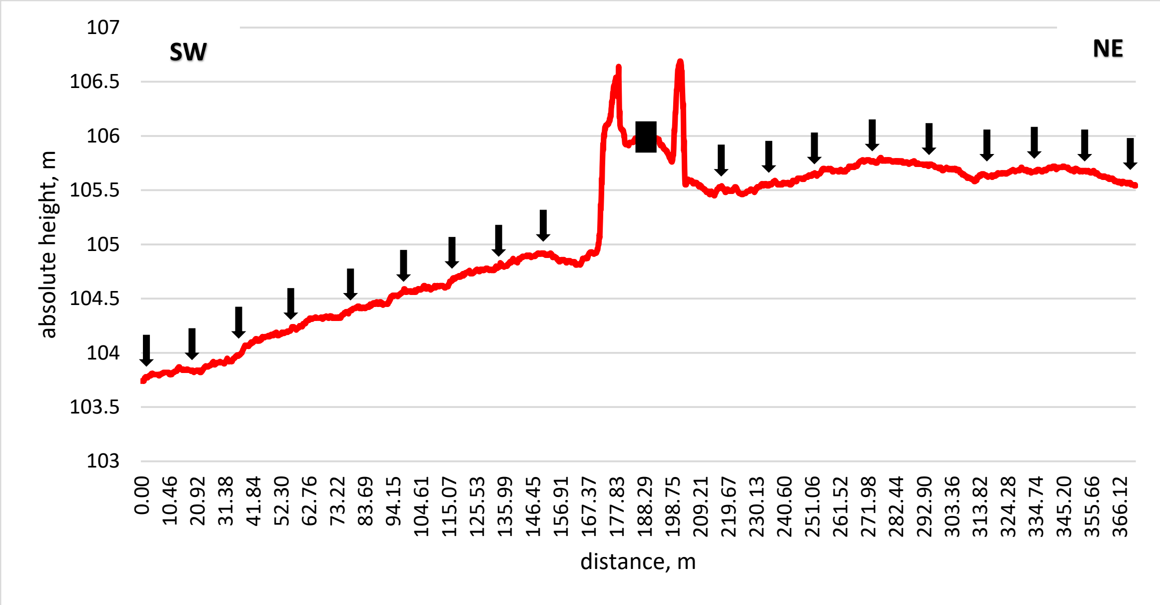

Fig. 2. Relief elevation profile from the most western point to the most eastern point (black arrows indicate sampling points, black square-place of the road) (based on UAV data)

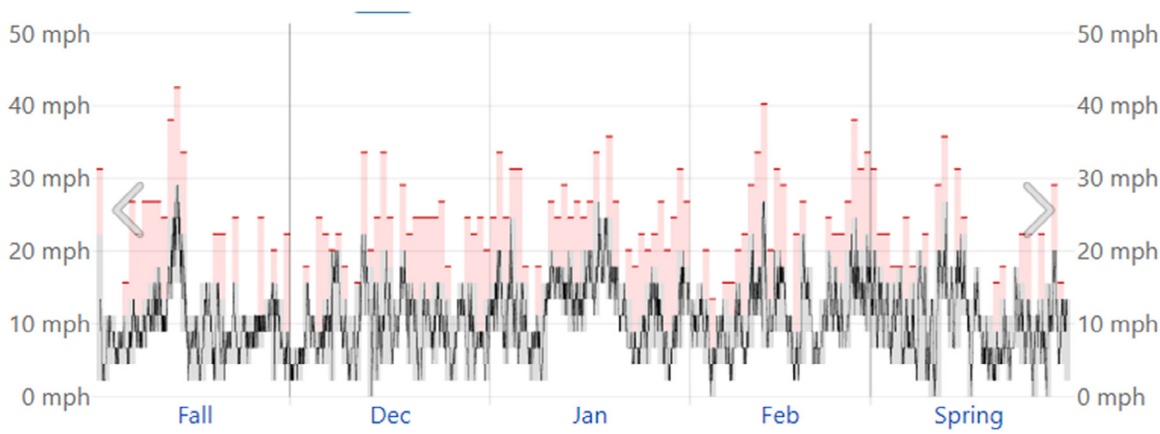

Fig. 3. The daily range of reported wind speeds (gray bars), with maximum gust speeds (red ticks).

chemical analysis. Once 90% of the sample had melted, it was de-iced at room temperature and chilled to finish the melting process. After that, the samples were put through polycarbonate filters with 0.45- μm pores and a 47-mm diameter to separate the water from the particles so they could be analyzed using inductively coupled plasma optical emission spectroscopy (Agilent 5800, ICP-OES). Nitric acid was used to digest the dust into a solution that was then injected into the plasma. This is done to bring the entire dissolved solid concentration into the instrument's operating range, lowering the detection limit of the technique. To allow any reaction gasses to escape, 2 mL of strong nitric acid reagent was applied to the samples and allowed to stand for 10 minutes (Rocha et al., 2022).

The samples were then treated with 6 mL of concentrated hydrochloric acid (SG 1.18) for another 10 minutes. To keep from making it very hard to dissolve chloride salts, nitric acid was added first, then hydrochloric acid, and finally hydrofluoric acid. The samples were then heated using EPA Procedure 3051 in a Milestone Ethos microwave system. The samples were then heated to 175 °C for 10 minutes and kept between 170 °C and 180 °C for another 10 minutes following a microwave digestion procedure and 5 minutes of cooling. The sample containers were transferred into a fume closet to achieve room temperature. To achieve a homogenous sample, the volume of the digests was increased with distilled water and then forcefully shaken in 100-ml volumetric flasks. The samples were allowed to settle overnight to remove any suspended solids (Rocha et al., 2022). A total of 35 chemical elements (metals) were identified.

License-compliant Stata Standard Edition software for Windows 64-bit x86-64 was utilized for statistical analysis. A correlation analysis was performed to determine the nature of the relationship and the significance level between metal concentrations in dust particles and distance. The bilateral correlation coefficients for specified metal levels in water dust, and snow were calculated.

RESULTS AND DISCUSSION

Tables 3-5 present the distribution of metals in the entirety of water from dust particles obtained from the snow layer per square meter subsequent to calculation. Based on the results of this study, the dust samples exhibited low concentrations of Cd, Eu, Gd, Ho, Pb, Tb, Tm, and Yb. Aluminum, calcium, magnesium, sodium, iron, barium, and phosphorus were among the most prevalent metals. The high concentrations observed at the sampling locations in close proximity to the road facilitate the differentiation of nearly all metals that exhibited detectable levels in the dust. The distribution pattern of different metals in dust particle dispersion exhibits variations with distance, as inferred from the results of visual analysis.

As per the findings of the Pan American Health Organization and the World Health Organization in 2011, inhalation of dust particles with a diameter of less than 10 micrometers can results in their lodging in the respiratory system. Particulate matter with a diameter of less than 2.5 micrometers is considered the most hazardous to human health due to its ability to penetrate deeply into the respiratory system. The study reveals that a proportion of approximately 9% of the overall particle size was observed to range between 15.4 μm and 40.3 μm, whereas the remaining 91% of particles were found to be below 2 μm, indicating a significantly elevated health risk. The concentration levels of metal elements detected in water, dust particles, and snow were found to be within the permissible limits set by the PAHO/WHO, indicating that there is no significant risk to human health.

Dust particles often exhibit variations in size and chemical composition. Particles of smaller size that are capable of traversing longer distances exhibit a distinct composition in comparison to larger particles that tend to settle in close proximity to the road. This corroborates analogous discoveries were made by other authors, namely Cheng et al. (2023) and Tang et al. (2023). The chemical composition of the dust on the leeward side of the road (located at the east of the roadbed) was observed to be comparatively higher. This finding suggests that the direction of the wind affects the movement of dust particles from the road. Despite their proximity, a significant inverse correlation was observed between the metal content of the dust and its longitudinal position relative to the road. Tables 1 and 2 present the correlation coefficients for points situated in the eastern and western regions, respectively.

By way of comparison, the correlation coefficients pertaining to points situated on the eastern side of the road exhibited greater magnitudes than those corresponding to points located on the western side. The aforementioned phenomenon may be elucidated by conducting a functional evaluation of the road with regards to the dispersion of metallic elements, particularly on the side of the road that is sheltered from the wind (i.e., the eastern side).

Table 4 presents a comprehensive overview of the types of metals present in snow water, devoid of any dust, along with their corresponding physical characteristics. The aforementioned phenomenon is attributed to the impact of said content of both the number

Table 1. Correlation matrix between distance and metal elements in the dust the at east

Metal	Coefficients
Al	-0.72***
Ba	-0.64**
Ca	-0.77**
Fe	-0.81***
K	-0.77**
Mg	-0.79***
Na	-0.78**
Zn	-0.84***

***, **, and * Indicates 1%, 5% and 10% level of significance respectively

Table 2. Correlation matrix between distance and metal elements in the dust the at west

Metal	Coefficients
Al	-0.72**
Ba	-0.50**
Ca	-0.56**
Fe	-0.69**
K	-0.63**
Mg	-0.71***
Na	-0.70**
Zn	0.06

***, **, and * Indicates 1%, 5,% and 10% level of significance respectively

of particles present in the snow and their level of solubility. The dissolution rate of metals originating from dust particles found in snow water is accelerated. It is possible that dust particles, which were smaller than the pores of the filter, may have penetrated the water, thereby contributing to its elevated concentrations. While infrequent, the particles have the potential to augment the metallic composition of thawed glacial water. The majority of the content in the solution pertains to the background values and is independent of the roadway's proximity. Al, Ba, Ca, Fe, K, Mg, Na, and Zn were the only elements to show this dependence. The value of the eastern side of the road is comparatively higher than that of the western side. Nevertheless, the degree of manifestation of this trend is comparatively less significant in relation to the metal content observed in dust particles.

The present study conducted a correlation analysis of metal content in meltwater with distance from the road to the east. The results indicate statistically significant correlations for Al ($r = -0.70$, $p = 0.050$), Ba ($r = -0.63$, $p = 0.050$), Ca ($r = -0.65$, $p = 0.050$), Fe ($r = -0.71$, $p = 0.001$), K ($r = -0.82$, $p = 0.001$), Mg ($r = -0.92$, $p = 0.001$), and Na ($r = -0.84$, $p = 0.001$).

The correlation between metal content and sample points located on the west side of the road is comparatively lower, specifically on the windward side. The variables Al, Ca, Mg, and Na exhibited a statistically significant negative correlation with distance, with correlation coefficients of -0.64, -0.40, -0.64, and -0.75, respectively. The p-values for all four correlations were 0.050, except for Na, which had a p-value of 0.001. The tabular data indicated that the metal content remained constant despite an increase in dissolved dust particles in the melted samples.

However, there was a slight modification in the distribution pattern, as depicted in Table 4.

Table 3. Metals content in dust from snow sample (µg/m2)

Metal	Distance from the road (m) and point code																		
	190	170	150	130	110	90	70	50	30	0	30	50	70	90	110	130	150	170	190
	9W	8W	7W	6W	5W	4W	3W	2W	1W		1E	2E	3E	4E	5E	6E	7E	8E	9E
Al	0.2	0.2	0.4	0.5	1.1	1.8	2.8	3.6	9.5		108.6	53.2	22.7	18.5	6.8	13.6	1.4	3.4	1.0
Ba	<0.1	0.1	0.1	0.3	0.1	0.2	0.9	3.3	0.8		87.5	6.1	14.4	1.1	2.1	0.8	0.2	0.2	0.1
Ca	1.1	0.6	1.0	1.0	2.6	4.4	6.4	7.6	24.1		187.7	73.3	18.7	22.6	10.5	6.3	1.2	1.9	1.2
Fe	0.8	0.5	1.1	2.0	2.8	5.0	7.2	12.5	25.3		232.9	110.3	52.4	43.5	17.7	17.9	3.0	4.9	2.4
K	0.1	0.1	0.4	0.2	0.4	0.9	1.2	2.2	5.8		37.4	15.2	6.9	6.3	2.1	3.1	0.4	0.7	0.3
Mg	0.2	0.2	0.3	0.3	0.7	1.2	1.8	2.4	5.7		68.8	30.6	10.8	10.2	4.2	3.6	0.6	1.0	0.5
Na	<0.1	0.1	0.2	0.1	0.1	0.4	0.7	2.0	4.0		22.9	6.0	4.9	1.6	1.2	0.7	0.1	0.2	0.1
Zn	<0.1	<0.1	<0.1	0.1	0.1	0.1	0.1	0.2	0.2		1.8	0.9	0.5	0.3	0.2	0.1	<0.1	<0.1	<0.1

Table 4. Metals content in water from snow sample (µg/m2)

Metal	Distance from the road (m) and point code																		
	190	170	150	130	110	90	70	50	30	0	30	50	70	90	110	130	150	170	190
	9W	8W	7W	6W	5W	4W	3W	2W	1W		1E	2E	3E	4E	5E	6E	7E	8E	9E
Al	<10	<10	<10	<10	<10	<10	99	<10	136		490	415	90	83	31	164	84	117	47
Ba	<10	<10	<10	<10	<10	<10	<10	<10	<10		35	91	91	<10	<10	<10	<10	<10	<10
Ca	1482	1268	1732	1100	1337	1203	1724	1360	2196		2687	8246	1685	1610	1012	1364	936	884	803
Fe	59	62	59	66	62	58	68	53	68		482	371	51	52	45	47	45	53	47
K	335	509	844	380	887	702	479	939	503		1432	710	1074	666	375	415	316	278	246
Mg	305	290	318	258	270	299	335	374	500		373	570	419	323	238	305	197	205	161
Na	207	437	1783	727	838	1727	958	1842	3060		3334	2334	1798	1806	763	937	723	927	616
Zn	77	53	30	63	93	6	15	37	7		57	34	5	31	29	25	95	32	5

Table 5. Metals content in snow sample (dust+water) (µg/m2)

Metal	**Distance from the road (m) and point code**																		
	190	**170**	**150**	**130**	**110**	**90**	**70**	**50**	**30**	**0**	**30**	**50**	**70**	**90**	**110**	**130**	**150**	**170**	**190**
	9W	**8W**	**7W**	**6W**	**5W**	**4W**	**3W**	**2W**	**1W**		**1E**	**2E**	**3E**	**4E**	**5E**	**6E**	**7E**	**8E**	**9E**
Al	<10	<10	<10	<10	<10	<10	102	<10	145		599	468	113	101	38	178	85	120	48
Ba	<10	<10	<10	<10	<10	<10	<10	<10	<10		122	97	106	<10	<10	<10	<10	<10	<10
Ca	1483	1268	1733	1101	1340	1208	1731	1368	2220		2874	8319	1704	1633	1023	1370	937	886	804
Fe	60	63	61	68	65	63	76	65	93		715	481	104	95	63	65	48	58	50
K	335	509	844	380	888	703	480	941	509		1469	726	1081	672	377	418	317	279	247
Mg	305	290	318	258	271	301	337	376	506		441	601	430	333	242	308	197	206	162
Na	208	437	1783	727	838	1728	959	1844	3064		3357	2340	1803	1808	764	938	723	927	616
Zn	<80	<80	<80	<80	<80	<80	<80	<80	<80		<80	<80	<80	<80	<80	<80	<80	<80	<80

The phenomenon is particularly evident in the cases of the chemical elements potassium (K) and sodium (Na). The aforementioned alterations were associated with the spatial disparity in the quantity of snow, encompassing its elevation and density.

The distribution of metals in dust has undergone significant evolution, as evidenced by Table 3. The metals, for which an elevation in their content has been documented, have undergone slight modifications. Furthermore, the augmented deposition of particles on the downwind side of the roadway has decreased, while it has significantly amplified on the upwind side. The observed phenomenon can be logically elucidated as reduction in the concentration of dust particles in the specimens with an increase in the distance from the roadway.

Table 5 displays the spatial arrangement of the aggregate metal content in the snow for every square meter of snow surface. The table presents the identified sampling points for seven metals, each with increasing contents. The aforementioned metals are Al, Ba, Ca, Fe, K, Mg, and Na. The influence of deposition on the concentration of K and Ba element was limited to a radius of 30 and 70 meters from the roadway, respectively. The concentration of Ca, Mg, and Na in the vicinity of the road exhibited an increase of up to 30 meters in the direction of the windward and up to 50 meters in the direction of the leeward. The impact of Fe content was found to be discernible with a range of 30 meters on the windward side and up to 90 meters on the leeward side. The distribution of Al is primarily influenced by the road, with a potential traceable impact of 70 meters in the windward side and up to 190 meters in the leeward side. The metals exhibited relatively higher concentrations on the eastern (leeward) side of the road. The phenomenon is particularly evident for aluminum and iron.

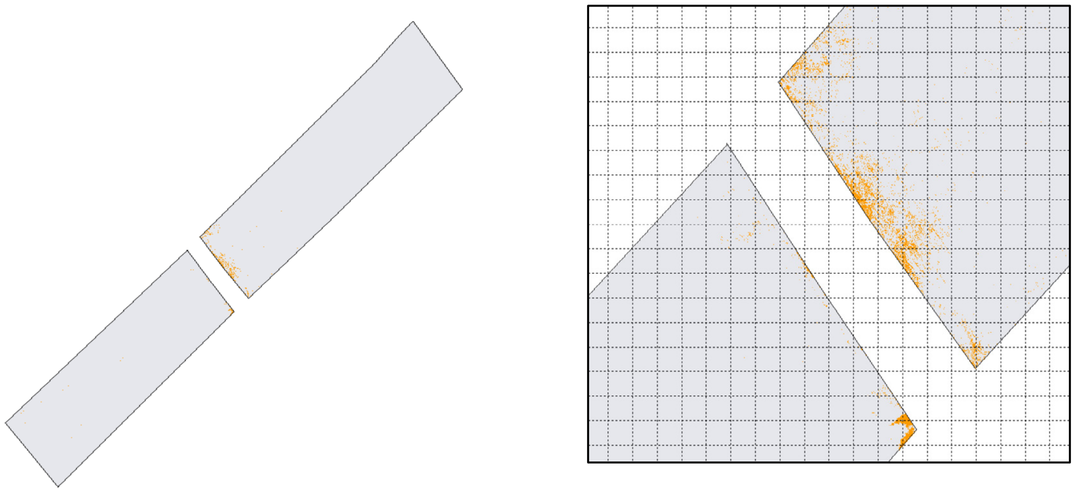

Fig. 4. Map of the weighted average coefficient of relative concentration (on the right - an enlarged roadside part of the site) (gray color - excess over the local background no more than 10%, orange color - excess 10-15%; dotted line shows a 10-meter grid).

The content map was presented as relative concentrations by utilizing the minimum content of each element within the test site as its background value. Each individual pixel within the map displays the percentage deviation in concentration of the specific element in comparison to the minimum concentration present on the site map. Subsequently, a map of average relative concentrations and a map of maximum concentrations for all elements were constructed for each pixel in the GIS. Figure 4 depict the map of metals distribution pattern. The map considers the proportional densities of all specified elements. However, when utilizing a map depicting average relative concentrations, it is possible to obtain more consistent and refined approximations of pollution. Based on the cartographic representation, it can be inferred that the area of impact stemming from the roadway is typically observable solely on the side sheltered from the wind, within a range of 20 to 40 meters from the thoroughfare, while factoring in all relevant variables.

However, it is noteworthy that within this particular area, the mean surplus of concentration only amounts to 10-15% in relation to the baseline measurements. The zone of influence of the road is indistinguishable on the windward side. When utilizing the relative concentration deviation maxima map as a parameter for determining the area of impact, it can be observed that the breath of the area if impact is likewise 20-40 meters from the road on the side sheltered from the wind. However, the deviations from the baseline are notably greater, reaching up to 110%. Furthermore, a limited area of impact is designated on the side of the road facing the wind, within a maximum strip of 10 meters. The manifestation of this area can be attributed to the microtopography, specifically the existence of a depression that facilitates the accumulation of dust emissions from the road.

This study demonstrated the notable influence of the dissemination of specific metals with dust and snow. Several scholarly investigations (Khdre et al., 2023; and Liu et al., 2022) have examined the accumulation of metals in plants, animals, and soil. However, these studies have not given significant consideration to the sources of these metals. These methodologies solely furnish data at a specific juncture within the assessment procedure. The lack of comprehensive information on metal dispersion originating from card roadways and its consequential impact renders the construction of a complete depiction unfeasible.

The focus of this study is primarily on the impact of dust particles from roadways, and the distribution of metals within water and snow cover. In both instances, elevated levels were documented. Shirakawa's (2022) research has proven that formaldehyde, soot, mercury and pesticides can all be present in small amounts in fresh snow. Despite the low levels of these substances, their presence has been verified. The resuspension of asphalt components and the influence of the prevailing wind offer a comprehensive comprehension of dispersion on the experimental site. Al though distance exerted an impact on a limited number of metals, the noteworthy concentration of these metals along the sides of the road and to the east of the experimental location cannot be disregarded.

The results of our study indicate that there are variations in the composition and water solubility of metals derived from road surfaces. The prevailing wind direction has an impact on pollution dispersion, according to our research findings. According to Korzeniowska's (2022) findings, the width of the zone with higher metal content was narrower on the windward side of the road, ranging from two to three times less than that observed on the leeward side. This was observed in the majority of the discovered metals.

Discrepancies were observed in the data obtained regarding the width of the zone of influence in comparison to the findings reported by Liu et al., 2023; and Voronova and Karpenko, 2010, which ranged from 150 to 180 meters. The observed phenomenon could potentially be attributed to variation in traffic density, weather patterns, terrain characteristics, and the methodology employed for delineating the zone of impact.

CONCLUSIONS

The study's results indicate that the presence of roads has a noteworthy influence on the dissemination of specific metals within dust and snow. The empirical investigation regarding the variation in metal concentration in dust, water, and snow with respect to distance provided support for our assertion. Despite the absence of a correlation between the metals, it was discovered that the road exhibited pollution tendencies within a range of 30-70 meters on the downwind side for metals such as Al, Ca, Fe, K, Na, and Mg. The concentration of these metals decreased as the distance from the road increased. It is noteworthy that the outer limit of the influence zone exhibits significant spatial variation in both instances. This variation is primarily attributed to the microrelief severity prevalent in the study region.

Consequently, the utilization of specimens collected along a singular axis from the thoroughfare to evaluate the impact of automobiles may encompass considerable inaccuracies. Our methodology enabled us to evaluate the influence of the roadway on ecological contamination caused by metallic substances, presented in the form of a cartographic representation with a spatial precision of approximately 10 centimetres at ground level. The prevailing wind direction at the testing location during the specified time frame may have contributed to the significant accumulation of metallic particulate matter observed at the eastern terminus of the roadway. The chemical make-up and size of dust particles have significant impact on their dispersion. The findings of this study demonstrate the impact of a road network on the dispersion of metals within a mixture of snow and dust.

However, over the course of the upcoming five years, further investigation is required to obtain dependable information regarding the extent of metal contamination.

GRANT SUPPORT DETAILS

The present research did not receive any financial support.

CONFLICT OF INTEREST

The authors declare that there is not any conflict of interests regarding the publication of this manuscript. In addition, the ethical issues, including plagiarism, informed consent, misconduct, data fabrication and/ or falsification, double publication and/or submission, and redundancy has been completely observed by the authors.

LIFE SCIENCE REPORTING

No life science threat was practiced in this research.

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REFERENCES

Aguilar, Y., Bautista, F., Quintana, P., Aguilar, D., Trejo-Tzab, R., Goguitchaichvili, A., & Chan-Te, R. (2021). Color as a new proxy technique for the identification of road dust samples contaminated with potentially toxic elements: The case of Mérida, Yucatán, México. *Atmosphere*, *12*(4), 483. doi:10.3390/atmos12040483

Al-Jashami, S. H., & Khudair, Z. H. (2022). Continental climate and its relationship to dusty phenomena and health effects in Iraq. *International Journal of Health Sciences (IJHS)*, 11608–11621. doi:10.53730/ijhs.v6ns4.11677

Alshetty, D., & Nagendra, S. (2022). Urban characteristics and its influence on resuspension of road dust, air quality and exposure. *Air Quality, Atmosphere, & Health*, *15*(2), 273–287. doi:10.1007/s11869-021-01102-x

Chang, Z., Qiu, J., Wang, K., Liu, X., Fan, L., Liu, X., … & Zhang, Y. (2023). The relationship between co-exposure to multiple heavy metals and liver damage. *Journal of Trace Elements in Medicine and Biology: Organ of the Society for Minerals and Trace Elements (GMS)*, *77*(127128), 127128. doi:10.1016/j.jtemb.2023.127128

Cheng, Y., Yu, H., Xie, S., Zhao, J., & Ye, Y. (2023). Study on the coal dust deposition fraction and site in the upper respiratory tract under different particle sizes and labor intensities. *The Science of the Total Environment*, *868*(161617), 161617. doi:10.1016/j.scitotenv.2023.161617

Dimitropoulou, E., Hendrick, F., Friedrich, M. M., Tack, F., Pinardi, G., Merlaud, A., …& Van Roozendael, M. (2022). Horizontal distribution of tropospheric NO_2 and aerosols derived by dual-scan multi-wavelength multi-axis differential optical absorption spectroscopy (MAX-DOAS) measurements in Uccle, Belgium. *Atmospheric Measurement Techniques*, *15*(15), 4503–4529. doi:10.5194/amt-15-4503-2022

Dytłow, S., & Górka-Kostrubiec, B. (2021). Concentration of heavy metals in street dust: an implication of using different geochemical background data in estimating the level of heavy metal pollution. *Environmental Geochemistry and Health*, *43*(1), 521–535. doi:10.1007/s10653-020-00726-9

Forastiere, F., Lurmann, F., Boogaard, H., & Hei Panel On The Health Effects Of Long-term Exposure To Traffic-related Air Pollution. (2021). Knowledge on adverse effects of traffic-related air pollution: have we filled the gap? What more do we need to know? *Environmental Health Perspectives*, *2021*(1). doi:10.1289/isee.2021.o-sy-004

Gonçalves, C., Rienda, I. C., Pina, N., Gama, C., Nunes, T., Tchepel, O., & Alves, C. (2021). PM10-bound sugars: Chemical composition, sources and seasonal variations. *Atmosphere*, *12*(2), 194. doi:10.3390/atmos12020194

Han, G., Liu, M., Li, X., & Zhang, Q. (2023). Sources and geochemical behaviors of rare earth elements in suspended particulate matter in a wet-dry tropical river. *Environmental Research*, *218*(115044), 115044. doi:10.1016/j.envres.2022.115044

Hernández-Terrones, L., Ayala-Godoy, J. A., Guerrero, E., Varelas-Hernández, G. H., Sánchez-Toriz, D. G., Flores-Moreno, M. F., & Pech-Perera, C. B. (2021). Composition and spatial distribution of metals and sulfur in urban roadside dust in Cancun, Mexico. *Environmental Forensics*, *22*(3–4), 351–363. doi:10.1080/15275922.2020.1850556

Hill, D. T., Jandev, V., Petroni, M., Atallah-Yunes, N., Bendinskas, K., Brann, L. S., …& Collins, M. B. (2023). Airborne levels of cadmium are correlated with urinary cadmium concentrations among young children living in the New York state city of Syracuse, USA. *Environmental Research*, *223*(115450), 115450. doi:10.1016/j.envres.2023.115450

Huo, C.Y., Li, W.-L., Liu, L.-Y., Sun, Y., Guo, J.-Q., Wang, L., … & Li, Y. F. (2023). Seasonal variations of airborne phthalates and novel non-phthalate plasticizers in a test residence in cold regions: Effects of temperature, humidity, total suspended particulate matter, and sources. *The Science of the Total Environment*, *863*(160852), 160852. doi:10.1016/j.scitotenv.2022.160852

Islam, N., Toha, T. R., Islam, M. M., & Ahmed, T. (2023). Spatio-temporal variation of meteorological influence on PM2.5 and PM10 over major urban cities of Bangladesh. *Aerosol and Air Quality Research*, *23*(1), 220082. doi:10.4209/aaqr.220082

Jalali, M., Farahani, E. A., & Jalali, M. (2022). Simulating phosphorus leaching from two agricultural soils as affected by different rates of phosphorus application based on the geochemical model PHREEQC. *Environmental Monitoring and Assessment*, *194*(3), 164. doi:10.1007/s10661-022-09828-6

Jasim, S. A., Mohammadi, M. J., Patra, I., Jalil, A. T., Taherian, M., Abdullaeva, U. Y., … & Alborzi, M. (2022). The effect of microorganisms (bacteria and fungi) in dust storm on human health. *Reviews on Environmental Health*, *0*(0). doi:10.1515/reveh-2022-0162

Khdre, A. M., Ramadan, S. A., Ashry, A., & Alaraby, M. (2023). Chironomus sp. As a bioindicator for assessing microplastic contamination and the heavy metals associated with it in the sediment of wastewater in Sohag Governorate, Egypt. *Water, Air, and Soil Pollution*, *234*(3), 161. doi:10.1007/s11270-023-06179-x

Kirilina, N. A. (2022). Changes in transport behaviour and road traffic injuries in Moscow during the covid-19 crisis. *Transportation Research Procedia*, *60*, 520–527. doi:10.1016/j.trpro.2021.12.067

Koju, N. K., Sherpa, C. D., & Koju, N. P. (2022). Assessment of physico-chemical parameters along with the concentration of heavy metals in the effluents released from different industries in Kathmandu valley. *Water, Air, and Soil Pollution*, *233*(5). doi:10.1007/s11270-022-05645-2

Korzeniowska, J. (2022). Heavy metal content in the soil along the Road No. 7 near chyżne. *Atmosphere*, *14*(1), 2. doi:10.3390/atmos14010002

Krasovitov, B., Fominykh, A., Levy, A., Kleeorin, N., & Katra, I. (2021). Dry deposition of dust particles during medium- and high-level dust storms to a forest canopy in a semi-arid region. *Atmospheric Pollution Research*, *12*(5), 101058. doi:10.1016/j.apr.2021.101058

Le Vern, M., Razakamanantsoa, A., Murzyn, F., Larrarte, F., & Cerezo, V. (2022). Effects of soil surface degradation and vehicle momentum on dust emissions and visibility reduction from unpaved roads. *Transportation Geotechnics*, *37*(100842), 100842. doi:10.1016/j.trgeo.2022.100842

Liu, Q., Li, X., & He, L. (2022). Health risk assessment of heavy metals in soils and food crops from a coexist area of heavily industrialized and intensively cropping in the Chengdu Plain, Sichuan, China. *Frontiers in Chemistry*, *10*, 988587. doi:10.3389/fchem.2022.988587

Liu, Y., Jin, T., Yu, S., & Chu, H. (2023). Pollution characteristics and health risks of heavy metals in road dust in Ma'anshan, China. *Environmental Science and Pollution Research International*, *30*(15), 43726–43739. doi:10.1007/s11356-023-25303-2

Mabood, F., Hadi, F., Jan, A. U., Ditta, A., Islam, Z., Siddiqui, M. H., … & Sabagh, A. E. L. (2021). Assessment of heavy metals and potential health risks associated with the consumption of vegetables grown on the roadside soils. doi:10.21203/rs.3.rs-1115842/v1

Onishi, K., Nojima, M., Sekiyama, T. T., Kurosaki, Y., Maki, T., Kurozawa, Y., & Yamagata, Z. (2022). Prediction of health effects of Asian dust in Japan. *Environmental Health Perspectives*, *2022*(1). doi:10.1289/isee.2022.p-0238

Oyewumi, O., Cavanaugh, C., Guzzardi, D., & Costa, M. (2022). Geochemical assessment of trace element concentrations in the Farmington River, Connecticut, Northeastern, USA. *Environmental Monitoring and Assessment*, *194*(5), 345. doi:10.1007/s10661-022-10013-y

PAHO/WHO (2011). Health situation in the Americas. Basic Indicators (4th ed). WHO Press. Pan American Health Organization, Washington, DC 20037, USA

Pospelov, P. I., Moscow Automobile and Road Construction State Technical University (MADI), Tatashev, A. G., Terentyev, A. V., Karelina, M. Y., Yashina, M. V., … & Moscow Automobile and Road Construction State Technical University (MADI). (2021). Bartlett flows and mathematical description of motor traffic flows. *H&ES Research*, *13*(6), 34–41. doi:10.36724/2409-5419-2021-13-6-34-41

Pozhitkov, R. Y., Tigeev, A. A., & Moskovchenko, D. V. (2021). Estimation of dust depositions in snow cover using earth's remote sensing data: Example of nizhnevartovsk. *Atmospheric and Oceanic Optics*, *34*(1), 19–25. doi:10.1134/s1024856021010103

Rocha, F., Alves, A., & Homem, V. (2022). Exploring the potential of sewage sludge as agricultural fertilizer: Determination of heavy metals and nutrients by microwave-assisted digestion followed by ICP-OES analysis. *Journal of Chemical Education*, *99*(9), 3218–3226. doi:10.1021/acs.jchemed.2c00044

Sarhan, M., Abd Elhafeez, A., & Bashandy, S. (2021). Evaluation of heavy metals concentration in soil and plants as affected by vehicular emission in alluvial soil at middle Egypt conditions. *Egyptian Journal of Soil Science*, *0*(0), 0–0. doi:10.21608/ejss.2021.89288.1460

Shirakawa, T., Ozeki, T., Kaneda, Y., & Matsuoka, N. (2022). Characteristics of snowfall and snow cover in Iwamizawa, Hokkaido, Japan, during 2020/21 winter season. *Journal of the Japanese Society of Snow and Ice*, *84*(4), 341–358. doi:10.5331/seppyo.84.4_341

Sidorenkov, N. S., & Hydrometeorological Research Center of Russian Federation, Moscow, Russia. (2021). On the problem of interrelation between extreme lunisolar tides in 2021 and weather change. *Hydrometeorological Research and Forecasting*, 157–162. doi:10.37162/2618-9631-2021-1-157-162

Sun, J., Zhou, G., Gao, D., Wei, Z., & Wang, N. (2020). Preparation and performance characterization of a composite dust suppressant for preventing secondary dust in underground mine roadways. *Chemical Engineering Research & Design: Transactions of the Institution of Chemical Engineers*, *156*, 195–208. doi:10.1016/j.cherd.2020.01.030

Suvetha, M., Charles, P. E., Vinothkannan, A., Rajaram, R., Paray, B. A., & Ali, S. (2022). Are we at risk because of road dust? An ecological and health risk assessment of heavy metals in a rapid growing city in South India. *Environmental Advances*, *7*(100165), 100165. doi:10.1016/j.envadv.2022.100165

Švédová, B., Matýsek, D., Raclavská, H., Kucbel, M., Kantor, P., Šafář, M., & Raclavský, K. (2020). Variation of the chemical composition of street dust in a highly industrialized city in the interval of ten years. *Journal of Environmental Management*, *267*(110506), 110506. doi:10.1016/j.jenvman.2020.110506

Tang, C., Zhang, Y., Zhou, Z., Yang, G., Jiang, H., Huang, Z., … & Gao, Y. (2023). The effects of particle size polydispersity and median diameter on the diffusion characteristics of aluminum dust. *Powder Technology*, *425*(118570), 118570. doi:10.1016/j.powtec.2023.118570

Vasil'ev, E. V., & Hydrometeorological Research Center of Russian Federation, Moscow, Russia. (2021). International competency requirements for public weather forecasters /. *Hydrometeorological Research and Forecasting*, *3*, 161–171. doi:10.37162/2618-9631-2021-3-161-171

Vlasov, D. V., Vasil'chuk, J. Y., Kosheleva, N. E., & Kasimov, N. S. (2023). Contamination levels and source apportionment of potentially toxic elements in size-fractionated road dust of Moscow. *Environmental Science and Pollution Research International*, *30*(13), 38099–38120. doi:10.1007/s11356-022-24934-1

Voronova, Ye., & Karpenko, O. (2010). Method for assessing the impact of a highway on the state of the elementospheric air of the roadside space // Bulletin of the Kharkiv National Automobile and Road University, 2010. No. 48.pp. 19-21.

Xu-Yang, Y., Dessert, C., & Losno, R. (2022). Atmospheric deposition over the Caribbean region: Sea salt and Saharan dust are sources of essential elements on the Island of Guadeloupe. *Journal of Geophysical Research Atmospheres*, *127*(22). doi:10.1029/2022jd037175

Yao, W., Gui, K., Zheng, Y., Li, L., Wang, Y., Che, H., & Zhang, X. (2023). Seasonal cycles and long-term trends of arctic tropospheric aerosols based on CALIPSO lidar observations. *Environmental Research*, *216*(Pt 2), 114613. doi:10.1016/j.envres.2022.114613

Yu, X., Zhao, Y., Feng, Y., Hu, X., Liu, J., Wang, X., …& Tian, F. (2022). Synthesis and performance characterization of a road coal dust suppressant with excellent consolidation, adhesion, and weather resistance. *Colloids and Surfaces. A, Physicochemical and Engineering Aspects*, *639*(128334), 128334. doi:10.1016/j.colsurfa.2022.128334

Zhou, G., Jing, B., Meng, Q., Liu, Y., Yang, W., & Sun, B. (2023). Study on coupling diffusion of composite dust and cloud-mist dedust technology in fully mechanized driving face of mixed coal-rock roadway. *Advanced Powder Technology: The International Journal of the Society of Powder Technology, Japan*, *34*(1), 103911. doi:10.1016/j.apt.2022.103911

Zong, Y., Xiao, Q., Malik, Z., & Lu, S. (2023). Exploring environment pollution and risk assessment of heavy metals in road dusts from a typical steel-Industrial City (Anshan), northeastern China. *Water, Air, and Soil Pollution*, *234*(1). doi:10.1007/s11270-022-06042-5