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Assessment of the Vertical Distribution of Elements in the 0–30 cm Soil Layer of an Industrial Area Using SEM-EDS

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Abstract This investigation aims to elucidate the elemental composition and distribution within the soil profile of an industrialized zone, focusing on the upper 30 centimeters. Soil samples were systematically collected from two distinct depths: 0-15 cm (topsoil) and 15-30 cm (subsoil), and their elemental characteristics were analyzed using Scanning Electron Microscopy coupled with Energy Dispersive Spectroscopy (SEM-EDS). The findings reveal that contamination predominantly accumulates within the topsoil layer, characterized by elevated levels of anthropogenic elements, while the subsoil retains a composition more reflective of natural geogenic minerals. These insights are instrumental in understanding the extent and vertical migration of pollutants in soils impacted by industrial activities, ultimately informing ecological risk assessments and remediation strategies.

Keywords Soil contamination, SEM–EDS, Vertical elemental distribution, Industrial pollution, Environmental assessment

1. Introduction

The rapid expansion of industrial activities over recent decades has markedly contributed to environmental contamination, with soils being particularly susceptible to anthropogenic inputs. Industries such as mining, metallurgy, and manufacturing release a variety of pollutants including dust, aerosols, and chemical residues that deposit onto soil surfaces. Over time, these pollutants can alter the physicochemical properties of soils, potentially jeopardizing ecological health and human safety.

The soil's uppermost layers are the primary recipients of atmospheric deposition, making them critical zones for detecting recent contamination. However, understanding the extent to which these pollutants penetrate deeper into the soil profile is essential for assessing long-term environmental risks. The vertical distribution of elements within the soil profile offers valuable insights into the dynamics of contaminant migration and natural attenuation processes.

The rapid development of industrialization has significantly impacted the environment, particularly the contamination of soil cover [1,2]. Activities related to mining, metallurgy, and other heavy industries release dust and aerosols into the atmosphere, which subsequently deposit onto the soil surface, thereby altering its physicochemical properties [3,4]. This process is especially impactful on the upper soil layers, as contaminants tend to accumulate there and, over time, may migrate into the lower horizons [5,6].

Studying the vertical distribution of elements within the soil profile is of critical importance in environmental assessment. Research indicates that the upper layers are enriched with anthropogenic contaminants, while the lower layers predominantly consist of natural geogenic elements [7,8]. Additionally, microscopic and spectral techniques such as SEM–EDS (Scanning Electron Microscopy coupled with Energy Dispersive Spectroscopy) enable rapid and accurate identification of both major and trace elements in soil samples [9,10].

The rapid development of industrialization and urbanization has significantly impacted the environment, particularly soil cover and contamination levels. Recent studies [11] emphasize that industrial activities and transportation emissions release heavy metals and chemicals into the atmosphere, which subsequently deposit onto soil surfaces, altering their chemical composition. This process predominantly affects the upper soil layers, where pollutants tend to accumulate, and over time, they can migrate into deeper layers [12].

Research by Zhang [13] highlights that emissions from metallurgical and other heavy industries generate dust and aerosols that settle on the soil surface, leading to changes in physical and chemical properties. These pollutants tend to concentrate in the topsoil initially, but with continued deposition and environmental conditions, they can migrate vertically, posing ecological risks to the subsurface layers.

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Furthermore, Chen and Zheng [14] observed that in industrial zones, heavy metal concentrations are significantly higher in the upper layers of soil, indicating recent contamination, while the deeper layers often contain naturally occurring elements.

Additionally, Li et al. focus on the migration of pollutants over time, noting that the vertical movement of harmful elements within soil profiles can cause long-term environmental hazards. Their findings suggest that understanding the vertical distribution of pollutants is crucial for assessing soil quality and developing effective remediation strategies.

2. Materials and Methods

The study area encompasses the soils surrounding the Olmaliq Mining and Metallurgical Complex. The soil samples were collected from a location approximately 500 meters east of the complex, within the vicinity of the industrial site.

Soil samples were collected from an area marked by intense industrial activity. Sampling was conducted at two depths to capture the vertical variation in elemental composition:

0–15 cm (topsoil): representing the zone most impacted by atmospheric deposition and human activity;

15–30 cm (subsoil): reflecting deeper, less disturbed soil layers.

The samples underwent thorough preparation for SEM–EDS analysis. High-resolution imaging and elemental mapping were performed in Map Spectrum Mode, allowing for qualitative and semi-quantitative assessments of the elemental constituents. The resulting spectra were analyzed to determine the mass percentages (wt.%) of detected elements.

3. Results and Discussion

Scientists analyzed soil samples taken from a region which showed signs of contamination at two different depth points which included the topsoil section between 0–15 cm and the subsoil section between 15–30 cm. The SEM–EDS Map Sum Spectrum method enabled researchers to determine the chemical elements present in both soil layers. The researchers studied how pollutants spread across different layers of the soil profile.

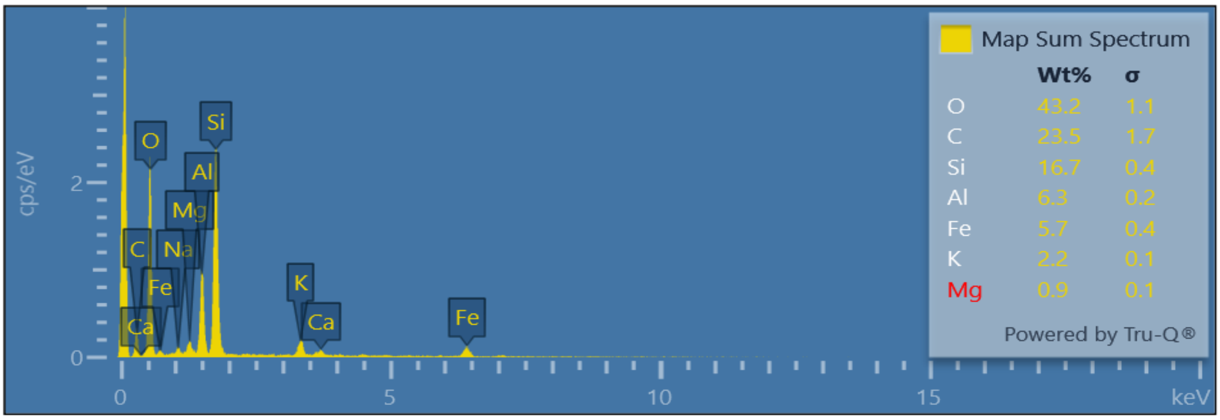


Figure 1. Map Sum Spectrum 0-15 cm

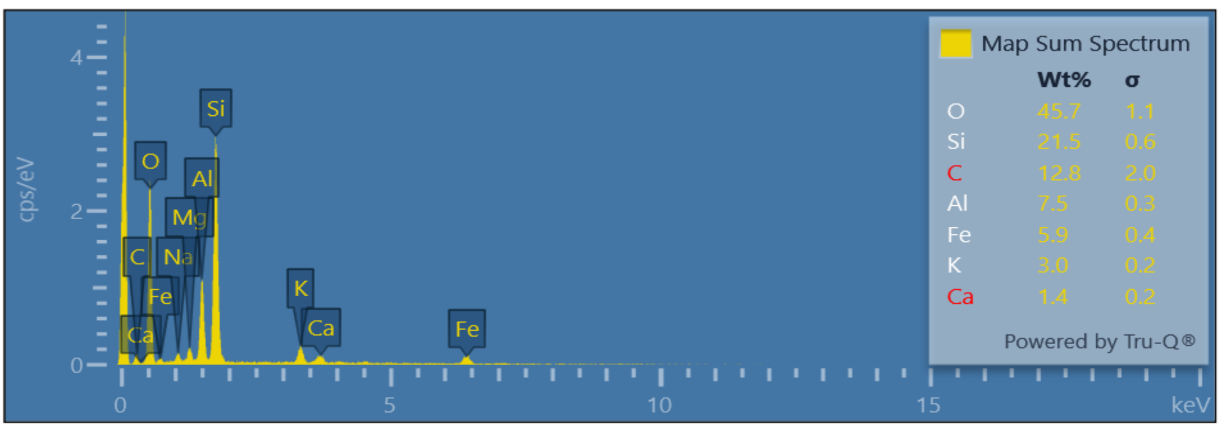
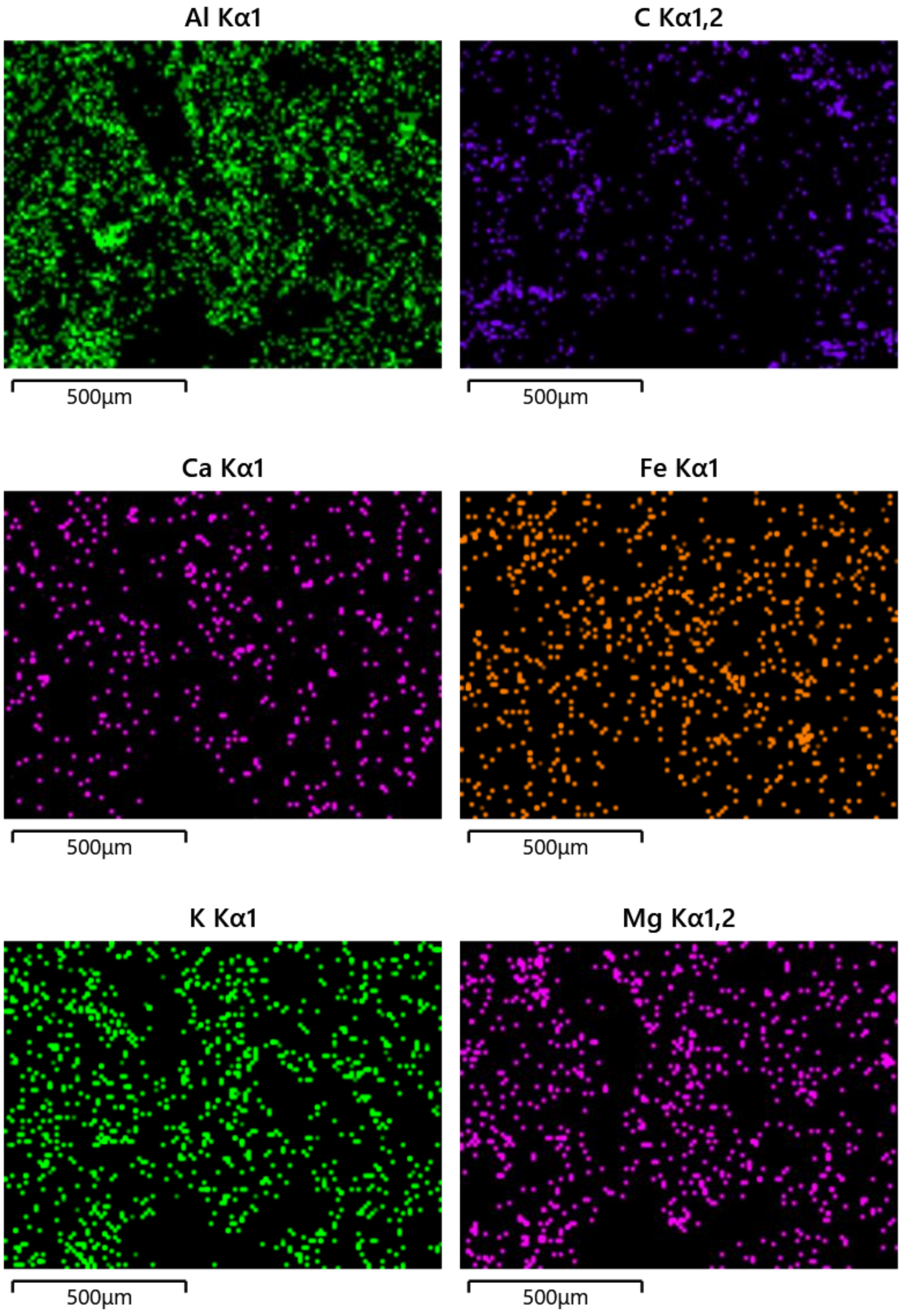


Figure 2. Map Sum Spectrum 15-30 cm

Elemental composition of the 0–15 cm layer (topsoil)

The 0–15 cm soil layer contained oxygen (O) at 43.24 wt.% and carbon (C) at 23.52 wt.%. The high carbon content shows that this layer contains organic matter and industrial dust from the atmosphere together with carbonate compounds. The research shows that human activities create their greatest impact on soil during the surface layer.



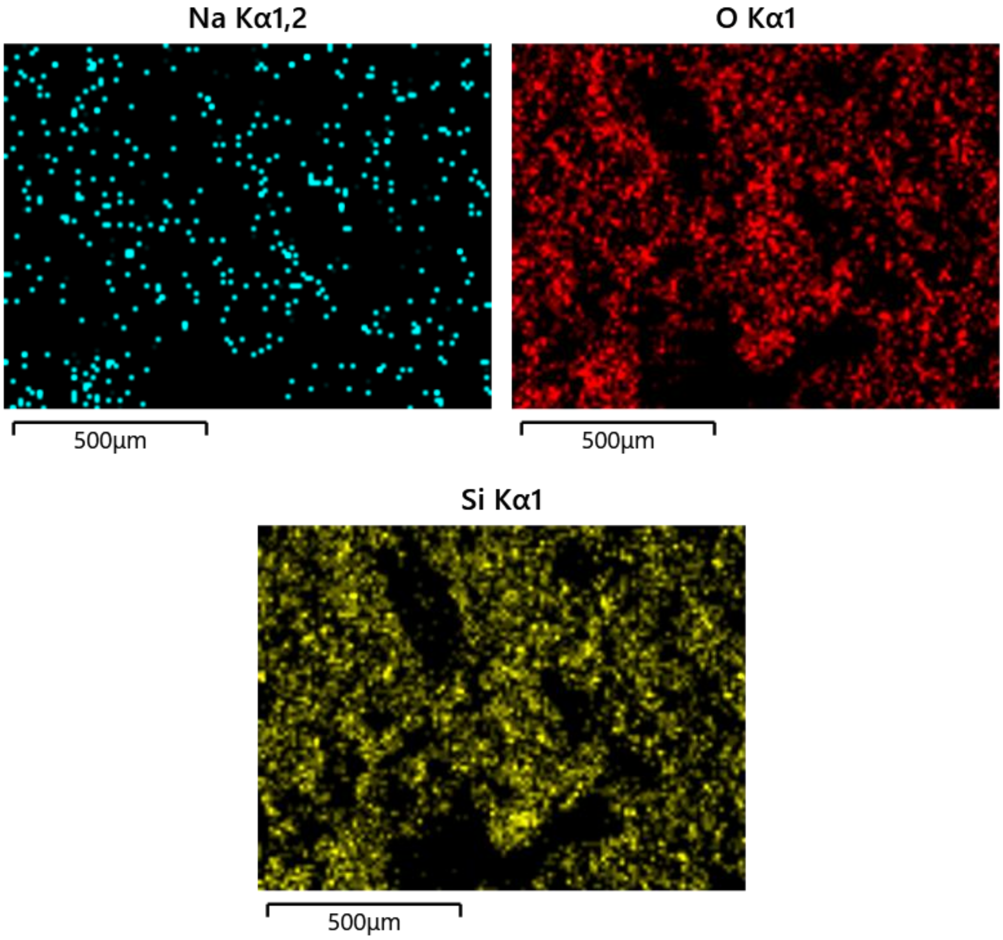


Figure 3. Element distribution obtained from SEM–EDS analysis. 0-15 cm

The analysis showed that silicon (Si) and aluminum (Al) made up 16.69 wt.% and 6.28 wt.% of the sample which confirmed the existence of aluminosilicate and quartz minerals. The 5.65 wt.% Iron (Fe) content indicates that technogenic particles from metallurgical operations have settled during the deposition process. The soil surface accumulation of industrial emissions together with dust particles explains why K, Mg, Ca and Na appear in the soil.

Elemental composition of the 15–30 cm layer (subsoil)

The oxygen (O) content reached 45.65 wt.% in the 15–30 cm layer because this section contained mostly oxide and silicate minerals. The subsoil layer contains silicon (Si) at 21.52 wt.% and aluminum (Al) at 7.47 wt.% which shows that the layer has a powerful natural mineral composition from geological sources.

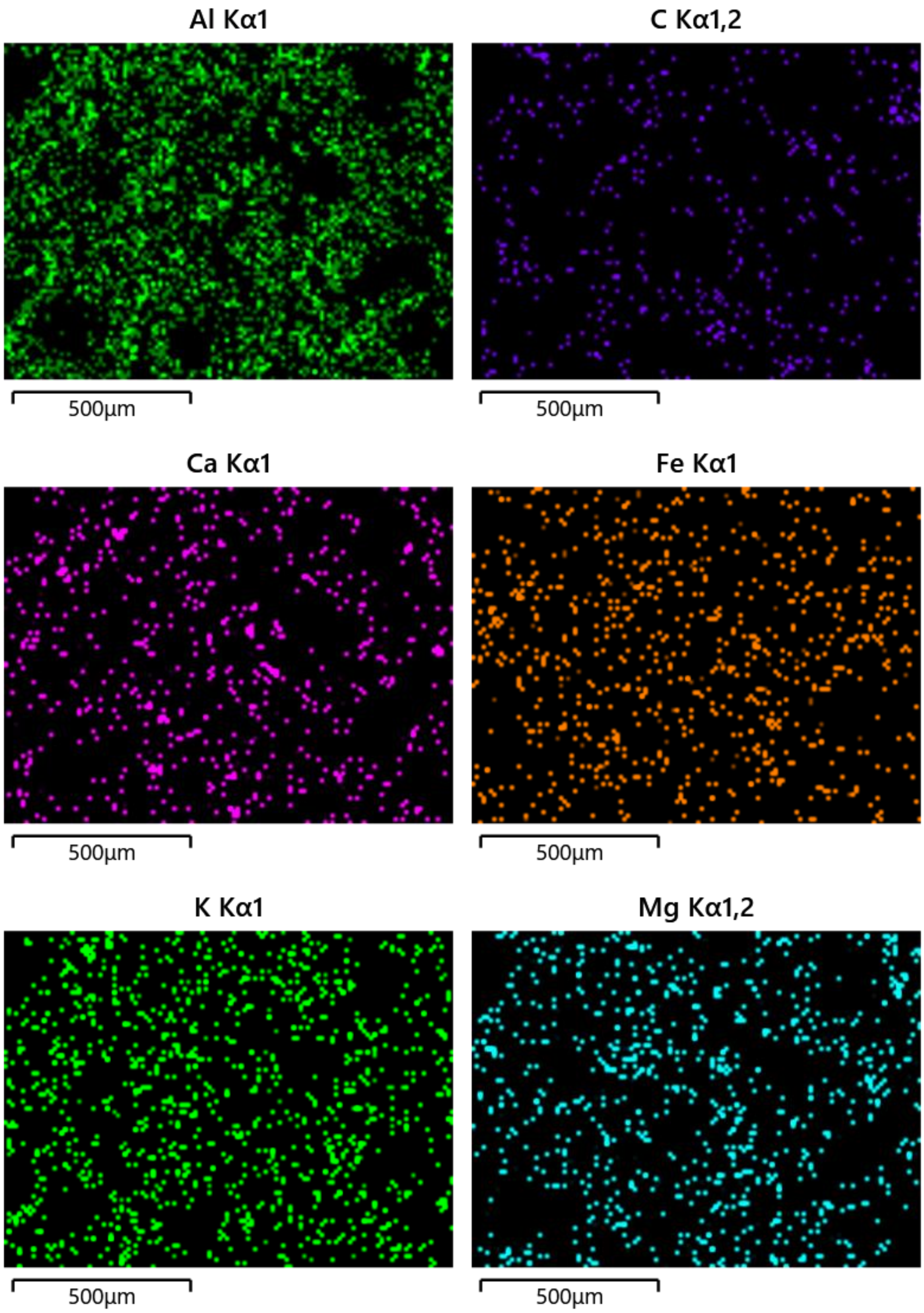
The carbon (C) content decreased to 12.78 wt.% which indicates that organic matter and technogenic carbonates mainly exist in the upper 0–15 cm soil layer. The 5.94 wt.% iron (Fe) content shows its ability to move vertically through soil layers when specific environmental factors exist. The soil contains mineralized subsoil layer because its Ca, Mg and Na content shows a small rise.

Comparative analysis between layers (0–15 cm and 15–30 cm) The depth-wise comparative analysis produced the following results. The 0–15 cm soil layer shows elevated carbon (C) levels which confirm that the contamination exists primarily at the top layer of the soil. The 15–30 cm soil layer contains elevated Si and Al concentrations because this section consists mainly of natural mineral substances.

The iron (Fe) levels between the two layers show identical values which indicate both human-made contamination and possible soil profile-wide iron distribution. The deeper layer contains more oxygen because its minerals exist in their oxidized states.

Characteristics of vertical contamination distribution

The research results show that industrial pollution exists mainly in the top 15 cm of soil which scientists identify as the most sensitive environmental area. The 15–30 cm soil layer shows evidence of Fe, Ca and Mg presence which suggests that pollutants will move through the soil layers at a slow rate.


Al Kα1
C Kα1,2
500µm
500µm
Ca Kα1
Fe Kα1
500µm
500µm
K Kα1
Mg Kα1,2
500µm
500µm

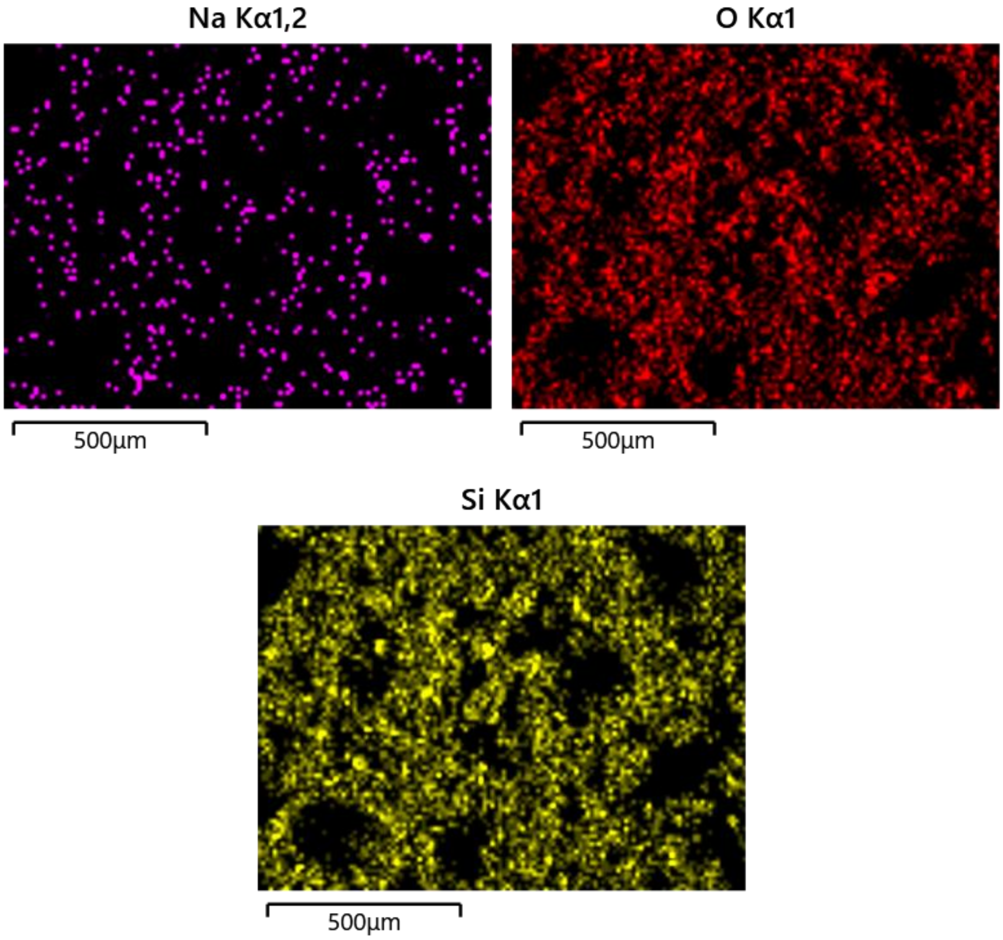


Figure 4. Element distribution obtained from SEM–EDS analysis

4. Conclusions

The findings of this investigation clearly demonstrate that the highest concentration of contaminants is confined to the uppermost 15 centimeters of the soil profile within the industrial area. This topsoil layer exhibits elevated levels of elements associated with industrial emissions and anthropogenic activity, whereas the deeper 15–30 cm subsoil predominantly reflects the natural mineralogical composition typical of the region.

However, the presence of certain elements within the subsoil indicates that the influence of industrial pollutants extends beyond the surface layer, suggesting a potential for long-term environmental impact. This implies that contaminants may gradually migrate downward over time, posing ongoing ecological risks. Consequently, these results underscore the importance of continuous monitoring and proactive management strategies to mitigate the sustained effects of industrial pollution on soil health and surrounding ecosystems.

REFERENCES

[1] Adriano, D. C. (2001). Trace elements in terrestrial environments. Springer.

[2] Alloway, B. J. (2013). Heavy metals in soils: Trace metals and metalloids in soils and their bioavailability. Springer.

[3] Chen, T. B., & Zheng, Y. M. (2011). Assessment of heavy metal contamination in urban soils. Environmental Monitoring and Assessment, 173, 673–687. https://doi.org/10.1007/s10661-010-0623-3.

[4] Kabata-Pendias, A., & Pendias, H. (2001). Trace elements in soils and plants (3rd ed.). CRC Press.

[5] Li, P., et al. (2017). Spatial distribution of heavy metals in industrial soils. Environmental Science and Pollution Research, 24, 10234–10245. https://doi.org/10.1007/s11356-017-9268-2.

[6] Li, X., et al. (2006). Heavy metal contamination of urban soils in China. Journal of Environmental Management, 78(2), 121–132. https://doi.org/10.1016/j.jenvman.2005.04.003.

[7] McBride, M. B. (1994). Environmental chemistry of soils. Oxford University Press.

[8] Sparks, D. L. (2003). Environmental soil chemistry (2nd ed.). Academic Press.

[9] Wu, J., et al. (2010). Heavy metal contamination in soils and crops. Science of the Total Environment, 408, 1343–1351. https://doi.org/10.1016/j.scitotenv.2009.11.009.

[10] Zhang, H., et al. (2015). Vertical distribution of heavy metals in urban soils. Environmental Pollution, 196, 295–303. https://doi.org/10.1016/j.envpol.2014.10.012.

[11] Alloway, B. J. (2019). Heavy metals in soils: Trace metals and metalloids in soils and their bioavailability. Springer.

[12] Chen, H., & Zheng, Y. (2022). Vertical distribution and pollution assessment of heavy metals in soils from industrial zones. Environmental Monitoring and Assessment, 194(5), 320. https://doi.org/10.1007/s10661-022-10050-7.

[13] Li, X., Wang, Y., & Zhang, L. (2021). Migration and accumulation of heavy metals in soil profiles near industrial areas. Journal of Environmental Management, 284, 112081. https://doi.org/10.1016/j.jenvman.2021.112081.

[14] Sparks, D. L., Johnson, A., & McBride, M. B. (2020). Soil contamination by atmospheric deposition of aerosols from industrial sources. Environmental Science & Technology, 54(3), 1512-1520. https://doi.org/10.1021/acs.est.9b05555.