Proceedings

Evaluation of heavy metals pollution in the soil of Helwan, Cairo, Egypt using magnetic and chemical analysis techniques

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Abstract: In the present study, we have applied magnetics and geochemical analysis in order to investigate the heavy metal contamination in Helwan area, Cairo, Egypt. We have collected 52 soil samples from Industry zones and urban areas. We characterized the spatial pollution pattern using ICP-MS and found enrichments in seven potentially toxic heavy metals; Cu, Zn, Pb, As, Sb, Cd, and Hg, located near industrial zones, with high pollution levels. The bulk magnetic susceptibility values (k) measured on samples range between a maximum of 3560×10^{-6} SI near the Industry Zone area and 168×10^{-6} SI locate in the eastern part of the study area (sandy soil), which is not fairly affected by pollution (un-urbanized). The mass-specific magnetic susceptibility (χ) measured on samples ranges between 0.058×10^{-6} and 2.83×10^{-6} m^3/kg. Thermomagnetic runs reveal that magnetite and Ti-rich titanomagnetite control the magnetic signal. The spatial distribution of the mass-specific magnetic susceptibility (χ) and Pollution Load Index (PLI) shows the highest values in industrial areas.

Keywords: Soil pollution; Pollution Load Index; Cairo

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1. Introduction

Magnetic susceptibility is the degree of magnetization of materials as a response to an applied magnetic field. Determining volume-specific susceptibility is a fast and cost-efficient method, and it is possible to use it as an indicator of anthropogenic contamination of some metals in sediments. But, application of magnetic methods alone is not enough, as there is no uniform correlation between magnetic susceptibility and geochemical composition. Therefore, in addition to determination of magnetic measurements at least some geochemical analysis should be also performed. Applying magnetic measurements in different investigations in environmental research was initiated by [1] and [2]. Following up this pioneering work, the possible application of magnetic measurements as a replacement for or in addition to expensive and complicated chemical analysis in contamination research was intensively investigated (e.g., [3]; [4]; [5]; [6]. Investigations performed in industrial areas have also shown that the distribution of magnetic susceptibility is closely connected with deposition of industrial dust and that determination of magnetic properties could be used as a method for the detection of the presence of heavy metals in soils and sediments. Magnetic method is promising and useful for identification of polluted areas. Because this method is fast and cost-effective, it is possible to handle dense important points from which chemical analysis should be performed [7] on the basis of obtained magnetic susceptibility maps. This cuts the costs of mapping heavy metals in the environment and contributes significantly to the quality of environmental research. This study aims for characterization of the spatial heavy metal distribution in Helwan industrial areas and its vicinities in comparison with different magnetic parameters. The paper demonstrates the main land-use features in the area and chemistry in relation to the obtained magnetic measurements, to end up with a deduction for the viability of magnetic measurements to express the distribution of pollutants in such complex area.

2. Materials and Methods

2.1. The study area

The study area, one of the most prominent contamination zones in Egypt, is located in the southern part of Cairo (Fig. 1). The area is located between 29.77° to 29.95° N and 31.29° to 31.385°E and represents about 187.3 km2. It is characterized mainly by the Mediterranean climatic conditions, which is characterized by scarce rains, mainly in winter, and hot dry summers.

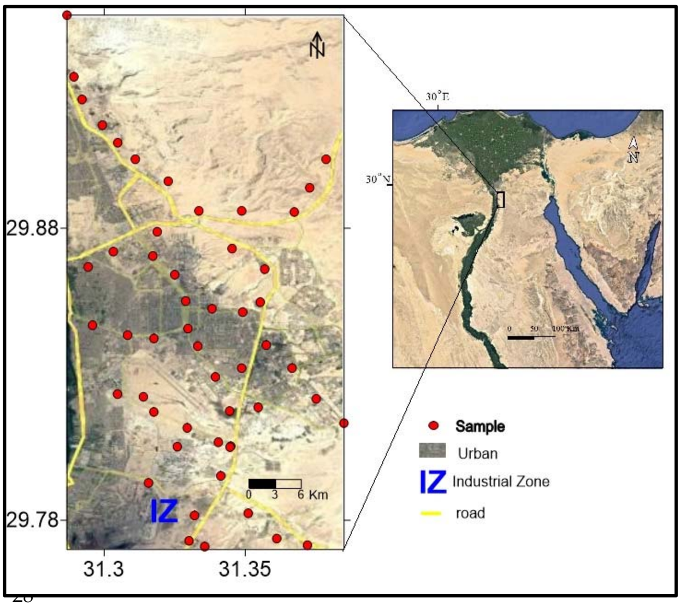

Figure 1. Location Map of Egypt showing the study area and sampling sites.

2.2. Sampling

We carried out sampling using a map prepared by Surfer 15.3, making use of information from Google earth satellite maps. The point's locations were determined using a Garmin GPS instrument. Samples were collected in in winter 2021 avoiding places with macro-magnetic objects, such as iron debris (nails, wires, etc.) and waste material. A total of 52 sites were selected to get surface samples aiming for possible discrimination of anthropogenic and natural contributions. Soil samples were air-dried, carefully mixed, homogenized and divided into smaller amounts to be representative for further chemical analysis, and magnetic measurements. In the present study we have studied the surface samples represent the uppermost 3-5 cm of the soil using chemical and magnetic analysis.

2.3. Laboratory magnetic measurements

Mass-specific magnetic susceptibility (χ) measurement is done for all samples after wrapping the sample material in a 10 cm3 cylindrical plastic vessel. To study the magnetic mineralogy, 22 surface samples were subjected to temperature dependent susceptibilities (k-T) measurements. Magnetic susceptibility and k-T measurements were carried out at Geomagnetism Laboratory, National Research Institute of Astronomy and Geophysics (NRIAG), Helwan, Cairo, Egypt. Magnetic susceptibility was measured at low field (200 A/m) applying two frequencies (976 and 15616 Hz), using an Agico MFK1-FA Kappabridge device at room temperature, and the results were then converted into mass-specific values. The k-T measurements were carried out using the same device with a CS4 temperature furnace for continuous heating from room temperature to 700 °C in air atmosphere.

2.4. Chemical analysis

A total of 22 samples were chemically analyzed for 37 elements using ICP-MS technique in ACME Lab, Vancouver, Canada. Pulverized samples were digested in open vessels on a hot plate using a combination of nitric, hydrochloric, hydrofluoric and per chloric acids to dissolve the silicate minerals.

3. Results and discussion

3.1. Chemical analysis

The chemical analysis for heavy metal (HM) concentrations show a large difference between the minimum and maximum concentration values, especially for Cu, Zn, Pb, As, Sb and Cd. The high standard deviation reflects a marked heterogeneity in the surface soil composition. The pollution load index in surface samples ranges between 0.24 and 21.4 with a median of 0.9 indicating that the pollution level in the study area fluctuates between no pollution (PLI < 1) and extremely polluted in south Helwan area and its surroundings (PLI = 2.2), followed by the Industry Zone area (PLI = 5.3).

3.2.Magnetic measurements

3.2.1. Magnetic minerology

The samples of Agriculture land are characterized by fairly reversible heating and cooling curves during Thermomagnetic susceptibility (K-T) cycles indicating titanomagnetite as the main carrier of magnetization in these rocks. The thermomagnetic susceptibility curves of the soil samples showed three Tc of 340 ◦C, 570 ◦C and 670 ◦C, indicating that Titano-magnetite, magnetite and hematite are dominate their magnetic properties (Figure 2-a). Samples inside the Industry Zone (Figure 2-b) are characterized by strong reversible heating and cooling curves during Thermomagnetic susceptibility (K-T) cycles, typical for multi-domain (MD) magnetite, which despite the masking effect of newly formed magnetite, confirms the existence of magnetite in the original samples.

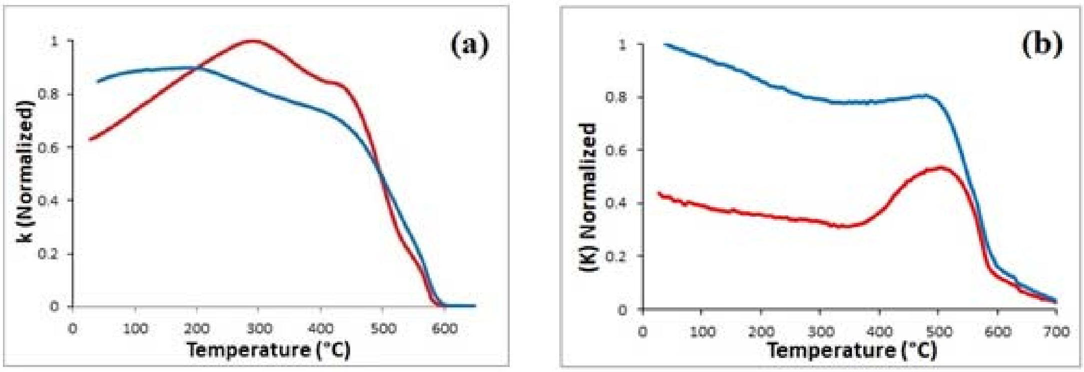

Figure 2. Thermomagnetic analysis (k-T curves) of representative soil sample for (a) agricultural, and (b) industrial land use area

3.2.2. Special distribution of surface magnetic susceptibility

The mass-specific magnetic susceptibility (χ) measured on samples ranges between 0.058 × 10-6 and 2.83 × 10-6 m3/kg (Fig. 3). The spatial distribution of the mass-specific magnetic susceptibility (χ) of low frequency (976) (Fig. 3) shows the highest values in the industrial zone. According to the surface magnetic susceptibility values, we classified the data into three ranges to Land use. The lowest range is from 0.05 -1 × 10-6 m3/kg and it is associated with sand soil. The range from 1×10-6 to 1.8 × 10-6m3/kg corresponds to agricultural soil. The last class is attributed to the Industry areas (polluted areas) (1.9- 2.83 × 10-6m3/kg).

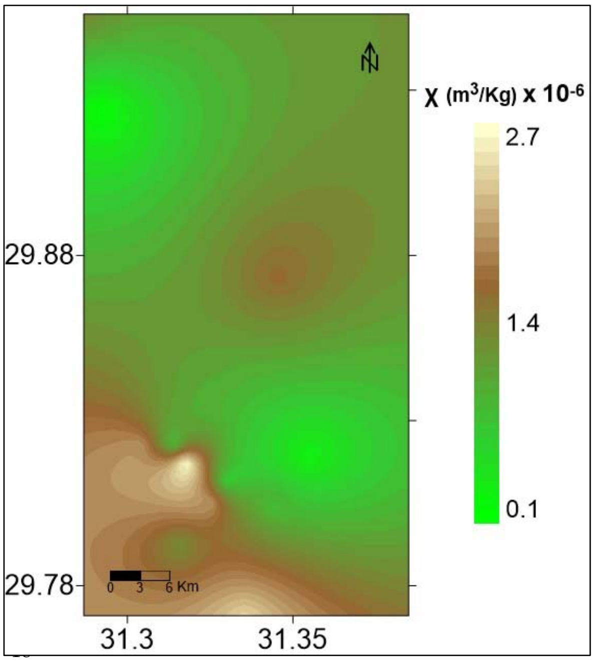

Figure 3: Spatial distribution of χ values.

4. Conclusion

The highest values of magnetic susceptibility and Toxic elements were found at the Industry zone, southeast of the study area.

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Conflicts of Interest: The authors declare no conflict of interest.

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