Use of magnetometry in assessment of soil and lake sediment pollution

Summary

The presented method of soil magnetometry is based on detection of magnetic particles in many industrial and urban dusts emitted to the atmosphere and deposited on the soil surface or water sediment. Magnetic particles are produced during fossil fuel combustion and other high temperature technological processes. In such conditions a transformation of paramagnetic iron minerals into the ferrimagnetic iron oxides occurs. The anthropogenic iron oxides are characterized by high magnetic susceptibility. Their presence in soil or sediment can be easily detected using simple laboratory or field magnetic susceptibility meters (χ or κ respectively) and on this basis a degree of environmental pollution caused by industrial and urban dust deposition can be assessed. Detected in a such way magnetic anomaly is the warning signal of potential contamination of the study area by heavy metals and other soil pollutants. The data presented here as well as data from literature point to direct or indirect correlations between magnetic particles and some heavy metals, mostly Pb, Zn, Cd and Cu, contained in industrial and urban dusts. Among the industrial dusts the highest χ values were measured for metallurgical dust. However, for the sake of the relatively large diameter of metallurgical particles they are transported on a short distance from the emission source and have a local importance. Because of the quantity and distribution of emission sources in Poland the largest amount of magnetic particles and related heavy metals is carried by fly ashes and power dusts from hard and brown coal burning.

The field study carried out during the last 10 years pointed at forest areas and ombrotrophic peatbogs as most suitable areas for κ measurement. In forest soils, in contrast to cultivated ones, the individual soil horizons are undisturbed by agrotechnical measures. Therefore the vertical distribution of susceptibility can be analyzed as an effect of multiannual deposition of anthropogenic dust. In the case of magnetic anomaly detection such an analysis felicitates the proper interpretation of their origin (either anthropogenic or natural). Anthropogenic ferrimagnetic mineral are concentrated in the uppermost 10 cm layer of forest soil (Of and Oh horizons). In the same horizons the highest concentration of heavy metal was observed. A study carried out in Katowice Forest District shows that in each case when κ value exceeded 100 x 10^{-5}, the concentration of at least one metal (mostly Pb) was over the threshold value.

In the case of ombrotrophic peatbogs very low or slightly negative value of susceptibility of organic matter is helpful for identifying even a small concentration of particulate magnetic pollutants, resulting from increased industrial dust deposition. The highest χ and heavy metal values were measured in peat bogs from Lower Silesia (Izera Mts. and Wegliniec Bog). However, an unequal distribution of ombrotrophic peat bogs on Polish territory is the reason why it cannot be used in assessment of the deposition rate in national scale, because most of them are located in areas with low annual dust fall (eastern Poland). However the study seems to be very useful for following pollution in historical aspect.

The analyses of magnetic parameters in bottom sediments from Żywiec Lake exhibit not only the presence of anthropogenic magnetic particles but also the seasonal changes in their content. In spite of relatively low absolute χ value, in 80% of samples collected in May 1970 the value was higher than in those collected in September. The effect is probably due to the spring accumulation of pollution including magnetic particles, stored on the frozen lake surface during the whole winter season (heating period). In the summer the magnetic particles were partially “diluted” in the mass of new diamagnetic and/or paramagnetic natural material carried by

the Sola River during the summer flood.

One of the calculable effects of measurements and studies carried out in the last decade was compilation of topsoil magnetic susceptibility maps of large areas (ca. 200 000 km^2) in Central Europe (based on the field measurements integrated with GPS data in 10 km grid) and topsoil magnetic susceptibility map of Poland (based on laboratory measurement of archival samples from national database in 5 km grid). The maps clearly show that the largest magnetic topsoil anomalies are located close to such European industrial centers as: Upper Silesia, Ostrava and Trinec area, “Black Triangle” area (Polish, Czech and German border area), north-eastern Saxony, northern Bohemia, and Leoben area (Austria) as well as some smaller areas connected with big cities (Prague, Wroclaw, Linz, Munich).

However the volume susceptibility (κ) measured in the field and mass susceptibility (χ) measurement in laboratory are not exactly the same parameters and the sample collection procedure in the case of archival samples from national database was not properly adopted for magnetometry purposes (removal of forest litter usually mostly affected by dust deposition), the distribution of κ and χ values on relevant maps were quite similar. Beside the mentioned areas the magnetic anomalies are located close to the urban agglomeration (Kraków, Trójmiasto, Łódź, Poznań, Częstochowa, Warszawa). There are also some small (in area) anomalies of natural origin connected with occurrence or former exploration of iron ores or outcrops of magnetite rich basaltic rocks.

In the area of magnetic anomaly, where more precise survey and designation of the range of contamination is required, the magnetometry may be a very useful tool. In local scale (town, district, quarter), the magnetic mapping of industrial and urban areas can be a very precise tool for fast preliminary survey of soil contamination. Because of speed and simplicity of field measurements, the density of measurement grid can be very high, allowing increasing accuracy in localization even small (in area) anomaly. Such small anomalies may be a result of a former wastes storage and other potentially hazardous substances (ash, slag, sewage sludge, flotation wastes etc.). Also some other potential applications of magnetometry (vehicle pollution distribution, land melioration processes study, soil erosion and archeology) with a special emphasize on their usefulness in national and European soil monitoring system was suggested.