Ber. Inst. Erdwiss. K.-F.-Univ. Graz	ISSN 1608-8166	Band 9	Graz 2004

ANALYSIS OF HEAVY METAL POLLUTION BY MAGNETIC METHODS – APPLICATIONS IN AUSTRIA

Monika HANESCH, Sigrid HEMETSBERGER & Robert SCHOLGER

Chair of Geophysics, Department for Geosciences and Geophysics, University of Leoben

Introduction

Pollution of soils by heavy metals constitutes a serious health hazard and therefore has attracted growing attention during recent years. Usually the content of heavy metals in soils is assessed by chemical measurements of soil samples. This method is time-consuming and expensive. Magnetic susceptibility measurements, however, can rapidly be done in the field and a relation between heavy metal content and magnetic susceptibility has been found in several studies (Bityukova et al., 1999; Hay et al., 1997; Heller et al., 1998). In the work shown here, we successfully applied magnetic susceptibility mapping for the delineation of polluted areas in Austria. Additional magnetic parameters may be used to distinguish anthropogenic and geogenic minerals and to determine the grain size of the magnetic minerals.

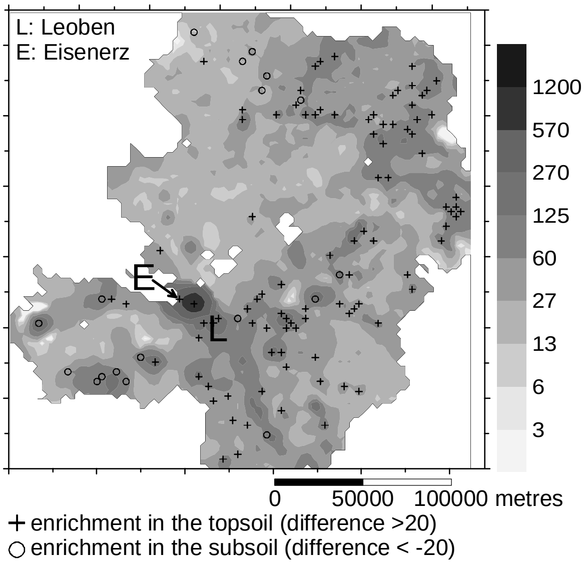

Figure 1: Magnetic susceptibility ($10^{-8}m^3kg^{-1}$) of the topsoil (0-20 cm) in Lower Austria, Burgenland and Styria. Leoben and Eisenerz were chosen for high resolution mapping (Section 4).

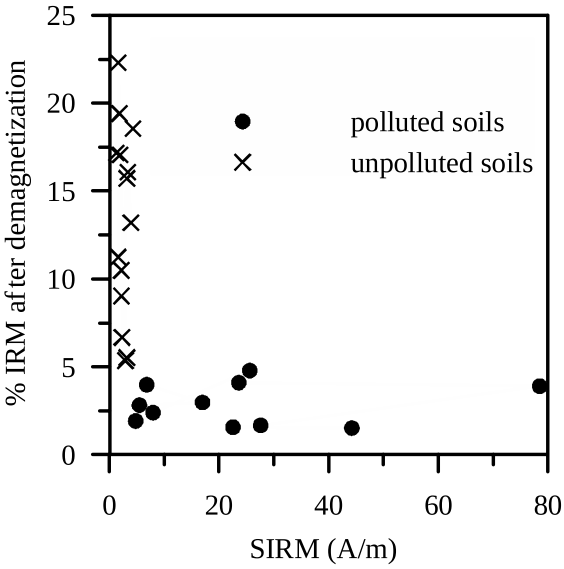

Figure 2: Saturation magnetisation (2500 mT) and rest of isothermal magnetisation (1450 mT) after demagnetising with an alternating field of 150 mT.

Large scale mapping of magnetic susceptibility

The magnetic susceptibility (unit: $10^{-8}m^3kg^{-1}$) of soil samples with known heavy metal content was measured in the laboratory to test the significance of susceptibility as a pollution indicator. We chose the dried and sieved samples of the soil surveys carried out in Lower Austria, Burgenland and Styria by the respective provincial governments (sampling grid: 4 by 4 km). The measurements were carried out with a Bartington MS2C loop sensor and an Exploranium KT9 instrument. Maps were produced for the topsoil (0-20 cm depth, Figure 1) and the subsoil (20-50 cm depth). Polluted areas typically show high values in the topsoil and lower values in the subsoil. Anomalies were defined where the difference between topsoil and subsoil exceeds $20 \cdot 10^{-8}m^3kg^{-1}$. All anomalies showed elevated heavy metal values and their origin could be explained by anthropogenic or geogenic sources (Hanesch and Scholger, 2002).

Magnetic mineralogy

The results of the large scale mapping were used to choose samples for a comparison between the magnetic mineralogies of polluted and unpolluted areas. The magnetisation of samples after applying a field of 2500 mT (SIRM) is much higher for polluted soils.

The stability of an isothermal remanent magnetisation was tested by first applying a magnetic field of 1450 mT (IRM) and then demagnetising it by an alternating magnetic field of 150 mT. The amount of "soft" magnetisation, which is removed below 150 mT, is larger for the polluted areas. The magnetic minerals produced by combustion of fossil fuels are easier to magnetise and demagnetise than the geogenic magnetic minerals.

Figure 2 shows a cross plot of SIRM and the rest of IRM after demagnetisation. Polluted and unpolluted soils form two distinct groups. These facts can be used for a separation of anthropogenic and geogenic minerals if there are doubts about the origin.

Regional mapping at high resolution

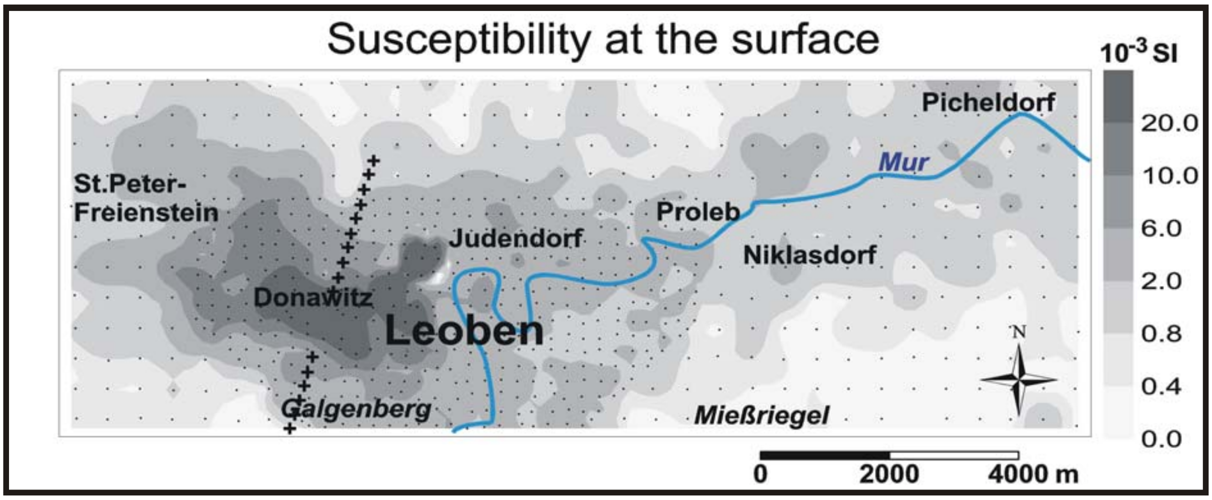

Figure 3: Contour plot of volume susceptibility around the city of Leoben. The black dots mark the measurement points. The steelwork is located at Donawitz. Transport of magnetic particles occurs dominantly along the valley of the river Mur.

The region around Leoben and Eisenerz is one of the largest anthropogenic anomalies in the study area (see Figure 1). To get a detailed picture of the distribution of pollutants in this region, two studies were carried out. The results for the Eisenerz area are shown in the paper by Hemetsberger and Scholger in this issue. The region around Leoben was chosen for a high resolution mapping. The measurement grid was 500 m by 500 m around the city and 250 m by 250 m in the centre (Figure 3). The Exploranium KT9 was used to determine volume susceptibility (unit: 10^{-3} SI). The main source of magnetically susceptible particles are the steelworks in Donawitz. The migration of particles towards the north and the south is limited by the morphology. The city lies 540 m above sea level while the mountain *Mießriegel* has a height of 1213 m.

A second susceptibility map was produced by measuring maple leaves in the Leoben area. The distribution of magnetic minerals was the same with the exception of the dumping areas northwest of the main anomaly. They are not visible in the leaf map which is a representation of the recent pollution (over 2-3 months) whereas the soil map shows the accumulation of pollutants over many years (Hanesch et al., 2003).

Statistical analysis for heavy metal data and magnetic susceptibility

The statistical analysis of heavy metal data and magnetic susceptibility for the soil survey samples in the Leoben area showed a significant correlation of susceptibility with several heavy metals (Zn, Cd, Hg, Pb, Cu, Cr) and with polycyclic aromatic hydrocarbons (Figure 4).

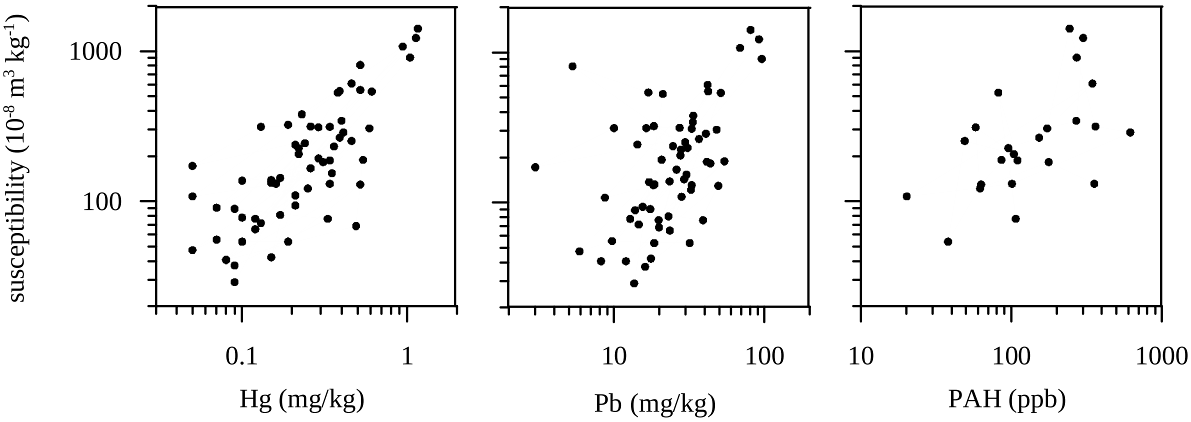

Figure 4: The scatter plots of susceptibility versus Hg-, Pb- and PAH-content demonstrate the correlation between susceptibility and these parameters over three orders of magnitude for the Leoben study area. Susceptibility measurements allow a rough estimation of the content of these pollutants in the individual soils. The two outstanding values in the lead graph (lead content low in comparison to susceptibility value) are two subsoil samples (20-50 cm). The elevated susceptibility is most probably caused by the parent material in these cases, as the samples have high values in Cr, Co and Cu, but exceptionally low values in the anthropogenic variables Pb, Mo and Cd.

Conclusions

In this study, magnetic susceptibility proved to be a powerful tool for pollution monitoring. Anthropogenic anomalies can be delineated by analysing the soil susceptibility of samples forming a grid over the study area. Polluted and unpolluted soils display distinct magnetic mineralogies. The main pollutants can be defined by additional chemical analyses. A correlation with the susceptibility values leads to an estimate of the distribution of pollutants over the investigated area.

References

BITYUKOVA L, SCHOLGER R, BIRKE M (1999) Magnetic susceptibility as indicator of environmental pollution of soils in Tallinn. Phys Chem Earth (A) 24 : 829-835

HANESCH M, SCHOLGER R, REY D (2003) Mapping dust distribution around an industrial site by measuring magnetic parameters of tree leaves. Atmos Env 37, no 36: 5125-5133 (doi:10.1016/j.atmosenv.2003.07.013)

HANESCH M, SCHOLGER, R (2002) Mapping of heavy metal loadings in soils by means of magnetic susceptibility measurements. Environ Geol 42: 857-870 (doi: 10.1007/s00254-002-0604-1)

HAY KL, DEARING JA, BABAN SMJ, LOVELAND PJ (1997) A preliminary attempt to identify atmospherically-derived pollution particles in English topsoils from magnetic susceptibility measurements. Phys Chem Earth 22 : 207-210

HELLER F, STRZYSZCZ Z, MAGIERA T (1998) Magnetic record of industrial pollution in forest soils of Upper Silesia, Poland. J Geophys Res 103, No. B8 : 17767-17747