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Magnetic Susceptibility as Proxy for Heavy Metal Pollution: A Site Study

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Abstract

A magnetic susceptibility field survey was undertaken at a former industrial iron production and processing site, measuring samples from different depth. The aim was to investigate the suitability of such field measurements for indicating heavy metal pollution. Geochemical analysis of soil samples showed close correlation of concentrations between Fe, Cu, Mn and Ni. In addition, Fe concentrations correlated with magnetic susceptibility field measurements, particularly when taken after removing the turf layer. An important finding of this study is that best correlation is obtained for magnetic susceptibility values higher than a site-specific threshold. These results demonstrate the potential of magnetic susceptibility field mapping for fast preliminary site assessment, greatly reducing the scale of subsequent geochemical sampling and analysis.

Introduction

Many countries world-wide face the legacy of past industrial activities in the form of contaminated and derelict land. At the same time, new commercial and housing developments require space and are increasingly encroaching on the cities' green belts and the countryside. For example, it is estimated that 200,000 new homes will be built over the next 15 years in the 'Major Growth Areas' of southern England alone (ODPM 2003). The re-use of derelict land ('brown-field sites') is therefore important for environmental and town planning reasons.

Reclaiming such sites for new use requires careful assessment and subsequent remediation, which can be costly activities. A major concern is often the high concentration of heavy metals found on sites of past industrial use. Excess levels are frequently identified through chemical analysis of soil samples. However, such investigations are costly and slow, especially for larger areas, requiring laborious sample collection and preparation. It is therefore advantageous for rapid site evaluation to investigate other parameters, which are linked to the sought after quantities but can be measured more easily ('proxies').

Mineral magnetic measurements provide detailed information about the composition, state and grain size of iron-oxides, the most common ferrimagnetic minerals in soils. It was shown (Beckwith *et al.* 1986, Petrovský and Ellwood 1999, p. 286) that they can be used successfully to derive proxies for soil contamination. In a case study from south France Lecoanet *et al.* (2003) established that bi-plots of magnetic susceptibility *vs.* ARM/SARM helped to distinguish the different sources of iron-oxides. Various mechanisms for the correlation of heavy metals with iron-oxides in soils have been identified, especially adsorption and incorporation. It was found that the individual contributions depend strongly on the source of contamination, local soil geology and geochemistry (Petrovský and Ellwood 1999, p. 312, Wehland *et al.* 2002). Where iron-oxide particles are discharged from industrial processes, associated heavy metals can either be incorporated into their atomic lattice or be adsorbed to their surfaces and their concentrations are therefore correlated. For example, Scholger (1998) found that iron producing and manufacturing industries in Styria emitted Zn, Pb, Ni, Cu and Cr together with macroscopic scale particles, which were easily quantified in river sediments through magnetic measurements.

While sample preparation and subsequent measurement of mineral magnetic properties is relatively quick, laboratory facilities with dedicated devices are required. Only volume magnetic susceptibility (κ) can, to date, be measured in the field. Several studies tried to evaluate the use of such measurements for the large scale mapping of areas contaminated with fly ash. In Poland, the aerosol output of power plants was successfully mapped by measuring topsoil magnetic susceptibility with a field sensor (Strzyszcz 1993, Heller *et al.* 1998). Comparable results were produced by studies in the Czech Republic (Kapička *et al.* 1999). Measurements carried out over a 10 km raster in England revealed enhanced levels of magnetic susceptibility in regions of heavy industry (Dearing *et al.* 1996). A principal component analysis of additional mineral magnetic measurements (Hay *et al.* 1997) showed that a combination of low field magnetic susceptibility and frequency dependent magnetic susceptibility resulted in an even better correlation. The latter property is sensitive to very fine-grained (SP) ferromagnetic particles in soil. In these studies, airborne pollutants were formed from iron-oxide particles and the measured magnetic susceptibility was hence directly proportional to the level of contamination. In another study, Hoffmann *et al.* (1999) successfully measured road traffic pollution by evaluating the spatial distribution of magnetic susceptibility in the nearby soils. Only a fraction of the pollutants were airborne. The strongest enhancement was found at the road's verge, indicating washed-down abrasion particles.

Few studies have attempted to apply a comparable methodology to the small-scale assessment of sites contaminated with heavy metals. For a confined research area in Bratislava, Slovakia, Ďurža *et al.* (1993) found some correlation of magnetic susceptibility with the total concentration of heavy metals but not with individual elements. Petrovský and Ellwood (1999, p. 300) discovered that magnetic susceptibility and Zn concentrations show very similar spatial distributions in a 20,000 m^2 area at the Litavka River, Czech Republic, where ashes from a lead smelter are weathering in the fluvisols. In other studies, however, poorer correlation between magnetic susceptibility and heavy metal concentrations were reported (Charlesworth and Lees 1997, 2001; Petrovský *et al.* 1998; Kapička *et al.* 1999).

It is the aim of this research to investigate the conditions under which on-site magnetic susceptibility measurements can be used for the rapid identification of areas with heavy metal contamination ('hot-spots'). This will allow subsequent geochemical sampling and analysis to be focussed on smaller areas, thereby decreasing costs and time considerably.

Method

Site description

The study area is located near Bradford, England, on a plateau 300 m above sea level formed from mainly Oakenshaw and Clifton Rocks of the Upper Carboniferous (Silesian) series. These rocks are underlain by the Westphalian lower coal measures consisting of the Crow, Black Bed and Better Bed seams, with Millstone Grit beneath. Such combination had made it possible to jointly exploit iron-ore and high quality coal, required for its processing. The Low Moor Iron Works were located close to the study area and produced high quality iron from 1789 to 1957. The selected study area had been the site of a tramway exchange and flat-heap iron-ore weathering, possibly leading to localised contamination of this area, beyond the general background enhancement from the Works' fly ash deposition. As recent amenity tree planting on it failed, heavy metal contamination from these localised activities was suspected. The area was hence considered suitable for a detailed comparison of magnetic susceptibility surveying and geochemical analysis to evaluate the heavy metal content and to test the use of magnetic susceptibility as proxy measurements.

Fieldwork

Sampling was conducted at the centre of 10m grids over the contaminated area (to give 22 samples A1 to H3, subset C), and at 10m intervals along a transect, either side of the contaminated area, to provide off-site control data (17 samples T0 to T20, subset T); see Figure 1. At each of the 39 sample locations two volume magnetic susceptibility values (κ) were recorded in the field with a Bartington MS2D coil, one with and one without turf layer. For the former, good contact between coil and ground was achieved due to direct contact with the short grass. For the latter, a stainless-steel spade was used to remove approximately 40 mm of the dense grass vegetation (turf) over an area of about 0.3 m^2, allowing close contact between sensor and bare soil. As field-coil measurements show a rapid fall-off with distance (Lecoanet *et al.* 1999), this direct contact helped to improve the relationship between magnetic susceptibility and geochemical data (see below). A 0.1 m Dutch Auger was then used to extract soil samples in two ‘spits’ of 0.1 m (‘shallow’ and ‘deep’ samples: 0.0-0.1 m and 0.1-0.2 m below the bare soil, i.e. 0.04-0.14 m and 0.14-0.24 m below the top surface). Since field measurements of volume magnetic susceptibility can vary considerably even for adjacent locations (Lees 1999), especially if taken through loose vegetation like long grass or leaf litter, repeat measurements around some points were recorded prior to the investigation. They were found to vary by not more than 3%. This very good repeatability was attributed to the short grass and firm ground on the site and subsequent recordings were hence based on single measurements.

Laboratory work

Each of the soil samples was mixed, air dried, disaggregated and sieved retaining the fraction smaller than 2 mm to reduce the biasing effect of air, water and pebbles. Then a 50 g subsample was obtained for subsequent analysis. Each 50 g sample’s mass specific magnetic susceptibility (χ) was measured in the laboratory with an a.c. bridge, then a 20 g subsample was taken from it for geochemical analysis. Each subsample was ground at amplitude 2.5 in a Fritsch Analysette agate ball mill for 15 minutes, then 1±0.01 g subsamples were digested in heated aqua regia. Cd, Cu, Cr, Fe, Mn, Ni, Pb and Zn concentrations were determined using a Pye Unicam PU7450 ICP-AES.

Through comparison with reference samples it was found that the accuracy of elemental concentrations, evaluated as the relative standard deviation, was about 5-7% for the different elements. The error of the laboratory measurements of mass specific magnetic susceptibility was found to be smaller than 3%, using repeat-measurements and comparison with reference samples.

Results

Geochemical analysis

Table 1 shows the Pearson correlation coefficients for Fe with all other metal concentrations, measured on the shallow samples. While for the whole data set correlations are not very strong (highest correlation of 0.81 for Ni), the investigated site itself (subset C) shows very distinct correlations between Fe, Cu, Mn and Ni (approx. 0.91) and a slight negative correlation with Pb (-0.24). The low correlation along the transect (highest value of 0.63 for Ni) confirms that it runs mainly through non-contaminated areas where the low levels of different elements vary nearly independently. Table 2 shows the correlation between the different heavy metals.

Magnetic susceptibility measurements

Descriptive statistics for the magnetic susceptibility measurements is summarised in Table 3, showing results for all measurements together and individually for the two subsets. To assess whether the results were normally distributed, relative differences between mean and median, and skewness were calculated. It can be seen that magnetic susceptibility is lower and less skewed along the transect than in the contaminated area, indicating that the transect can be regarded as 'background' for magnetic susceptibility. In the investigated area skewness is considerable and is not much reduced when applying a logarithm transformation as suggested by Lees (1999) (i.e. the distribution is not log-normal). This can be attributed to the inhomogeneous variation of contamination in the investigated area leading to some samples being far off a random-normal or log-normal distribution of magnetic susceptibility values.

Figure 2 shows the relationship between the four different measurements of magnetic susceptibility for the whole data set (volume magnetic susceptibility with and without turf layer, and shallow and deep mass specific magnetic susceptibility). Correlation of the shallow mass specific susceptibility with the other three measurements has Pearson coefficients of 0.828 (with turf layer), 0.969 (without turf layer) and 0.970 (deep).

The good correlation between field measurements without turf layer and shallow samples is not surprising since both probed the same ground. The shallow samples (0.1m thick) contribute more than 95% to the Bartington MS2D measurements that were taken after removal of the turf layer (Lecoanet *et al.* 1999). It is therefore possible to calculate an apparent bulk density from these two measurements ($\rho_A = \kappa_{without\,turf} / \chi_{shallow}$). The average of this measure was found to be 0.63×10^3 kg m^{-3} with a relative standard deviation of 26% of the mean. Based on the apparent bulk density for each sample location, the topsoil's apparent mass specific magnetic susceptibility was calculated from the field measurements with turf layer for ease of comparison. This calculation preserves relative changes observed in the volume magnetic susceptibility with and without turf layer. Figure 3(a) shows the resulting depth profiles for the contaminated area. Magnetic susceptibility increases at each position after removal of the turf and for most sample locations the shallow and deep samples have similar magnetic susceptibility with a slight decrease with depth (median of relative decrease with depth is 4%). The lower magnetic susceptibility of the turf layer can be related to the end of iron processing at the site in 1957 and confirms that magnetic susceptibility of the soil samples is related to past localised depositions rather than recent airborne particulate pollution. A comparison of magnetic susceptibility measurements from vegetation and soil samples was also used by Hanesch *et al.* (2003) to investigate the time of deposition. The weak decrease of magnetic susceptibility over the top 0.2 m of subsoil might be the result of soil mixing, possibly due to ploughing.

Magnetic susceptibility as proxy

To investigate whether magnetic susceptibility measurements can be used as proxies for heavy metal pollution on the site, the correlation of mass specific magnetic susceptibility from the shallow samples with Fe concentrations was examined. These two parameters were selected since, as shown above, iron is closely correlated with the heavy metal contaminants of the site and magnetic susceptibility of the shallow samples is closely correlated with the other magnetic susceptibility measurements. In addition, it is anticipated that iron, mainly in the form of its ferrimagnetic oxides, contributes most to the measured magnetic susceptibility. When comparing these two parameters for all samples a Pearson correlation coefficient of 0.836 is found, which is significant at 1%. For the two subsets the coefficients are –0.160 (transect) and 0.956 (contaminated site), respectively. The latter strong correlation is also reflected in very similar spatial distribution patterns (Figures 3(b) & 3(c)). The highest levels of contamination and magnetic susceptibility are found in the three west-most sample positions.

The very different results for the two subsets indicate that the correlation between magnetic susceptibility and heavy metal contamination only exists for the polluted samples, like those that carry magnetic inclusions. Incorporating 'background samples' into the statistical analysis can therefore adversely affect the results. However, when magnetic susceptibility is used as proxy measurement for site investigations, the separation of samples into 'background' and 'contaminated' is often not possible from the outset. Although the correlation for all samples of this study was already significant at 1% (see above), selecting a subset for which the magnetic susceptibility proxy measurements would be even more strongly correlated seems desirable. Upon closer investigation of the recorded values (Figure 4) it becomes clear that the correlation is better for higher values. If only samples above a threshold of $\chi_{shallow}=176 \times 10^{-8}$ m^3 kg^{-1} are considered, the correlation has a Pearson coefficient of 0.994 (solid line). This threshold is selected as a natural break since the inclusion of any sample below it decreases the correlation to 0.965 and lower. The threshold is 2% higher than the mean of all samples, 52% higher than their median and corresponds to an aqua regia Fe concentration of approximately 26,000 mg kg^{-1}. Using the average apparent bulk density calculated above, the threshold corresponds to a volume magnetic susceptibility of 111×10^{-5}. The so defined subset of samples that have higher magnetic susceptibility than the threshold (subset H) includes 15% of all samples. When comparing this derived subset (H) with the actual subsets (C and T) it is reassuring to note that it only includes samples from the contaminated area (C). The threshold is 67% higher than the background level as defined by the transect (T).

Discussion and Conclusion

Three major findings can be isolated from the measured results.

1. A pronounced positive correlation was found in the contaminated area between the concentrations of heavy metal elements Fe, Cu, Mn and Ni. Correlation with Pb is weakly negative.
2. A strong correlation between Fe concentration and mass specific magnetic susceptibility exists for the shallow samples with readings in excess of 176×10^{-8} m^3 kg^{-1}, which is 52% above the population’s median.
3. Field measurements of volume magnetic susceptibility correlate well with laboratory measurements, especially when removing the turf layer before recording.

Taken together, it can be confirmed that field measurements of volume magnetic susceptibility can be used as proxies to highlight areas of heavy metal contamination. The findings of this study importantly demonstrate that the correlation of results can be improved if the turf layer is removed before measurements are made and that good correlation only exists for samples of enhanced magnetic susceptibility. Although the threshold will be site specific, using a value 50% above the median of all samples proved to be an effective choice for the investigated site and is hence suggested for other studies.

This may explain why Ďurža *et al.* (1993) found only poor correlation of magnetic susceptibility with heavy metal concentrations, not exceeding a coefficient of 0.54. Their highest magnetic susceptibility measurement was only 28% above the median indicating weak enhancement across the investigated site. Similar observations can be applied to the investigation by Beckwith *et al.* (1986) who found that the correlation between heavy metals and magnetic susceptibility is lost if sediment samples with low magnetic susceptibility were added to the statistical analysis.

The investigated area of this study is part of an iron production and processing landscape. It was therefore expected that iron-oxides would be found together with other heavy metal pollutants. The success of magnetic susceptibility measurements in highlighting areas of contamination depends on these site conditions and may be different for sites of non-ferrous industries. For example, Strzyszcz (1993) found good correlation between magnetic susceptibility and Zn and Pb concentrations but mostly weak or even negative correlation with Fe. Since the contamination investigated by him mainly originated from power plants emitting fly ash, such differences to the present study are not unexpected. Given the slight negative correlation found on this contaminated site for Pb with other heavy metals, magnetic susceptibility is also negatively correlated with Pb. This is in accordance with findings by other authors (Gelisli and Aydin, 1998). The reasons for this negative correlation with Pb are to date unknown and further research into the causes is required.

Where sites are contaminated by ferrous industry, however, magnetic susceptibility could be used to identify hot spots of iron and associated heavy metals. Nickel and copper are included in guidelines on soil metal concentrations hazardous to human health in the United Kingdom (ICRCL, 1987) and the Netherlands (Ministry of Housing, Spatial Planning and Environment, 2000) and other hazardous metals could be associated with iron according to ore mineralogy. Inclusion of field magnetic susceptibility mapping in the preliminary non-intrusive site walkover after desk-based site history assessment could therefore indicate hot spots of hazardous metal contamination. Subsequent geochemical sampling and analysis will be necessary to determine metal concentrations relative to guidelines to reduce risk to human health.

This study confirms that fast and inexpensive field measurements of magnetic susceptibility have the potential to indicate areas of heavy metal contamination that may subsequently be investigated through geochemical analysis in more detail. Such staged approach reduces costs and time required for site investigations and will help with the analysis of contaminated and derelict land. It is important to investigate a sufficiently wide area such that background levels of magnetic susceptibility can be established. This helps to determine possible thresholds that must be considered to ensure the validity of proxy results. On sites where the source of contamination is not from recent air-born particles, correlation between field measurements of magnetic susceptibility and heavy metal contamination can be improved if a vegetation layer is removed prior to recording.

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References

Beckwith, P.R., Ellis, J.B., Revitt, D.M., Oldfield, F. 1986. Heavy metal and magnetic relationships for urban source sediments. Physics of the Earth and Planetary Interiors 42, 67-75.

Charlesworth, S. M., Lees, J. A., 1997. The use of mineral magnetic measurements in polluted urban lakes and deposited dusts, Coventry, UK. Physics and Chemistry of the Earth 22, 203–206.

Charlesworth, S. M., Lees, J. A., 2001. The application of some mineral magnetic measurements and heavy metal analysis for characterising fine sediments in an urban catchment, Coventry, UK. Journal of Applied Geophysics 48, 113-125

Dearing, J. A., Hay, K. L., Baban, S. M. J., Huddleston, A. S., Wellington, E. M. H., Loveland, P. J., 1996. Magnetic-susceptibility of soil - an evaluation of conflicting theories using a national data set. Geophysical Journal International 127, 728–734.

Ďurža, O., Gregor, T., Antalová, S., 1993. The effect of the heavy metals soil contamination on the magnetic susceptibility. Acta Universitatis Carolinae Geologica 37, 135–143.

Gelisli, K., Aydin, A., 1998. Investigation of environmental pollution using magnetic susceptibility measurements. European Journal of Environmental and Engineering Geophysics 3, 53–61.

Hanesch, M., Scholger, R. and Rey, D., 2003. Mapping dust distribution around an industrial site by measuring magnetic parameters of tree leaves. Atmospheric Environment 37, 5125–5133

Hay, K. L., Dearing, J. A., Baban, S. M. J., Loveland, P., 1997. A preliminary attempt to identify atmospherically-derived pollution particles in English topsoils from magnetic susceptibility measurements. Physics and Chemistry of the Earth 22, 207–210.

Heller, F., Strzyszcz, Z., Magiera, T., 1998. Magnetic records of industrial pollution in forest soils of Upper Silesia. Journal of Geophysical Research 103(B8), 17767–17774.

Hoffmann, V., Knab, M., Appel, E., 1999. Magnetic susceptibility mapping of roadside pollution. Journal of Geochemical Exploration 66, 313–326.

ICRCL, 1987. Guidance on the assessment and redevelopment of contaminated land. Interdepartmental Committee on the Redevelopment of Contaminated Land Guidance Note 59/83, London

Kapička, A., Petrovský, E., Ustjak, S., Macháčková, K., 1999. Proxy mapping of fly-ash pollution of soils around a coal-burning power plant: a case study in the Czech Republic. Journal of Geochemical Exploration 66, 291–297.

Lecoanet, H., Lévêque, F., Segura, S., 1999. Magnetic susceptibility in environmental applications: comparison of field probes. Physics of Earth and Planetary Interiors 115, 191-204

Lecoanet, H., Lévêque, F., Ambrosi, J.-P., 2003. Combination of magnetic parameters: an efficient way to discriminate soil-contamination sources (south France). Environmental Pollution 122, 229-234

Lees 1999. Evaluating magnetic parameters for use in source identification, classification and modelling of natural and environmental materials. In J. Walden, F. Oldfield and J. Smith (eds.) Environmental Magnetism: a practical Guide. Technical Guide No. 6 Quaternary Research Association, London

Ministry of Housing, Spatial Planning and Environment, 2000. DBO/1999226863 Circular on target values and intervention values for soil remediation. Netherlands Government Gazette of the 24th February 2000, no. 39, The Hague

ODPM 2003. *Improving the Delivery of Affordable Housing in London and the South East.* Environmental Resources Management, Office of the Deputy Prime Minister: London

Petrovský, E., Ellwood, B. B., 1999. Magnetic monitoring of air-, land-, and water-pollution. In B. A. Maher, R. Thompson (eds), Quaternary Climates, Environments and Magnetism. Cambridge University Press, Cambridge, chapter 8, pp. 279–322.

Petrovský, E., Kapička, A., Zapletal, K., Sebestova, E., Spanila, T., Dekkers, M. J., Rochette, P., 1998. Correlation between magnetic parameters and chemical composition of lake sediments from northern Bohemia - preliminary study. Phys. Chem. Earth 23, 1123–1126.

Scholger, R., 1998. Heavy metal pollution monitoring by magnetic susceptibility measurements applied to sediments of the river Mur (Styria, Austria). European Journal of Environmental and Engineering Geophysics 3, 25–37.

Strzyszcz, Z., 1993. Magnetic susceptibility of soils in the areas influenced by industrial emissions. In R. Schulin, A. Sesaules, R. Webster, B. V. Steiger (eds), Soil Monitoring. Birkhäuser Verlag, Basel, pp. 255–269.

Wehland, F., Panaiotu, C., Appel, E., Hoffmann, V., Jordanova, D., Jordanova, N. and Denut, I., 2002. The dam breakage of Baia Mare - a pilot study of magnetic screening. Physics and Chemistry of the Earth 27, 1371–1376

Figures

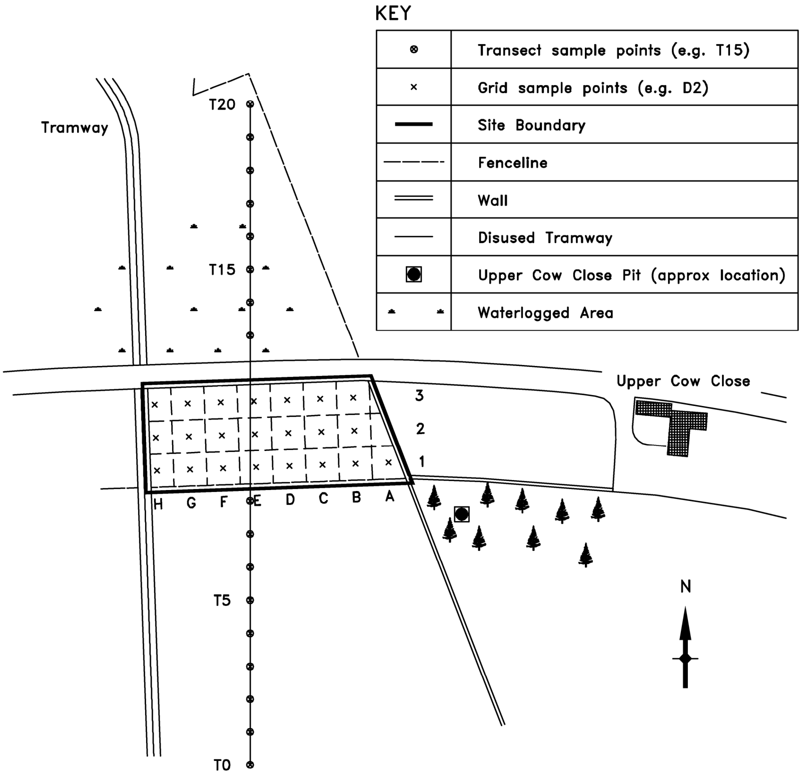

Figure 1: Site layout. Only minor earthworks survive of the 'tramway'. Upper Cow Close Pit refers to a presumed shaft of the Low Moor Iron Works.

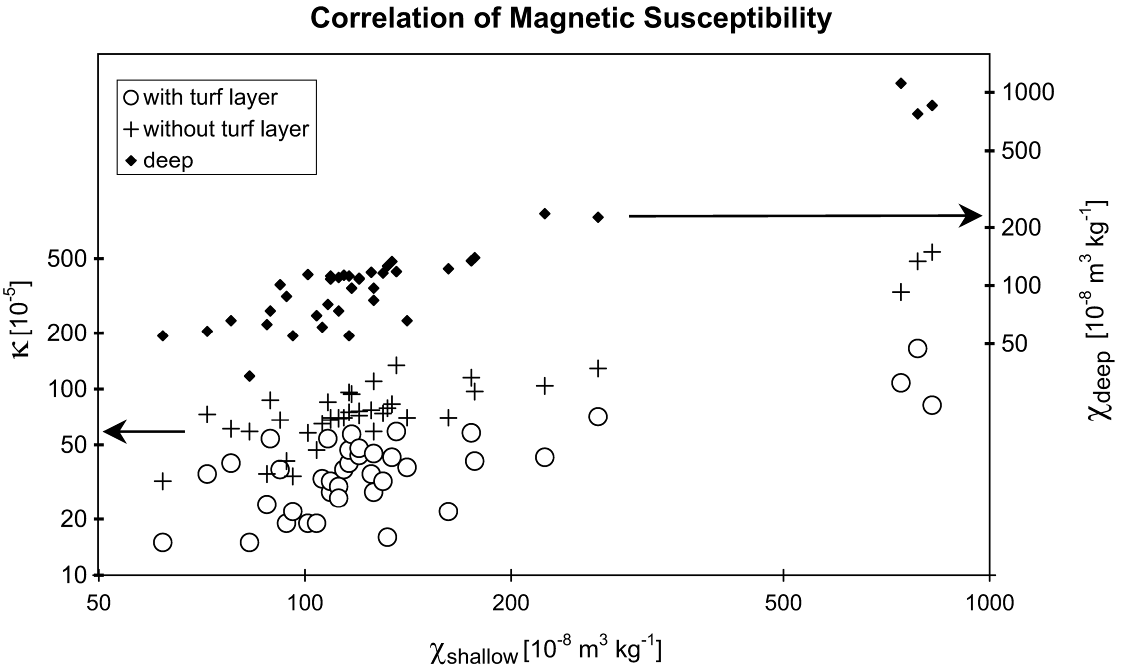

Figure 2: Relationships between four magnetic susceptibility measurements: volume magnetic susceptibility (κ in 10^{-5}, left axis) with and without turf layer, and shallow and deep mass specific magnetic susceptibility (χ in 10^{-8} m^3kg^{-1}, right and bottom axis).

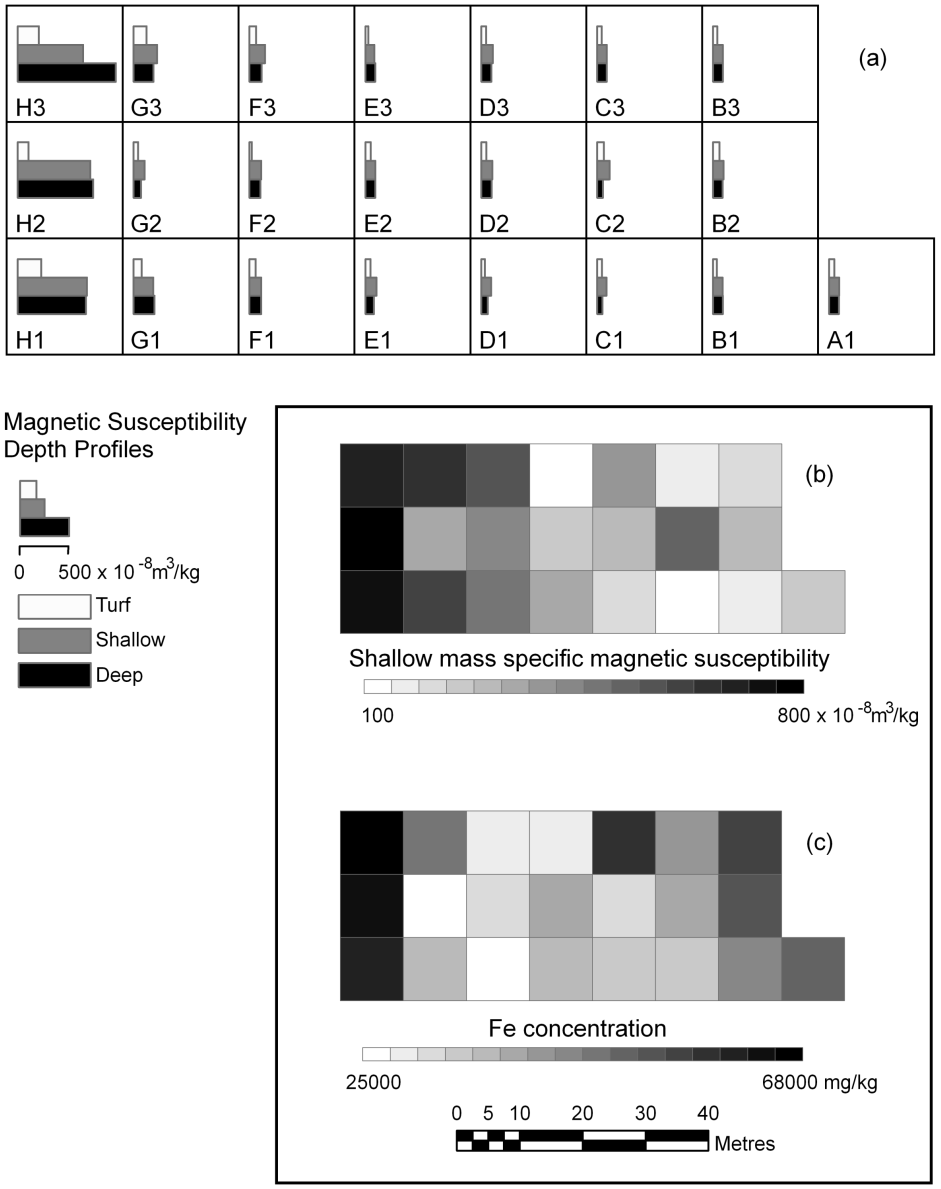

Figure 3: Spatial distribution of some measured parameters over the contaminated area. (a) depth profiles of mass specific magnetic susceptibility (topsoil apparent susceptibility (see text), shallow sample, deep sample); (b) mass specific susceptibility of shallow sample; (c) Fe concentration of shallow sample.

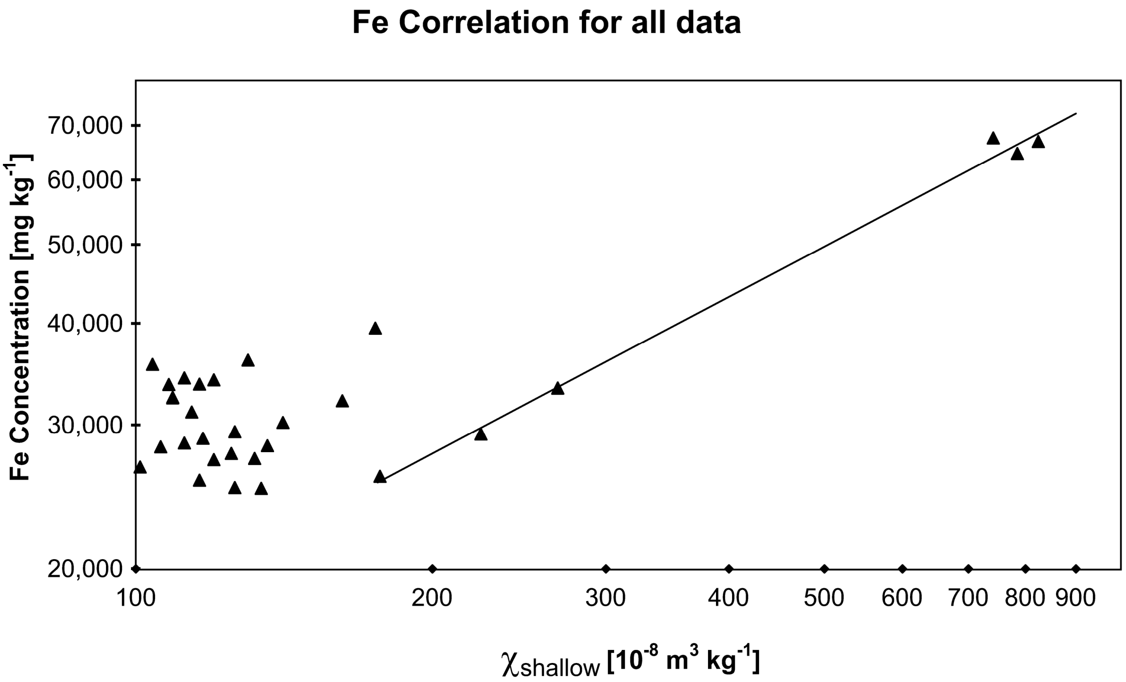

Figure 4: Comparison of Fe concentration and mass specific magnetic susceptibility for all shallow samples. The line indicates the correlation of samples above the site specific threshold for the mass specific magnetic susceptibility of 176×10^{-8} m^3 kg^{-1}.

Tables

Table 1: Pearson’s correlation coefficients for Fe with the other investigated metals for the shallow samples

Subset	Cd	Cr	Cu	Mn	Ni	Pb	Zn
All	0.337	0.345	0.718	0.712	0.813	0.040	0.196
C	0.274	0.333	0.924	0.918	0.905	-0.236	0.310
T	0.494	0.354	-0.178	0.218	0.632	0.292	0.318

Table 2: Pearson’s correlation coefficients between investigated heavy metals for all shallow samples

	Fe	Mn	Ni
Cu	0.924	0.856	0.868
Fe		0.918	0.905
Mn			0.850

Table 3: Descriptive statistics for magnetic susceptibility measurements. *Relative Standard Deviation* is calculated with respect to the mean and *Relative Median Increase* is the relative difference between mean and median.

	Field measurement with turf [10^{-5}]			Field measurement without turf [10^{-5}]			Shallow [10^{-8} m^3/kg]			Log(Shallow)			Deep [10^{-8} m^3/kg]		
Subset	All	T	C	All	T	C	All	T	C	All	T	C	All	T	C
Mean	42.6	36.8	47.1	104.2	71.0	129.9	172.4	105.4	224.2	2.1	2.0	2.2	163.5	81.1	227.1
Std Deviation	27.7	16.5	33.6	107.5	29.0	136.7	183.1	30.3	231.3	0.3	0.1	0.3	227.0	28.3	287.9
Relative Std Deviation	65%	45%	71%	103%	41%	105%	106%	29%	103%	12%	6%	13%	139%	35%	127%
Median	37.0	37.0	37.5	73.0	70.0	74.5	116.0	96.0	126.0	2.1	2.0	2.1	108.0	74.0	113.5
Relative Median Decrease	13%	-1%	20%	30%	1%	43%	33%	9%	44%	0%	1%	6%	34%	9%	50%
Skewness	2.7	0.0	2.5	3.3	0.5	2.5	3.1	1.0	2.2	2.1	0.3	1.8	3.3	0.4	2.4