Magnetic susceptibility properties of polluted soils

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Abstract An investigation of magnetic properties using magnetic susceptibility (c) and frequency-dependent susceptibility (c_{fd}) was conducted on representative modern pollutants, which include smelted slag dust, automobile exhaust dust and coal ash. Their magnetic susceptibility values are more than 500×10^{-8} m^3/kg, and frequency-dependent susceptibility values less than 3%, indicating that ample ferrimagnetic and scanty superparamagnetic grains occurred in the studied pollutants. Similar to the artificially synthetic polluted soils, the industrially-polluted soils display a negative relationship between magnetic susceptibility and frequency-dependent susceptibility. However, the unpolluted soils, e.g. the Quaternary loess in the Chinese Loess Plateau, show a positive relationship between them. In this note, we propose a convenient and effective approach for identifying the polluted soils.

Keywords: **polluted soil, magnetic susceptibility, frequency-dependent susceptibility.**

It has been intensively documented that parent materials and climate conditions have important influences on soil magnetic susceptibility (MS)[1,2]. Industrial pollutants, however, may make significant contributions to the enhanced MS of soils in polluted areas. Currently, people are increasingly attaching importance to the MS characteristics of the polluted soils[2]. With heavy-metal pollution aggravating, the polluted soil generally exhibits an MS enhancement[3−6]. Thus, the soil MS is possibly of interest as an indicator for identifying the soil polluted induced-industrially. In view of the rapidity, efficiency, cheapness, and convenience, MS measurement, if it can be used to identify the polluted soils, wi Tj -21ver

[2]. In this study

(Ⅴ) The loess samples collected from the past 150 ka loess-paleosol sequence at Xixian, Shaanxi Province.

In this study, the low-field and high-field magnetic susceptibilities for each sample were measured on a Bartington Instruments susceptibility bridge using a Model MS-2 sensor. The frequency-dependent susceptibility, c_{frd}, is usually defined as

$$c_{fd} = (c_{lf} - c_{hf}) / c_{lf} \times 100\%,$$

where c_{lf} and c_{hf} are the in-phase components of the susceptibility, which are typically measured at approximately 470 and 4 700 Hz, respectively.

2 Results and discussion

The smelted slag dust has an MS value of (15 868.7±32.4)×10^{-8} m^3/kg and an FDS value of 0.4%; the automobile exhaust dust, (540.7±0.7)×10^{-8} m^3/kg and 2.3%, and the coal ash, (5267.8±8.3)×10^{-8} m^3/kg and 0.6%. Evidently, their MS values are higher than 500×10^{-8} m^3/kg, and FDS values less than 3%, indicating that plenty of ferrimagnetic and absence of superparamagnetic grains occurred in the pollutants.

The FDS of the loess samples increases with MS increasing (fig. 1), but the FDS of the synthetic polluted samples decreases with the increase of MS (fig. 2). The MS and FDS patterns of the collected soil samples are in good agreement with those of the artificially synthetic polluted soil samples (fig. 3), suggesting that these soil samples have been polluted.

Soil magnetism results have shown that MS does not always increase with the increase of

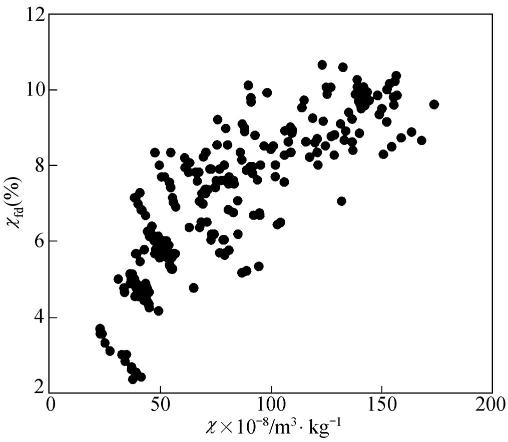

Fig. 1. c versus c_{fd} for Quaternary loess samples.

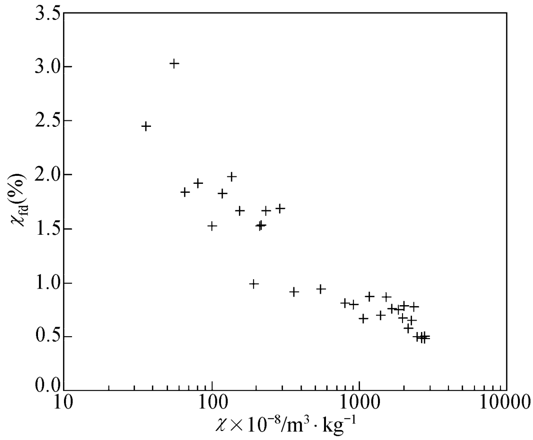

Fig. 2. c versus c_{fd} for the synthetic polluted soils.

pedogenesis, because soil MS is influenced by the evolutionary direction and extent of iron-bearing minerals in parent materials[8,9]. Considering that the maximum MS value is generally less than 400×10^{-8} m^3/kg, it may be abnormal if a soil has an MS value of more than 400×10^{-8} m^3/kg. Meanwhile, the soils developed from volcanic parent materials often have very high MS values (＞400×10^{-8} m^3/kg), which do not result from pollution usually. Therefore, we cannot conclude that the soils with abnormally high MS have been polluted.

The FDS of Chinese loess increases with the increase of MS, the fact of which is generally attributed to the production of ultrafine superparamagnetic ferrimagnets during pedogenic processes[10,11]. The FDS values of loess (3%—11%) and unpolluted soils are often higher than 3%[1)]. Usually, although the soils with volcanic parent materials have a higher MS value (＞400×10^{-8} m^3/kg),

1) Lü Houyuan, Quaternary environmental changes recorded by magnetic susceptibility and plant fossils: quantitative estimates of paleoclimates, Ph.D. Thesis, Institute of Geology, CAS, 1998, 1—31.

their FDS values (9%—12%) are also higher than 3% (fig. 4). All of them indicated that the unpolluted soils of FDS values are more than 3%. But the pollutants, the artificially synthetic samples and the polluted soils of FDS values are less than 3%, thus, the two values seem to be viewed as the thresholds. Considering that the studied pollutants evidently have higher MS ($>500\times10^{-8}$ m^3/kg) and lower FDS ($<3\%$), it can reasonably be deduced that if these pollutants are deposited in soil, its MS will increase and FDS will drop. This has been confirmed by the MS and FDS of the artificially synthetic samples and the polluted soils (fig. 3).

As shown in fig. 4, the polluted and the unpolluted samples display disparate distribution patterns of MS and FDS, suggesting that a soil with an MS value higher than 100×10^{-8} m^3/kg and an FDS value less than 3% has been polluted possibly. Furthermore, the pollution degree can be roughly inferred. The higher the MS, the lower the FDS, the more seriously the soil may be polluted.

In addition, the MS and FDS of polluted soils do not have a trend (fig. 4), which may result from the variable concentrations of ultrafine superparamagnetic ferrimagnets in the studied pollutants and soils with different pedogenic degrees.

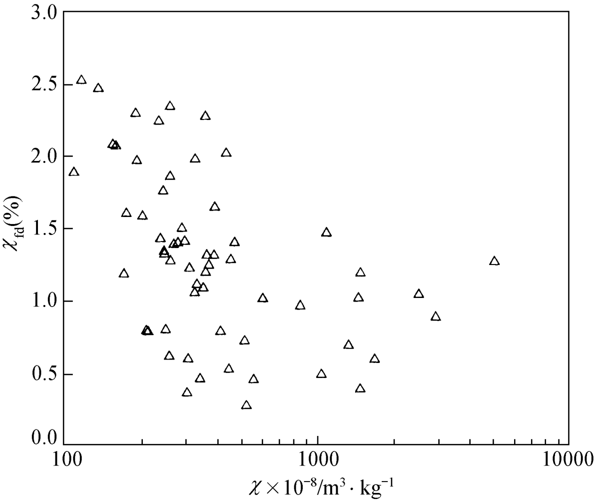

Fig. 3. c versus c_{fd} for the soil samples.

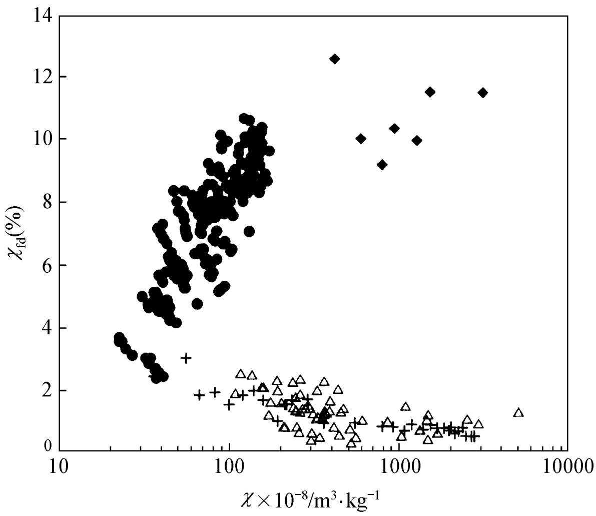

Fig. 4. c versus c_{fd} for the polluted and unpolluted soil samples. ●, Quaternary loess; ■, unpolluted soils from volcanic rocks; △, polluted soils; +, synthetic polluted samples.

3 Conclusions

Our results show that the industrial pollutants have different magnetic properties from the sediments and the unpolluted soils. We conclude that measurement of magnetic susceptibility and frequency-dependent susceptibility can serve as a convenient and effective method for detection of polluted soils.

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