B09

Transport of Pollutants around a High Building: Integrated Magnetic, Mineralogical and Geochemical Study

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SUMMARY

We studied the degree and distribution of traffic induced pollution at a 40 m high building at the side of a major road in Budapest by making magnetic, mineralogical and geochemical analysis on settled dust samples collected at different levels and at the front and back sides of the building. We observed strong seasonal dependence of the amounts of anthropogenic pollutants, which were highest during summer. This season was also characterized by strong vertical variation of the amounts of dust, of the magnetic susceptibilities (reflecting best the traffic induced pollution) and of the concentrations of Pb. All these have maximum values at 9 m, on both sides of the building. The pattern of the distribution does not correspond to what is predicted by an air flow model published for high buildings with similar morphology and wind conditions.

Introduction

The dust particles in the air are derived from natural (like rocks and soil) and from anthropogenic sources. The natural dust usually contains extremely small amount of iron minerals, therefore its magnetic susceptibility is very weak. If a dust contains anthropogenic iron or its oxides, even in low concentration, their presence will considerably enhance the susceptibility. As magnetic techniques easily detect magnetic pollutants and they are usually non-destructive, their application in environmental studies is gaining ground.

Iron containing pollutants get in the air from different industrial sources (i.e. iron works, steel processing, ore dressing, coal combustion plants) and vehicular traffic. They are often associated with potentially toxic heavy metals such as Pb, Zn, Cu, Cr, Ni, Mo, Cd. These materials have bad health effects, especially when the grain size is small (the limit is officially drawn at 10 micrometer) and because of associated toxic components. The tiny dust particles damage the respiratory system, including the lungs and trigger heart and vein blocks. Even if the grains are settled, the associated heavy metals poison soil and water.

While particulate matter from industrial sources mostly causes local pollution, health damaging emission from vehicular traffic is today a general problem of towns and rural areas crossed by roads with heavy traffic. The situation is especially serious in towns close to the main roads. The Budaörsi road in Budapest is one example, since the Vienna-Budapest and Zagreb-Budapest motorways, after merging, canalize the international and local vehicles into this road.

A few years ago, the susceptibility of tree trunks planted along a blind side street of the Budaörsi road was measured and the samples were also studied mineralogically (using SEM). The conclusion of the study was that the pollution from the main road penetrated the side street as far as 90 m, despite of the fact that the dominant wind is opposite to the spread of the pollutants (Márton et al., 2008). The present paper deals with the spread of the traffic induced pollution in vertical dimension, close to the spot where the horizontal penetration was studied.

Materials and methods

Settled dust samples were collected according to the Hungarian standard MSZ 21454/1-83 using glass pots of 2000 mL containing 500 mL distilled water and 0.500 ± 0.001 g of algaecide (analytical grade methyl 4-hydroxybenzoate) with continuous supply of the water. Altogether 8 sampling pots were placed on the front and the back sides, respectively of a building at the Budaörsi road at heights of 2, 9, 21 and 33 metres). The prevailing wind direction is towards the road (NW), which is strengthened by the dolomite hills behind and the plains in the front of the building. The building towers above its surroundings by 15-20 m so it may significantly influence the wind flow structures around itself. The continuous seasonal sampling started on the 1st of December, 2008. The sampling pots were drained at the first day of each season. The dust and water were separated by vacuum filtering using a Millipore filter with pores of 2 micrometer. The weight measurements of the air dried dust samples was followed by magnetic susceptibility measurements using KLY-2 Kappabridge which operates with one frequency. The susceptibility of a set of filters were also measured with MFK1instrument operating with three frequencies in order to estimate the contribution of superparamagnetic particles (less than 0.03 micrometer). Selected samples were magnetized in several steps with a pulse magnetizer and the acquired isothermal remanence (IRM) was measured after each step immediately after magnetization and at 5 minutes interval up to 30 minutes, while keeping the filters in the shielded measuring area of the JR-5A spinner magnetometer. The IRM experiments gave information about the type of magnetic mineral present in the pollutants and also about the contribution of fine magnetic particles.

Following the non-destructive magnetic experiments the dust was separated in ultrasonic bath from the filters. Bulk mineralogical composition of the samples were analysed by a Philips PW1710 X-ray diffractometer using the following sample preparation: 40 mg of the samples were suspended in ethanol and then they were sedimented onto steel plates with an area of 12 cm^2. For their heavy metal content (Ba, Cr, Cu, Fe, Mn, Pb, Zn), dust samples from the sampling period winter/2008 – spring/2009 were placed in alumina sample holders and analysed by a Thermo Niton XL3 type X-ray fluorescence spectrometer.

Results and interpretation

The vertical variation of dust amounts shows large seasonal differences (Fig.1, blue bars) and sometimes exceed the threshold limit value for gravitational dusts, 16 g/m^2 for 30 days in Hungary (Bartófi, 2000) Autumn and winter samples are characterized by low quantities and nearly uniform vertical distribution. For the latter we do not have a complete record for 2009, due to freezing and breaking of sampling pots. In spring samples the dust amounts are sharply decreasing upwards at the front side of the building, while a nearly uniform vertical distribution was found at the back side, with much higher values in 2010 than in 2009. The quantities of dust are largest in the summer samples. This may be partly due to excess growth of algae in the sampling pots despite of the algaecide used. In the vertical distribution a peak is observed at 9 m (2nd floor) both at the front and the back sides of the building.

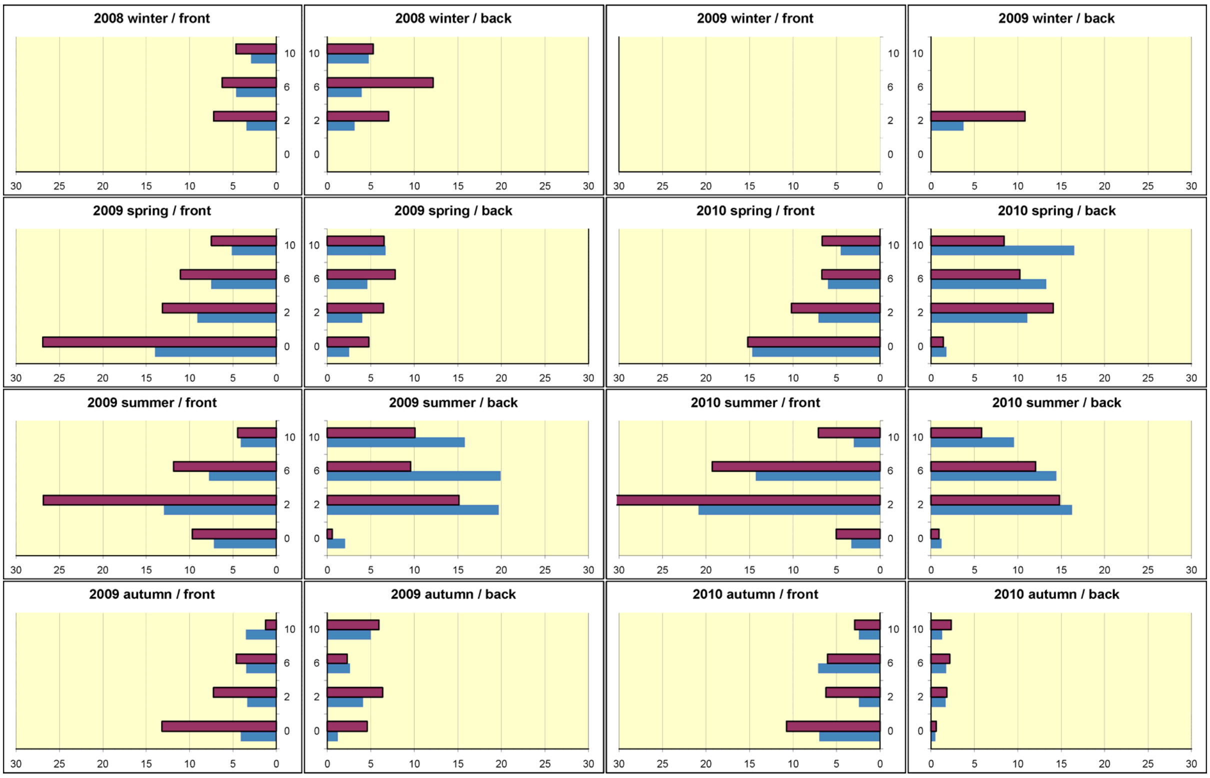

Figure 1 *Distribution of the amounts and apparent susceptibility of settled dust among collecting spots of the front and back sides of a high building at the side of a main road with heavy vehicular traffic in Budapest (Budaörsi út 45). Horizontal scale: mass and apparent susceptibility:* g/m^2 *and* 10^{-5}*SI, respectively.*

The magnetic susceptibility measurements with KLY-2 were evaluated first providing “apparent susceptibilities”, meaning that neither the volume nor the mass of the pollutants were taken into account. In this case we basically obtain information about the amount of magnetic pollutants in each sample. These values, varying between 6 and 480x10^{-6} SI, are not influenced e.g. by possible error in weight measurements, remnants of algaecide or algae. Next the mass susceptibilities were calculated, which facilitate comparison with the intensity of magnetic pollution at other spots and differently colleted materials (like PM10, settled dust collected at monthly basis). The mass susceptibilities at the different collecting sites at the Budaörsi road building vary between 1 and $8x10^{-6}$ m^2/kg on the front and $1–11x10^{-6}$ m^2/kg on the back side. These values are comparable with those measured in one of the most polluted industrial town in Hungary with heavy traffic, Miskolc, where the mass susceptibilities for PM10 vary between $1.5–11.5x10^{-6}$ m^2/kg, for settled dust at the most polluted spots are between $2–11x10^{-6}$ m^2/kg

The distribution of the apparent susceptibilities among collecting spots does not follow closely that of the amounts of dust (Fig.1, red bars). The differences are most striking for the back side, 2009 summer and 2010 spring, where the apparent susceptibilites show a decreasing trend from the 2^{nd} floor upwards, the values are lower in the back than in the front side of the building, while the amounts of the dust are unexpectedly high at the back side. A possible explanation is that the mass of the dust is increased by algae, while the susceptibility truly reflects the degree of pollution from traffic. It is interesting to note that the sharp peak at 9 m in summer samples is also observed in the magnetic susceptibilities.

The bulk mineralogical composition of the samples reflects primarily the geological characteristics of the sampling area. The main components are in the order of frequency: quartz, dolomite, feldspar, calcite, mica, chlorite (gypsum). In the autumn and winter samples the quartz, in the spring and summer samples the dolomite content is higher. This suggests that local material contributes more (cp. dolomitic hills behind the building) to dust in spring and summer, which is the period for high amount of precipitation and wind-storms, as well as for the deposition of large dust amounts. The most important metal-bearing phases identified mineralogically are magnetite and clay minerals (Sipos et al., 2010). Zinc is associated both to clay and magnetite particles, while lead only to the latter ones.

As IRM acquisition measurements document, the magnetic signal in the dust samples is coming from an easily saturating iron mineral, most probably magnetite. The IRM signal is decaying with time, which points to the presence of very fine magnetite particles in the dust (Márton and Hrouda, 2010). The contribution of superparamagnetic particles is also supported by measurements of the susceptibility at three frequencies. The decrease of susceptibility with higher frequencies is around 5 percent in all the measured dust samples and so is the decay of the IRM with time (Fig. 2). This value is similar to the one measured for an exhaust-gas filter, indicating that the magnetic particles in the studied dust samples are emitted by vehicles (Fig. 2). In addition, the decay rate of the IRM on alternating field (AF) demagnetization is exactly the same in both samples of Fig. 2, which further supports the common origin of the magnetic pollutants.

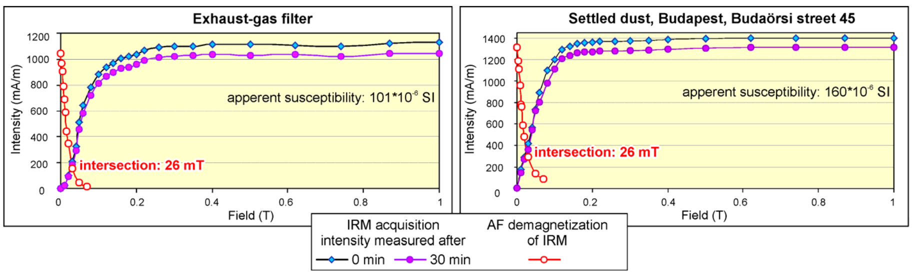

Figure 2 *IRM acquisition and AF demagnetization of IRM of a settled dust sample (Budaörsi út 45, 2^{nd} floor, back side) and an exhaust-gas filter.*

Some of the studied metals, such as Cu (73–382 mg/kg), Pb (76–3388 mg/kg) and Zn (399–3160 mg/kg) show significant enrichment in the settled dust samples when compared to background soil values. In contrast, Fe (2.1–5.1%), Ba (237–787 mg/kg), Cr (0–215 mg/kg), Mn (308–747 mg/kg) are characterized by similar concentrations as background soils. Enriched metals show large spatial and temporal variations with no characteristic trends, while background metals shows relatively uniform distribution.

The monthly metal deposition is as follows: 0.1–44 mg/m^2 for Pb, 1–38 mg/m^2 for Zn, 0.3–7 mg/m^2 for Cu, 44–671 mg/m^2 for Fe, 1–10 mg/m^2 for Mn, 0–2.3 mg/m^2 for Cr, 0.5–12 mg/m^2 for Ba. Threshold limit value is only given for Pb in Hungary (1.2 mg/m^2), which is exceeded in almost all studied samples. Highest values were found in the summer samples (even up to 35-times higher than the threshold limit value), while they are much lower in the winter and spring samples. Spatial metal deposition characteristics are similar to that of dust deposition.

Conclusions

1. Special magnetic experiments document that the type and grain size distribution of the settled dust collected at different levels of a 40 m high building close to a major road in Budapest correspond to that of an exhaust-gas filter, i.e. the magnetic pollution is traffic induced.

2. Traffic induced pollution
- is better reflected in the magnetic susceptibility than in the amount of the settled dust,
- strongly depends on the season: highest is during summer, lowest is in winter and autumn,
- has the most characteristic vertical pattern during summer, with a peak at 9 m, not only in the front but also in the back side of the studied 40 m high building.

3. The pattern of pollution we observed does not seem compatible with a general air flow model published for a high building with similar morphological and wind conditions (Lajos et al., 2008).

4. Cu, Pb and Zn show considerable enrichment compared with background values. It is the Pb (and the Fe) which exhibits a characteristic pattern in summer samples. This is similar to the pattern of susceptibility values in vertical dimensions at both, the front and the back sides of the building. This corroborates the first conclusion.

5. During summer, the magnetic pollution at 9 m and higher, on both sides of the building, corresponds to values observed at places polluted by heavy traffic as well as industrial sources. It is also worth noting that the concentration of Pb at 9 m and higher, at both sides of the building exceeds the threshold limit by 8–35 times during summer.

Acknowledgements

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