BOSHASTED 2000 Proceedings, p137-140, Harnessing Science & Technology for Development, 28 June - 1 July 2000, Gaborone.

Magnetic Measurements as a proxy for car pollution in Gaborone

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Emissions of vehicles represent a significant contribution to environmental pollution along roads. Pollutants from cars include gases such as (NO_x, CO, CO_2), solid components such as sort particles from exhaust system, abrasion products from the brakes and engine etc (Leven et al., 1999). Aerosols pollutants can reduce significantly the quality of the environment and seriously affect human health e.g. by contributing to high rates of allergies or diseases of the respiratory system. In this study, samples were collected at various distances from a busy road, Gaborone-Tlokweng road near Game store (See Figure 1). Non-magnetic adhesive paper pieces were used as sample collectors. Magnetic properties of the aerosols collected were measured using a highly sensitive magnetometer (AGM-Micromag). Magnetic properties measured include total magnetic moment, hysteresis loops and associated parameters such as coercivity. In general, observed hysteresis loops are typical for magnetite.

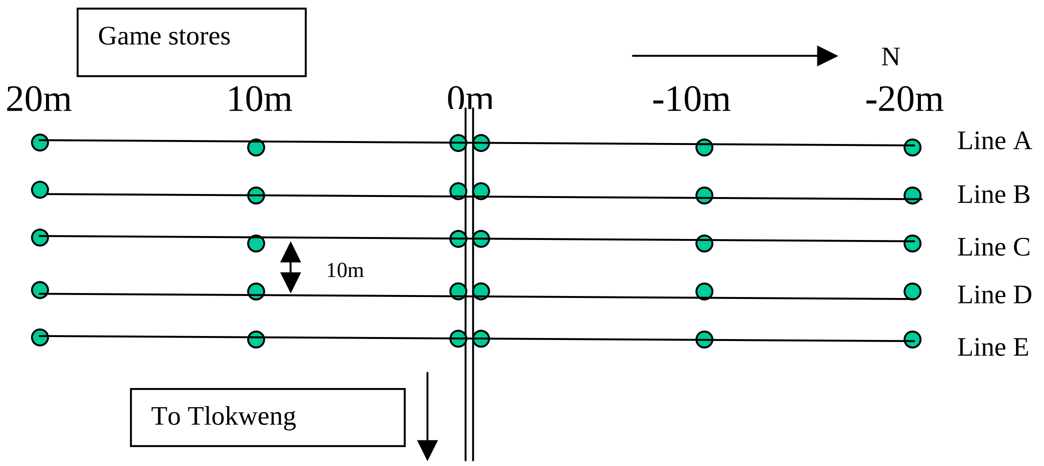

Figure 1 The figure shows a sketch (*not to scale*) of the arrangement of sample position (● symbol) in relation to the road for Lines A to E.

Sample holder characteristics

A problem often encountered in studying magnetic particles of fine particles such as those due to car pollution is finding a suitable sample holder. Previous studies used tree leaves (e.g. Matzka, 1999) and thorns (e.g. Hoffmann et al., 1999). The problem with these sample holders is the lack of control of the positions of samples since they depend on trees that are available close to the road. A suitable sample holder for car pollution fine particles study using AGM-Micromag should be non-magnetic, adhesive and small (~3 mm diameter). Croxley invincible mounts pieces of adhesive paper were found to be of suitable size. However, the paper has to be checked by measuring its magnetic properties. If the paper is suitable as a sample holder, it has to be diamagnetic (i.e. non-magnetic). This behaviour is briefly explained below.

The observed magnetic behaviour of certain minerals can be traced to the spinning and orbiting atomic electrons. It can be shown (e.g. Anderson et. al., 1985), that the orbital magnetic moment (m_{orbit}) and spin magnetic moment (m_{spin}), of an electron is given by

$$m_{orbit} = \frac{-m_l eh}{4\pi m} \quad (1)$$

$$m_{spin} = \frac{-m_s eh}{2\pi m} \quad (2)$$

where e is the electron charge, m is the electron mass, h is Plank's constant, m_l is an interger and m_s = +/- 1/2. The quantity $\frac{eh}{4\pi m}$ is known as the Bohr magneton (μ_B).
Upon application of a magnetic field (H) to a diamagnetic material, the field interacts with the electrons in such a way that their orbital motion changes. The change in velocity of electrons results in an induced magnetisation whose direction is opposite to that of the applied field. Thus a diamagnetic substance should display a straight line without any hysteresis loop. Figure 2 shows a straight line for magnetisation as a function of applied field for the Croxley mounts. This is clearly typical for a diamagnetic sample, hence the adhesive paper used is a suitable sample holder for use in car pollution studies. By applying a slope correction to the plot, the magnetisation becomes practically zero. All the hysteresis loops for car pollution samples had a slope correction applied to them to get rid of the contribution of the sample holder.

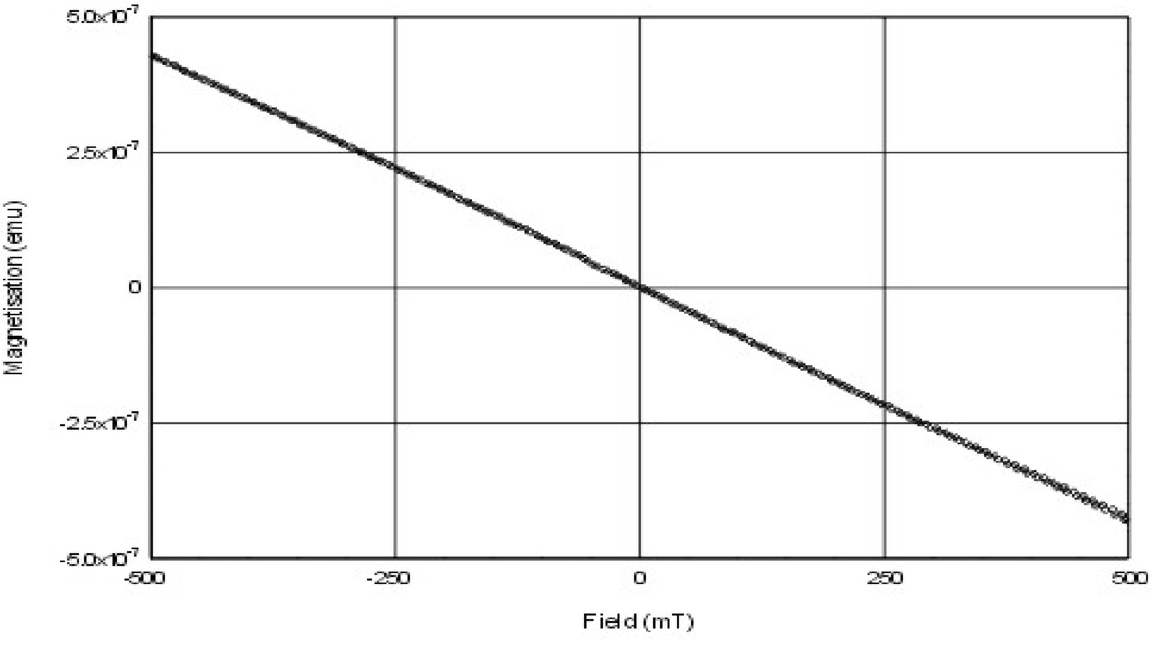

Figure 2 Magnetic hysteresis loop for paper sample holder used in this study. No slope correction applied.

Characteristics of hysteresis loops and total magnetisation for measured car pollutants

Figure 3 shows magnetic hysteresis loops for samples of Line A at 0m, 10m and 20m away from the road (southern side of the road). Hysteresis loops for other lines (i.e. Line B etc), are similar in pattern to those for line A, hence Figure 3 is a typical representation of samples of this study. It is clear from this figure that the samples readily saturates at fields less than 500 mT. This behaviour is typical of magnetite and atypical of hematite. This agrees with observations by Petrovsky et al. (2000) who showed that the most likely mineral carrier for observed magnetic properties in aerosol particulate study is magnetite. It is also evident from Figure 3 that the sample closest to the road (0m) has the largest total magnetisation while that furthest from the road (20m) has the lowest magnetisation. Figure 4 shows plotted values of total magnetisation as a function of distance from both sides of the road for Line A. It is clear from this figure that magnetisation values are in general larger on the southern side of the road than on the northern side. It can be inferred from this observation that the average wind direction during the duration of experimentation (36 hrs) was in the southern direction. Thus the asymmetric nature of the total magnetisation is a good indicator of average wind direction.

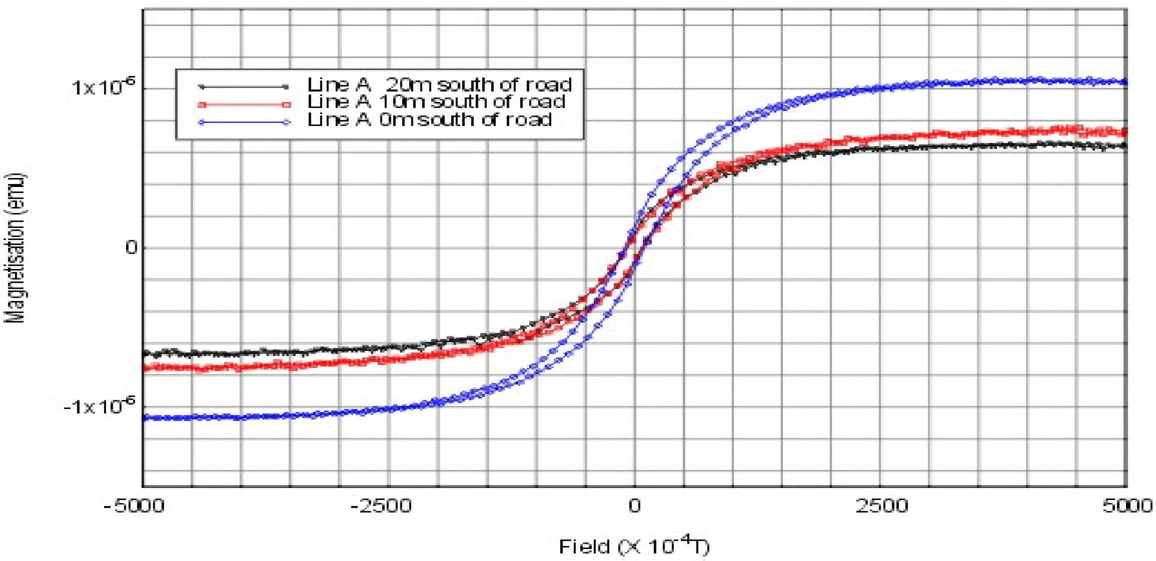

Figure 3 Magnetic hysteresis loops for samples along line A at distance 0m, 10m, and 20m away from the road (see Figure 1).

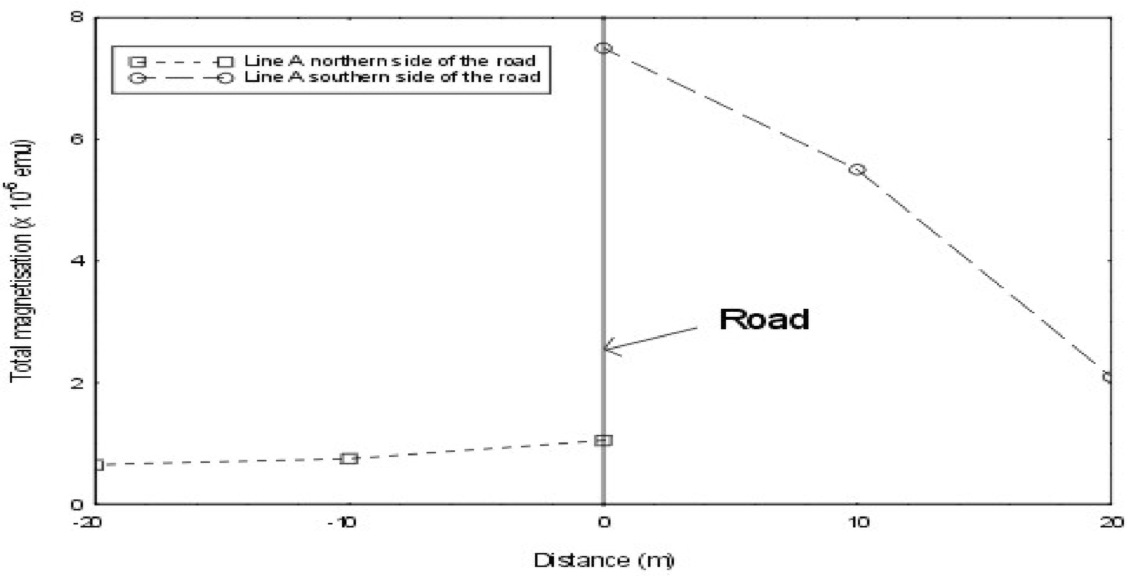

Figure 4 Total magnetic moment as a function of distance from the road for samples of Line A.

Characteristics of Magnetic Coercivities (H_c) of measured samples

Unlike the total magnetic moment, coercivity does not depend on the amount of magnetic material available. Instead it depends on the size and shape of magnetic individual particles that constitute the sample. Figure 5 shows measured magnetic coercivities as a function of position from the road. It can be seen from this figure that there is a general decrease in the value of coercivity with increasing distance from the road. This is contrary to expectation since larger particles (multidomain) are expected to be closer to the road than smaller particle (single-domain or pseudo-single-domain). However, such an expectation assumes that the same type of material falls closer as well as further away from the road, which may not be true. It should be noted that car pollution include all the particles liberated as a result of moving cars. This includes particles from tyres and the tarred road aggregates. Aerosols from factories are not expected to have affected the results since no factories are in the study area. However, further studies are necessary to determine whether the observed decrease in coercivities as a function of distance from the road is an indication of particle size or material difference. The observed values of the coercivities of around 10 mT are consistent with those for single or pseudo-single domain magnetite (Thompson and Oldfield, 1986; King and Williams, 1996).

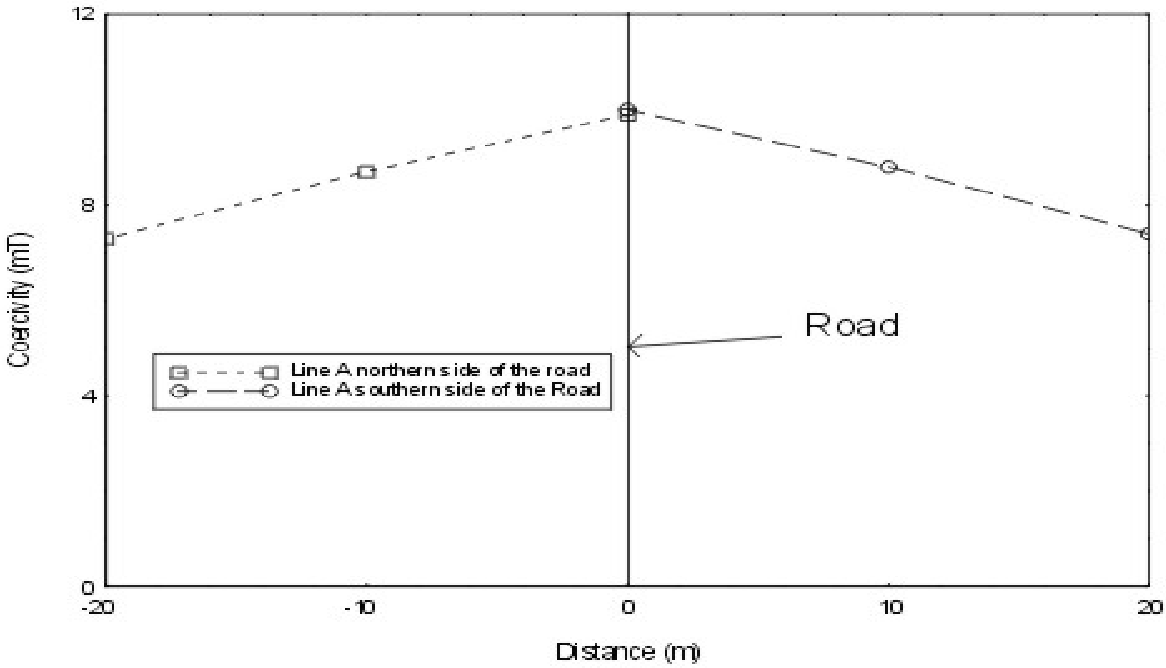

Figure 5 Coercivity values as a function of distance away from the road for Line A.

Conclusions

Hysteresis loops properties of aerosols obtained close to a busy road revealed that in general, magnetite is the mineral most likely responsible for observed total magnetisation. In general total magnetic moment decrease with distance from the road, a clear indication that the responsible magnetic particles are car pollution related. The effect of wind direction is to introduce non-symmetry in the measured total magnetic moment when two sides of the road are compared. This information could be very useful for town planning of walkways if the effect of car pollution on persons using the walkways is to be minimised.

References

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