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Mineral magnetism of atmospheric dust over southwest coast of India: Impact of anthropogenic activities and implications to public health

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ABSTRACT

We have used rock magnetic techniques in this study to assess atmospheric pollution at five stations in and around Mangalore city on the southwestern coast of India. Samples of dust were collected from two suburban areas (Thokkottu and Pumpwell located respectively ~10 km and 3 km from the city center), the city center itself (Milagres) and industrial/port areas (Panambur and Mangalore Refinery and Petrochemicals Limited (MRPL)). Low-frequency magnetic susceptibility (χ_{lf}), frequency-dependent susceptibility (χ_{fd}), susceptibility of anhysteretic remanent magnetization (χ_{ARM}) and isothermal remanent magnetization (IRM 20 to 1000 mT) were determined on 23 dust samples and inter-parametric ratios calculated. Results show that samples from suburban areas (particularly Thokkottu) are characterized by low χ_{lf} (<314.1×10^{-8} m^3 kg^{-1}) and up to 6% χ_{fd}, suggesting low levels of pollution and the presence of pedogenic magnetite possibly derived from soils by wind erosion. However, the average χ_{lf} of Milagres, Panambur and MRPL dust samples is high by factors of 9.2, 3.3 and 2.6 compared to that of the Thokkottu sample. The Milagres sample contains magnetically "soft" minerals like magnetite, possibly indicating its derivation from motor vehicle exhaust. In contrast, the Panambur dust sample is characterized by magnetically "hard" minerals such as hematite and goethite as it has an 8-fold higher HIRM value compared to the Thokkottu sample. This magnetic signature is perhaps the result of dust particles derived from the grinding of hematite-rich iron ore by the Kudremukh Iron Ore Company Limited (KIOCL) at Panambur and its storage and export through the nearby New Mangalore Port. However, the dust sample from MRPL has magnetically "soft" minerals like magnetite. This magnetic mineral may have originated from petroleum refining processes at MRPL. Particulate pollution from industrial activities and motor vehicle exhaust is a threat to human health and is known to cause cardiovascular and respiratory ailments. Therefore, the pollution levels brought out by this study warrant a comprehensive epidemiological study in the area of study.

1. Introduction

Atmospheric dust is composite due to the mixing of different components such as sea salt aerosol, soil-entrained dust, forest fire-generated smoke (from natural processes) and combustion of fossil fuels, industrial emissions and biomass-burning (from anthropogenic activities; Andreae et al., 1986; Evans and Heller, 2003; Flanders, 1994; Maher et al., 2008; Matzka and Maher, 1999; Shilton et al., 2005; Thompson and Oldfield, 1986). The relative proportions of the components in dust vary geographically depending on the nature of anthropogenic activities. It is well known that urban aerosol particles adversely affect human health. These particles have a size of <10 μm (PM_{10}; Kim et al., 2009; Prather et al., 2008), and they can easily enter the respiratory system and cause cardiovascular and respiratory ailments (e.g., Becher et al., 2001; Donaldson et al., 1998; Knutsen et al., 2004; Schwartz, 1996). Therefore, it is necessary to determine the constituents and sources of dust particles for assessing the status of the environment (Yang et al., 2010). Over the past few years, numerous studies were carried out to elucidate the sources of dust particles using a geochemical approach. For example, heavy metals were determined for dust samples from Saudi Arabia to determine their relationship with particle size as concentrations of Pb, Cr, Ni, Cu, Zn and Li tend to increase substantially with a decrease in particle size (Al-Rajhi et al., 1996). Al-Khashman (2004) measured the heavy metal concentrations of desert dust, street dust and soil samples from an industrial area in Jordan and documented high concentrations of elements like Fe, Cu, Ni, Zn and Pb in surface soils due to industrial activity. Chemical microwave digestion of aerosol samples followed by instrumental analysis of trace elemental concentrations using conventional methods is not only expensive but tedious. Nevertheless, in recent years, environmental magnetic techniques, which are simple, rapid, non-destructive, inexpensive and sensitive, were applied to determine the sources of magnetic minerals and the associated pollutants in atmospheric dust (Bućko et al., 2011; Wang, 2013).

Iron is one of the abundant transition group elements in the earth's crust. It is also a chief constituent of atmospheric dust (Chester et al.,

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1993). Magnetic minerals (ferrimagnetic or anti-ferromagnetic) may be derived either from the weathering and erosion of soil (Thompson and Oldfield, 1986) or anthropogenic activities such as ore concentration and metal extraction, fuel combustion and cement production (Dekkers and Petersen, 1992; Goddu et al., 2004; Hoffmann et al., 1999; Jordanova et al., 2008; Wong et al., 2006). Several studies have applied rock magnetic techniques for not only identifying the sources of pollutants like vehicular traffic, industrial emissions in the form of aerosol and fly-ash, but also for evaluating their impacts on terrestrial and aquatic environments (Dekkers and Petersen, 1992; Goddu et al., 2004; Hoffmann et al., 1999; Jordanova et al., 2004, 2008; Kapicka et al., 2000; Muxworthy et al., 2001; Petrovsky and Ellwood, 1999). These techniques were widely applied for tracing the sources of pollutants in soils (Hoffmann et al., 1999; Leocoanet et al., 2001), atmospheric dust collected on air filters (Maher et al., 2008; Spassov et al., 2004) and dust deposited on the canopy of many European cities (e.g., Hanesch et al., 2003; Moreno et al., 2003). In this study, dust samples collected from five locations in and around Mangalore, SW coast of India, were investigated for mineral magnetic properties to delineate the sources of airborne dust, i.e., natural processes and anthropogenic activities.

2. Materials and methods

2.1. Study area

Mangalore (12°52′12″ N, 74°52′48″ E) is located in Dakshina Kannada District of Karnataka State (Fig. 1). The city has a population of ~0.5 million and covers an area of 133 km^2. It lies between the Arabian Sea and the *Sahyadri* (the Western Ghat) mountain ranges. Mangalore is influenced by a tropical monsoon climate and receives high rainfall. The annual precipitation in the area varies between 350 and 400 cm, a major part of which is received during the summer monsoon (June to September). The area of study experiences a hot summer season (March to May) when temperature rises up to 38 °C, whereas during winter temperature drops to an average of ~20 °C. Economically, Mangalore is one of the fast growing cities in southern India and boasts of the New Mangalore Port, which is the ninth largest in India in terms of cargo handling. Several major industries located in the region include the Mangalore Chemicals and Fertilizers Ltd. (MCF), Kudremukh Iron Ore Company Ltd. (KIOCL) and Mangalore Refinery and Petrochemicals Ltd. (MRPL) besides small-scale industries. Keeping in view the rapid urbanization and industrialization taking place in the region, this study was taken up to characterize the sources of airborne dust in and around Mangalore city.

2.2. Materials

Dust samples were collected from five locations in and around Mangalore namely, Thokkottu, Pumpwell, Milagres, Panambur and MRPL (Fig. 1). Thokkottu and Pumpwell are suburban areas of Mangalore. Milagres is located in the heart of Mangalore city and is characterized by heavy vehicular traffic congestion. Panambur is the area where the Kudremukh Iron Ore Company Limited has set up a plant to grind hematite-rich iron ore, which is stored at and exported through the New Mangalore Port which is also located at Panambur.

Pre-weighed adhesive tapes (Flanders, 1994) were stuck on hard cardboards of ~300 cm^2 area and hung on the terrace of tall buildings (10–15 m height) over a month during February–March, 2009. The adhesive tapes containing the dust particles were neatly packed in 8-cc non-magnetic plastic bottles for mineral magnetic measurements.

2.3. Methodology

Standard rock magnetic methods (Oldfield, 1991; Thompson and Oldfield, 1986; Walden et al., 1999) were used to determine the magnetic properties of the dust samples. Magnetic susceptibility at low- (0.47 kHz; χ_{lf}) and high- (4.7 kHz; χ_{hf}) frequencies was measured on a Bartington Susceptibility Meter (Model MS2B) with a dual-frequency sensor. The sensor was calibrated by using the Fe_3O_4 (1%) standard supplied by the instrument manufacturer. Percentage frequency-dependent susceptibility (χ_{fd} %) was calculated from the difference between the low- and high-frequency susceptibility values (Dearing, 1999).

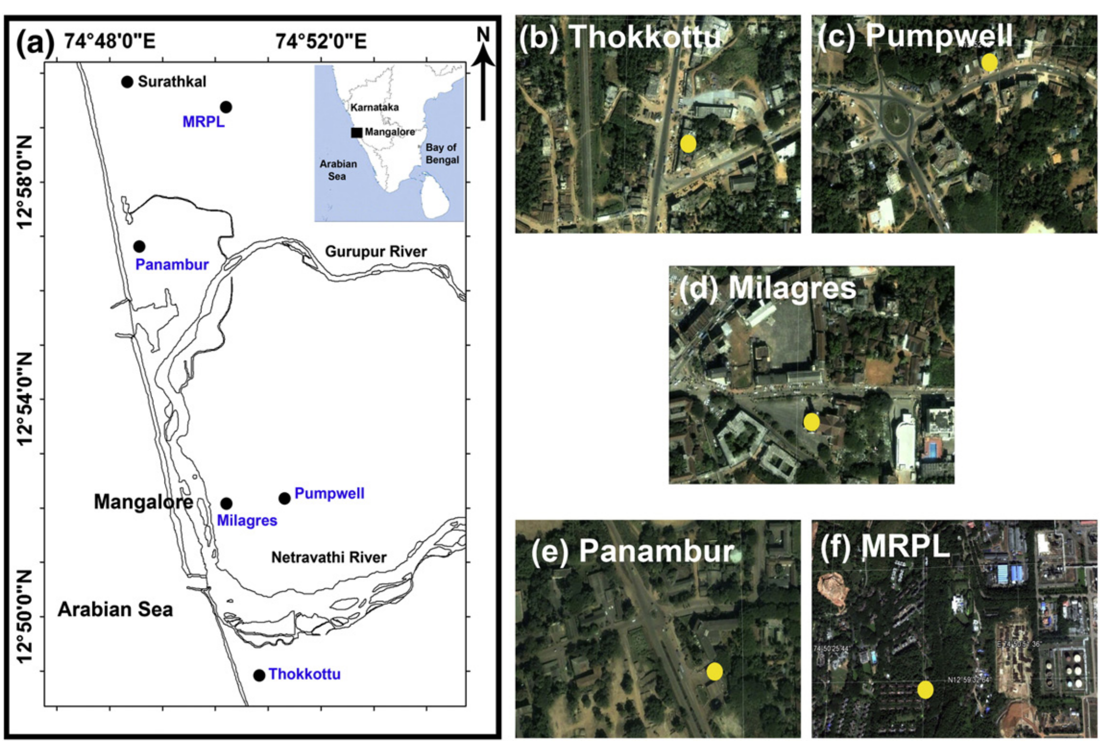

Fig. 1. Location of Mangalore city showing dust sampling sites. a) General location map of Mangalore; b) Thokkottu; c) Pumpwell; d) Milagres; e) Panambur; and f) MRPL. The sampling location at each site is marked with a yellow circle.