Integration of magnetic properties and heavy metal chemistry to quantify environmental pollution in urban soils, Kathmandu, Nepal

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The state of environment of the Kathmandu valley has been deteriorating due to various causative factors such as the traffic pollution dominant in the urban area, industrial activities including the cement factory, emissions from the traditional brick-kilns scattered throughout the Kathmandu valley, probably biomass burning and other factors that are not adequately known. Hence, it is important to recognize the major sources of the pollution, the share of each of these sources and also characterization of the type of pollution and quantification of the degree of pollution in space and monitoring so as to reveal the changes with time.

In order to characterize and quantify the degree of pollution we have been carrying out measurements of rockmagnetic properties (magnetic susceptibility, susceptibility vs. temperature characteristics, isothermal remanent magnetization (IRM) acquired stepwise at 18-20 steps up to 2.5 T DC pulse field) and chemical analyses on heavy metals (Cd, Co, Cr, Cu, Fe, Mn, Ni, Pb, Zn) by atomic absorption spectrometry of a variety of material (dust-loaded leaves of road-side trees, road dust and soils from decimetric to metric vertical sections etc.). The effectiveness of chemical analyses and magnetic methods in such studies has been well established (Devkota 2001, Gautam et al. 2004). Here we describe these properties for soils and describe the use of the pollution index based on selected heavy metals to compare the soil sections from sites variously affected by urban pollution and also the application of susceptibility or IRM as proxy parameters to rapidly characterize the soils.

A study of soils from vertical profiles from more than a dozen sites scattered in Kathmandu, and Kirtipur reveals that the mass-specific magnetic susceptibility (MS) fluctuates by three orders of magnitude. MS can be used to broadly categorize the soil intervals such as 'normal' (MS<10×10^{-8} m^3 kg^{-1}), 'moderately magnetic' (10–100 x 10^{-8} $m^3 kg^{-1}$), and 'highly magnetic' (MS >100 x 10^{-8} $m^3 kg^{-1}$). Except for thin Fe-oxide-enriched layers within the soil profile, soils far from road and industrial sites belong to the 'normal' category (e.g., the paddy field in Kirtipur, site K in **Figure 1**). In soils in close proximity to a road corridor, MS is highest at several cm depth and it remains at 'highly magnetic' level within the upper 20 cm interval after which it decreases with depth through 'moderately magnetic' level reaching to 'normal' at ca. 40 cm depths (i.e., east of Rani Pokhari and Exhibition ground, sites Hx7 and Hx8, respectively, shown in the **Figure 1**). The upper parts of soil profiles in city parks (i.e., Ratna Park, Balaju) exhibit MS within 'moderately magnetic' levels. SIRM is contributed mostly by three components of distinct median acquisition fields ($B_{1/2}$): soft ($B_{1/2}$ = 30 mT; magnetite-like phase), intermediate (160 mT) and hard (600 mT; hematite). In 'normal' intervals, soft and intermediate components contribute to 90% of SIRM. Within 'highly or moderately magnetic' soils, the contribution of soft and intermediate components seems to decrease with depth (e.g., from ca. 90% near the surface to 70% at 30 cm) in favor of the hard component. Susceptibility (logarithmic) variably correlates with heavy metals. We observe a very good positive correlation with all metals at Rani Pokhari (Hx7). However, for the Ratna Park (Hx3) there is very good positive correlation of MS and SIRM with Zn, Pb and Cu but poor and even negative correlation with Fe (Mn), Cr, Ni and Co (**Figure 2**). These data suggest that the use of MS for estimating heavy element content in urban soils of Kathmandu needs to be considered locally.

Our analysis of several soil profiles reveals that the contents of so-called 'urban elements' represented by Pb, Zn and Cu can be collectively used to compare the level of pollution among the sites. This is demonstrated in **Figure 3** in the example of 3 profiles which belong to Ratna Park, Balaju and Kirtipur, respectively. The contents of 3 metals are used to calculate the Tomlinson pollution load index (PLI) (Angulo 1996), which represents the number of times by which the heavy metal concentration in soils at particular horizon exceeds the background concentration (Chan et al. 2001). It is obvious from **Figure 3** that the PLI variation is very well reflected by variation of susceptibility and SIRM with depth and therefore the latter can be used as proxy of the former.

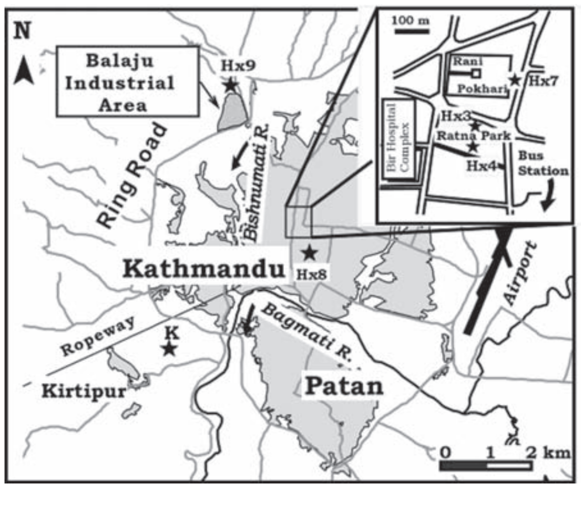

FIGURE 1. Schematic map of the Kathmandu urban area (lightly shaded) showing several soil coring sites (Hx*n*, and K, denoted by stars) which are the objects of investigation for magnetic properties and heavy metal chemistry

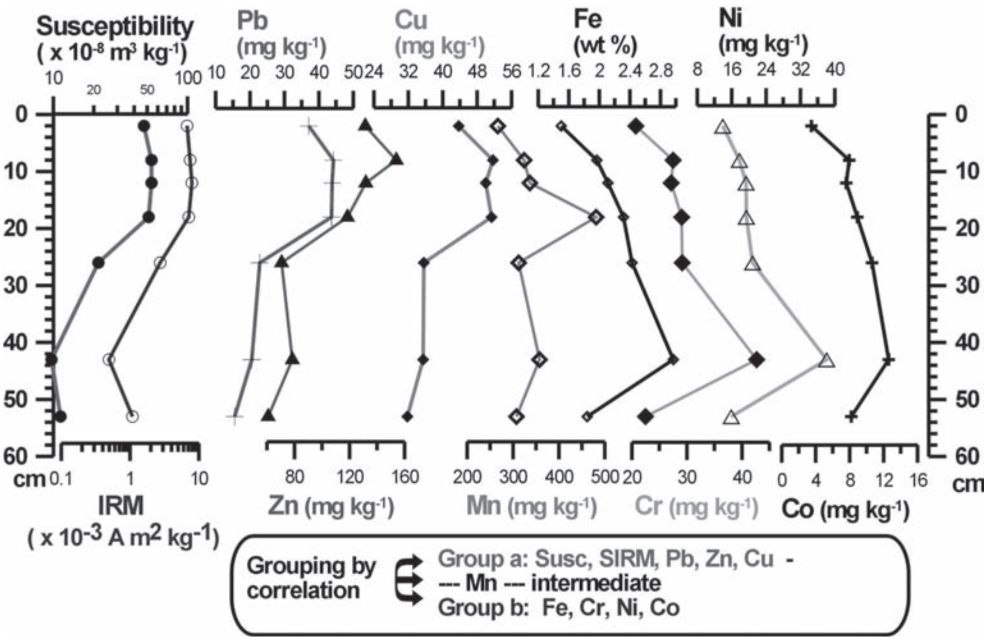

FIGURE 2. Downhole plots of magnetic parameters (susceptibility and isothermal remanences) and heavy metal contents in vertical soil profiles from Ratna park situated in the city center

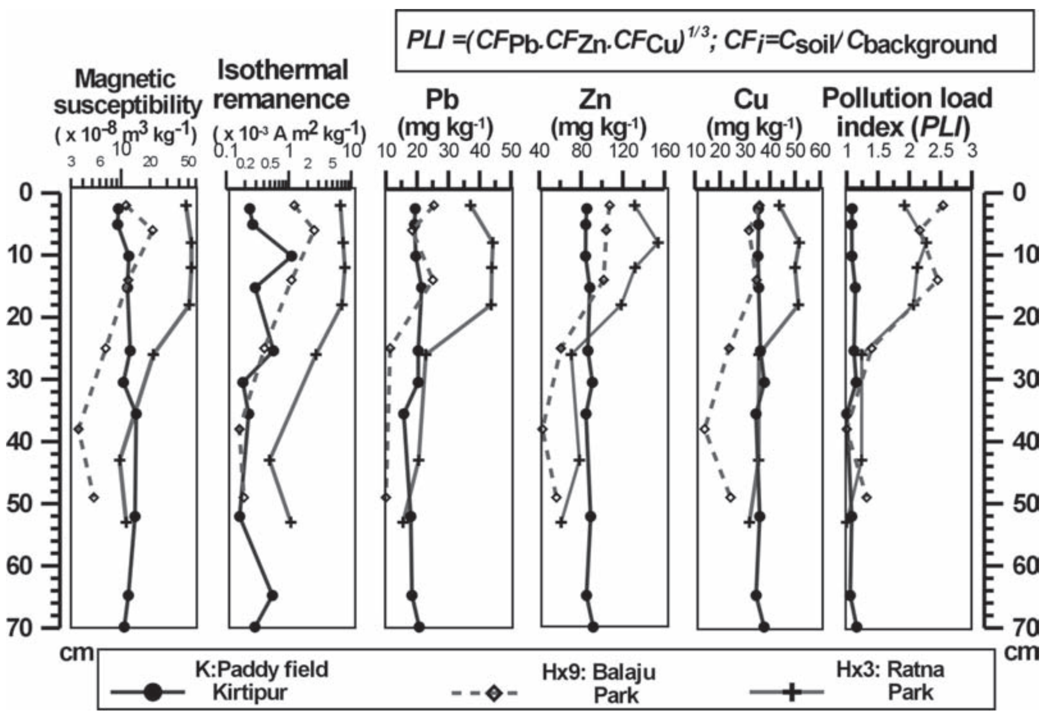

FIGURE 3. Comparison of the magnetic parameters and the pollution load index (PLI) based on the contents of 'urban elements' in 3 sites which are variously affected by urban pollution. Note the very good correlation between the magnetic properties and the PLI justifying the use of the former as proxy parameters

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