



## Magnetic Pollution of Soil Samples at Some Industrial Sites in Jos Metropolis, Plateau State, Nigeria

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**ABSTRACT:** Magnetic susceptibility of polluted material can give a general view of the degree of heavy metal pollution, prior to a more expensive and time-consuming chemical analyses. In this study, magnetic susceptibility measurements of 40 soil samples collected from some industrial sites of Jos Metropolis, were made using MS2G Sensor connected to Bartington MS 2 susceptibility meter. Volume magnetic susceptibility values ranged from  $0.00026 \times 10^{-5}$  SI to  $0.0650 \times 10^{-5}$  SI while low frequency mass specific susceptibility values ranged from  $0.1181 \times 10^{-6} \text{ m}^3\text{kg}^{-1}$  to  $20.3 \times 10^{-6} \text{ m}^3\text{kg}^{-1}$ . In both cases least and highest values are recorded at Zuma Steel and Dilimi respectively. Comparing low frequency mass specific susceptibility values obtained from industrial sites to that obtained from non-industrial sites, it was observed that samples 11 and 12 from JIB and all samples collected from Dilimi recorded values higher than the background soil samples thus indicating magnetic enhancement of soil at these locations by anthropogenic sources. The relationship between the volume magnetic susceptibility and mass specific susceptibility showed correlation of 0.983 implying that volume magnetic susceptibility results can be accepted in the absence of low frequency mass specific susceptibility measurement to assess magnetic pollution. The study also revealed that the magnetic behaviour of the dried soil samples collected from the industrial sites are controlled by concentration of ferrimagnetic minerals.

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Soil is an important component of the environment that supports crop and plant growth and land management is the basis for having a quality soil. Soil is an important and crucial component of our environment. It is necessary for plant growth-agricultural, horticultural, forest etc. Soil studies are important in Nigeria because Nigeria which was primarily agrarian before the oil boom is seriously trying to retrace its step back to agriculture and as a result Nigerians are farming anywhere there is an available land even in industry premises. During recent years magnetic measurement (in particular magnetic susceptibility) have become a generally accepted method to map spatial distribution of pollution, identify pollution sources, provide an alternative to conventional chemical analysis because its measurements are fast, cost-effective, non-destructive, sensitive and informative (Lu *et al.*, 2007). Therefore, the magnetic susceptibility of polluted material can give a general view of the degree of pollution, which can be mapped and studied prior to more expensive and time-consuming chemical analyses. Many soils worldwide exhibit magnetic properties that result from the presence of iron oxides in different forms and quantities. Ferrimagnetic minerals such as magnetite and maghemite are the most magnetic of the iron oxides while paramagnetic and antiferromagnetic iron

oxides such as goethite and hematite play a minor role in determining the magnetic character of a soil. Sources of magnetic minerals in soils are the parent material from which the soils are developed; in situ formation by pedogenic processes (Singer and Fine, 1989; Singer *et al.*, 1996); Aeolian deposition of dust (Maher *et al.*, 2003); anthropogenic processes such as industrial fly ashes (Petrovsky *et al.*, 2001) and flood deposition. In environmental studies, magnetic susceptibility measurements have been used in determining magnetic mineral content in materials and hence monitoring environmental pollution (Petrovský *et al.*, 2001, Blaha *et al.*, 2008 and Chaparro *et al.*, 2008). In addition, magnetic response of soils can serve as an effective surrogate indicator for heavy metal pollution (Ngama *et al.*, 2011). It is highly effective to detecting industrial, traffic material and other atmospheric pollutant (Francek, 1992, Kapicka *et al.*, 1999) and also for estimating anthropogenic pollution of soils in the urban areas (Hanesch and Scholger, 2005, Jordanova *et al.*, 2003, Akanbi and Aduyi, 2009). Jos enjoys a temperate climate and is a hub of industrial activities in Plateau State. Notable among them are food processing companies as well as construction firms. This sector has contributed quite significantly to productive employment creation and revenue generation in Plateau state. The Dilimi

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Gangare in Jos is a hub of small-scale mechanical garages that manufacture vehicle parts and provide other mechanical services to neighbouring states and is famous for its metal works. Other industrial centres that have contributed immensely to the development of the state include the Grand cereals and oil mill limited, the Jos International Breweries (JIB) Plc, the Zuma Steel West Africa (ZSWA) the Nigerian Bottling Company, and the NASCO group. Biotite granite rocks of the Jos-Bukuru Younger Granite Complex, Basement rocks, and volcanic rocks dominate the study area. Iron-containing minerals can be found in these igneous rocks (Singer *et al.*, 1996) and therefore the soils in this study area may contain some iron oxide. The parent material, soil age, pedogenic processes, biological activity, and soil temperature (Singer *et al.*, 1996) affect the concentration of (magnetic) iron oxides. The aim of this study is to use magnetic susceptibility to assess soil magnetic pollution at some industrial sites in Jos Metropolis, Plateau state, North Central, Nigeria.

#### MATERIALS AND METHOD

*Materials:* Bartington MS2 meter and MS2G Sensor (Bartington Instruments Ltd., Char bury, Oxford, England), Global Positioning System (GPS), A and Gulf Electronic Weighing Balance, Notepad, markers, masking tape, sample bags shovels and a plastic spoon.

*Method:* Soil samples were collected from industry premises and non-industrial locations (to serve as background samples). The coordinates of each location were noted. The samples were taken to the laboratory and air-dried to remove water. 1cm<sup>3</sup> pots were filled for the measurement of their volume magnetic susceptibility using the Bartington MS2G sensor and volume magnetic susceptibility measurements were made using the sensor in the laboratory. MS2G sensor is for small single samples measured at low frequency only. All measurements were conducted at the most sensitive "0.1" setting. An air reading was performed before and after each measurement. The values for volume magnetic susceptibility for five samples from each location were measured and the average volume magnetic susceptibility ( $\kappa$ ) calculated. Masses for these samples for each location were measured and the average mass calculated. The bulk density of a sample was calculated by dividing mass of sample by volume of sample. This was easy to calculate because all the MS2G samples are usually measured in pots of 1 cm<sup>3</sup>. Therefore, provided the pots are full, only the mass values vary. Low frequency mass specific susceptibility was then calculated using

$$\chi_{lf} = \kappa/\rho \quad (1)$$

Where  $\kappa$  is the volume magnetic susceptibility at low frequency and  $\rho$  is the bulk density of the sample. The dimension of mass susceptibility is therefore m<sup>3</sup>/kg.

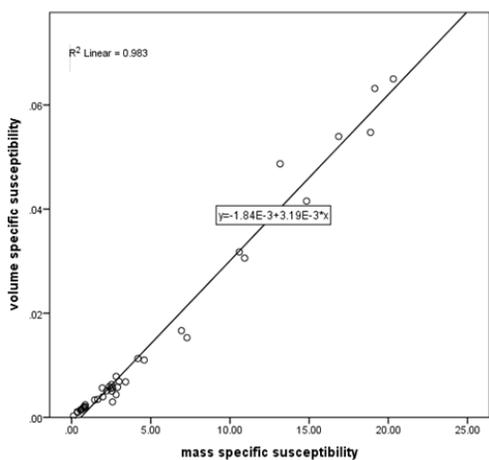
#### RESULT AND DISCUSSION

The results for volume magnetic susceptibility and low frequency mass specific susceptibility measurements is presented in Table 1. Volume magnetic susceptibility values range from 0.00026 x 10<sup>-5</sup> SI to 0.0650 x 10<sup>-5</sup> SI while low frequency mass specific susceptibility values range from 0.1181 x 10<sup>-6</sup> m<sup>3</sup>kg<sup>-1</sup> to 20.3 x 10<sup>-6</sup> m<sup>3</sup>kg<sup>-1</sup>. In both cases least and highest values are recorded at Zuma Steel and Dilimi respectively. The mean low frequency mass specific susceptibility of the different industrial sites decreases in the following order: Dilimi > JIB > Nasco > Coca-cola > Zuma Steel > Grand Cereal. There is significant difference in volume magnetic susceptibility and low frequency mass specific susceptibility values as seen in Table 1. The difference is because volume magnetic susceptibility is magnetization per unit volume while for mass specific susceptibility the bulk density of each sample is considered (Equation 1) as these samples are made of different particles with different masses depending on the makeup of the sample. These samples will therefore have different masses and hence different bulk densities. According to Dearing (1999), single sample susceptibility is not normally expressed on a volumetric basis, but on a basis of dry mass and some studies have used single homogeneous sample volume susceptibility values, notably studies of deep-sea sediments, but only where density is constant or where data are used to form ratios, which are independent of density. The relationship between the volume magnetic susceptibility and mass specific susceptibility (Fig 1) for this study show a high positive correlation with correlation coefficient of 0.983. The higher the absolute value of the correlation coefficient, the stronger the relationship and the sign of the correlation coefficient represents the direction of the relationship. This implies that in this study area that the volume magnetic susceptibility results can be accepted in the absence of low frequency mass specific susceptibility measurement to assess magnetic pollution. An infinite number of environmental conditions give rise to a very wide range of mineralogies and magnetic susceptibility values. According to Dearing (1999), as a rule-of-thumb, mass specific susceptibility values taken at low frequency,  $\chi_{lf}$ , of any sample with a value less than 0.1 x 10<sup>-6</sup> m<sup>3</sup>kg<sup>-1</sup> is controlled by the concentration of paramagnetic minerals and for values greater than this by ferrimagnetic minerals.

**Table 1: Magnetic Susceptibility Result**

S/No. Location	Longitude (°E)	Latitude (°N)	Volume mag. Susceptibility, $\kappa$ ( $\times 10^{-5}$ SI)	Mass specific Magnetic Susc, $\chi_d$ ( $\times 10^{-6}$ m <sup>3</sup> kg <sup>-1</sup> )	Magnetic Behaviour of samples
1. Grand cereal 1	8.8556	9.7600	0.00172	0.7166	Ferrimagnetic
2. Grand cereal 2	8.8854	9.7594	0.00147	0.6125	Ferrimagnetic
3. Grand cereal 3	8.8516	9.7572	0.00147	0.6129	Ferrimagnetic
4. Grand cereal 4	8.8544	9.7591	0.00787	2.8107	Ferrimagnetic
5. Grand cereal 5	8.8527	9.7577	0.00147	0.6125	Ferrimagnetic
6. Grand cereal 6	8.8550	9.7594	0.00580	2.9000	Ferrimagnetic
7. Grand cereal 7	8.8553	9.7594	0.00203	0.7807	Ferrimagnetic
8. JIB	8.8769	9.8691	0.00564	1.9380	Ferrimagnetic
9. JIB	8.8767	9.8694	0.01100	4.5833	Ferrimagnetic
10. JIB	8.8763	9.8686	0.00241	0.8607	Ferrimagnetic
11. JIB	8.8738	9.86583	0.01665	6.9375	Ferrimagnetic
12. JIB	8.8738	9.8655	0.01530	7.2857	Ferrimagnetic
13. JIB	8.8730	9.8655	0.00297	2.5826	Ferrimagnetic
14. Zuma Steel	8.8802	9.8616	0.01130	4.1851	Ferrimagnetic
15. Zuma Steel	8.8738	9.8652	0.00202	0.8782	Ferrimagnetic
16. Zuma Steel	8.8827	9.8619	0.00138	0.5520	Ferrimagnetic
17. Zuma Steel	8.8819	9.8619	0.00096	0.3840	Ferrimagnetic
18. Zuma Steel	8.8727	9.8694	0.00026	0.1181	Ferrimagnetic
19. Zuma Steel	8.8736	9.8655	0.00436	2.8100	Ferrimagnetic
20. Nasco/ Old airport	8.8730	9.8694	0.00346	1.6476	Ferrimagnetic
21. Nasco/ Old airport	8.8730	9.9055	0.00335	1.4565	Ferrimagnetic
22. Nasco/ Old airport	8.8733	9.9083	0.00394	1.9700	Ferrimagnetic
23. Nasco/ Old airport	8.8733	9.8730	0.00570	2.5909	Ferrimagnetic
24. Nasco/ Old airport	8.8708	9.8897	0.00504	2.5400	Ferrimagnetic
25. Nasco/ Old airport	8.8702	9.8722	0.00510	2.2113	Ferrimagnetic
26. Nasco/ Old airport	8.8727	9.8725	0.00689	2.9956	Ferrimagnetic
27. Coca-cola	8.8741	9.8733	0.00631	2.5240	Ferrimagnetic
28. Coca-cola	8.8716	9.8730	0.00591	2.3791	Ferrimagnetic
29. Coca-cola	8.8716	9.8706	0.00557	2.4652	Ferrimagnetic
30. Coca-cola	8.8700	9.8725	0.00682	3.4100	Ferrimagnetic
31. Coca-cola	8.9194	9.8363	0.00107	0.3566	Ferrimagnetic
32. Coca-cola	8.9197	9.8369	0.00185	0.8043	Ferrimagnetic
33. Dilimi	8.8950	9.9200	0.05474	18.8756	Ferrimagnetic
34. Dilimi	8.8952	9.9211	0.03059	10.9250	Ferrimagnetic
35. Dilimi	8.8961	9.9225	0.06500	20.3125	Ferrimagnetic
36. Dilimi	8.8963	9.9227	0.04154	14.8357	Ferrimagnetic
37. Dilimi	8.8961	9.9244	0.04871	13.1648	Ferrimagnetic
38. Dilimi	8.8950	9.9225	0.03177	10.5900	Ferrimagnetic
39. Dilimi	8.8966	9.9236	0.05396	16.8625	Ferrimagnetic
40. Dilimi	8.8941	9.9238	0.06318	19.1454	Ferrimagnetic

S/No- Sample Number



**Fig 1:** Relationship between Volume Magnetic Susceptibility and Mass Specific Susceptibility

In addition, negative values are controlled by the dominance of diamagnetic. There are exceptions though to this rule, especially in some weak samples where the susceptibility may be controlled by minute concentrations of ferrimagnetic minerals (Dearing, 1999). Table 1 also shows the magnetic behaviour of the dried soil samples and it was observed that each sample collected from the industrial sites are controlled by concentration of ferrimagnetic minerals. Soil samples collected from non-industrial sites were measured for background mass specific susceptibility as background susceptibility value should always be determined in an unimpacted soil in order to evaluate the relative enhancement due to anthropogenic influence (Lu *et al.*, 2007). These values are shown in Table 2.

**Table 2:** Magnetic Susceptibility values of Soil Samples collected from non-industrial sites

Sample Id	Longitude (°E)	Latitude (°N)	Volume susceptibility $\kappa$ ( $\times 10^{-5}$ )SI	Mass Specific Susceptibility, $\chi_{IF}$ ( $\times 10^{-6}$ m <sup>3</sup> kg <sup>-1</sup> )
A	8.965	10.044	0.00585	5.318
B	9.008	9.813	0.006926	6.296

The low frequency mass specific susceptibility values of background soil samples A and B are  $5.381 \times 10^{-6}$  m<sup>3</sup>kg<sup>-1</sup> and  $6.926 \times 10^{-6}$  m<sup>3</sup>kg<sup>-1</sup> respectively. These values were compared with the low frequency mass specific susceptibility values of the soil samples from the various industrial sites and it was observed that samples 11 and 12 from JIB and all samples collected from Dilimi recorded values higher than the background soil samples thus indicating magnetic enhancement of soil at these locations by anthropogenic sources.

**Conclusion:** In this study to assess magnetic pollution at industrial sites in Jos Metropolis North Central Nigeria, the result of the volume magnetic susceptibility and low frequency mass specific susceptibility data reveal magnetic pollution at some locations at JIB and all locations at Dilimi. This study also reveals that the volume magnetic susceptibility results can be accepted in the absence of low frequency mass specific susceptibility measurement to assess magnetic pollution.

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