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A Study on Magnetic Susceptibility of Suspended Dust-Loaded Yellow Flamboyant Leaves (Peltophorum Peterocarpum) For Understanding Pollution Levels in Industrial and Residential Zones of Visakhapatnam City, India.

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ABSTRACT:

In the present global industrial scenario, there is a need for the fast development of industrial sector to enhance the growth and economy of developing countries like India. But, at the same time, one must realize / recognize the importance of handling the issues regarding the environmental pollution to control it properly. One of the most important tasks is to identify the various sources of environmental pollution that is mainly linked with the fast growing industries in major cities in developing countries like India, one of which is Visakhapatnam city, in Andhra Pradesh state, which is recently selected as a smart city, by the Govt. of India.

One of the finest methods is to estimate the natural magnetic background signal using rock magnetic signals, which would give a clear picture of different levels of pollution in both the industrial and residential zones of the study area. This problem can be best studied in the laboratory by examining the magnetic signals produced by the deposited / suspended dust on biogenic material such as leaves, leaf blades, tree needles or grass etc. Yellow flamboyant (scientifically called as Peltophorum peterocarpum) trees, which are widely spread in the industrial and residential areas of Visakhapatnam city, which are identified to be best suited for the purpose of estimating the magnetic background signal. These trees are pronouncedly seen throughout the major roads, bus stations, at the streets of the residential places & also almost all zones of industrial importance in the Visakhapatnam city. The basic rationale behind the collection of leaf samples is that, the suspended dust, after its release from the various sources like motor vehicle emissions, road traffic, abrasion of tyres, brake linings as well as road surface, cycling of dust in suspension due to vehicular movement, dispersion of construction material etc., it may remain in air for some time.

Thereafter, most of this suspended dust ultimately gets deposited along the narrow roadside corridor forming an integral part of the road dust, roadside soil, vegetation and drainage system. The vegetative species are utilized as bio-monitors, as this suspended dust is accumulated gradually throughout the time.

Keywords: Biogenic material, Rock magnetism, Magnetic susceptibility, bio-monitors.

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1. INTRODUCTION

There are so many authors and pioneers worked on the magnetic studies of tree leaves, leaf blades, tree needles or grass. So many are pioneered in this subject and they repeatedly used this technique to study the problem of environmental pollution using rock, environmental magnetic and geochemical procedures.

As an example, Schädlich studied the magnetic susceptibilities of conifer needles as an indicator for fly ash depositional studies, for an industrial region in Germany (Schädlich et al. (1995)). Isothermal remanent magnetization (IRM) studies to estimate traffic pollution using roadside tree leaves birch (Betula pendule) in urban and suburban area, around the city of Norwich (UK) to identify spatial and temporal variations in vehicle-derived particulates by Matzka and Maher (1999). The spatial and temporal variations of carbon, nitrogen, sulphur and trace elements in the leaves of Quercus ilex within the urban area of Naples were analyzed by Alfani A et al. (2000). The way the optical and physiological properties on green plant leaves by the application of a permanent magnetic fields are demonstrated by Jovanic BR et al. (2002).

Magnetic properties of dust loaded tree leaves of deciduous trees (Platanus sp. and Quercus Ilex) in Rome city, Italy to estimate air pollution from vehicular traffic emissions were mapped by Moreno et al. (2003). Knab utilized magnetic susceptibilities of anthropogenic dust loaded coniferous tree needles in the Black Forest –area, SW Germany (Knab et al. (2003)). Studies on maple tree leaves in and around an Austrian industrial sitein Leoben reveals the extent of dust deposition by Hanesch et al. (2003). The magnetic response of soils and vegetation to heavy metal pollution is best studied by Jordanova N, Jordanova D, Veneva L, Yorova K, Petrovsky E. (2003). The magnetic properties of pine needles to monitor air quality in Cologne conurbation were studied by Urbat M, Lehndorff E, Schwark L. (2004). Similarly, Magnetic susceptibility and heavy metal content of dust-loaded cypress (mainly Cupressus corneyana), silky oak (Grevillea robusta) and bottlebrush (Callistemon lanceolatus) leaves as a proxy of traffic-related heavy metal pollution in Kathmandu city, Nepal was studied by Gautam et al. (2005).The studies of Magnetic biomonitoring of roadside tree leaves as a proxy of vehicular pollution were done (Prajapati S.K., Pandey S.K. and Tripathi B.D., 2006, Sharma A.P., Rai P.K., 2007).

i. Study Area

The present study is carried out in various industrial and residential zones of Visakhapatnam city. Visakhapatnam is a port city on the southeast coast of India in the state of Andhra Pradesh and often called "The Jewel of the East Coast" and the "City of Destiny". With a population of 2,091,811 and occupying 681.96 square kilometres (263.31 sq mi), it is the administrative headquarters of Visakhapatnam district, and the second largest city in the state of Andhra Pradesh and the third largest city on the east coast of India.

Visakhapatnam is located 625 kilometres (388 mi) east of Hyderabad and 781 kilometres (485 mi). North East of Chennai. It is situated in the middle of Chennai-Kolkata Coromandal Coast. The city is home to several state-owned heavy industries and a steel plant, one of India's largest seaports and has the country's oldest shipyard. Visakhapatnam has the only natural harbor on the east coast of India.

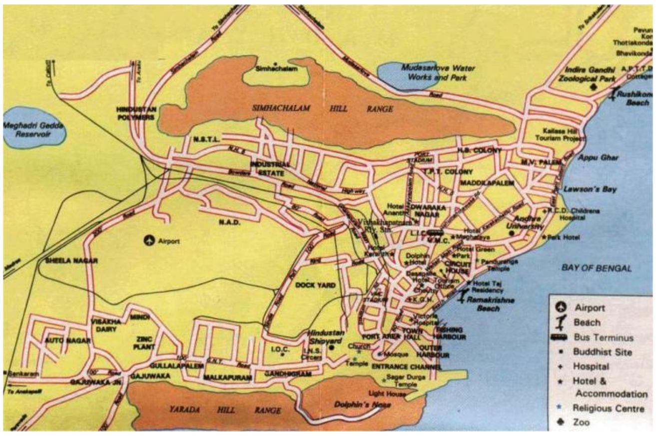

Fig.1 Sketch map of the study area

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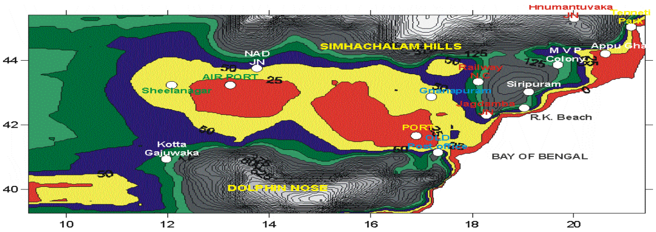

Fig.2 Elevation map of the study area show areas of various expected pollution sources

2. MATERIALS AND METHODS

2.1. Sample collection and preparation

In our field work, the suspended dust loaded leaf samples were collected at previously selected locations. 110 screening sites are selected for our study which covers both industrial and residential zones of Visakhapatnam city & their latitude, longitude & elevations are accurately measured using GPS. The Yellow flamboyant (Peltophorum peterocarpum) trees which are almost present everywhere on the highways, main roads, industrial & residential zones in Visakhapatnam city are selected at 110 screening sites to carry out our investigations. We carefully collected the leaves of this tree without disturbing its natural depositional extent of the suspended dust for magnetic analysis and to roughly identify the background signal for the dust collected from the roads.

Dust loaded Yellow flamboyant (Peltophorum peterocarpum) leaves (110 sample) were collected in the same areas where 2D loop sensor measurements were done. These samples were weighed and low and high susceptibility measurements were done.

All the 110 samples are carefully prepared in this way. Now, the weights of the bottles filled with dust loaded leaf samples are determined, from which the weights of the dust loaded leaf samples are calculated. Using **BARTOSOFT software**, susceptibilities are measured.

2.2 Magnetic susceptibility (MS)

Magnetic susceptibility is a dimensionless proportionality constant that indicates the degree of magnetization of a material in response to an applied magnetic field.

$$\kappa = M / H$$

Where, κ = Magnetic Susceptibility

M=Magnetisation

H=Applied Field

Mass specific measurements

The sensor is calibrated for a sample mass of 10g. Mass specific measurements are the preferred method of expressing measurements using this sensor. For dry materials and for materials of known density this provides the most useful measurement because simple weighing of the material is all that is required. Where sample mass departs from calibration mass the corrected value will be:

χ = Measured value of susceptibility / Sample density

Volume specific measurements

Where comparison only between identically prepared samples is required or where it is not desired to dry out wet samples then "volume" susceptibility can be recorded directly. Where sample volume departs from calibration volume the corrected value will be:

k = Measured value of susceptibility / Sample volume

2.3 Low and High frequency susceptibility measurements in the laboratory

The magnetic susceptibility system comprises a meter with a range of sensors for measuring the magnetic susceptibilities of many types of materials. The MS2 device measures the magnetic susceptibility. It operates by generating a low frequency, low intensity AC magnetic field around the sensor. The meter

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displays the value of magnetic susceptibility, when the materials are brought within the influence of the sensor by resulting change in the AC magnetic field. The resolution of the system is 2×10^{-6} SI units. The range of sensors allow measurements of individual soil or rock samples, sediment cores, soil surfaces, rock outcrops etc., in the laboratory as well as in the field.

The dust loaded leaf samples are now used for low frequency and high frequency susceptibility measurements using **BARTINGTON MS 2B Dual Frequency Sensor**.

This is a portable laboratory sensor which has the facility of making measurements at two different (low and high) frequencies. The Bartington Instruments MS 2B Dual Frequency Sensor measures mass dependent susceptibility (χ) in [m^3kg^{-1}], within an AC magnetic field amplitude of 80 Am^{-1} at low frequency (0.465 kHz or 465 Hz) and high frequency (4.65 kHz or 4650 Hz) ± 1%. Measurements made at these two frequencies are corrected for mass to account for any bulk density differences between the samples. Samples were measured at each of the above two frequencies, i.e., low-frequency mass-dependent susceptibility (χ_{lf}) and high-frequency mass-dependent susceptibility (χ_{hf}), both are measured in [m^3kg^{-1}]. When dual frequency measurements are not required, the results with best precision are obtained by LF (low frequency) measurements. This is shown in Fig.3

Fig .3: BARTINGTON MS 2B dual frequency sensor.

The coefficient of frequency dependency (χ_{fd}) can be expressed as the change in susceptibility per decade frequency divided by the low-frequency susceptibility (χ_{lf}) where the low frequency susceptibility will always have the higher value.

Materials containing fine grained magnetic particles exhibit frequency dependent susceptibility and this is particularly significant if there are single domain grains with their diameter is of the order of 0.03μm. If there are relatively small changes in diameter, then there occurs very rapid change in frequency dependency. These single domain grains are widely distributed in naturally occurring materials (like road dusts, suspended dusts on leaves of plants etc.,) in varying sizes which give rise to a fairly uniform frequency dependency of susceptibility in the low kHz range in which MS2 meter operates.

Frequency-dependent magnetic susceptibility (χ_{fd}) can be expressed as a percentage loss of susceptibility,

$$\chi_{fd\,\%} = \frac{[(\chi_{lf} - \chi_{hf})]}{\chi_{lf}} \times 100$$

Magnetic susceptibility is a measure of the degree to which a substance affects a known magnetic field and is a function of the concentration, grain-size, and type of magnetic minerals present in a sample (Begét et al., 1990). The above two types of magnetic susceptibility measurements are commonly used to infer specific magnetic grain-sizes and concentrations.

Measurements made at the two frequencies mentioned above are generally used to detect the presence of ultrafine (< 0.03 μm) superparamagnetic (SP) minerals occurring as crystals produced by bacteria or by mineral authigenic chemical processes occurring in soils. Samples where SP minerals are present will show slightly lower values when measured at high frequency; samples without the superparamagnetic minerals will show identical κ values at both frequencies (Dearing, 1999). Table 1 outlines the suggested $\chi_{fd\,\%}$ values for the occurrence SP grains in a environmental samples.

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Table 1: Interpretation of $\chi_{fd\%}$ values. When $\chi_{fd\%}$ > 10% use $\chi_{fd\%}$ as an estimate of SP concentration. (From Dearing, 1999).

Low $\chi_{fd\%}$	< 2.0	Virtually no SP grains
Medium $\chi_{fd\%}$	2.0 – 10.0	Mixture of SP and coarser grains, or SP grains < 0.05µm
High $\chi_{fd\%}$	10.0 – 14.0	Virtually all SP grains
Very High $\chi_{fd\%}$	> 14.0	Erroneous measurement , anisotropy, weak sample or contamination

These measured raw susceptibility values are processed for both the frequencies in our laboratory. Then, the processed data is used to for preparing low frequency susceptibility contour map of leaf susceptibilities for further magnetic analysis as shown in Fig.4. Susceptibility data collected from various sites of Visakhapatnam city which clearly demarcate the zones of low, intermediate and high pollution levels (shown by scale on the right) in the figure.

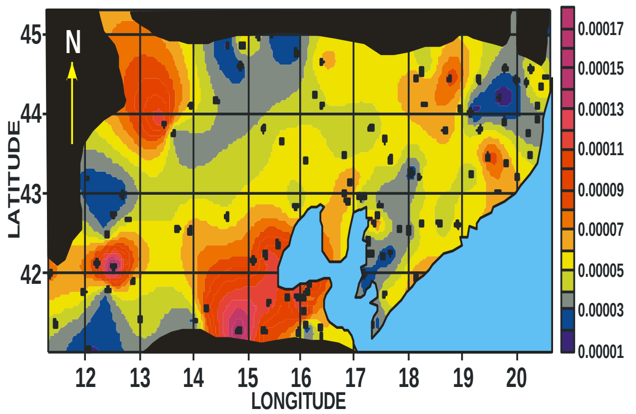

Fig. 4: The magnetic susceptibility contour map of low frequency (LF) dust loaded leaf susceptibilities collected from various sites of Visakhapatnam city.

3. RESULTS AND DISCUSSION

As observed from the low frequency magnetic susceptibility contour map, the variations of susceptibility are not unique. Different zones display different ranges of magnetic susceptibility patterns. The Yellow flamboyant (scientifically called as Peltophorum peterocarpum) leaves loaded with suspended dust depicts magnetic susceptibility variations in a way we can correlate them to the rates of pollution and sources responsible for them. The suspended dust loaded leaves collected from port area, which the industrial region in the entire Visakhapatnam city shows large amplitudes of magnetic susceptibilities at their respective latitudes and elevations above the mean sea level. Far away from it, the leafs collected from the zones especially from old post office, Purna market area, NAD road junction, airport, jnanapuram, kanchrapalem etc., also show high susceptibility signals. Whereas, leaf samples collected from areas including Appugarh, Chinawaltair, Siripuram, RTC Complex, Akkayyapalem, old post office nearer to Coastal Beach shows low range of susceptibilities at their respective latitudes and elevations above the mean sea level.

Leafs collected from residential sites also display a large ranges of susceptibility at some points. Various factors are attributed for these variations including, suspended dust originated from industrial zones, vehicular emissions and construction materials used for building activities

4. CONCLUSIONS

The enhanced amplitudes of magnetic susceptibility signals of Yellow flamboyant leaf samples collected from the port area is believed to be caused probably due to the fine magnetic particles, especially anthropogenic spherules with different ferromagnetic metallic contents of variable chemical composition emitted from the industrial zones and of vehicular emissions (Gautam et al., 2004b). Studies on road dusts collected from Visakhapatnam city, India shows that a significant amount of 7–50 µm (with a maximum of 300 µm) sized spherules (Goddu et al., 2004). Also, high amplitude magnetic susceptibilities of suspended dust loaded leaves collected from old post office, Purna market area, NAD road junction, airport, jnanapuram, kanchrapalem etc., strengthen the same view. Low range of leaf susceptibilities occur at the regions near beach road like chinawaltair, maharanipet, siripuram etc. This is due to the fact that, strong winds generated from the ocean surface, its direction and intensity carries away the suspended dust and deposited it farther from these regions. Natural inputs (Lithogenic and pedogenic sources) also contribute for these changes. The accumulation of dust suspended on leaves is affected by so many factors which undergo several spatio-temporal variations which in turn influences the magnetic susceptibilities of leaf samples.

Some of they include, elevations and distances of trees from roads, the amounts of anthropogenic and lithogenic inputs supplied to the tree leaves, the rate at which the wind blows in a specified direction etc (as it depends upon the monsoon appearance).

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