ISSN No: 2348-4845
International Journal & Magazine of Engineering, Technology, Management and Research
A Peer Reviewed Open Access International Journal

Magnetic Susceptibility Mapping of Top Soils Using MS 2D Loop Probe to Monitor Varying Pollution Anomalies of Industrial and Residential Zones of Visakhapatnam City, India.


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ABSTRACT

One of the major problems in the fast developing cities in India is to handle the problem of environmental pollution arising from various source components like fossil fuel combustion, cement and ceramic industries, metallurgy, land transport and road traffic and waste storage etc. Especially, in the cities like Visakhapatnam which is recently selected as one of the smart city from the newly formed state of Andhra Pradesh by the government of India, it is very important to identify and delineate the various sources of pollution from the above mentioned components.

The measurement of magnetic susceptibility of top soils along the major rims of the roads in and around the industrial sites and in the interior zones of the residential sites in the Visakhapatnam city enables us to delineate the levels of pollution at the respective sites. MS 2D magnetic susceptibility loop probe has the capability to produce the magnetic susceptibility scanning / mapping of the topmost zones of the soil, as it is specially designed for rapid assessment of the concentration of ferromagnetic materials in the top 100 mm of the soil / land surface, which can be carried out both in industrial and residential zones of Visakhapatnam city, India. Through this MS 2D probe survey, it is possible to estimate the levels of pollution and also it is possible to better delineate the zones of low, intermediate and high rates of pollution through the magnetic mapping of susceptibilities of road soils, both in the industrial and residential zones of Visakhapatnam city, India.

Keywords: ***Susceptibility scanning, Ferromagnetism, Susceptibility probe, Magnetic Susceptibility***

1. INTRODUCTION

The studies on the magnetic properties of top soils and road dusts is a fruitful field to understood the environmental pollution aspects caused by various source components like fossil fuel combustion, cement and ceramic industries, metallurgy, land transport and road traffic and waste storage etc. Several researches worked in this domain and added valuable information to this subject of study. The ferromagnetic content in soils released from cement-industries was studied by Strzyszcz, Z., 1995. The magnetic susceptibility of soils were modified by industrial emissions (Strzyszcz, Z., Magiera,T, Heller, F., 1996). Magnetic properties of top soils in industrial areas are mostly controlled by ferromagnetic minerals (Strzyszcz and Magiera 2001; Magiera et al. 2006). Vehicular emissions form an important component of environmental pollution studied by roadside dusts (Hoffman et al. 1999). The studies on the fly ash emitted from power plants in the soils possess high magnetic signals (Kapicka et al. 2000). An important major source of pollution is the vehicular transport, which predominantly accumulated at the edges of the roads (Knab et al. 2001).

Subsequent studies have confirmed the fact that, the main source of magnetic particles is the traffic pollution in the absence of heavy industries (Muxworthy et al. 2002; Moreno at al. 2003; Hanesh et al. 2003). Magnetic susceptibility measurements are successfully used to identify heavy metals in soils and how the soil type influences the magnetic susceptibility are also investigated (Hanesch M. & Scholger R. 2002, 2005). The relation between the magnetic properties of road dusts to industrial pollution and road traffic was best investigated in Visakhapatnam, India (Goddu et al. 2004). The magnetic techniques are best applied to study and characterize and quantify the degree of pollution in the Kathmandu urban area (Gautam et al. 2004, 2005). The rock magnetic parameters like mass-specific magnetic susceptibility, isothermal remanent magnetization (IRM) vs. temperature characteristics etc., are measured on top soils, road dusts, dust-loaded leaves to estimate the effects of environmental pollution. This paper was intended to study the rate of variation of magnetic susceptibility of the top soil surface which is mapped across the various zones of the viskhapatnam city (India), in order to distinguish different regions of varying levels of pollution.

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.

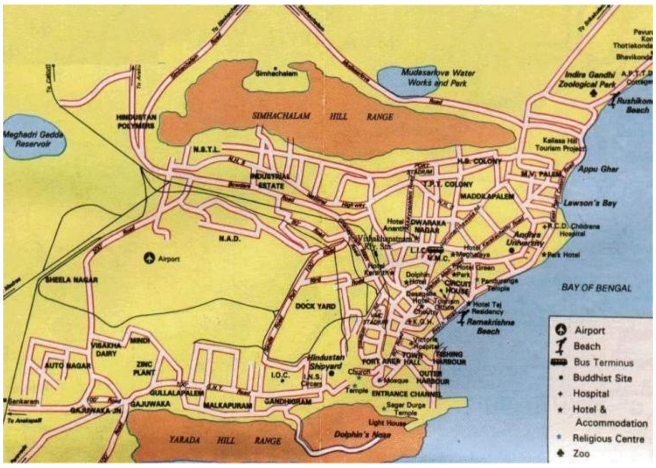

Fig.1 Sketch map of the study area

Major industries, residential areas, heavy traffic zones along with national highways are located in the study area and they mainly deal with production of iron material, smelting, petroleum processing and transport. The map of the study area is shown in the Fig.1 and the elevation map of Visakhapatnam city corresponding to the location of various pollution sources is shown in Fig.2. The elevation map of Visakhapatnam, it is appearing likely as a bowl in shape. The elevation values were mapped with the help portable Global Positioning System (GPS), exactly where latitude and longitude values are taken simultaneously along with MS2D loop probe survey. The respective longitudes and latitudes are taken along X–axis & Y-axis respectively for 110 measured sites of industrial, residential and heavy traffic zones respectively.

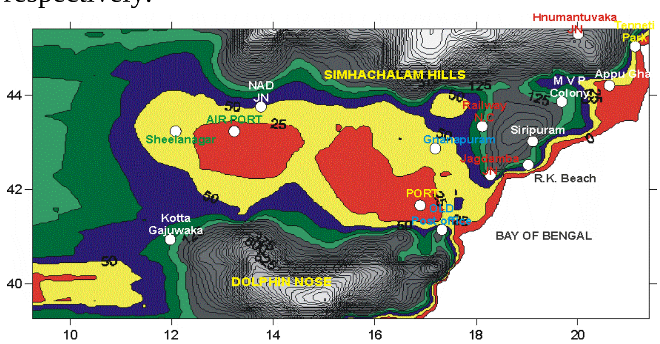

Fig.2 Elevation map of the study area show areas of various expected pollution sources

ISSN No: 2348-4845
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2. METHODOLOGY AND SAMPLING

2.1 Basic theoretical background

The magnetic state of a specimen is generally described by the following equation:

$B = \mu_0 (H + M)$ … (1)

Where, B is the flux density of the specimen in T (Tesla).

μ_0 is the permeability of free space in N. This is a constant (4π x).

H is the applied field strength in A.

M is the magnetisation of the specimen in A.

Dividing through by H we get:

$$\mu = \mu_0 + \mu_0 \kappa \;\; \ldots (2)$$

Where, μ is the permeability of the specimen (in N)

κ is the volume magnetic susceptibility of the specimen (dimensionless)

Rewriting, we get:

$$\mu_0 \kappa = \mu - \mu_0 \ldots (3)$$

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

$\kappa = M / H$ ...... (4)

Where,

κ = Magnetic Susceptibility

M=Magnetisation

H=Applied Field

The magnetic behaviour of materials is classified based on their magnetic susceptibilities are as follows:

Sl. No	Type of Magnetism	Nature of susceptibility	Example
1.	Diamagnetic	Weak negative susceptibility	Water, organic matter, plastics, quartz, feldspars, calcium carbonate
2.	Paramagnetic	Weak positive susceptibility	Weak positive susceptibility
3.	Ferromagnetic	Strong positive susceptibility	Pure iron, nickel, chromium
4.	Canted antiferromagnetic	Moderate positive susceptibility	Some iron oxides, e.g. hematite, goethite
5.	Ferrimagnetic	Strong positive susceptibility	Some iron oxides and sulphides, e.g. magnetite, maghemite, pyrrhotite, greigite

2.2. Data acquisition with MS2D loop probe

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 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 measurements on the samples are non-destructive in the sense that, they retain the original sample magnetic characteristics.

MS 2D loop sensor susceptibility meter was used to measure at various sites (110 screening sites) of Visakhapatnam. These measurements were done taking an area of 10 X 15 sq. ft. with a resolution of approx. 1 sq. ft. (total measurements 150 per grid).The selection of these points were chosen away from the main roads

MS 2D Surface Scanning Probe comprises a circular loop attached to a handle with an integral electronics unit and an extension tube through which the MS2 meter is attached. The probe can only be operated in conjunction with the MS2 probe handle. The MS 2D search loop field sensor is 185 mm mean diameter &

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International Journal & Magazine of Engineering, Technology, Management and Research
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overall height 90 mm, 0.5 kg weight with an operating frequency 0.958 kHz, which provides a depth of investigation approximately equal to its diameter. The field survey probe type MS2D is specially constructed to tolerate the moderate stresses encountered when it is pressed against the surfaces. It is designed to perform equally well on land or when submerged up to 5 meters in water with handle extension tubes. The probe handle is waterproof and suitable for immersion up to the depth of the electronics unit that is not fully sealed according to the manuals. This loop probe is designed to make surface measurements of soils, rocks, stream channels etc. It is simple and quick to use and is employed mainly in surface susceptibility mapping and reconnaissance surveys. The sensor provides a method for surveying and plotting the concentration of ferromagnetic minerals in the top circa 60 mm of the land surface. Its depth of response is 50% at 15 mm and 10 % at 60 mm. The MS2D magnetic susceptibility loop sensor / probe is shown in Fig.3.

Fig .3: BARTINGTON MS 2D magnetic susceptibility loop sensor

MS 2D probe handle and sensor

Coil

Initially, the sampling sites were selected to conduct MS 2D loop probe survey for surface soil susceptibility scanning of the Visakhapatnam city. These sampling locations to conduct the survey are carefully chosen by using Visakhapatnam city map which covers both residential and industrial areas. The latitude, longitude and elevations are measured with a Global Positioning System (GPS). Sampling points are selected in the form of a grid fashion at the selected zones to collect the raw susceptibility data using MS 2D loop probe from both the residential and industrial areas. One of the screening site on the national highway of Visakhapatnam city on high traffic area is shown in Fig.4.

Fig.4. A typical screening site on which MS2D loop probe survey was done in Visakhapatnam city national highway on the road corridor

Raw magnetic susceptibility measurements on top soils were done by using **BARTINGTON MS 2D** magnetic susceptibility loop sensor from 01-02-2013 to 31-03-2013(i.e., for a period of three months). Nearly 110 sites are screened using the MS 2D probe.

Soil susceptibility measurements were done along different areas (both industrial and non-industrial zones) of Visakhapatnam city. The measurement points are chosen away from the main roads of the Visakhapatnam city. The raw susceptibility measurements were done at various sites (110 screening sites) taking an area of 10 X 15 sq. ft., for the measurement in the form of a rectangular grid fashion with a resolution of approx. 1 sq. ft. (total measurements 100 to 150 per grid) using 2D loop sensor susceptibility meter. The selection of these site points were chosen away from the main roads of Visakhapatnam city.

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International Journal & Magazine of Engineering, Technology, Management and Research
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2.3 Data processing in the laboratory

After making all the raw susceptibility field measurements from various areas of Visakhapatnam city at 110 sites including industrial and residential zones using BARTINGTON MS 2D probe, the raw data is processed in the laboratory by using BARTOSOFT software. BARTOSOFT has been designed to acquire, correct, display, store and print data from Bartington susceptibility instrumentation. BARTOSOFT is provided free of charge with the MS2 (Magnetic Susceptibility) meter. This application is designed for operation with any of the sensors from the Bartington MS2 range. MS2 device can be simultaneously connected to the host PC running the application and the raw volume susceptibility measurements are recorded in the PC attached.

From the raw volume susceptibility data measured, absolute values of volume susceptibility are determined for all rectangular grid points at each site. Then, they are averaged to get average value of volume susceptibility. Likewise, the values are calculated for remaining sites for each rectangular grid and averaged. Based on the average volume magnetic susceptibilities calculated at each sample point for 110 selected sites, magnetic susceptibility contour map is prepared from the processed data with their respective latitude and longitude values which is as shown below in fig .5.

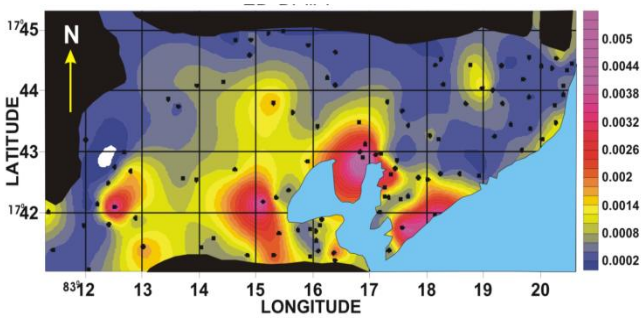

Fig.5: The average volume magnetic susceptibility contour map of BARTINGTON MS 2D loop probe - Susceptibility data collected from various sites of Visakhapatnam city which clearly demarcate the zones of low, intermediate and high pollution levels (shown by scale on the right).

3. RESULTS AND DISCUSSION

Enhanced values of susceptibility are mainly observed near industrial sites. But, it is not all the case. At some of the sites, there is less in magnitude. But, at some of the residential sites also, magnetic anomaly amplitudes are strong as suggested by fig. (5). The variations of magnetic susceptibility patterns are not unique.

The measurement of magnetic susceptibility on the ground surface and top-soils in the non-industrial sites and near residential zones of Visakhapatnam city shows elevated susceptibility values. The reason for this is mainly due to vehicular emissions and the construction materials that are present in the soils.

Close and near to industrial zones, magnetic susceptibility patterns are seemed to be high in magnitude. Especially, the port area displays strong magnetic susceptibility signatures compared to its surrounding regions. Also, the same can be observed in the regions of old post office, Purna market area, NAD road junction, airport etc. But, magnetic susceptibility patterns along the beach road shows less magnitude. The susceptibility variations are very less from Appugarh, MVP Colony, Siripuram and finally to old post office region adjacent to the beach road region in between. This zone depicts less values of susceptibility. This is clear from the average volume magnetic susceptibility contour map of top soils and ground surface all along the industrial and residential sites. Thus, the variations of magnetic susceptibility along these various zones are attributed to the effects of environmental pollution levels arising from various causes. The origin or sources of pollution are traced with the help of the studies of MS2D loop probe survey and then this is correlated with identification of various zones of pollution.

4. CONCLUSIONS

As depicted from the contour map of magnetic susceptibility variation with respect to latitudes and their corresponding elevations, port area shows high amplitude signals. This is also true for the regions near old post office, Purna market area, NAD road junction, Jnanapuram, Kancharapalem regions etc. These sites also displayed as high magnetic susceptibility zones from the contour map. So, there exists a correlation between magnetic susceptibility patterns of airport area along with these zones with respect to magnetic signals mapped from their top soils ate their respective latitudes and elevations. So, we understood this correlation between the above two distinct regions is due to the fact that, as they are less elevated zones above MSL, suspended dust from the nearby industrial exhausts fly towards these zones and settled there. It consists of iron rich ferromagnetic fine particles which are deposited as thick layers at these zones of less altitude (Goddu et al. 2004). Hence, there is no chance for the suspended dust to travel further high altitudes, along with the wind.

This suspended dust flies along with the wind which acts as a carrier & transports this fine magnetic material and finally deposited and settled in these zones of low altitudes. Vehicular emissions also largely contribute to the high magnetic signals at these zones, as they also emit magnetic fine particles due to combustion of fossil fuels which are suddenly released into the atmosphere and settled in the same zones. This leads to the enhanced susceptibility signals in the port area and also in the regions of old post office, Purna market area, NAD road junction, Jnanapuram, Kancharapalem etc.

Regions near RK beach road covering Appugarh, Chinawaltair, Pedawaltair, Siripuram, Jagadamba Junction to Old post office display magnetic signals of less magnitude. This indicates that, as these are zones of high altitude above the MSL, the strong winds blowing from the ocean surface carries away the suspended dust to farther areas and so there is no chance of accumulation of this suspended dust in these regions. Daily cleaning activities of the roads also reduces the top soil magnetic material and hence reduces their magnetic susceptibility. Thus, in conclusion, MS 2D loop probe scans the magnetic susceptibility of top soils which is related to the various factors responsible for different sources of pollution in industrial and residential sites of Visakhapatnam city.

ACKNOWLEDGEMENTS

We are thankful to the Council of Scientific and Industrial Research (CSIR), New Delhi, for providing financial assistance in the form of Junior Research Fellowship (vide CSIR Award No.: 09/1067(0002)/2012-EMR-1). Also we thank, Department of Science and technology (DST), Government of India for providing the necessary field and laboratory equipment for these studies in the form of research project.

Finally, we thankful to the "Centre for materials research",Central Research Laboratory (CRL), GITAM University, Rushikonda, Visakhapatnam, for providing necessary infrastructure & laboratory facilities for conducting this work.

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ISSN No: 2348-4845
International Journal & Magazine of Engineering, Technology, Management and Research
A Peer Reviewed Open Access International Journal

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