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Discussions

# Characterization of minerals

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particles in the state of Tamilnadu, India

# through ftir spectroscopy

Climate  
of the Past



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Received: 25 April 2013 – Accepted: 30 July 2013 – Published: 26 August 2013

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## Abstract

The abstract of this paper explains the presence of minerals in air which causes great concern regarding public health issues. The spectroscopic investigation of air dust particles of several samples in various locations in the state of Tamilnadu, India is reported.

5 Qualitative analyses were carried out to determine the major and minor constituent minerals present in the samples based on the FTIR absorption peaks. This study also identified the minerals like quartz, asbestos, kaolinite, calcite, hematite, montmorillonite, nacrite and several other trace minerals in the air dust particles. The presence of quartz is mainly found in all the samples invariably. Hence the percentage of quartz

10 and its crystalline nature were determined with the help of extinction coefficient and crystallinity index respectively.

## 1 Introduction

All over the world, air pollution is becoming a major concern. Governments in many countries are developing variety of technologies to reduce harmful minerals in air.

15 Both gaseous and particulates are emitted as pollutants from the various pollution sources. Suspended Particulates Matter (SPM) is constituted of aerosol dust or other particulates of size 1 to 200 microns suspended in air (Chandrasekaran et al., 1997).

Depending on the conditions, the fine and ultra-fine particulates may persist in the atmosphere for days or weeks and travel hundreds or thousands of miles from their source (Tyagi, 2009). Primary particles are those emitted directly from a source eg. Windblown soil, or soot from vehicle exhaust. Secondary particulates are those formed from the interaction of other compounds; for eg. Nitrate formation from the photo-oxidation of NO<sub>x</sub>, or the condensation and agglomeration of terpenes from a forest stand (Street et al., 1996).

25 It has been estimated that about 3 million people were die and many more suffered from serious health effects by every year because of air pollution as reported

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by WHO (WHO, 2003). The epidemiological literature has more than 100 published papers, which for the most part, support association of PM with increases in morbidity and/or mortality (WHO, 2000). The air pollution may cause serious health implications including high blood pressure, digestive problems, nerve and kidney disorders, mem-

5 ory and concentration problems, muscle and joint pain and also it affect the immune systems and may even lead to cancer. An estimate made by Central Pollution Control Board (CPCB) during the year 1995 showed that 2000 metric of air pollutants (Total Suspended Particulate Matter) are pumped into the atmosphere every day in Delhi, India (Tyagi, 2009). It is implied that maternal exposure to industrial metal dust or fumes  
10 during pregnancy may reduce fetal growth (Siew lai et al., 2010).

Particulate pollution is a serious health problem throughout the world, exacerbating a wide range of respiratory and vascular illness in urban areas (Wang Lie et al., 2006). Populations at risk from inhaled particles are those most susceptible to pulmonary and heart diseases, infants and elderly people. A joint study of the World Health Or-  
15 ganization (WHO), World Resource Institute (WRI) and the US Environmental Protection Agency (EPA) estimated that nearly 700 000 deaths worldwide are related to air pollution and that this number can escalate to 8 million deaths by 2020 (Working Group, 1997). Occurrence of respiratory diseases in South Asia resulting from air pollution both indoors  
20 and outdoors is estimated to be quite substantial. In each of the 23 cities with a million plus population in India, air pollution level exceed WHO standards (Sagareswar et al., 2011). Recent acknowledgement of the sensitivity of an air quality to changes in climate has initiated a closer examination of the relationships between meteorology and air quality (Pearce et al., 2011). The swift pace of industrial and economic activity in many developing countries contributed significantly to an increased  
25 level of air borne particulate matter, enriched in many toxic heavy metals (Sagareswar et al., 2011). Several studies have demonstrated the negative effect of particulate matter on human health and have confirmed an association between the elevated level of particulate air pollution and decline in lung function or increase in various respiratory diseases (Ttoni et al., 2012).

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Plants in urban areas may improve air quality by removal of gaseous pollutant and of particles (Wang Lie et al., 2006). Many scientist recommends growing green vegetation in and around the industrial/urban areas (Ghose and Majee, 2001; Shannigrahi et al., 2003). Heavy metals and other toxic particles have been shown to accumulate, causing damage and death of some species (Alfani et al., 1996). It also exerts aggravating effect on agricultural production and the green house effect (Ndukwe and Jenmi, 2008). In this paper, an attempt has been made to overlook on mineralogical compositions existing in air dust particles in various districts of Tamilnadu, India.

**2 Methods**

A large variety of field techniques for assessing settled dust have been described in the literature (Adams and Fordio, 2001). Keeping the above problem in view, the sus-pended particulate matter (SPM) has been under taken in Tamilnadu. The air sus-pended particles which are deposited on tissue papers at the height of 20 ft in road side and land area were collected (Ramasamy and Ponnusamy, 2009). These tissue papers were washed in distilled water. The settled dust particles at the bottom of container are then dried at 110 °C in oven and are used for analysis. The samples collected from 38 towns and cities of Tamilnadu, which are labeled as 1 to 111. The samples were mainly collected from the geogenic and anthropogenic polluted areas, i.e. vehicular area (say bus stand), industrial area and residential area which cover almost all major districts of Tamilnadu. Here residential area may come under the geogenic polluted area and the other two may comes under the anthropogenic. The sample collected areas are visualized (Fig. 1) and are listed out with their latitude and longitude in Table 1.

The major and minor minerals are qualitatively determined by using FTIR technique. The Nicolet avatar 360 series available in Centralized Instrumentation and Service Laboratory (CISL), Annamalai University, Chidambaram, Tamilnadu, India is made use of this in all the present work for recording the FTIR spectra of all the samples at room temperature. The samples are usually subjected to various pre-treatments in



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order to remove organic matter and certain other materials to improve the quality of the spectrum. The samples are mixed with Potassium Bromide (KBr) at various ratios like 1 : 10, 1 : 20, 1 : 30, 1 : 40 and 1 : 50. The pellets were prepared and the spectra were taken. The maximum absorption and large number of peaks were observed for the samples in the ratio of 1 : 20 (sample-KBr). The spectra were taken in the region of 4000–400  $\text{cm}^{-1}$ . The instrument scans the spectra 16 times in 1 min. The resolution is  $\pm 4 \text{ cm}^{-1}$  and its accuracy is  $\pm 1 \text{ cm}^{-1}$ .

The spectrum for each site was considered as a representative spectrum of the site. Sample of 2 mg is mixed with 40 mg of spectroscopic KBr in the ratio 1 : 20 using an agate mortar and pestle. Before mixing, necessary amount of KBr powder is dried at  $120^\circ \text{C}$  for six hours in an oven. Otherwise the broad spectral peak due to free OH will seriously affect the interpretation on the bound hydroxyls associated with any of the minerals. The major and minor minerals are qualitatively determined by FT-IR technique.

### 3 Results and discussion

The FTIR spectra of all samples are analyzed and the minerals are assigned using available literatures. The observed wave numbers from all the spectra are given in Table 2 along with their corresponding minerals name.

#### 3.1 Quartz

The silicate minerals are primary concern because of their relative abundance and importance. Quartz ( $\text{SiO}_2$ ) is common and invariably present in all the samples. The Si–O bonds are the strongest bonds in the silicate structure and can be readily recognized in the infrared spectra of such minerals by very strong bands in the region 900 to 1100  $\text{cm}^{-1}$  is due to stretching as well as less intense bands in the 400 to 800  $\text{cm}^{-1}$  region is due to bending. The quartz mineral in the sample were detected with

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bands at  $468\text{ cm}^{-1}$ ,  $693\text{ cm}^{-1}$ ,  $777\text{ cm}^{-1}$ ,  $800\text{ cm}^{-1}$ ,  $1077\text{ cm}^{-1}$ ,  $1090\text{ cm}^{-1}$ ,  $1144\text{ cm}^{-1}$ ,  $1861\text{ cm}^{-1}$  and  $1872\text{ cm}^{-1}$  and the IR absorption peaks were reported by many authors (Chester and Green, 1968; Farmer, 1974; Coates, 1977; Hlavay et al., 1978; Russell, 1987; Ko and Chu, 2005). The quartz is present in almost all samples. These assignments are in good agreement with the observation on the quartz mineral (Hlavay et al., 1978).

### 3.2 Calcite

Calcite is the most stable polymorph of calcium carbonate ( $\text{CaCO}_3$ ). Calcite crystals are trigonal-rhombohedral, though the actual calcite rhombohedra are rare as natural crystals. The frequencies of  $\text{CaCO}_3$  correspond, according to assignments reported by Herzberg (1945), to a symmetric stretching,  $\nu_1$ , an out-of plane bending,  $\nu_2$ , a doubly degenerate asymmetric stretching,  $\nu_3$  and a doubly degenerate planar bending  $\nu_4$ . The presence of IR absorption peaks at different frequencies like  $876\text{ cm}^{-1}$ ,  $1422\text{ cm}^{-1}$ ,  $1431\text{ cm}^{-1}$ ,  $1636\text{ cm}^{-1}$ ,  $1786\text{ cm}^{-1}$ ,  $1792\text{ cm}^{-1}$ ,  $1798\text{ cm}^{-1}$ ,  $2516\text{ cm}^{-1}$ ,  $2570\text{ cm}^{-1}$ ,  $2873\text{ cm}^{-1}$  and  $2982\text{ cm}^{-1}$  which are identified for calcite in the samples (Ndukwe and Jenmi, 2008; Adams and Fordio, 2001; Chester and Green, 1968; Farmer, 1974; Chester and Elderfield, 1967; Senthil Kumar et al., 2001). Among various frequencies  $876\text{ cm}^{-1}$  is due to the C=O stretching mode vibration. The frequency at  $1422\text{ cm}^{-1}$  is due to doubly degenerate asymmetric stretching mode vibration. The frequency at  $1431\text{ cm}^{-1}$  is due to  $(\text{CO}_3)^{2-}$  stretching mode vibration. The frequencies of  $1636\text{ cm}^{-1}$ ,  $1786\text{ cm}^{-1}$ ,  $1792\text{ cm}^{-1}$  are due to C = O stretching mode vibration. The frequency at  $1798\text{ cm}^{-1}$  is due to combinational mode of vibration. The frequencies of  $2516\text{ cm}^{-1}$ ,  $2570\text{ cm}^{-1}$ ,  $2873\text{ cm}^{-1}$  and  $2982\text{ cm}^{-1}$  are due to O–H stretching mode vibration. The symmetric stretching vibrations,  $\nu_3$  lying between  $1400\text{--}1450\text{ cm}^{-1}$  are interesting, as these vibrations are particularly sensitive to the side symmetry for the carbonate group. According to White (1971) if the peak is in between this range, the mineral prevailing low pressure during the formation or this peak increases in splitting of this vibration

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mode in calcite one can infer that the carbonate group becomes increasingly distorted in this phase with high compression. In the present case there is no splitting in this mode  $\nu_3$  but the peak at  $1422\text{ cm}^{-1}$  and  $1431\text{ cm}^{-1}$  is present within the range  $1400\text{--}1450\text{ cm}^{-1}$ . This indicates prevailing low pressure during the formation (Ramasamy et al., 2003).

### 3.3 Clay minerals

The term clay is generally applied to very fine mineral of fragments or particles which composed mostly of hydrous-layer silicates of aluminum, though occasionally it containing magnesium and iron. The  $\text{SiO}_2$  ratio is a formula in the key factor of determining the clay mineral types.

#### 3.3.1 Kaolinit

A typical dioctahedral species is kaolinit, with an ideal structural formula of  $\text{Al}_2\text{Si}_2\text{O}_5(\text{OH})_4$ . Kaolinite is electrostatically neutral and has triclini symmetry. Oxygen atoms and hydroxyl ions between the layers are paired with hydrogen bonding. The kaolinite clays are common soil minerals which often occur in atmospheric particulate matter. Infrared analysis of dust samples by Sakabe et al. (1965), indicate that kaolinite type clays may make up a significant fraction of the mineral content of the atmospheric aerosol.

The observed absorption frequencies of  $433\text{ cm}^{-1}$ ,  $938\text{ cm}^{-1}$ ,  $1623\text{ cm}^{-1}$ ,  $3623\text{ cm}^{-1}$ ,  $3695\text{ cm}^{-1}$  and  $3735\text{ cm}^{-1}$  are the characteristic peaks of clay mineral kaolinite. The frequencies at  $3623\text{ cm}^{-1}$ ,  $3695\text{ cm}^{-1}$  and  $3735\text{ cm}^{-1}$  are due to OH stretching of inner-surface hydroxyl groups (Russell, 1987). The frequencies at  $938\text{ cm}^{-1}$  and  $1623\text{ cm}^{-1}$  are due to OH deformation of inner-surface hydroxyl group and at  $433\text{ cm}^{-1}$  is due to Si–O deformation. The obtained peak values of this mineral matches very well with the results obtained by Madejova and Komadel (2011), Russell (1987), Ramaswamy and Venkatachalapathy (1992) and Hlavay et al. (1978). The



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intensity of the bands varies from sample to sample at different places, which means the amount of the kaolinite varies from sample to sample. It is also one of the most common mineral in ceramic industry (Jun Ojima, 2003). Almost all the samples in the present study are having kaolinite mineral. The inhalation of this dust mineral may de-

velop a pneumoconiosis which often referred as kaoliniosis. It is characterized by the presence of rounded opacities in the lung (Ross et al., 1993). The disordered kaolinite observed at the frequency at  $478\text{ cm}^{-1}$  due to the presence of Si–O–Si deformation vibration.

**3.3.2 Pyrophyllite**

Pyrophyllite is a phyllosilicate mineral composed of aluminium silicate hydroxide. It occurs in two more or less distinct varieties, namely, crystalline folia and which compact masses but distinct crystals are not known. In the ideal case, the structural formula is expressed by  $\text{Al}_2\text{Si}_4\text{O}_{10}(\text{OH})_2$  for pyrophyllite. Therefore, the 2 : 1 layers of these minerals are electro statically neutral and are held together with Van der Waals bonding.

One-layer triclinic forms are known for as polytypes of pyrophyllite. The frequency at  $737\text{ cm}^{-1}$  is due to O–H out of plane bending mode vibration, which is identified by Pyrophyllite minerals (Durig et al., 1971).

**3.3.3 Vermiculite**

The vermiculite ( $\text{Mg}, \text{Fe}^{2+}, \text{Al})_3(\text{Al}, \text{Si})_4\text{O}_{10}(\text{OH})_2 \cdot 4(\text{H}_2\text{O})$  unit structure consists of the sheets of trioctahedral mica or talc which separated by the layers of water molecules and these layers occupy a space about two water molecules thick. Vermiculite is present nearly 90 samples out of 111. The observed frequencies of vermiculite are  $670\text{ cm}^{-1}$  and  $811\text{ cm}^{-1}$ .  $670\text{ cm}^{-1}$  is due to Si–O Symmertrical bending mode vibration.

The frequency at  $811\text{ cm}^{-1}$  is due to O–H out of plane bending mode (Misiunas et al., 2005).

### 3.3.4 Smectite

Smectite is structural formula of the dioctahedral aluminous species may be represented by  $(Al_{2-y}Mg^{2+}_y)(Si_{4-x}Al_x)O_{10}(OH)_2M^+_{x+y}nH_2O$ , where  $M^+$  is the interlayer exchangeable cation expressed as a monovalent cation and where  $x$  and  $y$  are the amounts of tetrahedral and octahedral substitutions, respectively. The frequency at  $522\text{ cm}^{-1}$  for smectite is due to Al–O–Si deformation (Madejova and Komadel, 2011).

### 3.3.5 Palygorskite

Palygorskite are papyrus-like or fibrous hydrated magnesium silicate minerals and are included in the phyllosilicate group because they contain a continuous two-dimensional tetrahedral sheet of composition  $Si_2O_5$ . Palygorskite is present in all this samples which have frequencies of  $414\text{ cm}^{-1}$ ,  $512\text{ cm}^{-1}$ ,  $567\text{ cm}^{-1}$ ,  $1647\text{ cm}^{-1}$ ,  $1681\text{ cm}^{-1}$  and  $3611\text{ cm}^{-1}$ . The vibration assignment for  $414\text{ cm}^{-1}$  and  $512\text{ cm}^{-1}$  are due to Si–O de-formation.

The frequency at  $567\text{ cm}^{-1}$  is due to Si–O stretching mode vibration. The frequencies at  $1647\text{ cm}^{-1}$ ,  $1681\text{ cm}^{-1}$  and  $3611\text{ cm}^{-1}$  are due to O–H deformation (Madejova and Komadel, 2011).

### 3.3.6 Sepiolite

Sepiolite is a clay mineral, a complex magnesium silicate, a typical formula for which is  $Mg_4Si_6O_{15}(OH)_2 \cdot 6H_2O$ . It can be present in fibrous, fine-particulate, and solid forms. Sepiolite is present in all this samples which have frequencies of  $422\text{ cm}^{-1}$ ,  $1657\text{ cm}^{-1}$ ,  $3246\text{ cm}^{-1}$  and  $3619\text{ cm}^{-1}$ . The frequencies at  $422\text{ cm}^{-1}$ ,  $1657\text{ cm}^{-1}$ ,  $3246\text{ cm}^{-1}$  and  $3619\text{ cm}^{-1}$  are due to O–H stretching of hydroxyl group (Madejova and Komadel, 2011).

### 3.3.7 Imogolite

Imogolite is frequently found together in main clay component. Imogolite is an aluminium silicate clay mineral with formula  $Al_2SiO_3(OH)_4$ . The frequency at  $602\text{ cm}^{-1}$

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is assigned for imogolite mineral and it is due to O–H deformation mode (Madejova and Komadel, 2011). Imogolite is present nearly 50 samples. The spectrum of Proto-imogolite has substantially the same pattern as imogolite but is more diffuse. Proto-imogolite (Baranska et al., 2005) sols can be considered as highly dispersed forms of proto-imogolite allophone. The frequencies at  $680\text{ cm}^{-1}$  and  $854\text{ cm}^{-1}$  are observed for proto-imogolite. The frequencies at  $680\text{ cm}^{-1}$ ,  $854\text{ cm}^{-1}$  are due to Si–O bending mode.

### 3.4 Hematite

Hematite is the mineral form of iron (III) oxide ( $\text{Fe}_2\text{O}_3$ ). Hematite crystallizes in the rhombohedral system and it has the same crystal structure as limonite and corundum. According to Russell (1987) and Ramaswamy and Venkatachalapathy (1992) were observed the absorption frequencies of Hematite is explained well. It observed almost in the entire samples which shows peak at  $536\text{ cm}^{-1}$  which is the characteristic peak of hematite. The peak of hematite is due to Fe–O stretching mode vibration. In all these samples, the intensities of the hematite peaks are weak to medium. Hence this mineral can be considered as trace mineral, thus the inhalation of such small grain sized iron bearing mineral (hematite) along with other minerals will also create lung disease, because the particles are coated in the surface of lungs.

### 3.5 Asbestos

Asbestos is a naturally-occurring silicate mineral. The prolonged inhalation of asbestos fibers can cause serious illnesses, including malignant lung cancer, mesothelioma (a formerly-rare cancer strongly associated with exposure to amphibole asbestos) and asbestosis (a type of pneumoconiosis). Asbestos can be found naturally in the air outdoors and in some drinkable water including water from natural sources (Centre for Disease, 2010). Studies have shown that members of the general (non-occupationally exposed) population have tens of thousands to hundreds of thousands of asbestos

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fibers in each gram of dry lung tissue, which translates into millions of fibers and tens of thousands of asbestos bodies in every person's lungs (Medscape, 2010). The particle size and shape plays an important role in the inhalation and long penetration mechanisms, especially with amphibole fibrous (Coates, 1997). Generally Asbestos is

exhibit intense absorptions in the region  $1200\text{--}900\text{ cm}^{-1}$  of the infrared spectra. The spectrum of Asbestos is shown by the observed frequency at  $1033\text{ cm}^{-1}$  which is due to Si–O stretching mode vibration.

### 3.6 Chrysotile

Chrysotile or white asbestos is the most commonly disordered form of asbestos. It is a soft, fibrous silicate mineral in the serpentine group of phyllosilicates. As such it is distinct from other asbestiform minerals in the amphibole group. The idealized chemical formula is  $\text{Mg}_3(\text{Si}_2\text{O}_5)(\text{OH})_4$  (US Department, 2005). On the lines of Coates (1997) the presence of the band at  $605\text{ cm}^{-1}$  is due to chrysotile asbestos. The frequencies at  $405\text{ cm}^{-1}$  and  $453\text{ cm}^{-1}$  show the Chrysotile mineral, which are due to Si–O stretching mode vibration (Rector and Fayer, 1998).

### 3.7 Dolomite

Dolomite is a carbonate mineral composed of calcium magnesium carbonate  $\text{CaMg}(\text{CO}_3)_2$ . The mineral dolomite crystallizes in the trigonal-rhombohedral system. The IR absorption bands at  $582\text{ cm}^{-1}$  and  $2628\text{ cm}^{-1}$  show the presence of dolomite in the samples (Dolomite, 2001–2005). This dolomite mineral is present nearly in 53 samples. The frequencies assignment for  $582\text{ cm}^{-1}$  and  $2628\text{ cm}^{-1}$  are due to C–O symmetric stretching mode vibration (Russell, 1987).

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### 3.8 Nacrite

Nacrite  $\text{Al}_2\text{Si}_2\text{O}_5(\text{OH})_4$  is a clay mineral that is a polymorph or polytype of kaolinite. It crystallizes in the monoclinic system. Nacrite is present in nearly 90 samples. The observed frequencies of nacrite are  $905\text{ cm}^{-1}$ ,  $915\text{ cm}^{-1}$ ,  $1005\text{ cm}^{-1}$  and  $3648\text{ cm}^{-1}$ .

The frequencies at  $915\text{ cm}^{-1}$  is due to Al–Al–OH deformation of inner hydroxyl group. The frequencies at  $905\text{ cm}^{-1}$  and  $1005\text{ cm}^{-1}$  are due to Si–O stretching and at  $3648\text{ cm}^{-1}$  is due to O–H stretching of inner hydroxyl group (Russell, 1987).

### 3.9 Magnetite and gibbsite

Magnetite is a ferrimagnetic mineral with chemical formula  $\text{Fe}_3\text{O}_4$ , and a member of the spinel group. Gibbsite is an aluminium hydroxide mineral of the oxides and hydroxides group, with structural formula  $\text{Al}(\text{OH})_3$ . Gibbsite's structure is made up by the stacking of octahedral sheets of aluminium hydroxide. Each layer consists of octahedral six-fold coordinated  $\text{Al}^{3+}$  cations sandwiched between two close packed layers of OH (Jubb and Allen, 2010).

Magnetite is present in 60 samples and Gibbsite is present in 16 samples among the collected samples. Magnetite is observed at the frequencies of  $577\text{ cm}^{-1}$  and  $717\text{ cm}^{-1}$  and Gibbsite is observed at the frequencies of  $3300\text{ cm}^{-1}$  and  $3529\text{ cm}^{-1}$ . The frequency at  $577\text{ cm}^{-1}$  is due to Fe–O bending mode and at  $717\text{ cm}^{-1}$  is due to Fe–O bending mode vibration. The frequencies at  $3300\text{ cm}^{-1}$  and  $3529\text{ cm}^{-1}$  is due to O–H stretching mode vibration.

### 3.10 Aragonite

Aragonite is a carbonate mineral and is formed by biological and physical processes including precipitation from marine and fresh water environments. The study of aragonite in the infrared wavelength region was prompted by differences in the data on aragonite reported by Hunt et al. (1950) and Huang and Kerr (1960). The IR absorption peaks

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at  $1457\text{ cm}^{-1}$  and  $2520\text{ cm}^{-1}$  shows the Aragonite mineral and it presents nearly in 103 samples. The assignment for  $1457\text{ cm}^{-1}$  is due to C–O bending mode vibration and  $2520\text{ cm}^{-1}$  is due to O–H stretching mode vibration.

### 3.11 Montmorillonite

5 Montmorillonite is a very soft phyllosilicate group of minerals that typically form in microscopic crystals. The theoretical formula for montmorillonite i.e., without structural substitutions is  $(\text{OH})_4\text{Si}_8\text{Al}_4\text{O}_{20}\text{nH}_2\text{O}$ . The montmorillonite minerals are composed of hydrous aluminum silicates in the form of extremely small particles. The IR absorption peaks at  $3405\text{ cm}^{-1}$  shows presence of montmorillonite (Russell, 1987). It is presents  
10 nearly in 106 samples. This is due to O–H stretching mode vibration of water molecule.

### 3.12 Organic carbon

Total organic carbon (TOC) is the amount of carbon bound in an organic compound. Organic carbon forms are derived from the decomposition of plants and animals. They are capable of decay or are the product of decay. They contain organic compounds whose  
15 molecules contain carbon, oxygen, nitrogen and hydrogen (Pluske et al., 2013) Organic carbon is present in almost all the samples, which have frequencies at  $2853\text{ cm}^{-1}$  and  $2921\text{ cm}^{-1}$ . They are due to C–H symmetric stretching mode vibration.

### 3.13 Feldspar

The feldspar group of minerals are of several types having different compositions such as orthoclase, microcline, sanidine (K-feldspar), albite (Na-feldspar) and anorthite (Ca-feldspar). Though three feldspars (orthoclase, microcline and sanidine) are having the same chemical formula  $(\text{KAlSi}_3\text{O}_8)$  but differ in structure (orthoclase – monoclinic, microcline – triclinic and sanidine – tetrahedral). The observed frequency for feldspar is at  
20  $645\text{ cm}^{-1}$  and  $1772\text{ cm}^{-1}$ . The frequencies of hydrous feldspar are observed at

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440  $\text{cm}^{-1}$ , 591  $\text{cm}^{-1}$ , 1019  $\text{cm}^{-1}$  and 3417  $\text{cm}^{-1}$ . The observed frequency at 635  $\text{cm}^{-1}$  for orthoclase is due to Al–O coordination vibration (Coates, 1997). The observed frequency at 645  $\text{cm}^{-1}$  and 1772  $\text{cm}^{-1}$  for feldspar is due to Si–O stretching mode vibration (Russell, 1987). The frequency at 440  $\text{cm}^{-1}$  is due to O–H bending mode vibration at 591  $\text{cm}^{-1}$  and 3417  $\text{cm}^{-1}$  is due to O–H symmetric stretching mode vibration. Hydrous feldspar is observed at frequency 1019  $\text{cm}^{-1}$ , which has O–H deformation. The frequency at 727  $\text{cm}^{-1}$  is due to Si–O stretching mode vibration which is identified by the microcline feldspar. The frequency at 1113  $\text{cm}^{-1}$  is due to Si–O–Si stretching mode vibration which is identified by Microcline feldspar. Anorthite is the calcium end member of plagioclase feldspar. Plagioclase is an abundant mineral in the earth's crust. The formula of pure anorthite is  $\text{CaAl}_2\text{Si}_2\text{O}_8$ . The frequency at 1159  $\text{cm}^{-1}$  is due to Si–O stretching mode vibrations, which is identified by Anorthite mineral.

### 3.14 Other minerals

*Goethite* ( $\text{FeOH}$ ) is an iron bearing oxide mineral found in soil and other low-temperature environments. Goethite has had a reputation for making rather uninteresting, dull and dirty mineral specimens. Goethite is observed at the frequencies of 495  $\text{cm}^{-1}$  and 894  $\text{cm}^{-1}$  which are due to bending mode vibration. The frequency at 495  $\text{cm}^{-1}$  is due to Fe(III)–O–Si bending mode vibration. The observed frequency at 894  $\text{cm}^{-1}$  is due to O–H bending mode vibration. *Hectorite* ( $\text{Na}_{0.4}\text{Mg}_{2.7}\text{Li}_{0.3}\text{Si}_4\text{O}_{10}(\text{OH})_2$ ) is observed at the frequencies of 656  $\text{cm}^{-1}$  is due to Si–O stretching mode vibration (Ali et al., 2009).

*Dickite* ( $\text{Al}_2\text{Si}_2\text{O}_5(\text{OH})_4$ ) is a phyllosilicate clay mineral which is chemically composed of aluminium, silicon, hydrogen and oxygen. Dickite has a monoclinic crystal system and its crystal class is domatic. Dickite is observed at the frequency of 755  $\text{cm}^{-1}$  which has Al–O–Si of perpendicular vibration (Russell, 1987). *Botite* mineral shows the frequency at 3712  $\text{cm}^{-1}$  is due to O–H stretching mode vibration.

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Nowadays *Beidellite* ( $\text{Na}_{0.7}\text{Al}_4(\text{Si}_{7.3}\text{Al}_{0.7})\text{O}_{20}(\text{OH})_4 \cdot x\text{H}_2\text{O}$ ) has been defined as a dioctahedral Al-smectite with an average layer charge of 0.6 to 0.7. This charge is completely created by the substitution of  $\text{Si}^{4+}$  by  $\text{Al}^{3+}$  on the tetrahedral positions. Russell (1987) reported well-resolved OH-deformation bands at  $886\text{ cm}^{-1}$  for Al–Fe<sub>3</sub>–OH deformation in beidellite.

*Glaucanite* is ferric-iron silicate mineral with micaceous structure  $((\text{K},\text{Na})(\text{Fe}^{3+},\text{Al},\text{Mg})_2(\text{Si},\text{Al})_4\text{O}_{10}(\text{OH})_2)$ . Glaucanite has frequencies of  $984\text{ cm}^{-1}$  and  $3588\text{ cm}^{-1}$  which are due to Si–O stretching mode and O–H stretching mode vibration respectively (Palmer and Frost, 2006). *Baryte* is observed at the frequency of  $1182\text{ cm}^{-1}$  is due to Si–O–Si stretching mode vibration.

*Celadonite* is a mica group mineral, a phyllosilicate of potassium, iron in both oxidation states, aluminium and hydroxide with formula  $\text{K}(\text{Mg},\text{Fe}^{2+})(\text{Fe}^{3+},\text{Al})(\text{Si}_4\text{O}_{10})(\text{OH})_2$ . It crystallizes in the monoclinic system. Celadonite is observed at the frequency of  $1099\text{ cm}^{-1}$  which is due to Si–O of stretching mode vibration.

*Cerussite* ( $\text{Pb}(\text{CO}_3)$ ) is formed by the chemical action of carbonated water on the mineral galena. Cerussite mineral is identified by the frequencies of  $1385\text{ cm}^{-1}$  and  $1399\text{ cm}^{-1}$  are due to C–O bending mode vibrations (Palmer and Frost, 2006; Lascola and Andrews, 1987). *Ankerite* ( $\text{CaFe}_0.6\text{Mg}_0.3\text{Mn}_0.1(\text{CO}_3)_2$ ) mineral is identified by the frequency at  $1448\text{ cm}^{-1}$  is due to C–H bending mode vibration (Rebenstorf, 1988; Jubb and Allen, 2010). *Aliettite* ( $\text{Mg}_3\text{Si}_4\text{O}_{10}(\text{OH})_2\text{Ca}_{0.1}\text{Na}_{0.2}\text{AlFe}_0.7\text{Mg}_{0.5}\text{Al}_3\text{SiO}_{10}(\text{OH})_2 \cdot 3(\text{H}_2\text{O})$ ) mineral is identified by the frequencies of  $788\text{ cm}^{-1}$  and  $3675\text{ cm}^{-1}$  which is due to O–H stretching mode vibrations.

#### 4 Relative distributions of hazardous minerals

Almost all the samples are having the minerals like hematite, feldspar, quartz, asbestos, calcite, montmorillonite and kaolinite minerals. The relative distribution of major miner-



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als such as hematite, feldspar, quartz, asbestos, calcite, montmorillonite, and kaolin-ite are explained through the determination of extinction co-efficient of the characteristic peaks and frequencies ( $536 \text{ cm}^{-1}$ ,  $645 \text{ cm}^{-1}$ ,  $777 \text{ cm}^{-1}$ ,  $1033 \text{ cm}^{-1}$ ,  $1422 \text{ cm}^{-1}$ ,  $3405 \text{ cm}^{-1}$ ,  $3695 \text{ cm}^{-1}$ ) of respective minerals. The extinction co-efficient of above mentioned minerals have been calculated for all the air suspended samples under the investigation, by using the relation.

$$K = DA/m \quad (1)$$

Where,  $K$  – extinction co-efficient,  $D$  – optical density ( $D = \log I_0/I$ ),  $I_0$  – intensity of incident radiation,  $I$  – intensity of transmitted radiation,  $A$  – area of the pellet,  $m$  – mass of the sample.

The extinction co-efficient values are calculated. The maximum value for the mineral hematite is 29.4785, feldspar is 35.55715, quartz is 59.8161, asbestos is 22.8922, calcite is 23.3484, montmorillonite is 21.0083 and kaolinite is 21.8317. In overview, the amount of all the samples are visually indicated in Fig. 3a–d. Almost the same

trend is observed in all the three categories Vehicular Area, Residential Area and Industrial Area, since the quartz is distributed as a major constituent irrespective of the categories and hematite, feldspar etc. are in the next order. When it is focused in depth, the order of amount of quartz, hematite and feldspar are determined as Vehicular Area > Industrial Area > Residential Area. The asbestos are more in industrial area which may be due to the polluted air, solid wastages from the industry which are dissolved in air etc.

## 5 Crystallinity index of quartz

The crystallinity is defined as the fraction of crystalline materials in a mixture of crystalline and non-crystalline material. It is otherwise called as degree of disorder. When crystallinity is minimum, the minerals are said to be in disordered state and maximum

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then the minerals are considered to be in ordered state. Crystallinity is inversely proportional to the crystallinity index values.

Crystalline silica is one of the most abundant components in the dust samples both in from the geogenic and anthropogenic areas, i.e. natural and industrial environments.

5 The crystalline nature of quartz may be confirmed through the presence of peak at around  $695\text{ cm}^{-1}$ . According to Yariv and Mendelovici (1979), the absorption of band at  $695\text{ cm}^{-1}$  is due to the vibration of octahedral site symmetry and at  $777\text{ cm}^{-1}$  is due to the vibration in the tetrahedral site symmetry. The tetrahedral symmetry is stronger one than octahedral site symmetry. Hence, the present study indicates the presence

10 of quartz is in disordered state which may be due to smaller particle size. According to Krivascy and Hlavay (1993), the inhalation of the disordered or crystalline silica can create the lung disease. The concentration of this quartz is proportional to the toxicity. Due to the presence of quartz in dust, the inhalation of the quartz particles in the size of  $0.5\text{--}0.7\ \mu\text{m}$  may produce diseases such as chronic silicosis, acute silicosis, accelerated silicosis and silica tuberculosis (Ross et al., 1993). The variation of crystallinity index of quartz in vehicular area, residential area and industrial area are shown in Fig. 4. The average values of crystallinity index of vehicular area, residential area and industrial area are 4.98, 6.15 and 5.608 respectively. From these values, it is observed that the residential area have disordered quartz and the vehicular area shows the existence of  
20 well ordered quartz. The industrial areas have in between nature.

## 6 Summary

The FTIR techniques have employed in the present paper which provides a rapid, reproducible and accurate method of determination of minerals in dust qualitatively and quantitatively. From the above studies it is concluded as follows.

25 The various dust samples have analyzed through infrared spectroscopic technique which was collected from the geogenic and anthropogenic polluted areas in different sites of Tamilnadu indicates the presence of quartz, calcite, kaolinite, pyrophyllite,

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vermiculite, smectite, palygorskite, sepiolite and some more minerals. In general the minerals quartz, calcium carbonate, kaolinite, nacrite, chrysotile, goethite, pyrophyllite, smectite, sepiolite, hematite, montmorillonite and feldspar may be considered under the category of geogenic minerals and the other minerals like total organic carbon, as-  
 5 bestos, calcium carbonate, cerussite, vermiculite, aragonite, dolomite, magnetite and gibbsite may be considered under the category of anthropogenic minerals. Based on the references and the appearance of characteristic peaks shows the minerals like quartz, calcite, asbestos and kaolinite are considered as major constituent of the dust samples. The minerals such as montmorillonite and nacrite are considered as asso-  
 10 ciate minerals which may be found in traces. The availability of hematite, feldspar, quartz, asbestos, calcite, montmorillonite and kaolinite in various sites were determined through extinction co-efficient of all these samples. In this study the major constituent is quartz in all samples. The order of amount of major minerals like quartz, hematite and feldspar are determined as anthropogenic areas > geogenic areas, i.e. Vehicular  
 15 Area > Industrial Area > Residential Area. Moreover, from the crystallinity index value, the average value is higher at geogenic areas ie., residential area implies that the crystalline nature of quartz is poor and it is lower at anthropogenic areas ie., vehicular area shows the existence of well ordered quartz. As the minerals quartz and hematite are harmful to the human beings and the deciding factors for pollution, the Vehicular Area  
 20 is considered as the most polluted area. The inhalation of such minerals will lead to various respiratory diseases. The effect will be huge in the case of pregnant ladies. The toxicity is proportional to the concentration of these minerals. These forms of dis-ease are progressive with a continuing decrease of lung function even in the absence of further dust exposure.

## References

Adams, S. and Fordio, D: Monitoring of deposited particles in cultural properties the influence of visitors, Atmos. Environ., 35, 4073–4080, 2001.

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- Alfani, A., Maisto, G., Iovieno, P., Rutigliano, F. A., and Bartoli, G.: Leaf contamination by atmospheric pollutants as assessed by elemental analysis of leaf tissue, leaf surface deposit and soil, *J. Plant Physiol.*, **148**, 243–248, 1996.
- Ali, I. O., Ali, A. M., Shabaan, S. M., and El-Nasser, K. S.: Isomorphous substitution of Fe in the framework of aluminosilicate MFI by hydrothermal synthesis and their evaluation in p-nitrophenol degradation, *J. Photoch. Photobio. A*, **204**, 25–31, 2009.
- Andreea, L., Turcu, A., and Schapira R. M.: Parenchymal and Airway Diseases Caused by Asbestos, *Curr. Opin. Pulmon. Med.*, **16**, 155–161, [www.medscape.com/viewarticle/717218](http://www.medscape.com/viewarticle/717218), 2010.
- 10 Baranska, M., Schulz, H., Baranski, R., Nothnagel, T., and Christensen, L. P.: In situ simultaneous analysis of polyacetylenes, carotenoids and polysaccharides in carrot roots, *J. Agr. Food Chem.*, **53**, 6565–6571, 2005.
- Centre for Disease Control Article on Asbestos: available at: <http://www.atsdr.cdc.gov/asbestos/> (last access: 12 January 2010), 2013.
- 15 Chandrasekaran, G. E., Ramchandran, C., and Shetty, N.: Ambient air quality at selected sites in Bangalore City, *Indian Journal of Environmental Production*, **17**, 184–188, 1997.
- Chester, R. and Elderfield, H.: The application of infrared absorption spectroscopy to carbonate mineralogy, *Sedimentology*, **9**, 5–21, 1967.
- Chester, R. and Green, R. N.: The infrared determination of quartz in sediments and sedimentary rocks, *Chem. Geol.*, **3**, 199–212, 1968.
- Coates, J. P.: The IR Analysis of Quartz and Asbestos, Neolith Offset Ltd., Chesham, England, 1997.
- Durig, J. R., Karrikar, J. M., and Harriz, W. C.: Vibrational spectra and structure of small ring compound-XXII cyclopentanol, cyclopentanol-O-d, cyclopentanol d<sub>1</sub>, cyclopentanol d<sub>4</sub>, *Spectro. Chem. Acta*, **27**, 1955–1971, 1971.
- 25 Farmer, V. C.: The layer silicates, edited by: Farmer, V. C., *The Infrared spectra of minerals*. London, Mineral. Soc., 331–363, 1974.
- Ghose, M. K. and Majee, S. R.: Air pollution caused by opencast mining and its abatement measures in India, *J. Environ. Manage.*, **63**, 193–202, 2001.
- 30 Herzberg, G.: *Molecular Spectra and Molecular Structure. II. Infrared and Raman Spectra of Polyatomic Molecules*, Van Nostrand Co., New York, 178, 1945.

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- Hlavay, J., Jonas, K., Elek, S., and Inczedy, J.: Characterization of the particle size and the crystallinity of certain minerals by infrared spectrophotometry and other instrumental methods—II. Investigation on quartz and feldspar, *Clay. Clay Miner.*, 26, 139–143, 1978.
- Howie, R. A. and Broadhurst F. M.: X-ray data for dolomite and ankerite, *Amer. Mineral.*, 43, 5 1210–1214, [www.handbookofmineralogy.org/pdfs/dolomite](http://www.handbookofmineralogy.org/pdfs/dolomite), 1958.
- Huang, C. K. and Kerr, P. F.: Infrared study of the carbonate minerals, *Am. J. Mineral.*, 45, 311–324, 1960.
- Hunt, J. M., Wisher, M. P., and Bonham, L. C.: Infrared absorption spectra of minerals and other inorganic compounds, *Anal. Chem.*, 22, 1478–1497, 1950.
- 10 Jubb, A. M. and Allen, H. C.: Vibrational spectroscopic characterization of hematite, maghemite and magnetite, thin films produced by vapor deposition, *Appl. Mater. Interf.*, 2, 2804–2812, 2010.
- Jun Ojima: Determining of Crystalline Silica in Respirable Dust Samples by Infrared Spectrophotometry in the Presence of Interferences *J. Occup. Health*, 45, doi:10.1539/joh.45.94, 2003.
- 15 Ko, T. H. and Chu, H.: Spectroscopic study on sorption of hydrogen sulfide by mean of red soil, *Spectrochim. Acta A*, 61, 2253–2259, 2005.
- Krivascy, Z. and Hlavay, J.: Determination of quartz in dust samples by diffuse reflection FTIR spectroscopy, *J. Molec. Struct.*, 294, 251, doi:10.1016/0022-2860(93)80362-Y, 1993.
- 20 Lascola, R. and Andrews, L.: FTIR spectra of hydroxylamine-hydrogen fluoride complexes in solid argon, *J. Am. Chem. Soc.*, 109, 4768, doi:10.1021/ja00250a001, 1987.
- Madejova, J. and Komadel, P.: Baseline studies of the clay minerals source society: infrared methods, *Clay. Clay Miner.*, 49, 410–432, 2011.
- Misiunas, A., Niaura, G., and Talaikyt, Z.: Infrared and Raman bands of phytantriol as markers of hydrogen bonding and interchain interaction, *Spectrochim. Acta A*, 62, 945–957, 2005.
- 25 Ndukwe, N. A. and Jenmi, F. O.: Effects of vehicular exhaust fumes on urban air pollution in Lagos metropolis, *Poll. Res.*, 27, 539–543, 2008.
- Palmer, S. and Frost, R. L.: Synthesis and spectroscopic characterization of apjohnite and pickeringite, *Polyhedron*, 25, 3379–3386, 2006.
- 30 Pearce, J. L., Bringer, J., Nicholls, N., Hyndman, R. J., and Tapper, N. J.: Quantifying the influence of local meteorology on air quality using generalized additive models, *Atmos. Environ.*, 45, 1328–1336, 2011.

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- Pluske, W., Murphy, D., and Sheppard, J.: Organic Carbon, available at: [www.soilquality.org.au](http://www.soilquality.org.au), 2009.
- Ramasamy, V. and Ponnusamy, V.: Analysis on air suspended particles of coimbatore – a FTIR study, *Indian J. Phys.*, 83, 301–312, 2009.
- <sup>5</sup> Ramasamy, V., Dheenathayalu, M., Ponnusamy, V., Murugesan, S., and Mullainathan, S.: Characterisation of quartz and feldspars in white granites, *J. Curr. Sci.*, 3, 181–190, 2003.
- Ramaswamy, K. and Venkatachalapathy, R.: Infrared spectroscopic analysis of sedimentary formations of Neyveli lignite minecut-II, *Indian J. Pure Appl. Phys.*, 30, 171–175, 1992.
- Rebenstorf, B.: An IR study of the polymerization mechanism of the phillips catalyst, *J. Mol. Catal.*, 45, 263–274, 1988.
- Rector, K. D. and Fayer, M. D.: Vibrational dephasing mechanisms in liquids and glasses: vibrational echo experiments, *J. Chem. Phys.*, 108, 1794, doi:10.1063/1.475556, 1998.
- Ross, M., Nolan, R. P., Langer, A. M., and Cooper, W. C.: Health effects of mineral dusts other than asbestos, in: *Cooper in Health Effects of Minerals Dusts*, edited by: Guthrie, G. D. and
- <sup>15</sup> Mossman, B. T., Mineralogical Society of America, Washington DC, 28, 361–407, 1993. Russell, J. D.: Infrared methods, in: *A Hand Book of Determinative Methods in Clay Mineralogy*, edited by: Wilson, M. J., Blackie and Son Ltd, NY, 133, 11–67, 1987.
- Sagareswar Gummeneni, Yusri Bin Yusup, Murthy Chavali, and Samadi, S. Z.: Source apportionment of particulate matter in the ambient air of Hyderabad city, India, *Atmos. Res.*, 101, 752–764, 2011.
- <sup>20</sup> Sakabe, H., Matsushita, H., Hayashi, H., Nozaki, K., and Suzuki, Y: Mineral components and 3, 4-benzpyrene in air pollutants of Tokyo, *Ind. Health*, 3, 126–139, 1965.
- Senthil Kumar, P., Parthasarathy, G., Sharma, D. S., Srinivasan, R., and Krishnamurthy, P.: Mineralogical and geochemical study on carbonate veins of Salem-Attur fault zone, southern
- <sup>25</sup> India: evidence for carbonate affinity, *J. Geol. Soc. India*, 58, 15–20, 2001.
- Shannigrahi, A. S., Sharma, R. C., and Fukushima, T.: Air pollution control by optimal green belt development for Victoria Memorial Monument, Kolkata (India), *Int. J. Environ. Stud.*, 60, 241–249, 2003.
- Siew Lai Huang, Chun-Yang Yin, and Siaw Yang Yap: Particle size and metals concentration of <sup>30</sup> dust from a paint manufacturing plant, *J. Hazard. Mater.*, 174, 839–842, 2010.
- Street, R. A., Duckham, S. C., and Hewitt, C. N.: Laboratory and field studies of biogenic volatile organic compound emission from Sitka spruce (*Picea sitchensis* Bong) in the United Kingdom, *J. Geophys. Res.-Atmos.*, 101, 22799–22806, 1996.

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- Totoni, R., Prifti, L. and Mulla, E. F.: Particulate matter pollution: a continuing problem in Tirana's air quality: study and trends, *Asian J. Chem.*, 24, 2674–2678, 2012.
- Tyagi, S. K.: A need for in-depth studies of airborne particle size distribution in Delhi formulation of ambient air standard for  $PM_{2.5}$ , *Indian Journal of Air Pollution Control*, 9, 22–26, 2009.
- <sup>5</sup>US Department of Health and Human Services: Asbestos, Report on Carcinogens, 11th. edn., 2005.
- Wang Lie, Liu Liolan-You, Gao Shang-Yu, Hasi Eerdun, and Wangzhi: Physicochemical characteristics of ambient particles settings upon leaf surfaces of urban plant in Beijing, *J. Environ. Sci.*, 18, 921–926, 2006.
- <sup>10</sup>White, W. B.: Infra-red characterization of water and hydroxyl ion in the basic magnesium carbonate minerals, *Am. Mineral.*, 56, 46–53, 1971.
- WHO: Air Pollution, available at: <http://www.who.int/inffs/en/fact187.html> (last access: 23 June 2009), 2003.
- Working Group on Public Health and Fossil-Fuel Combustion, Short-term improvements in public health from global-climate policies on fossil-fuel combustion: an interim report, *The Lancet*, 350, 1341–1349, doi:10.1016/S0140-6736(97)10209-4, 1997.
- <sup>15</sup>World Health Organization, Guidelines for Air Quality, WHO/SDE/OEH/00.02, World Health Organization, Geneva, Internet address: <http://www.who.int/peh/air/airindex.htm>, 2000.
- Yariv, S. H. and Mendelovici, E.: The effect of degree of crystallinity on the infrared spectrum of <sup>20</sup>hematite, *Appl. Spectrosc.*, 33, 410, 1979.

Table 1. Latitude and Longitude of sites where the samples collected in Tamilnadu, India.

City/Town	Latitude	Longitude	District	Vehicle Area	Sample numbers	
					Residential Area	Industrial Area
Kanchipuram	12 50 <sup>00</sup> <sub>30</sub> N	79 42 <sup>00</sup> <sub>13</sub> E	Kanchipuram	1	2	3
Arakkona	13 4 <sup>57</sup> <sub>57</sub> N	79 40 <sup>14</sup> <sub>22</sub> E	Vellore		4,5,6	
Villupuram	11 56 <sup>22</sup> <sub>00</sub> N	79 29 <sup>51</sup> <sub>00</sub> E	Villupuram	7	8	9
Cuddalore	11 45 <sup>0</sup> <sub>00</sub> N	79 45 <sup>0</sup> <sub>00</sub> E	Cuddalore	10	11,12	13
Ranipet	12 55 <sup>42</sup> <sub>00</sub> N	79 19 <sup>56</sup> <sub>00</sub> E	Vellore	14	15,16	17
Krishnagiri	12 31 <sup>7</sup> <sub>00</sub> N	78 12 <sup>49</sup> <sub>00</sub> E	Krishnagiri	18	19	20
Vellore	12 54 <sup>59</sup> <sub>00</sub> N	79 7 <sup>56</sup> <sub>00</sub> E	Vellore		21	22
Hosur	12 43 <sup>58</sup> <sub>00</sub> N	77 49 <sup>48</sup> <sub>00</sub> E	Krishnagiri	23	24,25	26
Dharmapuri	12 7 <sup>38</sup> <sub>00</sub> N	78 9 <sup>28</sup> <sub>00</sub> E	Dharmapuri	27	28	29
Salem	11 39 <sup>51</sup> <sub>00</sub> N	78 8 <sup>45</sup> <sub>00</sub> E	Salem	30	31	32
Namakkal	11 13 <sup>10</sup> <sub>00</sub> N	78 10 <sup>4</sup> <sub>00</sub> E	Namakkal	33	34	35
Erode	11 20 <sup>32</sup> <sub>00</sub> N	77 43 <sup>38</sup> <sub>00</sub> E	Erode	36	37	38
Tiruppur	11 6 <sup>43</sup> <sub>00</sub> N	77 21 <sup>15</sup> <sub>00</sub> E	Tiruppur	39	40,41	42
Coimbatore	11 1 <sup>0</sup> <sub>00</sub> N	76 57 <sup>20</sup> <sub>00</sub> E	Coimbatore	43	44	45
Dharapuram	10 44 <sup>12</sup> <sub>00</sub> N	77 31 <sup>56</sup> <sub>00</sub> E	Tiruppur	46	47	48
Karur	10 57 <sup>26</sup> <sub>00</sub> N	78 4 <sup>51</sup> <sub>00</sub> E	Karur	49	50	51
Tiruchirappalli	10 47 <sup>25</sup> <sub>00</sub> N	78 42 <sup>16</sup> <sub>00</sub> E	Tiruchirappalli (Trichy)	52	53	
Ariyalur	11 8 <sup>13</sup> <sub>00</sub> N	79 4 <sup>32</sup> <sub>00</sub> E	Ariyalur	54	55	56
Neyveli	10 58 <sup>0</sup> <sub>00</sub> N	78 32 <sup>50</sup> <sub>00</sub> E	Cuddalore	57	58,59	60
Perambalur	11 13 <sup>59</sup> <sub>00</sub> N	78 52 <sup>59</sup> <sub>00</sub> E	Perambalur	61	62,60	64
Dindigul	10 22 <sup>2</sup> <sub>00</sub> N	77 58 <sup>49</sup> <sub>00</sub> E	Dindigul	65	66	67
Theni	10 0 <sup>37</sup> <sub>00</sub> N	77 28 <sup>36</sup> <sub>00</sub> E	Theni	68	69	
Madurai	9 55 <sup>30</sup> <sub>00</sub> N	78 7 <sup>11</sup> <sub>00</sub> E	Madurai	70,71	72	73
Virudhunagar	9 35 <sup>1</sup> <sub>00</sub> N	77 57 <sup>30</sup> <sub>00</sub> E	Virudhunagar	74	75	76
Paramakudi	9 32 <sup>42</sup> <sub>00</sub> N	78 35 <sup>27</sup> <sub>00</sub> E	Ramanathapuram	77		78
Sivakasi	9 26 <sup>54</sup> <sub>00</sub> N	77 47 <sup>53</sup> <sub>00</sub> E	Virudhunagar	79	80,81	103
Tuticorin	8 45 <sup>50</sup> <sub>00</sub> N	78 8 <sup>5</sup> <sub>00</sub> E	Tuticorin	82	83,84	85
Tirunelveli	8 43 <sup>58</sup> <sub>00</sub> N	77 42 <sup>0</sup> <sub>00</sub> E	Tirunelveli	86	87,88	89
Chidambaram	11 23 <sup>53</sup> <sub>00</sub> N	79 41 <sup>43</sup> <sub>00</sub> E	Cuddalore	90	91	92
Virudhachalam	11 30 <sup>50</sup> <sub>00</sub> N	79 19 <sup>40</sup> <sub>00</sub> E	Cuddalore	93		94
Tiruvallur	10 46 <sup>16</sup> <sub>00</sub> N	79 38 <sup>13</sup> <sub>00</sub> E	Tiruvallur	95		96
Mayiladuthurai	11 6 <sup>6</sup> <sub>00</sub> N	79 39 <sup>7</sup> <sub>00</sub> E	Nagapattinam	97		98
Thiruvottiyur	13 9 <sup>36</sup> <sub>00</sub> N	80 17 <sup>60</sup> <sub>00</sub> E	Thiruvallur	99	100	101
Avadi	13 7 <sup>12</sup> <sub>00</sub> N	80 5 <sup>60</sup> <sub>00</sub> E	Thiruvallur	102		104
Sriperumbudur	12 58 <sup>2</sup> <sub>00</sub> N	79 56 <sup>30</sup> <sub>00</sub> E	Kanchipuram		105,106	
Ambattur	13 5 <sup>60</sup> <sub>00</sub> N	80 9 <sup>36</sup> <sub>00</sub> E	Thiruvallur			107
Ayanavaram	13 6 <sup>1</sup> <sub>00</sub> N	80 13 <sup>45</sup> <sub>00</sub> E	Chennai	108	110	109
Koyambedu	13 4 <sup>0</sup> <sub>00</sub> N	80 11 <sup>0</sup> <sub>00</sub> E	Chennai	111		

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**Table 2.** The observed frequencies with corresponding minerals in all samples and tentative assignment of frequencies.

Sl. No	Minerals	Wave no. $\text{cm}^{-1}$	Total number of samples	Tentative assignment
1.	Quartz	468, 693, 777, 800, 1077, 1090, 1144, 1861, 1872	101, 90, 104, 45, 55, 13, 9, 1, 7	Si–O symmetric bending, Si–O symmetric stretching
2.	Calcite	876, 1422, 1431, 1636, 1786, 1792, 1798, 2516, 2570, 2873, 2982	95, 65, 41, 79, 2, 14, 1, 2, 5, 4, 2	doubly degenerate asymmetric stretching, $\text{CO}_3$ stretching, C = O stretching, combination mode, O–H stretching
3.	Kaolinite	433, 938, 1623, 3623, 3695, 3735	63, 3, 29, 8, 68, 8	Si–O deformation, O–H deformation, O–H stretching
4.	Disordered kaolinite	478	5	Si–O–Si deformation
5.	Pyrophyllite	737	4	O–H out of plane bending
6.	Vermiculite	670, 811	89, 1	Si–O symmetrical bending, O–H out of plane bending
7.	Smectite	52	3	Al–O–Si deformation
8.	Palygorskite	414, 512, 567, 1647, 1681, 3611	18, 2, 7, 20, 2, 1	Si–O deformation, Si–O stretching, O–H deformation
9.	Sepiolite	422, 1657, 3246, 3619	29, 20, 6, 17	O–H stretching
10.	Imogolite	602	50	O–H deformation
11.	Proto Imogolite	680, 854	3, 2	Si–O bending
12.	Hematite	536	110	Fe–O
13.	Asbestos	1033	101	Si–O stretching
14.	Chrysotile	405, 453	11, 4	Si–O stretching
15.	Dolomite	582, 2628	52, 1	C–O stretching
16.	Nacrite	905, 915, 1005, 3648	8, 47, 21, 14	Si–O stretching, Al–Al–OH deformation, O–H stretching
17.	Magnetite	577, 717	4, 56	Fe–O bending
18.	Gibbsite	3300, 3529	2, 14	O–H stretching
19.	Aragonite	1457, 2520	21, 82	C–O bending, O–H stretching
20.	Montmorillonite	3405	106	H–O–H stretching
21.	Organic Carbon	2853, 2921	106, 108	C–H stretching
22.	Feldspar group	635, 645, 1772, 727, 1113, 440, 591, 1019, 3417	5, 47, 9, 34, 29, 9, 4, 6, 1	Al–O coordination, Si–O stretching, O–H bending, O–H stretching, O–H deformation
23.	Goethite	495, 894	4, 1	Fe(III)–O–Si bending, O–H bending
24.	Hectorit	656	2	Si–O stretching
25.	Biotite	3712	28	O–H stretching
26.	Dickite	755	5	Al–O–Si perpendicular
27.	Beidellite	886	3	Al–Fe <sup>3+</sup> –OH deformation
28.	Glauconite	984, 3588	1, 6	Si–O stretching, O–H stretching
29.	Celadonite	1099	13	Si–O stretching
30.	Anorthite	1159	10	Si–O stretching
31.	Baryte	1182	5	Si–O–Si stretching
32.	Cerussit	1385, 1399	50, 3	C–O bending
33.	Ankerite	1448	5	C–H bending
34.	Aliettile	788, 3675	1, 50	O–H stretching

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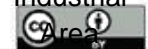


**Fig. 1.** The map showing the Districts covered for the sample collection in Tamilnadu, India

**Table 1.** Latitude and Longitude of sites where the samples collected in Tamilnadu, India

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City/ Town	Latitude	Longitude 22245	District	Vehicular Area	Residential Area	Industrial Area



Kanchipuram

N 12° 50' 3"

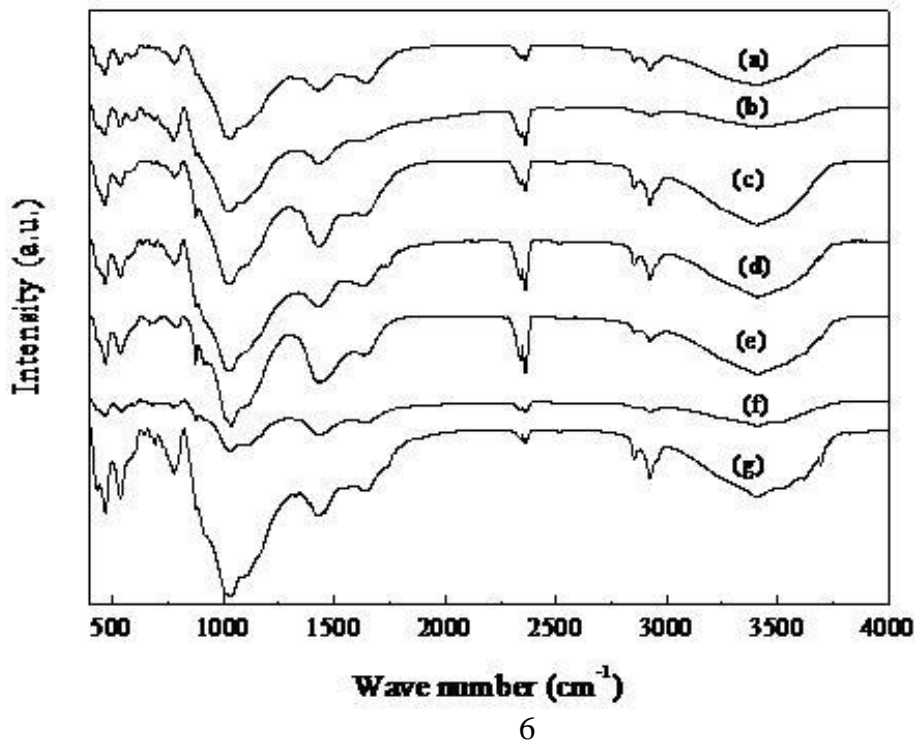
E 79° 42' 13"

Kanchipuram

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**Fig. 2.** The overlapped FTIR spectra of representative samples (a) sample no:1, (b) sample no:21, (c) sample no:41, (d) sample no:61, (e) sample no:81, (f) sample no:101 and (g) sample no:111.

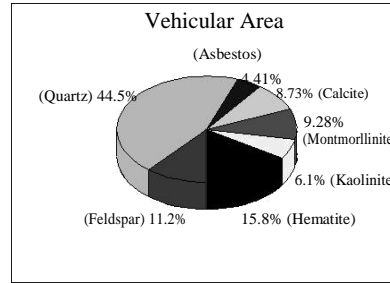
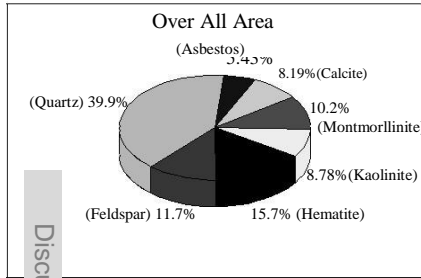
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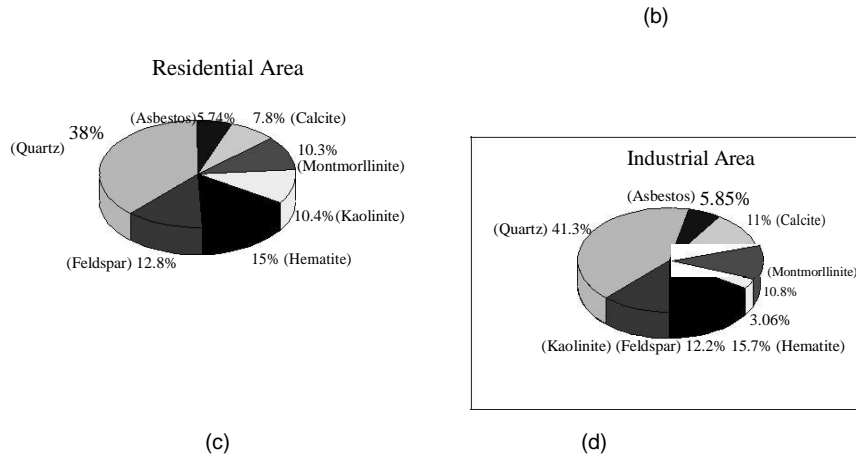
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**Fig. 3.** The distribution of minerals in all sites, (a) Overall Area, (b) Vehicular Area, (c) Residential Area and (d) Industrial Area.

**Fig. 3.** The distribution of minerals in all sites, (a) Overall Area, (b) Vehicular Area, (c) Residential Area and (d) Industrial Area.

### 5 Crystallinity index of Quartz

The crystallinity is defined as the fraction of crystalline materials in a mixture of crystalline and non-crystalline material. It is otherwise called as degree of disorder. When crystallinity is minimum, the minerals are said to be in disordered state and maximum then the minerals are considered to be in ordered state. Crystallinity is inversely proportional to the crystallinity index values.

Crystalline silica is one of the most abundant components in the dust samples both in from the

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