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Potentially toxic element (PTEs) related health risk assessment from air conditioner filter dust in and around Chennai metropolitan

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We report the health risk assessment of air conditioner filter dust collected from different parts of Chennai city, Southern India, using geochemistry and magnetic properties as proxy. The particle size analysis indicates dust particles range from 0.5 μm to 955 μm and the dust grains falling in the range between 30 to 40 μm. The XRD results indicate that the dust samples contain magnetite, hematite, goethite, and trace elements. The hazard index (HI) of trace elements for child and adult determined in our study shows the probable risk for elements as: Cr > Pb > Ni > Cu > Zn. The daily exposure for inhalation [carcinogenic and non-carcinogenic LDD_{inh}] and cancer risk for inhalation (CR_{inh}) were showing high risk and health impact for Cr followed by Ni. It is suggested from the study that higher ventilation rate assisted by means of a mechanical system and use of air conditioners with regular cleaning can improve the living conditions in the Metropolitan areas.

[**Keywords**: AC filter dust, Cancer risk, Health hazard, Magnetic susceptibility, Trace elements]

Introduction

Air pollution is a critical problem and growing concern, which affect human health in many ways. In the present investigation, the air quality parameters pertaining to indoor environment were investigated using dust in air conditioner (AC) filter, collected from a residential building, colleges, commercial shopping complex, household close to high traffic places in Chennai metropolitan, southern part of India. The potentially toxic elements (PTEs) concentration is frequently detected in the urban dust and sediments[1]. The toxic components in the urban dust are primarily from various sources like traffic-related activities[2,3], industrial and urban construction[4,5]. The atmospheric deposition also significantly contributes to the toxic elements from local sources and these pollutants are transported over long distances[6,7]. The toxic elements, especially heavy metal pollutants, present in the dust may cause health issues such as lung cancer, cardiovascular diseases, and increased lead contents in the blood[8]. The dust derived health hazard risk assessment is useful in evaluation of risk due to exposure to toxic elements and these datasets provide important information for residents and policymakers[9]. The environmental health hazard risk assessment in various environmental mediums like water, soil, and the atmosphere was reported by various workers[10]. The environmental health risk response from the biological system, including humans, dosage response studies from organisms, exposure assessment and risk studies were carried out using US environmental health hazards guideline[11] and modelling techniques[12]. The USEPA standards recommend the hazardous risk assessment level through various parameters including concentration level of pollutants, exposure time, type of species, and toxicity of the specific compound etc.[7]. Several works across the globe had studied the AC filter dust particulates and reported its risk factors over human health[13-15] and also reported by Indian researchers[16-18].

Chennai is a major metropolitan city of Tamil Nadu, which is situated on the south-western bank of Bay of Bengal. The investigation region is bounded by the latitude and longitude of 12°50' – 13°20' N and 80°10' – 80°40' E. The ground level of the investigation territory is about 6 m high from mean sea level (MSL). The study area is situated in a hot and subtropical climatic region and gets precipitation from the upper east rainstorm time frame. The major streams are running through the investigation area, specifically the Cooum River in the heart of the

Chennai and the Adyar River in the south-central part. The annual average temperature of Chennai is about 28.6 °C and precipitation is 1200 mm per year. The investigation territory is underlain by different geological units; i) the Archaean crystalline rocks, ii) solidified Gondwana and Tertiary sequence, and iii) the Recent Alluvium. The present study aims to: i) estimate heavy metal content in the urban indoor using dust settled in air conditioner filters; and ii) contemplate on human exposure hazard due to ingestion, inward breath, and dermal contact of the fine particles for kids, youngsters, and adults.

Materials and Methods

Twelve sample locations were chosen randomly from commercial and residential areas of Chennai city to collect the air conditioner (AC) filter dust (Fig. 1). Before sampling, the authors carried out a survey on

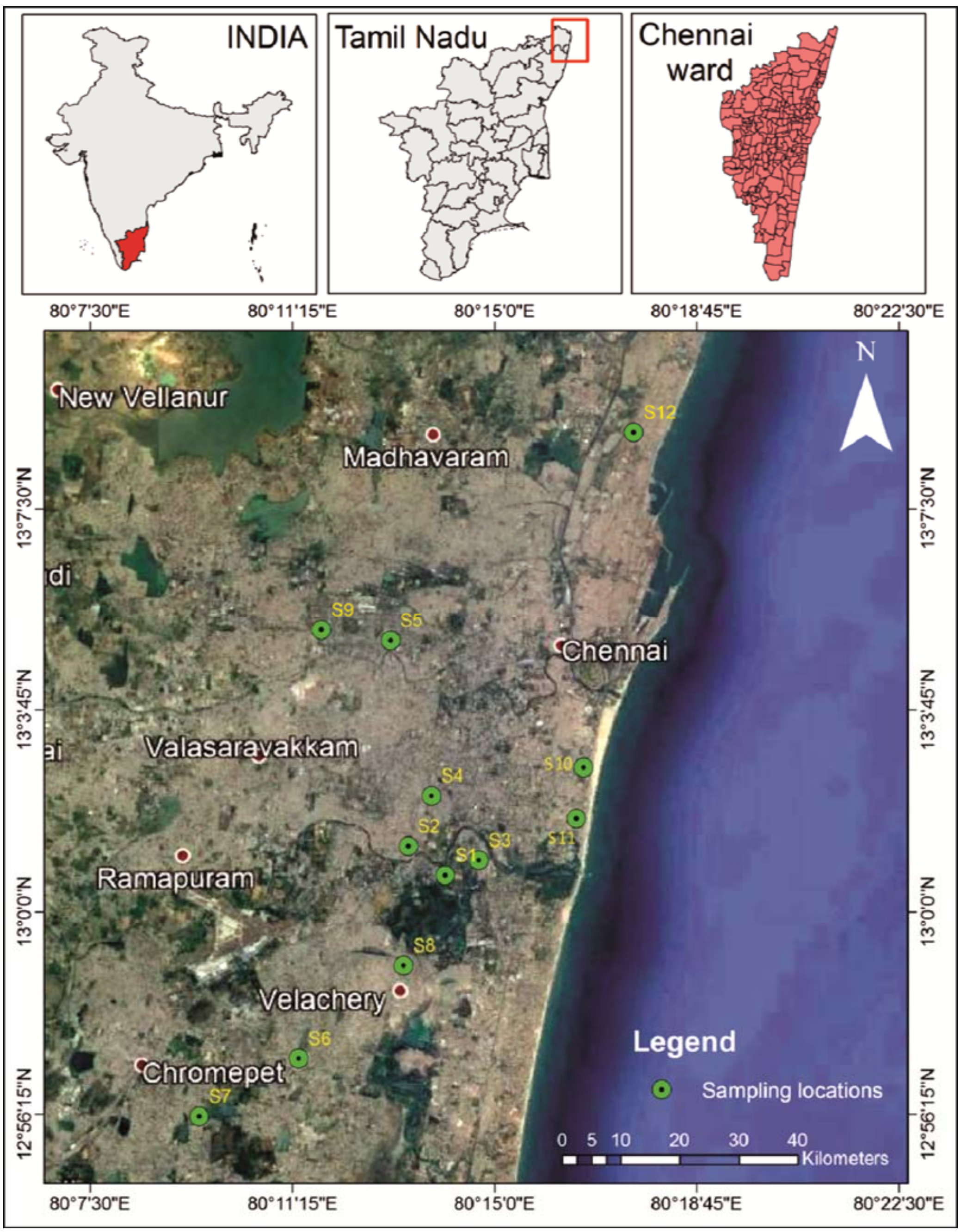

Fig. 1 — Location Map of the study area with sampling sites

indoor condition and AC usage in the study area. The survey involved on the age of buildings, the period of last renovation, aeration and types of air conditioner, maintenance of air conditioners, condition of work environment for staff or businesses, and day to day working hours. After the survey, the samples, i.e. the dust particles accumulated in the filters of the air conditioners were collected. While sampling, enough care has been taken, so that sampling points are widely distributed and covers all type of buildings such as residential buildings, colleges, commercial shopping complexes, buildings located near urban roadways, etc., from Chennai city. Necessary precautions were followed while collecting the samples as suggested by Ali *et al.*[19]. Before the collection of samples, the AC filter was pre-cleaned with 0.2 N HCl solution for avoiding the contamination. The dust sample was collected from residential areas in 30 days interval. The average running time of the air conditioner was 8 to 10 hours. It is maintained such that the measurable quantities are trapped in the sampler at the end of the sampling. The collected dust samples were kept in airtight containers for particle size analysis, XRD, trace element and magnetic susceptibility studies. The mineral characteristics were performed by powder X-ray diffractometer (BRUKER D2 PHASER powder diffractometer). Experiments were conducted with 2θ = 10° to 80° with rate of 2° per min. The sizes of the dust particle were analyzed using Laser Malvern Master sizer 2000. The analytical capability of the instrument ranges between 0.1-2000 µm respectively, with a 0.5 resolution.

The XRD and particle size measurements were done at Anna University, Chennai. The magnetic parameters were measured at CSIR-National Geophysical Research Institute, Hyderabad. The low frequency (0.47 kHz) and high-frequency magnetic susceptibility (4.7 kHz) measurements were performed on the samples (Bartington Susceptibility Meter-Model MS2B). The low frequency magnetic susceptibility (χ_{lf}) and high frequency magnetic susceptibility (χ_{hf}), and frequency dependency of magnetic susceptibility (χ_{fd}), were calculated as recommended by Dearing[20]. Samples were subjected to Isothermal Remanent Magnetization (IRM) at various fields from (20-1000 mT) on Molspin Pulse Magnetizer (MMPM-9, Magnetic Measurements, UK). The dust samples were subjected to acid digestion using the proportion of (HNO_3: HCl: HF – 3:2:1) as proposed by[21] using Atomic Absorption Spectrophotometer (Perkin Elmer Analyst 800). After the analysis, the exposure dose and risk characterization of trace elements were carried out for dust as per Young *et al.*[7].

Results and Discussion

The details of aggregate suspended particulate matter (SPM-in grams), running time of air conditioner per day and no of working days and total SPM are presented in Table 1. The high level of SPM was seen in the areas S1, S6, and S12. The size of particulate matter in the dust samples ranges from 0.5 µm to 955 µm. In the present study, the fine grains are prevalently falling under 30 to 40 µm (Fig. 2). The mineralogical studies on the dust samples were carried out using XRD and the finer fractions are found to be containing the magnetic minerals magnetite, hematite, and goethite (Fig. 3). The results of XRD indicate magnetite is present in these dust

Table 1 — Sampling and SPM summary for air conditioner filter dust from Chennai metropolitan

S. No	Site Name	Total running period (No of days)	Working time (hrs/day)	Total (hrs)	Total SPM (in gms)	Suspended Particulate Matter (SPM - in gms/day)
S1	Anna University	20	8	160	1.4	0.21
S2	Saidapet	30	8	240	0.3	0.03
S3	Kotturpuram	30	14	420	1.9	0.11
S4	T-Nagar	30	13	390	1.4	0.09
S5	Anna nagarRoundtana	30	10	300	3	0.24
S6	Keelakatalai	30	8	240	1.3	0.13
S7	Hasthinapuram	30	10	300	1.9	0.15
S8	Velachery	30	14	420	1	0.06
S9	Thirumangalam	30	14	420	3.6	0.21
S10	Queen Marry's college	30	8	240	2	0.20
S11	Santhome	30	15	450	3.2	0.17
S12	Tiruvottiyur	30	10	525	1.6	0.07

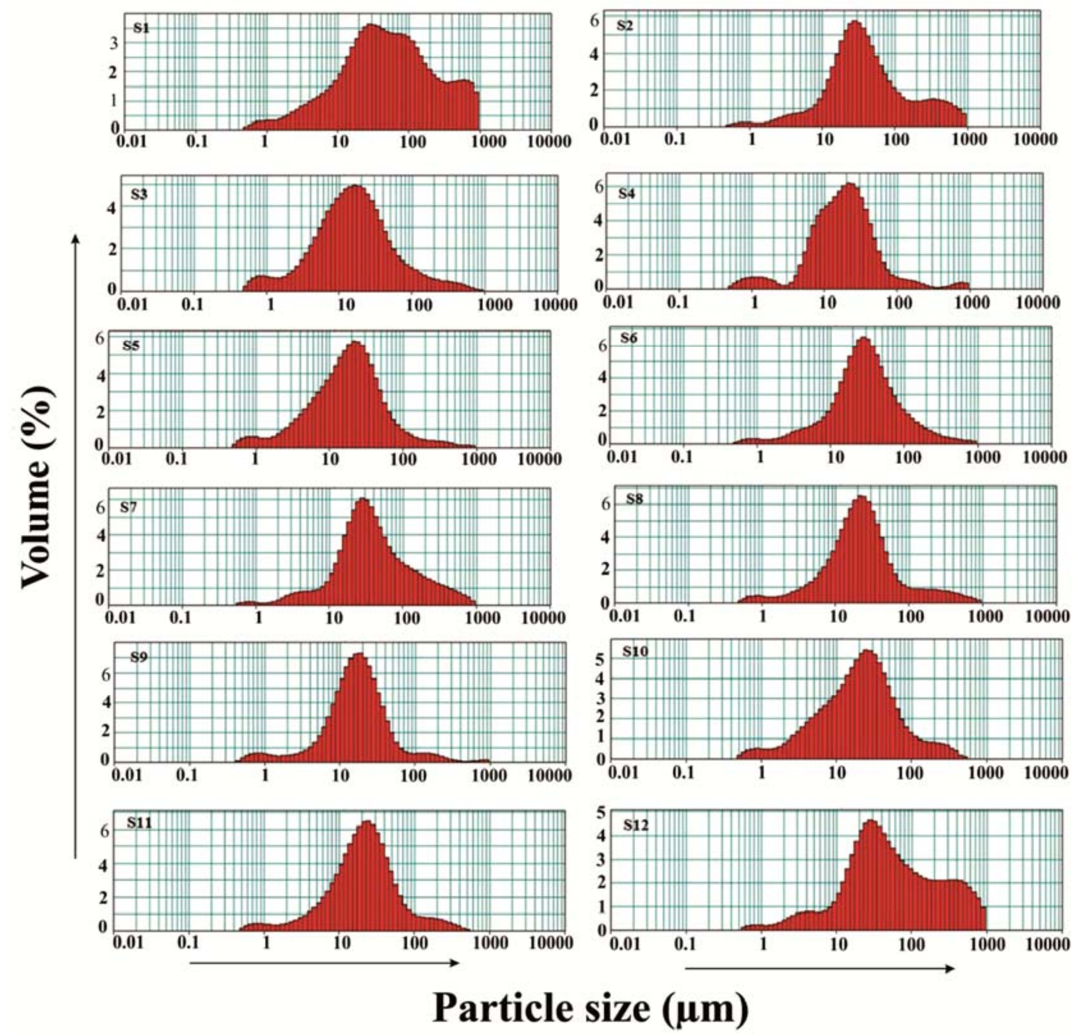

Fig. 2 — Particle size distribution of the dust samples from Chennai metropolitan

samples. Table 2 details the magnetic susceptibility data of filter dust samples. The value of magnetic susceptibility in low frequency ranges between 1.65 and 84.9 SI units with a mean estimate of 31.21 SI units. Similarly, the magnetic susceptibility in high frequency ranges between 1.85 and 78.95 SI units with a mean estimate of 30.07 SI. The maximum values of magnetic susceptibility were noticed in the roadside site and commercial areas (T-Nagar, Velachery). The XRD data shows that magnetic particle distribution in dust materials is primarily in the finer fractions. The sampling locations close to urban road renovation and metro rail constructions show high magnetic susceptibility. The moderate magnetic susceptibility was noticed in the busy road intersections and primary transport terminals. The magnetic susceptibility value and its trend of the filter dust particles primarily depend on the parent material of dust matter, climatic condition, and the level of the trace elements in the aerosol, which is mainly caused by the industrial and vehicular emissions.

Analysis of domain size and magnetic susceptility of dust samples

The magnetic susceptibility parameters for the 12 sampling sites are shown in Fig. 4 and presented in Table 2. Frequency-dependent susceptibility (χ_{fd}) is helpful to find super paramagnetic (SP) mineral fraction[20]. The average frequency dependent susceptibility of the urban dust is 1.75 % (Table 2). It can be observed from Table 2 that dust samples contain less amount of SP grains. Further, less than 2 % of χ_{fd} in a dust sample indicate that the grains are composed of coarse multi-domain (MD) or Pseudo-

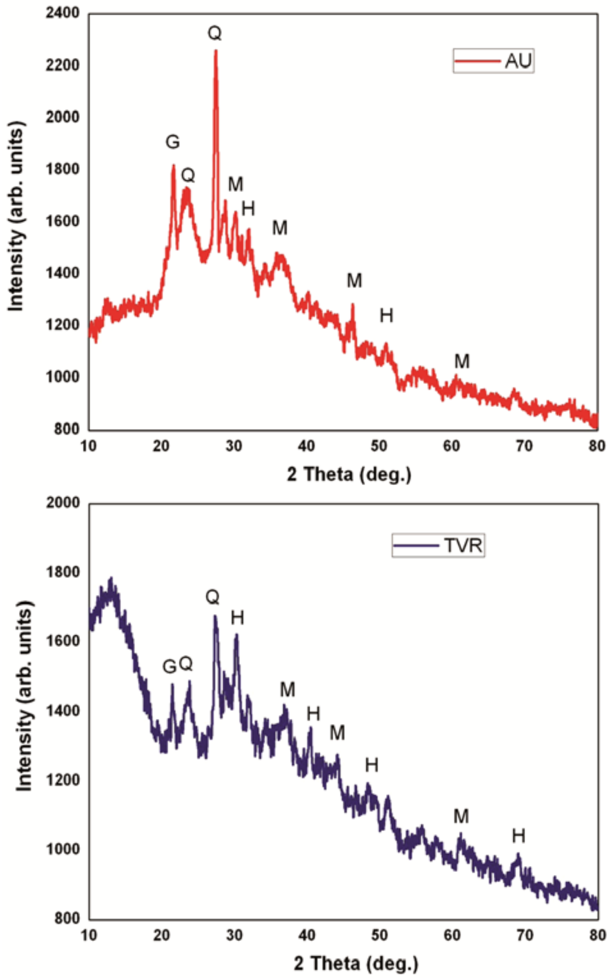

Fig. 3 — The X-ray diffraction pattern shown by air conditioner filter dust samples from following represenatative sampling sites: a) Anna University; and b) Tiruvottiyur (TVR). H-Hematite, Q-Quartz, M-Magnetite, and G-Goethite[38]

single domain (PSD) grains, which are dependent on frequency[22]. The dust samples from S2 and S7 have the least values of χlf, and their mean values are 103×10^{-8} m^3 kg^{-1} and 302×10^{-8} m^3 kg^{-1}, respectively. The high χlf values are shown by dust sample from S9 (mean = 18541×10^{-8} m^3 kg^{-1}), while dust samples from locations S3 and S10 exhibit moderate χlf values (mean = 17946×10^{-8} m^3 kg^{-1}; and 9117×10^{-8} m^3 kg^{-1}, respectively)[22].

In Figure 5, following abbreviations were used to represent the source and magnetic characteristics of the grains: SP-super paramagnetic grain; MD-frequency independent coarse multi-domain; SSD-stable single domain. Figure 5 shows a weak correlation between χlf and χ_{fd} which indicate that the dust grains chiefly derived from human and industrial sources[23,24]. However, the values of χ_{fd} are directly related to higher percentage of SP grains and higher χ_{fd} values are indicator of the pedogenic component in the samples[24,25]. Therefore, the results implicate the presence of SP grains in the sampling sites Kotturpuram (S3), Keelakatalai (S6), Thirumangalam (S9) and Tiruvottiyur (S12) are of pedogenic nature. The sites namely Anna University (S1), T-Nagar (S4), Velachery (S8) and Santhome (S11) comprise of stable single domain grains indicating weathered fraction from hard rocks. The Multidomain grains are present in the sites Saidapet (S2), Anna Nagar (S5), Hasthinapuram (S7) and Queen Mary's college (S10). These results imply that the magnetic minerals especially Magnetite could be of anthropogenic origin[23,25,26]. The possible source of these dusts in the urban topsoil and urban dust materials could be from

Table 2 — Environmental magnetic parameters for air conditioner filter dust samples from Chennai metropolitan

S. No	Magnetic susceptibility (SI)		Mass specific magnetic susceptibility	Frequency dependence of susceptibility	Isothermal Remenant Magnetism saturation field (mT)
	High frequency	Low frequency	$\chi_{lf}\times10^{-8}$m^{3}kg^{-1}	$\chi_{fd\%}$	
S1	22.4	23.1	3672.392	3	900
S2	1.85	1.654	103.375	-12	500
S3	58.4	59.8	17946.146	2	200
S4	22.6	23.5	3876.642	4	200
S5	19.2	19.1	1235.58	-1	150
S6	16.3	17.3	2125.019	6	200
S7	7.75	7.6	302.672	-2	200
S8	19.8	20.3	3999.403	2	200
S9	78.95	84.9	18541.784	7	750
S10	42.85	43.15	9117.246	1	200
S11	47.5	49	7259.825	3	800
S12	23.3	25.2	3688.191	8	1000

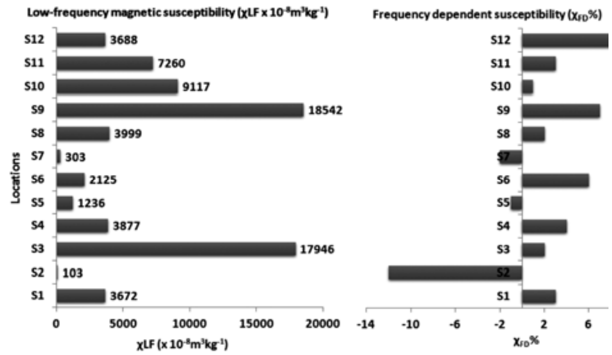

Fig. 4 — Bar diagrams showing the magnetic parameters for dust samples from the twelve locations

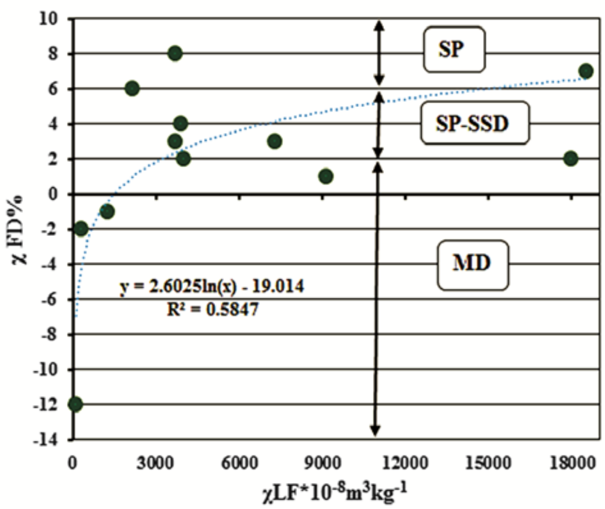

Fig. 5 — Cross plots of frequency-dependent susceptibility (χ_{fd}) and Mass specific magnetic susceptibility (χ_{lf}) for the urban dust particles (SP-Super paramagnetic grain; MD – Frequency independent coarse multi domain; SP-SSD- super paramagnetic stable single domain)

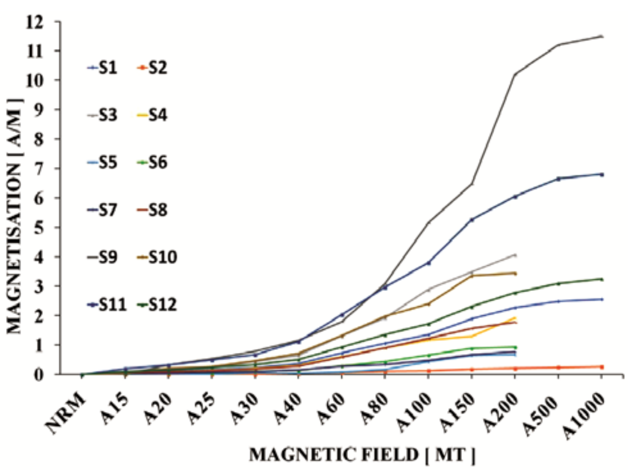

Fig. 6 — Isothermal remanence acquisitions (IRM) curves for air conditioner filter dust samples from Chennai metropolitan

different sources such as vehicular emission, road construction materials, from burning of fossil fuels[22,23], and dust from metallurgical and other industries[23].

Magnetization characteristics of dust samples

The isothermal remanent magnetization (IRM) technique is a straightforward assessment and characterization of ferromagnetic minerals. IRM acquisition curves unmistakably demonstrate that the dust samples are saturating in the inducing field between 200 to 500 mT, while few of them saturate after 750 mT. Saturation of Magnetization at 1T is used as an indicator of magnetic mineralogy[27], for example, saturation of magnetite is <600 mT and hematite is >600 mT. Figure 6 shows that majority of the samples are saturating within 200 mT indicating the presence of magnetite. Few samples show increasing trends in IRM acquisition curves indicating that they comprise of hard magnetic minerals such as hematite and goethite. The IRM values are given in Table 2. Razzaq *et al.*[26] suggested that the vehicle exhaust materials which are the product of the combustion-derived component, contain magnetite. During fuel combustion, impurities containing iron particles present in motor vehicles may be converted to iron oxides especially magnetite and hematite[28]. In general, the magnetic data for dust samples propose the presence of a ferrimagnetic (magnetite) as well as anti-ferromagnetic (hematite and goethite) minerals dominantly in SP/SSD grain sizes[25].

Health risk assessment of dust samples

The concentration of various elements from the study area was examined and classified (Table 3). The mean values of trace elements ranges (ppm) as follows: 24790.2 for Fe, 801.2 for Cr, 100.25 for Pb, 191.17 for Cu, 865.44 for Zn, 410.2 for Mn, 436.3 for Ni, 6.6 for Co. It is possible that the contaminants in the urban environment are from transport and industrial emissions. The assessment of health risk and total exposure of metal composition to human is validated through the study of metal concentration in filter dust[29]. The possible transportation pathways of trace elements in the human body are three types such as (a) direct ingestion of substrate dust particles (ADD_{ing}); (b) inhalation of suspended dust particles through mouth and nose (ADD_{inh}); (c) dermal absorption of heavy metals in particles adhered to exposed skin (ADD_{derm}). In the present work it is attempted to study the cancerous and non-cancerous elements and their exposure to humans through the equations provided by United States Environmental Protection Agency[29]. The affected humans identified for metal exposure risk assessment are infants, toddlers, children, teens, and adults. The non-carcinogenic heavy metal exposure and daily doses from ingestion, inhalation and dermal contact of dust were calculated by following equations. Table 4 details the shortened forms of each parameters[30,31]. Health risk assessment of the daily doses received via the above three exposure pathways were assessed by using the following equations[32,33].

$$ADD_{ing,m} = \frac{C_m \times IngR \times EF \times ED}{BW \times AT_{noncan}} \times 10^{-6} \qquad \ldots (1)$$

Table 3 — Elemental concentrations in the air conditioner filter dust (all the elements in µg/g)

S. No	Fe	Cr	Pb	Cu	Zn	Mn	Ni	Co
S1	40095.24	447.38	373.10	248.57	1505.71	518.10	119.52	1.43
S2	48636.36	439.55	205.00	204.09	1406.82	609.09	298.64	BDL
S3	28447.92	669.17	25.83	168.75	529.79	499.17	453.13	15.42
S4	26413.04	1658.70	47.39	290.87	664.78	613.70	956.96	5.22
S5	35960.00	526.60	71.00	181.00	1085.60	339.40	228.00	9.40
S6	15192.31	991.11	32.69	175.00	358.41	389.18	418.75	0.48
S7	3607.50	97.00	BDL	47.00	306.00	166.25	29.25	BDL
S8	2583.75	BDL	BDL	15.50	43.75	37.00	1.50	BDL
S9	10629.76	112.62	8.81	79.76	280.24	165.48	475.95	2.86
S10	25130.33	856.16	104.03	261.37	879.86	421.80	404.74	0.71
S11	25535.71	779.76	81.43	236.43	1053.81	453.33	559.52	11.67
S12	35250.00	2235.23	53.18	385.68	2270.45	709.77	1289.77	12.05

Table 4 — Exposure factor definitions and their detail abbreviation for every parameters for the urban dust daily dose model

	Meaning	Unit	Child	Adult	Reference
$ADD_{ing,m}$	Daily exposure amount of metals through ingestion	mg/(kg*day)	-	-	-
$ADD_{inh,m}$	Daily exposure amount of metals through inhalation	mg/(kg*day)	-	-	-
$ADD_{derm,m}$	Daily exposure amount of metals through dermal contact	mg/(kg*day)	-	-	-
$LADD_{inh,m}$	Lifetime average daily dose	mg/(kg*day)	-	-	-
C_m	Metal m concentration in urban Dust	mg/kg	Mean	Mean	This study
IngR	Ingestion rate	mg/day	200	100	USEPA (2001)
EF	Exposure frequency Exposure frequency	d/a	233	300	BMRIEP (2009)
ED	Exposure duration	a	6	24	USEPA (2001)
BW	Average body weight	kg	15	60.6	USEPA(2001); MEPC (2013)
AT_{noncan}	Average time for non-carcinogens	day	365 × ED	365 × ED	USEPA (1989)
AT_{can}	Average time for carcinogens	day	70 × 365	70 × 365	USEPA (1989)
InhR	Inhalation rate	m^3/day	5	15.7	BMRIEP (2009); MEPC (2013)
PEF	Particle emission factor	m^3/kg	1.32×109	1.32×109	BMRIEP (2009)
SA	Exposed skin area	cm^2	1600	4350	BMRIEP (2009)
SL	Skin adherence factor	mg/(cm^2 day)	1	1	BMRIEP (2009)
ABS	Dermal absorption factor	–	0.001	0.001	BMRIEP (2009)

BDL – Below Detection Limit

$$ADD_{inh,m} = \frac{C_m \times InhR \times EF \times ED}{PEF \times BW \times AT_{noncan}} \quad \ldots (2)$$

$$ADD_{derm,m} = \frac{C_m \times SA \times SL \times ABS \times EF \times ED}{BW \times AT_{noncan}} \quad \ldots (3)$$

The ascertained wellbeing hazard evaluation of exposure to metal in a child proposes that the immediate ingestion and inward breath were the reason for metals like Zn, Cr, and Ni in their framework[29]. The dermal contact is additionally following a similar trend of metal introduction. With respect to an adult, the metal concentration for the considered metals is increasing in the related trend: Zn > Cr > Ni > Cu > Pb. The hazard index (HI) was recorded for child and adult in the associated pathways: Cr > Pb > Ni > Cu > Zn (Table 5).

The lifetime daily average doses through inhalation and the carcinogenic risk of metals are calculated using the following equation[29,33]:

$$LDD_{inh,m} = \frac{C_m}{PEF \times AT_{can}} \left(\frac{InhR_{child} \times EF_{child} \times ED_{child}}{BW_{child}} + \frac{InhR_{adult} \times EF_{adult} \times ED_{adult}}{BW_{adult}} \right) \quad \ldots (4)$$

The calculated results of $LDD_{inh,\ m}$ and cancer risk for inhalation are tabulated in Table 5. The maximum level of daily dose of metals (Cr and Ni) inhalation value for lifetime is noted. The high health risk posed by carcinogenic risk (CR) was given high priority[34].

The risk of exposure to non-cancerous and cancer-causing trace elements in the air conditioner filter dust were studied using the output data sets of ADD_{ing}, ADD_{inh}, ADD_{derm} and LDD_{inh} based on the following equations[33]:

$$HQ_{p,m} = \frac{ADD_{p,m}}{RfD_{p,m}}; Where\ P = ing, inh, derm; = Zn, Cr, Pb, Ni\ and\ Cu \quad \ldots (5)$$

$$HI_m = \sum_p HQ_{p,m} \quad \ldots (6)$$

$$CR_{inh,m} = LADD_{inh,m} \times SF_{inh,m}; Where\ m = Cr, Ni \quad \ldots (7)$$

Where, m refers to the metal explored in the present investigation (Fe, Mn, Zn, Cr, Pb and Cu) for non-cancer causing and (Cr and Ni) for cancer causing, hazard quotient (HQ) is the hazard indicator for non-cancer-causing metals, p is the exposure pathways, ADD_{ing} is coordinate ingestion, ADD_{inh} is inward breath through the mouth and nose and ADD_{derm} is dermal contact[29,32] (USEPA 1989, 2001). The *ADI* values and Hazard quotient values (HQs) are given in Table 5. The Table 6 shows the calculation of non-cancerous risk for adults and children based on *RfD* values.

Table 5 — Non-carcinogenic risk for every metals and exposure pathways of urban dust

	Pb	Cr	Cu	Zn	Ni
			Child		
ADD_{ing}	7.11E-03	6.25E-02	1.63E-02	7.37E-02	3.71E-02
ADD_{inh}	1.35E-08	1.18E-07	3.08E-08	1.40E-07	7.03E-08
ADD_{derm}	5.69E-05	5.00E-04	1.30E-04	5.89E-04	2.97E-04
HI	2.14E+00	7.09E+01	4.18E-01	2.55E-01	1.91E+00
			Adult		
ADD_{ing}	1.13E-03	9.96E-03	2.59E-03	1.17E-02	5.92E-03
ADD_{inh}	1.35E-08	1.18E-07	3.08E-08	1.40E-07	7.04E-08
ADD_{derm}	4.93E-05	4.33E-04	1.13E-04	5.11E-04	2.57E-04
HI	4.18E-01	4.67E+01	7.42E-02	4.76E-02	3.44E-01

ADD_{ing} - Daily exposure amount of metals through ingestion; ADD_{inh} - Daily exposure amount of metals through inhalation; ADD_{derm} - Daily exposure amount of metals through dermal contact; HI – Hazard Index

Table 6 — Values of RfD (mg/(kg.day)) and SF $(mg/(kg.day))^{-1}$ for metals

	Cr	Cu	Ni	Pb	Zn
RfD_{ing}	3.00E-03	4.00E-02	2.00E-02	3.50E-03	3.00E-01
RfD_{inh}	2.86E-05	4.02E-02	2.06E-02	3.52E-03	3.00E-01
RfD_{dermal}	6.00E-05	1.20E-02	5.40E-03	5.25E-04	6.00E-02
SF	42		0.84		

RfD_{ing}- Reference dose ingestion; RfD_{inh} – Reference dose inhalation; RfD_{dermal} – Reference dose dermal contact; SF – Cancer Slope Factor

Table 7 — Carcinogenic risk of studied metals

	$LADD_{inh}$ (mg/(kg.day))	CR_{inh}
Cr	5.07689E-08	2.13229E-06
Ni	3.01605E-08	2.53348E-08

$LADD_{inh}$ – Lifetime average daily dose Inhalation; CR_{inh} – Cancer Risk Inhalation

The present study indicates that HI of all heavy metals in filter dust is of high values and suggests potential risks (Table 5). The reference measurement was ascertained utilizing United States Department of Energy's RAIS aggregation[30,31,35] (Table 6).

If *HQ* and *HI* values are less than 1, there is no direct risk to population. But there may be concern for potential non carcinogenic effects when these values exceed one as suggested by USEPA2001[29]. When both adults and children are concerned, among pathways of exposure, dermal pathway contributes the greatest non-carcinogenic risk followed by the ingestion pathway, while inhalation is the least contributor to the risk. The carcinogenic risk was calculated based on Ni and Cr. $CR_{inh, m}$ is representing the carcinogenic risk of metals Cr and Ni in the air conditioner filter dust which is inhaled. $SF_{inh, m}$ is the cancer slope factor through inhalation for Cr and Ni.

The US Environmental Protection Agency considers a cancer risk between the range $1*10^{-6}$ to $1*10^{-4}$ [USEPA 2004] acceptable for regulatory purposes. As per Ferreira & De Miguel[36] and U.S. Environmental Protection Agency[37], in the present study the carcinogenic risk falls close to the threshold value ($CR_{inh, m}$) indicating the possibility of cancer due to the risk from urban dust. The LDD_{inh} and CR_{inh} was higher for Cr followed by Ni (Table 7.). The chromium toxicity and their valency states (Cr^{+3} to Cr^{+4}) were changed depending on pH condition, available organic matter, Fe-Mn oxides and indigenous microorganisms[7]. On the basis of the non-carcinogenic and cancer risk assessment calculation, it can be suggested that Cr is showing high risk and health impact in the present study locations. HQ ingestion for filter dust showed about 65 % of total risk. Our study suggests that among the three pathways of trace elements, ingestion pathway poses major risk for human health.

Conclusion

The present study on potentially toxic elements and magnetic properties of air conditioners filter dust collected from twelve locations in and around Chennai city has demonstrated the magnetic mineral concentration, the magnetic susceptibility nature of the dust grains and developed a health risk assessment model. The XRD results indicated ferrimagnetic constituent in the mineralogical composition of filter dust and dominated by magnetite (most abundant), hematite and goethite. The magnetic susceptibility data suggest that the filter dust comprising of SP, SSD and MD sized magnetic grains. Therefore, these results imply that indoor air of these sampling sites contain both natural soil dust and anthropogenic derived heavies such as magnetite and trace metals which are definitely posing a health hazard and affect SPM level and human health. An evaluation of health risk on the trace element data of the filter dust from the study area exhibits that while Cr poses the highest cancer causing and carcinogenic risks in humans, Pb poses the next higher threat. While *HQ* and *HI* values lesser than 1 are not harmful, the values exceeding one are posing potential non-carcinogenic hazard, as suggested by USEPA 2001. The present study result indicates the values are more than one. The adult and child metal exposure dose shows that all the studied metals are posing health threat in the pattern as Zn > Cr > Ni > Cu > Pb, while the order for hazard index (HI) for child and adult is: Cr > Pb > Ni > Cu > Zn. The day to day exposure to inward breath and carcinogenic risk inhalation (LDD_{inh} and CR_{inh}) was showing high risk and health impact for Cr followed by Ni. The present study revealed an important direct connection between the potential risk and human health effects of trace elements in air conditioner filter dust. This study has brought out a hazard index which can directly affect the general health of people of the Chennai city. The magnetic approach has complimented the trace element results and brought out the significance of maintaining indoor air quality in urbanized and industrialized parts of Chennai city. Therefore, it is recommended that higher ventilation rate assisted by means of a mechanical system and use of air conditioners with regular cleaning can improve the living conditions in the Metropolitan areas like Chennai.

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Conflict of Interest

The authors declare that they have no known competing financial interests or personal relationships that could have appeared to influence the work reported in this paper.

Author Contributions

The present work was carried out in association of all the authors. KMB carried out sampling, analysis and prepared the draft of this manuscript. CLN supervised the work, and edited the manuscript. The co-authors SSV and MV critically evaluated the manuscript and KA provided technical support during the course of this work.

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