# Size Characterisation of Indoor Respirable Dust In Localities of North Delhi Region

A PROJECT REPORT

SUBMITTED IN PARTIAL FULFILMENT OF THE REQUIREMENTS

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MASTER OF TECHNOLOGY

IN

**ENVIRONMENTAL ENGINEERING**

Submitted by:


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JULY, 2020

# CERTIFICATE

I hereby certify that the Project Report titled "Size Characterisation Of Indoor Respirable Dust In Localities Of North Delhi Region" which is submitted by Surendra Singh Negi, Roll No. 2K18/ENE/11, Department of Environmental Engineering, Delhi Technological University, Delhi in partial fulfillment of the requirement for the award of the degree of Master of Technology, is a record of the project work carried out by the students under my supervision. To the best of my knowledge this work has not been submitted in part or full for any Degree or Diploma to this University orelsewhere.

29.7.20

**Dr. ANIL K. HARITASH**

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# CANDIDATE'S DECLARATION

I, Surendra Singh Negi, Roll No. 2K18/ENE/11 student of M.Tech Environmental Engineering, hereby declare that the Project Report titled "Size Characterisation Of Indoor Respirable Dust In Localities Of North Delhi Region" which is submitted by me to the Department of Environmental Engineering, Delhi Technological University, Delhi in partial fulfillment of the requirement for the award of the degree of Master of Technology, is original and not copied from any source without proper citation. This work has not previously formed the basis for the award of any Degree, Diploma Associateship, Fellowship or other similar title or recognition.

**(SURENDRA SINGH NEGI)**

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# ABSTRACT

Rapid growth in urbanization, industrialization was proven to be the major source of particulate emission which can cause serious health issues. As an individual spend most of their time in the indoor. This study was conducted to investigate the indoor air quality for presence of suspended particulate matter (SPM) in the localities of Rohini, Delhi. This region of Delhi is densely populated and having large number of mini and micro level of industries, high traffic density roads, residential areas, agricultural area, School and hospitals. Rohini, The region was divided in different areas according to the dominant activities like Industrial area, Agricultural area, Institutional area, Residential area, Sensitive area. Dust samples were collected from different areas for the analysis of the particle size present in the indoor environment. Particle size analysis showed the occurrences particle size range between 72±6nm-904±78nm, 77±6nm-904±82nm, 68±7nm-902±97nm, 28±5nm-904±78nm, 15.2±0nm-903.1±96.90nm in Residential area, Institutional area, Sensitive area, Industrial area, and Agricultural area respectively. Observed result also showed the Average presence of ultrafine particle was in order Institutional > Residential > Agricultural > Sensitive > Industrial. Weighted average of particle size showed the dominance of fine particles with the range between 483-902nm, 259-757nm, 665-902nm, 471-707nm and 296-903nm in residential, institutional, sensitive, industrial and agricultural area respectively. From the Average of weighted particle size it was found that major occurrence of particles of size 666nm, 596nm, 745nm, 615nm and 618nm in residential, institutional, sensitive, industrial and agriculture area respectively. It was concluded that the surrounding activities like Construct and Demolition, Traffic, indoor activities and Swabbing associated near the study areas could be the possible reasons for the occurrences of fine and ultrafine particles.

*Keywords:* SPM, Dust, Industrial, Residential, Institutional, Sensitive, Agricultural.

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# List of Abbreviations and Symbols

| | |
|---|---|
| **PM :** | Particulate Matter |
| **WHO :** | World Health Organization |
| **CPCB :** | Central Pollution Control Board |
| **SMPS :** | Scanning Mobility Particle Sizer |
| **AAS :** | Atomic absorption spectroscopy |
| **SPM :** | Suspended Particulate Matter |
| **UFP :** | Ultrafine Particles |
| **DMPS :** | Differential Mobility Particle Sizer System |
| **CPC :** | Condensation Particle Counter |
| **PND :** | Particle Count Number |
| **NAAS :** | National Ambient Air Quality Standards |
| **APS :** | Aerodynamic Particle Sizer |

# CHAPTER 1 INTRODUCTION

As individuals spend most of their time in the indoor environment, about 80%, so it attracts the attention of the researchers to uncover the quality of indoor air (Samet et al., 1991). The indoor air concentrations of particulate matter are six times higher than the outdoor (Klepeis et al., 2001). The indoor air contaminants may be derived from various sources like different indoor processes (e.g., smoking, cleaning, and cooking) (Massey et al., 2009). Building systems like ventilation and air conditioning also have a direct influence on the indoor air quality (Challoner et al., 2014). In urban areas traffic also plays significant role in influencing the indoor air quality by the process of combustion of fuel and the re-suspension of settled road dust (Osterlee et al., 1996). There are several studies which showed the effect of long time exposure to fine particles less then 2.5μm on the respiratory system (Abbey et al., 1995). Indoor processes like cooking, smoking, cleaning; movement of people generally affects the concentration of $PM_{2.5}$. The standards proposed by U.S Environmental Protection Agency for indoor pollutants have stimulated research on environmental diseases such as asthma, rhinitis, by exposure to humans and subsequently on children. In the similar environment, the health impact of air pollutant is higher in children as compare to the adults. Children and infants are more susceptible to the pollutants because of their fast growth and cell disintegration, growth of vital organ system (Moshammer et al., 2006).

In the developing country like India, significant increase in particulate matter pollution together with the significant increase in the human exposure is the major issue of concern. Around 3 billion peoples still have dependency on the solid flues for cooking their food and for other domestic purpose, which can increase the permissible level of fine particles in the indoor environment (Gautam et al., 2019). Around 3 million death/year and 3-4 million/year had been linked with the exposure to indoor and outdoor air pollution respectively (WHO, 2016). The study of indoor air quality emerged in late 1970s which showed the various cause and effects of indoor air pollution. As compared to the rural areas the pollution level is more in the urban areas along with other toxic pollutants generated by the combustion of fuel, burning of waste. The increased level of pollution in the environment not only affects the outdoor environment but also the indoor environment and it is of major concern because peoples spend about 80% of the time in the indoor environment. Various sources are responsible for the indoor air pollutants. They are emitted from various indoor processes (e.g. cooking, cleaning), emission materials, combustion of fuel, some pollutant enter from outside along with the water, air, soil. The concentration of pollutants in the indoor air environment depends on the relationship between volume of air in the space, emission rate of the pollutant, removal rate of pollutant, indoor and outdoor air exchange rate, and pollution concentration outside (Maroni et al., 1995).

The particulate matter outside are much influenced by the road traffic, construction, demolition, swabbing etc. In urban cities these activities are more pre dominant as compare to the rural areas hence, have more contribution in air pollution. Particulate matter emission from vehicle includes emission due to the combustion of fuel (exhaust emission) emissions due to wear and tear of vehicle parts such as brake, tyre and clutch and re-suspension of dust (non-exhaust emission). The non-exhaust emission has major contribution in coarse PM($PM_{2.5-10}$) while exhaust emission has major contribution in fine particulate matter($PM< 2.5$)(Abu-Allaban et al., 2003, Tervahattu et al., 2006). Different studies and policies has largely focused on the exhaust emission, strict regulations and upgraded technology resulted in the reduced contribution in total particulate matter by the exhaust emission (Thorpe et al., 2008, Dahl et al., 2006). Even after the minimum contribution from the exhaust emission, non-exhaust emission still has contribution to fine and ultrafine particles. The suspension and re-suspension of previously deposited material on the road surface are influenced by the vehicle-induced turbulence, tyre shear and due to the turbulence action of the wind, the type of road material used. These particles finally find their way to enter into the indoor air environment.

Entry of other contaminants like heavy metals and persistent pesticides in the indoor environment has been an additional concern (Leidy et al., 1993). In urban areas top soil and dust are the indicator of the heavy metal contamination from atmospheric deposition. Heavy metals like Cd, Cu, Zn etc predominantly found in the area close to the road due the traffic. Solomon and Hartford found the increased level of lead and cadmium in the indoor environment, sometime even higher than the outside. To control variety of pests in and around human habitations pesticides are used or sometime place these toxicants in the close proximity to humans. It has been demonstrated that the residues of the applied pesticides may enter into the indoor environment from the point of application by the action of some physical transporting agents, human activities.

Advancement in building design, especially in urban areas, are done to make the building more energy efficient as a result modern homes and offices are frequently more airtight than older structures as well as reduced the volume of the space. The use of other synthetic building materials like paints, varnishes. As the advancement have led to more comfortable building at lower running cost, at the same time it provide the indoor environment in which contaminants are readily produced and may buildup in a higher concentration than are found in outside.

Delhi, the capital of India is the densely populated having the population density of about 11,312/km$^2$. Data collected from Central Pollution Control Board showed the issue of high concentration of particulate in Delhi. Increase in air pollution with respect to particulate matter becoming a subject of public health concern. CPCB provides the data of air pollution in the atmosphere from various regions in the Delhi. So study has been found related to the toxicity assessment of indoor air in the North region of Delhi. This north region of Delhi is associated with the activities like industrial, agricultural, high traffic conditions etc which could have contribution in air pollution. Many sensitive areas (school, hospital etc) and residential areas are also present in these regions which are being affected by the surrounding activities. Hence the following study has been conducted with the following objectives.

- Impact of surrounding activities like Traffic, Construction etc in indoor air quality.
- To assess the concentration of particle associated heavy metals in indoor air.
- To suggest some suitable measures to improve the indoor air quality.

# CHAPTER 2 REVIEW OF LITERATURE

Regular supply of food and water is required by the human being along with the continuous supply of air. The quantity of air and water are relatively constant (10-20 $m^3$ and 1-2 l/d respectively). The air and water with of acceptable is essential for long and healthy survival. Recent study showed that about 92% of world's population (urban and rural) lives in a place having the air pollutants higher then acceptable limit recommended by WHO. Inevitably we inhale the surrounding air along with that many air pollutants present in the air. These pollutants come in contact with our cell and affect the human health. Researchers have developed various methods and studies to find out various sources of air pollution. They have also provided the mitigations measures to control the air pollution outside. Later studies showed that People spend most of their time (about 80%) within indoor environment (Samet et al., 1991). So it gains the attentions of researchers towards the indoor air quality in late 1970s. Several toxic compounds may present in the indoor environment like $CO_2$, CO, PAHs and heavy metals which may originates from various sources such as cleaning, heating, pollutants infiltrates from outside, traffic etc. Increased level of pollutants, higher then acceptable limit, may create many sever effects, especially children are more susceptible to the pollutants since they inhale higher volume of air then adults.

Most of the developed and developing countries suffer from the problem of air pollution. Increase in the population and their associated activities have influenced the air pollution in the environment. The presence of harmful compounds was already there in the environment which didn't caused much health effects because they were present in lesser concentration but many anthropogenic activities in the last few decades, triggered the level of pollution in the environment which affects the human health. Growing population, increase in number of vehicles and industries, violation of emission standards are some common reasons for the air pollution.

Among all pollutants, particulate matter has obtained more attention. The size of these particles in the atmosphere covers a wide range from few nanometers to the tens of micrometers. The particles of size greater than 2.5 µm but less then 10µm are termed as coarse fraction, generally formed by the disintegration of the larger solid particles. Dust from the agricultural processes, mining process, unpaved road etc due to action of wind, can be include in this category. The particles of size between 2.5µm-0.1µm are considered as the fine fraction. These particles are generally formed from the gases. The particles of size less then 0.1μm are considered as the ultrafine particles which formed by the nucleation i.e. condensation of low vapour pressure substances. Smaller particles are of more concern then the coarser because the larger the particle size more easily it will settle. The smaller size particles will remain in suspension in the environment and can enter into the human body. Due to the higher specific area of small particulate they have high tendency to accumulate the toxic elements over its surface. These particles along with the toxic elements have high probability to deposit in the respiratory tract.

The presence of these particulate matters is obvious in the outdoor environment due to the natural process but various studies showed that the indoor activities like cooking, smoking, etc also influence the concentration of particulate matter. The concentration of particulate matter in the indoor environment is about six times higher than the outside level (Klepeis et al., 2001). Coarser particulate matter have high tendency to settle in the outdoor environment either by its physical property or due to the vegetation barrier. But the finer fractions of the particulate matter find its way to enter into the indoor environment. These particulate matters are considered as the indirect source of exposure of heavy metal to human being. Presence of heavy metal at trace level presents in air, water, and soil play an important role in human life. The contribution of street dust has major part in the pollution in the urban areas. The street dust consists of vehicular emission, industrial emission, pollutants transported by wind and water. These factors are known to influence the level of pollutants in the dust. The region near the vicinity of the roads were found to have higher level of heavy such as Cu and Sb etc (Thorpe et al., 2008). The exhaust emission and the non exhaust emission, both have the contribution in influencing the particulate matter level in the urban areas. Modern technologies and regulations have proven to be effective in reducing the exhaust emission from the vehicle, but the non-exhaust emission still contributes to the fine and ultrafine particles (Thorpe et al., 2008, Dahl et al., 2006).

Generally due to the lack of availability of land in the urban areas population density is high, due to which structures in different locations like residential, sensitive, institutional etc are so congested so that the chances of affecting the surrounding life will be more with lesser area. The surrounding activities like construction, traffic, swabbing etc plays significant role in influencing the particulate matter in the environment. These particulate matters infiltrate into the indoor environment where some amount of particulate matter is already present, produced by cigarette smoking, combustion of fuel etc and finally affect the occupant's health. Overall concentration of indoor particles may depends upon the various factors like volume of the space, emission rate of pollutant, mixing pattern, ventilation rate, source location. With the advancement in the construction technique, individual prefers the airtight room to make the structure more energy efficient and to minimize the operational cost. Along with this the use of synthetic materials and furnishings may consider as source of indoor air pollutants. As a result, the pollutants which infiltrate into the room and those formed in room have high tendency to stay in the indoor environment and finally enter into the human body through respiration. There have been number of studies have been done in order to assess the indoor air quality.

Ismo K et al., (2000), the attempt was made to investigate the effect the outdoor air pollution on the indoor environment. The study was conducted during the winter season in an office building near Helsinki downtown, Finland. The site was located near the densely populated city having lots of office buildings and residential buildings. The site was having railroad tracks and several roads with high traffic near its vicinity. The study was conducted by two similar differential mobility particle sizer system (DMPS) placed simultaneously at two places; one at the roof top in front of the ventilation system (reflecting the outdoor concentration) and the second was placed in the office room. Ventilation system had mechanical supply and exhaust system. Continuous monitoring of ventilation rate was also done. Observed results showed the high dependency of outdoor concentration on indoor particle concentration which vary from 500 to $10^4$ $cm^{-3}$. The measured range of size varies from 7nm-500nm. Result also showed the strong influence of ventilation on indoor particle and gas concentration. The concentration of gases showed varying range from 0.5-8ppb for $So_2$, 38ppb for NO, and 70ppb for $NO_x$. The higher values were detected during the day time when the ventilation was on. The Analysis for Indoor to outdoor ratio as a function of ventilation rate and size it showed for the particle between 0.08-0.15µm seems not to be the function of ventilation rate and for the particle size larger then 90nm the ratio seems to increase with the higher value of ventilation rate.

Finn Palmgren et al. (2003), the study was done to find out the characteristics of the particles emitted from the vehicles and their contribution in the indoor and outdoor environment. The study was conducted on the four lane road in central Copenhagen, Jagtvej. The study was performed during the rush hours having traffic density approximately 26,000 vehicles along with the 6-8% of heavy vehicles. The measurements of fine and ultrafine particles were done with the help of scanning mobility particle sizer (SMPS). Quantification was done by using receptor modeling. Result showed that the particle size distribution from traffic emission showed a max at 20-30nm and non-traffic at approx 100nm. Diesel vehicles in the street were majorly responsible for the generation of ultrafine particles. The study also showed that the deposition rate of particle size between 100-500nm were negligible in the apartments. But for the particle size below 100nm diameter the deposition rate increases as the diameter decreases. It was observed that the penetration efficiency of particle size 100nm was about 60%.

T.L. Thatcher and D.W Layton (1994), in their study they investigated the deposition, re-suspension, and penetration of particles within a residence. The study was conducted two –story house in residential area in Livermore, CA. The house was occupied by the five occupants. The indoor activities like smoking, cooking, playing etc were considered during this period. The study was done for the duration of three months under two conditions, when the occupants were in the house and when they were not in the house. Their study concluded that for the particle size between 1-5um was observed to have deposition velocity matched with the settling velocity and for the particle size greater than the 10um has deposition velocity lesser then the calculated velocity. The penetration factor for the supermicron particle was measured by using the relation of deposition velocity and indoor/outdoor ratio and by restricting the condition of no re-suspension or generation activity. Also concluded that the re-suspension also have significant impact on the indoor particle concentration. It was found that, the concentration of super micron particles can increased up to 100% by just walking into the room. And the supermicron particles don't have any effect of either cleaning or walking (Lefcoe and Inculet 1975).

Yifang Zhu et al. 2004, the attempt were made to assess the penetration of ultrafine particle in the indoor environment. The study was conducted apartments which were near the Freeway in Los Angeles, CA. The study conducted by using scanning mobility particle sizer (SMPS) during the day and night time for different study period. Air Exchange Rate (AER) were measured for different sets of condition a) windows closed with fan off, b) windows open with fan on, c) window open and fan off. The study concluded that the penetration of ultrafine particle into the indoor environment under different ventilation conditions was a function of particle size and the ventilation conditions. The higher value of I/O ratio (0.6-`09) was observed for the ultrafine particles of size range between 70-100nm and the lowest value of I/O ratio (0.1-0.4) was observed for the particle size range between10-20nm.

Hyeon-Ju Oh et al. (2014), The concentration of particulate matter along with the concentration and distribution of microbial size of airborne bacteria and fungi in bio-aerosols which were present within the indoor air in childcare centers in korea. Indoor particulate matter samples were collected from ten childcare centers which were present near residential areas and near the heavy traffic areas. The average concentration of finer particulate matter (<PM2.5) in residential area was found to be 37-45 µg/$m^3$ and in near heavy traffic condition it was found to be 48-53µg/$m^3$.

V .S. Chithra et al. (2012) the study was conducted to investigate the indoor air quality of school building having natural ventilation. The study was performed in a school building which was located near the heavy traffic road in Chennai, India. The study was conducted for the duration of 60 days (34 days during winter and 26 days during summer). The result showed the concentration of $PM_{10}$, $PM_{2.5,}$ $PM_1$ was 149, 61, 43 µg/$m^3$ respectively during the winter and during summer it was 95, 32, 9 µg/$m^3$ respectively. Study also found that level were also exceeds the National Ambient Air Quality Standards (NAAS). Study also concluded that the higher value of I/O for $PM_{10}$ indicate the significant contribution from the activities within the classroom. The lower value of I/O for fine PM showed the penetration of fine particles originating from the adjacent road.

Dario Camuffo et al. (1999), In their investigation on indoor air quality in the public place. The study was performed at the Correr Museum, venice, Italy. The study was conducted to monitor the indoor microclimate, air pollution, deposition and origin of suspended particulate matter. The study was done in two phase one in summer and one in winter. The study concluded the effect of seasonal variation of indoor air quality. It was observed that the indoor/outdoor ratio of pollutant was more in summer then winter, as the use of door and windows are frequently used for better ventilation during the summer season.

Lidia Morawska et al. (2001), the study was attempt to find the relationship between the indoor and outdoor air quality in the residential environment. The study was conducted in residential area of Tingalpa, Brisbane. The site was located 10km away from the city centre and has mix conditions like old and new houses in terms of designs. Total 16 numbers of sites were selected for the study. Submicron particles number concentration and size distribution in range 15nm-685nm were measured with the help of scanning mobility particle sizer and the larger size particles were measured with the help of Aerodynamic Particle Sizer (APS). Result showed that the value of I/O ratio varies from 0.44-2.46 for the submicron particles with the overall average value of 1.07±0.44. It was found that in normal ventilation condition and no indoor source, the indoor air concentration of submicron particles was approximately similar to that found in outdoor. For supermicron particles the I/O ratio varies from 0.47-1.96 with the overall average value of 1±0.3. It was observed that under normal condition of ventilation and no indoor source, the indoor supermicron particle concentration follow the approximately similar value which was found outside. The study concluded that 85-95% of submicron particles present in the indoor and outdoor environment were of ultrafine range i.e. smaller then 100nm.

Naoki Kagi et al. (2006) in this study attempts were made to assess the indoor air quality in relation with the use of printer. The study was conducted to monitor the generation of VOCs, ozone and ultrafine particles by the use of laser printer/ink-jet printers. The study was performed in the office room with the printer placed at the centre of the room and using it intermittently for certain duration. Three sampling points were defined, above the printer, near the exhaust opening and 150cm away from the printer. The result showed that the while using the printer there was an increase in the concentration of ozone from 1.5 to 6ppb. It was also observed that during the use of printer the concentration of ultrafine particle of range lesser then 50nm showed higher value.

D. Wake and D. Mark (2002) the study was conducted to find out presence of ultrafine aerosols in the workplace. The study was conducted in the industrial area in UK. The industries consider in this study was mostly which majorly has heat treatment wok in it e.g. Galvanizing, metal and plastic welding, soldering etc. The measurement of particle number concentration and size distribution was carried out with the help of scanning mobility particle sizer and portable condensation particle counters. It was observed that the industries involving heat processes were found to produce the high level of ultrafine particle as compared to the outside environment. It was also observed that the ultrafine particles present in the study area were in the particle size range between 16.5-805nm.

Farhad Azarmi et al. (2014), the study was conducted to find the exposure of particles emitted from the construction and demolition activities. The study was performed under the experimental set up for the activities like concrete mixing, drilling and cutting. The study was performed to find out the emission of $PM_{10}$ $PM_{2.5}$ $PM_1$ and ultrafine particles during the activity. The measurement of particle number concentration and size distribution was done with the help of scanning mobility particle sizer and using GRIMM. The observations were taken under three conditions i.e. pre activity, during activity and post activity. The observed result showed that during the mixing of concrete the higher value of particle distribution number (PDN) as compared to the background concentration which varies from $2.31\times10^4$ – $3.80\times10^4$ $cm^{-3}$ which was approximately 3-12 higher than the peak background concentration. During cutting and drilling of hardened concrete the PND value was also very high i.e.$37.10\times10^4$ and $118.80\times10^4$ $cm^{-3}$ respectively. These values were approximately 3-8 times higher than the peak background value. The PND for demolition and dry recycling of concrete were found to have 2-6 times higher value then the cutting and drilling (Kumar et al., 2012). It was also observed that the particle number concentration and size distribution for different activity were different. For concrete mixing, drilling and cutting the size distribution was observed in the range of 5-100, 100-300 and 300-560nm respectively. And particle number concentration was in the $30.97\times10^3$, $279.11\times10^3$ and $732.7\times10^3$ for mixing, drilling and cutting respectively. Overall study showed that the construction and demolition activities have the potential to produce ultrafine particles higher than the concentration present in the normal conditions.

Ling Qiu et al., (2018) the study was conducted to fine the relation of the different vegetation structure with the particulate matter concentration. The study performed in the Baoji city, China. The city was surrounded by the mountains. Total 11 urban green spaces with different vegetation structures (horizontal structure, vertical structure and vegetation type) were considered along with the continuous monitoring of meteorological factors. Result showed that meteorological conditions have significant impact on particulate matter concentration. The concentration of $PM_{2.5}$ and $PM_{10}$ was found to have positive result with the wind velocity and humidity but had negative relation with the temperature. It was also observed that the any kind of vegetation structure don't have any significant impact on the $PM_{2.5}$ concentration where as open green space with lawn and broad-leaved space has negative effect on the concentration of $PM_{10}$ due to higher value of mass to volume on the leaf surface as compared to the $PM_{2.5}$ (Zhao et al.2014). The study showed that the effect of green space has limited scope in reducing the particulate matter if the area of green space is less than 2 ha.

E. Riesenfeld et al. (2000) the study was attempted to find the indoor air quality in the Hospital. The study was conducted at Strong Memorial hospital in Rochester, NY during the mmont of November and December. The study was conducted for the measurement of particle number concentration, Mass concentration and Particle size distribution with the use of Condensation Particle Counter (CPC), Particulate monitor and Electrostatic classifier respectively. The observations were done in the location 1) Inside the hospital 2) outside the hospital 3) environmental exposure chamber with purification of intake air. The observed results showed the number concentration of particle 0.007-3um and size distribution for particle 15-800nm. The study showed that in the morning time there was increase in the particle mass and number as compared to the evening. It was considered that this increase in the value possibly due to the operation of electronic equipment like vacuum cleaner, coffee machine and other medical equipments. The possibility of outdoor finer particle through the filtration system was also considered.

A. K. Haritash & C. P kaushik (2006), the study was done ton to find out the heavy metal associated with the respirable suspended particulate matter. The study was conducted in Hisar, Haryana during the period from July to December. The study area was bifurcate in different area (industrial, commercial, residential) according to the dominant activity. The study was done for the analysis of Pb, As, Ni, Cu, Mn, Fe, Mg by using AAS Atomic absorption spectrophotometer (AAS). Study showed the strong influence of meteorological on the heavy metal concentration in RSPM. Result showed that the turbulence condition had positive effect on the metal concentration along with the re-suspension and external input. Whereas other meteorological factor like low wind speed, low temperature and high humidity had negative impact on the concentration of pollutants. The study concluded that the concentration of heavy metal was found to follow the order pre-monsoon>monsoon>post-monsoon>autumn>winter. The overall average value of observed data showed the higher concentration in the residential area followed by industrial and commercial.

Omar. A. Al-Khashman (2004), the study was attempted to assess the heavy metal concentration associated with the dust particles present near the industrial area. The study was conducted in KIE one of the major industrial estate in Jordan. 20 samples from road side dust samples and the soil sample from two depths 0-20cm and 20-40cm were analyzed for the heavy metal analysis associated with these dust and soil samples. The analysis was done the help of AAS for Fe, Zn, Cu, Pb and Ni. The observed result for lead showed wide range from 2.1-314.1mg/kg, minimum value was from the sample collected from the furniture and wood industry sites and higher belongs to the sample collected from smelters, oven and mechanical sites. The observed value of Ni was in range 10-50mg/kg. The higher value of Ni was again found in the sample collected from the smelters, oven and electrical sites. The observed value of Zn was in range 15.4-136.9mg/kg and again the highest value was obtained from the sample collected from smelter, oven and mechanical site and the lower value was from the furniture site. The results obtained for road dust showed higher value of

Zn, Cu, Fe, Ni, Pb i.e.123, 80.2, 84.7,50, and 609.4 respectively. And the higher value was observed due to the car service centre. The study concluded that the presence of Zn, Cu, Fe, Ni, Pb in that area and the concentration of heavy metal was greater on the surface and decreased in the lower part.

Pat E. Rasmussen et. Al (2012), attempted to find the dust concentrations, metal loading, indoor loading rates in urban houses. In their study they have concluded that the dust loading rate in the locations 2 km away from any industry is less as compare to the locations within the 2 Km, but no difference in metal concentration. In non-industrial zones the smokers homes was found to have high metal loading rate then the non-smokers homes. They also found that the dust metal concentration of Pd, Cd, Zn were significant with the house age.

Fairus Muhamad Darus et al. (2010), In their investigation on presence of heavy metal in the nursery school buildings which are located near residential and industrial areas. The study was conducted to analyze the concentration of Fe, Al, Zn, Pb, Ba, Cu, Cr, Ni present in the indoor dust. The analysis of heavy metal was done with help of inductively coupled plasma-optical emission spectrometer (ICP-OES). The observed result concluded that the different outdoor activities like exhaust emission were mostly responsible for heavy metal concentration in the indoor air. The study concluded that the ventilation also influence the metal concentration. The concentration of heavy metal was found to follow the order Fe>Al>Zn>Pd>Cu>Cr>Ni.

**Health Effects of Particulate Matter**

Cities with the high particulate matter and high concentration of particulate matter by the burning of fuel were reported a verity of health effects due to the exposure with the PM. Also the ultrafine particles formed due to the exhaust emission enter into the human body through the nose and reach to other structures from the nervous system, affects the functioning of the organs. Many respiratory diseases, improper lung function, cancer etc have been reported due to the exposure with particulate matters (Wiseman & Zereini, 2009).

Longer exposure with particulate matter raises the risk of cardiovascular diseases (Bell et al., 2013, Martinelli et al., 2013).fine and ultrafine were found to be more toxic then the bigger particles. The fine and ultrafine particles, having high specific area, considered to be highly contaminated with the metals. This can induce the endothelial dysfunction, increase the risk of heart stroke (Miller et al., 2012). Small doses of lead can cause the cardiovascular diseases and also associated with the hypertension in human.

Many studies found out the relation between the long term exposure to polluted air and the cancer mortality. Particulate matter associated with the metals can promote carcinogenesis. Cells alter genes expression and DNA changes to DNA methylation that are typical of cell are undergoing transformation from healthy to cancerous type (Benbrahim-Tallaa et al., 2009).

As the metals are non biodegradable they remain in the tissue for the longer duration of time and can cause long term effect in the human body. They can raise the risk of many diseases like cancer, heart stroke, cardiovascular diseases, leukemia, etc. small children and infants are specifically vulnerable to the pollutants because of high berating rate, growth of vital organ system, and immaturity of metabolic pathways.

## 3.1 Study Area

The attempts were made to determine the characteristics of indoor respirable dust present in the different locations of north Delhi region, India. The samples were collected from locations during the month of November 2019. This region of Delhi is also having the high population density. This region is dominated by the residential area, sensitive area, industrial area, institutional area, agricultural area. Additionally, these areas have some roads with the high traffic density.

The study was designed to document the characteristics of the indoor dust which is mostly influenced by the associated activities near the sampling locations.


**Fig 3.1:** Sampling locations

## 3.2 Sample collection

The region under consideration was divided in five zones according to their dominance i.e. industrial, institutional, agricultural, industrial, and residential. Total 25 numbers of dust samples were collected from these areas. The dust accumulated over the blades of ceiling fan and the dust accumulated in the air conditioners filters. The dust was collected with the help of brush over the silver foil. After collecting each sample the brush was frequently cleaned so that the next sample could not affected by the previous sample.

**Table 3.1:** Metadata of sampling Locations

| S. No. | Coordinates | | Particulars |
|---|---|---|---|
| | Latitude (28º N) | Longitude (77ºE) | |
| 1 | 44′30″ | 07′08″ | Residential |
| 2 | 46′47″ | 03′08″ | Institutional |
| 3 | 43′34″ | 07′27″ | Sensitive |
| 4 | 44′55″ | 08′06″ | Industrial |
| 5 | 46′10″ | 01′32″ | Agricultural |

**Fig 3.2:** Dust Samples

**Fig 3.3:** Dust sample collection with the help of Brush


**Fig 3.4:** Extraction of dust sample from AC filter**.**

## 3.3 Preparation for analysis

### 3.3.1 Analysis for particle size

The samples collected were of mixed nature i.e. dust and fibers. The collected samples were analyzed for the particle size of dust. From the collected samples the only dust was taken out with the help of spatula. The aqueous solution of 0.001% was prepared by mixing 1mg per 100 ml of water. Due to presence of finer size particles probability of agglomeration was there, so to minimize the effect of agglomeration the prepared solution needs some other treatment before the final analysis. The prepared samples were first ultrasonicate for the five minutes and after that the it was stirred with the help of magnetic stirrers for five minutes. Then the finally prepared sample was inserted in the Nicomp particle size analyzer to analyze the particle size range present in the collected dust samples.

**Fig 3.5:** Digital Ultra Sonic Bath


**Fig 3.6:** Magnetic Stirrers

## Particle Size Analyzer (Nicomp N3000 Dynamic Light Scattering)


**Fig 3.7:** Particle size Analyzer

Particle size analyzer is used to identify the size of particle up to the nano range. The range of this particle size analyzer is 0.3µm-10µm, depending on the sample. This is used to analyze the particle size in the aqueous phase. The solution when placed in the cuvette the particles experience the Brownian motion in which particles have inverse relation with size i.e. smaller particles will move faster than then the larger particles. The cuvette is then placed in the instrument where the laser will hit the solution placed in cuvette. The particles in Brownian motion will scatter the incident light. This scattered light is then received by the detector placed at an specific angle. An autocorrelation function is generated by the time signature of light. Autocorrelation function itself is a function of size, having inverse relation with the size i.e. it declines more rapidly for smaller particle and vice-versa. This autocorrelation function will determine the Translational diffusion coefficient. Then the radius of the particle is calculated by using the Stocks-Einstein equation.

### 3.3.2 Analysis for heavy metal

**Acid digestion of dust samples**

All the dust samples were subjected to acid digestion process. 200mg of the dust sample from each site were taken in the conical flask each were accurately weighed. A combination of concentrated Nitric acid and concentrated sulfuric acid in ratio 3:1 was used for the acid digestion. Initially 10ml of acid was added. These were then heated on the hot plate at 110-120 $^{0}$C till the acid dried and formation of fumes stops. If the acid get dried and more fumes were still coming, additional amount of acid was added. After digestion, distilled water was added to the extracts of dust. This extract was then centrifuged for 20 min at 5000 rpm. Distilled water was added to the centrifuged extract till a volume of 25ml.The final extract will be used for the analysis of heavy metal with the help of Atomic Absorption Spectroscopy.

**Fig 3.8:** Acid Digestion of Dust samples on Hot Plate


**Fig 3.9:** Centrifuge

**Fig 3.10:** Extract of Dust after Dilution

## Heavy Metal Analysis on AAS(Analytik-jena novAA 305)


**Fig 3.11:** Atomic Absorption Spectroscopy

Atomic absorption spectroscopy (AAS) is a spectroanalytical procedure for the quantitative analysis of chemical elements using the absorption of optical radiation by free atoms in the gaseous state. The technique makes use of absorption spectrometry to assess the concentration of an analyte in a sample. It requires standards with known analyte concentration and relies therefore on Beer-Lambert law. In short, the electron of atom in the atomizer can be promoted to higher orbital for short period of time by absorbing a defined quantity of energy. This amount of energy i.e. wavelength is specific to a particular electron transition in a particular element. In general, each wavelength corresponds to only one element, and the width of the absorption line is only of order of a few picometers, which gives the technique its elemental selectivity the radiation flux without a sample and with a sample in an atomizer is measured using a detector, and the ratio between the two value is converted to analyte concentration or mass using the Beer-Lambert law. For the analysis, the standard solutions prepared were diluted to the required measure. The standard solution of Cd, Cr, Cu, Ni, Zn, Ar, were diluted to 10ppm solution. The standard solution of Fe and Al were diluted to 1ppm. All the dust samples were analyzed for heavy for heavy metal concentration in them.

## CHAPTER 4 RESULTS AND DISCUSSION

### 4.1 General Observations

The size distribution analysis of dust samples collected from the sites shows the dominance of the finer particles in the region with the particle size range between 107±11-904±82nm with zero proportion of coarser particle. Along with this small proportion of ultrafine particle was observed in some sites with the particle size range between 11.1±0-77±7.0nm. Overall average of the ultrafine particles from the different areas shows the higher occurrence of ultrafine particles in the Institutional area followed by Residential, Agricultural, Sensitive, and Industrial area i.e. 5.25, 4.40, 2.27, 1.32 and 0.16 % respectively. Whereas the higher occurrence of finer particles are observed in the Industrial area followed by the sensitive, Agricultural, residential and Institutional i.e. 99.83, 98.68, 97.73, 95.57 and 94.74%. The surrounding activities like traffic, construction and demolition, industrial operations, Swabbing etc near the sites, and the indoor activities like cooking, smoking, use of electronic and electrical appliance (printer, vacuum cleaner, coffee machines etc) could be the reasons for the occurrence of fine and ultrafine particles in the region. Along with local source generation meteorological factors like wind direction, wind speed, temperature, humidity etc also found to have much influence in the presence of fine and ultrafine particles. Weighted average of the particle size showed the dominance of finer particles with size range between 259.60-903nm in the study region. Whereas the overall average of weighted particle size of individual area showed the varying range of particle size i.e. 596.47, 615.6, 618.09, 666.80, and 745.09 nm for institutional, industrial, agricultural, residential and sensitive area respectively. Various studies find the relation between the mortality and ambient particle concentration. Long term of exposure to Particulate matter can cause the respiratory deceases and cardiac deaths in elders. The other effects of particulate matter exposure are increased pulse rate, increased respiratory symptoms, asthma exacerbation, increase in medicinal use and increase in hospital admissions. The exposure of particulate matter not only affect the adults but also have sever effects on the children as the children have high respiratory rate as compared to the adults and the ultrafine particles enters into the respiratory tract during inhaling process and have the tendency to accumulate in the respiratory tract and can cause severe decease to the infants. These particulate matters are found to be harmful itself but when these particulate matters associate with the metals, produced from any source, can cause the more harmful effect on the human body. Once these metals combined with the particulate matter they find their way to enter into the human body by inhaling process. The accumulation of metal in the human body can cause various problems like lung cancer, mental deceases, visibility problems, neurotoxicity, genotoxicity, liver problems etc. children are more susceptible to the heavy metal, as they have high inhalation rates, rapid growth, cell disintegration (Moshammer et al., 2006) . Therefore the presence of heavy metal has more toxicity to the children and infants. Different industries like steel plants, galvanizing industry, welding industries paint industries etc were found to be responsible for generate metal in the ambient air. Some of metals emitted by the industries are Pb, Cu, Zn, Hg etc. Along with the industries other source of heavy metal in the ambient environment are exhaust emission, non-exhaust emission, use of pesticides in the farms etc. somehow these metals associate with particulate matter and finally enter into the human body.

## 4.2 Dust Analysis of Residential Area

Table 4.1 illustrates the proportion of finer particulate matter is dominant in the indoor environment along with the ultrafine particles (<100nm). The range of particles from 72nm-904nm was found in the indoor environment of the residential area. Average proportion of fine and ultrafine particle was found to be 95.57% & 4.40% respectively. Weighted average of the particle size shows the occurrence of particle size of range between 448-902nm. The average of weighted particle size of the residential area was observed and it was found that the average particle size of 666nm has higher occurrence in the residential area. Human indoor activities like cooking, cleaning, and smoking influence the presence of fine and ultra fine particle in the indoor environment (Massey et al., 2009). Indoor human activities are held responsible for the emission of ultrafine particles with very high emission rate (Gehin et al., 2008). Along with the human indoor activity, ventilation process was also found to have the significant influence on the indoor environment (Koponen et al., 2000). In normal residential building (with natural ventilation) building shell does not have any effect on removing the infiltration of finer particles (Thatcher & Layton, 1994). Outside activities like Construction, swabbing near the residential area could have the contribution in the fine particulate matter (0.1µm-2.5µm) present in the indoor air. Construction and demolitions activities could have high potential to generate multiple times concentration of ultrafine and fine particles as compared to the background concentration of particulates (Farhad Azarmi et al., 2014).

**Table 4.1:** Site Description of Residential Area

| Site No. | Area | Site | Source | Associated Activity | Remark | Particle Size(nm) (NICOMP) | Weighted Average(nm) | Number of occupants | ventilation |
|---|---|---|---|---|---|---|---|---|---|
| **1** | Residential | B-6,Rohini Sector-17 (Second floor, just beside Bitumen road, Moderate traffic density) | AC | Construction | Mostly fibers | 93.2(14.2%) SD-12.90<br>552.2(85.8%) SD-28.90 | 483.70 | 1 | Window-6"×5" Door-6"×3" |
| **2** | Residential | B-6,Rohini Sector-17 (Third floor, just beside bitumen road, Moderate traffic density) | Fan | Construction | Dust | 902.8(100%) SD-97.20 | 902.80 | 5 | Window-5"×5" Door-6"×3" |
| **3** | Residential | H-5,Rohini Sector-16 (Second floor, just beside bitumen road, Moderate traffic density) | Fan | Swabbing | Mostly Dust | 72.80(3.4%) SD-6.10<br>192.20(26.40%) SD-17.50<br>904.00(70.30%) SD-78.50 | 688.72 | 4 | Window-7"×4" Door-6"×4" |
| **4** | Residential | Girls PG, Rohini Sector-17 (First floor, just beside bitumen road, Moderate traffic density) | AC | Traffic | only fibers | | | 2 | Window-7"×4" Door-5"×3" |
| **5** | Residential | Boys PG, Rohini Sector-17 (Second floor, Just beside bitumen road, Moderate traffic density) | AC | Construction | Mostly Dust | 637(100%) SD-6.10 | 637 | 2 | Window-7"×4" Door-5"×4" |

## 4.3 Dust Analysis of Institutional Area

Table 4.2 illustrates the presence of fine and ultrafine particles in the dust samples collected from the institutional. The particle present in the sample has range of particle size from 77nm-904nm. The average proportion of ultrafine and fine particle was found to be 5.26% and 94.74% respectively. The weighted average of particle size shows the particle size of range between 259-757nm in the institutional area. Overall average of weighted particle size present in the institutional area showed the dominance of 596nm size particle in the area. Among all the areas under consideration institutional area is found to have higher occurrence of ultrafine particles. Most of the sites in the institutional area were surrounded by the massive construction and demolition activities. These construction and demolition activities could the reason for the higher proportion of ultrafine particles. Construction and demolition activities were found to have high potential to generate multiple times higher concentration of fine and ultrafine particles, as compared to the background concentration (Farhad Azarmi et al. (2014). All the sites from Institutional areas have the natural ventilation. For the natural ventilation building shells are not much efficient in restricting the penetration of finer particles. (Thatcher & Layton, 1994). Demolition of the structure was found to have contribution in the increment of particulate matter which depends upon the various conditions (location, wind direction, time). The presence of fine particulate matter was also influenced by the heavy diesel equipments used for the construction and demolition of structure (Azarmi et al., 2014). This institutional area was prosperous in green belts. Plants and trees were found to be effective in reducing the particulate matter. For shorter distances less then 2km, green belts were proved to be more effective then the green space. The deposition of coarser particulate over the surface of the green cover and the penetration of finer particles into the atmosphere influences the concentration of finer proportion in the indoor environment. Green cover was not found to be much effective in reducing the level of $PM_{2.5}$ but was had negative relation with $PM_{10}$.

**Table 4.2:** Site Description of Institutional Area

| Site No. | Area | Site | Source | Associated Activity | Remark | Particle Size(nm) (NICOMP) | Weighted Average(nm) | Number of occupants | Ventilation |
|---|---|---|---|---|---|---|---|---|---|
| **6** | Institutional | Microbio lab, DTU Ground Floor,20m away from bitumen road, Low traffic density | AC | Demolition & Construction | Dust & Fibers | 108.7(11.3%) SD-11.90<br>737.5(88.7%) SD-94.80 | 666.44 | 10 | Window-4(6"×5")<br>Door-7"×5" |
| **7** | Institutional | Type-III Hostel, DTU<br>First floor, just beside bitumen road, Low traffic density | Fan | Construction | Dust & Fibers | 96.9(16.3%) SD-9.70<br>269.8(58%) SD-25.00<br>339.8(25.7%) SD-19.30 | 259.60 | 2 | Window-4"×5"<br>Door-7"×4" |
| **8** | Institutional | KCH Hostel, DTU Third Floor, Just beside bitumen road, Low traffic density | Fan | Construction | Dust & Fibers | 77.80(3.2%) SD-6.70<br>258.80(29.3%) SD-27.00<br>901.30(67.5%) SD-98.10 | 286.69 | 2 | Window-4"×5"<br>Door-7"×4" |
| **9** | Institutional | Class Room, DTU First floor,10m away from C.C road, Low traffic density | AC | Swabbing | Dust & Fibers | 139.4(37.9%) SD-11.70<br>901.2(62.1%) SD-98.8 | 612.47 | 60 | Window-4"×5"<br>Door-7"×4" |
| **10** | Institutional | Health care Centre, DTU<br>First floor, just beside bitumen road, Low traffic density | AC | Construction | Dust & Fibers | 90.7(6.8%) SD-9.30<br>142.5(11.9%) SD-9.60<br>904.0(81.2%) SD-82.30 | 757.17 | 10 | Window-5"×5"<br>Door-6"×4" |

## 4.4 Dust Analysis of Sensitive Areas

Table 4.3 illustrates the existence of major proportion of fine particles along with small proportion of ultrafine particles in the sensitive areas. Average fraction of fine particulate matter and ultrafine particle were found to be 98.68% and 1.32% respectively. The particle size range of fine particulate is observed between 138nm-902nm, and for ultrafine particle it is 68nm-77nm. Weighted average of particle size present in the sensitive areas are in the range between 665-902nm. From the average of weighted particle size it is observed that the particle of size 745nm is having the dominance in the sensitive area. The presence of ultrafine particles, among different sites in the sensitive area, is found in the hospital location i.e.14. All the sites could be highly influenced by the heavy traffic density near them. The roads with higher traffic density were found to have influence on the increment in the concentration of particulate matter which could be up to 15-20%, as compared to the quiet roads (Fischer et al., 1999). All the sites in the sensitive area have the natural ventilation in the infrastructure. Building shells are not much competent in restricting the infiltration of the particulate matter. Under infiltration, I/O ratio value approx to unity showed the penetration of larger size ultrafine particles (70-100nm) (Zhu et al., 2004). Indoor activities like operation of electrical appliances (vacuum cleaner, coffee machine), medical equipments etc could also be the reason for the occurrence of fine and ultrafine particles in the sensitive area.

**Table 4.3:** Site Description of Sensitive Area

| Site No. | Area | Site | Source | Associated Activity | Remark | Particle Size(nm) (NICOMP) | Weighted Average(nm) | Number of occupants | Ventilation |
|---|---|---|---|---|---|---|---|---|---|
| **11** | Sensitive | Dr B R Ambedkar Hospital Rohini Sector-5 (Basement, just beside bitumen road, high traffic density) | AC | Traffic | Mostly fibers | 138.9(12.8%) SD-15.60<br>877.9(87.2%) SD-42.50 | 783.30 | 25-30 | Window - 3(5"×5")<br>Door-2(6"×6) |
| **12** | Sensitive | Dr B R Ambedkar Hospital Rohini Sector-5 (Basement, just beside bitumen road, high traffic density) | Fan | Traffic | Dust & Fibers | 68.2(3.4%) SD-7.60<br>242.4(31.6%) SD-25.70<br>902.2(65%) SD-97.80 | 665.34 | 5 | Door-6"×4" |
| **13** | Sensitive | SKV School Rohini Sector-11 (First floor, just beside bitumen road, high medium density) | Fan | Traffic | Mostly Dust | 902.30(100%) SD-86.80 | 902 | 50 | Window - 3(4"×3")<br>Door-2(6"×4") |
| **14** | Sensitive | ESI Hospital Rohini Sector-15 (Ground floor, just beside bitumen road, high traffic density) | AC | Traffic | Dust & Fibers | 77.80(3.20%) SD-6.70<br>258.8(29.30%) SD-28.9<br>901.30(67.5%) SD-93.5 | 692.2 | 35-40 | Window- 14(6"×5")<br>Door-2(6"×6") |
| **15** | Sensitive | ESI Hospital Rohini Sector-15 (Ground floor, just beside bitumen road, high traffic density) | Fan | Traffic | Mostly Dust | 196.3(22.8%) SD-18.30<br>255.9(9.1%) SD-18.1<br>902.5(68.1%) SD-97.50 | 682.64 | 15-20 | Door-2(6"×6") |

## 4.5 Dust Analysis of Industrial Area

Table 4.4 illustrates the existence of various sized particulate matter present in industrial area. We found the average proportion of fine and ultrafine particulate was 99.83% & 0.16% respectively. Ultrafine particle of size 28nm and fine particles with size between 107nm-904nm were present in the indoor air. Weighted average of particle size present in the industrial area showed the range of size between 471-733nm. It was observed from the average of weighted particle size that the particles of size 615 had the dominance in the industrial area. Indoor Activities like movement of higher number of public and use of printers may affect the presence of finer particles concentration in the indoor air. Printers used in residents and offices were found to have contribution in the increment in the VOC & the ultrafine particle number (Stephens et al., 2013). High traffic density along with the heavy diesel trucks could be responsible for the presence of ultrafine particles and have the potential to generate multiple time higher concentration of the finer particles as compared to the background concentration level (Fischer et al., 1999). The traffic conditions have much influence on the generation of particulate matter. Some driving conditions resulted in the formation of ultrafine particles from the tire-road interaction, slipping of tire was found resulted in increment the concentration of ultrafine particles of size between 30nm-60nm. Different Industrial activities in this region may have serious contribution in the increment of particulate matter. This industrial area is mostly having the rubber, plastic, metal sheet industries in it. These industries could be the reason for the higher proportion of the fine and ultrafine particles in this area. Industrial activities were found to contribute SPM approximate seven times higher than the WHO standards and three times higher than CPCB (Nagar et al., 2018).

**Table 4.4:** Site Description of Industrial Area

| Site No. | Area | Site | Source | Associated Activity | Remark | Particle Size(nm) (NICOMP) | Weighted Average(nm) | Number of occupants | ventilation |
|---|---|---|---|---|---|---|---|---|---|
| **16** | Industrial | Medical Shop, Samaypur (Ground floor, just beside bitumen road, high traffic density) | AC | Traffic | Dust | 181.40(23.5%) SD-23.80<br>903.40(76.50%) SD-96.60 | 773.73 | 3 | Shutter-8"×6" |
| **17** | Industrial | Medical Shop, Samaypur (Ground floor, just beside bitumen road, high traffic density) | Fan | Traffic | Dust | 138.30(21.10%) SD-12.50<br>196.00(3%) SD-12.40<br>904.00(75.90%) SD-78.50 | 721.19 | 3 | Door-6"×4" |
| **18** | Industrial | Vijaya Bank, Samaypur (First floor, just beside bitumen road, high traffic density) | AC | Traffic | Dust | 107.90(12.70%) SD-11.90<br>524.60(87.30%) SD-58.50 | 471.67 | 40-50 | Window-4(4"×3")<br>Door-6"×6" |
| **19** | Industrial | Petrol Pump, Samaypur (First floor, just beside bitumen road, high traffic density) | AC | Traffic | Dust | 139.70(27.90%) SD-17.20<br>658.60(72.10%) SD-91.70 | 557.10 | 5 | Window-2(4"×3")<br>Door-6"×4" |
| **20** | Industrial | SBI Bank, Samaypur (First floor, just beside bitumen road, high traffic density) | AC | Traffic | Dust | 139(31.20%) SD-21.20<br>746.40(68.80%) SD-48.80 | 556.89 | 40-50 | Window-2(5"×4")<br>Door-6"×4" |
| **21** | Industrial | Shop, Samaypur (First floor, just beside bitumen road, high traffic density) | Fan | Traffic | Dust | 28.80(1%) SD-2.5<br>200.70(23%) SD-23.40<br>869.70(76%) SD-72.40 | 707.42 | 2 | Shutter-8"×6" |

## 4.6 Dust Analysis of Agricultural Area

Table 4.5 illustrates the existence of fine and ultrafine particles in the indoor environment. Observed values showed the wide range of particles from 75nm-903nm. Size of fine and Ultrafine particles present in the region was observed in the range between 15nm-75nm and 138nm-903nm respectively. Average proportion of ultrafine particles and fine particle was observed to be 2.27% and 97.73% respectively in the area. The presence of ultrafine particles in 22 & 23 sites were found higher as compared to the other sites in the agricultural area. Weighted average of particle size in the area showed wide range of particle between 296-903nm. Average of weighted particle size showed the dominance of particle size of 618nm in the agricultural area. Higher dependence on the diesel equipped vehicle for the agricultural practices like tilling, for hauling of crops etc could be the reason for the occurrence of finer particles. Diesel vehicles in the street were majorly responsible for the generation of ultrafine particles along with the non-exhaust emission (Finn Palmgren et al., 2003). Indoor activity like cooking, smoking tobacco, use of incense sticks etc could also be the reason for the occurrence of finer particles. Transportation of finer particles from the industrial or other source, which are away from the agricultural area, by the wind could also be the reason the higher value of finer particles. Meteorological factors like wind speed, wind direction, temperature, humidity etc was found to have higher influence on the concentration of fine and ultrafine particles.  Wide opening of the doors and windows for the fresh air, ventilation, to save the electricity allows the particles to infiltrate in the indoor environment.

**Table 4.5:** Site Description of Agricultural Area

| Site No. | Area | Site | Source | Associated Activity | Remark | Particle Size(nm) (NICOMP) | Weighted Average(nm) | Number of Occupants | ventilation |
|---|---|---|---|---|---|---|---|---|---|
| **22** | Agriculture | Shop, Khera kalan (First floor, just beside C.C Road, Low traffic density ) | Fan | Agricultural | Mostly Dust | 75.6(8.3%) SD-8.90<br>316.5(91.7%) SD-44.90 | 296.18 | 2 | Rolling shutter-10"×6"<br>Door-6"×4" |
| **23** | Agriculture | House, Khera kalan (Ground floor, Just beside C.C Road, Low traffic density) | AC | Agricultural | Mostly fibers | 11.1(1%) SD-0.0<br>188.1(37.3%) SD-24.00<br>783.3(61.7%) SD-27.80 | 553.56 | 3 | window-2(6"×5")<br>Door-2(7"×4") |
| **24** | Agriculture | House, Khera kalan (Ground floor, Just beside C.C Road, Low traffic density) | Fan | Agricultural | Mostly fibers | 903(100%) SD-97.00 | 903 | 3 | window-4"×3"<br>Door-7"×4" |
| **25** | Agriculture | House, Khera kalan (First floor, Just beside C.C Road, Low traffic density) | Fan | Agricultural | Mostly fibers | 138.1(24%) SD-13.90<br>903.1(76%) SD-96.90 | 719.5 | 6 | window-6"×5"<br>Door-"7×4" |

**Table 4.6:** Average Proportion of Fine and Ultrafine Particles in Different Areas

| S. No | Area | Ultrafine(%) (<0.1μm) | Fine (%) (<2.5μm) | Coarse (%) (<10μm) |
|---|---|---|---|---|
| **1** | Residential | 4.40 | 95.57 | 0 |
| **2** | Institutional | 5.26 | 94.74 | 0 |
| **3** | Sensitive | 1.32 | 98.68 | 0 |
| **4** | Industrial | 0.16 | 99.83 | 0 |
| **5** | Agricultural | 2.27 | 97.73 | 0 |

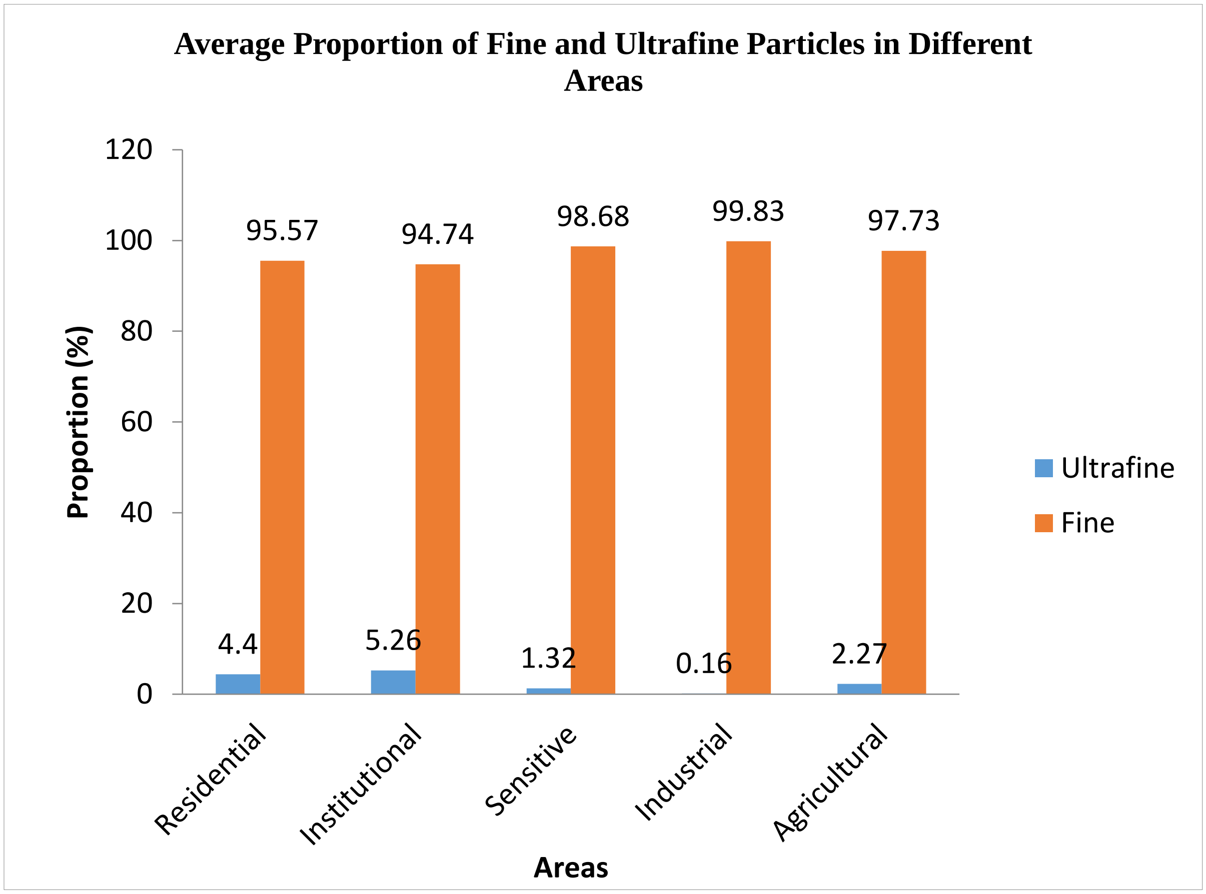


**Fig 4.1:** Average Proportion of Fine and Ultrafine Particles in Different Areas

**Table 4.7:** Average of Weighted Average of Particle Size Present in different Areas

| S. No | Area | Average Particle Size (nm) |
|---|---|---|
| 1 | Residential | 666.80 |
| 2 | Institutional | 596.47 |
| 3 | Sensitive | 745.09 |
| 4 | Industrial | 615.60 |
| 5 | Agricultural | 618.09 |

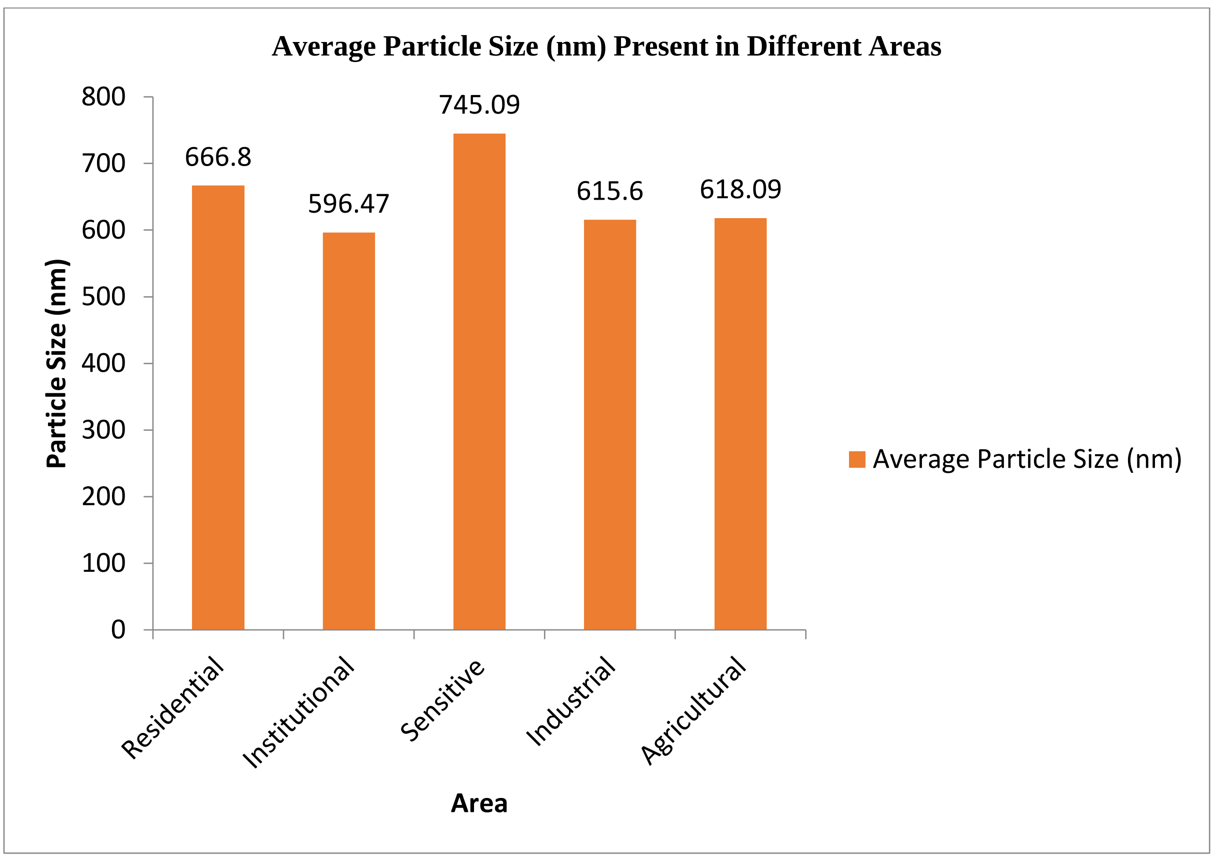


**Fig 4.2:** Average Particle Size (nm) Present in Different Areas

# CHAPTER 5 Conclusion

The particle size analysis of the dust collected from different locations showed the wide range of particle size present in the study area. The Result sowed the presence of ultrafine particle in order Institutional > Residential > Agricultural > Sensitive > Industrial Areas. The presence of fine particle was found in order Industrial > Sensitive > Agricultural > Residential > Institutional. Averages of weighted particle size showed the particle size of range between 666nm-745nm were dominant in the region. Adjacent activities like Construction & Demolition, Swabbing, indoor activities and Traffic emission could be the major source for higher occurrence of fine and ultrafine particle in the study area. Since the area is densely populated so the it can affect the large mass of people in the smaller area. As the presence of contaminated dust is harmful and have long term effects on the human body. Specially the children are very susceptible to particulate, particularly when these particulate matter are associated with the metal. Hence some preventive measures should be adopted to minimize the risk due to these contaminated dusts. Therefore, norms should be followed strictly for the traffic emission, use of new technology like electric vehicles to reduce the exhaust emissions, need to use good construction practices like temporary structures should be built around the construction, water spray should be use during the demolition, drilling and cutting operations, good housekeeping practices like vacuuming, wet mopping and the controlled use of ventilation system.

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