Characterization of Different Dust Sample for PM$_{10}$ & PM$_{2.5}$ Fraction to Establish its Impact in Raising Ambient PM$_{10}$ & PM$_{2.5}$ Levels in City of Narsinghpur

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Abstract- This research paper aims at establishing baseline PM10 and PM2.5 concentration levels in Narsinghpur city. The relative contribution of PM$_{10}$ and PM$_{2.5}$ concentrations are to be investigated in city because of city being overcrowded, congested and deteriorated air quality because of vehicular pollution. Dust lying on the roads is rich in fine particles which are lifted up by the movement of vehicles and become airborne in the atmosphere. Dust lift up from the roads remains continuous line source and impact fine dust levels into atmosphere. Emissions depend upon the load/weight and speed of vehicles and humidification of the dust besides the type of dust on the roads. Another major source of fine particles are stockpiles of construction material in urban centre. Last but not least, climate change resulting from environmental pollution affects the geographical distribution of many infectious diseases, as do natural disasters. The only way to tackle this problem is through public awareness coupled with a multidisciplinary approach by scientific experts. Particulate matter pollution is a significant environmental concern globally, linked to various adverse health effects. This research study employs a systematic approach, combining field measurements, data analysis, and literature review to evaluate the current scenario of PM10 and PM2.5 pollution in Narsinghpur City. The findings will contribute to a better understanding of the local air quality situation and facilitate the development of effective mitigation strategies.

Keywords- Dust sample characterization, ambient air pollution, particulate matter, PM$_{10}$, PM$_{2.5}$

Introduction
Ambient air pollution refers to the presence of harmful substances and pollutants in the Earth's atmosphere, primarily in outdoor or ambient air. These pollutants can be both natural and human-made and have adverse effects on human health, ecosystems, and the overall quality of life. Common sources of ambient air pollution include industrial activities, transportation, power generation, residential heating and cooking, agricultural practices, and natural phenomena such as dust storms and volcanic eruptions. These activities release various pollutants into the air, including gases, particulate matter, and chemical compounds. To assess impact of dust in ambient air it is very important to know the composition of dust of different sources by its careful analysis in terms of PM$_{10}$ & PM$_{2.5}$ fraction. To know these fractions correctly an instrumental technique is necessary to be developed. Conventional methods for fractionation of dust particles need to be modified into a instrumental technique as a part of this dissertation to aid in accuracy of results and required to get results quickly. A unit proposed expected to be designed and developed based on the combination of impactor based technology after literature review. Dichotomous based technology may appear to be most appropriate for such assessment. A system shall be developed and proposed to be used to study a road dust to report their contribution in raising PM 10 & PM 2.5 values, later this data can be useful for modelling and prediction of incremental dust concentration in ambient air by line source (Roads in the city). Emission loads from metallic and unmetalled roads shall be estimated using USEPA AP42 guideline where generated data shall be ultimately used and later this data may be useful for air pollution control and management. Another fact is that the half-lives of PM10 and PM2.5 particles in the atmosphere is extended due to their tiny dimensions; this permits their long-lasting suspension in the atmosphere and even their transfer and spread to distant destinations where people and the environment may be exposed to the same magnitude of pollution. They are able to change the nutrient balance in watery ecosystems, damage forests and crops, and acidify water bodies. As stated, PM$_{2.5}$, due to their tiny size, are causing more serious health effects. These aforementioned fine particles are the main cause of the “haze” formation in different metropolitan areas. Ambient air pollution poses significant risks to human health, particularly for vulnerable populations such as children, the elderly, and individuals with pre-existing respiratory or cardiovascular conditions. It can lead to respiratory diseases, cardiovascular problems, increased risk of lung cancer, and impaired lung development in children. Moreover, it can have detrimental effects on ecosystems, including damage to vegetation, reduction in crop yields, and disruption of ecosystems' delicate balance.
Efforts to mitigate ambient air pollution involve a combination of regulatory measures, technological advancements, and public awareness campaigns. These may include the implementation of emission standards for industries and vehicles, the promotion of cleaner energy sources, the development of efficient transportation systems, and the adoption of sustainable agricultural practices. Addressing ambient air pollution is crucial for safeguarding public health, preserving the environment, and ensuring a sustainable future for generations to come. It requires concerted global efforts, interdisciplinary collaborations, and a commitment to reducing pollutant emissions and promoting cleaner, healthier air quality.

Sources of PM$_{10}$ and PM$_{2.5}$

Particulate matter (PM) is a general term for extremely small particles and liquid droplets in the atmosphere. PM$_{10}$ refers to inhalable particles with diameters that are generally 10 micrometers and smaller, while PM$_{2.5}$ refers to fine inhalable particles with diameters that are generally 2.5 micrometers and smaller. PM$_{10}$ and PM$_{2.5}$ often derive from different emissions sources, and also have different chemical compositions. Emissions from combustion of gasoline, oil, diesel fuel or wood produce much of the PM$_{2.5}$ pollution found in outdoor air, as well as a significant proportion of PM$_{10}$. PM$_{10}$ also includes dust from construction sites, landfills and agriculture, wildfires and brush/waste burning, industrial sources, wind-blown dust from open lands, pollen and fragments of bacteria.

PM may be either directly emitted from sources (primary particles) or formed in the atmosphere through chemical reactions of gases (secondary particles) such as sulfur dioxide (SO$_2$), nitrogen oxides (NO$_x$), and certain organic compounds. These organic compounds can be emitted by both natural sources, such as trees and vegetation, as well as from man-made (anthropogenic) sources, such as industrial processes and motor vehicle exhaust.

The following table contains the standard categorisation of the PM$_{10}$ and PM$_{2.5}$:

<table>
<thead>
<tr>
<th>AQI Category</th>
<th>PM$_{10}$ Concentration (μg/m$^3$)</th>
<th>PM$_{2.5}$ Concentration (μg/m$^3$)</th>
<th>NO$_x$</th>
<th>CO</th>
<th>SO$_2$</th>
<th>NH$_3$</th>
<th>Pb</th>
</tr>
</thead>
<tbody>
<tr>
<td>Good</td>
<td>0 - 50</td>
<td>0 - 30</td>
<td>0 - 40</td>
<td>0 - 50</td>
<td>0 - 1.0</td>
<td>0 - 40</td>
<td>0 - 5</td>
</tr>
<tr>
<td>Satisfactory</td>
<td>51 - 100</td>
<td>31 - 60</td>
<td>41 - 80</td>
<td>51 - 100</td>
<td>2.1 - 10</td>
<td>41 - 80</td>
<td>201 - 5</td>
</tr>
<tr>
<td>Moderately polluted</td>
<td>101 - 200</td>
<td>64 - 100</td>
<td>81 - 168</td>
<td>101 - 2.1</td>
<td>81 - 168</td>
<td>201 - 5</td>
<td></td>
</tr>
<tr>
<td>Poor</td>
<td>201 - 300</td>
<td>120 - 280</td>
<td>169 - 391</td>
<td>0.7 - 17</td>
<td>391 - 801</td>
<td>2.1</td>
<td></td>
</tr>
<tr>
<td>Very poor</td>
<td>300 - 400</td>
<td>250 - 350</td>
<td>280 - 490</td>
<td>17 - 34</td>
<td>800 - 1200</td>
<td>5.0</td>
<td></td>
</tr>
<tr>
<td>Severe</td>
<td>400 - 600</td>
<td>350 - 500</td>
<td>400 - 68</td>
<td>400</td>
<td>1600 - 1800</td>
<td>3.5</td>
<td></td>
</tr>
</tbody>
</table>

* CO in mg/m$^3$ and other pollutants in μg/m$^3$; 2h-hourly average values for PM$_{10}$, PM$_{2.5}$, NO$_x$, SO$_2$, NH$_3$, and Pb, and 8-hourly values for CO and O$_3$.

Dichotomous Air Sampler

A dichotomous air sampler is a type of air sampling device used to collect airborne particles for analysis in environmental monitoring, occupational health studies, or research purposes. It is designed to separate particles into two size fractions: the inhalable fraction and the respirable fraction. The dichotomous air sampler works by drawing air through an inlet and then dividing the sample into two size fractions using a size-selective inlet or impactor. This separation is achieved by directing the air stream through a series of nozzles or impaction plates, which allow particles of different sizes to be collected on separate filters.

The sampler typically consists of the various components which are inlet, impacter plates, filters, pump and flow controller. The inlet is designed to control the size of the particles entering the sampler. It may include a size-selective inlet, such as a cyclone or impactor, to separate particles based on their aerodynamic size. The impactor plates are used to separate the air stream into two fractions. They are designed with precision nozzle sizes or impaction surfaces that allow particles of specific sizes to impact and deposit onto separate filters. The sampler has two filters, one for each fraction. The inhalable fraction filter collects larger particles, while the respirable fraction filter collects smaller particles. These filters are typically made of materials such as glass fiber or cellulose and are later analyzed for particle content. A pump is used to draw air through the sampler at a specified flow rate. It creates the necessary vacuum to pull the air sample through the inlet and onto the filters. The flow controller ensures that the air is drawn through the sampler at a constant flow rate, usually measured in liters per minute (L/min). After sampling, the filters can be removed and analyzed using various methods such as gravimetry, microscopy, or chemical analysis to determine the type and concentration of particles collected in each fraction.

Dichotomous air samplers are valuable tools in assessing air quality, investigating occupational exposures, and studying particulate matter in various environments. They provide important data for understanding potential health risks associated with airborne particles and can aid in regulatory compliance and decision-making processes. The
dichotomous air sampler is a dual-filter air sampler for the simultaneous collection of the fine (PM2.5) and the coarse (PM10-2.5) particles contained within PM10. The dichotomous air sampler allows differential mass determination between the fine and coarse fractions contained within inhalable particulate matter. This instrument also allows the user to perform chemical analysis comparison of the two size fractionated samples.

The basic premises of this instrument is the dual flow configuration. This proven technology utilizes two flow controlled channels that adjust the flow to a constant volumetric flow rate within each channel. Information from standard pressure and temperature sensors is measured, stored and used to make the corrected flow rate possible. A well engineered user interface and touch screen display allow the operator complete control over this instrument with very little training. Flow data, event markers, pressure and temperature data can be downloaded from any internet connection via an on-board IP address. An optional weather station is available to monitor and log air temperature, barometric pressure, relative humidity, precipitation amount, wind direction and wind speed. All of this information is stored on a very large removable memory card. Traditional 47 mm filter cassettes and the classic PM10 (16.7 LPM) inlet are used for their well documented reliability and user familiarity.

Dichotomous Sampling: Dichotomous sampling is a technique used in environmental monitoring to separate and collect airborne particles or gases based on their size or other properties. It involves the use of a sampling device that divides the air stream into two separate fractions, typically based on aerodynamic particle size. The fractions collected can then be analyzed separately to determine the concentration and composition of specific particles or gases.

Sampling Area and Sample Collection Procedure
Certain sample collection points have been chosen in Narsinghpur city to analyze the concentration of PM10 and PM2.5.
1. Narsinghpur Railway Station: A bustling hub of transportation with trains arriving and departing regularly, catering to both local and long-distance commuters.
2. Narsinghpur Bus Stand: The main bus terminal of the city, serving as a major transit point for buses traveling within and outside Narsinghpur.
3. Narsinghpur Main Market: A vibrant commercial area where locals and visitors flock to shop for a variety of goods, including clothing, electronics, household items, and fresh produce.
4. Narsinghpur District Hospital: As the primary healthcare facility in the city, the hospital is often crowded with patients, doctors, and medical staff attending to various medical needs.
5. Narsinghpur District Court: A significant judicial complex where legal proceedings take place, attracting lawyers, litigants, and court personnel, making it a busy location throughout the day.
6. Narsinghpur Central Park: A popular recreational spot, especially during weekends and evenings, where people gather for leisure activities, picnics, and outdoor sports.
7. Narsinghpur College Campus: The educational hub of the city, bustling with students attending classes, participating in events, and engaging in various academic and extracurricular activities.
8. Narsinghpur Vegetable Market: A busy marketplace where farmers, vendors, and buyers converge to trade and purchase fresh fruits, vegetables, and other agricultural produce.
9. Narsinghpur Railway Colony: A residential area near the railway station, known for its hustle and bustle as commuters and railway employees go about their daily routines.
10. Narsinghpur Police Station: A vital law enforcement facility that remains busy with officers, crime victims, and individuals reporting incidents, ensuring public safety and maintaining law and order in the city.

The materials used to carry out this analysis are brush, dust collection pan, oven and sieves of sizes 600 micron, 250 micron, 180 micron, and 75 micron.

Dust sample Collection Procedure
1. Collected the sieved dust and put it in oven 90 degree celcius for 1 Hr.
2. Sieved it down through 600 > 250 > 180 >75 Micron Sieves.
3. Collected the sieved dust and put it in oven 90 degree celcius for 1 Hr.
4. Took sample of 5gm dust.

Methodology
A dichotomous air sampler is a device used to collect airborne particles for analysis, typically in environmental monitoring or occupational health studies. It operates by separating particles into two size fractions: respirable and non-respirable.

Ensuring the sampler is clean and in proper working condition. Calibration is done for the sampler according to the manufacturer's instructions, if required. A suitable filter media to the sampler is attached. The filter media should be appropriate for the type of particles to collect and analyze. Sampling duration should be determined based on the specific requirements of study or regulations governing air sampling. Setting of flow rate is carried out of the sampler according to the manufacturer's instructions or as per the sampling protocol. Typically, the flow rate is adjusted to separate particles...
into respirable and non-respirable fractions. Ensuring that the sampler is operating correctly before initiating the sampling, the sampler at the designated start time is started and sampler is set to collect samples for the desired duration.

**Dichotomous Dust sampler Operation Procedure:**
1. Carefully cleaned the dust chamber, impactor and cabinet.
2. Filter put in Decicator with blue silica.
4. Took initial filter paper weight and without filter holder.
5. Put filter paper in Holder PM10 and PM2.5
6. Set the run time to 60 mins in data logger for machine run
7. Set the log rate at 2 mins.
8. Started the machine
9. Flow rate set with the help of rotametre at 16.5 Lpm (Litres per minute) pressure
10. After 60 mins removed the filter holder and weighted the final dust.

**Preparation of Sample**

1. Collect dust with the help of brush and dust pan.
2. Sieve down the dust
3. Collect sieved dust and put it in oven at 90°C for 1hr.
4. Make at least 3 samples of 3gm or as desired.
5. Put these samples in desiccator so that these cannot absorb moisture.

**Conditioning the Membrane Filter prior to use**

As the total mass of fine particles likely to be deposited is very small, while handling the Membrane filters for use in PM10 & PM 2.5 particulate sampling, care should be taken to avoid contaminating the filter in any manner. In fact even electrostatic charge on the filter can affect your weighment. To minimize errors follow the precautions mentioned below:

1. Minimize exposure of the filters to open air. Keep them covered inside the filter carriers provided with the instrument.
2. The membrane is a fine and fragile material, take care to handle the filter only by the support ring on its edge using non-serrated forcep.
3. Inspect the filters against a light source for pinholes and loose contamination.
4. To equilibrate the filters keep them in a controlled environment (such as a desiccator) at 25 degrees C and RH less than 35% for at least 16 hours.
5. Weigh the filters on a micro-balance with a resolution of at least 0.01 milligram. For best results it is advisable to use a balance with a resolution of 0.001 mg and re-weigh the filters a few times and confirm repeatability of the weight. Reject the weighment if the weight varies by more than 10ug.
6. Each filter has a Number printed on its periphery. Record the Initial Filter weight and ID.
7. To avoid handling of the fragile membrane filters in the field it is a good idea to load a pre-weighed filter in a filter cassette in the clean lab environment. Along with each instrument Ecotech provides spare filter cassettes for this purpose. Place the filter cassette in the covered carrier / box provided for this purpose.

The AES 900 sampler uses two filters in each run. The filter holder on the right hand side will receive PM2.5 particulates while the filter holder on the left side will receive particles between the size range of 10 to 2.5 microns. To load the membrane filters in the AES 900 sampler loosen filter holders where the cassettes having membrane filters can be
placed. Note there is a small step on the filter holder that enables you to locate each filter cassette centrally on the respective filter holder.
Place both filter cassettes and fit the filter holder properly.

**Operation procedure for Dust sample Profiling**
1. First open the dust chamber, to open loose wing nut provided at the top of lid and remove the lid.
2. Clean dust chamber & PM10 impactor with the help of brush, vacuum cleaner and acetone.
3. After cleaning, put 3gm dust sample in the dust charging cup and close the dust chamber.
4. Take initial weight of the conditioned filter paper with filter cassette and place it into the cassette holder.
5. Set test time and log time, in our case we have taken 60 min as sampling time and 2 min as log time.
6. Check the flow of 16.67 LPM entering to the dust chamber with the help of mounted rotameter. If not set to 16.67 adjust to 16.67 with adjustable valve.
7. After completion of test remove and take final weight of the filter paper with filter cassette for calculation of PM10 & PM2.5 concentration.
8. After that clean the dust chamber.

**Result and Discussion**
We have taken sample of 8 points in Jabalpur and done analysis with the help of dichotomous dust sampler and got different results with different days and then aggregate concentration of PM$_{10}$ and PM$_{2.5}$ has been determined. All these data are shown in the following table 2 and table 3

<table>
<thead>
<tr>
<th>Location</th>
<th>1 May</th>
<th>16 May</th>
<th>30 May</th>
<th>Aggregate</th>
</tr>
</thead>
<tbody>
<tr>
<td>Railway Station</td>
<td>97</td>
<td>125</td>
<td>117</td>
<td>113</td>
</tr>
<tr>
<td>Bus Stand</td>
<td>88</td>
<td>118</td>
<td>110</td>
<td>105</td>
</tr>
<tr>
<td>Main Market</td>
<td>92</td>
<td>117</td>
<td>116</td>
<td>108</td>
</tr>
<tr>
<td>District Hospital</td>
<td>84</td>
<td>123</td>
<td>115</td>
<td>107</td>
</tr>
<tr>
<td>District Court</td>
<td>96</td>
<td>118</td>
<td>118</td>
<td>111</td>
</tr>
<tr>
<td>Central Park</td>
<td>89</td>
<td>121</td>
<td>117</td>
<td>109</td>
</tr>
<tr>
<td>College Campus</td>
<td>95</td>
<td>119</td>
<td>112</td>
<td>109</td>
</tr>
<tr>
<td>Vegetable Market</td>
<td>96</td>
<td>123</td>
<td>113</td>
<td>111</td>
</tr>
<tr>
<td>Railway Colony</td>
<td>91</td>
<td>128</td>
<td>115</td>
<td>111</td>
</tr>
<tr>
<td>Police Station</td>
<td>95</td>
<td>119</td>
<td>112</td>
<td>109</td>
</tr>
</tbody>
</table>

**Table 2- Concentration of PM$_{10}$ (µg/m$^3$)**

<table>
<thead>
<tr>
<th>Location</th>
<th>1 May</th>
<th>16 May</th>
<th>30 May</th>
<th>Aggregate</th>
</tr>
</thead>
<tbody>
<tr>
<td>Railway Station</td>
<td>58</td>
<td>69</td>
<td>64</td>
<td>64</td>
</tr>
</tbody>
</table>

**PM2.5**
Bus Stand | 55 | 65 | 61 | 60
Main Market | 57 | 66 | 62 | 62
District Hospital | 54 | 71 | 61 | 62
District Court | 57 | 66 | 60 | 61
Central Park | 53 | 67 | 62 | 61
College Campus | 58 | 68 | 59 | 62
Vegetable Market | 57 | 71 | 58 | 62
Railway Colony | 56 | 72 | 57 | 62
Police Station | 58 | 68 | 58 | 61

**Table 3 – Concentration of PM$_{2.5}$ (µg/m$^3$)**

On the basis of data provided in table 2 and table 3, concerned graph for PM$_{10}$ and PM$_{2.5}$ concentrations are shown in following fig 1 and fig 2.

**Fig 1 – Graphical representation of PM$_{10}$ concentration**
Fig 2 – Graphical representation of PM$_{2.5}$ concentration

A total of 8 collection points were selected in Narsingpur city to analyse concentration of PM$_{10}$ and PM$_{2.5}$. In summer season it is found that Heat waves often lead to poor air quality. The extreme heat and stagnant air during a heat wave increase the amount of particulate pollution.

**Conclusion**

After studying the received values and comparing it with the standard categorization of Air Quality parameters in Table 4, we can conclude the following:

<table>
<thead>
<tr>
<th>Location</th>
<th>PM2.5 Aggregate</th>
<th>PM2.5 Category</th>
<th>PM10 Aggregate</th>
<th>PM10 Category</th>
</tr>
</thead>
<tbody>
<tr>
<td>Railway Station</td>
<td>64</td>
<td>Moderately Polluted</td>
<td>113</td>
<td>Moderately Polluted</td>
</tr>
<tr>
<td>Bus Stand</td>
<td>60</td>
<td>Satisfactory</td>
<td>105</td>
<td>Moderately Polluted</td>
</tr>
<tr>
<td>Main Market</td>
<td>62</td>
<td>Moderately Polluted</td>
<td>108</td>
<td>Moderately Polluted</td>
</tr>
<tr>
<td>District Hospital</td>
<td>62</td>
<td>Moderately Polluted</td>
<td>107</td>
<td>Moderately Polluted</td>
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<td>District Court</td>
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<tr>
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<td>111</td>
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<tr>
<td>Police Station</td>
<td>61</td>
<td>Moderately Polluted</td>
<td>109</td>
<td>Moderately Polluted</td>
</tr>
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</table>

Table 4: Categorisation of PM10 and PM2.5
REFERENCES: