Assessment of $PM_{2.5}$ Mass Concentration in Ambient Air of Jorhat, Assam

A dissertation submitted for the partial fulfilment of the requirements for the degree of B. Sc. in Chemistry (Paper DSE-603) under Dibrugarh University

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CERTIFICATE

*This is to certify that the dissertation entitled "**Assessment of $PM_{2.5}$ Mass Concentration in Ambient Air of Jorhat, Assam**" is submitted by **Sonkalpita Baruah**, a B.Sc. 6th semester student of the Department of Chemistry, N. N. Saikia College, Titabar for the partial fulfillment of B.Sc. degree in Chemistry (Paper: DSE-603), is a record of original research work carried out by her under the supervision of **Dr. Ashutosh thakur**, Scientist, CSIR-NEIST, Jorhat. She has fulfilled all the requirements for submitting the dissertation for the B.Sc. degree. The results embodied with this dissertation have not been submitted to any other college or institute for any other degree or diploma to the best of my knowledge.*

29/05/25

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CERTIFICATE

This is to certify that the project report entitled ***"Assessment of $PM_{2.5}$ Mass Concentrations in Ambient Air of Jorhat, Assam"***, submitted by ***Sonkalpita Baruah***, a student of B.Sc. 6th semester, Department of Chemistry, Nanda Nath Saikia College, Titabor, Jorhat, Assam, embodies the winter training carried out by him under my supervision and guidance during the period from 01/12/2024 to 20/01/2025 at Coal & Energy Group, CSIR-North East Institute of Science and Technology, Jorhat, Assam.

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I hereby declare that the project report titled "***Assessment of $PM_{2.5}$ Mass Concentrations in Ambient Air of Jorhat, Assam***" submitted to the Department of Chemistry, Nanda Nath Saikia College, Titabor, in partial fulfillment of the requirement of the award of the Bachelor of Science Degree in a record of Bonafide work carried out under the supervision and guidance of ***Dr. Ashutosh Thakur,*** Scientist, CSIR-NEIST, Jorhat. The matter embodied in this project has not been submitted by us for the award of any other degree.

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Abstract:

The study explored the issue of $PM_{2.5}$ air pollution around the CSIR-NEIST campus, located near the busy NH-37 highway in Jorhat, Assam, over a one-month period. The results showed consistently high levels of fine particulate matter, with concentrations ranging from 48.75 $\mu g/m^3$ to 75 $\mu g/m^3$. The average level was 57.22 $\mu g/m^3$, which is much higher than the World Health Organization's (WHO) 24-hour safe limit of 25 $\mu g/m^3$, and several concentrations exceeded India's National Ambient Air Quality Standards (NAAQS) 24-hour limit of 60 $\mu g/m^3$. These findings highlight a serious and ongoing air quality problem in the area. The pollution comes from several every day and seasonal sources, including crop burning, wood and biomass used for cooking and heating, emissions from small industries, and heavy traffic, especially from buses along NH-37. Even when traffic slowed down on weekends, pollution levels stayed high, showing that the problem is more complex than just vehicle emissions.

Keywords: Air pollution, Air Pollutant, $PM_{2.5}$, PM_{10}, Mass concentration, Vehicle density.

1.Introduction:

Air represents a necessary mixture of gases, which will form this planet's atmosphere, providing the necessary components to sustain living things. It is predominantly made up of nitrogen, at about 78%, and oxygen, about 21%, with trace amounts of others such as argon, carbon dioxide, neon, helium, methane, and hydrogen. This mixture is integral to many biological, chemical, and physical processes. Although the exact makeup of air can differ slightly with geographical location, altitude, and environmental conditions, its basic ingredients are relatively unchanged. Nitrogen is the primary gas, serving as an oxygen diluent, and is essential to the nitrogen cycle, which is vital for plant growth. Oxygen is the second most abundant gas used in the respiration process of most living organisms, allowing for the conversion of food into energy. Although they constitute only trace concentrations, these gases also play important roles in the proper functioning of our atmosphere. Carbon dioxide, for instance, is crucial for plant photosynthesis, the way plants convert sun rays into energy. Ozone in the stratosphere protects life on Earth by shielding Earth from harmful ultraviolet radiation coming from the sun. This transcends the chemistry of air because it is absolutely essential to keeping life on earth alive. The atmosphere protects in the sense of maintaining temperatures to protect Earth from harmful rays in the sun and supports ecosystemic sustenance so that there might be proliferation across the diversified nature. It involves carbon dioxide, methane, water vapor, among a myriad of other gaseous compositions forming its makeup as natural greenhouse contributors or elements with relevance to keeping this Earth in moderate temperatures.

1.1 Chemical Composition of Air:

The Earth's atmosphere is a mixture of gases that is quite complex, with nitrogen (N_2) being the most abundant component, making up about 78% of dry air by volume. Oxygen (O_2) is the second most prevalent gas, constituting about 21% of the atmosphere. The remaining 1% is composed of trace gases, which include argon at 0.93%, carbon dioxide at about 0.04%, and traces of neon, helium, methane, krypton, and hydrogen, among others. Concentration in the air of water vapor (H_2O) varies profoundly from place to place and is a function of temperature, ranging from 0.01% to 4% by volume. This increasing presence of heavy metals in the air poses a concern, especially about anthropogenic influences and their eventual health impacts. They are mostly described as having an atomic weight ranging from 63.5 to 200.6 with a specific gravity over 5.0. The two forms-particulate and gaseous of these metals were of concern in the course of the present study for incorporation into atmospheric components. The most common heavy metals in air include lead (Pb), mercury (Hg), cadmium (Cd), chromium (Cr), arsenic (As), zinc (Zn), copper (Cu), and nickel (Ni). They all come from a variety of sources, which are mainly industrial activities. The volume of heavy metals discharged into the atmosphere by industry is enormous, ranging from mining and smelting to fossil fuel combustion, waste incineration, and vehicular emission. Lead is still a problem in many developing countries, despite the global phase-out of leaded gasoline, and can be found in the air near industrial areas. Mercury, mainly in its gaseous elemental form, can travel long distances in the atmosphere, and it is mainly emitted from coal-burning power plants, cement production, and artisanal gold mining. Cadmium pollution typically comes from metal production, battery manufacturing, and waste incineration. The concentration of heavy metals varies greatly with locale, weather patterns, and vicinity to emission sources. Urban and industrial areas have been found to have generally higher concentrations in comparison

to areas in the open countryside. Fine particulate matter ($PM_{2.5}$ and PM_{10}), as well as mercury, appear in the form of vapor in the air. Heavy metals suspended in the atmosphere can stay there for long and cover many distances before getting deposited to soil and water bodies through dry and wet deposition.

Table 1: Typical composition of dry air by volume near Earth's surface.

Gas	Symbol	Percentage (%) by volume
Nitrogen	N_2	78.8
Oxygen	O_2	20.95
Argon	Ar	0.93
Carbon dioxide	CO_2	0.04
Neon	Ne	0.0018
Helium	He	0.0005
Methane	CH_4	0.0002
Krypton	Kr	0.0001
Hydrogen	H_2	0.00005
Xenon	Xe	0.000009

1.2 Air Pollution and its Sources:

Air pollution is a major environmental and public health issue worldwide, with diverse sources and complex effects on human health, ecosystems, and the climate. Air pollution is a complex mixture of anthropogenic and naturally occurring particulate matter, noxious gases, and volatile organic compounds suspended within Earth's atmosphere. This harmful brew includes

direct-generating pollutants consisting of sulfur oxides, nitric oxides, and carbon monoxide from industrial practices, automobile vehicles, and all fossil fuel-combustions, as well as secondary gaseous contaminants like ground level ozone and any other photochemical oxidative compounds that appear through chemical formations in the earth's atmosphere. The widespread abundance of ultra fine particulate particles, especially in $PM_{2.5}$ and PM_{10}, presents very serious respiratory hazards because they reach deep into alveolar spaces in the pulmonary tissues. This atmospheric contamination leads to a chain of negative impacts, such as respiratory morbidity, cardiovascular complications, and the degradation of ecosystem health through acid rain and bioaccumulation of toxic substances. The synergistic interaction between these pollutants and meteorological conditions may lead to phenomena such as photochemical smog and thermal inversions, which enhance the concentration and persistence of airborne contaminants in urban environments.

The diverse sources of atmospheric pollution include a complex network of anthropogenic and biogenic emissions, which all combine to degrade the quality of the air. Industrial plants, including petrochemical complexes, metallurgical operations, and manufacturing installations, emit significant amounts of criteria pollutants, volatile organic compounds (VOCs), and hazardous air pollutants from their stack emissions and fugitive releases. Fossil fuel combustion in thermal power generation plants is an important source that emits sulfur oxides, nitrogen oxides, and particulate matter while increasing the atmospheric carbon dioxide load. Emissions from internal combustion engines of vehicles in the form of compression-ignition as well as spark-ignition types emit a complex mixture of pollutants such as carbon monoxide, unburned hydrocarbons, and nitrogen oxides, especially in urban agglomerations with dense traffic. Agricultural activities add significantly through volatilization of ammonia from livestock operations and fertilizer application and through the deployment of slash-and-burn techniques which emit particulate matter and

different pyrolytic products. The construction/demolition industry emits enormous amounts of fugitive dust loaded with crystalline silica and other respirable particles. Domestic operations, such as residential heating with biomass combustion and waste incineration, produce fine particulate matter and several organic pollutants. Natural sources, while frequently neglected, include volcanic eruptions that release sulfur dioxide and particulates, biogenic VOC emissions from vegetation, and windblown mineral dust from arid region.

1.3 Types of air pollutants:

Air pollutants come in various forms and can be categorized into several types. The most common air pollutants include particulate matter (PM), which consists of tiny particles suspended in the air, such as dust, soot, and smoke. Gaseous pollutants are another major category, including carbon monoxide (CO), nitrogen oxides (NOx), sulfur dioxide (SO2), and volatile organic compounds (VOCs). Ground-level ozone, formed by the reaction of NOx and VOCs in sunlight, is a significant component of smog. Greenhouse gases, such as carbon dioxide (CO2) and methane (CH_4), contribute to global warming and climate change. Other air pollutants include lead and other heavy metals, as well as persistent organic pollutants (POPs) like dioxins and furans. Some pollutants, like pollen and mold spores, are naturally occurring, while others, such as chlorofluorocarbons (CFCs) and radioactive contaminants, are primarily human-made. These various types of air pollutants can have significant impacts on human health, the environment, and the Earth's atmosphere, making their monitoring and reduction crucial for maintaining air quality and overall environmental health.

Table 2: Air pollutants and their major sources.

Air Pollutants	Major Sources
Particulate Matter ($PM_{2.5}$ and PM_{10})	Vehicle emission, industrial processes, construction and demolition, wood burning, agricultural activities.
Carbon monoxide (CO)	Vehicle exhaust, industrial processes, residential heating.
Nitrogen oxides (NO_x)	Vehicle emissions, power plants, industrial boilers.
Sulfur dioxide (SO_2)	Coal-fired power plants, industrial processes, volcanic eruptions.
Volatile organic compounds	Paints and solvents, gasoline stations, industrial process, vehicle emissions.
Ground level ozone (O_3)	Formed by NO_x and VOCs reaction in sunlight.
Lead (Pb)	Lead-batteries, metal processing industries, aviation fuel.
Carbon dioxide (CO_2)	Fossil-fuel combustion, deforestation, industrial processes.
Methane (CH_4)	Agriculture (livestock), oil and gas production.
Chlorofluorocarbon (CFC)	Refrigerants, aerosol propellants.
Ammonia (NH_3)	Agricultural activities, livestock waste, fertilizer production.

1.4 Particulate Matter (PM):

Particulate Matter (PM) is a heterogeneous assembly of solid particles and liquid droplets dispersed in the atmospheric medium, characterized by widely ranging physicochemical properties and diverse aerodynamic dimensions. Such atmospheric aerosols encompass a very broad spectrum of morphological features, from the ultrafine particles with diameters <0.1 micrometers

(μm), the fine particles, up to coarse particles >10 μm. In this regard, the terms PM_{10} and $PM_{2.5}$ stand for particles of an aerodynamic diameter less than or equal to 10 and 2.5 micrometers respectively, while the latter is known as fine particulate matter owing to its strong potential for delivering a deep pulmonary effect. The chemical composition of PM is a very complex matrix containing inorganic compounds including sulfates, nitrates, ammonium, and diverse species of metals, both organic and elementary carbon, as well as biological species like endotoxins, cell fragments, and mineral dust. All the particles show substantial spatiotemporal variation in their composition according to primary sources of emission versus secondary formation due to atmospheric chemistry. The process of nucleation, condensation, and coagulation during which size distribution and chemical characteristics are modified impacts the atmospheric aerosols. Such aerosols have removal mechanisms like dry deposition, precipitation scavenging, and Brownian diffusion, controlling their atmospheric lifetime and generally smaller particle sizes, characteristically longer atmospheric life spans due to lower gravitational settling velocities.

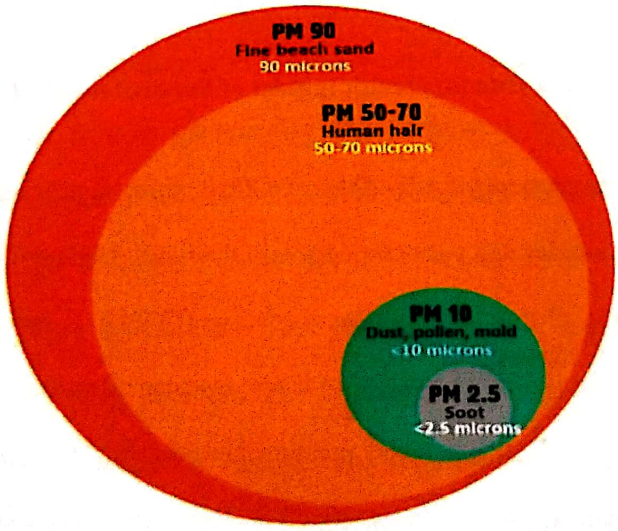

Fig 1: Size of particulate matters (PM_{10} and $PM_{2.5}$) in comparison with beach sand.

Table 3: Types of particulate matter and their primary sources.

Types of particulate matter	Size range	Primary Sources
PM_{10}(Course particle)	≤10μm	Road dust, construction/demolition, mining operations, agricultural activities, industrial processes
$PM_{2.5}$(Fine particle)	≤ 2.5μm	Vehicle exhaust, power plants, industrial combustion, residential wood burning, forest fires, secondary formation from gases.
$PM_{1.0}$(very fine particle)	≤ 1.0μm	Fresh vehicle exhaust, industrial combustion processes, welding operations, photochemical reactions in atmosphere, electronic equipment emissions, heating systems.

1.5 Environmental and Human Health Impact of Particulate Matter:

Particulate matter, specifically $PM_{2.5}$ and PM_{10}, poses significant environmental and health risks. These fine particles can penetrate deep into the lungs, leading to respiratory issues such as asthma and chronic obstructive pulmonary disease (COPD). Additionally, exposure to these pollutants is linked to an increased risk of cardiovascular diseases, including heart attacks and strokes, due to their effects on blood pressure and systemic inflammation. Exposure over a prolonged time span has also been categorized as carcinogenic, enhancing the likelihood of lung cancer and other cancers through mechanisms such as DNA damage and oxidative stress.

Moreover, $PM_{2.5}$ and PM_{10} can have adverse effects on neurological health, which may lead to cognitive decline and mental health problems. Especially vulnerable groups in this regard include children and the elderly, who call for specific strategies to minimize exposure and maintain their health.

Exposure to $PM_{2.5}$ and PM_{10} has been linked to an increased risk of cardiovascular disease, including heart attacks, strokes, and arrhythmias. This is due to the pollutants' ability to increase blood pressure, alter cardiac function, and promote systemic inflammation. Understanding this concept is vital in assessing the cardiovascular health impacts of $PM_{2.5}$ and PM_{10}. Background and objectives Exposure to particulate matter ($PM_{2.5}$) has been associated with increased cardiovascular outcomes, mediated by a hypothesized biological mechanism of systemic inflammation and oxidation (Dabass et al., 2016). Prolonged exposure to $PM_{2.5}$ and PM_{10} has been classified as carcinogenic to humans, increasing the risk of lung cancer and other types of cancer. This is due to the pollutants' ability to cause DNA damage, oxidative stress, and epigenetic changes. Understanding this concept is critical in assessing the cancer risk associated with $PM_{2.5}$ and PM_{10}. Long-term exposure to airborne $PM_{2.5}$ is associated with increased lung cancer risk but the underlying mechanism remains unclear. We also monitored plasma levels of candidate microRNAs in exposed subjects at varying levels of air $PM_{2.5}$ and further studied the abnormal expression of the targeted genes of these microRNAs in human lung cancer (Liu et al., 2015). Both $PM_{2.5}$ and PM_{10} have shown neurotoxic effects, causing cognitive impairment, anxiety, and depression. Since they can easily pass through the blood-brain barrier, $PM_{2.5}$ and PM_{10} induce oxidative stress, inflammation, and neurodegeneration. This concept is essential in understanding the neurological impacts of $PM_{2.5}$ and PM_{10}. A limited number of studies have been undertaken to assess the role of PM and UFP in CNS diseases, including migraine, headache, stroke, Alzheimer's

disease, and Parkinson's disease (Loane et al., 2013). Personal protective equipment, such as masks, can be effective in reducing exposure to $PM_{2.5}$ and PM_{10}. Understanding the effectiveness of these devices is crucial in developing strategies to protect public health, especially in areas with high levels of air pollution. PPE can also be used to protect the environment from the individual such as in the case of cleanroom apparel and medical devices for infection control (Stull, 2002). Environmental justice is a critical concept in understanding the disproportionate health impacts of $PM_{2.5}$ and PM_{10} on vulnerable populations, including low-income communities and communities of color. Understanding environmental justice is essential in developing effective strategies to reduce health inequities and promote environmental justice.

1.6 Air Quality Index (AQI):

The Air Quality Index, being a highly sophisticated numerical scale used to measure the amount of different air pollutants in the atmosphere, offers an essential and standardized approach for effectively communicating information on air quality to the general public in an understandable manner. It systematically classifies air quality into a range of discrete levels, including but not limited to the following: good, moderate, unhealthy, and hazardous, hence making it easier to communicate vital information to individuals concerning the possible health effects that could be experienced as a result of exposure to air pollution. The levels represented in the AQI are largely determined by a few principal pollutants, which include Particulate Matter (PM), Nitrogen Dioxide (NO_2), and Ozone (O_3), all of which play a key role in determining the overall level of air quality and its associated health effects.

1.7 Air pollution status of India:

India confronts a formidable atmospheric contamination predicament, with an overwhelming majority of its metropolitan centers exhibiting hazardous Air Quality Index (AQI) measurements. According to the World Air Quality Index (AQI) Report 2023, India harbors 14 of the world's 20 most polluted metropolitan regions, with Delhi persistently maintaining its position as the world's most polluted capital city, exhibiting an annual $PM_{2.5}$ concentration of 92.6 $\mu g/m^3$ approximately 18 times the World Health Organization (WHO) recommended threshold of 5 $\mu g/m^3$. The deteriorating air quality situation is particularly egregious in the Indo-Gangetic Plain, where a concatenation of anthropogenic and meteorological factors exacerbates the crisis. Industrial emissions contribute approximately 35% of $PM_{2.5}$ levels, while vehicular emissions account for 40% of nitrogen oxide concentrations in urban atmospheres. Agricultural residue combustion in neighboring states contributes to seasonal spikes, with Punjab and Haryana recording over 75,000 stubble burning incidents annually. The economic ramifications are equally devastating, with air pollution-related health issues causing productivity losses estimated at $150 billion annually, equivalent to 5.7% of India's GDP. The situation is further compounded by the fact that 63% of Indian monitoring stations reported $PM_{2.5}$ concentrations exceeding national standards (40 $\mu g/m^3$), while 99% exceeded WHO guidelines. Metropolitan regions like Mumbai, Kolkata, and Bangalore demonstrate annual average $PM_{2.5}$ levels of 54.3, 84.7, and 39.5 $\mu g/m^3$ respectively. The crisis has reached such proportions that approximately 1.67 million deaths annually are attributed to air pollution, with respiratory diseases, cardiovascular complications, and pulmonary disorders being the primary health implications.

1.8 Air pollution status of Assam (Jorhat):

Air pollution in Jorhat, Assam presents a complex environmental predicament that merits meticulous scrutiny. According to recent air quality monitoring data, Jorhat exhibits fluctuating levels of particulate matter (PM), with $PM_{2.5}$ concentrations frequently exceeding the National Ambient Air Quality Standards (NAAQS) threshold of 60 $\mu g/m^3$ during winter months. The city's Air Quality Index (AQI) often oscillates between 'moderate' to 'poor' categories, particularly during the pre-monsoon period when anthropogenic activities compound with natural dust suspension. The predominant pollutants in Jorhat's airshed include $PM_{2.5}$, PM_{10}, and NOx, with significant contributions from vehicular emissions along the arterial roads, especially near the Jorhat-Mariani Road junction. Industrial emissions from the tea processing units scattered across the district contribute substantially to the local air pollution matrix. Biomass burning, particularly during agricultural residue disposal seasons, exacerbates the situation, introducing considerable quantities of carbon monoxide and volatile organic compounds into the atmospheric column. The diurnal variation in pollution levels demonstrates peak concentrations during morning hours (0700-1000 hrs.) and evening periods (1800-2200 hrs.), correlating with heightened vehicular movement and temperature inversion conditions. The geographical positioning of Jorhat, coupled with its meteorological parameters such as wind speed (averaging 2-3 m/s) and relative humidity (typically 70-85%), influences pollutant dispersion patterns. The monsoon season (June-September) provides natural mitigation through wet deposition, temporarily ameliorating the air quality indices. The data indicates a gradual upward trend in pollution levels over the past quinquennium, necessitating implementation of stringent emission control protocols and sustainable urban development strategies.

2. Literature Review:

Kalaiarasan et al. (2018) conducted a source apportionment study on particulate matter (PM_{10} and $PM_{2.5}$) in urban Mangalore, India, where measurements exceeded national ambient air quality standards (NAAQS) limits, with the highest concentrations of 231.5 $\mu g/m^3$ for PM_{10} and 120.3 $\mu g/m^3$ for $PM_{2.5}$. Chemical mass balance (CMB) modeling revealed that vehicular emissions contributed 70% to both PM_{10} and $PM_{2.5}$, with paved road dust and diesel/gasoline vehicle emissions being major sources for PM_{10}, and two-wheeler, four-wheeler, and heavy vehicle emissions contributing significantly to $PM_{2.5}$.

Tiwari et al. (2009) examined PM_{10}, $PM_{2.5}$, and PM_1 mass concentrations in Delhi, India, from August to December 2007 and reported large variations with ranges of 20-180 $\mu g/m^3$ during the monsoon season and 100-500 $\mu g/m^3$ in winter, with a maximum up to 1200 $\mu g/m^3$ during Deepavali fireworks. Their study indicated that increased particulate matter concentrations were associated with peaks in relative humidity and decreased levels with peaks in ambient temperature. Simulations based on mean mass scavenging coefficients have shown varying washout characteristics for PM_{10} versus $PM_{2.5}$ and PM_1 for varying rainfall durations. Air-mass pathway analysis employing the HYSPLIT (Hybrid Single-Particle Lagrangian Integrated Trajectory) model further captured the role of monsoon and winter air-mass circulations in the observed concentrations of PM_{10}, $PM_{2.5}$, and PM_1 in Delhi.

Yadav et al. (2023) conducted a study on assessment of Fine Particulate matter ($PM_{2.5}$) and its inimical impact on environment and human health in Agra. Their several analysis such as inductive coupled plasma mass spectroscopy (ICP-MS), inductive coupled atomic emission spectroscopy (ICP-AES), atomic adsorption spectroscopy (AAS) , inductive coupled plasma

optical emission spectroscopy (ICP-OES) showed the presence of various heavy metals including Pb, Zn, Ni, Fe, Mg, Mn, Cr, Cu, Cd, C, Si, Al, Na, S, K, Fe, Mg, Ca, F, Ba, As, Co, Mo, Be, V, Sc and B in the ambient air. The authors states that the presence of heavy metals in $PM_{2.5}$ is a major concern, as these elements can contribute to a range of health problems, including respiratory illness, cardiovascular disease, infertility and cancer. This research also highlights the importance of considering the impact of seasonal variations on $PM_{2.5}$ levels, as higher concentrations are observed during the winter months due to increased residential heating and decreased atmospheric dispersion. They reported that the average $PM_{2.5}$ concentration in Agra has been found to be between 6-32 times higher than the WHO limit and 1-4 times higher than the NAAQS limit. $PM_{2.5}$ concentrations in Agra are highest in winter (91.2 $\mu g/m^3$ to 350.92 $\mu g/m^3$), followed by post-monsoon (92.1$\mu g/m^3$ to 143.3$\mu g/m^3$), summer (56.1$\mu g/m^3$ to 112 $\mu g/m^3$), and monsoon (28$\mu g/m^3$ to 125$\mu g/m^3$).

Radulescu et al. (2017) studied to investigate the chemical composition of airborne particulate matter ($PM_{2.5}$) collected from Targoviste city area in the summer of 2015. In this study authors utilized three analytical techniques to perform qualitative, quantitative and morphological characterization of PM. In this study, the content of nine elements (Pb, Cd, Cr, Ni, Cu, Mn, Al, Zn, and Fe) is determined using Inductively Coupled Plasma - Mass Spectrometry (ICP-MS). The measured concentration of these metals is then compared with values reported by the International Agency on urban area to determine the minimal element level which cannot be considered as a potential health risk for the urban population. Authors used Scanning Electron Microscopy - Energy Dispersive Spectrometry (SEM-EDS) to analyze the morphological characteristics of $PM_{2.5}$ samples. They performed elemental analysis of samples using EDS, revealing that airborne particles mainly consist of elements like C, O, Si, Ca, N, and S and inorganic and organic

functional groups (CO_3^{2-}, NH_4^+, SiO_4^{2-}, NO_3, carbonyl and aliphatic carbons are present) of PM samples are studied using Attenuated Total Reflectance - Fourier Transform Infrared Spectrometry (ATR-FTIR). The study's results highlight the importance of understanding the chemical composition of PM2.5, as it can contribute to understanding the potential health risks associated with exposure to these particles and inform effective mitigation strategies.

Cachon et al., 2023 presents a thorough physicochemical characterization of airborne particulate matter ($PM_{2.5}$ and $PM_{>2.5}$) collected in Cotonou, Benin. They apply a range of techniques including laser granulometry, BET method, ICP-MS, IC, CHNS analysis, and GC-MS to determine the physical and chemical properties of PM samples. Results from their analysis showed that $PM_{>2.5}$ samples have agglomerates of fine particles, and $PM_{2.5}$ samples showed higher concentrations of inorganic elements and organic compounds, which dominated the anthropogenic origin. In the analysis of water-soluble ions, they noticed that Ca^{2+}, SO_4^{2-}, NO_3^-, Na^+, and Cl^- were at relatively higher concentrations associated with traffic emission, sea salt influence, and industrial activities. The other findings of their study indicate that PAHs ratios and fatty acids ratios potentially point to key sources of pollution. Indeed, the significantly high concentrations of PAHs, especially benzopyrene, point to significant contributions from vehicle exhaust and incomplete combustion. Therefore, their study concludes that PM in Cotonou comes from anthropogenic origins.

Rabha et al. (2022) conducted a study on the atmospheric particulate matter composition in the urban area of Jorhat, India. In this study, they analyzed the rare-earth elements and heavy metals by using the PMF model for source apportionment of PM_{10}. According to their findings, PM_{10} concentrations are almost near the limit of the CPCB but more than the WHO limit. They

analyzed PM_{10} samples to determine the elemental composition using high-resolution inductively coupled mass spectrometry (HR-ICPMS) and reveals that the concentrations of heavy metals are below critical levels prescribed by WHO for Europe, except for Fe, Zn and Ba. The mean total REE concentration (ΣREE) in PM_{10} was 0.97 ± 0.59 ng m^{-3}, with a positive anomaly of Eu and Tm, suggesting anthropogenic and natural contributions. They found that there were five major sources of PM_{10} in the urban area mainly from combustion of coal and vehicular emission followed by biomass burning, soil dust, and industrial emission. This study is the first to report the presence of valuable REEs in Indian atmospheric particulate samples.

Varrica and Alaimo.,2022 studied the trace element solubility in PM_{10} and $PM_{2.5}$ in Palermo, Italy. They collected daily filter samples of PM_{10} and $PM_{2.5}$ from three sampling stations: one urban, one suburban, and one rural. The elemental composition of the particulate matter was determined by ICP-MS. The water-soluble trace elements were calculated by ICP-MS after leaching of the samples with ultrapure water. They identified the enrichment factor, leaching coefficient, and major ion constituents of particulate matter. The authors found that PM_{10} and $PM_{2.5}$ concentrations at the urban site were greater than at the suburban and rural sites. In addition, they reported the enrichment factors of Cu, Mo, Sb and Zn being higher than 20, implying an anthropogenic origin. The leaching coefficient was larger than 40% for Sr in PM_{10}, and larger than 35% for Zn, Cu, Mo, Ni, and Sb in $PM_{2.5}$. This clearly shows that it is more bioavailable. Factor analysis revealed three types of sources to be water soluble: anthropogenic, geogenic and sea spray. This study establishes that the high levels of heavy metals and their solubility in the urban area are a public health concern, hence demanding further research and mitigation efforts.

Sonwani and Kulshreshtha.,2019 discussed the morphological and elemental characterization of PM_{10} and TSPRW samples collected from two sites: Jawaharlal Nehru University (JNU) and Badarpur industrial area (BDP) in Delhi, India. The authors had used scanning electron microscopy coupled with energy dispersive X-ray spectrometer (SEM-EDX) to analyze the morphology, elemental composition and source identification of the samples. The results indicate that the major constituents of PM_{10} at JNU are soot aggregate\es, Fe-rich particles, calcium/potassium sulfate crystals, and biological particles. BDP samples have a large amount of fly ash particles, aluminosilicate particles, and high carbon contents, indicating a significant contribution from coal power plants and vehicle emissions. This study uses Enrichment Factors (EFs) to further explore the sources of elements. The results show strong enrichment factors of C, N, and F at both locations, which have a strong input from anthropogenic sources. Mixed sources were identified by the EFs for S and Pb since both natural and anthropogenic components are present in these elements. Non-enriched values in the EFs for Cl, Ca, and Fe indicate these elements are contributed mainly by natural sources. The findings underscore the importance of considering both morphological and elemental analysis to understand the complex sources of air pollution in Delhi, India. Their study points out that coal power plants, vehicles, industries, and natural sources like sea salts and mineral dust play a crucial role in the elemental composition of aerosols in this region

Chen et al. (2015) conducted a study at Nankai University on the heavy metal pollution of $PM_{2.5}$ in Tianjin, China, was assessed through the analysis of ambient $PM_{2.5}$ samples collected in June, August, and October 2012. In this study, the concentrations of $PM_{2.5}$ and heavy metals—specifically Ni, Cu, Pb, Zn, Cr, Cd, Hg, As, and Mn—were determined using gravimetric analysis and inductively coupled plasma-mass spectrometry (ICP-MS). Their findings revealed that the

heavy metals were present in the following descending order of concentration: Cu, Zn, Pb, Mn, Cr, Ni, Cd, As, and Hg. Notably, the concentration of cadmium (Cd) exceeded the secondary level of the National Ambient Air Quality Standard of China (GB 3095-2012) by 1.3 times, while the other metals remained within permissible limits. Enrichment factor analysis suggested that Cu, Zn, Cd, Pb, and Hg predominantly originated from anthropogenic sources. Principal component analysis further identified vehicle exhaust, chemical waste, and coal-burning activities as the primary contributors to heavy metal emissions. This study highlighted the potential health risks associated with exposure to these metals via the respiratory system, ranking them in terms of risk levels: Cr, Cd, As, Ni, Cu, Pb, Mn, Zn, and Hg. They concluded that the risk levels for all nine metals were found to be below the acceptable threshold set by the U.S. EPA (10−6/year), indicating a relatively low risk to human health from these pollutants in the studied area.

Lee et al., 2013 analyzed the distribution of about 19 elements in $PM_{2.5}$ samples collected from a roadside sampling station in Daejeon, Korea. The study used collision cell technology-inductively coupled plasma-mass spectrometry (CCT-ICP-MS) for the elemental analysis. The authors used SRM 2783 air particulate filter media from the National Institute of Standards and Technology (NIST) for quality assurance. They found that relative errors for most elements are lower than 30% and standard deviations of the repetitive analysis also lower than 20%. Distribution ranges for measured elements were over four orders of magnitude. They have used enrichment factor analysis to find that Sb, Se, Cd, As, Zn, Pb, and Cu are highly enriched in $PM_{2.5}$ samples; this is considered an anthropogenic source. The enrichment factor values of these elements were much higher than those of the major crustal elements, such as Al, Ca, K, Ti, and Si, which implied a significant contribution from anthropogenic sources. The correlation analysis indicated a strong correlation between $PM_{2.5}$ and major crustal elements, such as Fe, K, Ti, and Si, indicating that the

concentrations of $PM_{2.5}$ near the roadside were mainly affected by resuspended road dust. Their study also established significant relationships between the elements emitted from vehicular emissions and fossil fuel combustion, which agrees with their enrichment factor analysis,

Manousakas et al., 2014 investigated the water-soluble and acid-soluble fractions of $PM_{2.5}$ samples collected from two different Greek cities, Patras and Megalopolis, using ICP-MS for chemical analysis. In this study, the total elemental analysis was carried out by microwave assisted digestion with a mixture of HNO3 and HF, while water was selected as the extraction solvent for the water-soluble fraction. To confirm the extraction procedure, recoveries were conducted on two certified reference materials, namely, NIST SRM 1648 Urban Particulate Matter and NIST 1649a Urban Dust. The concentrations of the total extracted metals from the two certified materials are shown to be highest for Zn and lowest for Co. Nickel is found to be the most soluble, while Fe and Ti showed the least solubility. The LOD was calculated using three times the standard deviation of the blank values. The accuracy and precision of the extraction protocol were evaluated by the use of the SRMs NIST 1649a Urban Dust and NIST 1648 Urban Particulates. The authors found that the concentrations of Cd, Cr, Cu, Fe, Mn, Ni and Pb were not significantly different between the two cities. However, As, Co, Rb, Sr, Ti, V and Zn were enriched significantly in Patras compared to Megalopolis. The water-soluble fractions of Cd, Co, Cu, Ni, Sr, V and Zn were significantly higher in Patras than in Megalopolis, suggesting that anthropogenic sources contribute more to $PM_{2.5}$ levels in Patras. The authors concluded that the concentration of Cd in Patras exceeds the European Commission's assessment threshold, and that the concentration of water-soluble metals in both cities exceed the levels associated with an increased risk of pediatric asthma. Ent factor analysis.

Graney et al., 2004 conducted a study on human exposure and epidemiological study in Baltimore, MD, to enhance characterization and source apportionment of human exposure study samples. Their study focused on the application of Inductively Coupled Plasma Mass Spectrometry (ICP-MS), Energy Dispersive X-ray Fluorescence (XRF), and Instrumental Neutron Activation Analysis (INAA) to determine the concentrations of water- and acid-extractable metals in PM2.5 collected on Teflon filters. Their results demonstrated that the leaching procedure led to partial extraction of metals from the $PM_{2.5}$, with most of the extractable components of the metals being in a water-soluble form. A comparison of $PM_{2.5}$ trace metal concentrations from indoor air samples collected from a central indoor site versus concurrently collected personal exposure (PE) samples indicated that resident activities result in exposure to higher concentrations of soluble trace metals. The median amounts of elements determined by XRF and INAA were compared to ICP-MS results. They found that the solubility of individual elements ranged from as low as 17% (Ti) to as much as 100% (La and Zn) and the solubility of each element was found to be different, suggesting that different elements have different potential bioavailability from respiratory exposure to particulate material.

Saxena et al., 2022 studied the Diwali firecrackers contribution to air quality in Lucknow City, India. Their study monitored the air quality during the Diwali festival of 2020 with particulate matter (PM_{10} and $PM_{2.5}$), gaseous pollutants (SO_2 and NO_2), water-soluble ions, and 17 metallic elements using ICP-MS, ion chromatograph, and SEM-EDX. The researchers used air samplers placed at 7 locations representing air pollution hotspots across the city; residential, commercial, and industrial areas. Their results revealed that concentrations of PM_{10}, $PM_{2.5}$, SO_2, and NO_2 were substantially higher on Diwali night compared to the pre-Diwali and post-Diwali night. The average concentration of PM_{10} during the nighttime of Diwali was 558 $\mu g/m^3$ exceeding NAAQS

by 458% and WHO by 1140%. The authors also found a significant increase in the concentration of metals associated with PM_{10} and $PM_{2.5}$ particles, particularly Al, K, Ba, and B in PM_{10} and Zn, Al, Ba, and K in $PM_{2.5}$. They concluded that the burning of firecrackers during Diwali significantly contributes to air pollution in Lucknow City, posing a serious threat to human health due to the release of toxic elements and fine particulate matter. This study's findings bring out the need for regulatory approaches to reduce air pollution as well as give a push towards greener crackers to make Diwali less polluting.

3. Method and Methodologies:

3.1 Study Area:

Jorhat is the district of Upper Assam and one of the state's fastest expanding metropolitan areas. Jorhat is located at 26.75°N and 94.22°E. It has an average elevation of 116 meters (381 feet). The municipality covers an area of 9 square kilometers (3.5 sq mi) and has 19 wards with a population of 71,398 as per the 2011 census. The district spreads over 2,851 square kilometers (1,101 sq mi) and had a population of 870,000 according to a 1991 census. Population density at that time was 306 persons per square kilometers (793/sq mi). Jorhat has a mild to moderate climate. Summers here receive a lot of rain, while winters get very little. The temperature here averages 23.7 °C (74.7 °F). Annual precipitation amounts to approximately 2699 mm / 106.3 inches. The NH-37 highway grapples with considerable traffic problems, causing congestion and environmental issues. Heavy traffic, especially during peak hours, includes commercial vehicles, private cars, and two-wheelers. The numerous tea gardens along the route result in frequent heavy vehicle movement, causing bottlenecks. During harvest seasons, agricultural vehicles exacerbate road congestion. Bus traffic on NH-37 contributes notably to air pollution levels in Jorhat. The continuous operation of state and private buses results in substantial diesel emissions. Long-distance buses frequently idle during stops, increasing pollutants like sulfur dioxide and particulate matter. Pollution levels peak during high travel seasons due to increased bus service frequency. Older bus models often exceed current emission standards, leading to higher pollutants. Jorhat's geographical features further trap pollutants, particularly in winter. The concentration of bus terminals along NH-37 heightens pollution exposure for local inhabitants. The persistent operation of buses severely compromises air quality along the highway. The contributions of two-wheelers and light motor vehicles to pollution are particularly pronounced in winter. Winter temperature

inversion traps cold air, hindering pollutant dispersion. The heavy presence of two-wheelers and personal vehicles creates a consistent emission of harmful exhaust. Additionally, cold engines in winter require prolonged warm-up times, increasing fuel consumption and emissions.

3.2 Sample Collection:

Atmospheric particulate matter samples ($PM_{2.5}$ and PM_{10}) were collected from the parking zone of CSIR-NEIST, near NH-37, Jorhat, Northeast India (26º44′16.08″N and 94º9′20.9″E). Sampling was carried out from 17th December 2024, to January 24, 2025, everyday (8 hrs. per day) on glass microfiber filter papers utilizing $PM_{2.5}$ sampler (APM550, Envirotech, India) and PM_{10} sampler (APM460 NL, Envirotech, India). Mass concentrations of $PM_{2.5}$ and a PM_{10} were determined with the gravimetric method, calculating the mass difference between the pre-and post-weighted filter paper.

Fig 2: Parking zone of sampling site at CSIR-NEIST, Jorhat

Fig 3: During the sampling process of $PM_{2.5}$ sampler.

3.3 Instrumentation and Working Principle:

APM550 Sampler (Ambient Particulate Matter 550): Ambient air enters the APM 550 MFC sampler through an omnidirectional inlet designed to provide a clear aerodynamic cut-point for particles larger than 10 microns. The airstream then passes through a WINS (Windows Internet Name Service) Impactor that retains the fraction between PM_{10} and PM $_{2.5}$. The PM_{10} and $PM_{2.5}$ impactors used in the APM550 MFC (Mass Flow Controller) are based on designs standardized by USEPA (United States Environmental Protection Agency), and as such, the system complies with international norms for $PM_{2.5}$ samplers. The sampling rate is held constant at 16.7 LPM (liters per minute) by a mass flow controller. An ambient air temperature sensor and barometric pressure sensor have been provided to automatically compensate for temperature and pressure while reporting flow rate in volumetric flow units. The APM550 MFC has an in-built data logger that records air temperature, filter temperature, and flow rate and also totalizes and records the volume

of air sampled. PC-based software is provided for downloading the monitoring data. (www.envirotechindia.com)

Fig 4: Fine Particulate Sampler, APM550 (Envirotech, India)

APM460 NL Sampler (Ambient Particulate Matter 460 Noiseless): The APM 460 NL is used for monitoring PM_{10} in the ambient air in Eco-Sensitive Areas. The special design of the blower impeller and acoustic material used in the blower ensures that it does not produce any unpleasant noise while in operation. Thus, the machine can be operated even in silent areas like a library, hospitals, wildlife sanctuary and other noise-sensitive areas, including residential areas. The APM 460 NL sampler uses an improved cyclone (with a sharper cutoff) to separate the coarser particles (>10 microns) from the air stream before filtering it on the 0.5-micron pore-size filter, allowing a measurement of both TSP and the respirable fraction of suspended particulate matter (National Environmental Engineering Research Institute, CSIR-NEERI). An additional advantage of this blower is a very low variation in flow rate in the 190-230V input power supply range, and

because of the brushless motor, equipment downtime and maintenance efforts are also considerably reduced. (www.envirotechindia.com)

Fig 5: Particulate Sampler, APM460 NL (Envirotech, India)

4. Objective of the study:

This study aims to measure the levels of $PM_{2.5}$ in the area around CSIR-NEIST in Jorhat, Assam, over the course of one month. The goal is to see how these levels compare to the safety limits set by both the World Health Organization (WHO) and India's National Ambient Air Quality Standards (NAAQS). By doing this, the study hopes to better understand the extent of air pollution in the area and highlight any health or environmental concerns that may come from long-term exposure to polluted air.

5. Result and Discussion:

The mass concentrations of $PM_{2.5}$ found in the sampling site are given below:

Table 4: $PM_{2.5}$ mass concentration for 24 hrs. in $\mu g/m^3$ in CSIR-NEIST campus.

Date	Mass concentration	NAAQS's limit for 24 hrs.	WHO's limit for 24 hrs.
18/12/2024	62.5	60	25
19/12/2024	50	60	25
20/12/2024	48.75	60	25
21/12/2024	65	60	25
23/12/2024	50	60	25
24/12/2024	52.5	60	25
25/12/2024	50	60	25
26/12/2024	62.5	60	25
27/12/2024	50	60	25
28/12/2024	50	60	25
30/12/2024	62.5	60	25
31/12/2024	62.5	60	25
1/1/2025	75	60	25
2/1/2025	50	60	25
3/1/2025	50	60	25
4/1/2025	71.25	60	25
6/1/2025	50	60	25
7/1/2025	62.5	60	25
8/1/2025	50	60	25
9/1/2025	75	60	25
10/1/2025	53.75	60	25
11/1/2025	62.5	60	25
15/1/2025	50	60	25
16/1/2025	56.25	60	25
17/1/2025	50	60	25
18/1/2025	50	60	25
20/1/2025	50	60	25
21/1/2025	50	60	25
22/1/2025	70	60	25
23/1/2025	50	60	25
24/1/2025	68.75	60	25

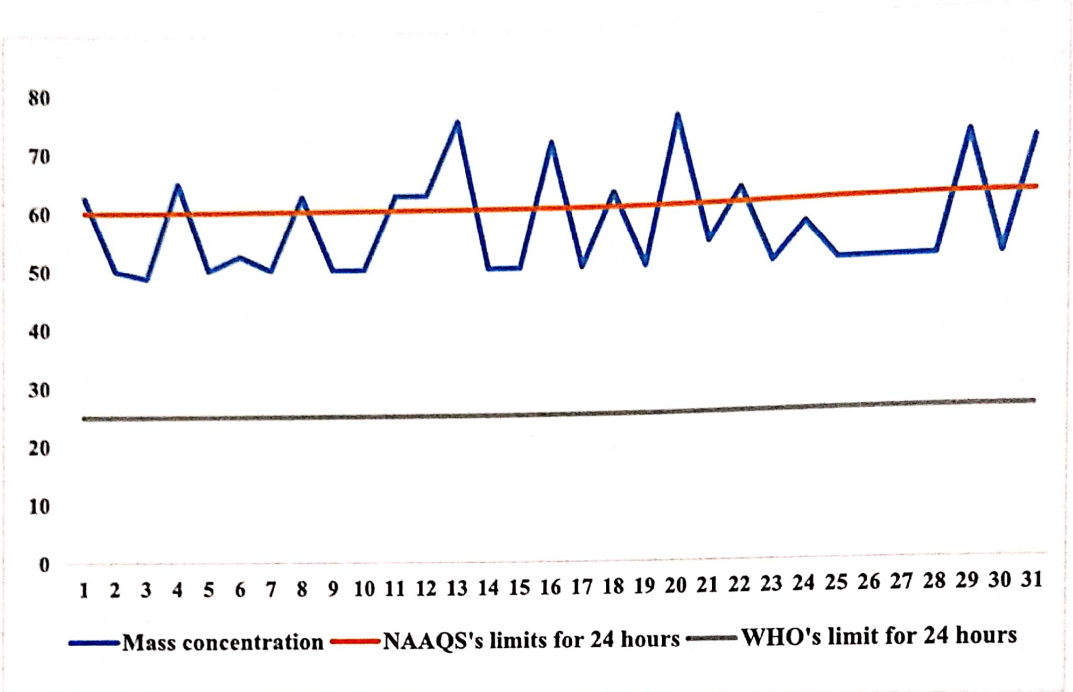

Fig 6: Comparison of $PM_{2.5}$ mass concentration with NAAQS and WHO.

Table 5: Statistical data from Table 4.

Statistical measures	Values (µg/m³)
Mean (Average)	57.22
Median	52.5
Range	26.5
Highest	75
Lowest	48.75

The maximum $PM_{2.5}$ concentration recorded during the one-month sampling period was 75 µg/m³, while the minimum was 48.75 µg/m³, resulting in a range of 26.5 µg/m³. Some

concentrations exceeded the National Ambient Air Quality Standards (NAAQS) 24-hour permissible limit of 60 µg/m³, and all concentrations of PM2.5 were above the World Health Organization (WHO) recommended 24-hour guideline of 25 µg/m³. The monthly average concentration was 57.22 µg/m³, which is significantly higher than both the WHO's annual guideline of 5 µg/m³ and the NAAQS annual limit of 40 µg/m³, indicating elevated levels of $PM_{2.5}$ throughout the sampling period.

The area around CSIR-NEIST struggles with consistently high levels of $PM_{2.5}$ pollution, much of it coming from a mix of everyday activities and seasonal events. During harvest time, farmers often burn leftover crop residue, which releases large amounts of particulate matter into the air. Nearby communities also rely on burning wood and other biomass for cooking and warmth, especially during colder months, which adds to the pollution. Small local factories contribute as well, steadily pumping out emissions into the surrounding neighborhoods. In winter, the problem gets even worse due to temperature inversions that trap pollutants close to the ground, keeping the dirty air from dispersing.

Table 6: Vehicle survey conducted during $PM_{2.5}$ sampling.

Date	Time	Total Vehicles
20/12/2024	11-12	1515
21/12/2024	11-12	1290
22/12/2024	10-11	932
23/12/2024	3-4	1310
24/12/2024	2-3	1145
25/12/2024	9-10	1107
26/12/2024	12-1	1055
27/12/2024	2-3	1288
28/12/2024	3-4	1167
02/01/2025	9-10	987

One of the biggest contributors, however, is traffic, especially along NH-37 near CSIR-NEIST. The road sees heavy use throughout the week, with buses and other vehicles constantly on the move. Buses in particular, with their frequent stops and long idling times, release a significant amount of $PM_{2.5}$. Our vehicle survey data showed that traffic is lighter on weekends, which led to a small dip in pollution levels, but even then, the air quality didn't improve much. Throughout the sampling period, $PM_{2.5}$ concentrations remained worryingly high, frequently crossing both the Indian government's 24-hour safety limit of 60 $\mu g/m^3$ and the World Health Organization's guideline of 25 $\mu g/m^3$. It paints a clear picture: air pollution in this area isn't just an occasional problem; it's a persistent challenge that demands attention.

6. Future Work:

To further investigate the extent of ambient air pollution caused by heavy metals, it is essential to employ highly sensitive and precise analytical techniques. Inductively Coupled Plasma Mass Spectrometry (ICP-MS) stands out as one of the most powerful methods for detecting and quantifying trace levels of metals and metalloids in ambient air aerosol samples. Due to its low detection limits, wide dynamic range, and capability for multi-element analysis, ICP-MS is particularly suitable for monitoring airborne particulate matter and evaluating its metal content. A critical step before ICP-MS analysis is the preparation of samples to ensure accurate, reproducible, and representative results. Sample preparation typically involves the collection of airborne particles, followed by processes such as digestion, dilution, and filtration. Proper sample preparation not only minimizes potential contamination but also ensures that the analytes of interest are fully solubilized and compatible with the ICP-MS system. In the following sections, we will discuss the detailed sample preparation workflow for ICP-MS analysis of heavy metals in ambient air samples, including sampling techniques, acid digestion procedures, and quality control measures to validate the analytical results.

6.1 Sample Preparation:

The samples were retrieved with glass microfiber filter paper. The filter paper was cut into a ½ strip. Once the filter paper was cut, microwaves were used to digest the samples. This method ensures that the samples are successfully digested prior to analysis. The use of quartz filter paper plays a pivotal role in minimizing contamination and ensuring the integrity of acquired samples throughout the processing process.

6.2 Microwave Digestion:

Microwave digestion was performed on the samples using a specific protocol. Initially, 10 ml of concentrated nitric acid (HNO_3) and 2 ml of hydrogen peroxide (H_2O_2) were added to a microwave vessel containing ½ of the glass microfiber filter paper. The samples were then subjected to microwave digestion at 180°C for 50 minutes. Following the digestion process, the resulting solutions were carefully transferred into centrifuge tubes. To ensure thorough homogenization and standardization of the samples, sonication was conducted for approximately 120 minutes. This method effectively breaks down the samples, facilitating subsequent analysis by ensuring that the elements of interest are in a suitable form for detection and qualification.

6.3 Sample Dilution and Preparation for ICP-MS Analysis:

Following sonication, the samples were subjected to a dilution process to prepare them for analysis. Specifically, 1 mL of the digestate sample was combined with 9 mL of distilled water, resulting in a 1:10 dilution. This mixture was then thoroughly mixed to ensure homogeneity.

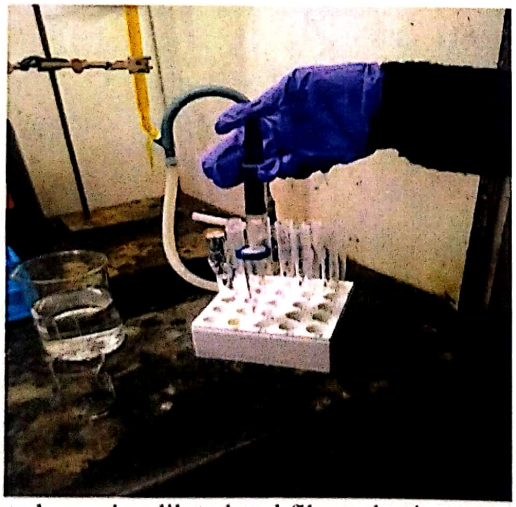

Fig 7: Digested samples diluted and filtrated using a 0.4-micron syringe filter.

Subsequently, the diluted samples were filtered using a syringe filter with a pore size of 0.22 microns to remove any particulate matter that could interfere with the analysis. The filtered samples were then prepared for Inductively Coupled Plasma Mass Spectrometry (ICP-MS) analysis. This standardized procedure ensures that the samples are adequately diluted and free from particulates, thereby facilitating accurate and reliable ICP-MS results.

6.4 Working Principle of ICP-MS:

The sample of interest is prepared for analysis, which may include various sample preparation techniques such as digestion, dilution, extraction, or filtration. The sample is then introduced into the ICP-MS instrument. Inductively Coupled Plasma (ICP) Generation: The sample is aerosolized and introduced into an argon plasma generated by an inductively coupled plasma torch. The torch generates a high-temperature plasma by using radio frequency (RF) energy to induce an electric field. The plasma reaches temperatures of around 6,000-10,000 Kelvin. Ionization and Excitation: In the plasma, the high temperatures cause the atoms in the sample to undergo ionization and excitation processes. Electrons from the outer shells of the atoms are promoted to higher energy levels or completely removed, resulting in the formation of ions.

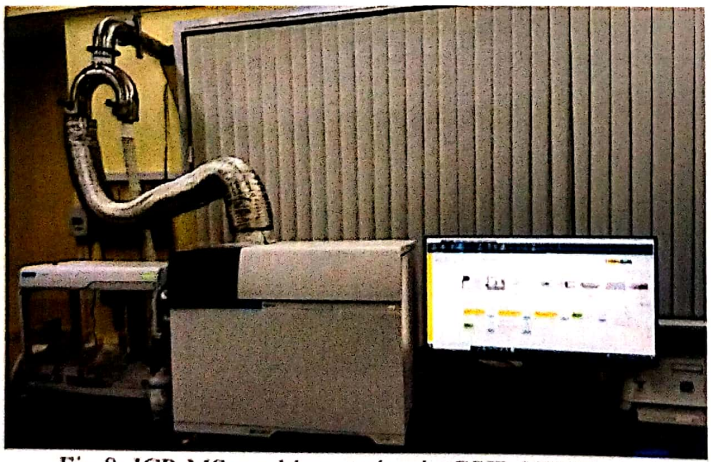

Fig 8: ICP-MS working station in CSIR-NEIST, Jorhat.

Mass Separation: Ions removed from the plasma are drawn into a mass spectrometer. In this instrument, it is possible to apply a combined electric and magnetic field to make the ions be separated according to their m / z ratio (mass-to-charge ratio). Such separation could be done employing a mass analyzer such as a quadrupole, a magnetic sector, or a time-of-flight (TOF) analyzer.

Ion Detection: The separated ions are detected by an ion detector, which measures their abundance. The most common type of detector used in ICP-MS is a Faraday cup detector, which measures the ion current. Other types of detectors, such as electron multipliers or ion-to-photon detectors, may also be used in certain configurations.

Data Acquisition and Analysis: The detected ion signals are collected and processed by the instrument's data acquisition system. The system converts the ion currents into digital data, generating a mass spectrum. The mass spectrum displays the intensity of ions at different m/z values, providing information about the elemental composition and concentrations of the analytes present in the sample.

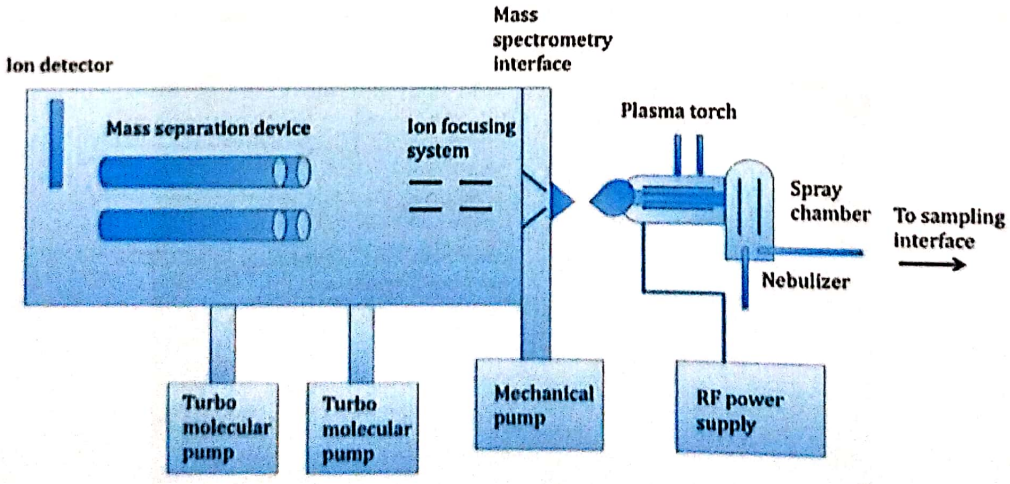

Fig 9: Schematic diagram of ICP-MS.

7. Conclusion:

This research sheds light on the ongoing challenge of $PM_{2.5}$ pollution around CSIR-NEIST, with consistently high pollution levels throughout the study period. The data shows that $PM_{2.5}$ concentrations ranged from 48.75 $\mu g/m^3$ to 75 $\mu g/m^3$, with an average of 57.22 $\mu g/m^3$, all of which are well above the World Health Organization's recommended limit of 25 $\mu g/m^3$ and the Indian government's safety limit of 60 $\mu g/m^3$ for 24-hour exposure. The pollution sources are diverse, including seasonal crop burning, biomass burning for cooking and heating, emissions from small local industries, and high traffic volumes along NH-37, especially buses that contribute heavily to pollution. Even though traffic is lighter on weekends, pollution levels still remain high, showing that the issue is complex and driven by multiple factors. This research highlights the urgent need for better air quality monitoring, more effective pollution control measures, and increased awareness about the health risks of long-term exposure to fine particulate matter. It's clear that tackling this problem will require a coordinated approach from both the community and local authorities.

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9. Photo Gallery:

Fig 1: Sampling zone of CSIR-NEIST.

Fig 2: During sampling time.

Fig 3: Digital analytical balance.

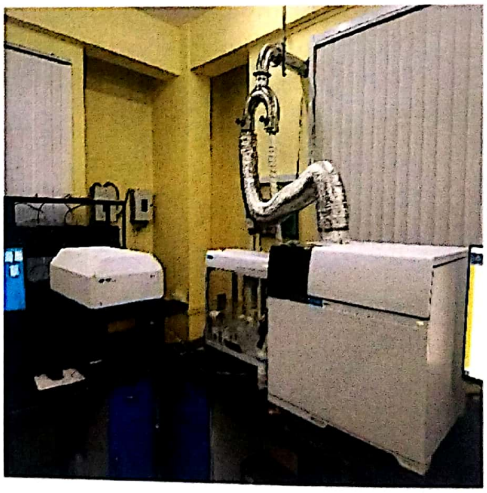

Fig 4: ICP-MS working station.

Fig 5: Glass fiber filter paper before sampling.

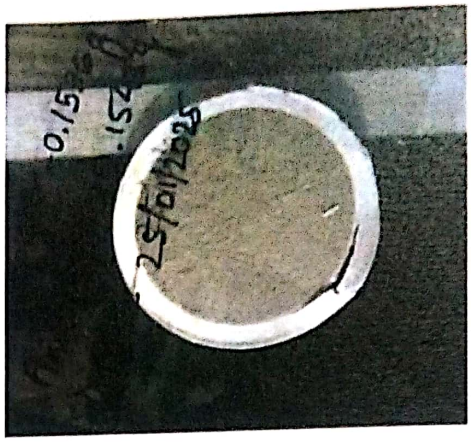

Fig 6: Glass fiber filter paper after sampling.

Fig 7: During vehicle survey in front of CSIR-NEIST.