PULMONIC HEALTH EFFECT OF AIR BORNE PARTICULATE MATTER IN GILGIT, PAKISTAN

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requirements for the award of the degree of

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Dedication

I dedicate this project to Allah Almighty my creator, my strong pillar, my source of inspiration, wisdom, knowledge and understanding. He has been the source of my strength throughout this work.

This study is also wholeheartedly dedicated to my beloved parents, who have been my source of inspiration and gave me strength when I thought of giving up, who continually provided their moral, spiritual, emotional, and financial support. And who encouraged me all the way and whose encouragement has made sure that I give it all it takes to finish that which I have started.

Acknowledgement

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Librarians at Bahria University also deserve special thanks for their assistance in supplying the relevant literatures. My fellow postgraduate students should also be recognized for their support. My sincere appreciation also extends to all my colleagues and others who have provided assistance at various occasions. Their views and tips are useful indeed. Unfortunately, it is not possible to list all of them in this limited space. I am grateful to all my family members for constant support.

ABSTRACT

Air pollutants impermanence is elevated, with about 7 million deaths in keeping with annum across the planet human being stated. More than 90% of the towns in terrible nations and almost 50% of the metropolises in the prosperous international locations with inhabitants more than 100 thousand are not residing according to the WHO air first-class regulations. Quantitative research was carried out for data collection. The present study was carried out to investigate the pulmonic health effect of air borne particulate matter in Gilgit Baltistan, Pakistan. The selected particulate matter includes $PM_{2.5}$, PM_{10}. The collected PM were characterized using different techniques such as Fourier Transformed Infrared Spectroscopy (FTIR), Scanning Electron Microscopy (SEM) and Energy Dispersive X-ray Spectrometry (EDX). Pulmonary symptoms assessment were analysed via questionnaire based collected information about different symptoms such as cough, phlegm, chest pains, and wheezing etc. For the evaluation of respiratory issues in general public, lung's function assessment was performed. A digital handled spirometer was used to perform a lung function test (SP10W Contec). The results revealed that FTIR results show the presence of various functional groups such as sulphate, ammonium, nitrate, and carbonate ions in PM_{10} and $PM_{2.5}$. SEM results revealed that the surface morphology of $PM_{2.5}$ is somewhat clearer while the PM_{10} are present in clusters, adhering to the surface, and there is no direct contact between particles, many particles were seen to have spherical, irregular, flat, or other morphologies. EDX results shows that the bulk sample's elemental analysis revealed the following patterns of abundance: O > C > S I > Al >Fe > Ca >Na >Ti > Mg > K > S > O. The questionnaire based pulmonary symptoms assessments results revealed that 75% of the respondents were aware about the climatic changes happening due to air pollution cased by particulate matters ($PM_{2.5,}$ PM_{10}) while 95% of the respondents were aware about the diseases caused by particulate matters ($PM_{2.5,}$ PM_{10}) such as cough, phlegm, chest pain, respiratory problems, lungs diseases etc. The lungs' function results were based on FEV1, FVC, FVC/FEV1, PEF. The maximum values were observed in the region of Sarwar and

NLI Kashrote Associate. The emerging technologies must be used to control the release of particulate matters through anthropogenic activities.

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Chapter 1
Introduction

1.1. Introduction

The term air pollutants is described as incidence of single or supplementary impurities within the ecosystem, which include dirt, vapors, smokes, fuel, 'fog', odor, or vapor in portions or through appearances, and of a length that can be unfavorable to anthropological, instinctive or shrub life, to house or that restricts unfavorably in the at ease amusement of lifestyles or belongings. Thus, it is far believed that an atmospheric situation, in which there are materials at better intensities than environs ranges, is contaminating if there are outcomes that may be evaluated on people, organisms, flowers or substances. Surrounded by airborne impurities, tiny dust particles present in surrounding depends on is certainly one and only of the maximum vital phrases that effect the physical condition (Krzyzanowski & Cohen, 2008).

Even though several substantial sports (fissure, blaze, and so forth). May possibly additionally announce exclusive impurities in the ecosystem, anthropogenetic sports are the general purpose of eco-friendly airborne toxic waste. Threatening chemical compounds can run away to the natural world via disaster, however several in-flight pollutions are announced from business accommodations and different sports and might trigger unfavorable consequences on individual strength and the ecosystem. A vent poison is any ingredient which may harm human beings, organisms, flora or raw material. However, human beings are worried an air waste product may additionally cause or promote to a boom in impermanence or extreme contamination or may additionally present a gift chance to fitness of living being. As dedication of might be or now not a ingredient creates a fitness chance on the way to people have being primarily established upon proven, epidemiologic, creature research which display to publicity to a material is connected with fitness consequences. In the situation of individual well-being, "chance" is the chance that a poisonous health impact may also occur (Kampa & Castanas, 2008).

Atmospheric pollutants due to particulate depend (PM) is an ability danger to environments and individual existence as well as a provider to climatical modifications; it is accepted as a global subject (Pope *et al.,* 2006; Kampa & Castanas, 2008). Air pollutants impermanence is elevated, with about 7 million deaths in keeping with annum across the planet human being stated. More than 90% of the towns in terrible nations and almost 50% of the metropolises in the prosperous international locations with inhabitants more than 100 thousand are not residing according to the WHO air first-class regulations (WHO, 2016).

1.2. Atmospheric Pollutants

Atmospheric pollution can be classified according to its source, either primary or secondary. Primary pollution consists of pollutants that are directly released from distinguishable sources (fixed, mobile, and natural sources), such as particulate matter, hydrocarbons, and metals. Secondary pollution, on the other hand, is generated in the environment by the reaction between primary pollutants or between air components and by photoactivation, hydrolysis or corrosion. Examples of secondary pollutants include ozone, other photo-chemical oxidants such as peroxy-acetyl nitrate and oxidized hydrocarbons (HC). The pollutants can be classified according to their biochemical composition, such as organic components like hydrocarbons (HC), alcohols and esters, and inorganic components like, CO and CO2, and metals. They can also be classified according to their physical state, like gases (oxides of nitrogen, oxides of sulphur, CO, and CO2, O3) and solids or liquids (e.g., metal particles, asbestos, carbon, mastic, nitrate, sulphate, microorganisms, dioxins, and furans). Common pollutants that are present in urban areas are referred to as reference pollutants (CO, NOx, O3, SO2, and PM10). Their usage depends on the intensity of industrial activities and traffic. In addition to these, numerous other compounds unique to each type of industry are present, such as acrylonitrile, benzene, dichloromethane, formaldehyde, polycyclic aromatic hydrocarbons (PAHs), vinyl chloride, carbon disulfide, 1,2-dichloromethane, styrene, tetrachlorethylene, toluene, trichlorethylene, arsenic, asbestos, and heavy metals (Garcia *et al.,* 2018).

1.3. Pollutant Categories

The most significant change in the atmosphere's composition is usually caused by burning fossil fuels for energy production and moving. Different special poisons have been identified, each with their own distinct characteristics, discharge levels, environmental persistence, distance-transportability and potential health impacts on humans and animals (Makra *et al.,* 2015). However, they have a few connections which categorized to 4 groups:

1. Gaseous pollutants (e.g. SO_2, NOx, CO, ozone, Volatile Organic Compounds).
2. Persistent organic pollutants (e.g., dioxins)
3. Heavy metals (e.g., lead, mercury)
4. Particulate Matter

1.3.1. Gaseous Pollutants

Carbonated contaminants make contributions to a superb volume in arrangement versions of the environment and are specifically due to burning of ancient remains (De Sario *et al.,* 2013). Oxides of nitrogen which unexpectedly reduces with ozone or militants within the system producing NO2. Ozone present in the lower atmosphere is created a chain of reactions involving NO2 and volatile organic compounds, which are triggered by sunlight, can occur. In contrast, Carbon Monoxide is air pollution caused by road transport is primarily composed of carbon monoxide, a result of incomplete combustion. Even though the main source of human caused SO2 is the burning of sulfur-surrounding fossil fuels (mainly coal and heavy oils) and the processing of sulfur-bearing ores, volcanic and oceanic activities are the primary environmental foundations of this pollutant. Finally, Volatile Organic Compounds (VOCs), which are mainly produced by incineration activities for strength construction and side road transportation, are the most significant contributors to emissions, making up roughly 2% of the total. This category of compounds includes organic chemical species with benzene. Inhaling these gaseous pollutants can have adverse effects on the respiratory system, as well as inducing hematological issues and cancer (such as carbon monoxide and benzene) (Rai *et al.,* 2011).

1.3.2. Persistent Organic Pollutants

Persistent organic pollution form a poisonous organization of chemical substances. These persistent toxins remain in the natural surrounding for extended phases of moment and become increasingly more concentrated as they move up the food chain. Examples of such pollutants include insecticides, herbicides etc. The term "dioxins" is often used to refer to both polychlorinated dibenzo-dioxins (PCDDs) and polychlorinated dibenzo-furans (PCDFs). In terms of toxicity, polychlorinated biphenyls (PCBs) are often considered to be similar to dioxins. (Schecter *et al.,* 2006). Dioxins are a by-product of combustion processes that involve substances containing chlorine, such as plastics. These pollutants can settle on the soil and water, but they are not soluble, so they do not pollute water supplies. Plants usually take in dioxins through the soil, or insect killer, and the toxins accumulate in the food chain due to their capacity to bind to lipids (WHO, 2003).

1.3.3. Heavy Metals

Heavy metals are naturally found in the earth's crust and include elements such as lead, mercury, cadmium, silver, nickel, vanadium, chromium, and manganese. These metals are not able to be ruined and carried through the airborne, entering mineral water sources and the nutrition trade. They can also be released into the ecosystem from combustion, wastewater discharges, and manufacturing processes. At low concentrations, trace elements can enter human bodies and act as essential nutrients to retain average processes. However, at higher levels, these same trace elements can come to be poisonous. (Jarup, 2003). Heavy metals can be a risk to human health due to their tendency to accumulate in the body over time. This process, known as bioaccumulation, occurs when a chemical is caught in and accumulated more rapidly than it can be destroyed (Sawidis *et al.,* 1995).

1.3.4. Particulate Matter (PM)

Particulates rely on are extremely tiny striking fragments in our ecosystem and include natural and inanimate particles. There is an outstanding distinction of their size, beginning and chemistry (Alam *et al.,* 2012; Mazzarella *et al.,* 2012). Particulate Matter (PM) are airborne contaminants composed of varying mixtures of solid particles and liquid globules in the air, created by both ecological and human movements (Poschl, 2005). Foremost traces of tiny molecules in air pollution are industrial unit, furnaces, vehicle engines, industrial processes, fires, and natural wind-borne dust. The particles vary in size, with those less than 2.5µm and 10µm referred to as PM2.5

and PM10, respectively. The magnitude of the debris establishes the area within the breathing territory that it can guarantee in. Fragments less significant than 0.1 μm in flowing distance are classed as ultrafine debris, those smaller than 1 μm are categorized as fine debris, and those larger than 1 μm are classified as coarse debris. These particles, when inhaled, can settle in the upper airways or the lung alveoli, depending on their size. Not even an individual factor is detected that can justify the majority of PM effects. The composition of PM is an important factor for measuring the fitness effects of debris, as it can absorb and transfer a variety of pollutants. The dimensions, floor, range, and composition all play a role in determining the effect of debris on fitness. Evidence strongly suggests that ultrafine and fine particles pose a greater risk to mortality and cardiovascular and respiratory health than the larger (coarse) particles. Common components of such particles include metals, natural compounds, biologic elements, ions, reactive gases, and carbon particles. The toxicity of PM (Particulate Matter) is determined by its metal substance, manifestation of PAHs and other natural components such as toxins present within the human body. (Rai *et al.*, 2011).

PM consists of both liquid and solid particles which can be characterized by their size, shape and chemical composition. These factors vary depending on the source of emission and how the particles are transported into the environment. Ambient particles can be categorized into three categories, depending on their aerodynamic diameter: PM10 (greater than or less to 10 μm), PM2.5 (equal to or less than 2.5 μm) and PM1 (equal to or less than 0.1 μm) (Gualtieri *et al.*, 2009). The primary pollutants emitted directly into the environment by the PM of the Prime Minister are contrasted with the secondary pollutants, which are formed due to chemical reactions (Mazzarella *et al.*, 2007). Sources of ambient particulate matter (PM) can be both natural and anthropogenic. Ecological traces include brush, wood fires, volcanic eruptions, etc. while anthropogenetic causes include vehicle exhaust, biomass burning, fuel combustion, industrial and petroleum refinery emissions, and more. Secondary ambient particulates are also formed through various environmental mechanisms (Seinfeld *et al.*, 1998).

1.4. Effect of Particulate Matters on Human Health

Inhalable PM saturates intensely into the lungs (breathing machine) inflicting fitness problems inclusive of diabetes, stroke, allergic reactions, bronchitis, cancer, cardiovascular difficulties or maybe dying (Kim *et al.,* 2015). $PM_{2.5}$ has been identified as the fifth most dangerous airborne pollutant, with a reported 4.2 million fatalities and 103.1 million disabilities in 2015 (Cohen *et al.,* 2017). Their impact on health of living being is governed by numerous factors when entering affected areas (Fubini & Fenoglio, 2007). Research has indicated that inhaling asbestos fibers can potentially result in lung cancer, asbestosis, mesothelioma, and pleural fibrosis, depending on the amount and type of exposure.

In order to understand the chances of dust remain present in surrounding on health of living beings and the natural environment, it is essential to evaluate its mass concentration, identify its sources of emission, and analyze the transport mechanisms. Furthermore, an understanding of the chemistry of particulate matter would be beneficial in determining its potential impact on human health and the environment. It is essential to have a thorough understanding of the morphology of particulate matter (PM) and its elemental composition, as this has a direct impact on the climate and may lead to various health issues. (Kwiatkowski *et al.,* 2013).

Inhaling crystalline silica can be more dangerous than amorphous silica, as it can lead to health conditions such as common lung conditions include silicosis, chronic obstructive pulmonary disorder, tuberculosis, chronic bronchitis, and lung cancer (Merget *et al.,* 2002). The ingestion of particulate matter that is rich in clay minerals has been reported to have minimal or no toxic effects (Carretero *et al.,* 2006).

1.5. Pulmonic Health Effect of Air Borne Particulate Matter

The composition of airborne particles can vary greatly, as it is affected by a wide range of emitting sources and its interaction with the environment. The smaller the size of the debris, the more likely it is to penetrate entirely into the breathing passage, thus increasing the chances of damaging health effects. (Waseq, 2020). The particulate matter smaller than 2.5 µm (PM2.5) is able to pass into the pulmonary alveoli and disrupt the process of gas exchange. The long-term exposure to airborne particles can lead to the improvement of breathing and issues related to cardio muscles, as well as lung cancer. Moreover, these act as a vector for other hazardous substances, including hydrocarbons and heavy metals, which can be inhaled and absorbed into the bloodstream and tissues. Additionally, pollution can cause discoloration and damage to buildings and monuments. (Zhang & Phillips, 2018). According to the NEQ's guidelines, countries should aim to keep air pollution levels below 5 μg/m3 (annual average) and 15 μg/m3 (24-hour average) for no more than 3 to 4 days per year. Doing so can help reduce the burden of disease and short-term and long-term illnesses (WHO).

1.6. Scenario of Particulate Matter Contamination in Pakistan

PM has gained more attention during the last decade due to increase in anthropogenic activities such as suburbanization, economic development, and vehicular ejection many mechanisms of the arena, mainly in building nations. Pakistani towns are encountering critical pollutants-associated troubles; accordingly. The research into the organic work of art, length, and syllable structure of particles in Pakistan, particularly in little yet quickly-developing municipalities, is severely limited. However, it is clear that PM has had a noticeable impact on air quality in the area. (Shahid *et al.,* 2018). Their sound impacts on air quality and living being in the urban areas of northern Pakistan have not been studied in depth. This study was conducted in selected towns of Gilgit to gain a deeper understanding of the PM in the region.

The geomorphological observe of PM suggests that floating debris may be in standard (sphere-shaped, lengthened, and so forth.) in addition to abnormal form (Panda & Nagendra, 2018). SEM in aggregate (SEM – EDX). This procedure is useful for gaining insight into the sound structure and size of PM, as well as for identifying potential production suppliers (Salma et al, 2002).

The intentions of the current work were to scrutinize as the Rapid urbanization increases the concentration of particulate matters (PM) in district Gilgit. The size distribution and chemical composition of PM in the study area has not been explored yet. Many cases are reported on the respiratory health issues in Gilgit Baltistan (Hussain *et al.,* 2016). So, the chemical evaluation of ambient air quality necessary in order to know its contribution in lungs function decline among general public of Gilgit.

1.7. Objective

- To characterize particulate matter collected from Gilgit.
- To determine the respiratory health status of Gilgit.
- To evaluate respiratory risk associated with particulate matter.

Chapter 2
Methodology

2.1. Site Description of Sampling Location

Gilgit (formerly the Northern Areas of Pakistan) is scattered across an expanse of 272,496 km2. The location lies among 72°N and 27.5°N and among 34.5 °E and 37°E. About 44% of the vicinity is protected via mountains (rocks, wetlands, and many others.), 50% is alpine pasture, 4% forests, and 1% cultivable waste, while best 1% is below cultivation. Three high mountain tiers, particularly the Himalayas, Karakorum, and Hindu Kush, are observed within the location. The place is domestic to 5 of the area's maximum peaks of above 8000 m and about 50 peaks with elevations of 7000 m. Along with other international-well-known peaks, Nanga Parbat (called Killer Mountain) and K2 (Mount Godwin-Austen) are positioned in the vicinity. This location is surrounded via way of China, India, and Afghanistan, and it's far separated from Tajikistan thru the narrow Wakhan strip (Ashfaque *et al.,* 2015).

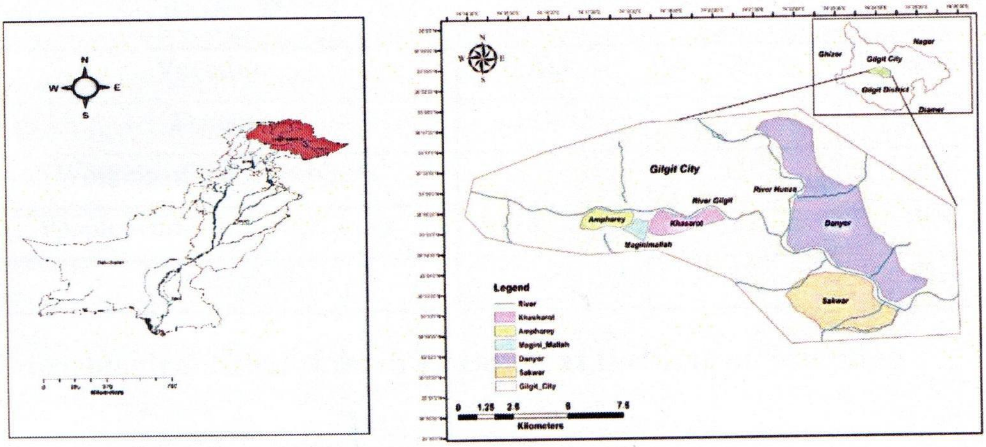

Figure 2. 1 Map of Study Area

2.2. Sample Collection

Samples were collected from six different areas of Gilgit including Sarwar, Danyore, Amphry, Majini, NLI Associate Kashrote. The selected study sites were the most urban areas of Gilgit due to rapid urbanization, large mining activities, open burning of wood and plastic, cement factories etc. Roughly 50 number of people were involved in data collected from each selected site. The experiments were compiled using Low volume sampler (Catrambone *et al.,* 2019). The PM were collected using a Low Volume Sampler (LVS) (Leckel, Germany) in two size fractions: $PM_{2.5}$, and PM_{10}. During the study period, sampling were done on a daily basis for 24 hours each, from 7 a.m. to 7 a.m. Samples were taken in triplicates. Before being appropriately placed in the stream containers of the selection for procedure, the filters were pre-weighted and conditioned. The filters were handled with extreme care and caution using forceps during the sample process. The screens were slanted and acclimatized before being placed in a Petri-dish and stored in the refrigerator-freezer at 40 Celsius to prevent volatile components from evaporating due to destruction carried out by warm air while waiting for more evaluation had to be done. The hydrometric bulk was obtained by detracting the majority of the empty filter from the mass of the packed filter. Each filter was weighed thrice in the past and later sampling and the standard data was assessed (Usman *et al.,* 2020).

Table 2. 1 Characteristics of population

Population Characteristics, n = 250

Variables	Age	N	Percentage
Female	29 - 55	97	39%
Workers of indoor projects		110	44%
People working in open areas	18 - 70	25	10%
Unemployed		18	7%

2.3. Meteorological Conditions of Location at the time of Sampling

During sampling duration data of temperature, precipitation, air quality and relative humidity were collected from the meteorological station of EPA.

2.4. Characterization of Particulate Matter and Respiratory Health Assessment

- Fourier transform infrared spectroscopy

- Scanning electron microscopy (SEM)
- Energy Dispersive X-Ray Analysis (EDX)

2.4.1. Fourier transform infrared spectroscopy

Fourier transformed infrared (FT-IR) spectroscopy was used to identify the functional groups of the obtained PM, which is deemed one of the best approaches. This procedure was employed to determine the functional groups in minerals. For all filters, FT-IR in transmission mode was recorded.

2.4.2. Scanning electron microscopy (SEM)

The samples were analyzed using a field emission scanning electron microscope equipped with an Octane Elite EDX detector. The surface of the sample was characterized using a Scanning Electron Microscope (SEM) under high vacuum conditions and with the appropriate accelerating voltage. SEM technology has been utilized in various studies to analyze the shape, chemical makeup, density, and source of particles.

2.4.3. Energy Dispersive X-Ray Analysis (EDX)

Researchers used EDX analysis to calculate the weight percentage of each constituent in PM in order to determine its power. The weight proportions of each element present in PM1, PM2.5, and PM10 particles were calculated using the EDX spectra obtained from the blank filter. The EDX spectra of each individual particle were manually deleted from the blank filter spectra, and the mean percentage of each element was determined. The quantity of fragments in every single company was determined, and the calculation of each group was calculated (Usman *et al.*, 2022).

2.5. Pulmonary Symptoms Assessment

All participants completed a standard pulmonary symptom–identification questionnaire. Cough, phlegm, chest pains, and wheezing were among the symptoms. It will also change to include whether these symptoms will link to regular experience and/or exacerbated by upper body microbial infections. A walk-through survey were used to determine the division of 8 working hours established on interest level for each procedure (Sarwar *et al.,* 2021).

2.6. Lungs Function Assessment

For the evaluation of respiratory issues in general public, lung's function assessment were performed. A digital handled spirometer were used to perform a lung function test (SP10W Contec) (Sarwar *et al.,* 2021). The three parameters including FeV1, PEF, FVC were analyzed. The samples were collected from Sarwar, Danyore, Amphry, Majini, NLI Associate Kashrote are among the areas in Gilgit where representative samples were taken.

2.7. Statistical Analysis

The statistical analysis were done in order to find the correlation between PM composition and respiratory disorders among study area residents. For statistical analysis, SPSS 21.0 were used.

Chapter 3

Results and Discussion

3.1. Characterization of Particulate Matter and Respiratory Health Assessment

3.1.1. Fourier Transform Infrared Spectroscopy (FTIR)

FTIR analysis was carried out for each sample collected from all the selected locations. From analysis it was noticed vibrational frequencies in-PM_{10} and $PM_{2.5}$-filters that correspond to the sulphate, ammonium-nitrate, and carbonate ions (603, 615, 670, and 1100 cm^{-1} for SO_4^{2-},1414 cm^{-1} for NH_4^+; 825 and,1356cm^{-1} for NO^{3-}, and 713, 730, and 877cm^{-1} for carbonate ions) (CO_3^{2-})· Spectra showing assimilation regularities at 825 and 1356 cm^{-1} (group NO_3^-), at 615 and 1100 cm^{-1} (group SO_4^{2-}), and at 1414 cm^{-1} (NH_4^+ ion) confirm the presence of $(NH_4)2SO_4$ and NH_4NO_3 compounds. More coarse than tiny particles show evidence of $CaSO_4$ $2H_2O$. The generally recognized theory that the sulfation process is significant in urban contexts is supported by the frequent presence of $CaSO_4$ $2H_2O$ signals.

Although they are not present in the cleans assembled at the residential station, organic compounds can be found in the abrasive and delicate element sections of the municipal positions. Aliphatic hydrocarbons are (2850, 2920, and 2950cm^{-1}). The occurrences at 2924and2850cm^{-1} are caused by CH_2 bonds, whilst the spreading incidence at 2950 cm-1 is attributed to CH_3 aliphatic carbon enlarging absorption. Aliphatic carbon CH_3 and CH_2 bond bending contributes to an absorption peak at 1460 cm^{-1}. The absorbance peak for a C = C group, located at 1596cm^{-1}, can also be seen in the $PM_{2.5}$ filter spectra. Due to overlapping peaks caused by numerous other kinds of fragments that understand IR light within the same range, it is difficult to identify other peaks for the C = C aromatic group (1463-1511-1596cm^{-1}) spectrum.

The literature proves the identification of various functional groups present in the FTIR analysis of $PM_{2.5}$ and PM_{10}. Absorption frequencies in all varieties (for rough and delicate fragments) range from 590 cm^{-1} to 1610 cm^{-1} with the manifestation of various functional groups such as O-H, C=C, SO_4^{2-}, NH_4^+ (Ghauch *et al.,* 2006; Michalski, 2016). The existence of $CaSO_4.2H_2O$ is more noticeable in crude particles than in tiny particles. The widespread occurrence of $CaSO_4.2H_2O$ signals lends support to the commonly held belief that the sulfation process is essential in urban contexts (Ferm & Sjöberg, 2015). The existence of such groups in the

PM10 substantiated that mining activities, automotive emissions, transportation, and coal burning had all had a significant impact on the area (Vasilatou *et al.*, 2017; Pay *et al.*, 2010).

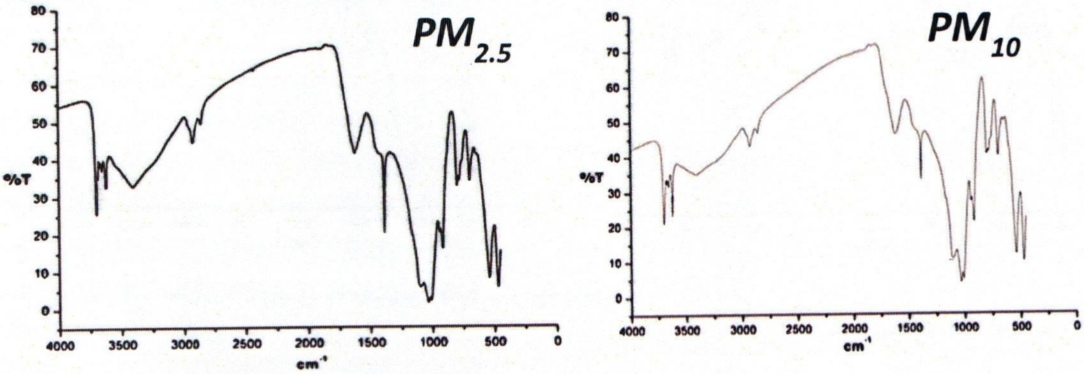

Figure 3.1 (a) FTIR Analysis of Sakwar, $PM_{2.5}$ AND PM_{10}

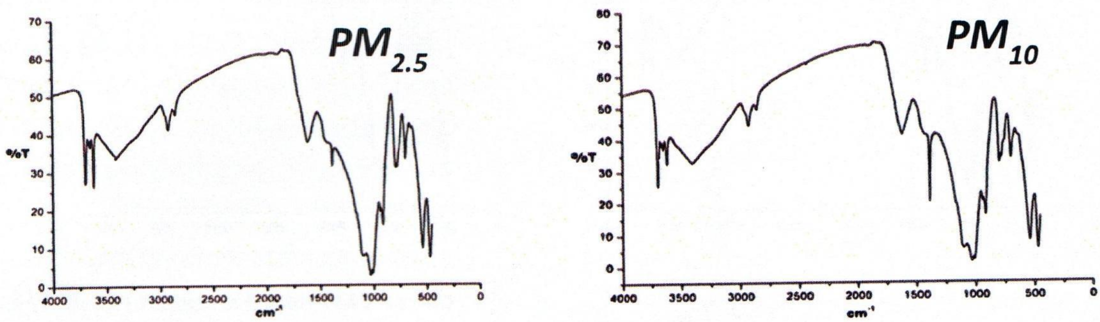

Figure 3.1 (b) FTIR Analysis of Danyore, $PM_{2.5}$ AND PM_{10}

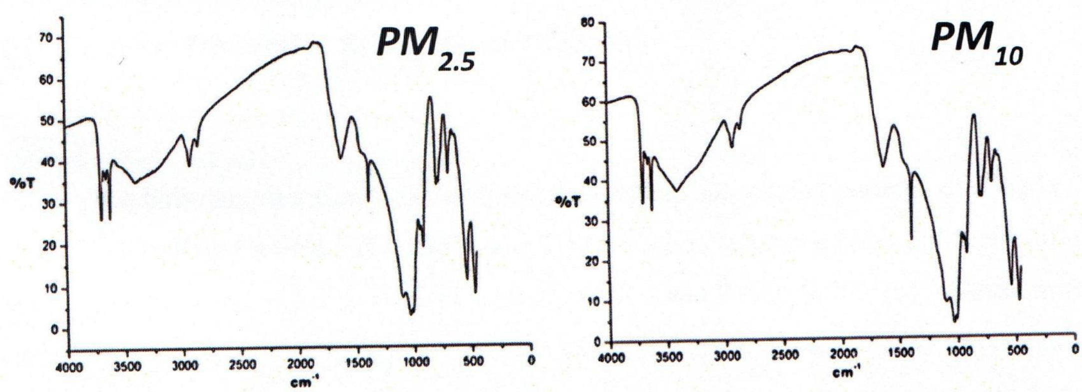

Figure 3.1 (c) FTIR Analysis of Amphry, $PM_{2.5}$ AND PM_{10}

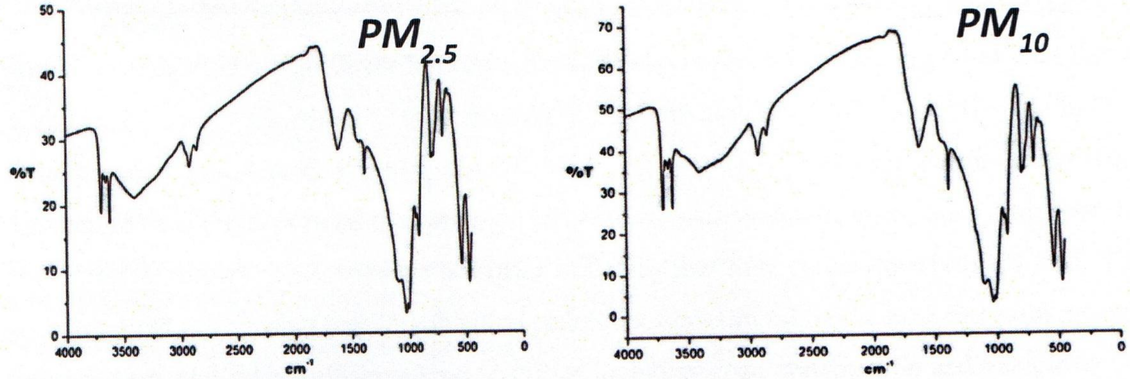

Figure 3.1 (d) FTIR Analysis of Manini, $PM_{2.5}$ AND PM_{10}

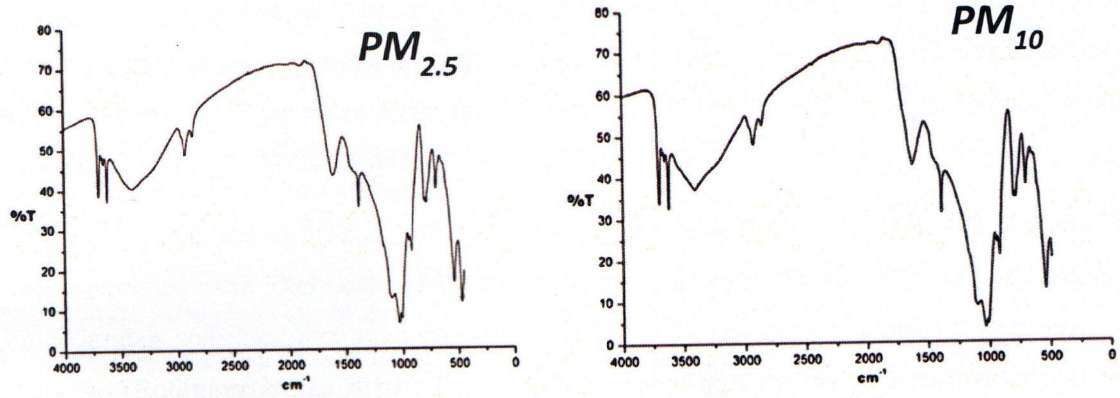

Figure 3. 1(e) Associate Kashrote $PM_{2.5}$ and PM_{10}

3.1.2. Energy Dispersive X-Ray Analysis (EDX)

The bulk sample's elemental analysis revealed the succeeding patterns of abundance: O > C > S I > Al >Fe > Ca >Na >Ti > Mg > K > S > O. Carbon (C), a byproduct of incineration from burning biomass and/or fossil fuels, is present in PM_{10} and $PM_{2.5}$. Sulfur (S), potassium (K), and carbon (C) were found combined, Analysis of the air in the local area showed evidence of carbonaceous soot particles, likely originating from sources such as industrial and agricultural burning, wood burning in homes, and coal burning in factories and brick businesses.

Oxygen (O), silicon (Si), iron (Fe), magnesium (Mg), sodium (Na), and calcium (Ca) presences indicated a significant buildup of crustal clay minerals originating from dust that had been resuspended. Regardless of their size and form, both particles (PM_{10} and $PM_{2.5}$) included the same elements (Al, Ca, C, Fe, Mg, Mn, Ni, O, K, Si, Na, Ti, V, and Zn). These elements were discovered, and they revealed the presence of carbonaceous material, mica, quartz-like particles, and alumina silicate. The presence of sulfur indicates that they came from burning fuel. These particles most likely came from combustion processes, agricultural fields, road and earth crust dust resuspension, and other anthropogenic activities including road construction and vehicle activity. These particles' predominant elemental make-up included Al, Si, O, C, Na, K, Fe, Mg, and Ca, indicating the existence of aluminosilicates and CaCO3, which were most likely derived from geological sources. The XRD results of PM_{10}, $PM_{2.5}$ shown in figure 3.2. When the current study was compared to other published works, it was found that geogenic mineral/clay particles and other anthropogenic particles from the burning of fossil fuel and biomass had accumulated (Bhardwaj *et al.*, 2017) (Bhuyan *et al.*, 2016).

Literature shows the somewhat similar finding related to EDX analysis of $PM_{2.5}$ and PM_{10}. These particles were likely created by soil dust, dust kicked up from the ground and roads, and other human activities like road construction, vehicular movement, burning, and agricultural practices (Rodrguez *et al.*, 2019). These particles come in a variety of forms and sizes. Single particle analysis with EDX revealed that particles were most likely particles in the air can be biogenic, such as plant parts and pollens; geogenic, including road dust and resuspended soil dust; or anthropogenic, such as carbonaceous particles and fly ash. (Hu *et al.*, 2016; Pipal *et al.*, 2011; Usman *et al.*, 2022).

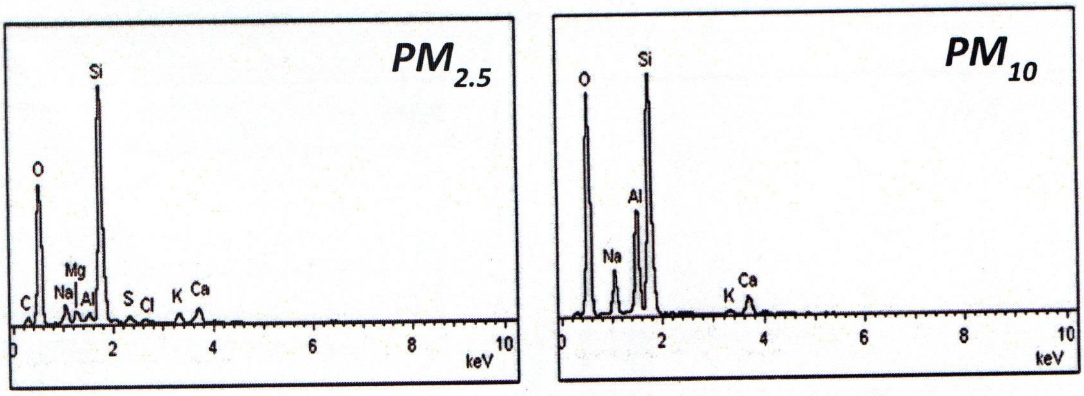

Figure 3.2 (a) EDX Analysis of Sakwar, $PM_{2.5}$ AND PM_{10}

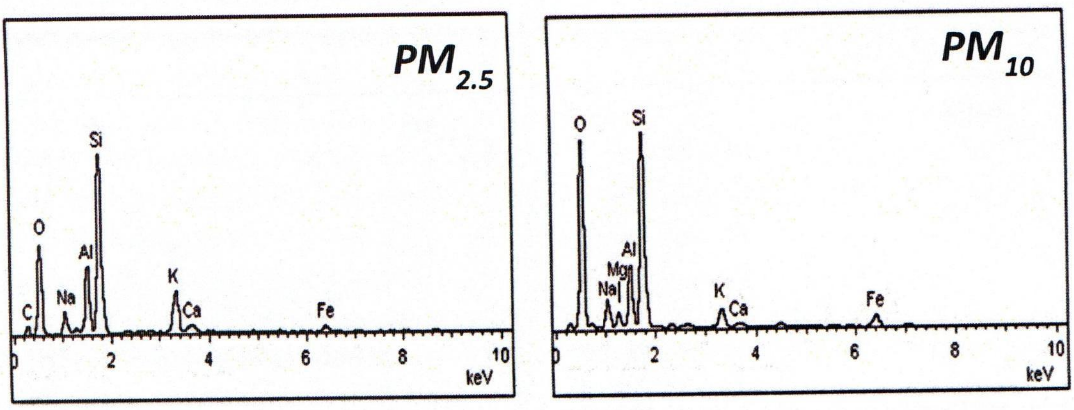

Figure 3.2 (b) EDX Analysis of Danyore, $PM_{2.5}$ AND PM_{10}

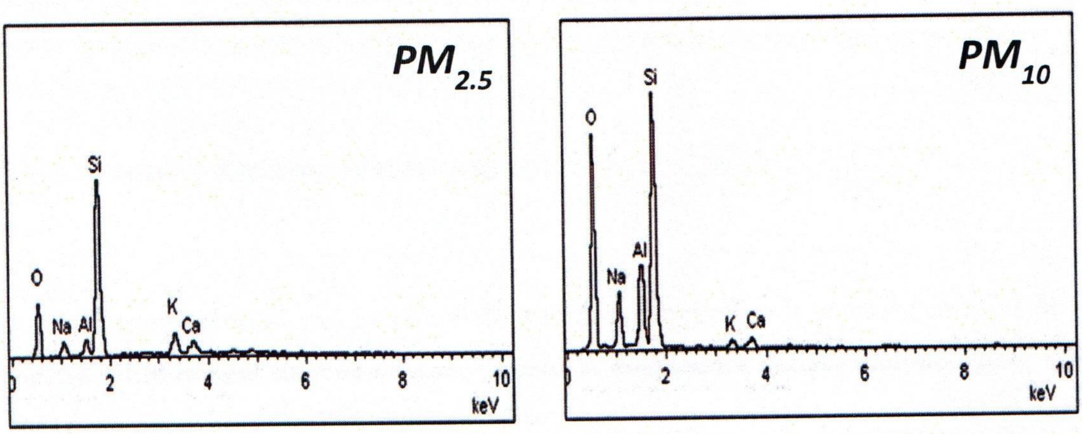

Figure 3.2 (c) EDX Analysis of Amphry, $PM_{2.5}$ AND PM_{10}

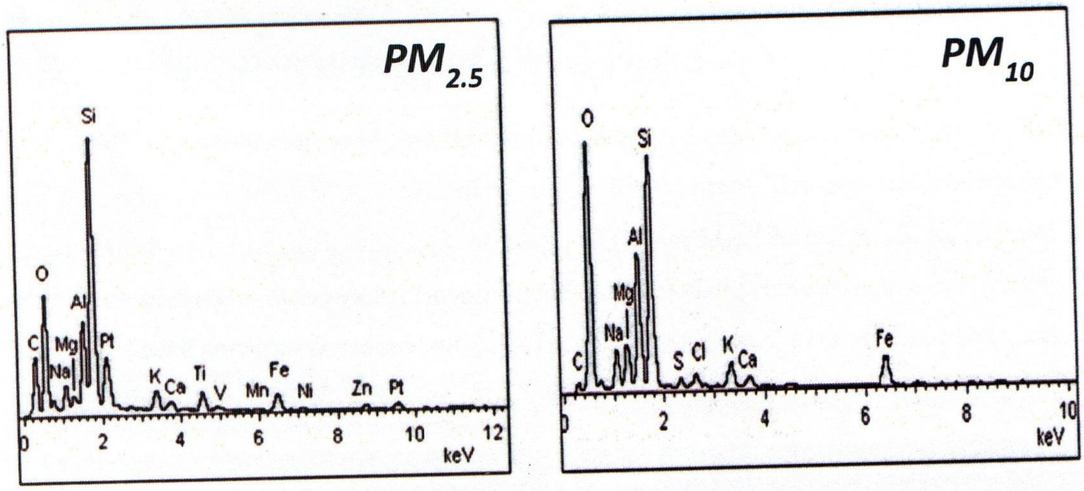

Figure 3.2 (d) EDX Analysis of Majini, $PM_{2.5}$ AND PM_{10}

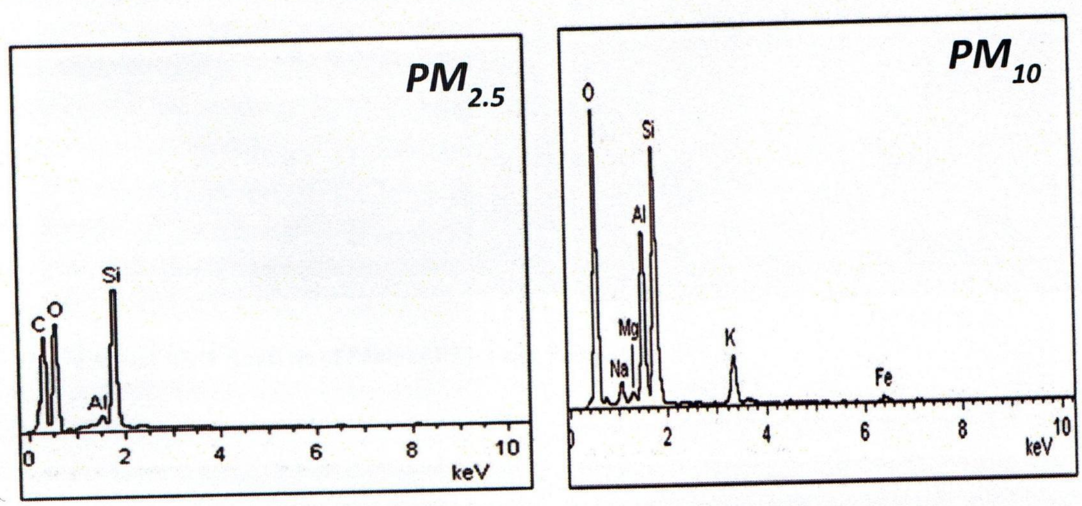

Figure 3. 2(e) EDX Analysis of Associate Kashrote $PM_{2.5}$ and PM_{10}

3.1.3. Scanning Electron Microscopy (SEM)

The most crucial tool for interpreting surface morphology is scanning electron microscopy (SEM). SEM images shown in figure 3.3 used to examine the surface morphology of PM10 and PM2.5. In comparison to PM2.5, the surface morphology of PM2.5 is somewhat clearer. When compared to the surface morphology of PM10, which demonstrates that particles are present in clusters, adhering to the surface, and there is no direct contact between particles, many particles were seen to have spherical, irregular, flat, or other morphologies.

These particles are produced by the combustion of car exhaust, natural gas emissions, coal, and atmospheric condensation reactions of sulphate and nitrate. These particles are primarily made up of carbon and road dust, with little amounts of O, Na, Mg, Ca, Zn, Al, S, K, Ba, and Fe. Some of the particles are carbonaceous, car-produced particles that primarily come from nearby biomass burning. These particles contained NO2, SO2, and organics and were released from human-made sources (Jiang *et al.,* 2018; Tao *et al.,* 2014; Zang *et al.,* 2014; Franzin *et al.,* 2020).

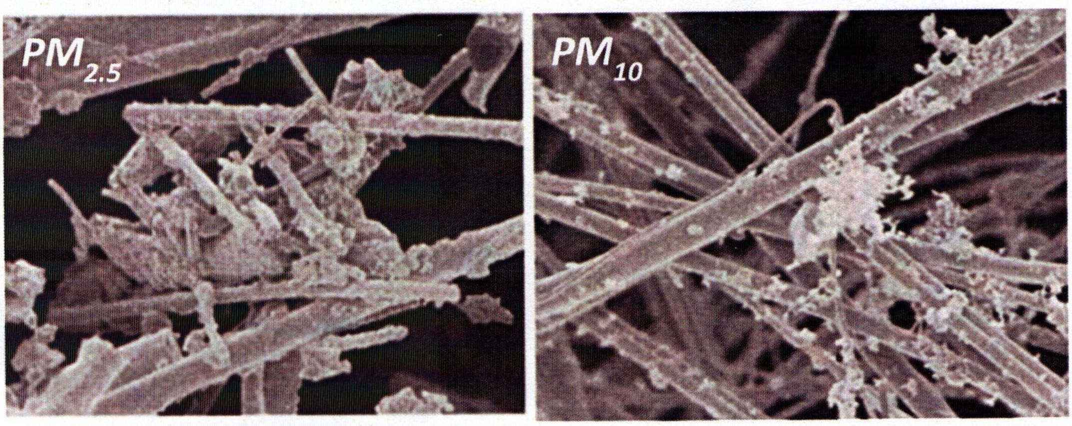

Figure 3. 3(a) SEM Analysis of Sakwar $PM_{2.5}$ and PM_{10}

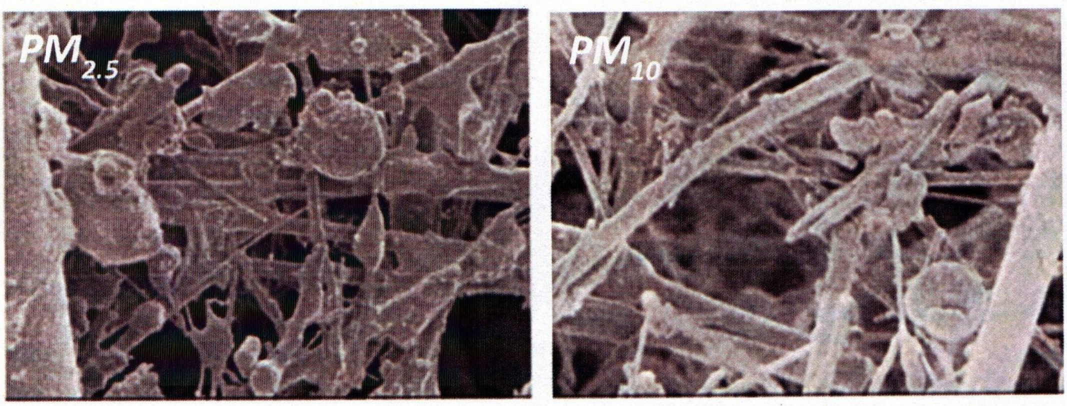

Figure 3. 4(b) SEM Analysis of Danyore $PM_{2.5}$ and PM_{10}

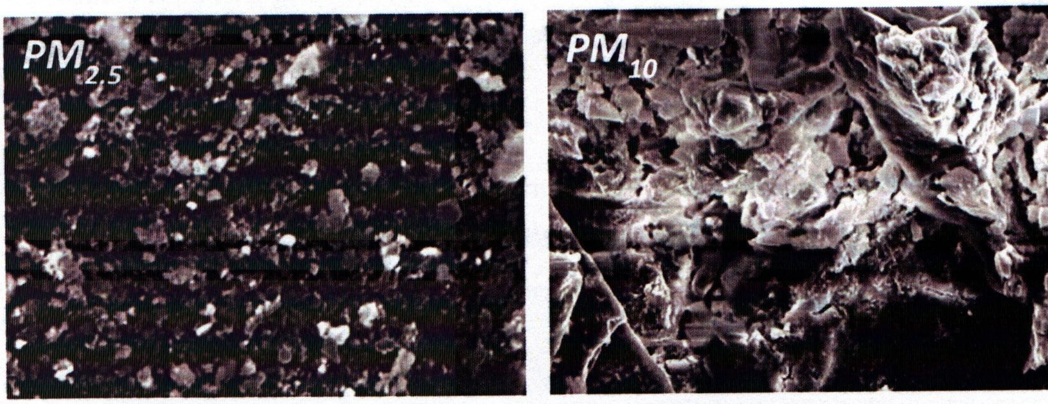

Figure 3. 5(c) SEM Analysis of Amphry $PM_{2.5}$ and PM_{10}

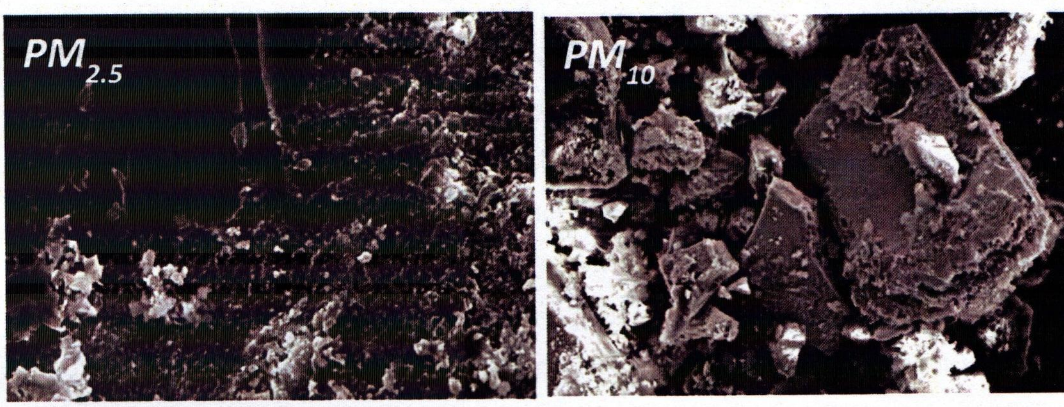

Figure 3. 6 (d) SEM Analysis of Majini $PM_{2.5}$ and PM_{10}

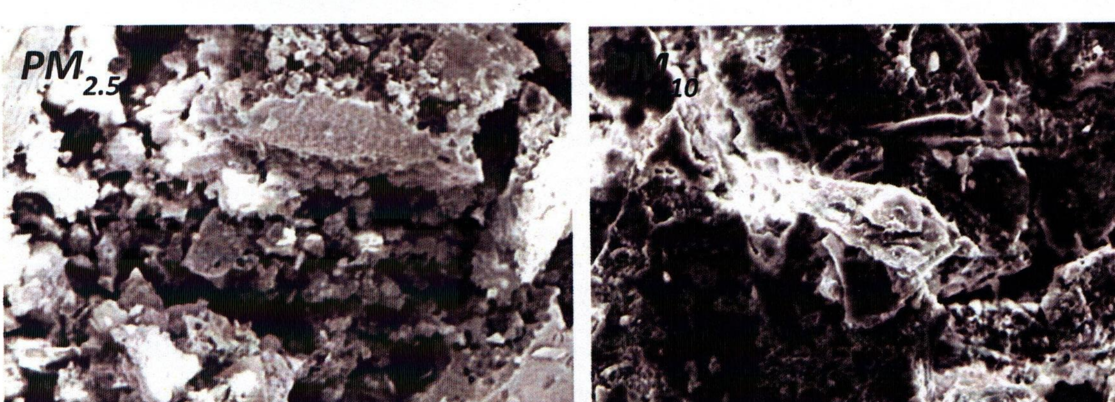

Figure 3. 7 (e) SEM Analysis of Associate Kashrote $PM_{2.5}$ and PM_{10}

3.2. Pulmonary Symptoms Assessment

The pulmonary symptoms assessment of was carried out through a standard pulmonary symptom–identification questionnaire. A walk-through survey were used to determine the division of 8 working hours based on activity level for each procedure.

The data was collected from a questionnaire data to analyze the pulmonary symptoms assessment of public exposed to PM. Majority of the respondents (89%) shows the positive results that yes, air pollution has an effect on human health. While 6% of the respondents were disagree. The maximum positive respond is 50% showing that half number of the people are affected from air pollution. 30% of the people don't have idea about it while the recorded minimum number is 20%. Air pollution badly effect human health because the presence of dust particles in air enter into human body through inhalation. The maximum number of respondents i.e., 70% are aware about the air pollution and their effect on human health while the minimum number of people i.e., 30% replied negatively, that they are unaware of air pollution. Climate change is the biggest issue raised due to rapid air pollution. A large number of respondent's showed negative response about climate change that they don't have idea about climate change i.e., 5-% while 40% respondent's showed positive response that they are aware about the climate change.

The 70% of respondents respond that respiratory problems are majorly caused by air pollution. 15% of the respondents think that global warming is also caused by air pollution. 5% of the respondents answered that soil erosion is also caused by air pollution while 10% of the public do not have idea about it. The maximum i.e., 65% respondents respond that Nitrogen (N_2) is not responsible for global warming. Similarly, 15% of the respondents respond that Methane (CH_4) is not contributor in global warming. While on average 10% of the respondent replied that sulfur dioxide (SO_2) and carbon dioxide (CO_2) are not the global warming contributors. The suspended particles present in air are varied according to their size and nature. The 70% of the respondents answered that the maximum number of particles present in air having the size < 10 µm. 15% of the respondents replied that particles size is < 0.1 µm. 10% replied that their size is < 1 µm while the remaining 5% respond that they are < 100 µm. As we know that the air borne particles cause a lot of diseases in human. 95% of the respondents respond that the group 1 of the air borne particles include that carcinogen (which cause cancer) while 5% respondents respond that they are not included in group 1.

Presence of particulate matter in air cause air pollution which leads to human diseases. A large number of diseases are caused by particulate matter such as respiratory problems, skin infections, eye infections. The about mentioned disease are included in survey in order to find respondent's view. The maximum number of respondents i.e., 40% choses respiratory infections are caused by presence of particulate matters. 35% respond that eye infections while 25% selected skin infections are caused by particulate matter presence in air.

On average 40% of respondents select that they feel sputum, shortness of breath and wheezing while 20% respond that they do not feel any such symptoms. The chest attacks are common in public from last few years which result in increases mortality rate. From survey it was found that in 65% of the respondents 3 or more chest attacks was diagnosed. 30% of the respondents suffered from 1 or 2 chest attacks. But the very few numbers i.e., 5% of respondents does not suffer from any chest attacks. As respiratory problems are directly related with particulate matters presence. 70% of the respondents feel respiratory problems most of the days in a week. 25% suffer from such problems everyday while only 5% of the respondents suffer few days in a week from respiratory problems. 90% of the respondents select that having respiratory problems stop them from doing only one or two things which they would like to do in their daily life while the 10% of the respondents select that these respiratory issues stop them doing most of the things they would like to do.

Having chest problems because of particulate pollution also effect public in their daily. 60% respondents answered that due to chest problems they cannot play any sports and fail to perform other physical activities where 35% replied that they cannot do any household core meanwhile, 5% think that they cannot go out for entertainment or recreation after facing chest problems. Cough is the most common symptom and also a side effect of respiratory problems. 73% of the respondents select that they usually have cough but excluding the clearing of through meanwhile 27% of the respondents respond that they do not suffer from such problems. Phlegm during cough is very common. 30% of the respondents replied positively to the situation that they phlegm from chest while having severe cough while maximum number of respondents replied negatively i.e., 70%. On average the maximum number of years obtained from survey regarding trouble with phlegm is 6 years. A huge number of respondents explains that cough, shortness of breath are most common problems facing with phlegm.

Table 3. 1 Overall Disease Assessment

Sites	Cough	Phlegm	Cough with Wheezing	Respiratory Infections
Sarwar	75%	60%	50%	90%
Danyore	89%	78%	45%	89%
Amphry	62%	55%	60%	92%
Majini	90%	75%	75%	78%
NLI Associate Kashrote	88%	60%	70%	90%

3.3. Lungs Function Assessment

The lungs' function assessment of the patients were carried out. Total 15 number of respondents were analyzed from each study site.

Table 3. 2 Lung's Function Assessment

Sites	FEV1	FVC	FEV1/FVC	PEF
Sarwar	37.5 ± 11.9	21.90 ± 6.67	1.71	75.5 ± 6.5
Danyore	30.7 ± 4.77	19.62 ± 4.42	1.56	69.8 ± 2.49
Amphry	29.9 ± 3.92	12.7 ± 3.21	2.35	50.3 ± 1.79
Majini	30.9 ± 4.77	18.4 ± 5.01	1.67	67.6 ± 2.99
NLI Associate Kashrote	35 ± 9.52	20.1 ± 5.97	1.74	72.8 ± 5.98

Table 3.2 illustrates the findings of lungs functions assessment which were carried out via spirometer. The average process was based on FEV1, FVC, PEF. FEV1 is defined as the maximum amount of air expelled in one second. The highest FEV1 value was recorded from Sarwar and NLI Associate Kashrote which were 37.5 ± 11.9 and 35 ± 9.52 respectively. Similarly, FVC value explained the total amount of air exhaled. In FVC value the greatest value observed was 21.90 ±

6.67 and 20.1 ± 5.97. The PVC values explained the air flowing out of the lungs. similar to FEV1

Sites	**FEV1**	**FVC**	**FEV1/FVC**	**Obstructive and restrictive disease analysis**
Sakwar	38%	22%	1.71	Restrictive diseases are most found
Danyore	31%	20%	1.56	
Amphry	30%	13%	2.35	
Majini	31%	19%	1.67	
NLI Associate Kashrote	36%	20%	1.74	

and FVC values the highest PEF values were recorded in Sarwar and NLI Associate Kashrote i.e., 75.5 ± 6.5 and 72.8 ± 5.98. similar findings were reported in literature (Lopes, 2019; Heijkenskjöld *et al.*, 2017).

Table 3. 3 Obstructive and restrictive disease analysis

Table 3.3. illustrate the obstructive and restrictive disease analysis of the selected study sites. The percentages shows that restrictive diseases are most common in the community, the highest FEV1-FVC value was recorded in Amphry.

Chapter 4

Conclusion and Recommendations

4.1. Conclusion

The current analysis were based on the analysis of $PM_{2.5}$ and PM_{10}. The collected PM were characterized using different procedures such as FTIR, SEM and EDX. Pulmonary symptoms assessment were analyzed via questionnaire based collected information about different symptoms such as cough, phlegm, chest pains, and wheezing etc. For the evaluation of respiratory issues in general public, lung's function assessment were performed. A digital handled spirometer were used to perform a lung function test (SP10W Contec). The results revealed that FTIR results show the presence of various functional groups such as sulphate, ammonium, nitrate, and carbonate ions in PM_{10} and $PM_{2.5}$. SEM results revealed that the surface morphology of $PM_{2.5}$ is somewhat clearer while the PM_{10} are present in clusters, adhering to the surface, and there is no direct contact between particles, many particles were seen to have spherical, irregular, flat, or other morphologies. EDX results shows that the bulk sample's elemental analysis revealed the following patterns of abundance: O > C > S I > Al >Fe > Ca >Na >Ti > Mg > K > S > O. The questionnaire based pulmonary symptoms assessments results revealed that 75% of the respondents were aware about the climatic changes happening due to air pollution caused by particulate matters ($PM_{2.5}$, PM_{10}) while 95% of the respondents were aware about the diseases caused by particulate matters ($PM_{2.5}$, PM_{10}) such as cough, phlegm, chest pain, respiratory problems, lungs diseases etc. The lungs' function results were based on FEV1, FVC, FVC/FEV1, PEF. The maximum values were observed in the region of Sarwar and NLI Kashrote Associate. The emerging technologies must be used to control the release of particulate matters through anthropogenic activities. Pulmonary symptoms assessment concluded that Majini was the most polluted area. High ratio of respiratory infections were found in Amphry i.e., 92%. Phlegm issues were reported in Danyore i.e., 78% respectively. Cough and cough with wheezing was highly reported in Majini i.e., 90% & 75% respectively. Pulmonary lung function assessment test concluded that restrictive disease were commonly found in the selected study areas.

4.2. Recommendations

- We can reduce particulate matter
- Not to burn wood, leaves or any yard waste
- Stop smoking especially indoor
- Walk, cycle or use public transport or share vehicle wherever possible
- Pay attention to your maintenance of your vehicle to reduce particulate matter
- Use to reduce particulate matter in homes and offices
- Conserve energy by using solar energy, bio-gas, rainwater harvesting etc. to control pollution from particulate matter

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