Assessment of Air Pollution by PM_{10} and $PM_{2.5}$ in Nawabshah City, Sindh, Pakistan

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Abstract—**Increased traffic density due to urbanization is a major cause of air quality deterioration. Atmospheric particulate matter (PM) constitutes one of the most challenging issues in environmental research. This study was designed to assess PM_{10} and $PM_{2.5}$ pollution at ten main locations in Nawabshah. Analysis of PM_{10} and $PM_{2.5}$ pollution was carried randomly at different selected locations of the city. The highest concentration of PM_{10} was found at Mohini bazar (MB) and the highest concentration for $PM_{2.5}$ was found at New Naka (NN). The mean concentration of PM_{10} was 78.3% higher than world health organization (WHO) standards and 35% than Pakistan's National Environmental Quality Standards (NEQS). The mean concentration of $PM_{2.5}$ was 47.3% and 26.3% higher respectively. Mean concentrations of $PM_{2.5}$ on day-2 and day-10 were found lower than those set by NEQS, while mean concentrations of PM_{10} on all days exceeded the WHO and NEQS standards indicating that the city was heavily polluted more with PM_{10} than with $PM_{2.5}$. Re-suspension of dust particles due to traffic flow, open burning of unmanaged solid waste on the sides of the road and in the street, and improper handling of construction and demolition waste were identified as the main sources for PM pollution in the city. Exposure to higher levels of PM_{10} and $PM_{2.5}$ can cause health problems. High levels of PM_{10} and $PM_{2.5}$ are a call for the implementation of strict measures to control PM pollution at Nawabshah in order to protect public health and the environment.**

Keywords-particulate matter; pollution; environmental deterioration; human health; strict measures

I. INTRODUCTION

Potential threats to human health and the environment mainly due to air pollution have now become an increasing concern, attracting attention [1]. Air pollution is one of the most critical global issues. Urban air pollution epitomizes a global problem with a substantial effect on public health, primarily in major cities where the daily mass concentration of airborne particulate matter (PM) exceeds the permissible levels set by the WHO and NEQS [2]. Airborne PM comprises a complex mixture of different solid and liquid particles suspended in the air either for a long or short time depending upon their size and chemical composition in space and time [3, 4]. According to [5], PM is a heterogeneous mixture of organic, inorganic and biological compounds (e.g., dust, soot, metals, salts, polycyclic aromatic hydrocarbons (PAHs), aromatic amines, bacterial products (endotoxins) and fungi). PM pollution is mostly described in terms of particle size. Aerodynamic diameter is one of the most important criteria to classify PM into different categories. Transportability of PM in the atmosphere and inhaling ability can be described according to its aerodynamic diameter [6]. PM size fractions range from PM_1, $PM_{2.5}$, PM_4, PM_7, to PM_{10}. PM with an aerodynamic diameter $\leq$10 microns is known as coarse particles (PM_{10}) and PM with an aerodynamic diameter $\geq$2.5 microns is termed as fine particles ($PM_{2.5}$) [5, 7-9].

PM (e.g., $PM_{2.5}$ and PM_{10}) are generated from a variety of sources including natural and human sources. Natural sources include windblown surface soils, sea sprays and pollutants from forest fires [10, 11]. Man-made sources for $PM_{2.5}$ include motor vehicles and fossil fuel combustion. Sources for PM_{10} include construction and demolition activities, traffic-related resuspension of particles, abrasion of brakes and tires and industrial process related emissions [4, 12]. In the current study, the major sources of PM emissions were associated with road traffic. Authors in [13] reported that major sources for the release of PM were related to traffic. Presently the world's most considerable health risks are primarily associated with air pollution,

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particularly PM pollution [14, 15]. Like other air pollutants, PM is also considered as one of major concern [2, 4]. The presence of PM poses more danger to human health than that of ground-level ozone and other common air pollutants (like carbon monoxide) [8]. Particle size is one of the significant features which stimulus the accumulation rate of particles in the respiratory system. The severity of health problems depends upon the size of PM. The smaller the PM size, the more deeply it will enter the body and affect the respiratory tract [16-19]. The health effects can be acute or chronic respiratory disorder (e.g., cardiovascular and lung cancer), depending upon the particle size [20, 21]. Exposure to PM pollution may also cause increase in hospital admission, respirational symptoms, exacerbation of prolonged respiratory, decrease lung function and premature death [22-25]. Authors in [9] reported that an estimated 4.2 million people died worldwide mainly due to exposure of $PM_{2.5}$ in 2015. Authors in [26] elucidated that PM≤10 increased the prevalence of respiratory and cardiovascular disorders.

Air pollution, particularly PM pollution, became a major issue in Nawabshah as it is expanding rapidly due to population growth, vehicle number, urbanization, and industries like Habib Sugar Mill (HSM) and Bandhi Sugar Mill (BSM). This study was designed to assess air quality deterioration by PM_{10} and $PM_{2.5}$ pollution and to identify PM_{10} and $PM_{2.5}$ sources in Nawabshah, which has not been done previously by any study. The objectives of the current study are:

- To survey the city areas and determine the sensitive points where PM concentration is significant.
- To assess the concentration of PM in the ambient air of Nawabshah.
- To visit the hospitals and assess the health impacts associated with PM pollution.

Findings of the current study will be helpful for the government and environmental protection agencies to take strict measures for monitoring and control of PM pollution and to bring the levels according to standards provided by the local and international environmental agencies.

II. MATERIALS AND METHODS

A. Site Description and Selection

Nawabshah is located in Shaheed Benazirabad district and is the central city of Sindh province. Nawabshah has latitude 26.25°N and longitude 68.4°E. Being located at the center of district Sindh, Pakistan, Nawabshah is considered as one of the most important and rapidly expanding cities. HSM is also located in Nawabshah and during operation time of HSM, many pollutants are released in the atmosphere, including PM which can travel over a long/short distance depending upon the seasonal variation. A research study was conducted to assess and identify the current situation of pollution associated with PM and sources from which these particles were originated. Significant health impacts, which may be caused by PM pollution, were also assessed by visiting various hospitals. Health impact information was based on consulting with doctors, and it was assumed that respiratory diseases could be caused by exposure to PM pollution. In addition, the locations selected for carrying out this research work were categorized as (a) highly dense commercial and (b) residential areas. Selecting the locations for PM pollution assessment required comprehensive study and the selection of the sites was based upon the criteria of increasing urban population growth, rapidly increasing quantities of transportation and the development level of the city. In order to get information about $PM_{2.5}$ and PM_{10} in Nawabshah, 10 main locations with different characteristics were selected for assessment. Assessment of $PM_{2.5}$ and PM_{10} pollution was carried out at different times and days. Data were collected at each location for later analysis. Table I shows the locations and their labels in Nawabshah city, selected for data collection.

TABLE I. CITY LOCATIONS

Location names	Labels
New Naka	NN
Hospital Road	HR
Masjid road	MR
Mohini bazar	MB
Sakrand road	SR
Railway station	RS
Bucheri road	BR
Habib Sugar Mills	HSM
Society Chowk	SC
Quaid-e-Awam University of Engineering, Science and Technology	QUEST

B. Equipment and Data Collection

Hourly concentrations of PM_{10} and $PM_{2.5}$ were taken for a month. The selection of sites was based on traffic oriented areas and on the occurrence of highest concentrations to which the population is likely to be directly or indirectly exposed. AEROCET 531 was used to assess the concentrations of PM_{10} and $PM_{2.5}$. This equipment can be used for testing/measuring PM size fractions PM_1, $PM_{2.5}$, PM_4, PM_7, PM_{10} and total suspended particles (TSP). AEROCET 531 is a portable battery-operated unit which counts small particulates, calculates their mass profile per cubic foot of air samples and provides real time information. The equipment tests particle size of $PM_{2.5}$ and PM_{10}. The real time count information is displayed on LCD in two channels. The stored particle count data is used for 8 particle sizes and an algorithm derives the mass concentration for the sample.

III. RESULTS AND DISCUSSION

A. Assessment of PM_{10} and $PM_{2.5}$ Pollution in Nawabshah

Urbanization and growth in energy use leads to significant impacts on air quality. Polluted air is considered as a severe problem globally, affecting the quality of life and environment to a greater extent. The selected city for the survey is passing from this serious issue, particularly PM pollution which is affecting public health, the value of life and the environment. The assessment of PM_{10} and $PM_{2.5}$ pollution was carried out at various locations of Nawabshah. Random sampling at each location was carried out. Statistical analysis of PM data was carried out by daily average concentrations of PM_{10} and $PM_{2.5}$ using Origin Pro 9.0 software. Table II shows the daily mean, maximum and

minimum concentrations of $PM_{2.5}$ and PM_{10}. The obtained results were compared with other national researches regarding PM pollution in other cities of Pakistan. PM pollution was assessed at these locations at different times and dates, and Figure 1(a)-(j) represents the levels of PM_{10} and $PM_{2.5}$ on various days in the selected locations of Nawabshah city. The trend in the assessment of PM_{10} and $PM_{2.5}$ pollution in the selected sites was different depending upon the traffic density, domestic and commercial activities, and industry presence like Habib Sugar Mills Limited. Each location of the city was assessed 10 times. During different assessment, observations were made on the concentration of PM_{10} and $PM_{2.5}$ and the sources due mainly to which the concentrations were elevated. From Figure 1(a), it seemed that the highest concentration (277µg/m^3) of PM_{10} was found at MB, indicating a higher level of PM pollution at the particular site. Some of the locations (e.g., SR, RS, SC, and QUEST) at day-1 were found with $PM_{2.5}$ pollution below the NEQS (Figure 1(a)). HSM was found more polluted with PM_{10} on day-2 (Figure 1(b)). The reason could be the storage and transport of bagasse, produced from the sugar mill resulted in the release of particles in the atmosphere and hence elevated concentration. For $PM_{2.5}$, the highest concentration of 41µg/m^3 was found at NN on the same day. Many of the locations excluding NN, BR, HSM, and SC were found with $PM_{2.5}$ levels below NEQS Pakistan (Figure 1(b)). On day 3-5, it seemed from Figure 1(c)-(e), the highest concentrations were observed at HSM. The lowest concentrations of the same particles were found at QUEST. In the case of $PM_{2.5}$, elevated levels on the same days were noted at HSM, HR and NN respectively (Figure 1(c)-(e)). From Figures 1(f) and 1(g)), higher levels of PM pollution were found at NN. The lowest concentration for $PM_{2.5}$ was found at QUEST on day-7 (Figure 1(g)). Concentrations of $PM_{2.5}$ at some locations were below NEQS, and some were very near to NEQS (Figure 1(a)-(j)). However, in the case of PM_{10}, it was evaluated that most of the locations were heavily polluted and concentrations were very much higher than NEQS. Some locations such as QUEST on days 3-6 were found having less PM_{10} concentration than NEQS, possibly due to low traffic density in the current area. There is a link road connecting Nawabshah and Hyderabad via Sakrand. On these days the traffic density over there was lower. Some other locations (e.g., HR on day-5, RS on day-6 and MB, BR and HSM on day-7) were also found with less PM_{10} concentration than NEQS. The highest and lowest concentrations were noted for both PM_{10} and $PM_{2.5}$. It was noted that the overall highest mean concentration of PM (e.g. PM_{10}) was found as 230.8µg/m^3 on day-1. Simultaneously the highest mean concentration of $PM_{2.5}$ was reported as 47.5µg/m^3 on day-6. The PM levels were exceeding WHO guidelines set for $PM_{2.5}$ (see Table III [31]). The PM levels also exceeded the permissible levels set by NEQS. The mean concentrations of PM_{10} were 69.96-79.06% and 9.9-37.18% higher than those of WHO and NEQS. Meanwhile, the mean concentrations of $PM_{2.5}$ were 24.9-47.36% and 5.66-26.3% higher than the guidelines set by WHO and NEQS. On day-2 and day-10 the mean concentration of $PM_{2.5}$ was below the NEQS, and on day-1, day-4 and day-9 were very near to the NEQS, indicating lower $PM_{2.5}$ pollution in the city.

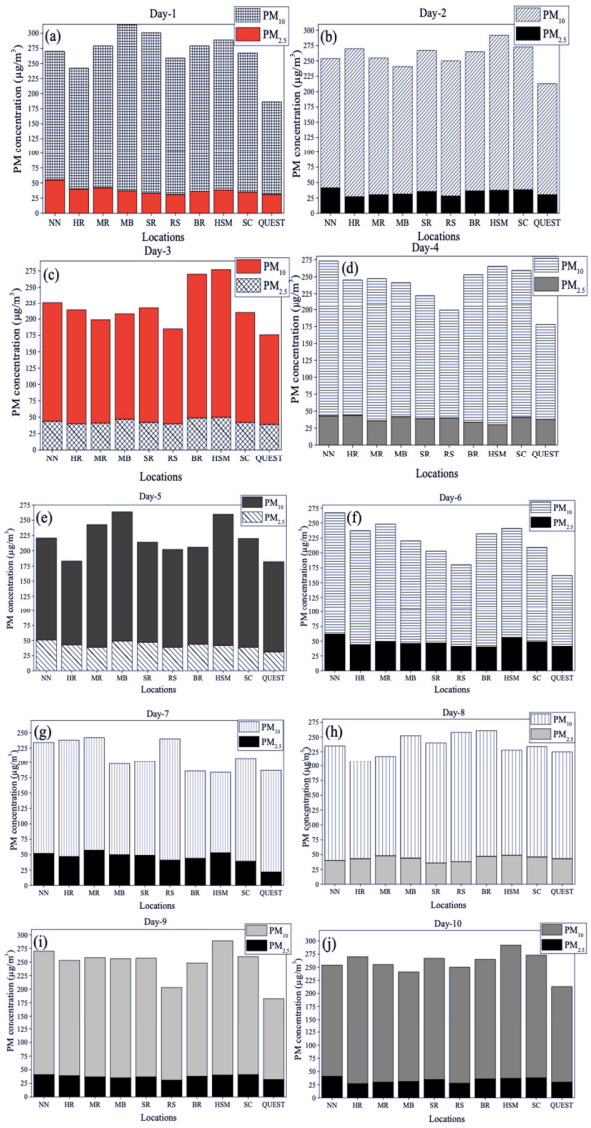

Fig. 1. Concentrations of PM_{10} and $PM_{2.5}$ at different days in various locations of Nawabshah city.

The mean concentrations of PM_{10} were found higher than the NEQS, indicating that the city was heavily polluted with PM_{10} (Table IV). It is important to mention that the city was more polluted with PM_{10} than with $PM_{2.5}$. It was observed that concentrations of $PM_{2.5}$ and PM_{10} at most of the locations of Nawabshah city exceeded the WHO and NEQ standards established by the government indicating that the city was heavily polluted with both PM_{10} and $PM_{2.5}$. These exceeded levels of PM pollution urged the environmental protection agencies to take strict remedy measures for the control of PM pollution.

B. Sources of PM Pollution in Nawabshah

The population is increasing rapidly and consequently demands and lifestyle are changing. The increasing number of vehicles led to exceeded PM levels. Further, it was observed that the main sources for the release of PM were

associated with burning activities e.g. HSM and automobiles. Dust storms usually take place in the surroundings and in the city and significant movement of the particles via wind from one place to another contributed to the suspension of a large amount of dust and sand particles in the environment. Movement of these particles from heavily polluted to less polluted areas caused the deterioration of air quality in the city. It was observed during the assessment that transportation was one of the main sources of re-suspension of PM in the city. Re-suspension of dust particles due to traffic flow, burning of unmanaged solid waste, improper handling of construction, and demolition waste were the main identified sources of PM pollution in the city.

TABLE II. PM MINIMUM AND MAXIMUM CONCENTRATIONS

Days	Particulate matter types			
	PM_{10} (µg/m^3)		$PM_{2.5}$ (µg/m^3)	
	Min.	Max.	Min.	Max.
Day-1	155	277	31	55
Day-2	183	255	27	41
Day-3	137	227	39	50
Day-4	140	235	30	44
Day-5	140	218	31	51
Day-6	121	205	40	62
Day-7	131	199	22	57
Day-8	165	220	36	49
Day-9	150	249	31	41
Day-10	183	255	27	41

TABLE III. MEAN VALUES OF PM_{10} AND $PM_{2.5}$ COMPARED WITH WHO AND NEQ STANDARDS

Days	Particulate matter					
	PM_{10} (µg/m^3)			$PM_{2.5}$ (µg/m^3)		
	Obtained	WHO	NEQ	Obtained	WHO	NEQ
Day-1	230.8	50	150	37.8	25	35
Day-2	224.7	50	150	33.3	25	35
Day-3	174.9	50	150	43.4	25	35
Day-4	199.5	50	150	38.7	25	35
Day-5	177.1	50	150	42.4	25	35
Day-6	172.4	50	150	47.5	25	35
Day-7	166.5	50	150	45.4	25	35
Day-8	192.4	50	150	43.4	25	35
Day-9	210.5	50	150	37.1	25	35
Day-10	224.7	50	150	33.3	25	35

C. Health Impact Associated with PM Pollution

Air pollutants, if not managed appropriately may have adverse health, and environmental impacts and PM is one of the air pollutants posing serious health impacts to humans. It is recognized that an increase in respiratory diseases is often associated with PM pollution, mainly due to PM_{10} and $PM_{2.5}$ air pollution. According to the Environmental Protection Agency (EPA) short-term and long-term exposure of humans to high concentrations of PM_{10} and $PM_{2.5}$ can cause numerous health impacts and even deaths [27-30]. People of the city were suffering from various health problems like asthma, chronic bronchitis respiratory symptoms, weakened lung function, and cardiovascular diseases. Several hospitals were visited during the research. Table IV shows the hospitals visited and some patients who were possibly affected by PM pollution. In the National Medical Center, Zohaib Medical Centre, Civil Hospital, and Jinnah Medical Center, respectively about 20-30, 15-20, 40-60 and 15-25, patients were hospitalized per day out of which 15-25, 10-12, 20-30 and 10-12 people were possibly suffering from the diseases mentioned above. This study was conducted in 2015, so the current situation might be worse.

TABLE IV. HOSPITALS VISITED DURING THE SURVEY

Hospital Name	Total patients visiting per day	No of possibly affected patients
National Medical Centre	20-30	15-25
Zohib Medical Centre	15-20	10-12
Civil Hospital Nawabshah	40–60	20- 30
Jinnah Medical Centre	15-25	10-12

IV. CONCLUSION

In this paper, assessment of $PM_{2.5}$ and PM_{10} concentrations in Nawabshah was carried out, and the obtained results were analyzed and compared with air quality standards. Mean concentration of PM_{10} was 78.3% higher than WHO standards and 35% than NEQS. Similarly, the mean concentration of $PM_{2.5}$ was 47.3% and 26.3% higher than the respective standards. These concentrations indicated that the air quality was deteriorated with the rapid growth of urbanization and transportation, and the public health was significantly affected. Poor air quality monitoring, open burning of trash in the environment, improper management and handling of all types of solid waste, devastation of the paving material by road traffic and the release of PM from HSM were the main causes of elevated concentrations of $PM_{2.5}$ and PM_{10} in Nawabshah. PM_{10} and $PM_{2.5}$ levels in Nawabshah exceeded national and international air quality standards and adversely affected the public health. The adverse health effects of PM have provoked the government to progressively set strict regulations and policies to control environmental pollution of various emission sources, particularly $PM_{2.5}$ and PM_{10}. Government and other environmental agencies may focus on regulating pollutants released from vehicles and industries and may grow more plants along the roadsides which can reduce the re-suspension of PM in the air. It is also their responsibility to bring PM pollution to an acceptable level as recommended by WHO and NEQS to protect the public health and the environment in general.

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