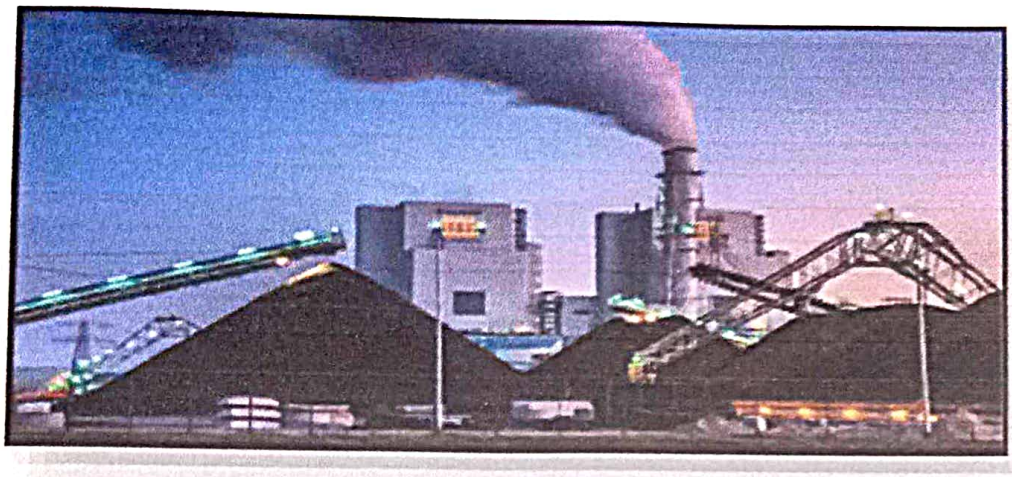
Assessment of Ambient Air Quality Parameters Within a Coal-based Thermal Power Plant

(A report submitted in partial fulfillment of the requirements for the award of degree of Master of Civil Engineering in the Faculty of Engineering and Technology of Jadavpur University)



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DECLARATION

The Thesis titled **"Assessment of Ambient Air Quality Parameters within a Coal-based Thermal Power Plant"** is prepared and submitted for the partial fulfillment of the continuous assessment of **Master of Civil Engineering** (Environmental Engineering Specialization), of Jadavpur University (Session 2022-2023).

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Place: Jadavpur University

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RECOMMENDATION CERTIFICATE

It is here by certified that this Thesis titled **"Assessment of Ambient Air Quality Parameters Within a Coal-based Thermal Power Plant"** is prepared and submitted for the partial fulfillment of the continuous assessment of Master of Civil Engineering (Environmental Engineering Specialization) of **Jadavpur University** by **Bikul Kumar Singh** a student of the said course for the session 2022-2023 under our supervision and guidance. It is also declared that no part of thesis of said work has been presented or published elsewhere.

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CERTIFICATE OF APPROVAL

This is to certify that this thesis is hereby approved as an original work conducted and presented satisfactory to warrant its acceptance as a prerequisite to the degree for which it has been submitted. It is implied that by this approval undersigned do not necessarily endorse or approve any statement made, opinion expressed or conclusion drawn therein, but approve the thesis only for the purpose for which it is submitted.

Final Examination for evaluation of thesis

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Abbreviations

WHO	World Health Organization
USEPA	United States Environmental Protection Agency
TPP_S	Thermal Power Plants
TSPM	Total Suspended Particulate Matters
PM	Particulate matters
NAMP	National air quality monitoring programme
NAAQS	National ambient air quality standards
CPCB	Central pollution control board
IGT	Indra Prastha gas turbine
IP	Indra Prastha
WBEG	World bank emissions guidelines
ISCT3	Industrial source complex short term model version 3
TSP	Total suspended particulate matter
CEA	Central electricity authority
DPCC	Delhi pollution control committee
TERI	The energy and resource institute

KTPS	Kolaghat thermal power plant Station
COPD	Chronic obstructive pulmonary disease
PM_{10}	Particulate matter (Particles less than 10 μm in Diameter)
$PM_{2.5}$	Particulate matter (Particles less than 2.5 μm in Diameter)
SO_2	Sulphur Dioxide
NOx	Nitrogen Oxides
CO	Carbon Monoxide
O_3	Ozone
CPCB	Central Pollution Control Board

Chapter-1

Introduction

Fig: -1.1: Key features of WHO Report

1.1 General

Air pollution is a worldwide and a local issue caused by energy generation. It refers to global warming deterioration in human environmental health and local-global sustainability. The pollutants which are generated from various sources (e.g., Thermal power plants, Refineries, household combustion equipment, chimneys have become one of the leading environmental hazards to human and planet health. The component of pollutants that result from burning fossil fuels (oil and gas) and coal have been studied, such as sulfur dioxide, carbon dioxide nitrogen oxides and particles. Both sulfur dioxides and nitrogen oxides interact with water to produce acid rain.

Clean air is the most important and essential requirement to sustain healthy lives for human kind and those of the supporting ecosystems which in return affect the human well-being. Due to the industrialization and urbanization in this era, releases of various types of emission and particulate matter is a threat to the different types of eco systems as well as life of the human beings. Now day's anthropogenic emissions of various kinds are being pumped into the atmosphere (called primary pollutants) and lead to the formation of new pollutants due to chemical reactions in the atmosphere (called secondary pollutants). These are building up the concern of ambient air pollution as a prominent global threat to human health in many ways.

So, it is very important that the hazardous impacts from environmental pollution are to be regularly reported and monitored. Among various kinds of pollution, the air pollution has attracted high priority in respect of environmental regulation since the environmental damage due to such pollution mostly affects human welfare by way of adverse health on the population exposed to it. It is undoubtedly an alarming fact that in recent years, air quality has deteriorated in alarming pace in most large cities in India.

1.2 Genesis

Historically, air pollution started with the discovery of fire and human exposure to the chemical species produced during biomass burning (combustion of wood and vegetation) in poorly ventilated locations where concentrations could reach levels that are harmful to human health. During the 19th century, the Industrial Revolution led to the emission of significant amounts of air pollutants via the combustion of a variety of fossil fuels (coal, oil, and gas). In particular, the air pollution in London during the 19^{th} and 20^{th} centuries became particularly problematic. The most significant, documented London air pollution

episode occurred during the winter of 1952. Smoke from combustion mingled with London fog to become "smog," a term coined in the early 20th century by Harold Antoine des Vœux, a member of the Coal Smoke Abatement Society, at a conference of the American Medical Association in London. The stagnant atmosphere during the 1952 event, which contained high concentrations of sulfur dioxide (SO_2), nitrogen oxides (NO_x), and atmospheric particles (including sulfate), contributed to the deaths of several thousands.

1.3 Impact of Air Pollution on Human Health

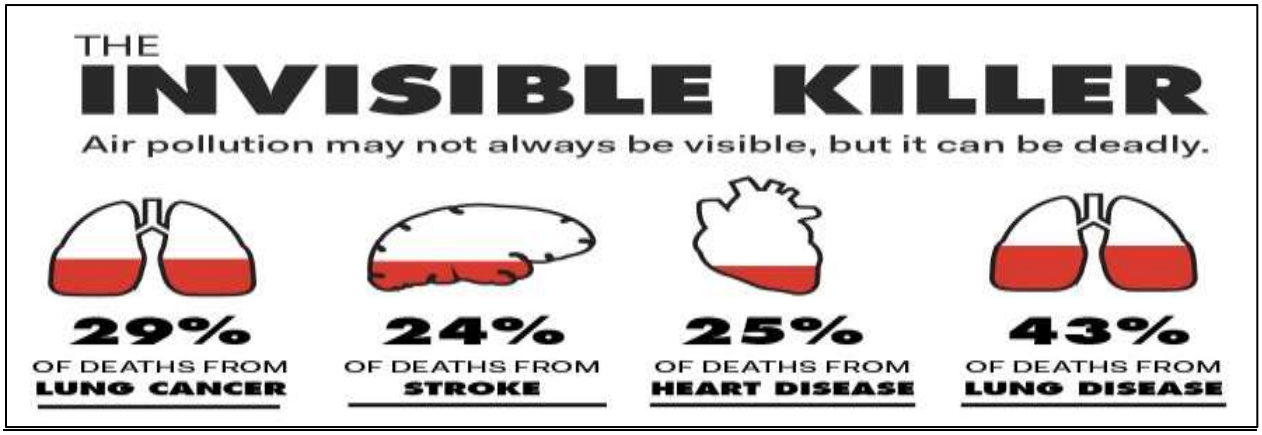


Fig: -1.2 Image source: World-heart-fedreration.org

People exposed to toxic air pollutants at sufficient concentrations and durations may have an increased chance of getting cancer or experiencing other serious health effects. These health effects can include damage to the immune system, as well as neurological, reproductive (e.g., reduced fertility), developmental, respiratory, and other health problems. In addition to exposure from breathing air toxics, some toxic air pollutants such as mercury can deposit onto soils or surface waters, where they are taken up by plants and ingested by animals and are eventually magnified up through the food chain. Like humans, animals may experience health problems if exposed to enough air toxics over time. It is evident that air pollution does cause many functional disorders in the organs of human body. Mainly, it hampers the respiratory and lung function by several magnitudes. The effects can be both long-term and short-term. Not all individuals experience polluted air the same way. However, the result depends on the duration of the exposure, as well as on the dose received. Short-term cases may include, but are not limited to nose and eye itching, nose and throat irritation, headaches, allergic reactions, nausea, and some milder upper respiratory infections. The long-term ones are the more serious ones such as lung cancer, heart disease, also brain damage, especially in children, kidney and liver damage, especially in elderly people and the air pollution may further complicate an already existing medical condition. Air pollution is a major problem in urban areas. As shown above picture in 2012 alone, 7 million deaths in the world were attributable to the combined effects of ambient (3.7 million) and household (4.3 million) air pollution (WHO, 2014). Air Pollution is one of the leading causes of deaths and

premature deaths in the world (as of 2010). Ischemic heart disease is at the forefront in this ranking of causes, and COPD, lower respiratory tract infections, lung cancer are also amongst the top five causes of deaths worldwide. Kolkata is placed among the most air polluted cities in the world with respect to SPM (According to The Times of India report 20/12/2017). In the analysis of the air pollution data of city, it is found that the concentration of SPM is much higher than the other pollutants. Much of the pollution is due to the economic and industrial development of the city and the appearance of versatile industries, such as the paper and pulp, organic and inorganic chemical industry, plastic, rubber, iron and textile industries, power plants etc. The main source of industry originated air pollution is the cluster of industries that use coal combustion to operate. Strong link between chronic exposure to air pollution and pulmonary, hematologic, immune system, and genotoxic changes that can lead to a number of diseases, such as respiratory illness, cardiovascular problems, and cancer is established (According to WHO). SPM with a diameter of less than 10 micrometers (PM_{10}) is too small to be filtered by the natural protective mechanisms of the human respiratory system. Apart from health implications, particulates also affect visibility and damage infrastructure. According to the Comprehensive Mobility Plan 2001 to 2025, Kolkata, around 70 per cent of Kolkata's 18 million inhabitants suffer from respiratory problems such as asthma and lung cancer, which are caused by pollution from the city's chaotic transport sector. Studies carried out by Chittaranjan National Cancer Research Institute have reported more than 60 per cent children in Kolkata with lung function impairments compared to 24 per cent in cleaner areas. Healthy individuals and non-smokers also show respiratory symptoms and lung function impairment. Though there are numerous toxicological studies showing negative effects of particles on a cellular level, like cytotoxicity, mutagen city, and DNA reactivity, the mechanisms causing negative effects on human health are not yet fully understood. But there is strong evidence that health effects depend on particle composition, particle surface area, and particle size with stronger effects for fine and ultrafine particles. The association of more negative health effects with fine particles may be caused by their capability to penetrate deeper into the human lung than coarse particles.

Chapter-2

Theoretical Considerations

2.1 Definition of Air Pollution

According to the **Air (Prevention and Control of Pollution) Act, 1981,** "air pollution is the presence of any solid, liquid, or gaseous substance in the atmosphere in such concentration as may be or tend to be injurious to human beings or other living creatures or plants or property or environment".

According to **WHO,** Air pollution is **contamination of the indoor or outdoor environment by any chemical, physical, or biological agent that modifies the natural characteristics of the atmosphere**. Household combustion devices, motor vehicles, industrial facilities and forest fires are common sources of air pollution
WHO data show that almost all of the global population (99%) breathes air that exceeds WHO guideline limits and contains high levels of pollutants, with low and middle-income countries suffering from the highest exposures.

USEPA describes air pollution as "the presence of contaminants or pollutant substances in the air that interfere with human health or welfare, or produce other harmful environmental effects". In other words, it can be explained as the introduction of some material which affect or try to affect human beings, animals, vegetation, materials, climate etc. adversely.

2.2 Sources of Air pollution

Natural source: Natural sources of air pollution include volcanic activity, dust, sea-salt, forest fires, lightening etc.

Anthropogenic source: These sources include stationary point sources (e.g., emission from industries) mobile sources (e.g., vehicular emission, marine vessels, airplanes etc.) waste disposal landfills, open burning etc.

2.3 Types of Air Pollutants

Air pollutants can be categorized by various means

- **Based on source of origin**

1. **Natural air pollutants:** These are emitted from natural sources such as volcanic activity, dust, sea salt, forest fires, lightening soil out gassing etc.

2. **Anthropogenic air pollutants:** These pollutants include the emissions from different man-made sources like stationary point sources (e.g., vehicular emission, marine vessels, air planes etc.), waste disposal landfills, controlled burning etc.

- **Based on method of origin**

1. **Primary air pollutants:** Those pollutants which are emitted directly from any emission source in the atmosphere are termed as primary air pollutants. E.g., Sulphur dioxide (SO_2) Carbon monoxide (CO) Lead (Pb) Ammonia (NH_3) etc.
2. **Secondary air pollutants:** Secondary air pollutants are formed by the reactions between primary air pollutants and normal atmospheric constituents. In some of the cases, these pollutants are formed by utilizing the solar energy e.g., Ozone, Peroxyacetyl nitrate (PAN), Smog, Sulfuric acid and nitric acid etc.

- **Based on chemical composition**

1. **Organic air pollutants:** Examples are hydrocarbons, aldehydes, ketones, amines, alcohols etc.
2. **Inorganic air pollutants:** Examples are carbon compounds (CO and carbonates) Nitrogen Compounds (NO_x and NH_3), Sulphur compounds (H_2S, SO_2, SO_3, H_2SO_4) Halogen compounds (HF, HCL etc.) fly ash silica etc.

- **Based on state of matter**

1. **Gaseous air pollutants:** Pollutants which are in the form of gas are termed as gaseous air pollutants e.g., SO_2, NO_x, O_3 CO Etc.
2. **Particulate air pollutants:** Particulate air pollutants or Particulate matter (PM) Can be defined as the microscopic solid or liquid matter suspended in the earth's atmosphere. There are various subtypes of particulate matter:
    a. Total suspended particulate matter (TSPM): The concentration of Particulate Matter which is obtained when a high-volume bulk sampling is done on a filter substrate. It includes particles of all size
    b. PM_{10}: These are the particles less than 10 μm in diameter
    c. $PM_{2.5}$: These are the particles less than 2.5 μm in diameter
    d. $PM_{1.0}$: These are the particles less than 1 μm in diameter

Note: Particle which lies between 10 μm to 2.5 μm are termed as coarse particles whereas particles with diameter less than 2.5 μm are called as fine particles. Fine particles also include ultra-fine particles of size less than 0.1 μm ($PM_{0.1}$).

2.4 Significant Parameters of Air Quality

Air pollution consists of a complex mix of various substances in different physical and chemical states and these arise from various sources. Many of them are believed to be gravely harmful to human health. Eminent international institutions like the World Health Organization (WHO) consider a certain set of air pollution indicators to get closer to

quantification and monitoring of air pollution as quantification of all the air pollutants has not yet been feasible on a global scale. WHO focuses on four health- related air pollutants, namely, particulate matter (PM), measured as particles with an aerodynamic diameter lesser than 10 µm (PM10) and lesser than 2.5 µm ($PM_{2.5}$), nitrogen dioxide (NO_2), Sulphur dioxide (SO_2) and ozone (O_3).

2.5 National Air quality Monitoring Programme (NAMP)

To monitor and control of various air pollutants, Central Pollution Control Board (CPCB) has been provided with various powers and functions under the Air (Prevention and Control of pollution) Act, 1981. After this, CPCB had launched a nationwide program viz. National Air Quality Monitoring Program (NAAQM) in 1984, which has been renamed as National Air Quality Monitoring Programme (NAMP). Present status of NAMP consists of 804 operating stations covering 344 cities/towns in 28 states and 6 Union Territories of the country. The growth in number of stations under operation is given in Figure below.

Fig. 2.1: Image source: National Ambient Air Quality Monitoring NAAQMS/45/2019-2020

2.6 Source Apportionment Study

To improve the air quality management system, there is also the need of knowing the particular source of pollution and its quantitative contribution to the ambient air quality. This can be done through the source apportionment study. There may be two ways for apportioning pollution, (i) A top-down approach starting with monitoring of pollution, and (ii) A bottom-up Approach starting with the activity data (like Fuel Consumption). Source apportionment study is based on tracking down the sources through receptor modeling and it helps in identifying the source and extent of their contribution CPCB has initiated the source apportionment studies in six major cities (i) Delhi, (ii) Mumbai (iii) Chennai, (iv) Bangalore, (v) Pune, And (vi) Kanpur.

2.7 National Ambient Air Quality Standards (NAAQS)

For developing a programme for the effective management of ambient air quality and to reduce the damaging effects of air pollution, development of national ambient air quality standards (NAAQS) is a pre-requisite. Central Pollution Control Board had adopted first

ambient air quality standards on November 11, 1982. These standards have been revised by CPCB in 1994, and later in 2009.Under the provisions of the Air (Prevention & Control of Pollution) Act, 1981, the CPCB has notified fourth version of National Ambient Air Quality Standards (NAAQS) in 2009. This revised national standard aims to provide uniform air quality for all, irrespective of land use pattern, across the country. There are 12 identified health-based parameters, which are to measure at the national level and with a view to have data comparison, need for uniform guidelines for monitoring, sampling, analyses, sample flow chart, data sheet based on standard method has been felt. Table 2.1 & 2.2 shows the NAAQS (National Ambient Air Quality Standards) as adopted by CPCB.

Table-2.1: National Ambient Air Quality standards (NAAQS) – 1994

Pollutant	Time weighted Averaged	Concentration in Ambient Air		
		Industrial Area	Residential, Rural, and Other Areas	Sensitive Area
Sulphur dioxide (SO_2)	Annual average	80 µg/m^3	60 µg/m^3	15 µg/m^3
	24 hours average	120 µg/m^3	80 µg/m^3	30 µg/m^3
Oxides of Nitrogen as NO_2	Annual average	80 µg/m^3	60 µg/m^3	15 µg/m^3
	24 hours average	120 µg/m^3	80 µg/m^3	30 µg/m^3
Suspended particulate matter(SPM)	Annual average	360 µg/m^3	140 µg/m^3	70 µg/m^3
	24 hours average	500 µg/m^3	200 µg/m^3	100 µg/m^3
Respirable particulate matter(≤10um)	Annual average	120 µg/m^3	60 µg/m^3	50 µg/m^3
	24 hours average	150 µg/m^3	100 µg/m^3	75 µg/m^3
Lead	Annual average	1 µg/m^3	0.75 µg/m^3	0.50 µg/m^3
	24 hours average	1.5 µg/m^3	1 µg/m^3	0.75 µg/m^3
Carbon monoxide(CO)	Annual average	5 mg/m^3	2 mg/m^3	1 mg/m^3
	24 hours average	10 mg/m^3	4 mg/m^3	2 mg/m^3
Ammonia (NH_3)	Annual average		0.1 mg/m^3	
	24 hours average		0.4 mg/m^3	

Table-2.2: National Ambient Air Quality Standards (NAAQS)—2009

Pollutant	Time weighted Averaged	Concentration in Ambient Air	
		Industrial, Residential, Rural and other Areas	Ecologically sensitive Area (notified by Central Government)
Sulphur dioxide (SO_2) µg/m³	Annual 24 hours	50	20
		80	80
Nitrogen dioxide (NO_2), µg/m³	Annual 24 hours	40	30
		80	80
Particulate matter (<10µm or PM_{10}, µg/m³	Annual 24 hours	60	60
		100	100
particulate matter(<2.5µm) or $PM_{2.5}$, µg/m³	Annual 24 hours	40	40
		60	60
Ozone(O^3), µg/m³	8 hours 1 hour	100	100
		180	180
Lead (Pb), µg/m³	Annual 24 hours	0.50	0.50
		1.0	1.0
Carbon monoxide (CO) µg/m³	Annual 24 hours	02	02
		04	04
Ammonia (NH_3), µg/m³	Annual 24 hours	100	100
		400	400
Benzene C_6H_6 µg/m³	Annual	05	05
Benzo (a)pyrene (BAP) Particulate phase only ng/m³	Annual	01	01
Arsenic (As), ng/m³	Annual	06	06
Nickel (Ni), ng/m³	Annual	20	20

2.8 Criteria Air Pollutants

The Clean Air Act requires USEPA to set National Ambient Air Quality Standards (NAAQS) for six common air pollutants (also known as "criteria air pollutants"). These pollutants are found all over the U.S. They can harm the health and the environment, and cause property damage.

Notes: National Ambient Air Quality Standards established by Environmental Protection Agency for six "criteria" pollutants in outdoor air, NAAQS are currently set for carbon monoxide, ground level ozone, nitrogen dioxide, particulate matter, and sulfur dioxide
Criteria Air pollutant: These pollutants are particulate matter, photochemical oxidants (including ozone), carbon monoxide, sulfur oxides and lead EPA call these pollutants "criteria" air pollutants because it sets NAAQS for them based on the criteria, which are characterizations of the latest scientific information regarding their effects on health or welfare.

2.9 Potential pollution from thermal power plant

The wastes generated by thermal power plants are typical of those from combustion processes. The exhaust gases from burning coal and oil contain primarily particulates (including heavy metals, if they are present in significant concentrations in the fuel), sulfur and nitrogen oxides (SOx and NOx), and volatile organic compounds (VOCs).For example, a 500 MWe plant using coal with 2.5% sulfur (S), 16% ash, and 30,000 kilojoules per kilogram (kJ/kg) heat content will emit each day 200 metric tons of sulfur dioxide (SO_2), 70 tons of nitrogen dioxide (NO_2), and 500 tons of fly ash if no controls are present. In addition, the plant will generate about 500 tons of solid waste and about 17 giga- watt-hours (GWh) of thermal discharge (*Thermal Power: Guidelines for New Plants*, n.d.).

2.10 Human Exposure

People are exposed to toxic air pollutants in many ways that can pose health risks, such as by:

- Breathing contaminated air.
- Eating contaminated food products, such as fish from contaminated waters; meat, milk, or eggs from animals that fed on contaminated plants; and fruits and vegetables grown in contaminated soil on which air toxics have been deposited.
- Drinking water contaminated by toxic air pollutants.
- Ingesting contaminated soil. Children are especially vulnerable because they often ingest soil from their hands or from objects they place in their mouths.
- Touching (skin or eye contact) contaminated soil, dust, or water (for example, during recreational use of contaminated water bodies). Once toxic air pollutants enter the body, some persistent toxic air pollutants accumulate in body tissues. Predators typically accumulate even greater pollutant concentrations than their contaminated prey. As a result, people, and other animals at the top of the food chain that eat contaminated fish or meat are exposed to concentrations that are much higher than the concentrations in the water, air, or soil.

2.11 Pollutants from Thermal Power Plants

Crude coal includes carbon, nitrogen, sulfur, ash, trace mercury, etc. When these elements undergo combustion, emissions such as NO_x, SO_2 and SO_3 are released in the atmosphere- Table 2.3.

Table 2.3: Pollutants from Coal Combustion and Control

Constituents	Pollutant	Control Method
Carbon	Heat, CO_2	Boilers
Nitrogen	NO_x SO_2	Burner and selective catalytic reduction system Wet and dry flue gas Desulfurization
Sulfur	SO_3	Wet electrostatic Precipitators
Ash	Ash	Electrostatic, Precipitator, Fabric filter, Ash handling system
Mercury	Hg^{++}, HgO	Powdered activated carbon injection, Wet flue gas desulfurization

2.11(a) Emission Norms

Emissions norms as per World Bank and Indian Context are shown in Tables 2.4 and 2.5 below

Table 2.4: Indian norms

Pollutant	Thermal power plants installed before Dec 31 2003	Thermal power plants installed after Dec 31 2003	Thermal power plants installed after January 1, 2017
PM mg/Nm^3	100	50	30
SO_2 mg/Nm^3	600 (for units < 500MW) 200 for units > 500MW)	200	100
NOx mg/Nm^3	600	300	100
Hg mg/Nm^3	0.03	0.03	0.03

Table 2.5: World Bank Norms

Pollutant	24-hour average	Annual average	
PM_{10} mg/m^3	150	50	
TSP mg/m^3	230	80	
NO_2 mg/m^3	150	100	
SO_2 mg/m^3	150	80	

2.11(b)Emission Control Technologies for Thermal Power Plants

Coal thermal power plants are one of the primary sources of artificial air emissions, particularly in a country like **India**. **Ministry of Environment and Forests and climate change** has proposed draft regulation for emission standards in coal-fired power plants. This includes significant reduction in **Sulphur-dioxide, oxides of nitrogen, particulate matter, and mercury emissions.** The first step is to evaluate the technologies which represent the best selection for each power plant based on its configuration, fuel properties, performance requirements, and other site-specific factors. Flue Gas Desulfurization System, Spray Dryer Absorber (SDA), Circulating Dry Scrubber (CDS), Limestone-based Wet FGD, Low NO_X burners, Selective Non-Catalytic Reduction, Electrostatic Precipitator, Bag House Dust Collector, all of which have been evaluated and installed extensively to reduce SO_2, NO_X, PM, and other emissions. Each control technology has its advantages and disadvantages. Thermal power plants result in emissions of sulfur-dioxides (SO_2), nitrogen oxides (NO_X), particulate matter (PM) and metals like mercury (Hg). Ministry of Environment and Forest has issued a draft notification in April 2015 that proposes to regulate SO_2, NO_X and Hg in coal-fired thermal power plants. Emission control technologies include electrostatic precipitators, fabric filters, wet and dry flue gas desulfurization, catalytic reduction, dry sorbent injection, etc. are also plays a vital role in controlling the air pollution.

2.12 Actions to reduce air pollution from a coal thermal power plant (Emilian Stefane al)

In this paper the various methods of ash and slag deposit surfaces stabilization and its advantages and disadvantages are discussed. The objective of this study is to review the materials, procedures, or processes in order to stabilize the top layer of slag and ash deposit.

Materials and methods in case studies

2.12(a) Sprinkler equipment

- This consists in keeping moist the surface of the deposit using a sprinkling and watering installation composed of pressure water pipes, hydrants, and mobile rain wings. Since the dust cloud that is formed in the middle of the storage yard has an elevation that is too high to be kept under control by the water curtain, this method also did not lead to the expected results. The results obtained after the experiment were not satisfactory. The main disadvantage of this solution is the rapid evaporation of the water from the surface of the storage yard and the necessity of permanent movement of the sprinkling system upon the entire surface of the storage yard, leading to an important handwork level.

2.12 (b) Coating with sodium silicate

- This experimental method was sprinkling the deposit surfaces with sodium silicate solution. This method has been proposed by Institute for Energy Research and Development Bucharest (ICEMENERG), as a conclusion. In order to coat the 1st compartment, 70 tones sodium silicate of SD type was used. The spreading solution has been formed with sodium silicate and water 1:1, according to the ICEMENERG study. Taking into account that the surface of the 1st compartment is about 12 ha it results a sprinkling rate of about 1.16 kg solution for 1 square meter and a specific cost very low. Because the summer has been characterized by abundant rains and strong wind, after few weeks the sodium silicate layer damaged itself and the scattering begun. However, the sprinkling had to be repeated after about 3 months in order to keep the 3 to 5mm protective layer formed at the surface of the storage yard. The method had to be generally applicable, no matter weather is, that is why other solution or method had to be found.

2.12 (c) Coating with bituminous solution

- This is a new method, the coating with bituminous solution. There have been carried several laboratory tests in order to determine the bituminous solution type that behaves in the best manner for the proposed purpose. It has been ascertained that the slag and ash samples pulverized with "cationic bituminous emulsion with bitumen changed with polymers and natural rubber latex and with a percentage of 65% bitumen", code SBC-PL, indicated during the time a good stability upon the ash surface, a high adherence, and a good elasticity, preventing in this way future detachments. The results obtained after the surface's coating with bituminous solution of a waste dump of 12 ha allow us to assert that the proposed method may be a solution of the issue regarding the pollution provoked by slag and ash waste dumps, under the condition of observance the preparation and sprinkling technology. After one month from applying this method upon the waste dump, it has been ascertained the preserving of the characteristics of the formed protective layer. This was favored by the abundant rains immediately after the application of the protector layer. Due to this fact, after a short time the results of the coating became negligible. A precise monitoring of air pollution concluded that method was not completely satisfactory.

2.12 (d) New technology for preparation, transport and storage of slag and ash, dense slurry

- By this technology the collected slag and ash are mixed with water in the average proportion of 1:1. So mixed, through the chemical reactions that take place in the grey components of ash and slag and water result new chemical compounds, insoluble, what lead to the reinforcing of the slurry at the storage area surface. This mixture becomes an ash rock in the entire deposit mass. The essence of the technology consists in the continuously mixing of the moistened transport, activating in this way the chemical substances of cement type from ashes and the formation of the homogenous dense sludge that is pumped at the storage yard where it reinforces itself. The so attained deposit has following characteristics: higher volumetric density; lower porosity, respectively permeability; deposit surface is reinforced, is not covered with fine ash and insensible at the action of wind scattering; it does not have in excess water that may affect its stability; noxious chemical substances contained by the slag and ash are retained and slag and ash from the boilers with water in a proportion solid/liquid 1:1, by hydraulic fixed in the formed ash rock; better quality geotechnical characteristics regarding the stability.(1)

2.13 Environment Impact Assessment of Thermal Power Plant for Sustainable Development (Kumar, S, et al.2013)

The thermal power plant has serious impacts on land, soil, air and various social impacts the thermal power plants are also said to emit large amount of mercury and generate large quantity of fly ash which destroys the surrounding environment. These plants also consume a large amount of water. Due to these problems, they require a proper Environmental impact assessment before commencement of the project which is not done judiciously in our country. Various problems and effects are arising due to the operations of thermal power plants among them are discussed here

- Environmental impact during operational stage.
  Among thermal based power generation, coal-based power plants are highest in: Air pollution, Waste generation, Water consumption, Emission of mercury, Greenhouse gas emission.
- Air pollution due to thermal power plants
  Air Pollution from point source: Particulates matter, Gaseous emission - Sulphur dioxide, oxides of nitrogen, carbon monoxide, carbon dioxide, Hydrocarbon.
- Air Pollution from non-point source: Transportation of coal, Loading/unloading of fuel, Coal storage yard, Fly ash handling & Transportation, Coal storage yard. Considering the statements environmental impact assessment is necessary for operation.

2.14. WHO guidelines and health effects: The case study of coal fired power plants. (Barriera, A., et al,2017)

This report focuses on the health and economic impacts of air pollution from the production of electricity from fossil fuels, particularly coal.

World Health Organization air quality guidelines

WHO air quality guidelines (AQGs) are intended to support measures to achieve air quality that protects the health of people. These guidelines are based on a comprehensive set of scientific evidence relating to air pollution and its health consequences.18 The AQGs were published in 1987 and updated in 1997, based on the existing scientific evidence at the time and evaluated by experts. In 2005, based on subsequent studies of the effects of air pollution on health, the information on particulate matter O_3, NO_2 and SO_2 was updated, with new guideline values for each of them. However, as WHO itself states, epidemiological evidence indicates that the possibility of adverse health effects persists even when guideline values are reached. Thus, some countries may decide to adopt stricter national air quality standards, setting lower concentration values.19 However most air quality objectives set by national governments are more permissive than those recommended by WHO.

Table 2.6: WHO Guideline values

Pollutant	Guidelines values WHO (µg/m³)	Average period
$PM_{2.5}$*	10	1 Calendar year
PM10	20	1 Calendar year
	50	24 hours
O_3**	100	8 hours
	40	1 Calendar year
NO_2	40	1 Calendar year
	200	1 Hour
SO_2***	20	24 hours

* For $PM_{2.5}$, the WHO chose a maximum concentration of 10 µg/m³ as the maximum annual mean from which health effects could be expected was within values ranging from 11 to 15 µg/m³, according to available scientific literature.

** In 2005, WHO reduced the proposed value for ozone in the latest update of its AQG, from 120 to 100 µg/m³ (maximum daily average of 8 hours) as evidence on the effects on health from epidemiological studies carried out over the years has shown that harmful effects occur with concentrations below 120 µg/m³. Nevertheless, ozone can have harmful effects on sensitive groups, such as asthmatics and the elderly, at concentrations even below this new guideline value.

*** The adoption of this low value is a precautionary measure due to the uncertainty about the causality of SO_2 on the negative impacts on health, and the difficulty in determining safe levels (below which there are no harmful effects).

2.14 (a)Coal: emissions into the air and health impacts

Emissions into the air

- The production of electricity from coal is one of the main sources of CO2 emissions. Its carbon emission factor (grams of CO_2 for every kilowatt-hour of electricity produced) depends on the type of coal burnt. It varies from 860 gCO_2/kWh of anthracite to 1,020 of lignite. Meanwhile the carbon emission factor of natural gas is 400.24.
- CO2 and other GHG emissions into the atmosphere are responsible for trapping the heat of the sun in the lower layers of the atmosphere – which would otherwise escape into space – thereby generating global warming. The impacts of climate change include alterations to habitats or the melting of the ice caps, which can lead to the extinction of species of flora and fauna. This not only permanently alters the balance of the environment but also has profound economic and social consequences. At present, almost the entire scientific community agrees on the need to take urgent measures to stop and reverse this process. In addition, coal power plant is also responsible for important emissions of NO_X, SO_2 and particulate matter, among others, which contribute significantly to air pollution and impact severely on human health.

2.14(b) Main health effects of pollutants evidenced by scientific studies

- Exposure to PM2.5 is associated with an increase in systemic inflammatory response and oxidative stress, as well as with variations in the biomarkers of cardiovascular inflammation such as Creative protein (CRP) and fibrinogen. Long-term exposure promotes the progression of cardiovascular diseases and has been associated with an increase in total mortality – particularly, the increase in cardio respiratory mortality and mortality from lung cancer. It is also related to respiratory diseases.
- NO_2 is a highly reactive and equally hazardous health pollutant present in most of the urban and industrial areas. Prolonged exposure to NO_2 can cause damage to the respiratory system and is associated with increased symptoms of bronchitis and asthma, lung function impairment, and lung cancer. Numerous epidemiological studies conducted in Europe and the rest of the world conclude that between 5 and 7 percent of lung cancer cases in ex-smokers and non-smokers may be associated with exposure to high concentrations of this pollutant. It is also related to an increase in mortality.
- SO_2 has been associated with an increase in asthma and chronic bronchitis, as well as with a decrease in lung function and bronchial inflammation. Hospital admissions for heart disease and mortality increase on days when SO_2 levels are higher.

Chapter-3

Literature Survey

3.1 General

Literature survey is a systematic method for identifying, evaluating, and interpreting the work. A literature survey is undertaken to decide how to move forward with a research idea – what has been done, and what interesting avenues of future work this opens to be investigated. Here the subject matter of the present study has been classified from three different perspectives through global, national, and regional perspectives.

3.2 Global scenario

3.2.1 Air pollution in a thermal power plant city: In Turkey (Artun, GülzadeKüçükaçıl, et al.2017)

Ambient concentrations of nitrogen dioxide (NO_2), sulfur dioxide (SO_2), ozone (O_3) and volatile organic compounds (VOCs) were measured at several locations in Kütahya, a severely polluted city and characterized as a thermal power plant city, in Turkey. Two-week extensive passive sampling campaigns were carried out in summer and winter at 108 sampling sites that were classified into three main groups as urban, rural, and industrial. All pollutant concentrations showed an increasing pattern in winter, except for ozone. The concentrations of VOCs were substantially higher particularly at sampling sites with high traffics and population densities. Power plants were noted as important sources for VOCs since high concentrations were measured especially around the powerplants. Highest NO_2 levels were observed in the city center while there was a general decrease in the concentration levels far away from the city center. Considerably higher SO_2 levels were observed in the settlements where local coal is used for residential heating. Seasonal variations in SO_2 concentrations were quite low around the thermal power plants indicating their important effect on atmospheric levels**.** Major air pollutants emitted from thermal power plants that use coal are sulfur dioxide (SO_2), nitrogen oxides (NO_X), volatile and semi volatile organic compounds (VOCs and SVOCs), carbon dioxide (CO_2) and various elements. SO_2 is one of the most important pollutants emitted from power plants. However, quantities of the pollutants emitted from the power plants are based on different parameters such as chemical composition of the coal and control technology.

3.2.2 Ambient air pollution of the Stara Zagora Region from the "Maritsa East" Power complex

Analysis has been made on the processes that take place in the atmosphere with the emissions of SO_2, NO_x and particulate matter from thermal power plants and lead to the formation of secondary pollutants photochemical and acidic smog. The monitoring of the atmospheric air in the Stara region in 2003-2005 has shown that the main source of pollution is the three thermal power plants of the "Maritsa East". It has been found that the ambient air pollution of the region is influenced by the following factors:- Considerably primary oxidation of SO_2 to SO_3 in the fuel installations of the thermal power plant at high levels of the pollutants in flue gases, absence of purification of SO_3 in the emitted flue gases, joint action of the factors above with high humidity of the atmospheric air leads to the formation of acidic fog, Secondary oxidation process with pollutants in the atmosphere and formation of photochemical smog under certain meteorological conditions. So in order to control and forecast the danger of air pollution in the atmosphere and the fuel installations of the thermal power plants have to be set under permanent control.

The main sources for pollution of the atmospheric air in the Stara Zagora region are the three thermal powerplants (TPP's) of the "Maritsa East' power complex. Because of the enormous quantities of the emissions, the TPP's produce pollution levels with SO_2, NO_x and particulate matter that considerably exceed the permitted levels in the country. The amount of the emitted flue gases to the atmosphere is 4.5×10^{10} Nm^3 per year with an average content of 15000mg SO_2 and 250mg NO_x pro each normal cubic meter. During the past few years frequent ambient air pollution cases in the region have been observed. **Two of them, in the summer of 2005, were very serious and grew up into an ecological and social problem for the region until now there as on for these air pollution cases have not been correctly clarified.**

3.2.3 Japan: Impact on air quality by increase in air pollutant emissions from thermal power plants

The amount of thermal power generation has increased significantly in Japan since the Great East Japan Earthquake in 2011, resulting in increase in emissions of air pollutants. The ratio of thermal power generation rapidly increased from 62% to 89%. As the power generation in the Kinki district of Japan depended heavily on nuclear power generation, the ratio of thermal power generation increased from 46% to 80%. It resulted in the increase in emissions of air pollutants. The emissions of NOx, SO_2, PM_{10}, $PM_{2.5}$, NH_3 from thermal power stations shown in Figure 1 were estimated. The emissions of NOx, SO_2 from the thermal power stations in the Kansai Electric Power Co. were given from the electric power generation performance in 2014. The emissions of PM_{10}, $PM_{2.5}$, NH_3 were estimated from the emission database of EAGrid2010-JAPAN in 2010. The emissions from the thermal power stations in other companies were predicted from the electric power generation ratio in the Kansai Electric Power Co. and other companies. The hourly variation of the emissions each month

was considered from the hourly variation of the electric power generation in 2012. Figure 3.2 shows the emissions of NO_x and SO_2 each power station in 2010 and 2011. In the Kainan oil power station, the emissions extremely increased in 2012, because the Kainan oil power station was the peak load electricity source. On the other hand, the emissions in the Kobe coal power station in 2012 were almost same as 2010, because the Kobe coal power station was used as the base load electricity source.

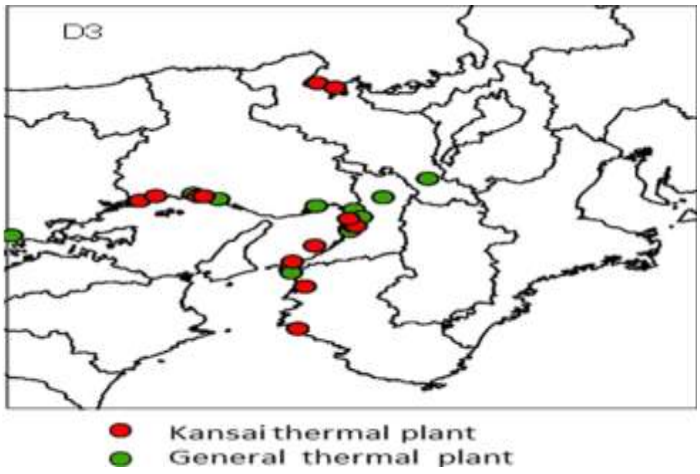


Fig. 3.1 Location of thermal power plants

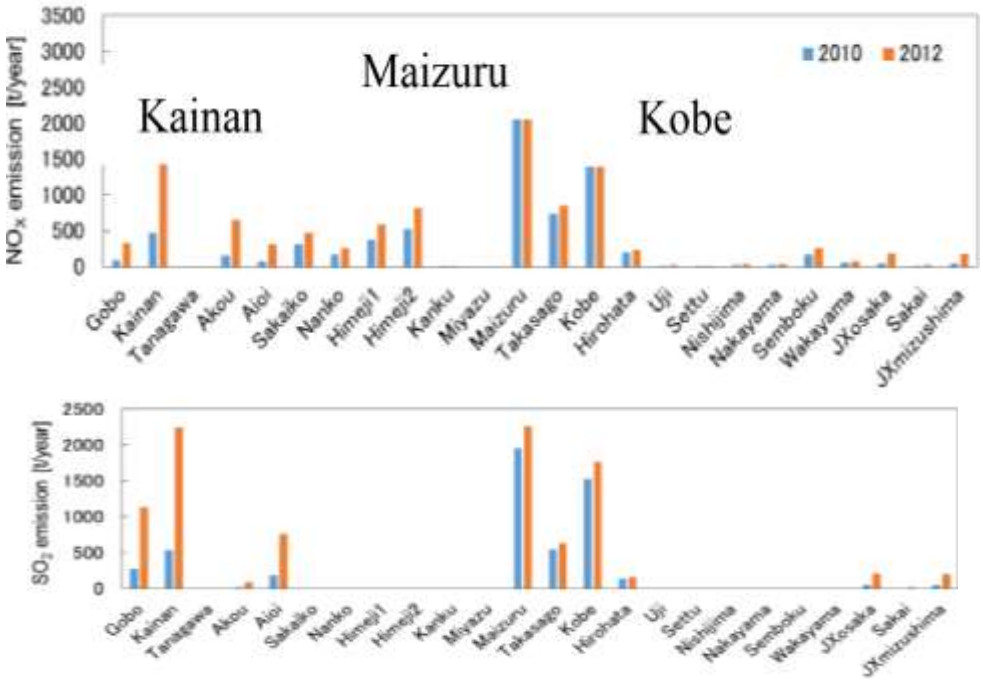


Fig. 3.2: NO_X and SO_2 emissions from thermal plant in 2010 and 2012

3.2.4 Air Pollution Caused by Coal-fired Power Plant in Middle Taiwan

1. Achieving goals of industrial development and environmental sustainability is not the zero-sum game. But contradiction exists between energy and air pollution. Taichung City, located in central Taiwan, has a world's second largest thermal power plant, carbon emissions ranked first in the world, a plant supply about 19% of Taiwan's electricity consumption, emissions of coal in the air, of course, lead to serious air pollution in Taichung and neighboring areas. 15% of the Taichung city's $PM_{2.5}$ is discharged from the Taichung thermal power plant. Taichung City Environmental Protection Agency listed data to prove "Taichung thermal power plant is the largest source of fixed pollution in Taichung," the city $PM_{2.5}$ annual emissions of 8498 tons, all factories are regarded as fixed sources of pollution, emissions of 2690 tons, "half of which All contribute to the Taichung thermal power plant, with an emission of 1244 metric tons", which is equal to 15% of the city's $PM_{2.5}$ being discharged from the Taichung thermal power plant. Dr. Chan also takes the Dalin Power Plant in Kaohsiung as an example. Since September 2012, the concentrations of PM_{10} and $PM_{2.5}$ in the adjacent Linyuan Station have dropped after the stop working of Units 1 and 2 in the Dalin Power Plant. In particular, $PM_{2.5}$ From 45.6 in 2011 to 29.5 in 2014, "it dropped by 16 in 3 years and the national standard was 15, equivalent to a national standard of 3 years." $PM_{2.5}$ is highly correlated with lung adenocarcinoma and has long been a first-class carcinogen of the World Health Organization (WHO). Due to the small size, less than 1/28 of the hair diameter, small enough to carry heavy metals, dioxin and germs penetrate the respiratory system, directly to the chest, and the body with blood circulation. Taiwan's Healthy Air Action Alliance Dr. G. Ye pointed out that $PM_{2.5}$ no safety value, only the lower the better.

3.2.5 An emerged of air pollution and ever – Increasing particulate matter in Pakistan; A critical review

Air Pollution in Pakistan and its harmful effects

- Air pollution is emerging as one of the major environmental concerns of the 21st century, and its impacts are becoming prominent overtime.
- According to (UNECE 2020) the last few decades, it has severely affected human health, quality of life and is being ranked among the greatest environmental risks to human health
- According to (WORLD BANK, 2016), it is responsible for the deaths of about 6.5 million people annually round the world.
    - Each year more than 5.5 million people experience premature deaths from illness caused by breathing polluted air
    - One third of deaths associated with strokes, Lung Cancer Chronic respiratory disease has been linked with air pollution. On the top of this according to WHO,

about 90% of population in low- and middle-income countries do not have access to clean air.

- IHME (2019) reported that air pollution reduces life expectancy on average by 1 year and 8 months globally.
- The Asian Continent is severely affected by air pollution with the highest particulate matter concentrations that have been reported in South Asia, South East Asia and West Asia respectively.
- According to the report (World air quality, 2019) majority of most polluted cities of the world are in south Asia, which had 4 of the top five polluted countries and 30 out of 40 world's most polluted cities in 2019. South Asian countries like **India, Bangladesh and Pakistan** have remained the most polluted countries in the world.
- According to the state of global air report, 2019 the highest annual $PM_{2.5}$ in 2017 were also observed in South Asia with Nepal, India, Bangladesh, and Pakistan having the highest exposures respectively.

Table 3.1: **Comparison of AQI and PM $_{2.5}$ of Lahore and other major cities around the Globe.**

World Ranking	City	2019	JAN	FEB	MAR	APR	MAY	JUN	JUL	AUG	SEP	OCT	NOV	DEC
1	Ghaziabad, India	110	205	29	89	86	96	62	45	33	37	158	235	235
2	Hotan, China	110	60	70	189	151	128	57	119	126	87	103	114	106
3	Gujranwala, Pakistan	105	220	127	86	70	65	53	59	48	67	107	144	217
12	Lahore, Pakistan	89	199	110	73	62	53	44	39	40	54	104	134	182
21	Dhaka, Bangladesh	83	181	145	107	70	52	35	36	31	37	64	94	146
24	South Tangreng Indonesia	81	44	61	48	60	87	107	102	90	100	104	88	76
70	Kabul, Afghanistan	58	145	58	40	16	11	96	28	31	34	45	60	196
102	Lalapasa, Turkey	53	124	110	59	28	20	23	22	23	20	34	81	100
137	Kathmandu, Nepal	48	102	62	65	55	60	29	15	11	13	30	58	75
150	Hanoi, Vietnam	46	59	36	50	40	45	36	30	33	48	43	66	72
151	Manama, Bahrain	46	53	39	45	41	56	44	40	52	54	63	33	37
199	Bolemfonteim, South Africa	42	12	11	-	42	62	102	72	49	33	28	20	16
200	Nakhon, Ratchasima	42	42	67	68	41	28	17	15	-	-	-	-	32
1924	Tokyo, Japan	11	11	17	13	11	12	10	10	12	9.4	8.9	9.8	13
2045	London, United Kingdom	11	12	17	10	21	10	86	78	92	6.8	9.3	12	10

3.2. 5 (a) Sources of Air Pollution in Pakistan.

Several atmospheric pollutants like NO_x, SO_2, CO, Particulate Matter, etc. have been reported to occur in high concentrations in Pakistan. Studies like Shahid et al. (2015) have linked the presence of these atmospheric pollutants to different sectors. For NO_x, primary sources include the transportation and industrial sectors, responsible for around (43.2% and 39.6%) of the total annual emissions. Major Sources of SO_2 and CO include industrial and thermal power generation, residential and transportation sectors, responsible for around (75.6% and 14.6%) and (62.9% and 23.6%) of total annual emissions, respectively. Although these studies do provide a basic picture, but the lack of source apportionment and cross sectoral studies make it difficult to understand the complex situation comprehensively.

Table 3.2: Pollutant concentrations projected through different years in Pakistan under Business-as-usual Scenario

Pollutant Species	2015	2020	2025	2030	2035
	in Ktons				
CH_4	1.39	1.76	1.69	1.65	2.57
CO	7.83	108	149.09	190.18	367.82
CO_2	39,437.94	80,043.72	91,011.62	101,979.50	181,491.50
N_2O	0.25	6.89	9.66	12.41	24.12
NOx	103.89	232.98	271.19	309.4	557.77
PM_1	3.36	339.83	481.47	623.1	1214.98
PM_{10}	17.9	3917.13	5561.65	7206.17	14061.38
$PM_{2.5}$	7.09	1120.69	1590.08	2059.45	4017.65
PMBC	0.22	4.22	5.87	7.52	14.58
PMOC	0.21	23.5	33.3	43.12	84.08
PMTSP	26.69	6765.54	9608.29	12,451.06	24,297.77
SO_2	660.9	1983.7	2446.52	2909.34	5359.65
VOC	0.94	5.07	6.67	8.28	15.74

3.2.6 Positive association between outdoor air pollution and the incidence and the severity of COVID-19. A review of the recent evidences

- Mehmood et al. (2020) raised the question of whether air pollution could be worsening the death rates due to covid-19 in India and Pakistan, countries where the concentration of $PM_{2.5}$ were then 700 and 1000 $\mu g/m^3$ in New Delhi and Lahore respectively.
- According to WHO official covid-19 data at the time (June 20,2020) India was being the 4^{th} worst affected country by covid-19 with more than 395048, infected cases and 12948 deaths, while Pakistan had recorded over 171666 cases and of infection with 3382 deaths.
- A link between air levels of NO_2 and $PM_{2.5}$ and COVID-19 infection severity were also reported who examined specific areas of India and other five countries (China, Italy, Russia, Chile, and Qatar). Since rate of severity and deaths to those residing in less polluted zones, it was concluded that air pollution had a positive influence on the rate of propagation and severity of covid-19 cases.
- Although population density was found to be an important factor for the rapid spread of SARS- COV-2 it was also suggested that past exposures to high levels of $PM_{2.5}$ and PM_{10} could led to higher risks of covid-19 mortality.
- It is examined the influence of lockdown and unlock periods on PM_{10} $PM_{2.5}$, CO and O_3 concentration in five Indian mega cities (Bangalore, Chennai, Delhi, Kolkata, and Mumbai as well as the role of pollutant concentrations air quality index and Meteorological variable on covid-19 daily confirmed cases and deaths. The result showed a significant co-relation of $PM_{2.5}$ PM_{10} CO, O_3 concentration with the confirmed cases and deaths during the lockdown period. Among these pollutants O3 showed the highest variability, upto 34% for covid-19 confirmed cases and deaths.

- In **Pakistan** examined the air quality and covid-19 distribution during pre-lock down in Lahore, Karachi, Peshawar, and Islamabad. Data on levels of PM $_{2.5}$ and NO_2 collected during the different periods were used. All these cities were showed a high incidence of covid-19 cases, since the high concentration of $PM_{2.5}$ were also observed, it was suggested that air pollution showed be significantly reduced in order to diminish the risks of potential cases of COVID-19

3.2.7 Coal Quality plays a great role in environmental impact as well as gaseous emissions

- The blessing indeed property Barakpukuria (Bangladesh) plant has some adverse effect also. The major effects of the power station are the exhaust emission. The emissions are SO_x and NO_x, which are principal pollutants of coal based thermal power plants.
- It is also worth to note that very high amount of SO_x, NO_x and SPM which disperse over 25 km radius and cause respiratory and related ailments to

human beings and animal kingdom.

- The SPM also includes RSPM (respirable particulate matter) and both type of fine particles normally spread over 25kms from the thermal power plants

Survey and analysis

- Survey to the inhabitants: A survey was directed to the surrounding area within about 5km from the power plant. A conversion was made among 210 people of different profession near by the plant area to investigate their impact on health. They informed about their health condition (suffered by the Barakpukuria power plant). The survey was based on several questions about asthma, allergy, skin disease, and other respiratory problems on their health impact.

Table 3.3: Result of the survey

Variable	Asthma	Allergy	Skin disease	Other respiratory problem	Total	Percentage
Agree	5	7	6	12	30	14
Undecided	35	33	24	28	120	58
Disagree	20	10	30	30	80	38
Total	60	50	60	50	210	100

Table 3.4: Analysis of wastewater (drained)

Water parameters	Gut side boundary drain	Outside drain water
Mn	0.19 mg/l	0.26mg/l
pH	7.2	7.4
Total count	7.5 x10^4 C.F.U/100 ml	10 x 10^4 C.F.U/100ml
Total coliform	28	28
Fecal coliform	9	9
AS	0	0
SO_4^{2-}	2.4mg/l	3.1mg/l
NO_3^-N	0.4mg/l	1.6mg/l
Fe^{3+}	0.45mg/l	0.61mg/l

COAL ANALYSIS

Coal consumption (at rated load)

- Each unit per day: 1200 Ton
- Total for 2 units per day: 2400 Ton
- Coal consumption/KWH: 0.4 kg
- Annual ash generation:0.08 million Ton
- Cooling water consumption/h:800-1200Ton

Table 3.5: Fly ash analysis

Oxides	Percentage
SiO_2	54.4
Al_2O_3	35.6
Fe_2O_3	2.9
TiO_2	3.2
Mn_3O_4	0.11
CaO	0.56

3.2.8 The environmental implications of coal usage as an energy resource for residential heating in Kabul city.

Pollutant properties of coal

- A pollutant is a destructive substance that is not a natural component of the environment. There are many factors that causes air pollution, the major air pollutants resulting from solid fuel combustion are: SO_2, SO_3, the oxides of sulfur, carbon monoxide, CO_2, the oxides of nitrogen, NO, and NO_2, and particulate matters that mainly consist of very fine particles of grime and ash.
- Coal is made of more than 50 chemical elements, with the extraction, purification, transportation, and consumption of coal causing significant air pollution and profoundly affecting human health animal life, water, soil, ecosystems, plants, and the air.
- Radioactivity Property: Coal produces carcinogenic radiation, which causes lung cancer, cell mutations, asthma, and other types of radiation-related menace. The concentration of radionuclide activity in fly ash from a coal-fired power plant using high-sulfur and low-sulfur coals is shown in Table 3.6. As a result, people who work in coal plants or live nearby the plants suffer from radiation-related afflictions and diseases.

Table 3.6

Radio nuclide	High sulfur	Low sulfur
Uranium-238	181	161
Radium-226	189	143
Lead-210	315	178
Radium-228	76	125

- It consists of different toxic metals. (i.e., lead, thallium, barium, cadmium, chromium, mercury, and nickel). Mostly coal mines and coal consumption power plants are located around the riversides and high hills. Groundwater and surface water in the coal mine rush into the pit as a result of the hydro geological circumstances in the mining area. As a result, the groundwater level drops, the surface water system is impaired, and the water supply is depleted.

- **Greenhouse Gas Emission**: Water vapor (H_2O), carbon dioxide (CO_2), methane (CH_4), ozone (O_3), nitrous oxide (N_2O), and chlorofluorocarbons (CFC) are examples of greenhouse gases. The primary greenhouse gas released as a byproduct of the combustion of fossil fuels is carbon dioxide (CO_2)
- **Coal can be Deadly**: Around 3.7 million premature deaths from environmental particulate air exposure occurred in 2012, including 482,000 in Europe and 94,000 in Canada and the United States reported by WHO. Some sources of coal mortality include suffocation, asthma, pneumonia, lung cancer, and hypoxia. According to estimates, burning solid fuels like coal for cooking and heating results in around 1 million pneumonia fatalities in children under 5 and 1 million cases of chronic obstructive pulmonary disease per year.

3.2.9 Predicting the non-carcinogenic health hazards associated with emissions from developing coal-fired power plants in Payra, Bangladesh (Hossain, M., Ahmed, T., & Ali, et al.2020)

In this paper it is simulated the spatial distribution of air pollutants such as SO_2, NOx, $PM_{2.5}$, and PM_{10}, to estimate short term and long-term health risks and to assess the compliance with ambient air quality standards and guidelines.

- These pollutants (SO_2, NOx, $PM_{2.5}$, and PM_{10}) have been associated with many direct and indirect adverse health impacts, including respiratory diseases, asthma attacks, skin disease, genetic mutations, and cardiovascular diseases
- According to the Global Burden of Disease Study exposure to outdoor fine particulate matter $PM_{2.5}$ is the fifth leading risk factor for death worldwide, accounting for 4.2 million deaths and 103.1 million disability-adjusted life-years during 2015.
- A review of epidemiological studies in Italy, Spain, France, and the Netherlands found that even low concentrations of SO_2 (less than 10 ppb 24-h average) are associated with increased risk of death from heart and lung conditions (USEPA 2008).
- Studies on short-term increase in NO_2 concentration have demonstrated association with increased daily mortality and hospitalization for respiratory and cardiovascular diseases.
- Studies conducted among the children residing in the nearby communities of a major coal-fired power plant in Hadera, Israel, showed a significant rise in asthma and respiratory related conditions, prominently on children experiencing chest symptoms, in the decade after the plant became operational (Goren and Hellmann 1997; Yogev-Baggio et al. 2010).
- According to Mokhtar et al. (2014) a study on impacts of coal-fired power plant in Malaysia, predicted short-term carcinogenic health risks owing to elevated concentrations of arsenic and chromium, while short-term non-carcinogenic health risk was predicted for elevated SO_2 concentration.

3.2.10 Impacts of regional industrial electricity savings on the development of future coal capacity per electricity grid and related air pollution emissions – A case study for China (Yue, H., Worrell, et al.2021)

To identify the most economical way, a cost performance analysis is carried out in this study to compare the investment and air quality benefits of electricity savings compared to end- of-pipe controls.

- Here, it is comprehensively evaluating the impacts of industrial electricity savings via energy efficiency improvements on the deployment of coal-fired power plants by 2040 targeting to reduce air pollutant emissions in China.
- Coal-fired power plants have been massively deployed in China (more than 3,000 coal generation units in service in 2016), and are responsible for ~ 19%, ~21% and ~ 11% of China's total SO_2, NO_x and PM emissions, respectively, seriously impacting local air quality.
- Air pollutants can also be removed by flue gas control devices. However, traditional pollution control systems reduce power generation efficiency and increase CO_2 emissions due to the consumed additional energy and resources (e.g., sorbents and catalyst).

3.2.11An integrated analysis of air pollution from US coal-fired power plants (Filonchyk, M., & Peterson, M. P. et al.2023)

This study applies an integrated approach using both terrestrial and satellite data to specifically examine emissions from coal fired power plants and its spatial extent. The study also highlights the effectiveness of government policies to reduce emissions.

- According to US government data, major emitters of SO_2, NOx, and CO_2 in the US are the Martin Lake power plant in East Texas, the Labadie power plant near St. Louis, Missouri, and the James H Miller Jr plant near Birmingham, Alabama.
- It was found that emission of pollutants from the country's energy sector has been steadily declining, with annual emissions of sulfur dioxide (SO_2) and nitrogen oxides (NOx) decreasing from the US electric power sector between 1990 and 2020 by 93.4% and 84.8%, respectively, and carbon dioxide (CO_2) by 37% between 2007 and 2020. Although overall emissions from coal fired power plants are declining, some individual plants have yet to install environmental equipment to control emissions.

  Most important to human health, the burning of coal results in emissions of particulate matter ($PM_{2.5}$ and PM_{10}), ozone (O_3), nitrogen oxides (NOx), carbon dioxide (CO_2),sulfur dioxide (SO_2), methane (CH_4), volatile organic compounds (VOCs) and over 80 hazardous air pollutants such as mercury, lead, arsenic and benzene inhaling air with high concentrations of these pollutants can irritate the respiratory system, especially severe exposure for short periods of time Long-term exposure may contribute to the development of asthma and a potential increase in susceptibility to respiratory infections. These pollutants have significant impact on acid deposition, smog formation visibility and radiative forcing.

Emission characteristics for US power plants

- Coal-fired power plants are equipped with continuous emissions monitoring systems (CEMS) that directly measure stacks emissions. In accordance with the Clean Air Act (CAA) developed by the US Environmental Protection Agency (EPA), air pollutants such as CO_2, SO_2 and NOx (NOx = NO and NO_2) are criteria pollutants when considering the amount of emission from the combustion of different types of fuel in the process of generating electricity.
- The overall emission levels depend on the size of the boiler, the amount of coal used and the efficiency of the environmental equipment installed at the stations.
- Data from the EPA (Environmental protection agency) shows the total emissions of air pollutants for 2020. This data monitors how much SO_2, as well as greenhouse gases such as CO_2, NOx, CH_4 and N_2O, were emitted by each coal-fired power plant in the country during the year.

Discussion and conclusions:

- A summary of the some of the other major findings of this study include:

1. There are 48 power plants operating in the country with a capacity of more than 1500 MW, of which 20 stations have a capacity of more than 2000 MW
2. Over the past few decades, the US electricity generation mix has shifted from coal to natural gas and renewable, leading directly to lower CO_2 emissions for electricity generation.
3. Since 2007, there has been a downward trend in CO_2 emissions, mainly due to the reduction in the use of coal. In2020, US power plants emitted 1449 Mt CO_2 into the atmosphere, a 67% decrease from 2422 Mt CO_2 in 2007. The share of coal in CO_2 emissions decreased by 60.4%, from 1986 Mt CO_2 in 2007 to 787 Mt CO_2 in 2020.
4. SO_2 and NO_x emissions from the US electric power sector decreased by 93.4% and 84.8% respectively between 1990 and 2020. Coal accounted for 92.8% (1991) to 73.9% (2020) of total SO_2 emissions and 90.3% (1993) to 43.6% (2020) of NOx emissions.
5. The largest pollutant emitters in the country are the largest coal-fired power stations: Martin Lake, Labadie, Gibson, and James H Miller Jr. However, since 2000, most of the examined power plants have significantly reduced emissions of pollutants into the atmosphere.
6. The most notable NOx reductions were recorded at Rockport (–1980%) and Cumberland (–1229%); SO_2 at Scherer (–17,156%), James H Miller Jr (–7388%) and Roxboro (–3575%) stations; and CO_2 at Rockport (–325%), Scherer (–216%) and Roxboro (–174%) stations
7. An increase in the use of coal was noted in 2021, a result of higher prices for natural gas. It is uncertain whether this trend in the increased use of coal will continue. Increasing demand for electricity to charge the large number of electric cars may continue a reliance on coal for power generation thereby negating in part the environmental advantage of electric vehicles.

3.3 Indian Scenario

3.3.1 Atmospheric emissions and pollution from the coal-fired thermal power plants in India (Kansal, Arun, Mukesh Khare, and Chandra Shekhar Sharma et al.2011)

In India, of the 210 GW electricity generation capacities, 66% is derived from coal, with planned additions of 76 GW and 93 GW during the 12th and the 13th five year plans, respectively. Atmospheric emissions from the coalfired power plants are responsible for a large burden on human health. In 2010 to 11, 111 plants with an installed capacity of 121 GW, consumed 503 million tons of coal, and generated an estimated 580 ktons of particulates with diameter less than 2.5 mm ($PM_{2.5}$), 2100 ktons of sulfur dioxides,2000 ktons of nitrogen oxides, 1100 ktons of carbon monoxide, 100 ktons of volatile organic compounds, and 665 million tons of carbon dioxide. These emissions resulted in an estimated 80,000 to 115,000 premature deaths and 20.0 million asthma cases from exposure to $PM_{2.5}$ pollution, which cost the public and the government an estimated INR 16,000 to 23,000 crore (USD 3.2 to 4.6 billion). The emissions were estimated for the individual plants and the atmospheric modeling was conducted using CAMx chemical transport model, coupled with plume rise functions and hourly meteorology. The analysis shows that aggressive pollution control regulations such as mandating flue gas desulfurization, introduction and tightening of emission standards for all criteria pollutants, and updating procedures for environment impact assessments, are imperative for regional clean air and to reduce health impacts. For example, a mandate for installation of flue gas desulfurization systems for the operational 111 plants could reduce the $PM_{2.5}$ concentrations by 30 to 40% by eliminating the formation of the secondary sulfates and nitrates. Coal-fired power generation comes with significant costs to environment and human health. **Most importantly for human health, combustion of coal releases emissions of sulfur dioxide (SO_2), nitrogen oxides (NO_X), particulate matter (PM), carbon monoxide (CO), volatile organic compounds (VOCs), and various trace metals like mercury, into the air through stacks that can disperse this pollution over large areas.** Of the estimated annual anthropogenic emissions in India, the thermal power plants account for~15% for $PM_{2.5}$, ~30% for NO_x, and ~50% of SO_2. For 2010-11 the total estimated annual emissions are 580 ktons for $PM_{2.5}$,1200 ktons for PM_{10}, 2100 ktons of SO_2, 2000 ktons of NO_x, 1100 ktons of CO, 100 ktons VOC_s and 665 million tons of carbon dioxide (CO_2). The total estimated emissions by state are presented in Table 3.7.

Table-3.7: Total annual emissions (rounded) from coal-based power plants in India in 2010-11

State	$PM_{2.5}$ (tons)	PM_{10} (tons)	SO_2 (tons)	NO_x (tons)	CO (tons)	VOC (tons)	CO_2 (tons)
Andhra Pradesh	51,500	107,500	199500	187500	104000	9500	62.8
Bihar	15,500	31,000	43000	39500	22500	2500	13.5
Chhattisgarh	39,000	84000	187000	172500	97500	9000	58.9
Delhi	7500	14,500	20500	20000	11000	1000	6.4
Gujarat	53,000	111,000	214000	220000	122500	11500	74.0
Haryana	23,500	50,000	100500	93500	52500	5000	31.7
Jharkhand	15,500	31,500	50500	48500	26500	2500	15.9
Karnataka	17,500	36000	61500	58500	32000	3000	19.4
Madhya Pradesh	49,500	100,000	139500	130500	73000	7000	43.9
Maharashtra	80,500	167,000	300500	278500	156500	14500	94.6
Orissa	40,000	85000	171000	159500	89500	8500	53.9
Punjab	16,500	34000	56000	53000	29000	3000	17.5
Rajasthan	14,500	30,000	55500	52000	29000	3000	17.5
Tamil Nadu	36,500	74000	108500	104500	56500	5500	34.2
Uttar Pradesh	83,500	168500	235500	225000	122500	11500	74.1
West Bengal	40,000	83500	152000	143000	79000	7500	47.8
Total	**580,000**	**1,200000**	**2,100000**	**2000000**	**1,100000**	**100000**	**665.4**

3.3.2(a) Atmospheric pollution: Delhi

Recent strategies for air pollution control in Delhi have largely neglected the emission reduction measures from thermal power plants (TPPs), which are the second most polluting sources. The present study investigates how the ambient air quality of Delhi would improve if the World Bank emission guidelines (WBEG) for the TPPs were to be implemented. To accomplish this, a comprehensive inventory of point, area, and line sources was conducted in the selected study area, primarily aiming to estimate the sectoral emission contributions to ambient air quality. The Industrial Source Complex Short–Term Model, Version 3 (ISCST3) was used to predict the ambient concentrations of total suspended particulates (TSP), Sulphur dioxide (SO_2), and nitrogen dioxide (NO_2) at seven monitoring sites (receptor locations) operated by the Central Pollution Control Board (CPCB) for the period from July 2004 to June 2005. The ISCST3 model predictions for TSP and NO_2 were satisfactory at all receptor locations. However, for SO_2, the model predictions were satisfactory at only two receptor locations. The vehicles contributed 58% of the total ambient air pollution, followed by TPPs contributing 30%. The study estimates that adoption of WBEG may reduce the ambient air pollution due to TPPs emissions by 56% to 82%, bringing it within the National Ambient Air Quality Standards (NAAQS) set for industrial areas in India, except at one location where TPP's contribution to ambient air pollution is negligible compared to vehicular emissions.

3.3.2 (b) Source Emission Inventory

TSP, SO_2, and NO_2 emissions from point, area, and line sources in the study area were computed and compiled for each month during the study period. Selection of SO_2, NO_2, and TSP as criteria pollutants is based on the rationale that: a) these are the significant pollutants emitted from TPPs, b) they are the only air pollutants which are subject to current Indian standards and WBEG, c) they are measurable/continuously monitored by regulatory authorities, d) changes in parameters can be predicted by the modelling process.

3.3.2(c) Emissions from TPPs Business – As – Usual (BAU) scenario

Monthly emissions from TPPs during the study period were obtained from Central Electricity Authority (CEA), Delhi Pollution Control Committee (DPCC), and individual TPPs. At Rajghat and IPTPPs, only TSP and SO_2 are monitored, whereas, in gas–based TPPs, only NO_2 is monitored as emissions of TSP and SO_2 are very low. At Badarpur TPP, all the three pollutants i.e., TSP, SO_2 and NO_2 are monitored. The NO_2 emissions from other coal–based TPPs were estimated using an emission factor of 2.64 kg/ton for coal, whereas, NO_2 emissions from fuel–oil consumption was estimated using an emission factor of 7.5 kg/ton (CPCB,1994). Fuel–oil is used as an auxiliary fuel in coal–based TPPs. For gas–based TPPs, the emission factors for TSP and SO_2 were taken as 0.008 g/m^3 and0.0096 g/m^3, respectively (TERI,1992). Average emission characteristics of TPPs are shown in Table 3.8

Table-3.8: Average emission rates and characteristics of TPPs

TPP	Temperature (K)	Exit velocity (m/s)	TSP (gm/s)	SO_2 (gm/s)	NO_2 (gm/s)
Rajghat[c]	366.4	4.0	22.3[a]	73.2[a]	21.5[b]
IGT[d]	384.0	1.6	0.36[a]	0.1[b]	12.6[a]
IP[d]	402.1	8.2	14.5[a]	45.1[a]	28.8[b]
Badarpur[c]	401.7	25.2	237.9[a]	1233[a]	405.4[a]
Pragati[c]	372.0	2.3	0.7[b]	0.08[b]	23.8[a]

[a]Values taken from DPCC and CEA records for actual in field monitoring
[b] Values derived from emission factors and specific fuel consumption for the given month
[c]Average of 12 months of two stacks
[d]Average of 12 months of three stacks

3.3.3 The mortality impacts of current and planned coal-fired power plants in India

In this paper, it is examining the mortality implications of electricity generation from the 2018 stock of coal-fired power plants in India, as well as from new plants (or extensions of current plants), at various stages of the planning process as of 2019.

- Several studies have analyzed the air pollution or human health impacts specifically contributed from coal-fired power generation. Deaths attributed to all sources of ambient $PM_{2.5}$ total 846,000 in 2018. Deaths range from 162,000 in Uttar Pradesh to 878 in Goa. Most of the variation in deaths across states is due to variation in state population; however, deaths per 100,000 persons due to ambient air pollution are highest in the Indo Gangetic plain
- For all of India, coal plants are responsible for over 78,000 deaths in 2018, or ~9.2% of deaths associated with ambient $PM_{2.5}$. The biggest impacts of power plants on ambient $PM_{2.5}$ occur in the Indo-Gangetic plain and in northeast and central India

From the literature review it is found that Coal plant deaths are reduced by over 170,000 in Uttar Pradesh and in West Bengal, the two states that experience the largest increases in deaths associated with coal plant expansion; however, reductions of between 50,000 and 60,000 deaths occur in Bihar, Maharashtra, Andhra Pradesh, and Tamil Nadu. (11)

3.3.4 Inequality in air pollution mortality from power generation in India (Sengupta, S., Thakrar, S. K., et al.2023)

- According to the report (Carbon Brief 2019, World Resources Institute 2019, BP 2020) India is the world's third largest emitter of greenhouse gases (GHGs) with 40% of its emissions coming from coal dominated power generation
- Between 7% and 21% of the estimated 1.1 million premature deaths in Indian associated with $PM_{2.5}$, solid or liquid particles suspended in the atmosphere, come from power generation.
- The Government of India has targets to increase zero-emission generation to 50% of all power capacity by 2030 and net-zero emissions by 2070 (Government of India 2015, Vaidyanathan 2021). It has also announced stricter limits on SO_2 and NO_X emissions in 2015 (Ministry of Environment Forest and Climate Change 2015) which could reduce respective emissions by up to 80%–90%

McDuffie et al. (2021) estimate approximately 74 000 deaths due to $PM_{2.5}$ (~6.5% of all $PM_{2.5}$ premature mortality) from coal in energy production in South Asia (India, Pakistan, Bangladesh, Nepal, and Bhutan) with the coal belt in eastern India having large contributions of $PM_{2.5}$ from coal mining and burning

3.3.5 Monitoring particulate matter in India: recent trends and future outlook (Pant, P., Lal, R. M., Guttikunda, et al.2019)

- Particulate matter (PM) has been identified as one of the most critical environmental risks globally and poor air quality (AQ) including exposure to PM has been associated with morbidity and mortality due to respiratory, cardiovascular, and cerebrovascular diseases.
- A significant proportion of the global population lives in areas that exceed the World Health Organization (WHO) Air Quality Guidelines, particularly in low- and middle-income countries.
- PM also has climate effects including its direct role in light scattering and absorption of sunlight and thermal radiation and the indirect role in acting as cloud condensation nuclei (CCN) and impacts visibility and general well-being.
- In India, 99.9% of the country's population resides in areas that exceed the WHO Air Quality Guideline of 10 $\mu g/m^3$ (annual average), and half of the population resides in areas where the Indian National Ambient Air Quality Standard (NAAQS) for PM2.5 (40 $\mu g/m^3$) is exceeded.
- According to Global Burden of Disease (GBD) estimates, the average population weighted $PM_{2.5}$ concentration is 74.3 $\mu g/m^3$, and exposure to outdoor (ambient) air pollution is linked to 133.5 deaths per 100,000 people per year. Another study estimated that exposure to $PM_{2.5}$ is linked to ~600,000 premature deaths per year in India.
- According to NAAQS-2009 standards for $PM_{2.5}$ both 24h (60$\mu g/m^3$) and annual (40 $\mu g/m^3$) which is higher than the WHO air quality guidelines.
- According to NAMP (National air quality monitoring programme) as of September 2018 for key pollutants Sulfur dioxide (SO_2), Nitrogen dioxide (NO_2) PM10/ RSPM and $PM_{2.5}$ are monitored at 703 Air quality stations across 307 cities and town.
- System of Air Quality and Weather Forecasting and Research (SAFAR) network (http://safar.tropmet.res.in/) was launched in Delhi in 2010 by the Indian Institute of Tropical Meteorology (IITM, Pune) in collaboration with the Indian Meteorological Department (IMD) and the National Centre for Medium Range Weather Forecasting (NCMWRF) and is supported by the Ministry of Earth Sciences (MoES). The program currently runs in Delhi (launched in 2010), Pune (launched in 2013), Mumbai (launched in 2015), and Ahmadabad (launched in 2017) with plans for expansion to Bangalore, Kolkata, and Chennai.
- The network has ten air quality monitoring stations (AQMS) in each city equipped with real-time, continuous monitors for a range of pollutants including PM_1, $PM_{2.5}$, PM_{10}, O_3, nitrogen oxides (NOx), SO_2, black carbon (BC), methane (CH_4), non-methane hydrocarbons (NHMC), VOCs (BTEX) and mercury (Hg), and meteorological variables including solar radiation, rainfall, temperature, relative humidity, wind speed, and direction.
- According to National Air quality monitoring Programme (NAMP) network PM_{10} concentration were higher in northern India (namely, Rajasthan, Uttar Pradesh, Delhi, Jharkhand, and Punjab) compared to southern state.

Future outlook for air quality data in India

Air pollution remains a leading environmental concern in India, and a review of current monitoring and data management strategies indicates lack of consistency across different networks (e.g., differences in methodologies for estimation of AQI). Given the very high levels of PM in many parts of the country, India has also been in the international spotlight with several cities listed among the worst in terms of air quality, and increasingly, there is public pressure for action on air pollution

3.3.6 Assessment of the impact of a thermal power plant, Kolaghat, West Bengal (Mondal, Ismail, et al.2016)

The Kolaghat Thermal Power Plant is a major Thermal Power Plant in West Bengal, India. It is located at Macheda (approx.) and 55 km from Kolkata. The evaluation of the maximum concentration of air pollutes such as SO_2, NO_X, and suspended particular matter is usually considered of primary important for environmental impact assessment. The effect of the power plant emission on water, soil, and eco-physiological characteristics such as pH, DO, water conductivity, organic matter concentration in soil; Leaf injury symptoms, number and distribution of plant species; chlorophyll content in leaves, percentage of photosynthesis activities leaf area; accumulation in algae etc. seemed to be a functional of the pollutant gradient existing in the area. Due to the fly ash Environmental impact has been originated pollution in the KTPS. Which is the main problem of the coal based thermal power system; the coal which is used in KTPP is mostly in type of bituminous, of Gondwana age, (Table 3) it is a poor-quality coal with high ash content (about 5–50 %), and low calorific value, resulting in large volume of ash production per unit of energy generation. In Earlier studies various researchers had worked on ash pond of KTPS and reported on Indian radio activity of fly ashes from thermal power plants indicate that the Indian fly ashes contain 1.8–6.0 ppm of U and 6.0–15.0 ppm Th. However, recent studies have shown that ash generated from coal contains as much as 50 ppm of 232Th (Mandal and Sengupta 2011); 1 ppm Th = 4.046 Bq/kg and 1 ppm U = 12.36 Bq/kg;. The water quality has day to day decrease by various harmful components such as silica, zinc, cooper, calcium- oxides, aluminum, which is jumble of fly ash. That component is polluted the ground water intensity and surface water. Coal at the thermal power plant produced CO_2, SO, NO, and CFCS and other in organic air particles' which is the main sufficient of water, plant, and surface consummation system. These particles are mainly responsible for greenhouse effect.

Table-3.9: Chemical composition of fly ash produced from different coal

Sl. no.	Chemical component (% by wt.)	Coal types from which fly ash is produced		
		Bituminous	Sub-Bituminous	Lignite
1	Silica (as SiO_2)	20-60	40-60	15-45
2	Aluminum (as Al_2O_3)	5-35	20-30	10-25
3	Iron oxide (as Fe_2O_3)	10-40	4-10	4-15
4	Calcium (as CaO)	1-12	5-30	15-40
5	Magnesium (as MgO)	0-5	1-6	3-10
6	Sulphuric anhydride (as SO_3)	0-4	0-2	0-10
7	Sodium (as Na_2O)	0-4	0-2	0-6
8	Potassium (as K_2O)	0-3	0-4	0-4

As per the report at present 401,603 metric ton coal is used in KTPS and 1,74,577 metric ton fly ash was generated of the plant (Jan, 2016 source KTPS). However, the quality of air also depends on sunlight variability, speed of air, transport of wind, topography, recirculation of air, horizontal dispersion of pollution by wind etc.

3.3.7 Ambient Air Pollutant Levels in the vicinity of NTTPS Thermal Power Plant (Padmavathi, P., Jyotsna Cherukuri, et al.2015)

Coal-fired thermal power plants are responsible for a considerable amount of air pollution in the environment. **Main emissions from coal-fired thermal power plants are CO_2, NO_x, SO_x, and air-borne inorganic particles such as fly ash, carbonaceous material (soot), suspended particulate matter (SPM), and other trace gas species.** Thermal power plants, using about 70% of total coal in India are among the large point sources having significant contribution (47% each for CO_2 and SO_x) in the total point sources of emissions in India. SO_x emissions from coal combustion mainly depend on the sulphur content in the coal unlike the emissions of CO_2 and NO_x which depends on the operating conditions and the design of the plant. Chakraborty et al. (2008) measured SO_x emissions in the range of 7.445-8.763 g/kWh for thermal plants of the 250 MW capacities. CO_2 and SO_x emissions are influenced by the chemical composition (particularly carbon and sulphur content) of coal and the coal usage per unit of electricity. NO_X emissions are estimated based on equilibrium reaction calculated at an average gas temperature of 1200 K. Chakraborty et al. measured NO_x emissions in the range of 1.81-2.37 g/kWh for plants of the 250 MW capacities. NO_x emissions are influenced by the excess air used during combustion and the coal usage. Due to continuous & long-lasting emission of SO_x and NO_x, which are the principal pollutants of coal-based power plants, surrounding structures, buildings, monuments of historic importance and metallic structures are affected very badly. Here it is analyzed the ambient air quality, in the vicinity of Narla Tata Rao Thermal Power Station (NTTPS) located in the Ibrahimpatnam village of Andhra Pradesh by measuring the concentration of SO_x, NO_x and particulate matter using standard methods. For analysis five sampling sites were selected around the thermal power plant under study covering industrial and residential areas. The results showed that the concentration of the air pollutants both in industrial and residential areas are within the

standard values recommended by NAAQS (National Ambient Air quality standards) but particulate matter PM_{10} is in the threshold levels in all the sampling sites. This will lead to adverse effects on long term exposure especially on vegetation and human health. Five sampling sites namely Konda Palli, Ibrahimpatnam, Jupidi, Ferry village and Guntupalli villages were selected covering industrial and residential areas. They are located at different distances in the vicinity of the power plant. Sampling for the air pollutants in these areas was done during the months of April- June 2013.The results are shown in tabular form and pictorial form which is compared with NAQS (National Ambient Air Quality system) are as follows.

Table 3.10: Concentrations of SO_x, NO_x, PM_{10}, and $PM_{2.5}$ in µg/m³ in the selected sampling sites

Name of the sampling site	SO_x	NOx	PM_{10}	$PM_{2.5}$
Ibrahimpatnam	31.2	42.5	92	45
Kondapalli	18	32	88	42
Jupidi	18	21	62	38
Ferry village	17	22	81	40
Guntupalli	21	33	89	46
NAAQ standard value	**80**	**80**	**100**	**60**

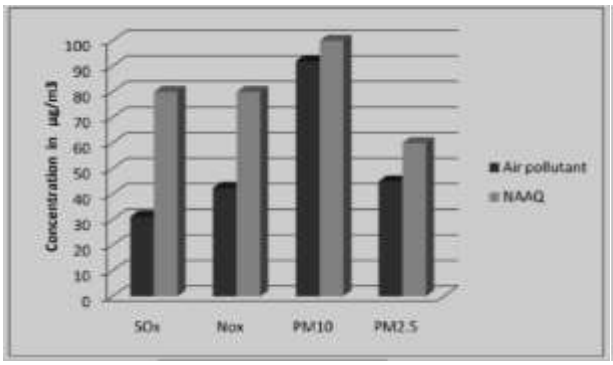


Fig 3.3: Air pollutants level at Ibrahimpatnam

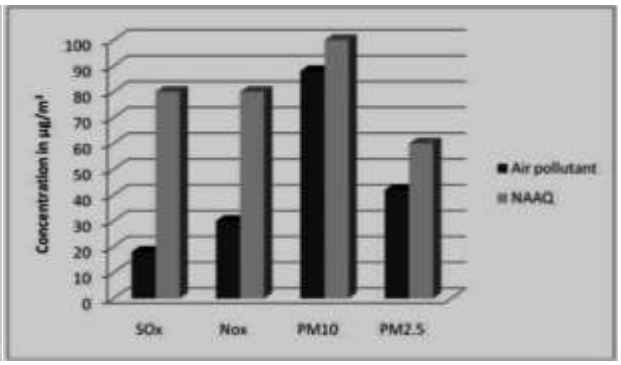


Fig:3.4 Air pollutant levels at Kondapalli

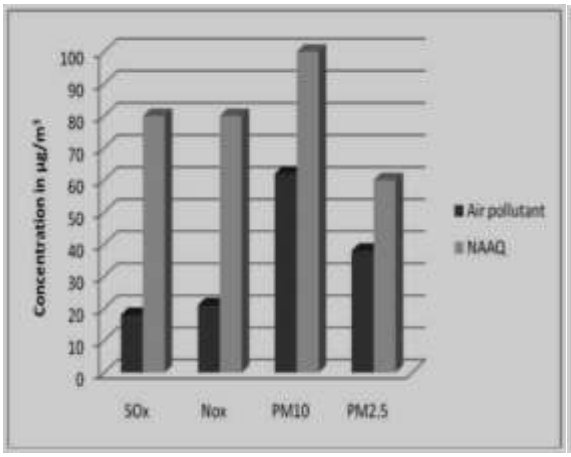


Fig 3.5: Air pollutant Levels at Jupidi village

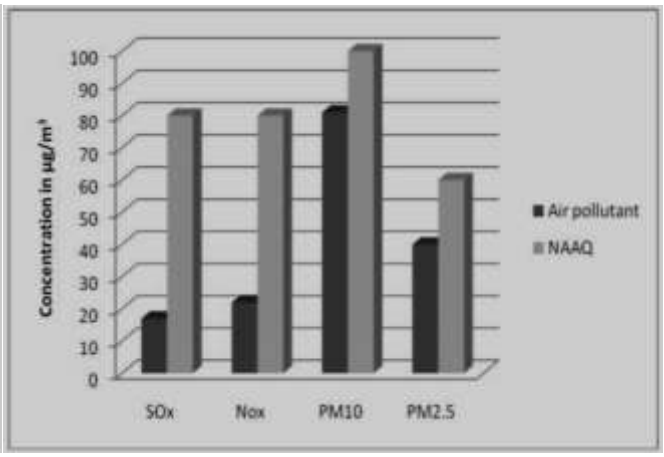


Fig 3.6: Air pollutant Levels at Ferry village

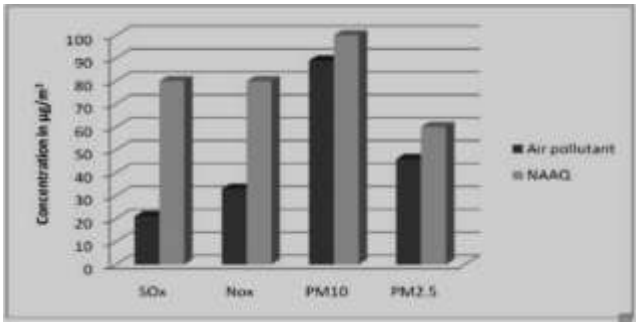


Fig 3.7: Air pollutant Levels at Guntupalli village

3.3.8 Air pollution in India (Comparing with USA and China)

- Air pollution is second biggest health issue in India and caused 12.5% of total deaths in India this includes deaths from particulate matter 0.67 million 0.48 million from household pollutions.
- 18.1% of global population lives in India and among them air pollution deaths according to DALYs (deaths and disability-adjusted life years) account 51.4% of global air pollution deaths
- According to WHO 2016 report 92% of the world's population is presently exposed to pathetic air quality standards which is said on WHO guidelines

Table 3.11: WHO guidelines of $PM_{2.5}$ and PM_{10}

Pollutants	Annual mean	24 hours mean
$PM_{2.5}$	10µg/m^3	25µg/m^3
PM_{10}	20µg/m^3	50µg/m^3

- In China, pollutants were analyzed in 31capital cities and observed strong co-relation between $PM_{2.5}$ and PM_{10} and these particles were found maximum high in northern region.
- In India also the particulate matter was high in the northern Indo Gangetic regions
- In USA PM pollution is relatively higher in California and Arizona than other states

Table: 3.12 No. of monitoring stations PM_{10} and $PM_{2.5}$ in India, USA, and China

Name of country	Name of ground monitoring stations
India	92 $PM_{2.5}$ 573PM_{10}
USA	838 $PM_{2.5}$ 567PM_{10}
China	1568PM

Source: Xingchuan et al.2018

- It is clearly seen average daily $PM_{2.5}$ and PM_{10} concentration in USA in 2014–2017 are from 2.79 – 21.64 µg/m^3 and 7.94-61.06 µg/m^3 respectively

which are below WHO IT-1 and IT-2 standards.

- The ranges of the daily average concentration of $PM_{2.5}$ and PM_{10} in China are from 6.03 – 126.03 μg/m^3 and15.58 – 217.04 μg/m^3. $PM_{2.5}$ increased by 6.19% in the years 2014 to 2015.
- The average daily concentrations in India are very much higher than WHO IT – 1 standard. $PM_{2.5}$ ranges from 15.16 –536.5 μg/m^3 and PM_{10} ranges from 44.6 - 646.3 μg/m^3.
- The overall $PM_{2.5}$ concentration is 1.7 times of China and 8.7 times of USA. Whereas PM_{10} is 1.5 times of China and 6.4 times of USA.
- The concentration in 2017 decreased by 9.5% for $PM_{2.5}$ but increased by 31.9% for PM_{10} compared to 2014. Pollutants trends are hardly been changed.

3.3.9 Human health risk assessment in open cast coal mines and coal fired thermal power plants: Madhya Pradesh

- The study area is in a region of highly mechanized open cast coal mines and coal fired thermal power plants located in Singrauli coal field industrial complex in Singrauli and Sone Bhadra districts of Madhya Pradesh and Uttar Pradesh India.
- The Singrauli coalfield is located between 23˚47′ and 24˚12′N and 81˚48′ and 82˚52′ E spreading over an area of 2200 Km^2.
  Sampling was simultaneously performed for 24h for SPM (suspended particulate matter), PM_{10}, and $PM_{2.5}$ every week two days (Monday and Friday) for two consecutive years (2016 and 2017).
  The collected samples carried out in the laboratory for further processing and analysis using Ion-Chromatography, ICP-OES, CHNS Analyzer, Mercury analyzer and DBAAS.
- Harmful factors assess metals risk on human health to have harmful effects on the human body through exposure.
- The health index of all carcinogenic and non-carcinogenic are varied from 3.9E-06-5.6E-04 and 6.2E-06-6.9E-04 for male, 3.4E-06-4.9E-04 and 5.4E-06-6.0E-04 for female, and 4.2E-06-6.1E-04 and 6.8E-06-7.6E-04 for children in $PM_{2.5}$ and PM_{10} in the study area.
- Four metals (arsenic, cadmium, chromium and nickel) associated with particulate matter were considered to investigate carcinogenic to which coal-based plants increase the risk of exposure to the elements and metalloids
- copper, chromium, nickel, mercury, cadmium, arsenic, were found to be 2.14×10^{-08} for male, 1.86×10^{-08} for female, 1.59×10^{-08}, for children in PM2.5 and 2.77×10^{-08} for male, 2.40×10^{-08} for female, and 2.06×10^{-08} for children in PM10.The total risk level generated by the nine metals, i.e., lead, zinc, manganese,
- This total risk level was higher in PM_{10} associated metals than the $PM_{2.5}$ related metals. The level of risk generated through carcinogenic metals was

significantly higher than the risk level generated by non-carcinogenic metals.

3.3.10 Social Cost of Air Pollution from Thermal Power station in West Bengal

Public health externalities vis-à-vis Power generation

1) Respiratory illness
2) COPD (chronic bronchitis and emphysema)
3) Headache
4) Disease of the eye
5) Dermatological Problem
6) Asthma
7) Hypertension
8) Depression and neurobehavioral Problems
9) Cancer

Table 3.13: Population living near thermal power stations

Area	Population density per Km^2	Estimated population within 10 km radius (314 km^2)
Bandel TPS	4682	1470148
Kolaghat TPS	2132	669672
Bakreshwar TPS	584	183532

*Based on Census of India, 2001

Table: 3.14 Minimal cost of treatment of illness related to emissions from Bandel, Kolaghat, and Bakreshwar Thermal Power Plants in West Bengal

Illness	Cost of treatment per year (rupees) for employees and local people		
	BTPs	KTPs	BKTPs
Respiratory illness	187725000	73424500	9304000
COPD	108047400	15377200	1768600
Headache	16102200	8479100	735500
Eye irritation	23905400	9389200	297400
Skin Problems	31826200	9094800	76000
Hypertension	193606640	580078740	2439840
Asthma	4351000	12427800	85400
Depression and neurobehavioral	84929000	27779000	5096000
Lung cancer	440278029	194804398	24270033
Total	1129770869	408783838	44072773

3.3.11 An assessment of soil contamination due to heavy metals around a coalfired thermal power plant in India: Kolaghat, West Bengal

In this paper the attempt has been made to study the extent of soil contamination around one of the largest thermal power plants of India located at Kolaghat, West Bengal India.

- It is also one of the major environmental problems after the different emissions associated with the use of coal as fuel in thermal power plants is the production of ash. This problem is particularly important for Indian power stations because most of the power stations use poor quality coal with 5–50% ash yielding about 100 million tons of ash per annum.
- Chemical analysis of the top soils and the soils collected from the different depth profiles surrounding the ash ponds, show that the top soils are enriched in the trace elements Mo, As, Cr, Mn, Cu, Ni, Co, Pb, Be, V, Zn, which show maximum enrichment (2–5) in the top soils collected from all the soil profiles. These elements are also enriched in the pond ash.
- Migration of the trace elements from waste disposal sites to surrounding ecosystems is a complex process. Trace elements present on the surface of ash particles are readily leached and tend to contaminate the groundwater.
- Most trace elements act as micro-nutrients to certain plants but become toxic at enhanced levels in the soil, thereby contaminating the land.

Outcome

- The pH of the soil was in the acidic range 4.5–5.2 in all the soil samples studied. The pH of ash deposited was also acidic in nature i.e., 4.5. The pH of the background soil was alkaline (8.2), which showed that the acidic nature of the pH of the soils near the ash ponds was because of ash disposal. The top soils of all the soil profiles from all the ash ponds are characterized by dominance of SiO_2 followed by Al_2O_3, Fe_2O_3, K_2O and TiO_2. The trace elements in decreasing order of abundance in all the soil profiles around the four ash ponds are Mn, Ba, Rb, Sr, V, Zn, Cr, Ni, Cu, Pb, Mo, Be and As.

Conclusion

The present work thus shows significant amount of contamination of the top soil due to ash disposal. The contamination is more pronounced in the soils within or close to the predominant wind direction. The concentrations of all the trace elements in all the soil profiles around the ash pond are higher than the background. The order of concentrations of Mn, Ba, V and Cr in profile soils is like that found in pond ash.

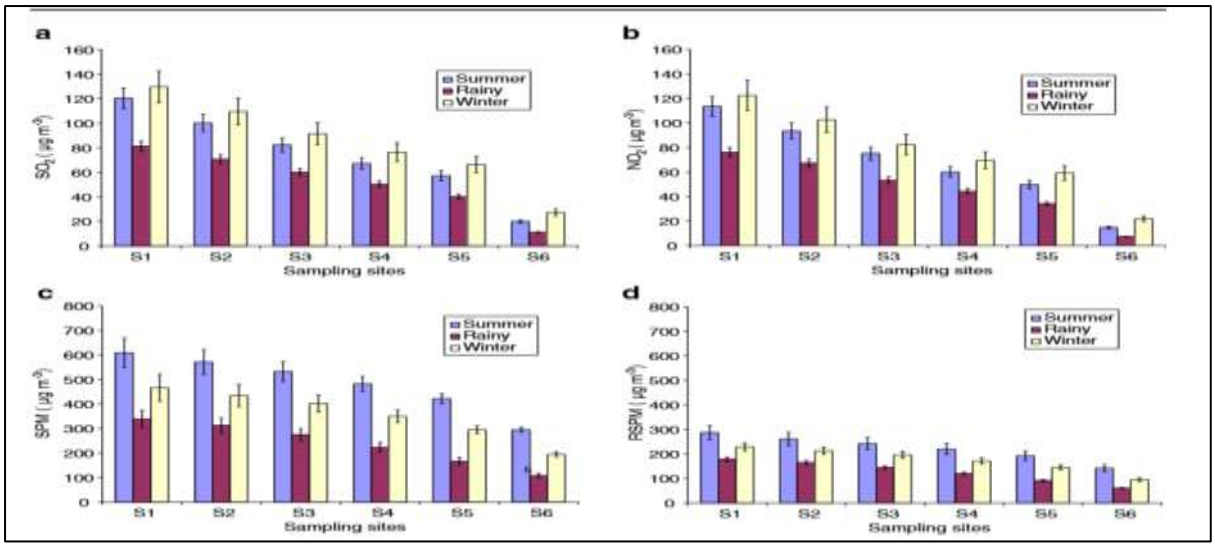
3.3.12 Biochemical responses in tree foliage exposed to coal-fired power plant emission in seasonally dry tropical environment: Uttar Pradesh

The study was carried out around the Anpara Thermal Power Plant (TPP), situated at Sone Bhadra district, UP, India (Latitude 24°10 –24°12 N and longitude 82°46 –82°48 E).

- The study area was at a different distance to thermal power plant (TPP) within 8.0 km range and a reference site was selected in eastern direction at 22.0 km and for the purpose of study five sites were selected.
- Ambient SO_2, NO_2, SPM, RSPM and DFR (dust-fall rate) showed significant spatial and temporal variation at different sites.
- The main air pollutants generated by coal-based power plants are fly ash, Sulphur dioxide, carbon and nitrogen compounds, non-combustible hydrocarbons, and heavy metals.
- The two most common tree species, Ficus bengalensis L. (Evergreen tree) and Dalbergia sisso Roxb. (Deciduous tree) were selected as test plants.
- Several studies have been conducted to assess the effects of pollution on different aspects of plant life such as overall growth and development, anatomy and biochemical changes. Some plant species have been identified to be able to absorb, detoxify and tolerate high level of pollution.

Results of the research on plants:

Pollutant concentration showed marked spatial as well as temporal variations as shown in (Fig. 3.8 a–e)



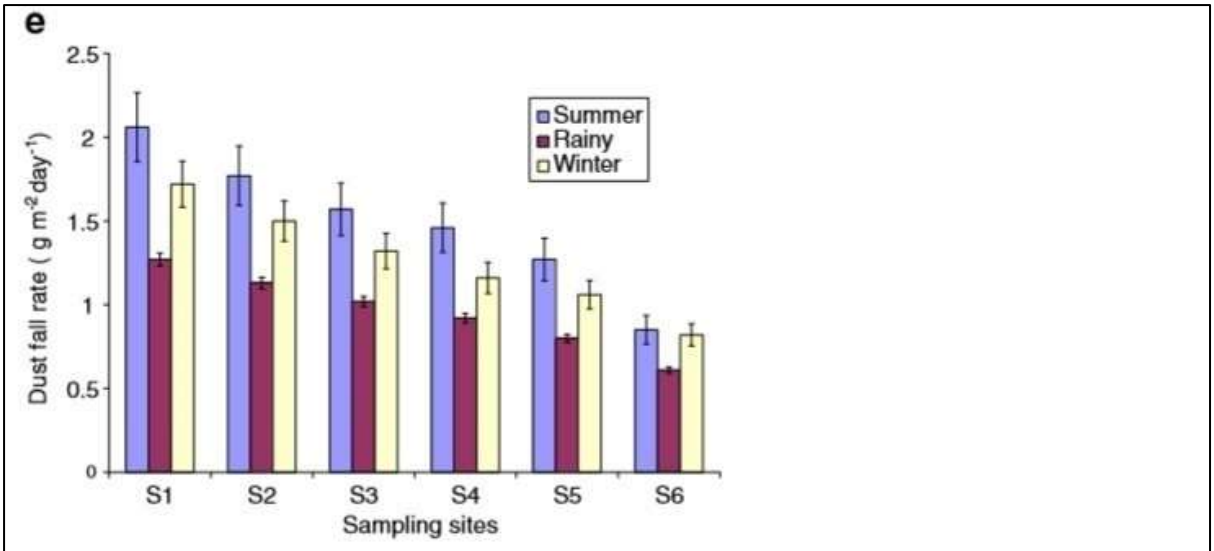


Fig. 3.8 a-e Seasonal variation of SO_2, NO_2, SPM, RSPM and Dust fall rate at selected sampling sites

- The results showed that the pigment contents (chlorophyll a, chlorophyll b, and carotenoids) were maximum in rainy season and minimum in winter and/ or summer season. In case of D. sissoo Roxb., all three pigment types were maximum in rainy followed by summer and least in winter season whereas in case of F. benghalensis L., highest values were recorded in rainy followed by winter and minimum in summer season.
- **Conclusion:**
  Significant changes were observed in the biochemical parameters and foliar sulphur content of both F. benghalensis L. and D. sissoo Roxb. plants growing at different sites around the thermal power plant. However, despite these changes, plants were flourishing well at the polluted environment. The results of this work indicate that F. benghalensis L. and D. sissoo Roxb are resistant plants against air pollution.

3.3.13 Environmental Impact Assessment of Kolaghat Thermal Power Plant area, West Bengal, India- A Geospatial Approach

The objective of the study is the effect of the environment on surrounding 5 K.m of the Kolaghat thermal power plant following effect on ground water and water body due to the thermal plant and effect on plant species selected from polluted area (KTPS) of the biochemical analysis of plant species.

- Vegetation (NDVI): The normalized difference vegetation index (NDVI) is a simple graphical indicator that can be used to analyze remote sensing measurements, typically but not necessarily from a space platform, and assess whether the target being observed contains live green vegetation or not. It is estimated that lowest value found in the Rupnarayan river side and in the upper part of surrounding agriculture field in value is high.
- Thermal Effect: Kolaghat temperature says today increase. The variation of temperature in Kolaghat is 24˚C to 35˚C. Kolaghat mainly temperate zone however temperature variation so low due to Rupnarayan river. The variation of

temperature has an effect of the criteria of other physiological condition. The surface water temperatures in the present study have shown significant rising trends for both pre-monsoon and monsoon periods. The annual composite surface temperature of Kolaghat region during the period 1990-2015 varied from 24°C in the year 1990, month of February to 35°C in the year 2015, month of March.

- Water Quality Effect: The KTPS surrounding area had a measured pH ranging from 6.8 to 8.9 in three-time tests of a range of locations in 2015-2016. Stream water usually ranges from a pH of 7.5 to a pH of 8.9; this range is considered to be an optimal range for most aquatic life. The natural pH range of surface water is largely determined by the fly ash of the KTPS, for example Koloni side areas will result in ph-8.9 and streams having naturally higher pH levels and Rakhsachak areas will have naturally low pH levels. Carbon dioxide from the atmosphere can also affect the pH of a river; when it mixes with the water it increases its soil fertility. Decrease the pH level (below optimum level) impact killed fish and damage physical property-still sufficient for the aquatic life to survive. Amount of DO on KTPS is 5.38 mg/l.
- Impact of Plant Species: As a result, the plant species of the surrounding area are decreasing day to day.
- Impact of Air Pollution: The pollution of air is the most serious problem. Other biophysical condition and human structure of phenomena are also depended on air. One of the major criteria of air pollution industry and urbanization. from industries the air pollution is caused dust particles, heavy metal (<300 micron) is oriented the structure of the chimney of industries. The air pollution is the cost by emission of particles that is held by toxic organic disposition. UNESCO has said the air pollution is consider when level of air is less than 130 microns. However, the quality of air also depends on sunlight variability, speed of air, transport of wind, topography, recirculation of air, horizontal dispersion of pollution by wind etc. The variability of pollution, atmospheric pressure and difference in diurnal heating and cooling has impact on air circulation. Changes in climate also change air circulation of process. From the above discussion it is concluded that air quality is depend upon various factors.

3.3.14 Impact of Thermal Power Pollution on Livestock: A Multivariate Analytical Interpretation from Confronting Social Ecology. (Acharya, S. K., Quader, et al.2020)

Research area: At the vicinity of Kolaghat thermal Power plant.

- Coal is widely used in power generation in different countries. Although, the presence of carbon, hydrogen and sulfur in coal facilitates the energy generation in coal combustion, some pollutants including carbon dioxide, Sulphur dioxide, Nitrogen dioxide, particulate matter (PM) and heavy metals are accumulated in air and water and lead to severe environmental and health impacts as a result of leaching, volatilization, melting, decomposition, oxidation, hydration, and other chemical reactions.

- In addition, fly ash, in both wet and dry forms, is mobilized and induces severe impacts including bone deformities and kidney dysfunction, particularly with exposure of radio nuclides. The emission of these gases has been correlated with many health problems directly and indirectly, including skin, cardio vascular, brain, blood and lung diseases, and different cancers. The CO_2 emission from coal combustion, during power generation, also leads to the interaction of CO_2 with particulate matter ($PM_{2.5}$), which thereby changes the air quality and leads to increased asthma attacks and other respiratory and cardio vascular diseases with underlying poor life status. In haling particulate matters may cause some dangerous diseases, including chronic obstructive pulmonary disease (COPD) and lung cancer
- Cattle grazing nearby coal-fired power stations are exposed to fly ash. Fly ash consists of finely divided particles with size ranging from 5 to 120 µm. It is composed of oxides of iron, silicon, aluminum, magnesium, calcium, sodium, and potassium. Along with oxide, fly ash also contains toxic elements such as antimony, arsenic, beryllium, cadmium, fluorine, lead, mercury, selenium, thallium, and vanadium. These pollutants are dispersed and transported throughout the region and reach the population through numerous exposure pathways like inhalation, ingestion, and dermal absorption. The majority of the bovine lungs derived from mining and industrial areas was dirty pink in color and mottled with black pigment. Airborne pollution of pasture with heavy metals cause disorders in cattle characterized by poor condition, chronic diarrhea, reduced growth and weight, bilateral per orbital alopecia, multifocal alopecia, excessive lacrimation, and declined fertility. A high concentration of mercury in the soil is observed to be translocated top land subsequently to the grazing cattle. In cattle, absorb mercury is distributed throughout the body and is stored mainly in the liver and kidneys.
- **Result:** The result has also revealed that the impacts of fly ashes generated by Kolaghat Thermal Power Station have got prominent impacts on the productivity of milk by cattle. Goats and poultry birds are also suffering heavily by fly ash produced by Kolaghat Thermal Power Station. As a greater number of livestock is reared in proximity to Kolaghat Thermal Power Station, more the total impacts will be upon them. These negative impacts have reflected upon their general productivity level. As in cattle, the milk productivity and in poultry the egg laying capacity has drastically reduced. The quality of milk, poultry meat is also being affected by Kolaghat Thermal Power Station Alongside human health, the livestock productivity and health is also being perceived negatively impacted by Kolaghat Thermal Power Station Several toxic substances have been found in those fly ashes and among them 'Hg' (mercury) is the most toxic to cattle. It accumulates on their liver, and kidney. And it has been found that water contaminated with mercury has more impacts on their bodies than any other sources. Fodder exposed to this fly ash has also a catalytic effect upon biochemical properties of cattle.

3.4 Research Gap

Assessment of PM_{10} and $PM_{2.5}$ related pollution originating from Thermal Power Plants is not very common for the state of West Bengal. Specific studies on concentration of different forms of particulate matters are very much essential for their proper management. An in-depth study in regard of the state of West Bengal will be a timely proposition. The secondary pollutants that are produced by the gaseous and volatile organic compounds (VOC_s) and semi volatile organic compounds in the atmosphere from thermal power plants should also be considered for monitoring and in-depth analysis to set the mitigation plan.

Chapter-4

Objective & Scope of Work

4.1 Objective

Based on the available literatures, it can be concluded that, air pollution, especially that caused by particulate matter and secondary pollutants is an escalating cause of concern for scientists, engineers, policy makers and common people all over the world. Consequently, monitoring of particulate matter and secondary pollutants has become an urgent task. As the finer particles affects more collection of data pertaining to fine particulates has becomes more important in the present day's perspective.
Thus, the objective of the proposed study can be summarized as **"to assess the air pollution potential of a coal based thermal power plant for West Bengal."** Kolaghat Thermal Power Plant (KTPP), East Medinipur, West Bengal has been considered as the study area for the present research.

4.2 Scope of the Work

- Comprehensive study of Kolaghat Thermal power plant situated in West Bengal, India and different air quality parameters in respect of emission and ambient air quality standard.
- Collection and analysis of secondary data of Kolaghat Thermal power plant.
- Monitoring the air pollutant concentrations in the vicinity of the three selected Stations viz. Station 1 (Gate no. 2), Station 2 (KTPP township), Station 3 (intake pump house).
- Monitoring of different air pollutants at different locations and different ambient conditions for the observation and analysis to find the variation pattern.

Chapter-5

Materials & Methodology

5.1 Instruments

In course of the present study Fine Particulate Sampler (APM 550, Envirotech) and PM1 Particulate Sampler (APM 577, Envirotech) were used for particulate monitoring.

Fig. 5.1: APM 550 Envirotech

Fig. 5.2: APM 577 Envirotech

5.1.1 Working Principle of Fine Particulate Sampler (APM 550, Envirotech)

The fine particulate sampler is used for sampling fine particles ($PM_{2.5}$ fraction) and is based on impactor designs standardized by USEPA for ambient air quality monitoring. Ambient air enters the sampler system through an omni-directional inlet designed to provide a clean aerodynamic cut-point for particles greater than 10 microns. Particles in the air stream finer than 10 microns proceed to a second impactor that has an aerodynamic cut-point at 2.5 microns. The air sample and fine particulates exiting from the PM2.5 impactor are passed through a 47 mm diameter Teflon filter membrane that retains the fine particulate matter. The sampling rate of the system is held constant at 1 m^3/hr by a suitable critical orifice. The standard system is provided with a Dry Gas Meter to provide a direct measure of the total air volume sampled.

5.1.2. Sampling and Analysis of $PM_{2.5}$ by Gravimetric Method

- **Principle of the method**

An electrically powered air sampler draws ambient air at a constant volumetric flow rate (16.7 lpm), which is maintained by a volumetric flow controller coupled to a microprocessor into specially designed inertial particle-size separator (i.e. impactors). In this separator, the suspended particulate matter in the PM2.5 size ranges is separated for collection on a 47 mm Poly Tetra Fluoro Ethylene (PTFE) filter over a specified sampling period. Each filter is weighed before and after sample collection to determine the net gain due to the particulate matter. The mass concentration in the ambient air is computed as the total mass of collected particles in the $PM_{2.5}$ size ranges divided by the actual volume of air sampled, and is expressed in $\mu g/m^3$. The microprocessor reads averages and stores five-minute averages of ambient temperature, ambient pressure, filter temperature and volumetric flow rate. In addition, the microprocessor calculates the average temperatures and pressure, total volumetric flow for the entire sample run time and the coefficient of variation of the flow rate.

- **Analysis**

Gravimetric mass analysis was performed using single pan electronic balance. Gravimetric analysis of filters used the difference method to determine the mass of the collected aerosol. The pre-weight of each filter was measured prior to being sent into the field for sampling. Once exposed and returned to the sample handling room, the filter was removed from petri dishes and the post-weight of the filter was measured after conditioning. The mass of the aerosol was determined by calculating the difference between the pre and post weights.

- **Calculation**

The equation to calculate the mass of fine particulate matter collected on a Teflon filter (PTFE) is as below:

$$\mathbf{M_{2.5} = (M_f - M_i)\ mg * 10^3\ \mu g}$$

where,

$M_{2.5}$ = total mass of fine particulate collected during sampling period (μg)
M_f = final mass of the conditioned filter after sample collection (mg)
M_i = initial mass of the conditioned filter before sample collection (mg)
10^3 = unit conversion factor for milligrams (mg) to micrograms (μg).

Field records of $PM_{2.5}$ samplers were required to provide measurements of the total volume of ambient air passing through the sampler (V) in cubic meters at the actual temperatures and pressures measured during sampling. The following formula was to be used if V was not available directly from the sampler:

$$\mathbf{V = Q_{avg} * t * 10^{-3}\ m^3}$$

where,

V = total sample value (m^3)
Q_{avg} = average flow rate over the entire duration of the sampling period (L/min)
t = duration of sampling period (min)
10^{-3} = unit conversion factor for litres (L) into cubic meters (m^3)
The equation given below can be used to determine $PM_{2.5}$ mass concentration:

$$\mathbf{PM_{2.5} = M_{2.5} / V}$$

where,

$PM_{2.5}$ = mass concentration of $PM_{2.5}$ particulates ($\mu g/m^3$)
$M_{2.5}$ = total mass of fine particulate collected during sampling period (μg)
V = total volume of air sampled (m^3)

5.1.3 Working principle of PM_1 particulate sampler (APM 577, Envirotech)

The APM 577 is a manual method for sampling very fine sub-micron particles (PM_1 fraction). The sampler is based on impactor design standardized by Indian Institute of Technology, Kanpur. The air enters in the system through an omni-directional inlet designed to provide a clean aerodynamic cut point for particles. The air sample and fine particulates exiting from the PM_1 impactor are passed through a 47mm diameter PTFE filter membrane that retains the sub-micron PM_1 dust. The sampling rate of the system is held constant at 10 lpm by a suitable critical orifice. A dry gas meter is incorporated to provide a direct measure of the total air volume sampled. Time totalizer provides information on actual run time of sampling. An electronic timer is also provided to start the sampling and shut off the sampler as per requirement of sampling, thus eliminating the presence of manpower at site. The monitoring is carried out by Gravimetric method (APM 577, Envirotech). Thus, the procedure of the analysis and calculation is more or less similar to the procedure followed for $PM_{2.5}$ FPM Sampler.

5.1.4. DustTrak II Aerosol Monitor (Model- 8530, TSI)

The DustTrak II Aerosol Monitor (Model-8530, TSI) is a desktop battery-operated, data-logging, light-scattering laser photometer that gives real-time aerosol mass readings. It uses a sheath air system that isolates the aerosol in the optics chamber to keep the optics clean for improved reliability and low maintenance. It is suitable for clean office settings as well as harsh industrial workplaces, construction and environmental sites, and other outdoor applications. The DustTrak II Aerosol Monitor measures aerosol contaminants such as dust, smoke, fumes, and mists. It is a very useful tool to monitor PM.

Fig. 5.3: DustTrak II Aerosol Monitor (Model-8530, TSI)

Features and Benefits of DustTrak II (Model-8530)

- Measure aerosol concentrations corresponding to PM_1, $PM_{2.5}$, PM_{10} or size fractions
- STEL alarm set point
- Automatic zeroing (with optional zero module) minimizes the effect of zero drift
- Perform in-line gravimetric analysis for custom reference calibrations
- Manual and programmable data logging functions
- Aerosol concentration range 0.001 to 400 mg/m^3
- Environmental protected and tamper-proof with Environmental Enclosure
- Cloud Data Management System for efficient remote monitoring
- Heated Inlet Sample Conditioner to reduce humidity effects
- Desktop unit

Calibration

The DustTrak II (Model-8530, TSI) monitor is factory calibrated to the respirable fraction of standard ISO-12103-1, A1 test dust. The DustTrak monitor can be easily calibrated to any arbitrary aerosol by adjusting the custom calibration factor. The DustTrak monitor's custom calibration factor is assigned the value of 1.00 for the factory calibration to standard ISO test dust. This procedure describes how to determine the calibration factor for a specific aerosol. To determine a new calibration, factor some way of accurately measuring concentration of aerosol is needed, which is referred as reference instrument. A gravimetric analysis is often the best choice.

5.1.5 Continuous Air Quality Monitoring Stations

Fig. 5.4: Continuous Ambient Air Quality Monitoring Stations

The equipment and methods which is shown and described previously was initially set to planned to analyses and will be used for collection of raw data for this thesis work, but due to some unavoidable circumstances the plan must be changed. The work is forwarded in the following way: the data is collected from the equipment CAAQMS (Continuous air quality monitoring stations) as shown in the figures 5.4, it's methodology and working principles are discussed and the analysis is based on daily variations, monthly variations and spatial variations which is discussed in result and discussion section from the page no. 69 -136

5.1.6 Working principle of Continuous Ambient Air quality monitoring station (CAAQMS)

Technical specifications for continuous ambient air quality monitoring (CAAQM) station

Housing/Container: It is designed for housing the ambient air quality monitoring instruments to protect them from dust and heat. Temperature and Humidity sensors shall be installed in the housing for checking the humidity and temperature inside the station.

Three nos. 19" racks shall be installed inside the station so that the analyzers are easily accessible from front and back for calibration and maintenance.

Dimensions: Inside length: 4200 mm
Inside width: 3500 mm
Inside height: 2500 mm

Frame: All the material used for the construction of the floor, frame, roof frame etc, the 4 corner posts and 8 integrated, reinforced container corners should be of metal. The exterior panel of the container shall be made of pre-coated MS Sheet of approved colour shade. All other steel parts should be hot dipped galvanized having minimum rate of galvanization of 275 gm/m^2 (IS 277). All joints of like metal such as steel-to-steel or aluminum-to-aluminum shall be protected against corrosion by liberal application of joining compound. All joints of dissimilar metals such as steel to aluminum shall be protected against corrosion due to galvanic action by liberal application of dielectric compound as well as jointing compound on both mating surfaces. For lifting / fixing the container, International Standard eyebolts should be provided at the corners.

Panelling: The outer panelling will be of 1.2 mm of Pre-coated MS sheet to withstand external impacts and abrasions. Outer side of the MS Sheet i.e. exposed face of the sheet, shall be permanently colour coated with silicon modified polyester coating of dry film thickness (DFT) 20 micron (min.) of approved colour shade over primer. Inner face of the sheet shall be provided with suitable precoating of minimum 7 off-white colour. The inner panelling will be of PVC coated 2 mm thick aluminium sheet, fixed over an inlay of 4 mm marine plywood. 100 mm thick polyurethane insulation will be used between the outer and inner walls (Pre-coated MS sheet and Marine plywood) as insulating material. Z spacers, if required shall be made out of at least 2 mm thick galvanized steel sheet of grade 275 as per IS:277

Floor: The floor will be in the frame of 600 x 600 mm centre to centre with 50 x50 x 6 mm MS angle. The floor surface will be of 19 mm marine plywood covered with robust 16 quality Vinyl flooring; 2 mm thick of approved colour. The floor should be of acid and alkaline resistant, waterproof, easily cleanable / washable. Bottom plate of thickness 2 mm hot dipped galvanised MS Plate shall be provided.

Outer Door: One door of size 2000 x 900 mm will be provided at the front side (L = 4200 mm) of the station with isolated 3 – point locking & door handle flush fitted. Electric Power Supply Box: Three - phase (3Ø) electrical wiring will be laid in ducts. Copper wiring of appropriate gauge will be used. The terminal board should be mounted in a central power distribution box. Over voltage protection for each phase shall be provided along with the lightning arrestor. 2 numbers Emergency cut off switch & Thermostat switch (max 35°C) for power disconnection, 6 free sockets and 3 fluorescent lamps for lighting will be provided.

Container Foundation (RCC)
L x W: 6000 x 6000 mm

Height 300 mm from ground Pillars: Nine concrete pillars of 300 mm above the ground level and below the ground level with 200 x 200 mm beam and between pillar bricks to be used for filling the space (concrete ratio of 1:2:4). Outer wall of the foundation to be plastered with 1:4, Cement: Sand ratio and same has to be painted with weather proof coat. Top of the platform: RCC 150 mm with concrete ratio of 1:1:2 and to plaster and painted with weather proof paint. Staircase: RCC Steps to approach the main door of the container and the UPS / Gas room door in the side to be provided and each step should not be more than 150 mm Security Cabin A 4 feet x 4 feet wooden / Panelled security cabin with chair and small folding table for security guard with covered overhead selves to be provided separately with the station container.

Continuous Ambient Air Quality Monitoring Analysers for SO_2, NO-NO_2-NOx, NH_3, CO, O_3 and BTX

The analyzers should be 19" rack mounting model with facilities for fixing the analyzers from front side. The front panel should have ON / OFF Switch. The display of the entire important status signal viz. Sample flow, temperature, concentration, range selection, manual / auto mode, zero / span mode and all error messages should be on front panel. The analyzers should operate at operating voltage 230 volts 10 volts AC and 50 Hz 3% frequency. The power supply input to be protected against spikes from and to the analyser by an LC filter. The power connection cable should be CEE type complete with 15 Amperes plug adaptable to Indian mains socket. The analyzers must function properly in Indian conditions without any defect between 0 – 50°C ambient temperature, 10 – 95% relative humidity and in high ambient dust levels. The data capture rate should not be less than 90% of operational time. The Manufacturer shall provide comprehensive hands-on training for operational & preventive maintenance for one week in the respective State for three persons per station. The analyzers should complete with calibration system. The calibration system should be delivered along-with respective span gas cylinder and permeation tubes. The span gas concentration should be within 60 – 90% of first measuring range. The analyzer must have zero-point internal calibration system and in agreement with minimum detection limit of each analyzer. The calibration procedures are to be integrated into the software system for automatic calibration & remote calibration.

Permeation Tube

The analyzer of SO_2, NO-NO_2-NOx, NH_3 and BTX should have the permeation bench with NIST certified permeation tube for the span check in the analyzer. The date of Calibration Certificate of Permeation Tube should not be older than 30 days on the date of commissioning of the respective analyzer. Thus, it is desirable that the consignment of permeation tubes may be dispatched separately.

Calibration Gas Cylinder

The supplier has to supply the calibration gas cylinder (highly polished aluminium 10 Liters water capacity), along with SS Regulator, traceable to NIST for each component (SO_2, NO, CO, NH_3, Benzene & Toluene) along with SS regulator for the multipoint calibration.
The synthetic air and N_2 cylinder (99.99% purity with certificate) should be in Carbon Steel cylinder of 47 liters water capacity along with SS Regulator. The analyzers shall be supplied with all ancillaries necessary for operation with pump (preferably in built) and any other items such as charcoal scrubber, Teflon air sample intake filter, drier, Teflon tubing suitable for connection to air sampling manifold. All such items are to be itemized. Dust filter in all the analyzers should be provided before solenoid valve to protect frequent chocking of solenoid valve. The connector systems for out-going signal for recording and the computer terminal should be on back panel with screw type connecting pins. All ambient gas analyzers shall be approved by the USEPA / TUV / MCERTS / EN. However, in case of BTX and Ammonia Analyzer specifications as given will be considered. Method of measurement used shall also comply with the stipulation on National Ambient Air Quality Standards (NAAQS) 2009 (Details of Methods of Measurement is available at MoEF and CPCB websites). All analyzers shall be microprocessor controlled with automatic calibration using an external dilution calibrator and calibration standards. All analyzers should be fully integrated in the rack cabinet, fully calibrated, and tested before supply and ready for start – up.

Quality control and standard

Data shall be collected and validated according to USEPA standards using the methodologies included in 40 of federal regulations. All analyzers shall have current USEPA reference or equivalent method designation and shall be of the latest design. The supplier shall submit a Standard Operating Procedure for the air quality monitoring stations to the Buyer at the time of bid submission. This Standard Operating Procedure shall be approved by the Buyer prior to award. The Standard Operating Procedure shall contain the following:

i. Operating procedures for all analyzers and meteorological sensors
ii. Calibration procedures
iii. Calibration schedule
iv. Maintenance procedures
v. Maintenance schedule
vi. Data validation procedures
vii. Quality Assurance procedures
viii. Sample quality assurance documentation
ix. Sample Air Quality Report

The calibration procedures for analyzers shall conform to USEPA methodologies and shall include daily calibration checks, by weekly precision checks and linearity checks every six weeks. All analyzers shall undergo full calibration in every three months. Data obtained from these calibration checks and copies of associated Quality Assurance and calibration documentation, shall be submitted to the Buyer along with the Air Quality Data. Air

Quality Data shall be submitted to the Buyer on Real Time basis through automated system and on a monthly basis in the form of an Air Quality Report. This report shall include tabular and graphic information on gas and dust concentrations as well as meteorological data for each site. The data shall be reported in the form of 15-minute averages and shall also include daily, weekly, and monthly averages, minimum, maximum, standard deviations, total data captured and percent data capture. It should also have stat validation mechanism and delayed data check mechanism. The Air Quality Report shall also include wind roses where wind speed and direction are measured. Upon 24-hour notice from the Buyer, once per year, the supplier shall agree to submit to an audit of calibrations, conducted, using pre-approved US EPA methodologies, by a third party. The results of these audits shall be made immediately available to both the supplier and buyer.

Sampling System

A suitable sampling system as specified by USEPA having 10 ports manifold and fitted with a suction pump to draw ambient air. System duly equipped with moisture removal systems should be provided for sampling of ambient air separately for gaseous and dust measurement.
Gases sampling system:
Height of the sampling system: Approx. 1.0 meter above the roof
Roof entry cut out: Stainless Steel
Conduit: Stainless Steel
Inner sampling system: Borosilicate glass
Sampling head: Stainless Steel
Manifold: 10 ports for tubes 6 x 1 mm, self-tightening. Sample air flow sensor unidirectional sample air flow measuring device should be installed at the sampling system to measure the flow of ambient air through sampling system. The output of signal should be connected to computer to ascertain the continuous flow of sample from ambient air. The suction pump operational status should also be connected to the computer as a separate channel.

Ambient Air Quality Monitoring Analysers (Gas)

Ambient Sulphur Dioxide (SO_2) Analyser

Principle: Pulsed UV Fluorescence
Measurement: SO_2 in Ambient Air
Display: Digital
Ranges: Auto ranging 0 - 200 ppb
Lower Detectable Limit: 1 ppb
Noise Level: 0.5 ppb
Zero Drift: < 1 ppb/24 Hrs. with automatic zero compensation
Span Drift :<1 ppb in 24 hrs.
Linearity: ± 1% of full scale
Response Time: 120 sec or less

Span check facility: Built in permeation bench

Ambient Oxides of Nitrogen (NO-NO_2-NOx) Analyser

Ambient Ammonia Analyser (NH_3)

Principle: Chemiluminescence (NH_3 conversion to NO by oxidation). NO_2 is also converted to NO. The difference obtained by measuring NO in output of two sample stream as equal to NH_3). Measurement NH_3 in Ambient Air Display Digital Ranges Auto ranging 0 -1000 ppb, Lower Detectable Limit 1 ppb.

Principle: Chemiluminescence
Measurement:NO-NO_2-NOx in Ambient air
Display: Digital
Ranges: Auto ranging 0-2000 ppb
Lower detectable limit: 0.1 ppb

Ambient Ozone (O_3) Analyser

Principle: UV photometric /chemiluminescence
Measurement: O_3 Ambient air
Display: Digital
Range: Auto ranging 0-500 ppb
Lower detectable limit: 1.0 ppb

Ambient BTX Analyser

General

A complete analyzer system comprising of sampling pump, transfer line, analyzer, detector, calibrator, computer hardware and software for instrument control, data storage, display, acquisition, processing and for selective determination of volatile compounds in ambient air optimized for Benzene, Toluene, Ethyl Benzene and o, m, p – Xylenes. Continuous unattended measurement system of individual BTX should work without external cryogenic cooling. System should have protocol compatible to communicate and transfer data to DAS. Raw data storage capacity without erase minimum for three month or more. The system should be delivered with all necessary spares, consumables, tubing etc. for making it functional.

Technical specifications

A single stage membrane Pump collect ambient sample automatically an inbuilt adsorption trap. Subsequent, the sample will be dissolved and injected on wide bore capillary gas chromatographic separation. Sample volume controlled by thermal mass flow controller (dust protected). Sample flow range may be 20 -100 ml/min or more (adjustable). Sample volume should be between 400 ml – 1.0 liter or more of ambient air

over a 10-15 min sampling cycle. All sample transfer tubing should be in stainless steel and flow and pressure sensor to be preferred with digital display.

Continuous Ambient Air Quality Monitoring Analysers (Particulates)
Continuous PM_{10} Monitoring Analyser (-Ray Attenuation)

Based on the principle of -ray attenuation, particulate sampled through the instrument and collected on fiberglass filter tape. Before and after sampling, - ray radiation is measured by scintillation/ G.M. counter. An internal microprocessor handles all sequences and automatically calculates the concentration of PM_{10}.
Principle: -ray attenuation
Particle Size Cut Off: 0 - 10 Microns
Measuring Range: User selectable (0 – 500, 0 – 1000 & 0 -2000 g/m^3) with auto ranging feature
Resolution: 1% of the measurement range
Lower Detectable Limit: 2 g/m^3
Detector: Plastic Scintillator/ GM Counter
Air Flow Rate: At least 1.5 m^3/ hr
Filter Material: Glass Fiber Filter
Display: LED / LCD
Sampling Head: Dynamic heated sampling head for measurement of PM_{10}, with adjustable temperature 20 – 70°C
Calibration: Reference membrane facility should be provided for calibration of analyzer.

Continuous $PM_{2.5}$ Monitoring Analyser (-Ray Attenuation)

Based on the principle of -ray attenuation, particulate sampled through the instrument and collected on fibreglass filter tape. Before and after, sampling - ray radiation is measured by scintillation / G.M. counter. An internal microprocessor handles all sequences and automatically calculates the concentration of $PM_{2.5}$.
Principle: -ray attenuation
Particle Size Cut Off: 0 – 2.5 Microns
Measuring Range: User selectable (0 – 500, 0 – 1000 & 0 -2000 g/m^3) with auto ranging feature
Resolution: 1% of the measurement range
Air Flow Rate: At least 1.5 m^3/ hr.
Filter Material: Glass Fibre Filter
Display: LED / LCD
Sampling Head: Dynamic heated sampling head for measurement of $PM_{2.5}$ with adjustable temperature 20-70°C
Calibration: Reference membrane facility should be provided for multipoint calibration of analyser.

Meteorological system

The meteorological instrumentation should be interfaced directly with the data acquisition system after passing through a lightening protection isolation box. A crank up telescope 10 meters tower should be created for mounting of meteorological sensors. The relative humidity and solar radiation sensors should be mounted on the tower. The specifications are as follows:

Wind Speed
Range (operation): 0-60 m/s or better, Sustainability: Up to 75 m/s, Accuracy: $\pm$ 0.5 m/s or better resolution: 0.1 m/sec

Wind Direction
Range: 0–359-degree, Accuracy $\pm$ 3 degree or better
Resolution:1 degree, Sensor type: Ultrasonic

Ambient Temperature
Range: 10^0C to 60^0C, Accuracy: $\pm$ 0.2^0C or better (with radiation shield), Response: 10 seconds in still air, Resolution: 0.1^0C

Rainfall
Range: 0.2mm, Sensor type: Tipping bucket rain gauge or any other suitable sensor

Ambient Particulate Analyzer (PM_{10} & $PM_{2.5}$ Based on the Principle "Tappered Element Oscillating Microbalance" (TEOM) confirming to USEPA Automated Federal Equivalent Method (FEM) Designation (EQPM-0609-182/EQPM-0822-207/EQPM-0822-208) Specifications TEOM 1405-DF Ambient Particulate Analyzer ($PM_{2.5}$ & PM_{10}) =Dual TEOM (FDSM)

Regulatory Designations

- Approval and Certificates: U.S. EPA approved $PM_{2.5}$ equivalent Analyzer (EQPM-0609-182), USEPA PM_{10}-$PM_{2.5}$ Equivalent Monitor (EQPM-0822-207), US EPA PM_{10} and equivalent monitor (EQPM-0822-208) and TUV-PM2.5 and PM10 equivalent monitor. Operating range.
- The temperature of the sampled air may vary between 40^0C and 60^0C. The TEOM sensor and control unit must be whether protected within the range of 8 to 25^0C. An optional complete outdoor Enclosure provides complete weather protection

Sample Flow

- Activol flow control system uses the mass flow sensors and the measured ambient temperature and pressure to maintain constant volumetric flow rates.
- Main flow rate: Fine PM filter: 3.01/min; Coarse PM Filter: 1.671/min
- Bypass flow rate: 12.01/min

Data storage

- Internal data logging of user specified variables; Capacity of 500000 records

Filter media

- Sample filter: Pallflex TX40, 13 mm effective diameter
- Sample conditioner filter: 47 mm diameter housed in an FRM- Style molded filter cassette, maintained at 4˚C. Suitable for collecting and archiving time-integrated PM samples for subsequent laboratory analysis. Sample conditioning 24 hours

5.2 Details of the Study Area

The Kolaghat Thermal Power Plant is a major Thermal Power Plant in West Bengal, India. It is located near Mecheda and 55 km from Kolkata. It is situated on the right site of the Rup Narayan River bank which is under the district of Purba Medinipur, West Bengal. The North - East direction are situated Howrah district, 50 Km North - West of Haldia. And KTPP covers about 900 acres of land out of which 871.89 acres lie in the Panskura-II Block and the rest in the Sahid Matangani block, Tamluk. The Fig.5.5 (A, B, C, & D) shows the study area of the present work.

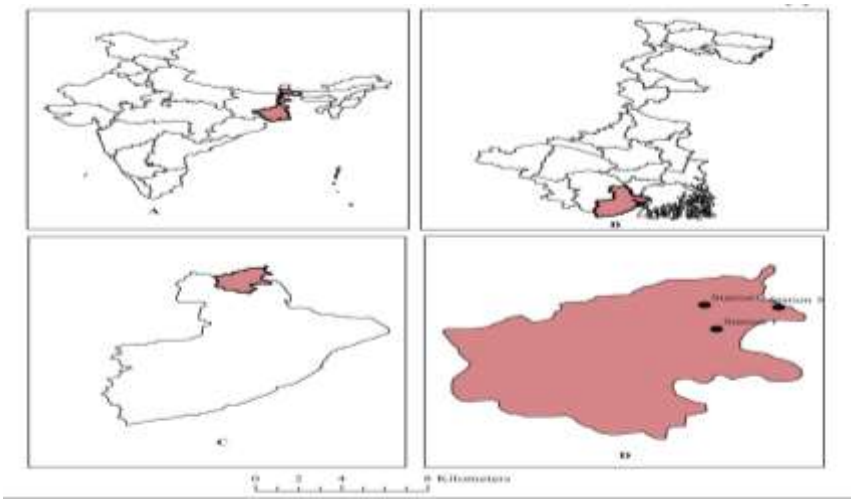


Fig: 5.5 Location of study area Map

Figure A- Map of India showing West Bengal

Figure B- Map of West Bengal showing Purba Mednipur

Figure C- Map of Purba Mednipur showing Kolaghat Block

Figure D- Kolaghat block showing the locations of the sampling points, the sampling points are:

The longitudinal and latitudinal extent of the stations viz. **Station 1 (Gate no.2), Station 2 (KTTP Township) and Station 3 (Intake Pump House)** are given below:

Station 1 (20^0 24' 55.25" N, 87^0 51' 54.39" E)

Station 2 (22^0 26' 06.8" N, 87^0 51' 08.2" E)

Station 3 (22^0 25' 33.9" N, 87^0 53' 30.6" E)

Chapter-6

Result and Discussion

Coal-based Thermal Power Plants (TPPs) are accountable for a disparate share of emissions of both particulate and gaseous air pollutants and has been categorized as highly polluting activities. Coal thermal power plants contribute to over 50% Sulphur dioxide (SO_2) concentration, 30% oxides of nitrogen (NOx), 20% particulate matter (PM) in the ambient air. Delayed modernization of old TPPs, use of high sulfur and high ash containing local coals, legacy fly ash stocks, fugitive emissions due to coal and ash handling are the factors contributing to air pollution. The total installed generation capacity of thermal power plants in West Bengal was 14,691 MW [Central: 6913 MW (NTPC-2,100, DVC-4,813) State: 5,295 MW and Private Sector: 2,483 MW] as of March 2020. Kolaghat is one of the major Coal Based Thermal Power Station (TPS) under West Bengal Power Development Corporation Limited (WBPDCL) where six 210 MW unit are operational. Kolaghat TPS was chosen as the main source to assess the air quality of the area. Secondary data of following air pollutants were collected from the said TPS to assess the air quality where TPS is the main source of air pollution and consequently back ground concentration of various pollutants may be neglected.

Table 6.1: Pollutants analyzed

Sl. No.	Pollutants Name
1	**PM_{10}**
2	**$PM_{2.5}$**
3	**SO_2**
4	**NO_x**
5	**CO**
6	**O_3**

- Ambient air quality data were collected in the month of April, May, and June 2022 and analyzed through the Microsoft office excels 2007 of the system of Windows 8.1. From the figures it is observed that their concentration level is within the permissible limit according to the National Ambient air quality standards which is shown and discussed here. The permissible limits of the pollutants are shown in the Table 6.2.

Table 6.2: Analyzed pollutants and their permissible limit (NAAQS, 2009)

Name of the Pollutants	24 hourly Permissible Limit	Annual Permissible Limit
PM_{10} (µg/m^3)	100	60
$PM_{2.5}$ (µg/m^3)	60	40
SO_2 (µg/m^3)	80	50
NOx (µg/m^3)	80	40
CO (mg/m^3)	4.0	2.0
	Hourly Permissible Limit	**8 – hourly Permissible Limit**
O_3 (µg/m^3)	180	100

- Secondary data were collected at **Station 1 (Gate no.2 of the TPP), Station 2 (KTTP Township) and Station 3 (Intake Pump House)**

- Variation in pollutant concentrations is studied in the order of following pattern:
    1. **Daily variations**
    2. **Monthly variations**
    3. **Spatial variations**

6.1 Daily variation analysis for the month of April, 2022

Station 1(Gate no. 2)
Status of PM_{10} concentration

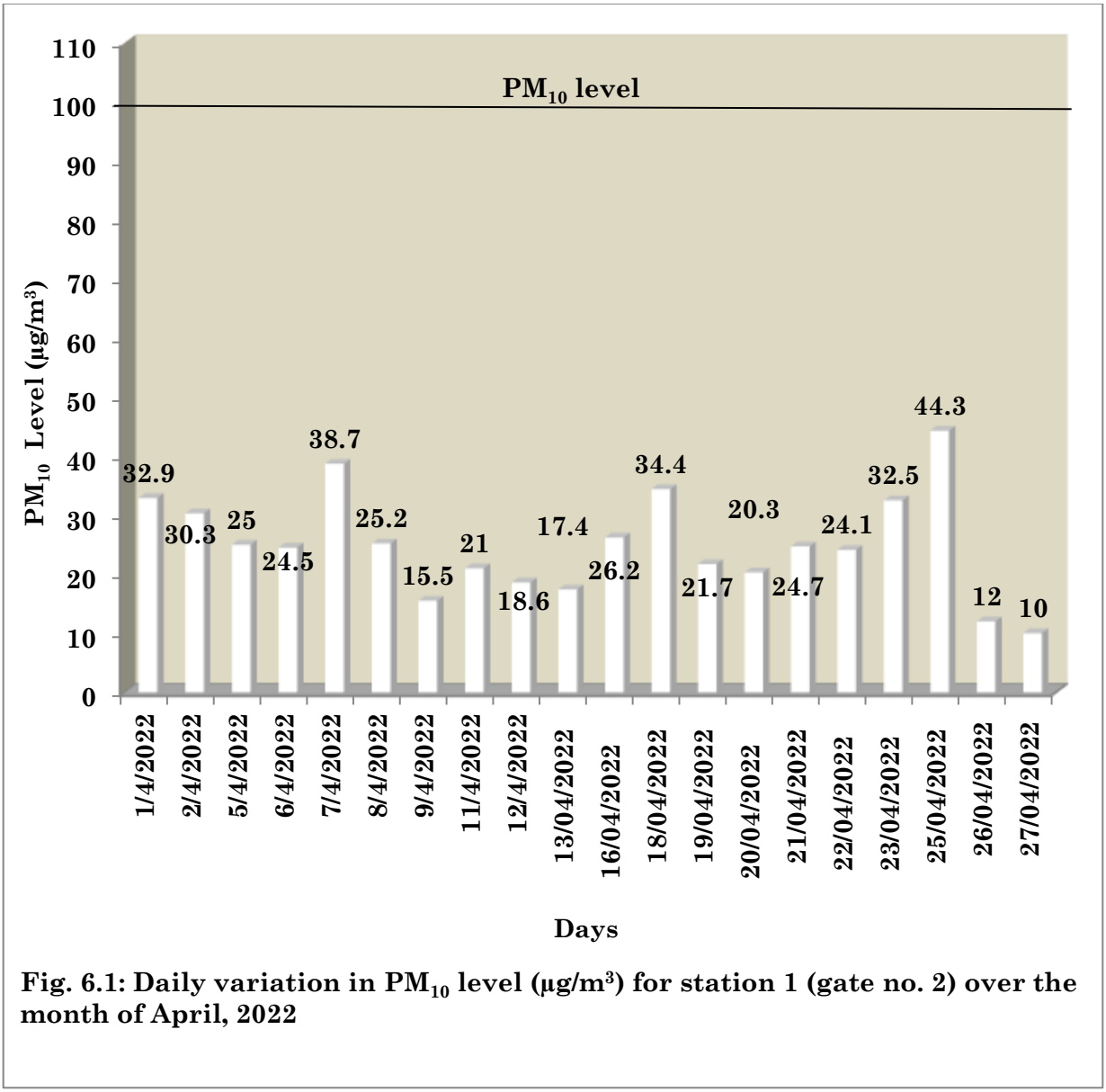


Fig. 6.1: Daily variation in PM_{10} level (µg/m³) for station 1 (gate no. 2) over the month of April, 2022

The daily variation in PM_{10} level at the Station 1 over the month of April, 2022 is shown in the Fig. 6.1. The maximum pollutant concentration is found to be 44.3 µg/m³ on 25th April 2022 and the minimum concentration of 10 µg/m³ is observed on 27th April 2022. Average PM_{10} concentration for the month of April at Station 1 is found to be 24.965 µg/m³. The range of PM_{10} concentration (10 – 44.3 µg/m³) observed for station 1 over the month of April lied well below the 24-hourly permissible limit of 100 µg/m³.

Status of $PM_{2.5}$ concentration

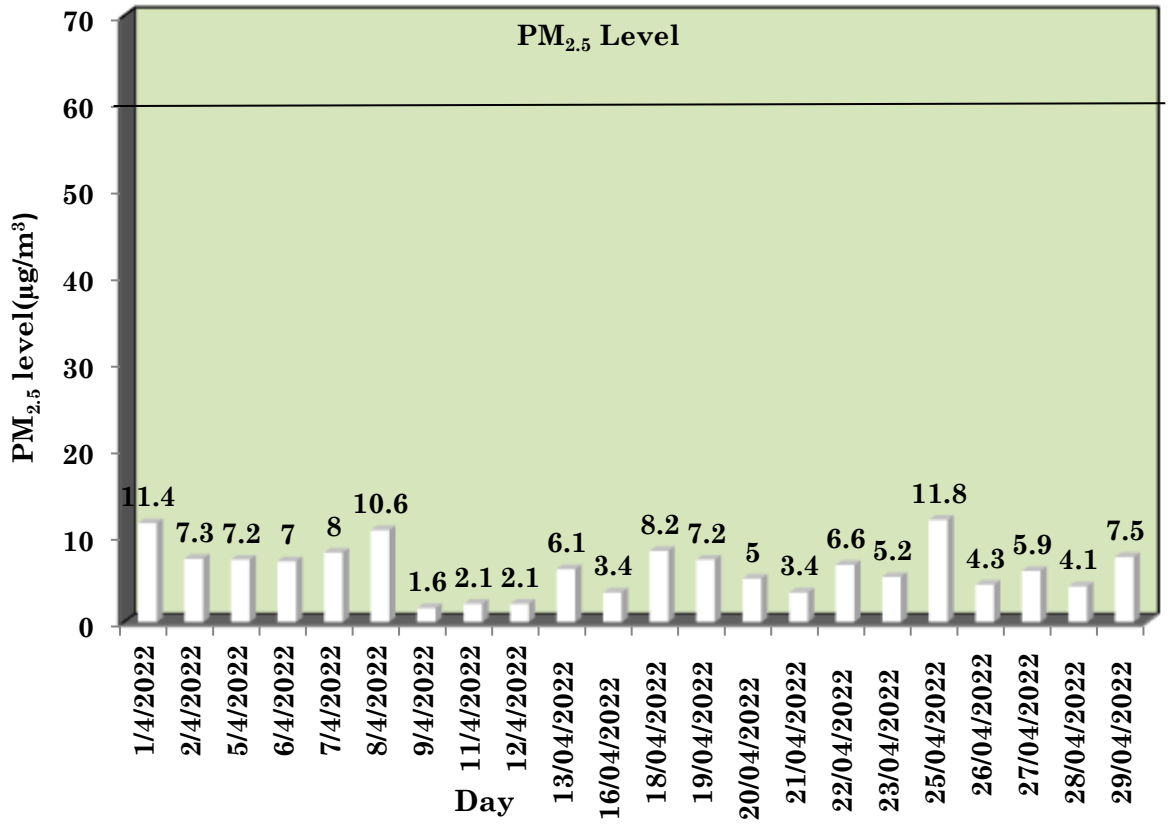


Fig. 6.2: Daily variation in $PM_{2.5}$ level (µg/m³) for station 1 (Gate no. 2) Over the month of April 2022

The daily variation in $PM_{2.5}$ level at the Station 1 over the month of April, 2022 is shown in the Fig. 6.2. The maximum pollutant concentration is found to be 11.8 µg/m³ on 25th April 2022 and the minimum concentration of 1.6 µg/m³ is observed on 9th April 2022. Average $PM_{2.5}$ concentration for the month of April at Station 1 is found to be 6.2 µg/m³. The range of $PM_{2.5}$ concentration (1.6 – 11.8 µg/m³) observed for station 1 over the month of April lied well below the 24-hourly permissible limit of 60 µg/m³.

Status of SO_2 concentration

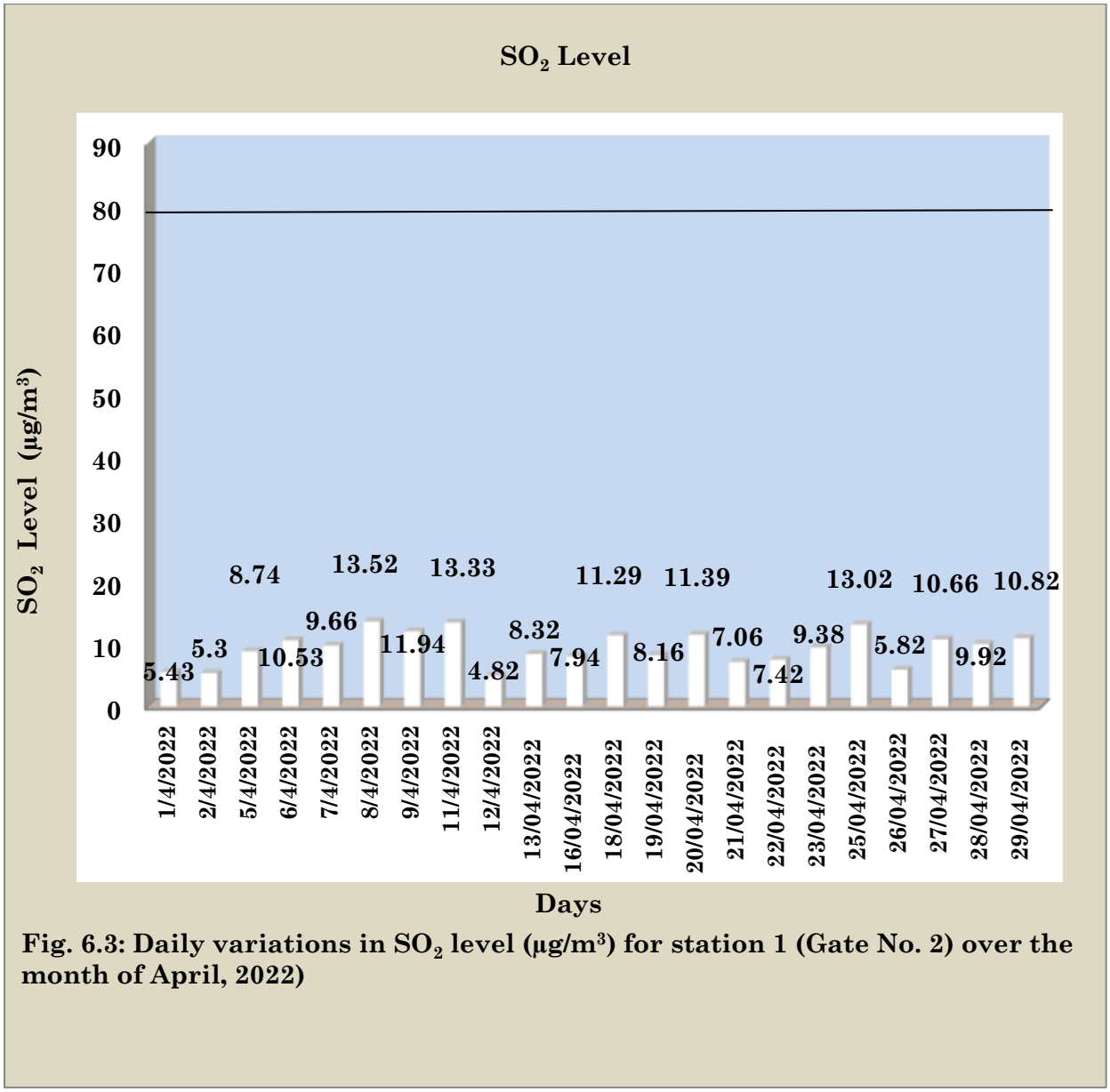


Fig. 6.3: Daily variations in SO_2 level (µg/m³) for station 1 (Gate No. 2) over the month of April, 2022)

The daily variation in SO_2 level at the Station 1 over the month of April, 2022 is shown in the Fig. 6.3. The maximum pollutant concentration is found to be 13.52 µg/m³ on 8th April 2022 and the minimum concentration of 4.82 µg/m³ is observed on 12th April 2022. Average SO_2 concentration for the month of April at Station 1 is found to be 9.3 µg/m³. The range of SO_2 concentration (4.82 – 13.52 µg/m³) observed for station 1 over the month of April lied well below the 24-hourly permissible limit of 80 µg/m³.

Status of NOx concentration

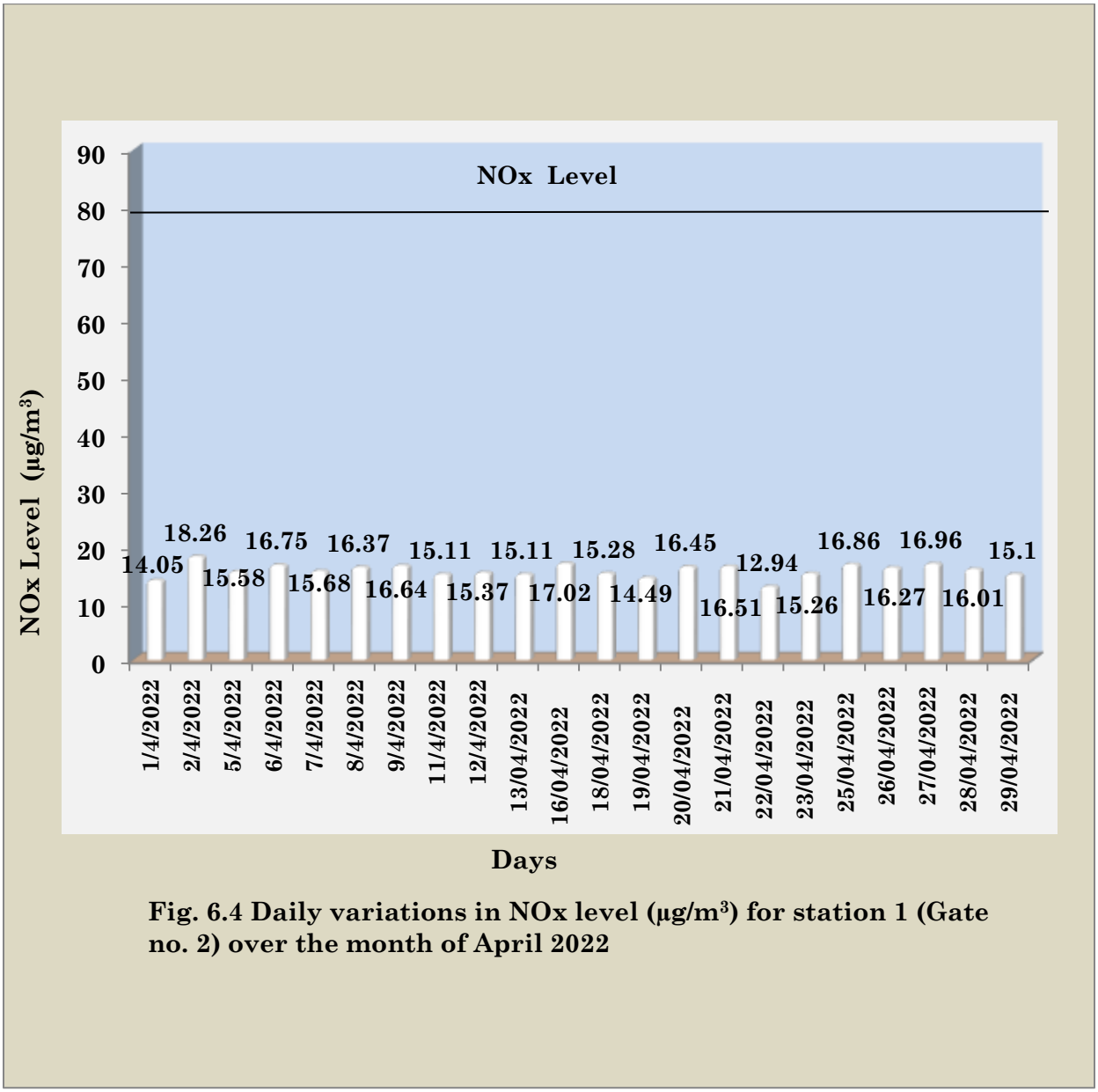


Fig. 6.4 Daily variations in NOx level (µg/m³) for station 1 (Gate no. 2) over the month of April 2022

The daily variation in NOx level at the Station 1 over the month of April, 2022 is shown in the Fig. 6.4. The maximum pollutant concentration is found to be 18.26 µg/m³ on 2nd April 2022 and the minimum concentration of 12.94 µg/m³ is observed on 22nd April 2022. Average NOx concentration for the month of April at Station 1 is found to be 15.8 µg/m³. The range of NOx concentration (12.94 – 18.26 µg/m³) observed for station 1 over the month of April lied well below the 24-hourly permissible limit of 80 µg/m³.

Status of CO concentration

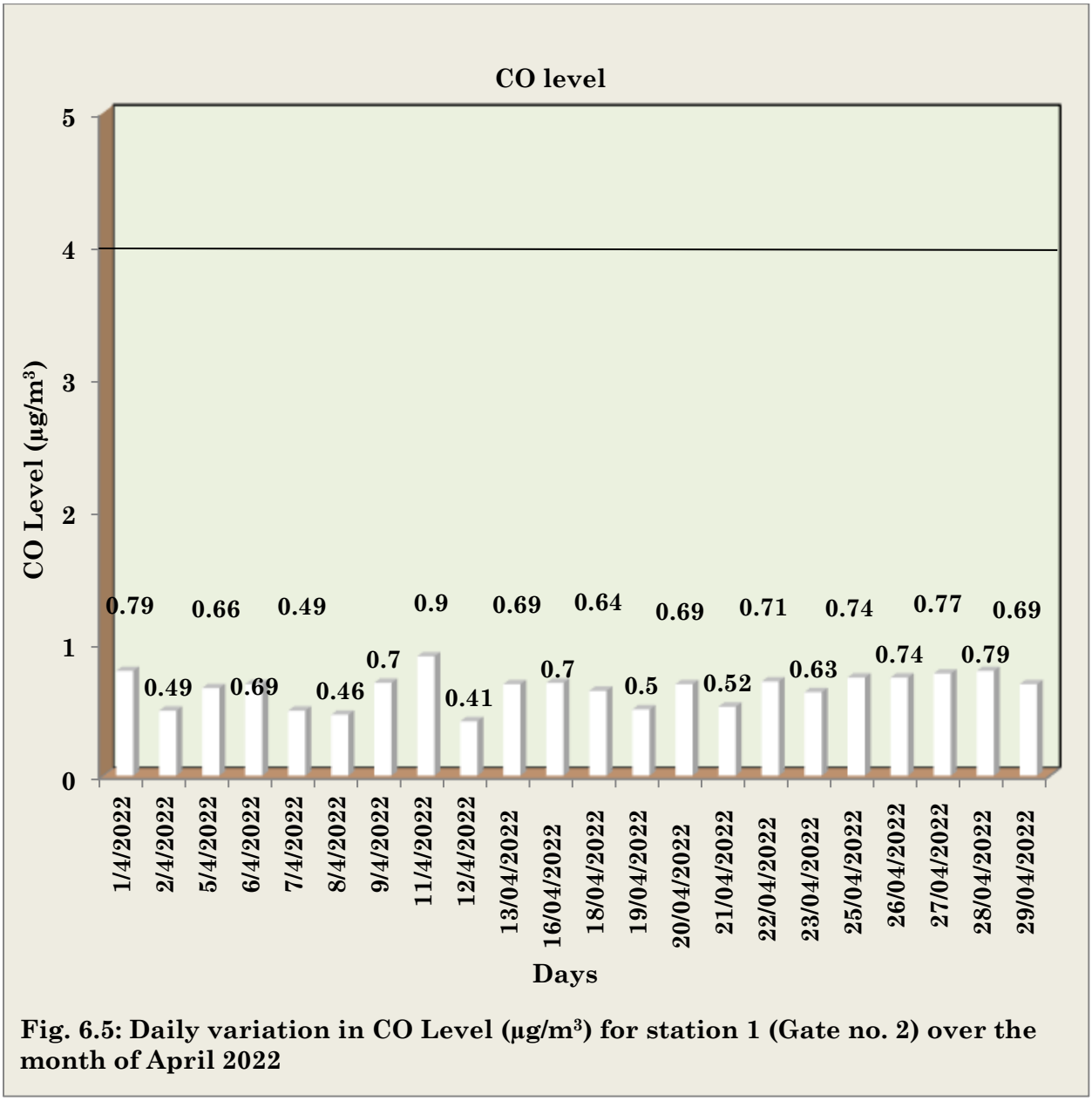


Fig. 6.5: Daily variation in CO Level (µg/m³) for station 1 (Gate no. 2) over the month of April 2022

The daily variation in CO level at the Station 1 over the month of April, 2022 is shown in the Fig. 6.5. The maximum pollutant concentration is found to be 0.9 µg/m³ on 11th April 2022 and the minimum concentration of 0.41 µg/m³ is observed on 12th April 2022. Average CO concentration for the month of April at Station 1 is found to be 0.7 µg/m³. The range of CO concentration (0.41 – 0.9 µg/m³) observed for station 1 over the month of April lied well below the 24-hourly permissible limit of 4.0 µg/m³.

Status of O_3 concentration

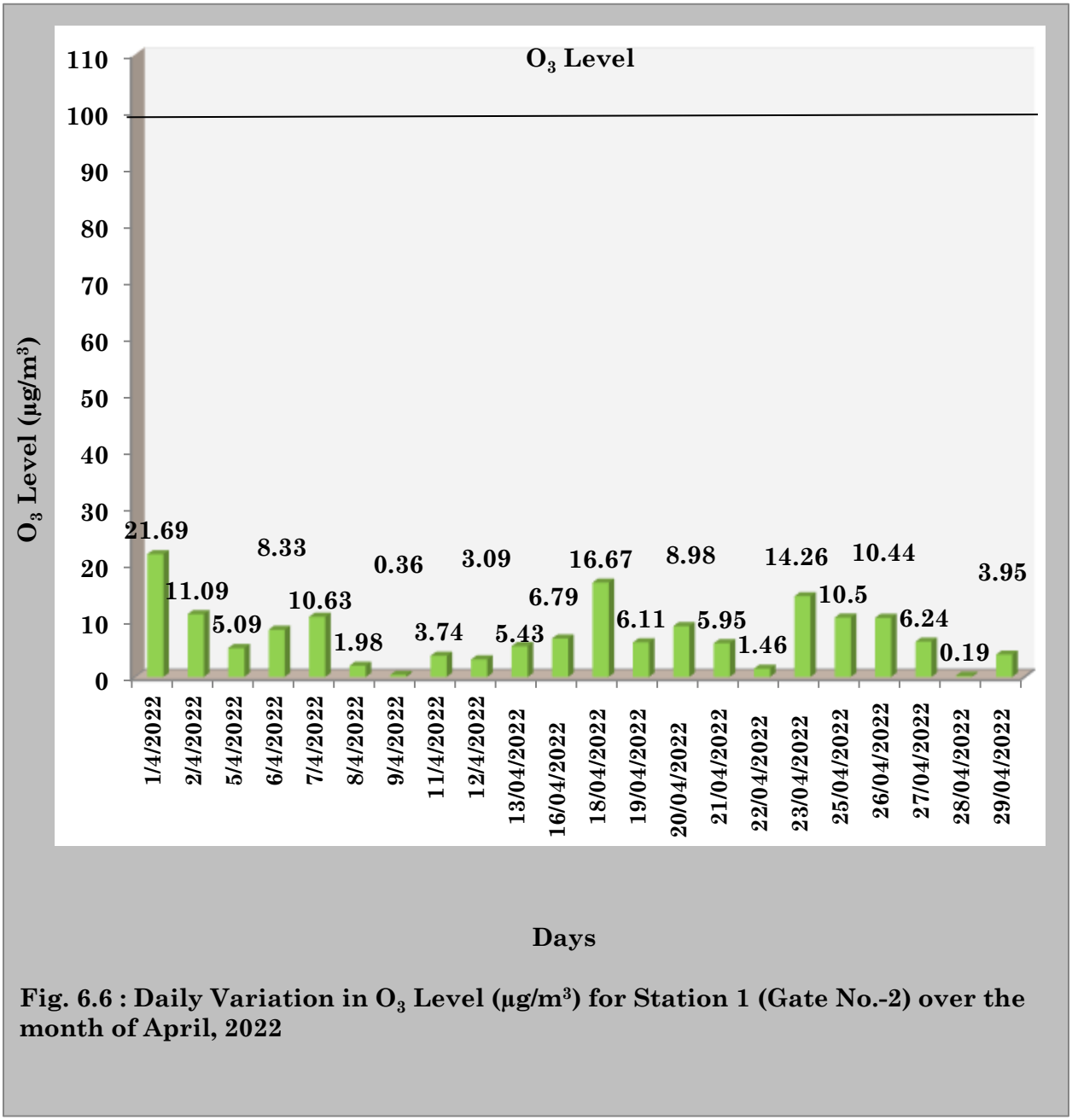


Fig. 6.6 : Daily Variation in O_3 Level (µg/m³) for Station 1 (Gate No.-2) over the month of April, 2022

The daily variation in O_3 level at the Station 1 over the month of April, 2022 is shown in the Fig. 6.6. The maximum pollutant concentration is found to be 21.69 µg/m³ on 1st April 2022 and the minimum concentration of 0.19 µg/m³ is observed on 28th April 2022. Average O_3 concentration for the month of April at Station 1 is found to be 7.41 µg/m³. The range of O_3 concentration (0.19 – 21.69 µg/m³) observed for station 1 over the month of April lied well below the 8 hourly permissible limits of 100.0 µg/m³.

❖ **Station 2 (KTTP Township)**

Status of PM_{10} concentration

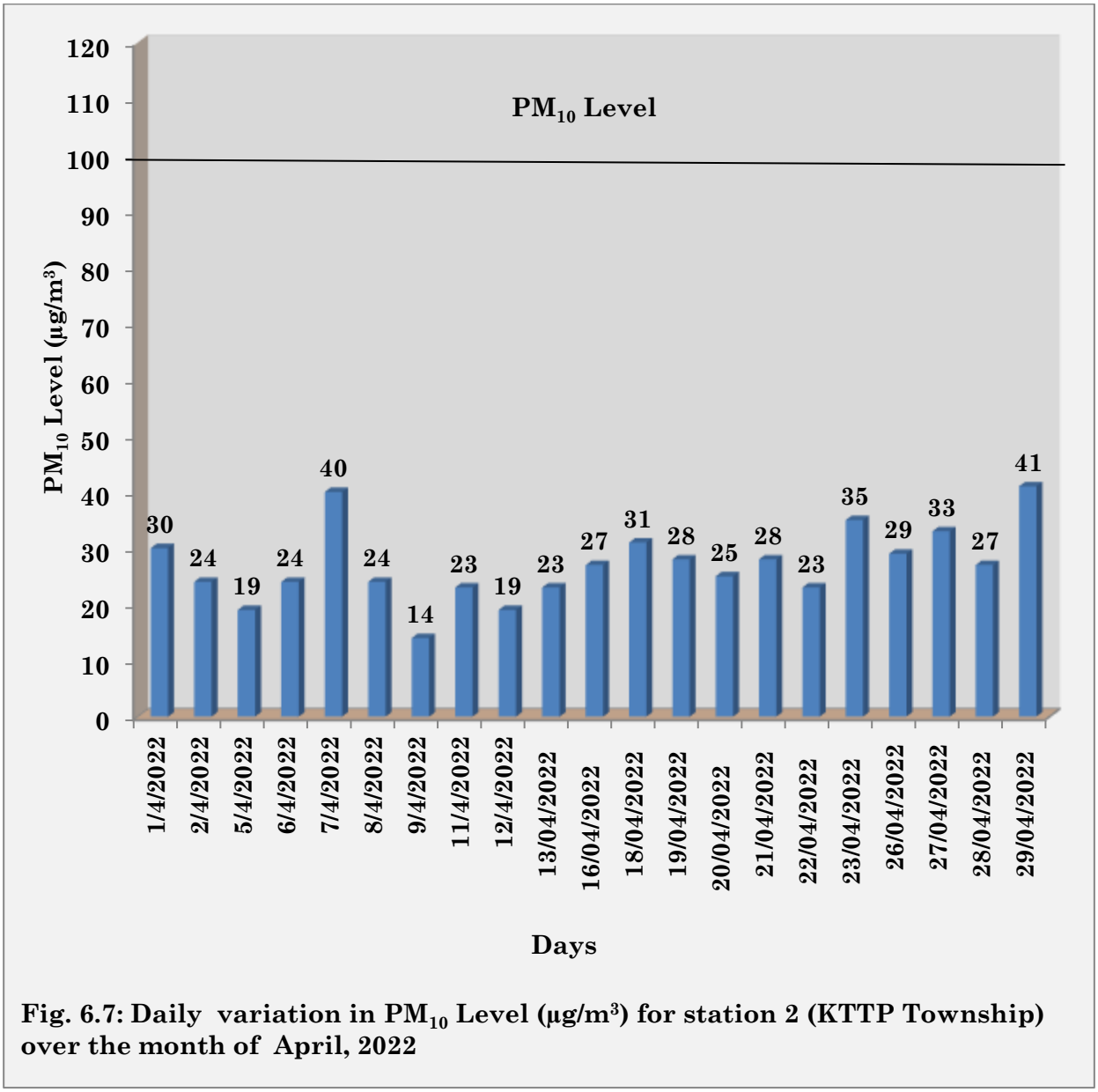


Fig. 6.7: Daily variation in PM_{10} Level (µg/m³) for station 2 (KTTP Township) over the month of April, 2022

The daily variation in PM_{10} level at the Station 2 over the month of April, 2022 is shown in the Fig. 6.7. The maximum pollutant concentration is found to be 41 µg/m³ on 29th April 2022 and the minimum concentration of 14 µg/m³ is observed on 9th April 2022. Average PM_{10} concentration for the month of April at Station 2 is found to be 27 µg/m³. The range of PM_{10} concentration (14 – 41 µg/m³) observed for station 2 over the month of April lied well below the 24-hourly permissible limit of 100 µg/m³.

Status of $PM_{2.5}$ concentration

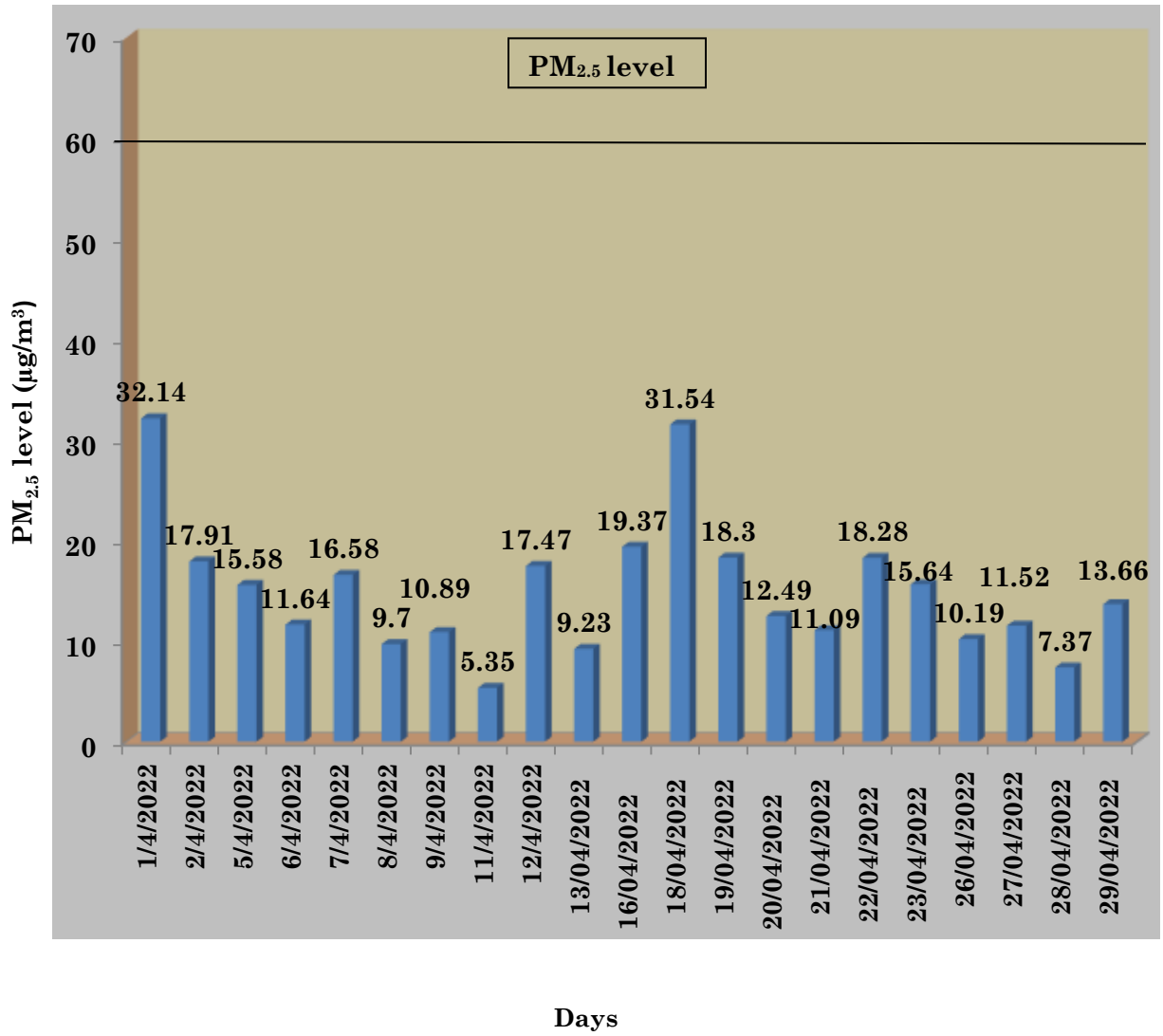


Fig. 6.8 Daily variation in $PM_{2.5}$ level (µg/m³) for station 2 (KTTP Township) over the month of April 2022

The daily variation in $PM_{2.5}$ level at the Station 2 over the month of April, 2022 is shown in the Fig. 6.8. The maximum pollutant concentration is found to be 32.14 µg/m³ on 1st April 2022 and the minimum concentration of 5.34 µg/m³ is observed on 11th April 2022. Average $PM_{2.5}$ concentration for the month of April at Station 2 is found to be 15.04 µg/m³. The range of $PM_{2.5}$ concentration (5.34 – 32.14 µg/m³) observed for station 2 over the month of April lied well below the 24-hourly permissible limit of 60 µg/m³.

Status of SO_2 concentration

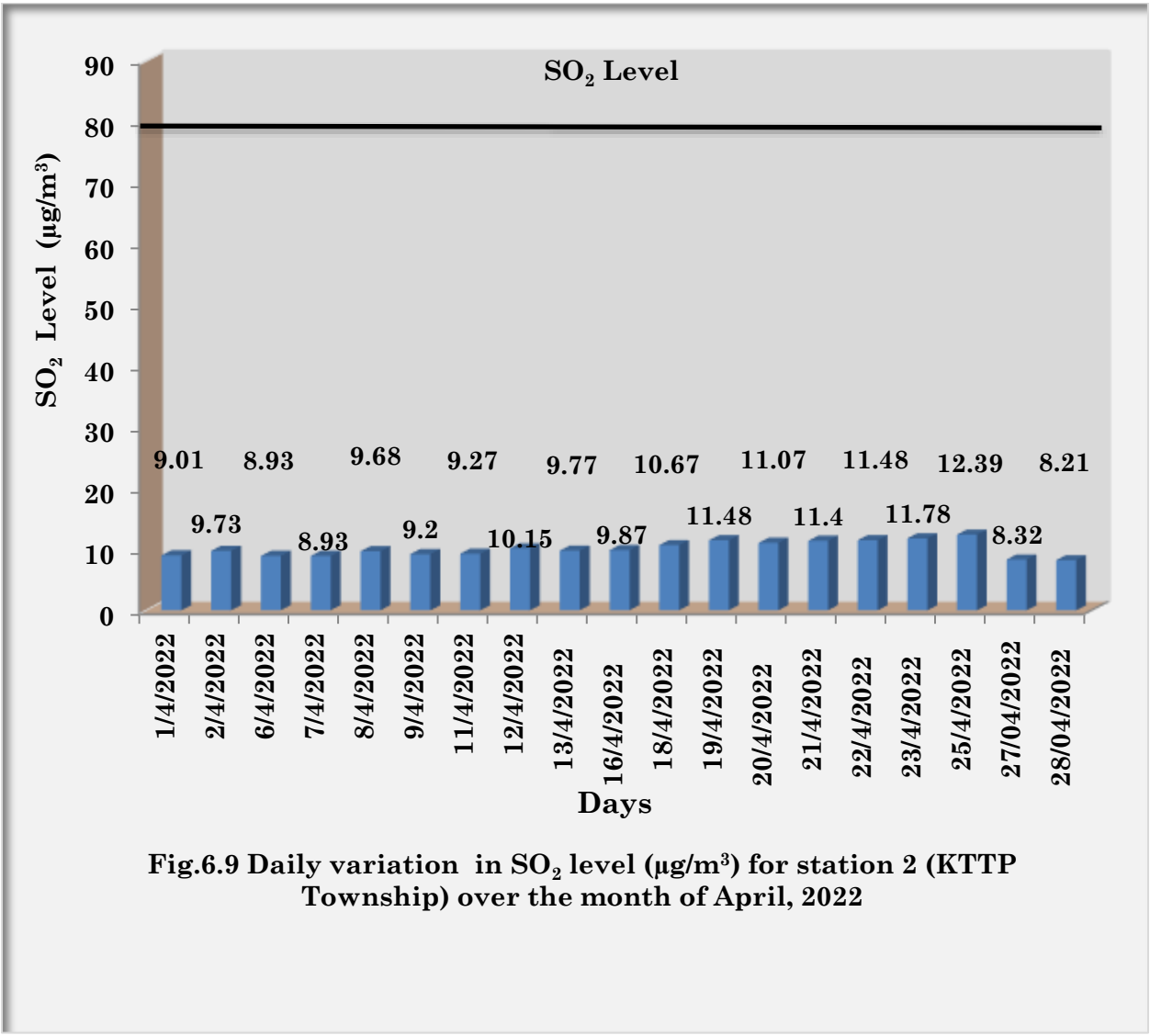


Fig.6.9 Daily variation in SO_2 level (µg/m³) for station 2 (KTTP Township) over the month of April, 2022

The daily variation in SO_2 level at the Station 2 over the month of April, 2022 is shown in the Fig. 6.9. The maximum pollutant concentration is found to be 12.39 µg/m³ on 25th April 2022 and the minimum concentration of 8.93 µg/m³ is observed on 6th April 2022. Average SO_2 concentration for the month of April at Station 2 is found to be 10.07 µg/m³. The range of SO_2 concentration (8.93 – 12.39µg/m³) observed for station 2 over the month of April lied well below the 24-hourly permissible limit of 80 µg/m³.

Status of NOx concentration

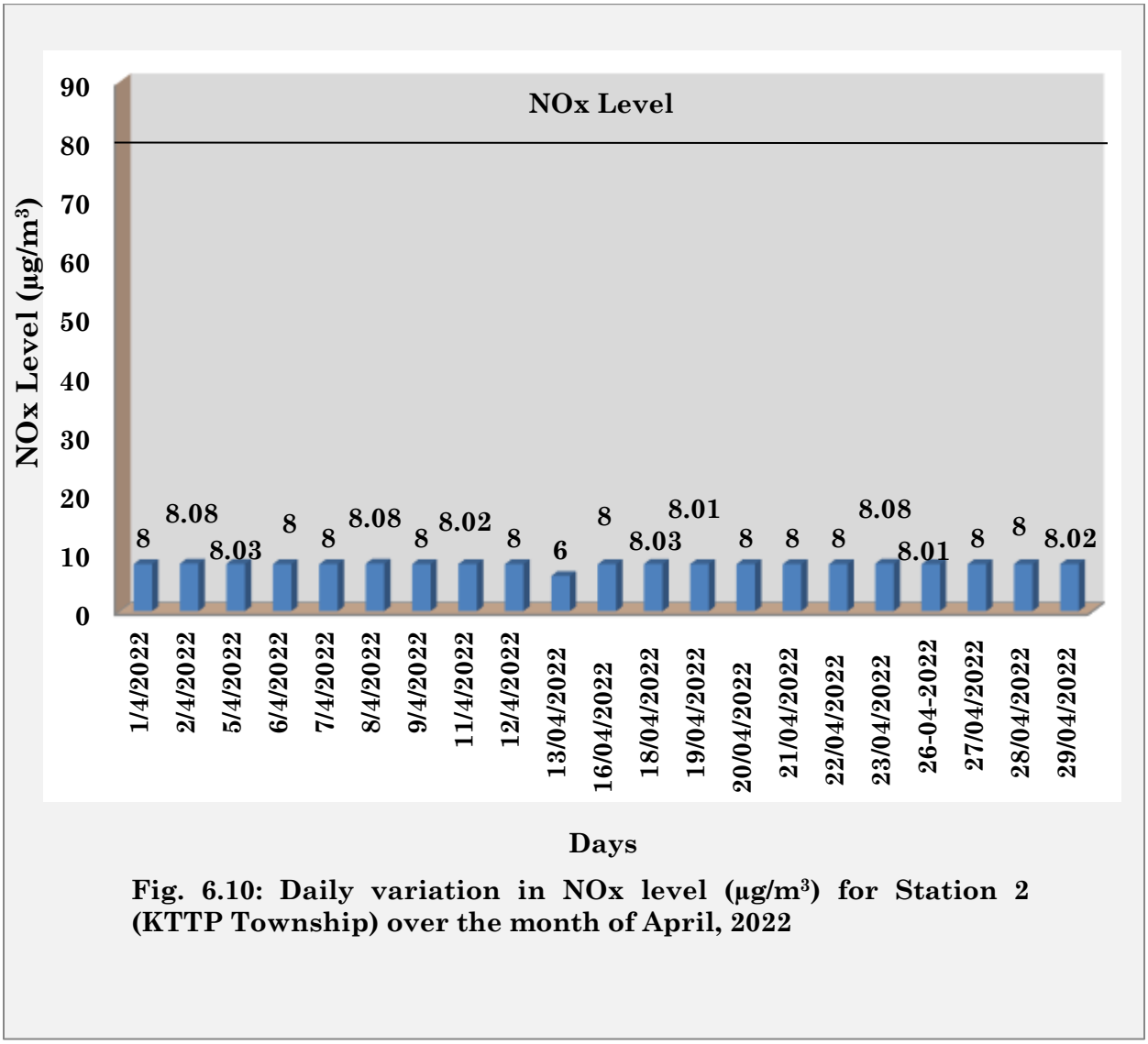


Fig. 6.10: Daily variation in NOx level (µg/m³) for Station 2 (KTTP Township) over the month of April, 2022

The daily variation in NOx level at the Station 2 over the month of April, 2022 is shown in the Fig. 6.10. The maximum pollutant concentration is found to be 8.08 µg/m^3 on 8th April 2022 and the minimum concentration of 6 µg/m^3 is observed on 13th April 2022. Average NOx concentration for the month of April at Station 2 is found to be 7.9 µg/m^3. The range of NOx concentration (6.0 – 8.08 µg/m^3) observed for station 2 over the month of April lied well below the 24-hourly permissible limit of 80 µg/m^3.

Status of CO concentration

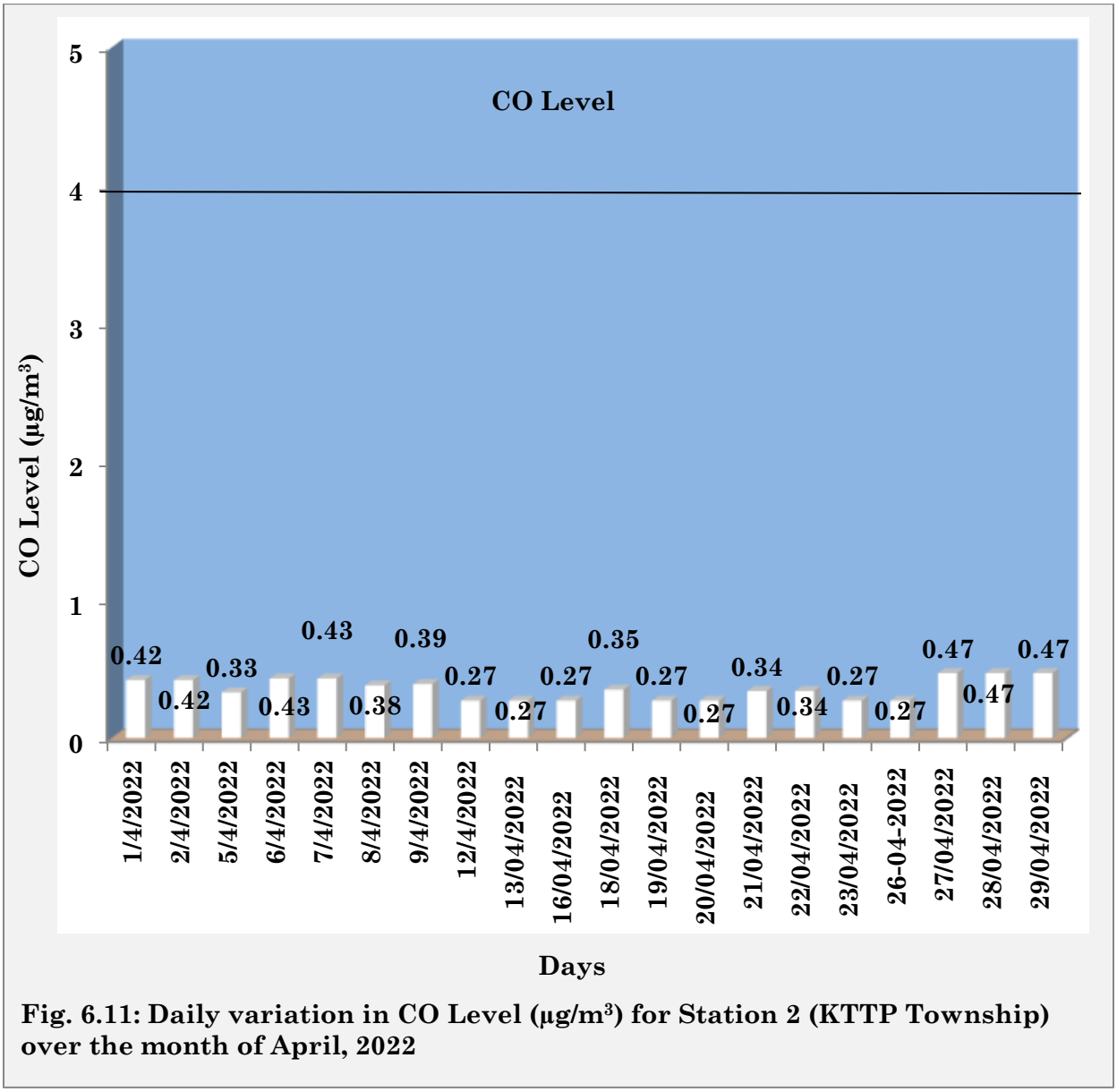


Fig. 6.11: Daily variation in CO Level (µg/m³) for Station 2 (KTTP Township) over the month of April, 2022

The daily variation in CO level at the Station 2 over the month of April, 2022 is shown in the Fig. 6.11. The maximum pollutant concentration is found to be 0.47 µg/m³ on 27th, 28th and 29th April 2022 and the minimum concentration of 0.27 µg/m³ is observed on 12th, 13th 16th, 19th, 20th, 26th, 27th April 2022. Average CO concentration for the month of April at Station 2 is found to be 0.36 µg/m³. The range of CO concentration (0.27 – 0.47 µg/m³) observed for station 2 over the month of April lied well below the 24-hourly permissible limit of 4.0 µg/m³.

Status of O_3 concentration

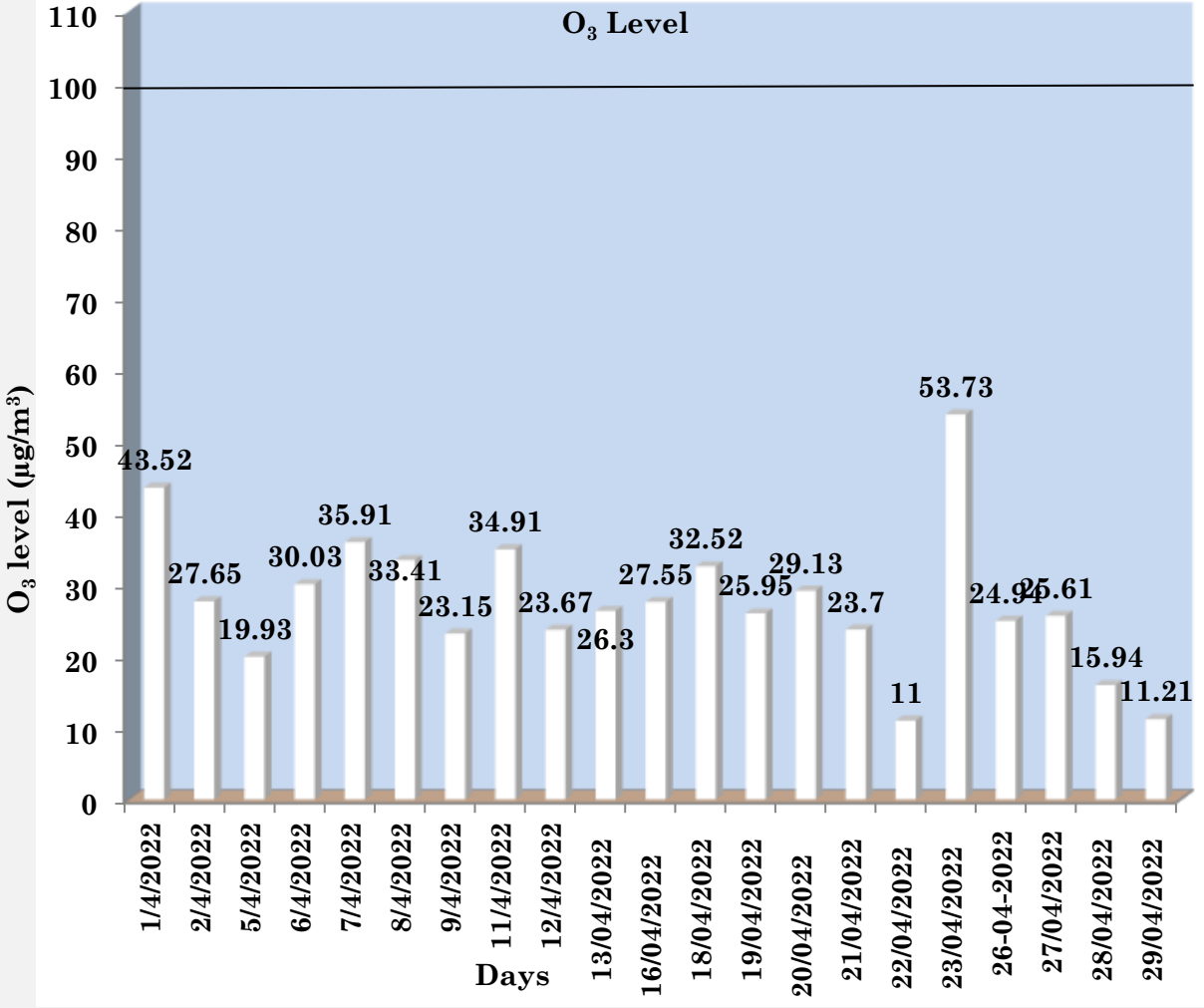


Fig.6.12: Daily variation in O_3 level (µg/m³) for station 2 (KTTP Township) over the month of April, 2022

The daily variation in O_3 level at the Station 2 over the month of April, 2022 is shown in the Fig. 6.12. The maximum pollutant concentration is found to be 53.73 µg/m³ on 23rd April 2022 and the minimum concentration of 11.0 µg/m³ is observed on 22nd April 2022. Average O_3 concentration for the month of April at Station 2 is found to be 27.6 µg/m³. The range of O_3 concentration (11.0 – 53.73 µg/m³) observed for station 2 over the month of April lied well below the 8 hourly permissible limits of 100.0 µg/m³.

Station 3 (Intake Pump House)

Status of PM_{10} concentration

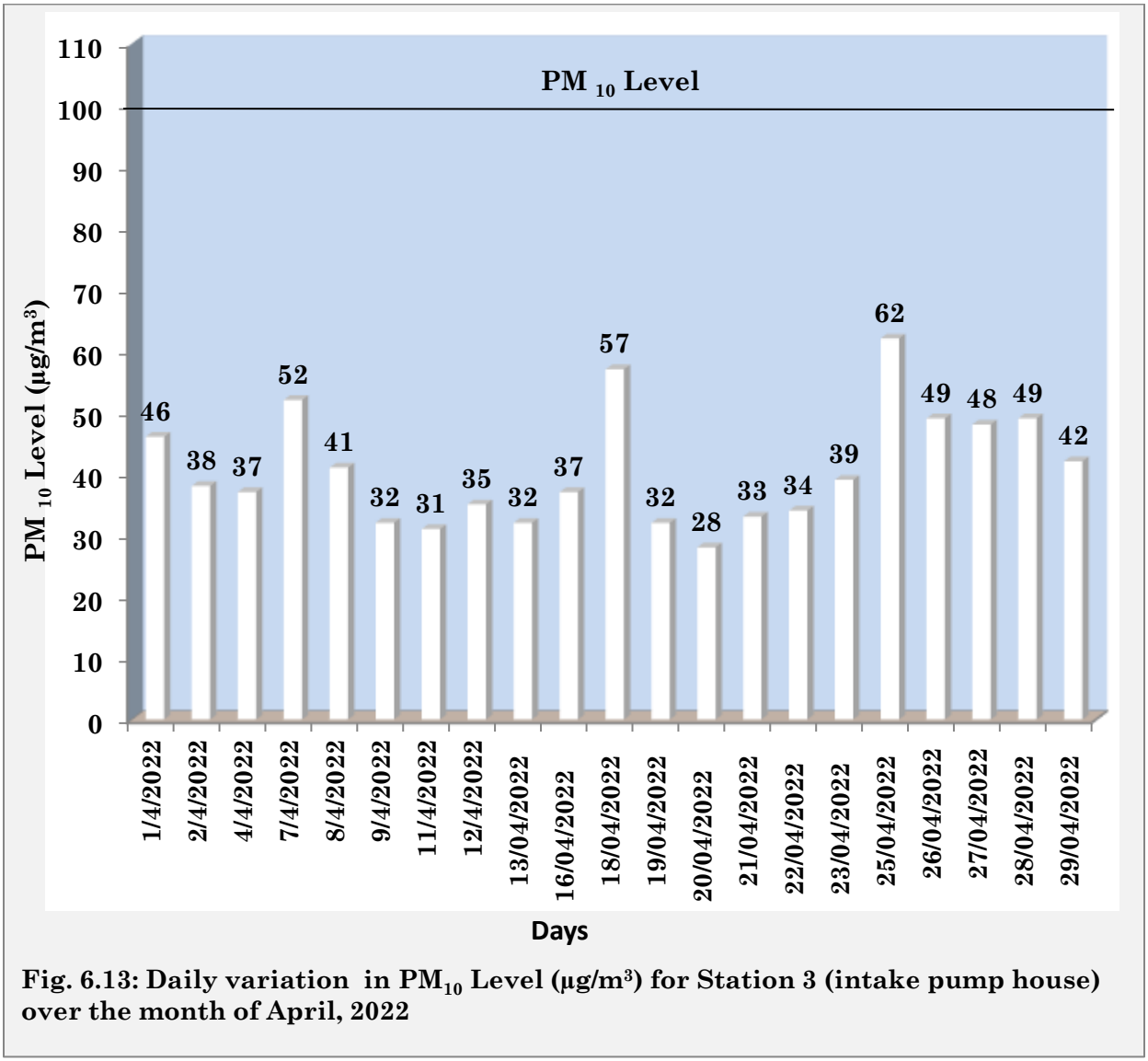


Fig. 6.13: Daily variation in PM_{10} Level (µg/m³) for Station 3 (intake pump house) over the month of April, 2022

The daily variation in PM_{10} level at the Station 3 over the month of April, 2022 is shown in the Fig. 6.13. The maximum pollutant concentration is found to be 62.0 µg/m³ on 25th April 2022 and the minimum concentration of 28 µg/m³ is observed on 20th April 2022. Average PM_{10} concentration for the month of April at Station 3 is found to be 40.6 µg/m³. The range of PM_{10} concentration (28 – 62 µg/m³) observed for station 3 over the month of April lied well below the 24-hourly permissible limit of 100 µg/m³.

Status of $PM_{2.5}$ concentration

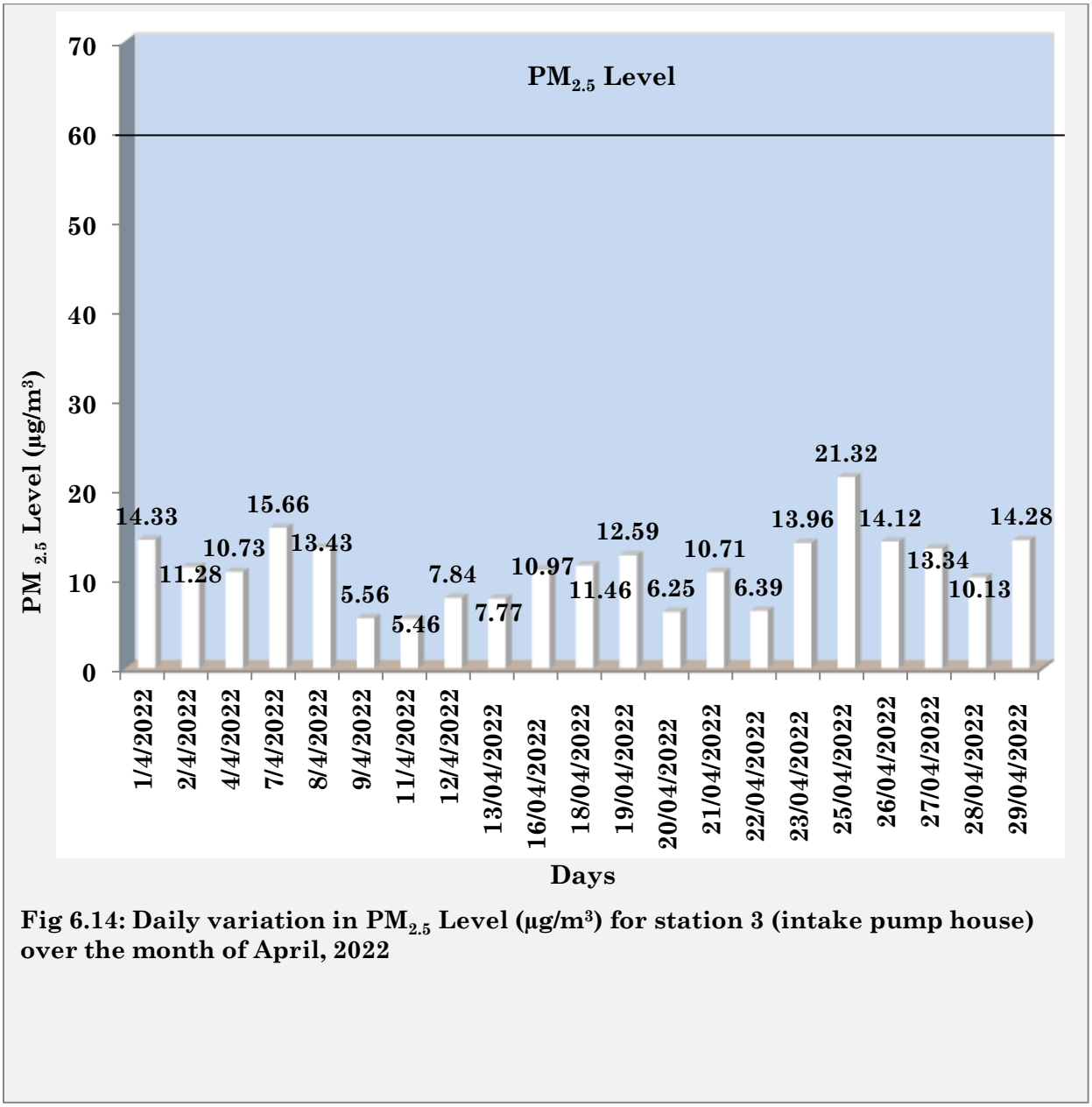


Fig 6.14: Daily variation in $PM_{2.5}$ Level (µg/m³) for station 3 (intake pump house) over the month of April, 2022

The daily variation in $PM_{2.5}$ level at the Station 3 over the month of April, 2022 is shown in the Fig. 6.14. The maximum pollutant concentration is found to be 21.32 µg/m³ on 25th April 2022 and the minimum concentration of 5.46 µg/m³ is observed on 11th April 2022. Average $PM_{2.5}$ concentration for the month of April at Station 3 is found to be 11.3 µg/m³. The range of $PM_{2.5}$ concentration (5.46 – 21.32 µg/m³) observed for station 3 over the month of April lied well below the 24-hourly permissible limit of 60 µg/m³.

Status of SO_2 concentration

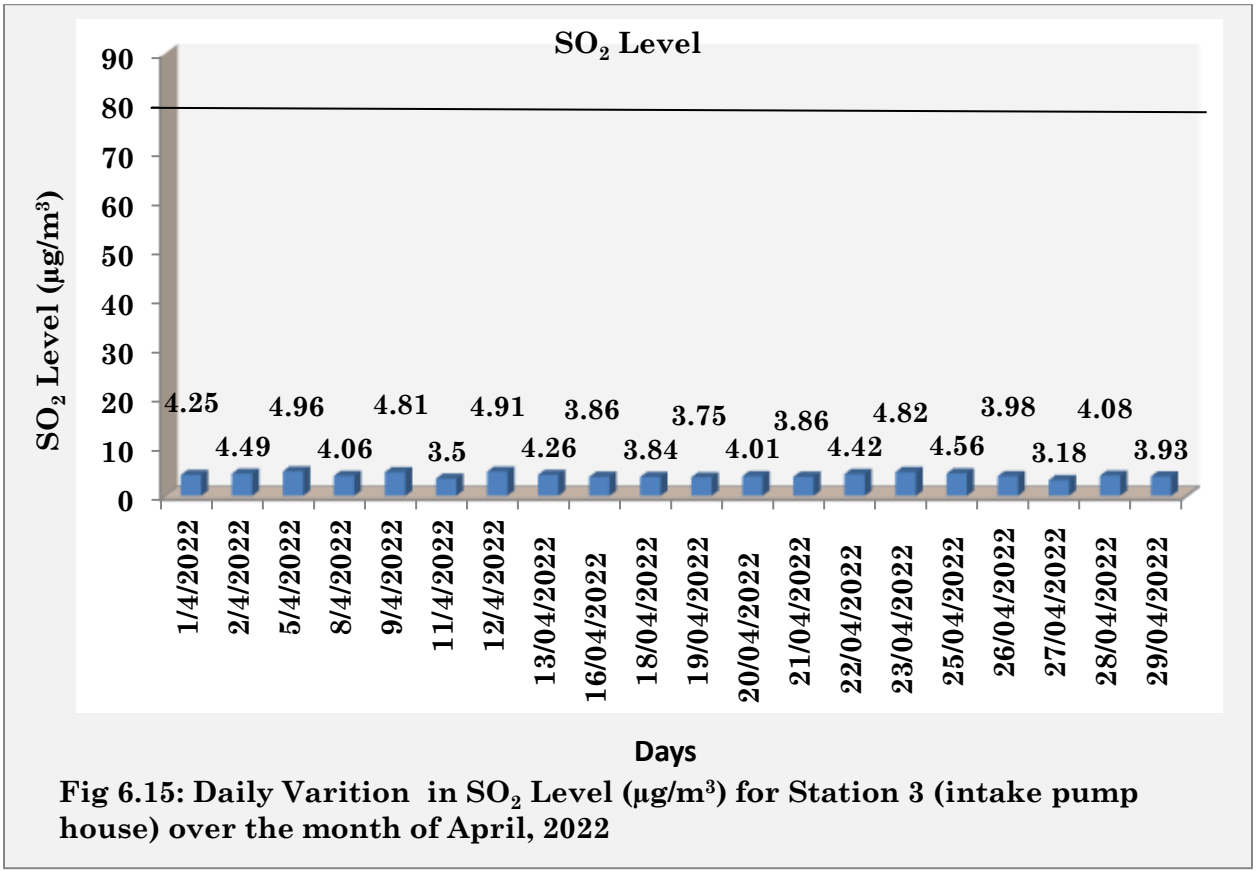


Fig 6.15: Daily Varition in SO_2 Level (µg/m³) for Station 3 (intake pump house) over the month of April, 2022

The daily variation in SO_2 level at the Station 3 over the month of April, 2022 is shown in the Fig. 6.15. The maximum pollutant concentration is found to be 4.96 µg/m³ on 8th April 2022 and the minimum concentration of 3.18 µg/m³ is observed on 27th April 2022. Average SO_2 concentration for the month of April at Station 3 is found to be 4.2 µg/m³. The range of SO_2 concentration (3.18 – 4.96 µg/m³) observed for station 3 over the month of April lied well below the 24-hourly permissible limit of 80 µg/m³.

Status of NOx concentration

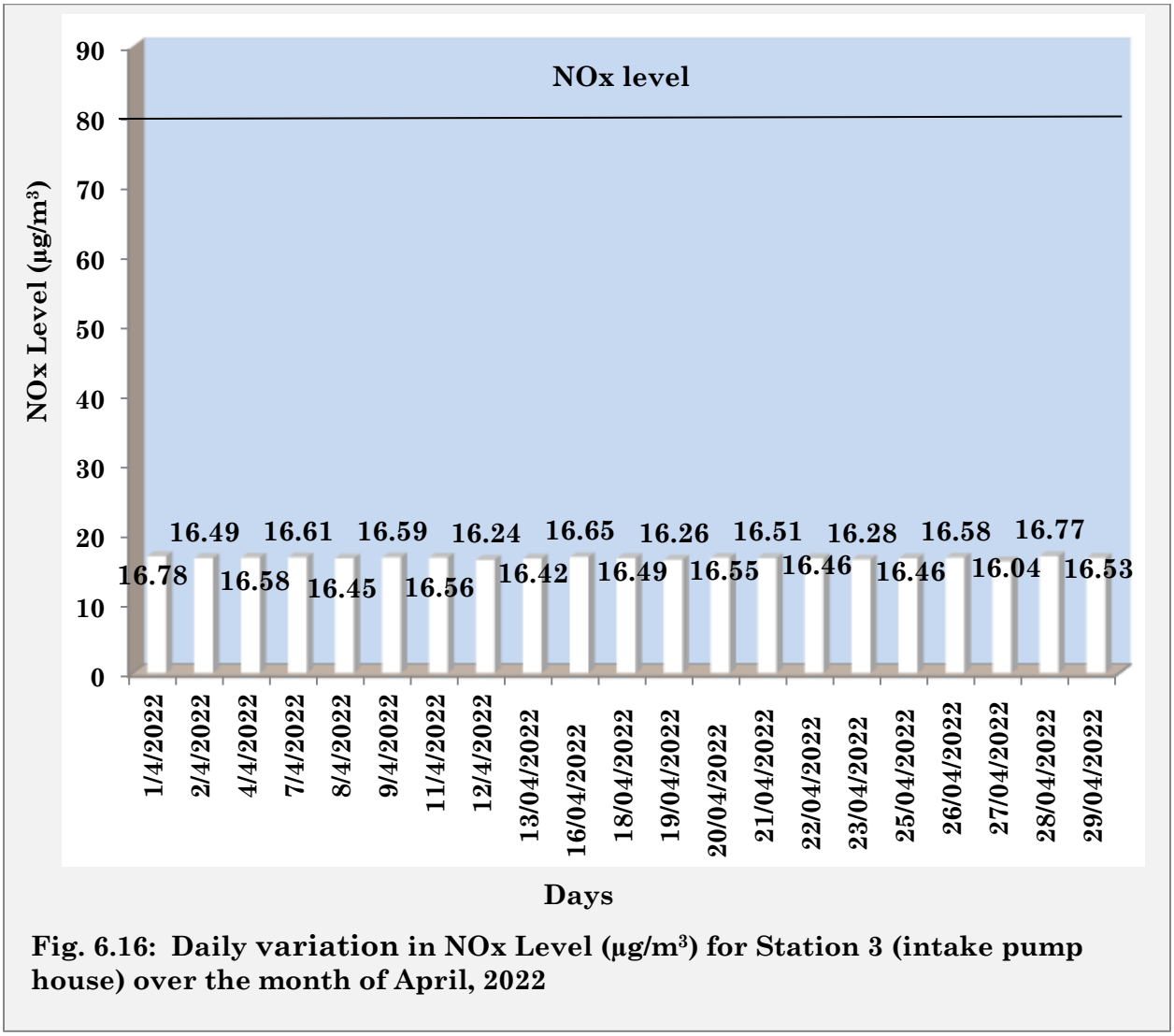


Fig. 6.16: Daily variation in NOx Level (µg/m³) for Station 3 (intake pump house) over the month of April, 2022

The daily variation in NOx level at the Station 3 over the month of April, 2022 is shown in the Fig. 6.16. The maximum pollutant concentration is found to be 16.78 µg/m³ on 1st April 2022 and the minimum concentration of 16.04 µg/m³ is observed on 27th April 2022. Average NOx concentration for the month of April at Station 3 is found to be 14.93 µg/m³. The range of NOx concentration (16.04 – 16.78 µg/m³) observed for station 3 over the month of April lied well below the 24-hourly permissible limit of 80 µg/m³.

Status of CO concentration

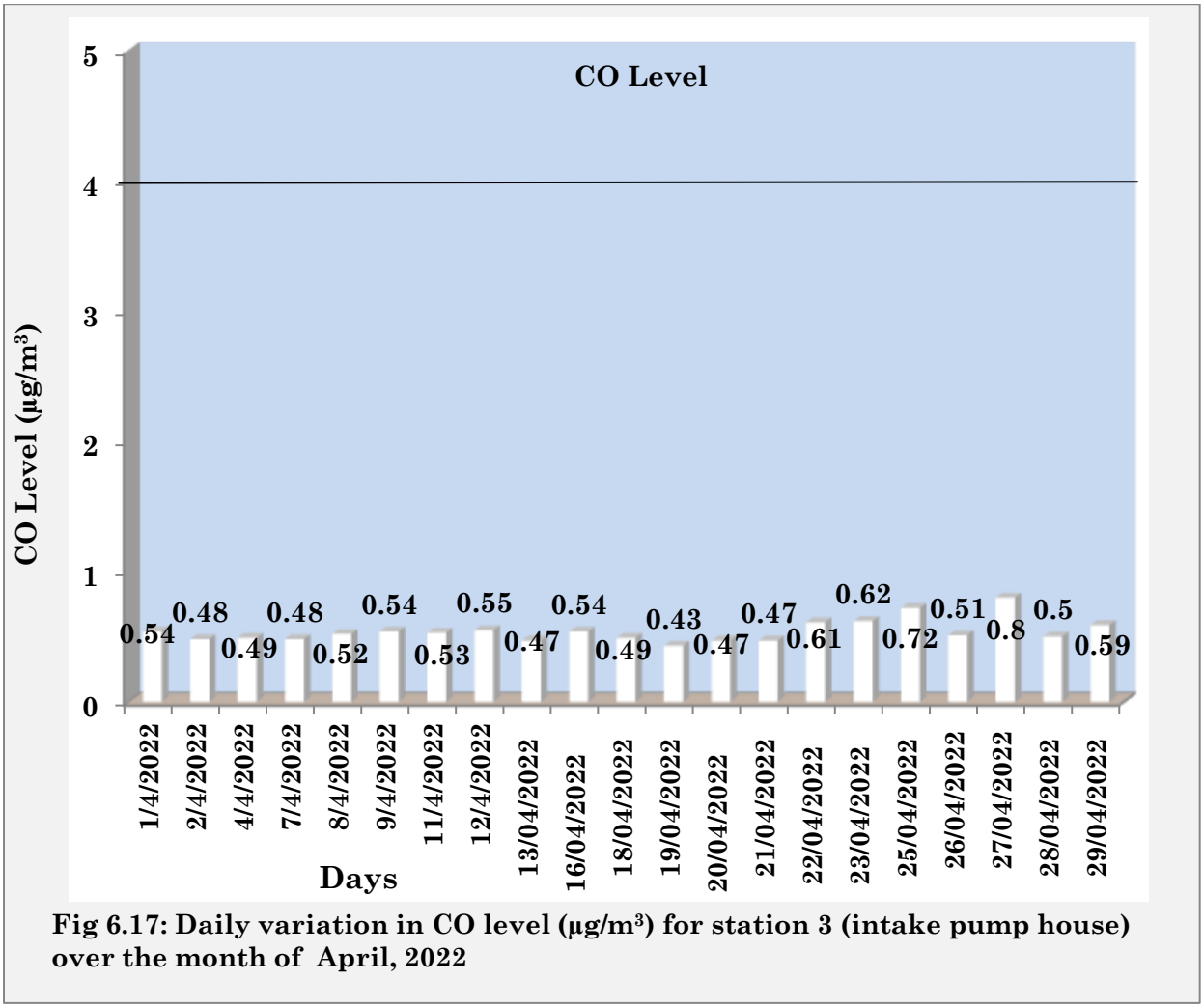


Fig 6.17: Daily variation in CO level (µg/m³) for station 3 (intake pump house) over the month of April, 2022

The daily variation in CO level at the Station 3 over the month of April, 2022 is shown in the Fig. 6.11. The maximum pollutant concentration is found to be 0.8 µg/m^3 on 27th April 2022 and the minimum concentration of 0.43 µg/m^3 is observed on 19th April 2022. Average CO concentration for the month of April at Station 3 is found to be 0.54 µg/m^3. The range of CO concentration (0.43 – 0.8 µg/m^3) observed for station 3 over the month of April lied well below the 24-hourly permissible limit of 4.0 µg/m^3.

Status of O_3 concentration

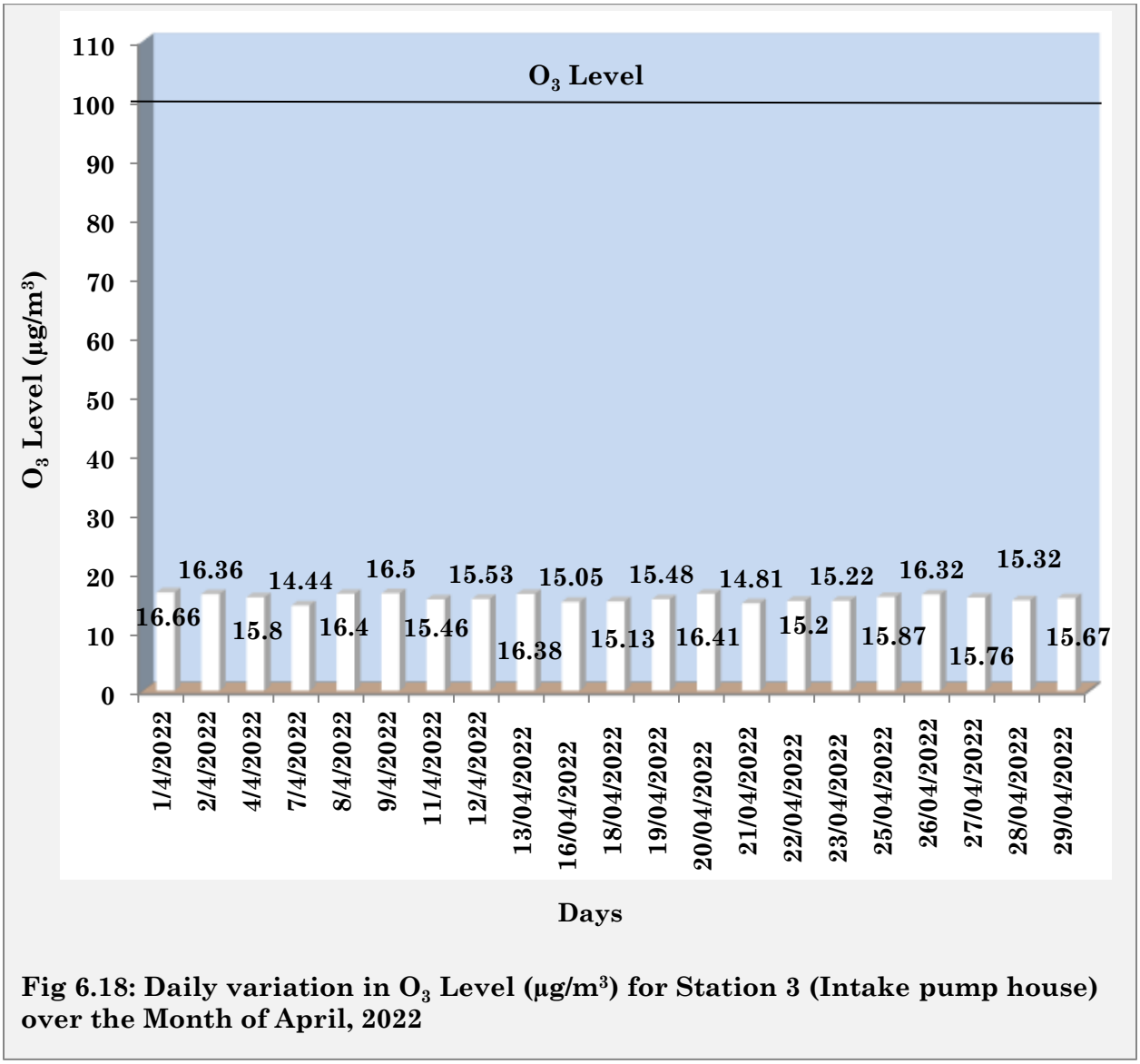


Fig 6.18: Daily variation in O_3 Level (µg/m³) for Station 3 (Intake pump house) over the Month of April, 2022

The daily variation in O_3 level at the Station 3 over the month of April, 2022 is shown in the Fig. 6.18. The maximum pollutant concentration is found to be 16.66 µg/m³ on 1st April 2022 and the minimum concentration of 14.44 µg/m³ is observed on 7th April 2022. Average O_3 concentration for the month of April at Station 3 is found to be 15.7 µg/m³. The range of O_3 concentration (14.44 – 16.67 µg/m³) observed for station 3 over the month of April lied well below the 8 hourly permissible limits of 100.0 µg/m³.

6.1.1 Discussions on concentration variation for the month of April in all three stations

The summary of mean pollutant concentration prevailing at three monitoring stations over the month of April, 2022 for six criteria air pollutants is furnished in the table 6.3.

Table 6.3: Mean pollutant concentration of the pollutants over the month of April, 2022

Pollutants	Concentration (µg/m³)		
	Station1	Station 2	Station 3
PM_{10}	24.965	27	40.666
$PM_{2.5}$	6.18	22.854	11.313
SO_2	9.294	13.967	4.148
NOx	15.821	7.92	16.490
CO	0.654	0.356	0.540
O_3	7.40	27.607	15.703

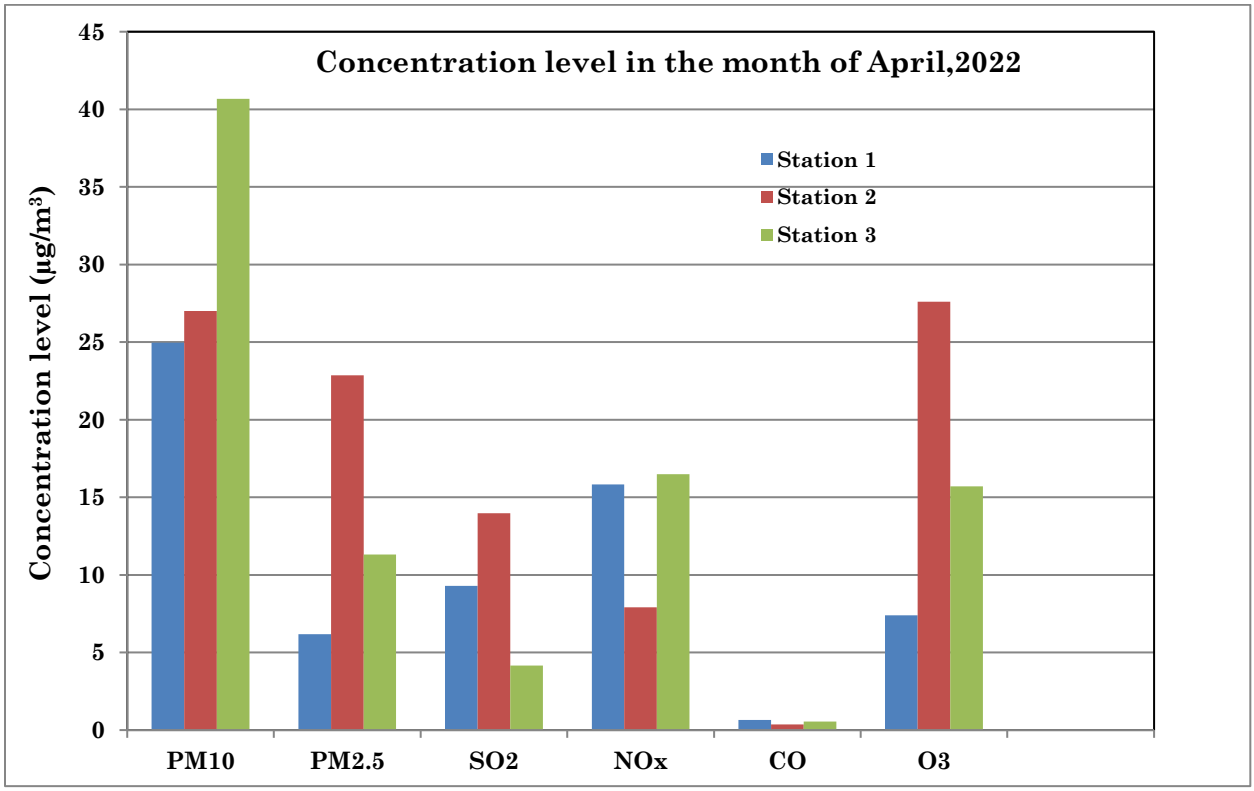


Fig 6.19: Variation in pollutant concentrations for three stations for the month of April, 2022

6.2 Daily variation analysis for the month of May, 2022

- **Station 1 (Gate No.2)**

Status of PM_{10} concentration

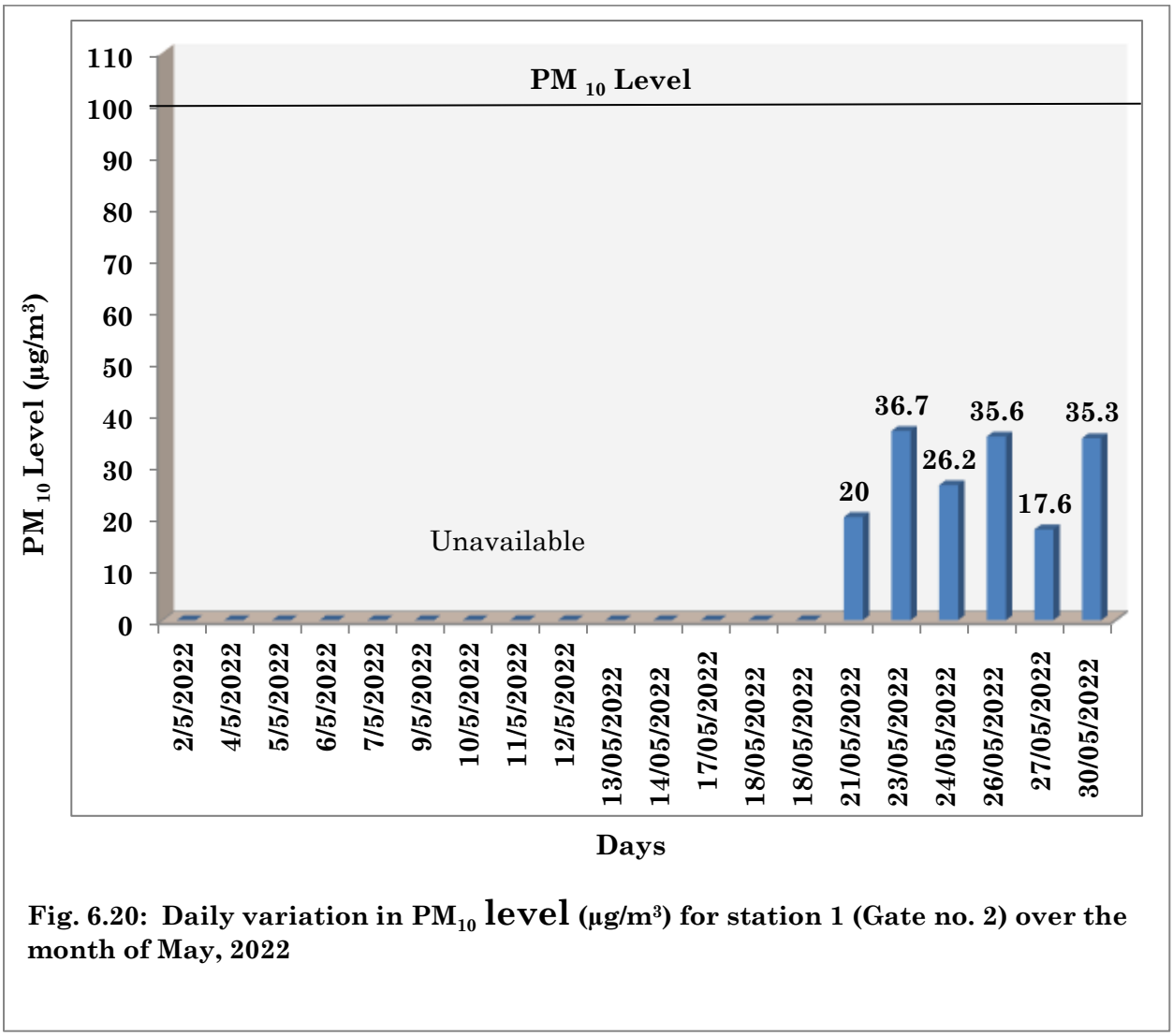


Fig. 6.20: Daily variation in PM_{10} level (µg/m³) for station 1 (Gate no. 2) over the month of May, 2022

In the above figure 6.20 the following days showing there is unavailable of the data this is due to malfunctioning of the Continuous ambient air quality monitoring station. And when it is functioning normally the maximum concentration level reading shows 36 µg/m^3 on 25th May, Minimum concentration reading is 17.6 µg/m^3 on 27th May and the average concentration value is 28 µg/m^3 for station 1

Status of $PM_{2.5}$ concentration

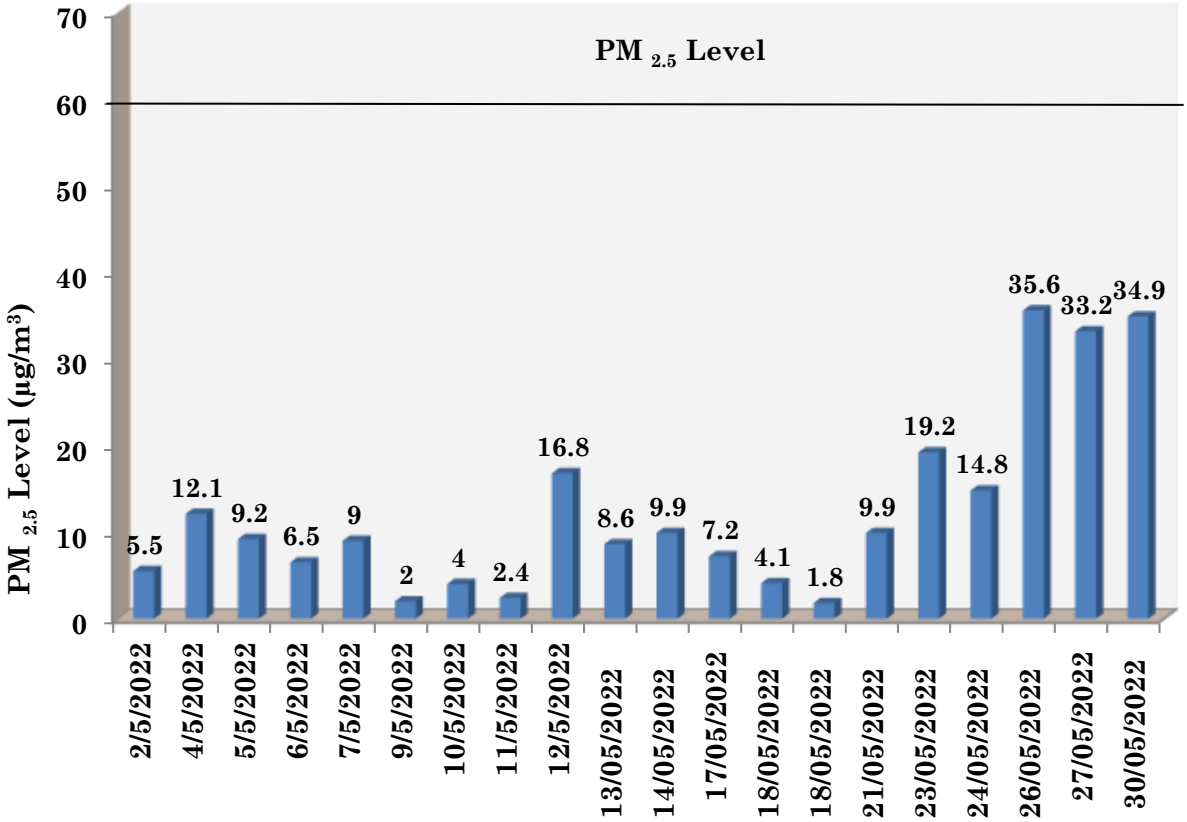


Fig. 6.21: Daily variation in $PM_{2.5}$ Level (µg/m³) for station 1 (Gate No 2) over the month of May, 2022

The daily variation in $PM_{2.5}$ level at the Station 1 over the month of May, 2022 is shown in the Fig. 6.21. The maximum pollutant concentration is found to be 35.6 µg/m³ on 26th May 2022 and the minimum concentration of 1.8 µg/m³ is observed on 18th May 2022. Average $PM_{2.5}$ concentration for the month of April at Station 1 is found to be 12.3 µg/m³. The range of $PM_{2.5}$ concentration (1.8 – 35.6 µg/m³) observed for station 1 over the month of May lied well below the 24-hourly permissible limit of 60 µg/m³.

Status of SO_2 concentration

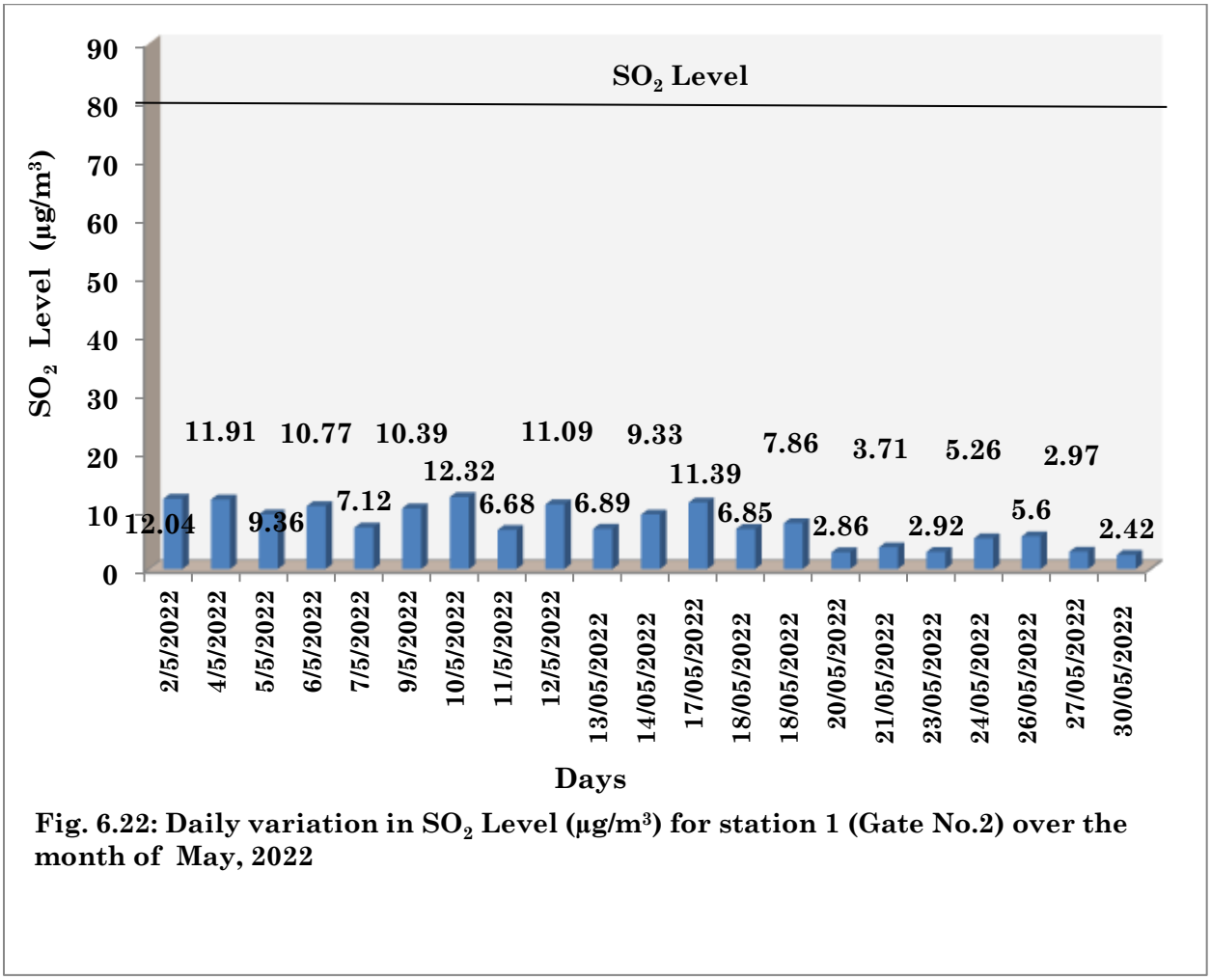


Fig. 6.22: Daily variation in SO_2 Level (µg/m³) for station 1 (Gate No.2) over the month of May, 2022

The daily variation in SO_2 level at the Station 1 over the month of May, 2022 is shown in the Fig. 6.22. The maximum pollutant concentration is found to be 12.04 µg/m³ on 2nd May 2022 and the minimum concentration of 2.42 µg/m³ is observed on 30th May 2022. Average SO_2 concentration for the month of May at Station 1 is found to be 7.6 µg/m³. The range of SO_2 concentration (2.42 – 12.04 µg/m³) observed for station 1 over the month of May lied well below the 24-hourly permissible limit of 80 µg/m³.

Status of NOx concentration

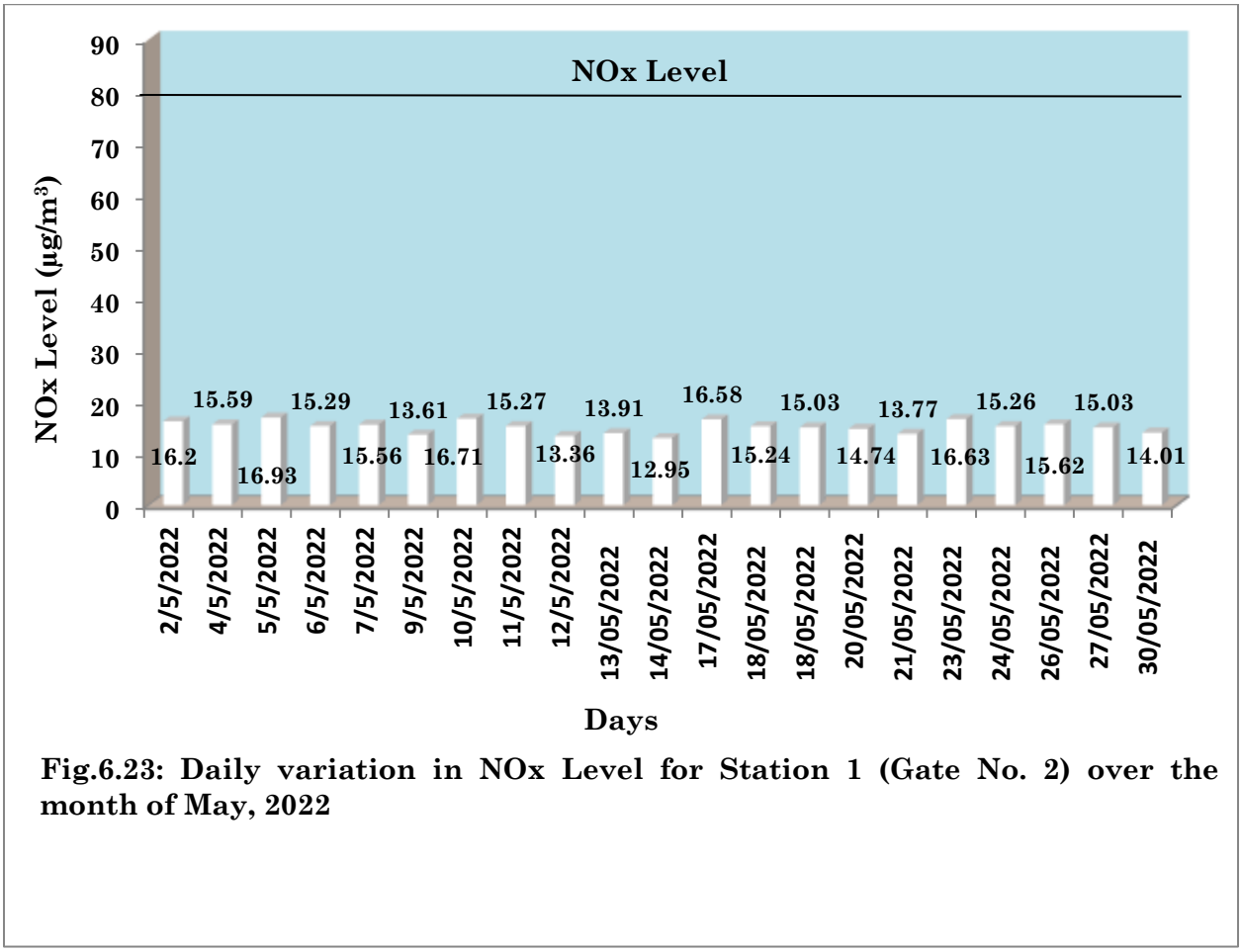


Fig.6.23: Daily variation in NOx Level for Station 1 (Gate No. 2) over the month of May, 2022

The daily variation in NOx level at the Station 1 over the month of May, 2022 is shown in the Fig. 6.23. The maximum pollutant concentration is found to be 16.93 µg/m^3 on 5th May 2022 and the minimum concentration of 13.36 µg/m^3 is observed on 12th May 2022. Average NOx concentration for the month of May at Station 1 is found to be 15.1 µg/m^3. The range of NOx concentration (13.36 – 16.93 µg/m^3) observed for station 1 over the month of May lied well below the 24-hourly permissible limit of 80 µg/m^3.

Status of CO concentration

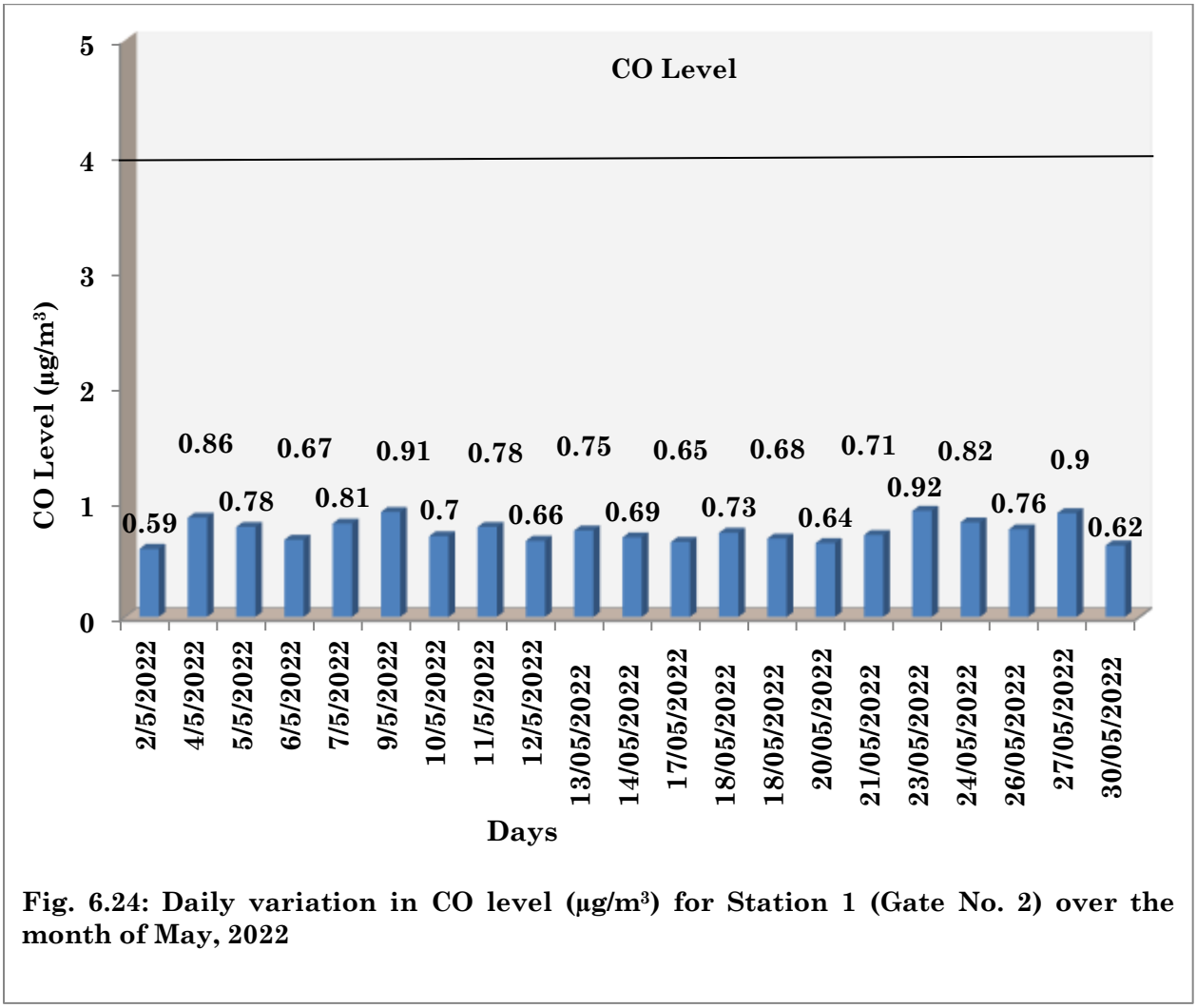


Fig. 6.24: Daily variation in CO level (µg/m³) for Station 1 (Gate No. 2) over the month of May, 2022

The daily variation in CO level at the Station 1 over the month of May, 2022 is shown in the Fig. 6.24. The maximum pollutant concentration is found to be 0.92 µg/m³ on 23rd May 2022 and the minimum concentration of 0.59 µg/m³ is observed on 2nd May 2022. Average CO concentration for the month of April at Station 1 is found to be 0.74 µg/m³. The range of CO concentration (0.59 – 0.92 µg/m³) observed for station 1 over the month of May lied well below the 24-hourly permissible limit of 4.0 µg/m³.

Status of O_3 concentration

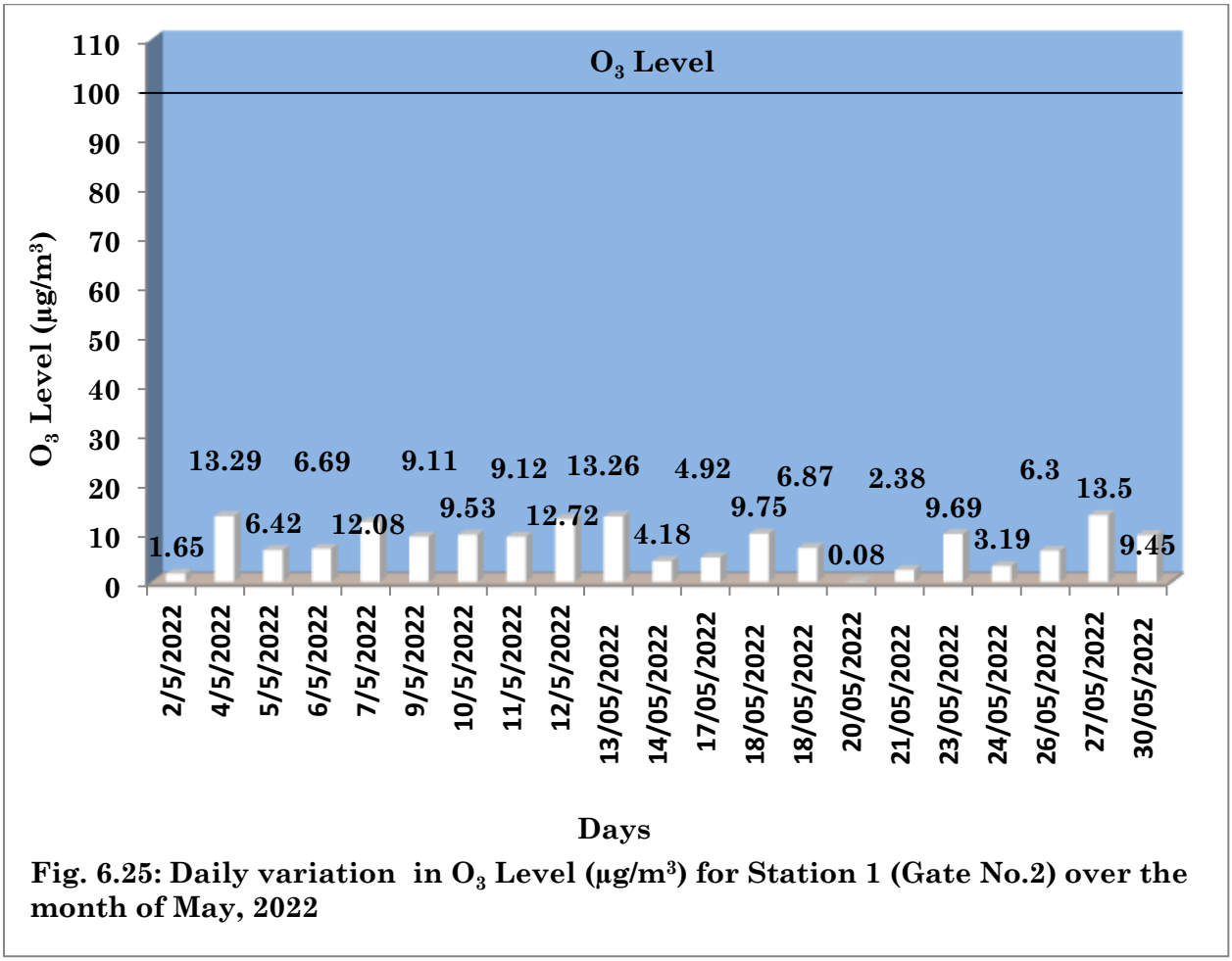


Fig. 6.25: Daily variation in O_3 Level (µg/m³) for Station 1 (Gate No.2) over the month of May, 2022

The daily variation in O_3 level at the Station 1 over the month of May, 2022 is shown in the Fig. 6.25. The maximum pollutant concentration is found to be 13.5 µg/m³ on 27th May 2022 and the minimum concentration of 0.08 µg/m³ is observed on 20th May 2022. Average O_3 concentration for the month of May at Station 1 is found to be 17.8 µg/m³. The range of O_3 concentration (0.08 – 13.5 µg/m³) observed for station 1 over the month of May lied well below the 8 hourly permissible limits of 100.0 µg/m³.

❖ **Station 2 (KTTP Township)**

Status of PM_{10} concentration

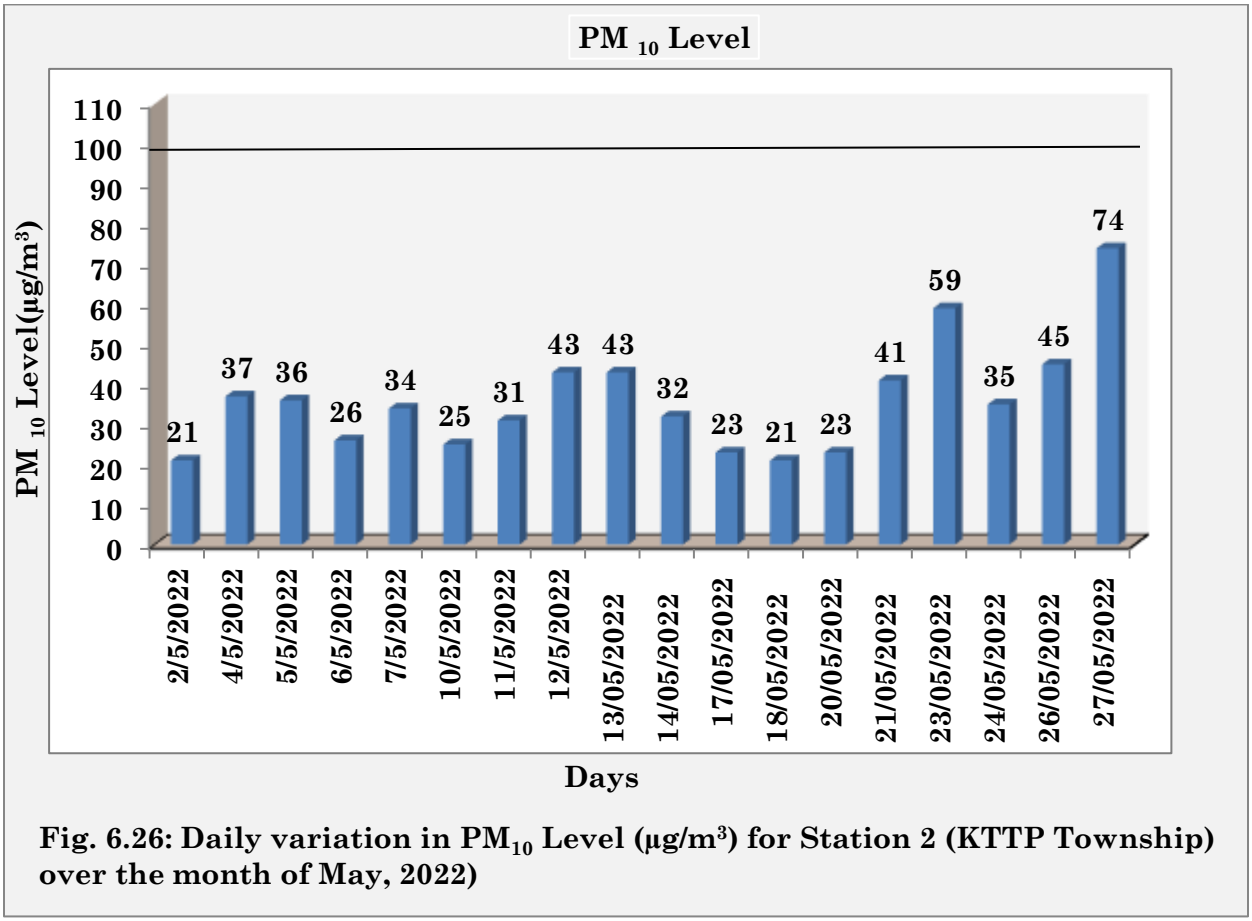


Fig. 6.26: Daily variation in PM_{10} Level (µg/m³) for Station 2 (KTTP Township) over the month of May, 2022)

The daily variation in PM_{10} level at the Station 2 over the month of May, 2022 is shown in the Fig. 6.26. The maximum pollutant concentration is found to be 74.0 µg/m³ on 27th May 2022 and the minimum concentration of 21 µg/m³ is observed on 2nd and 17th May 2022. Average PM_{10} concentration for the month of May at Station 2 is found to be 36 µg/m³. The range of PM_{10} concentration (21 – 74 µg/m³) observed for station 2 over the month of May lied well below the 24-hourly permissible limit of 100 µg/m³.

Status of $PM_{2.5}$ concentration

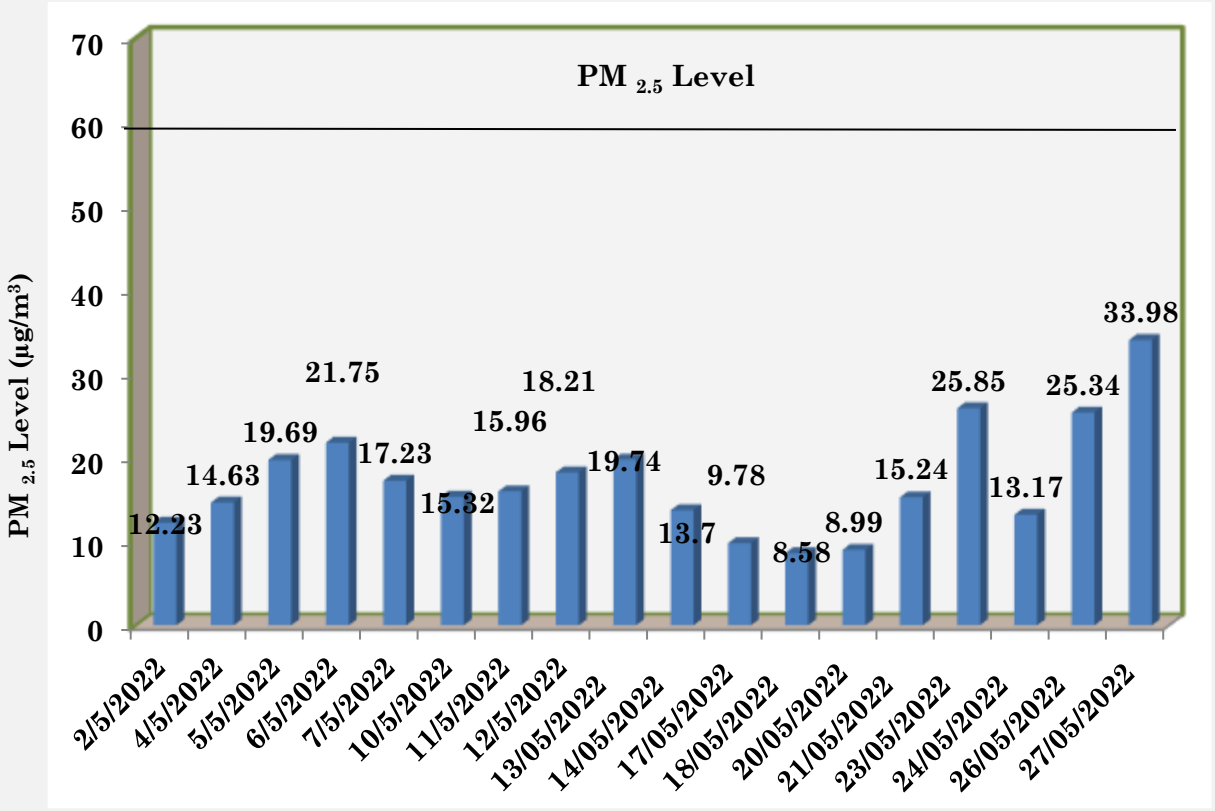


Fig. 6.27: Daily variation in $PM_{2.5}$ Level (µg/m³) for station 2 (KTTP Township) over the month of May, 2022

The daily variation in $PM_{2.5}$ level at the Station 2 over the month of May, 2022 is shown in the Fig. 6.27. The maximum pollutant concentration is found to be 33.98 µg/m³ on 27th May 2022 and the minimum concentration of 8.58 µg/m³ is observed on 18th May 2022. Average $PM_{2.5}$ concentration for the month of April at Station 2 is found to be 17.2 µg/m³. The range of $PM_{2.5}$ concentration (8.58 – 33.98 µg/m³) observed for station 2 over the month of May lied well below the 24-hourly permissible limit of 60 µg/m³.

Status of SO_2 concentration

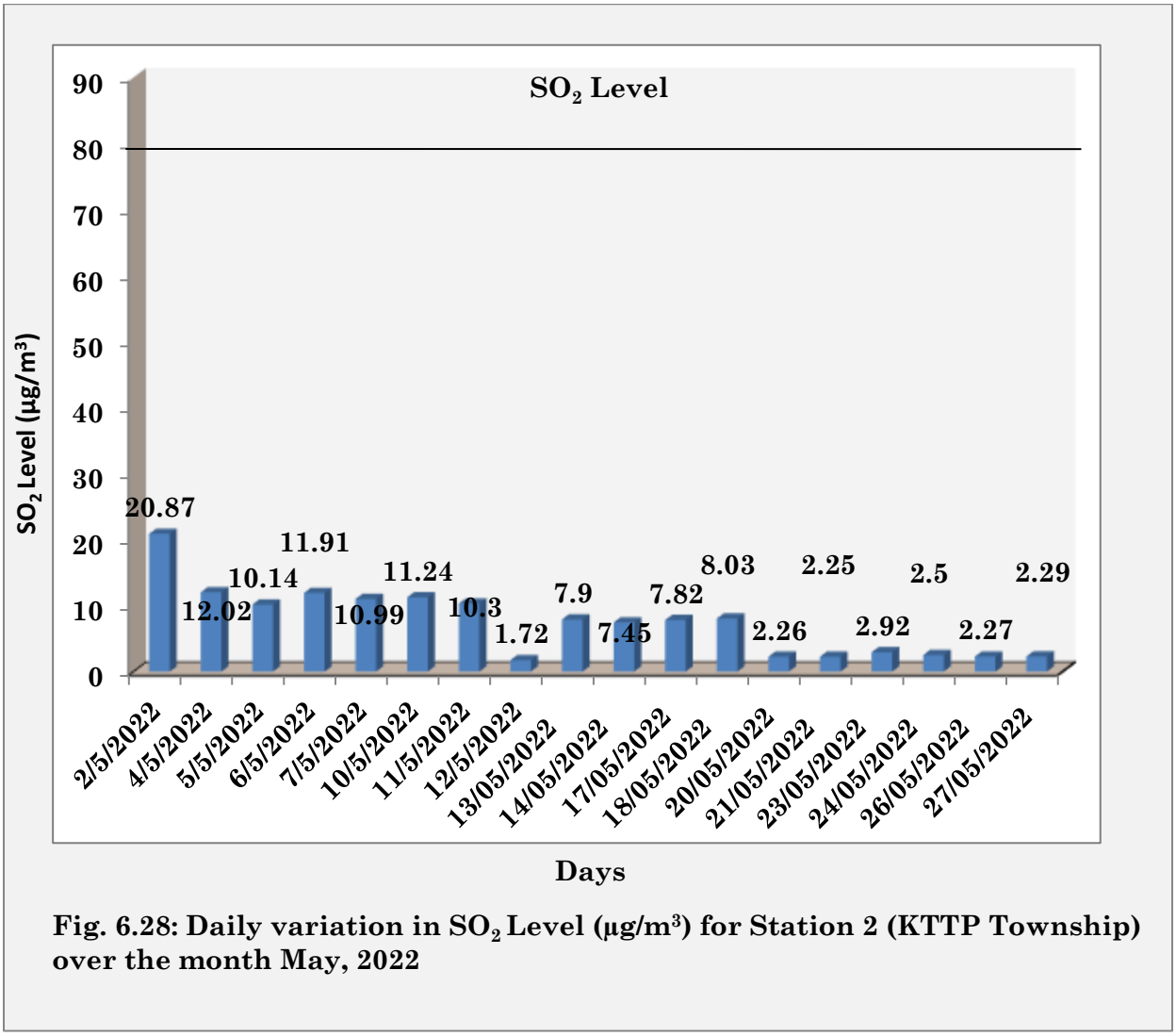


Fig. 6.28: Daily variation in SO_2 Level (µg/m³) for Station 2 (KTTP Township) over the month May, 2022

The daily variation in SO_2 level at the Station 2 over the month of May, 2022 is shown in the Fig. 6.28. The maximum pollutant concentration is found to be 20.87 µg/m³ on 2nd May 2022 and the minimum concentration of 1.72 µg/m³ is observed on 12th May 2022. Average SO_2 concentration for the month of May at Station 2 is found to be 7.5 µg/m³. The range of SO_2 concentration (1.72 – 20.87 µg/m³) observed for station 2 over the month of May lied well below the 24-hourly permissible limit of 80 µg/m³.

Status of NOx concentration

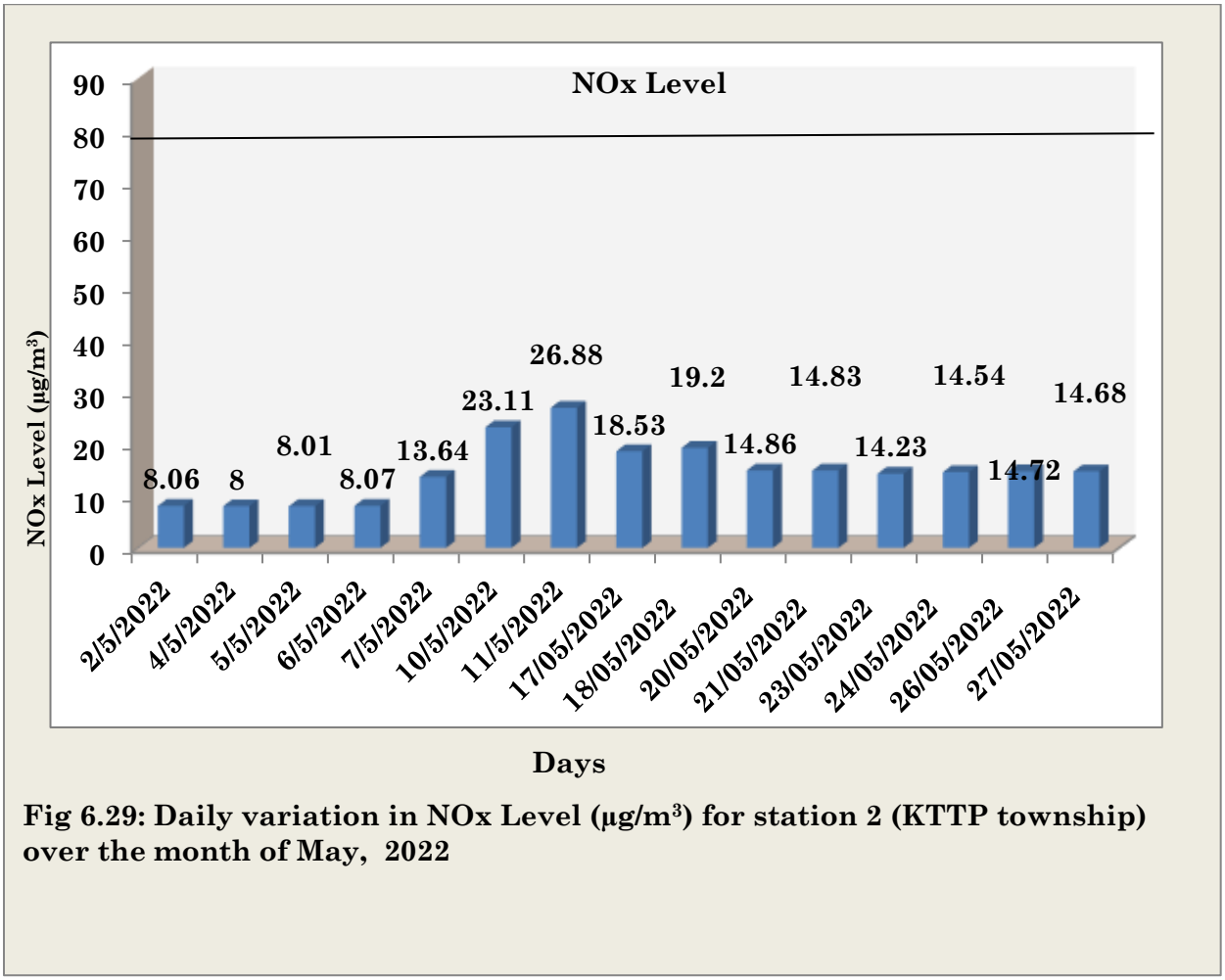


Fig 6.29: Daily variation in NOx Level (µg/m³) for station 2 (KTTP township) over the month of May, 2022

The daily variation in NOx level at the Station 2 over the month of May, 2022 is shown in the Fig. 6.29. The maximum pollutant concentration is found to be 26.88 µg/m³ on 11th May 2022 and the minimum concentration of 8 µg/m³ is observed on 4th May 2022. Average NOx concentration for the month of May at Station 2 is found to be 12.3 µg/m³. The range of NOx concentration (8 – 26.88 µg/m³) observed for station 2 over the month of May lied well below the 24-hourly permissible limit of 80 µg/m³.

Status of CO concentration

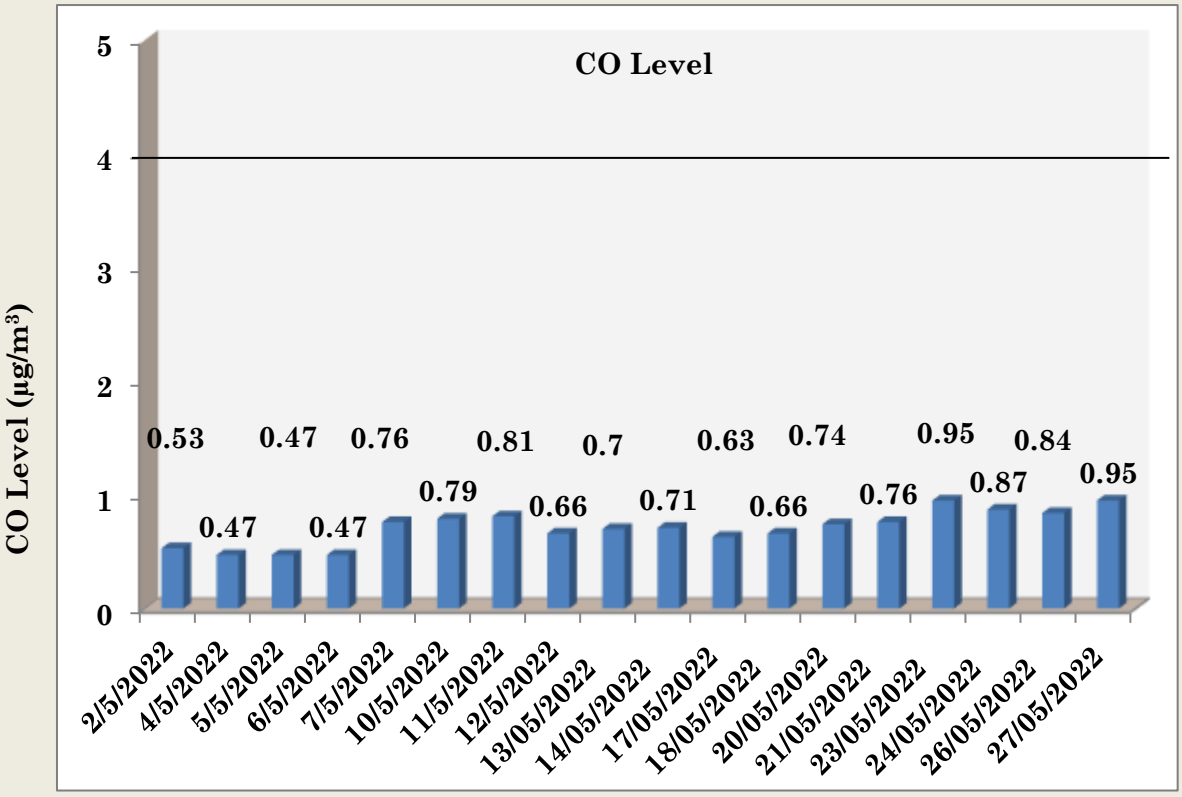


Fig 6.30: Daily varition in CO level (µg/m³) for station 2 (KTTP township) over the month of May, 2022

The daily variation in CO level at the Station 2 over the month of May, 2022 is shown in the Fig. 6.30. The maximum pollutant concentration is found to be 0.95 µg/m³ on 23rd May 2022 and the minimum concentration of 0.47 µg/m³ is observed on 4th 5th and 6th May 2022. Average CO concentration for the month of April at Station 2 is found to be 0.71 µg/m³. The range of CO concentration (0.47 – 0.95 µg/m³) observed for station 2 over the month of May lied well below the 24-hourly permissible limit of 4.0 µg/m³.

Status of O_3 concentration

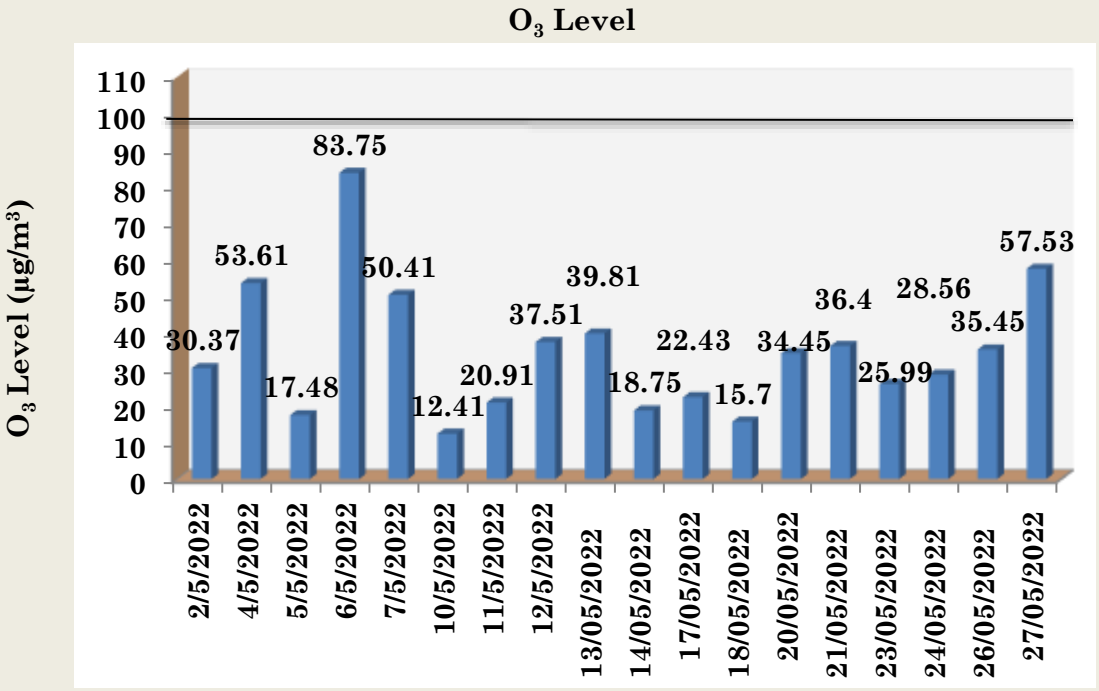


Fig 6.31: Daily varition in O_3 level for Station 2 (KTTP Township) over the month of May, 2022

The daily variation in O_3 level at the Station 2 over the month of May, 2022 is shown in the Fig. 6.31. The maximum pollutant concentration is found to be 83.75 µg/m^3 on 6th May 2022 and the minimum concentration of 12.41 µg/m^3 is observed on 10th May 2022. Average O_3 concentration for the month of May at Station 2 is found to be 34.5 µg/m^3. The range of O_3 concentration (12.41 – 83.75 µg/m^3) observed for station 2 over the month of May lied well below the 8 hourly permissible limits of 100.0 µg/m^3

❖ **Station 3 (Intake Pump House)**

Status of PM_{10} concentration

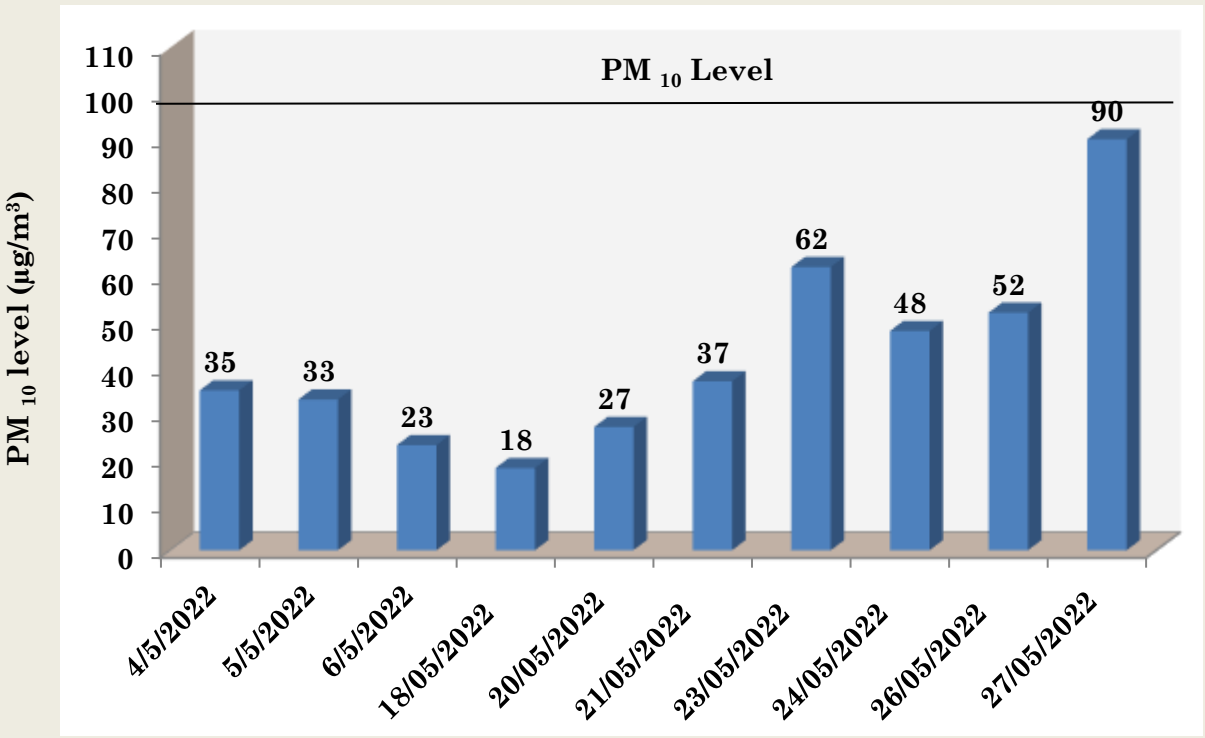


Fig 6.32: Daily variation in PM_{10} Level (µg/m³) for station 3 (intake pump house) over the month of May, 2022

The daily variation in PM_{10} level at the Station 3 over the month of May, 2022 is shown in the Fig. 6.32. The maximum pollutant concentration is found to be 90.0 µg/m³ on 27th May 2022 and the minimum concentration of 18 µg/m³ is observed on 18th May 2022. Average PM_{10} concentration for the month of May at Station 3 is found to be 42.5 µg/m³. The range of PM_{10} concentration (18 – 90 µg/m³) observed for station 3 over the month of May lied well below the 24-hourly permissible limit of 100 µg/m³.

Status of $PM_{2.5}$ concentration

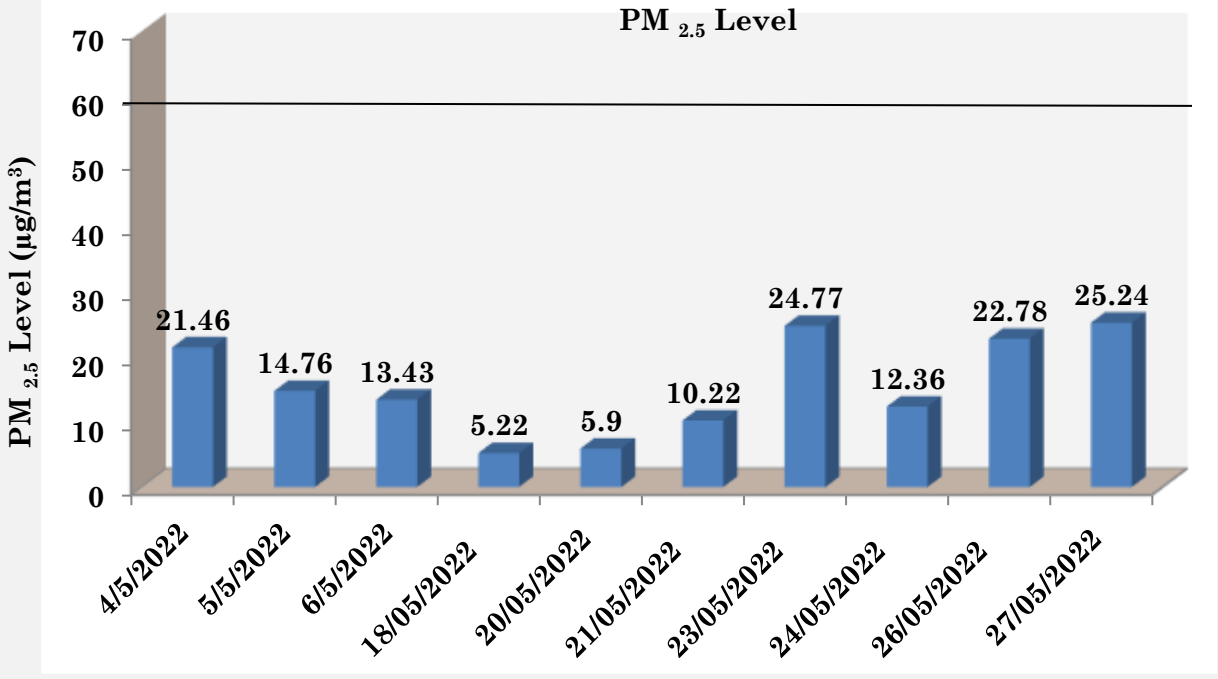


Fig 6.33: Daily variation in $PM_{2.5}$ level (µg/m³) for station 3 (intake pump house) over the month of May, 2022

The daily variation in $PM_{2.5}$ level at the Station 3 over the month of May, 2022 is shown in the Fig. 6.33. The maximum pollutant concentration is found to be 25.24 µg/m³ on 27th May 2022 and the minimum concentration of 5.9 µg/m³ is observed on 20th May 2022. Average $PM_{2.5}$ concentration for the month of April at Station 3 is found to be 15.6 µg/m³. The range of $PM_{2.5}$ concentration (5.9 – 25.24 µg/m³) observed for station 3 over the month of May lied well below the 24-hourly permissible limit of 60 µg/m³.

Status of SO_2 concentration

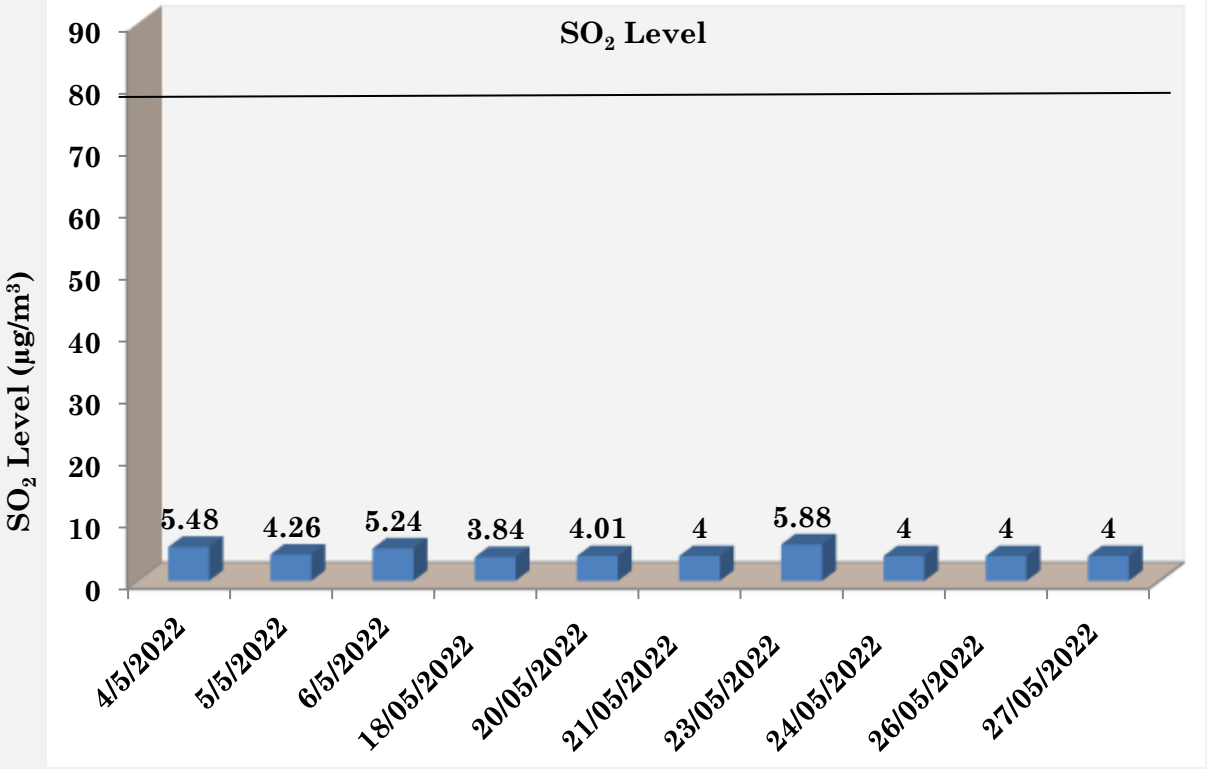


Fig 6.34: Daily Variation in SO_2 Level (µg/m³) for station 3 (intake pump house) over the month of May, 2022

The daily variation in SO_2 level at the Station 3 over the month of May, 2022 is shown in the Fig. 6.34. The maximum pollutant concentration is found to be 5.88 µg/m³ on 23rd May 2022 and the minimum concentration of 4 µg/m³ is observed on 21st May 2022. Average SO_2 concentration for the month of May at Station 3 is found to be 4.5 µg/m³. The range of SO_2 concentration (4 – 5.88 µg/m³) observed for station3 over the month of May lied well below the 24-hourly permissible limit of 80 µg/m³.

Status of NOx concentration

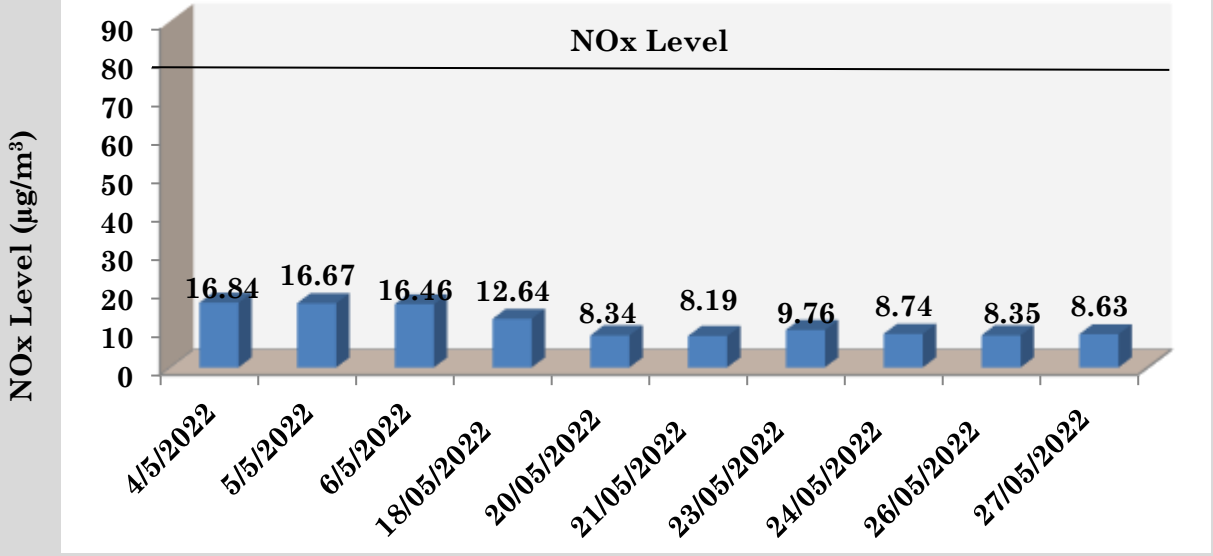


Fig 6.35: Daily Variation in NOx Level For station 3 (intake pump house) over the month of May, 2022

The daily variation in NOx level at the Station 3 over the month of May, 2022 is shown in the Fig. 6.35. The maximum pollutant concentration is found to be 16.84 µg/m^3 on 4th May 2022 and the minimum concentration of 8.19 µg/m^3 is observed on 21st May 2022. Average NOx concentration for the month of May at Station 3 is found to be 11.46 µg/m^3. The range of NOx concentration (8.19 -16.84 µg/m^3) observed for station 3 over the month of May lied well below the 24-hourly permissible limit of 80 µg/m^3.

Status of CO concentration

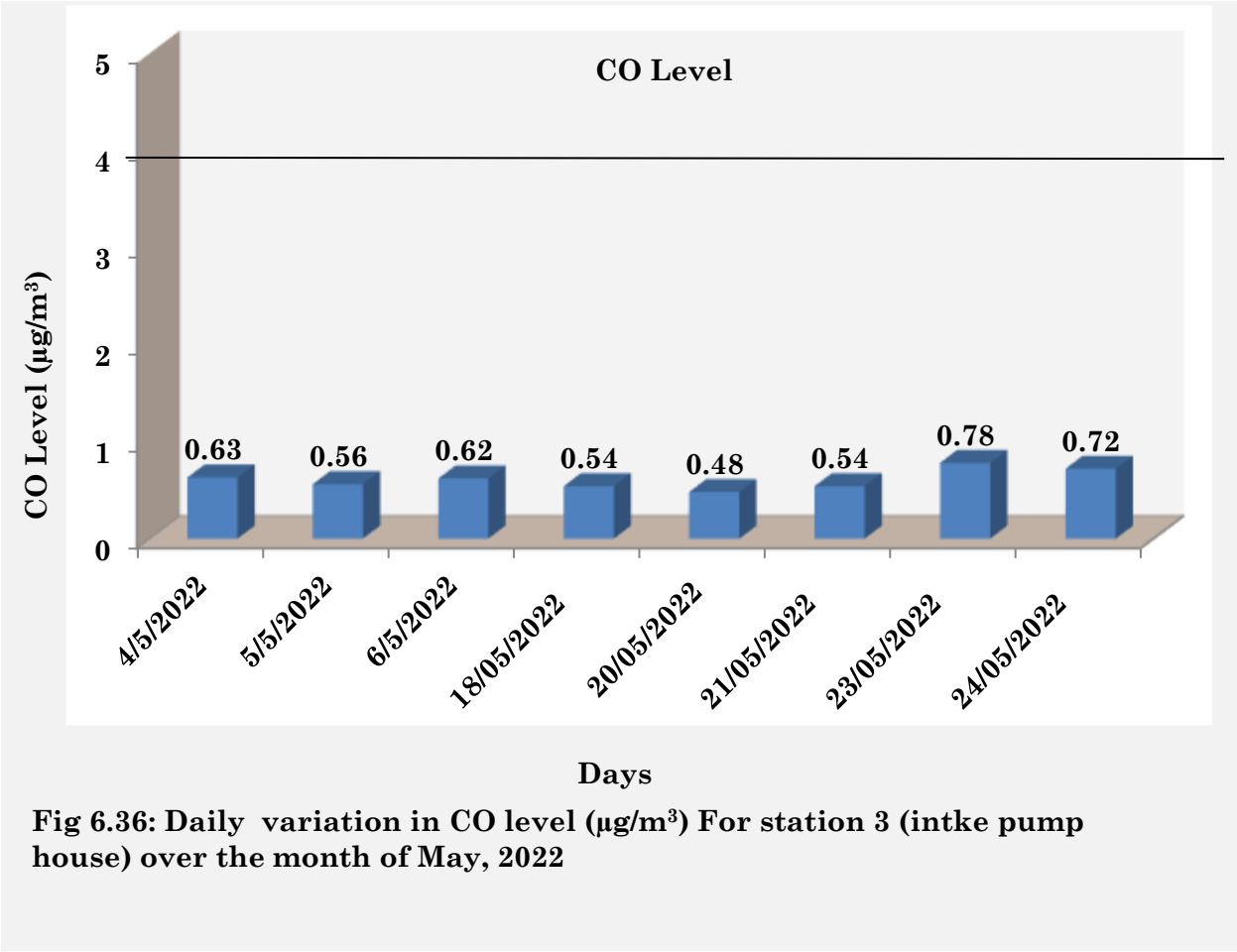


Fig 6.36: Daily variation in CO level (µg/m³) For station 3 (intke pump house) over the month of May, 2022

The daily variation in CO level at the Station 3 over the month of May, 2022 is shown in the Fig. 6.36. The maximum pollutant concentration is found to be 0.78 µg/m^3 on 23rd May 2022 and the minimum concentration of 0.48 µg/m^3 is observed on 20th May 2022. Average CO concentration for the month of May at Station 3 is found to be 0.5 µg/m^3. The range of CO concentration (0.48 – 0.78 µg/m^3) observed for station 3 over the month of May lied well below the 24-hourly permissible limit of 4.0 µg/m^3

Status of O_3 concentration

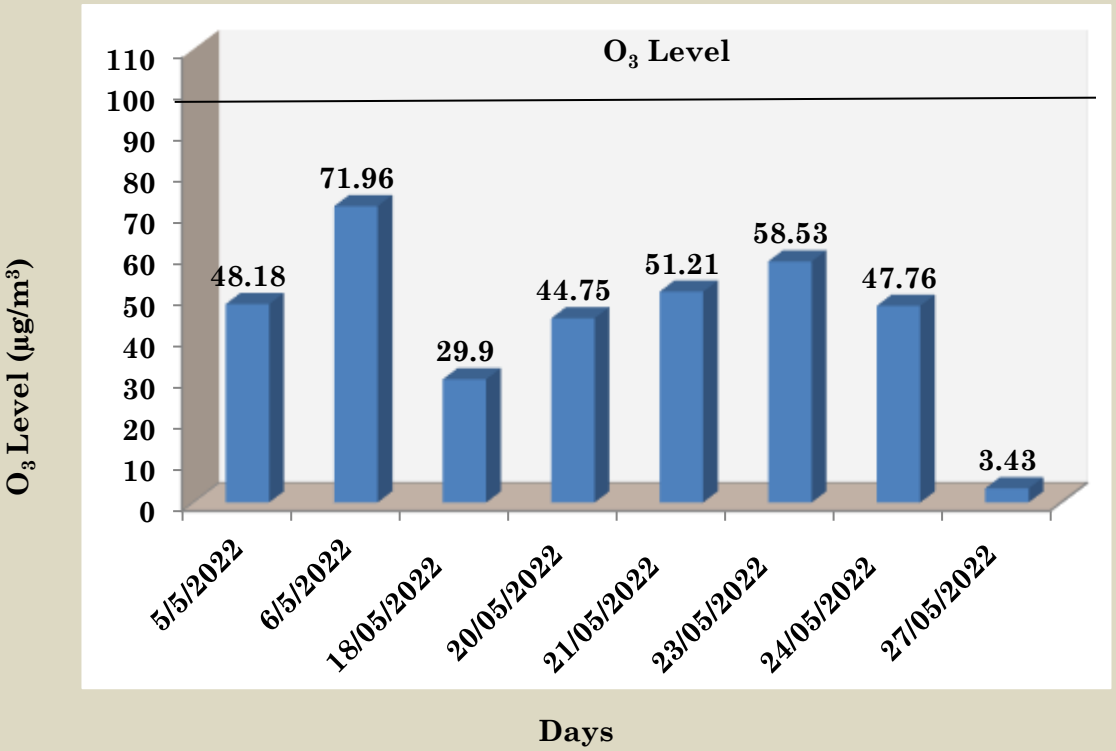


Fig 6.37: Daily variation in O_3 Level (µg/m³) for station 3 (intake pump house) over the month of May, 2022

The daily variation in O_3 level at the Station 3 over the month of May, 2022 is shown in the Fig. 6.37. The maximum pollutant concentration is found to be 71.96 µg/m³ on 6th May 2022 and the minimum concentration of 3.43 µg/m³ is observed on 27th May 2022. Average O_3 concentration for the month of May at Station 3 is found to be 35.6 µg/m³. The range of O_3 concentration (3.43 – 71.96 µg/m³) observed for station 3 over the month of May lied well below the 8 hourly permissible limits of 100.0 µg/m³

6.2.1 Conclusion of concentration level for the month of May in all the three stations

The summary of mean pollutant concentration prevailing at three monitoring stations over the month of May, 2022 for six criteria air pollutants is furnished in the table 6.4.

Table 6.4: Mean pollutant concentration of the pollutants over the month of May, 2022

Pollutants	Concentration (µg/m^3)		
	Station 1	Station 2	Station 3
PM_{10}	28.5	36.055	42.5
$PM_{2.5}$	12.335	17.18	15.614
SO_2	7.606	7.493	4.471
NOx	15.109	14.757	11.462
CO	0.744	0.709	0.608
O_3	7.818	34.528	44.465

❖ Graphical presentation of the above data

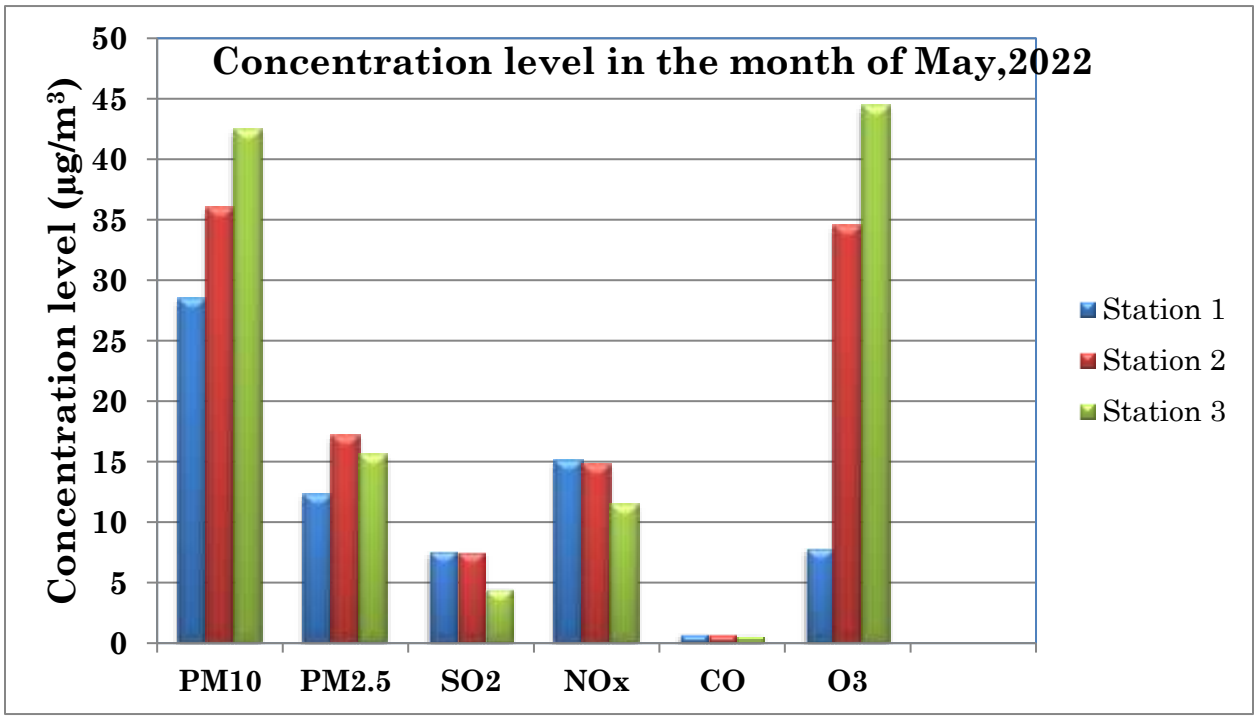


Fig 6.38: Variation in pollutant concentrations for three stations for the month of May, 2022

6.3 Daily variation analysis for the month of June, 2022

❖ **Station 1(Gate no.2)**

Status of PM_{10} concentration

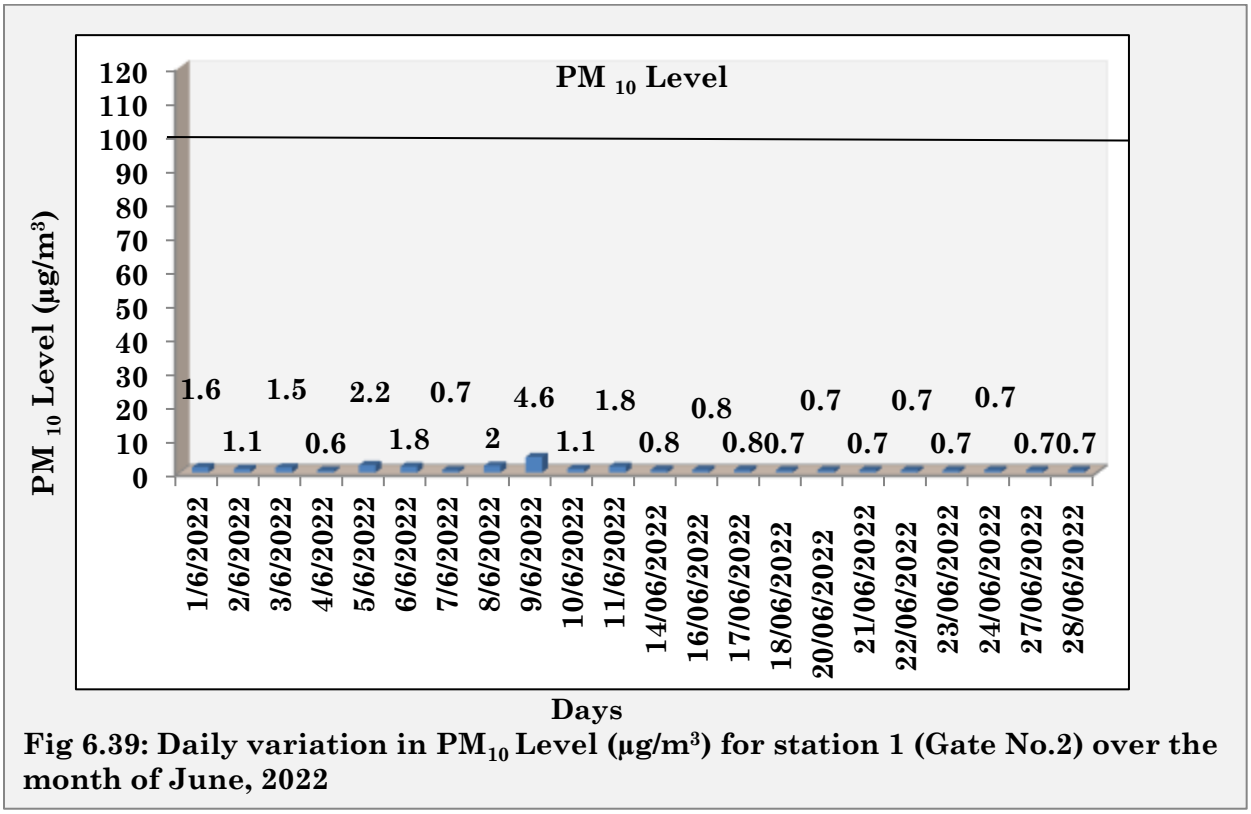


Fig 6.39: Daily variation in PM_{10} Level (µg/m³) for station 1 (Gate No.2) over the month of June, 2022

Note: This is not the correct value or reading comes from the Continuous air quality monitoring station. This is happened due to the malfunctioning of the continuous air quality monitoring station

Status of $PM_{2.5}$ concentration

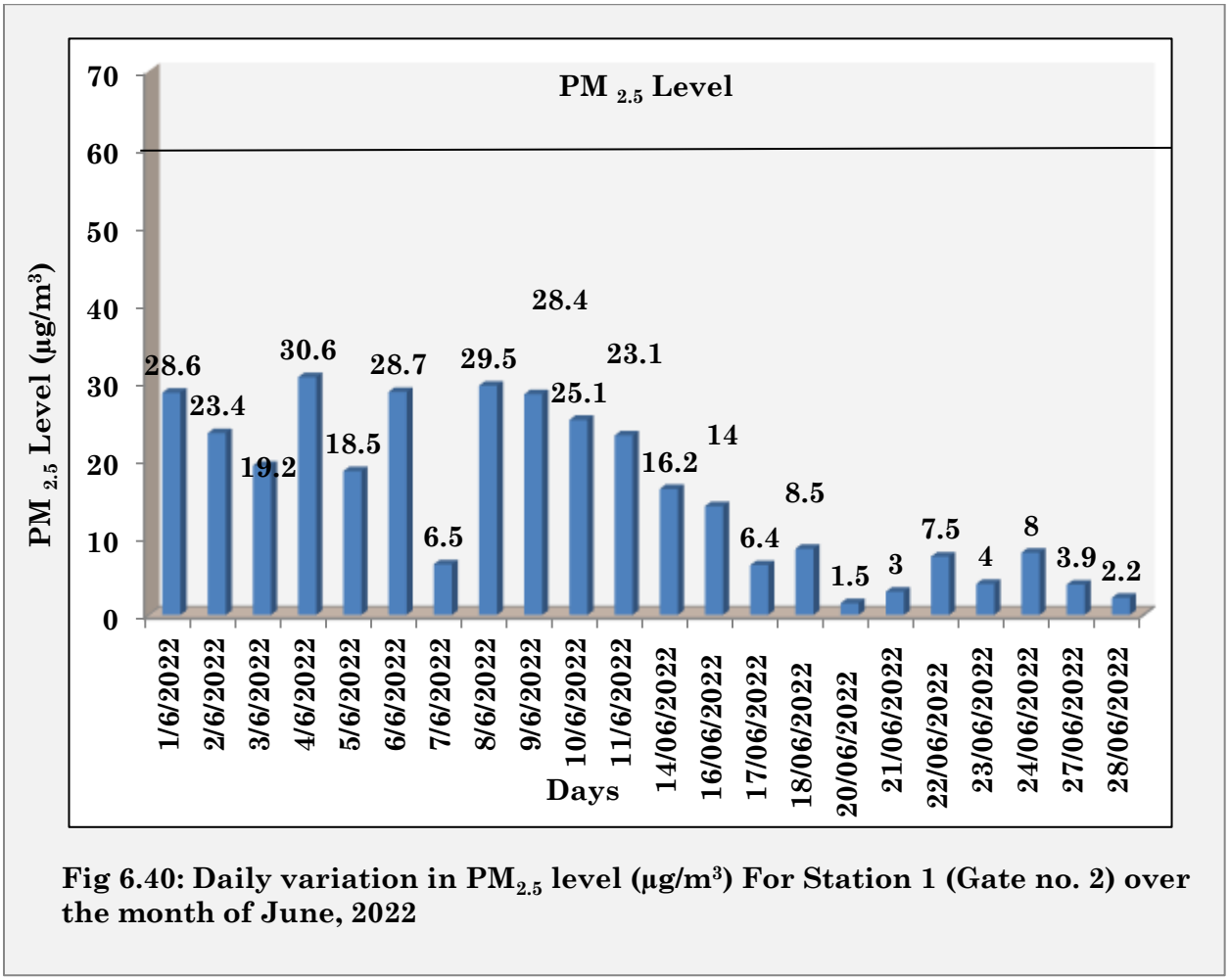


Fig 6.40: Daily variation in $PM_{2.5}$ level (µg/m³) For Station 1 (Gate no. 2) over the month of June, 2022

The daily variation in $PM_{2.5}$ level at the Station 1 over the month of June, 2022 is shown in the Fig. 6.40. The maximum pollutant concentration is found to be 30.6 µg/m³ on 4th June 2022 and the minimum concentration of 1.5 µg/m³ is observed on 20th June 2022. Average $PM_{2.5}$ concentration for the month of June at Station 1 is found to be 15.3 µg/m³. The range of $PM_{2.5}$ concentration (1.5 – 30.6 µg/m³) observed for station 1 over the month of May lied well below the 24-hourly permissible limit of 60 µg/m³.

Status of SO_2 concentration

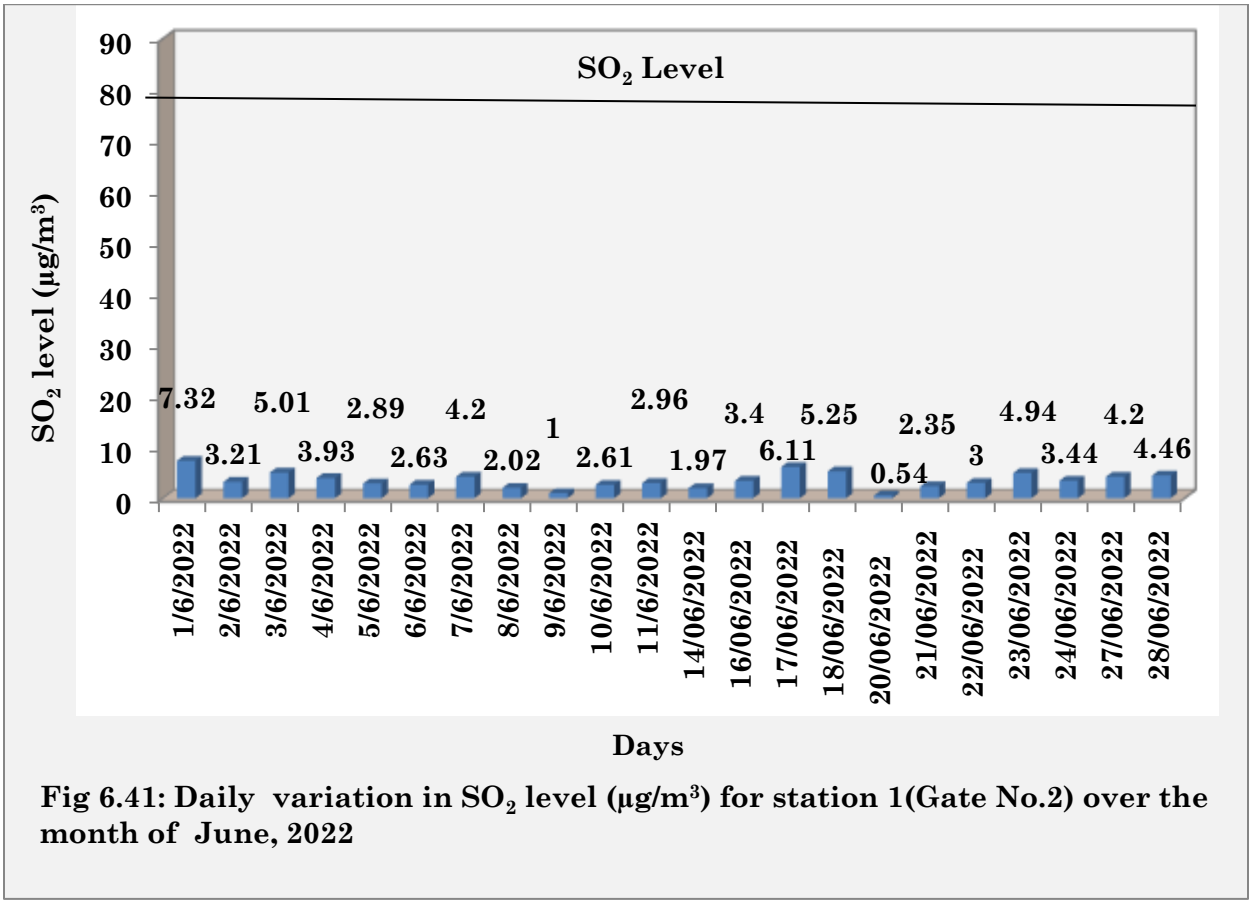


Fig 6.41: Daily variation in SO_2 level (µg/m³) for station 1(Gate No.2) over the month of June, 2022

The daily variation in SO_2 level at the Station 1 over the month of June, 2022 is shown in the Fig. 6.41. The maximum pollutant concentration is found to be 7.32µg/m³ on 1st June 2022 and the minimum concentration of 0.54 µg/m³ is observed on 20th June 2022. Average SO_2 concentration for the month of June at Station 1 is found to be 3.52 µg/m³. The range of SO_2 concentration (0.54 – 7.32 µg/m³) observed for station 1 over the month of June lied well below the 24-hourly permissible limit of 80 µg/m³.

Status of NOx concentration

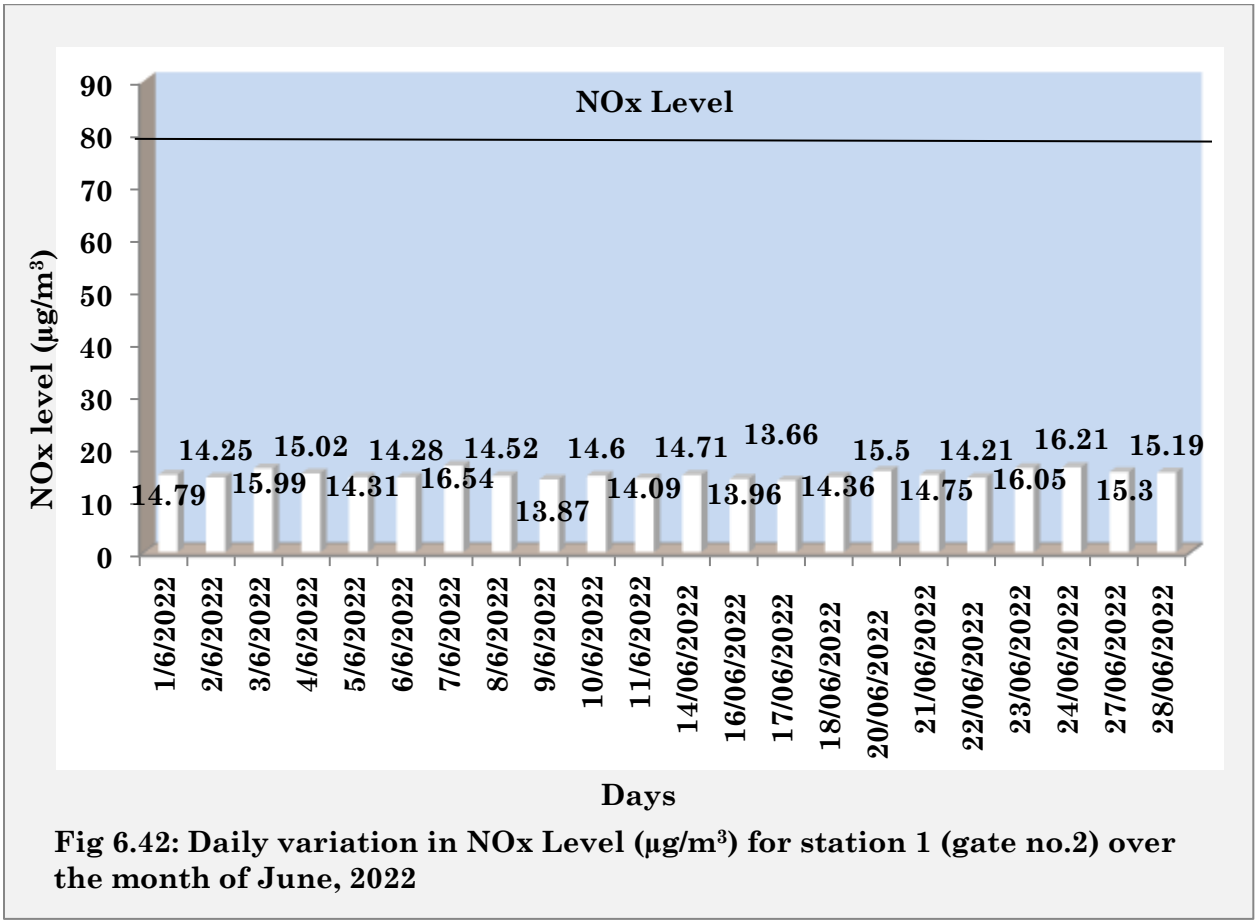


Fig 6.42: Daily variation in NOx Level (µg/m³) for station 1 (gate no.2) over the month of June, 2022

The daily variation in NOx level at the Station 1 over the month of June, 2022 is shown in the Fig. 6.42. The maximum pollutant concentration is found to be 16.54 µg/m^3 on 7th June 2022 and the minimum concentration of 13.66 µg/m^3 is observed on 17th June 2022. Average NOx concentration for the month of June at Station 1 is found to be 14.2 µg/m^3. The range of NOx concentration (13.66 – 16.54 µg/m^3) observed for station 1 over the month of June lied well below the 24-hourly permissible limit of 80 µg/m^3.

Status of CO concentration

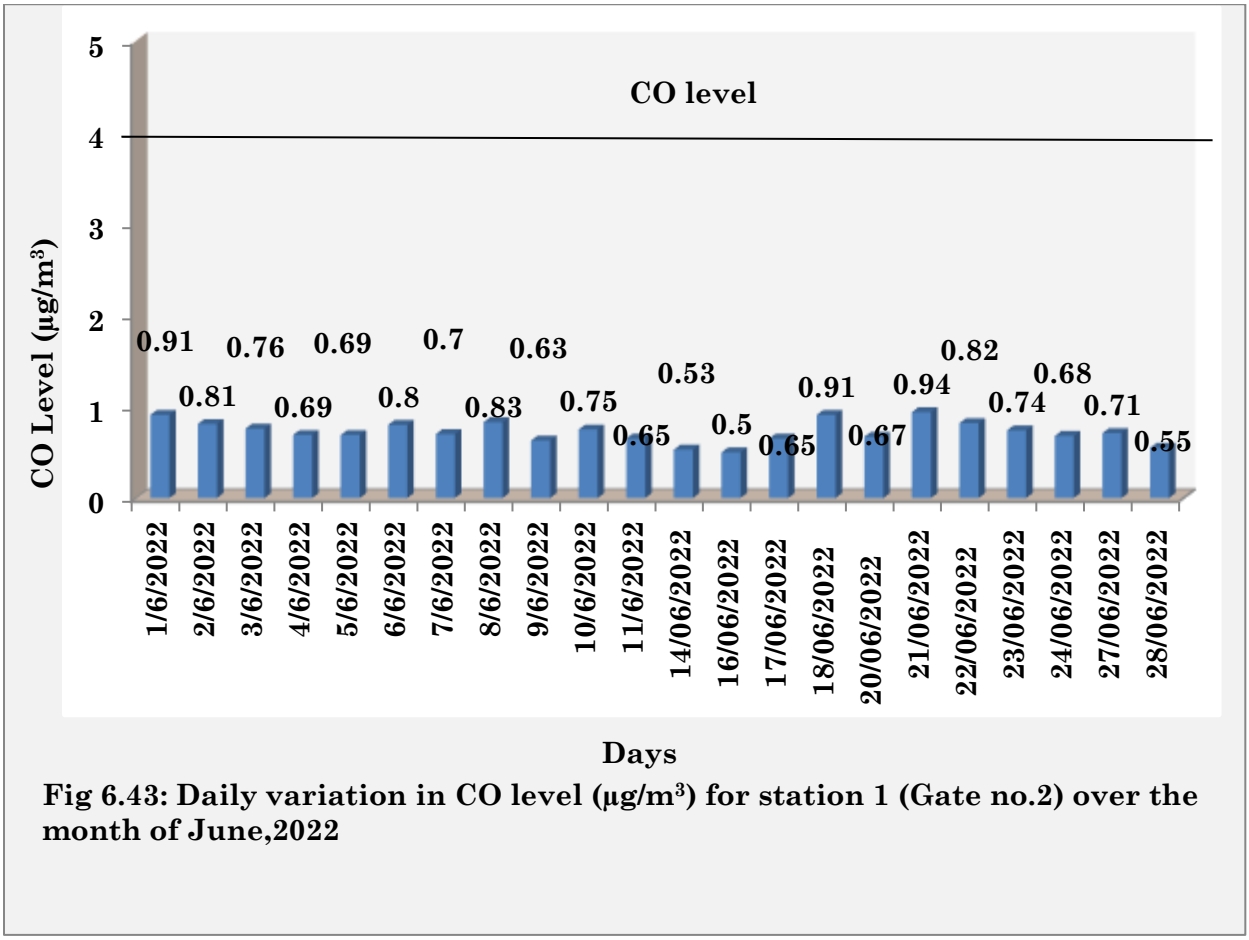


Fig 6.43: Daily variation in CO level (µg/m³) for station 1 (Gate no.2) over the month of June,2022

The daily variation in CO level at the Station 1 over the month of June, 2022 is shown in the Fig. 6.43. The maximum pollutant concentration is found to be 0.94 µg/m³ on 21st June 2022 and the minimum concentration of 0.5 µg/m³ is observed on 16th June 2022. Average CO concentration for the month of June at Station 1 is found to be 0.7 µg/m³. The range of CO concentration (0.5 - 0.94 µg/m³) observed for station 1 over the month of June lied well below the 24-hourly permissible limit of 4.0 µg/m³

Status of O_3 concentration

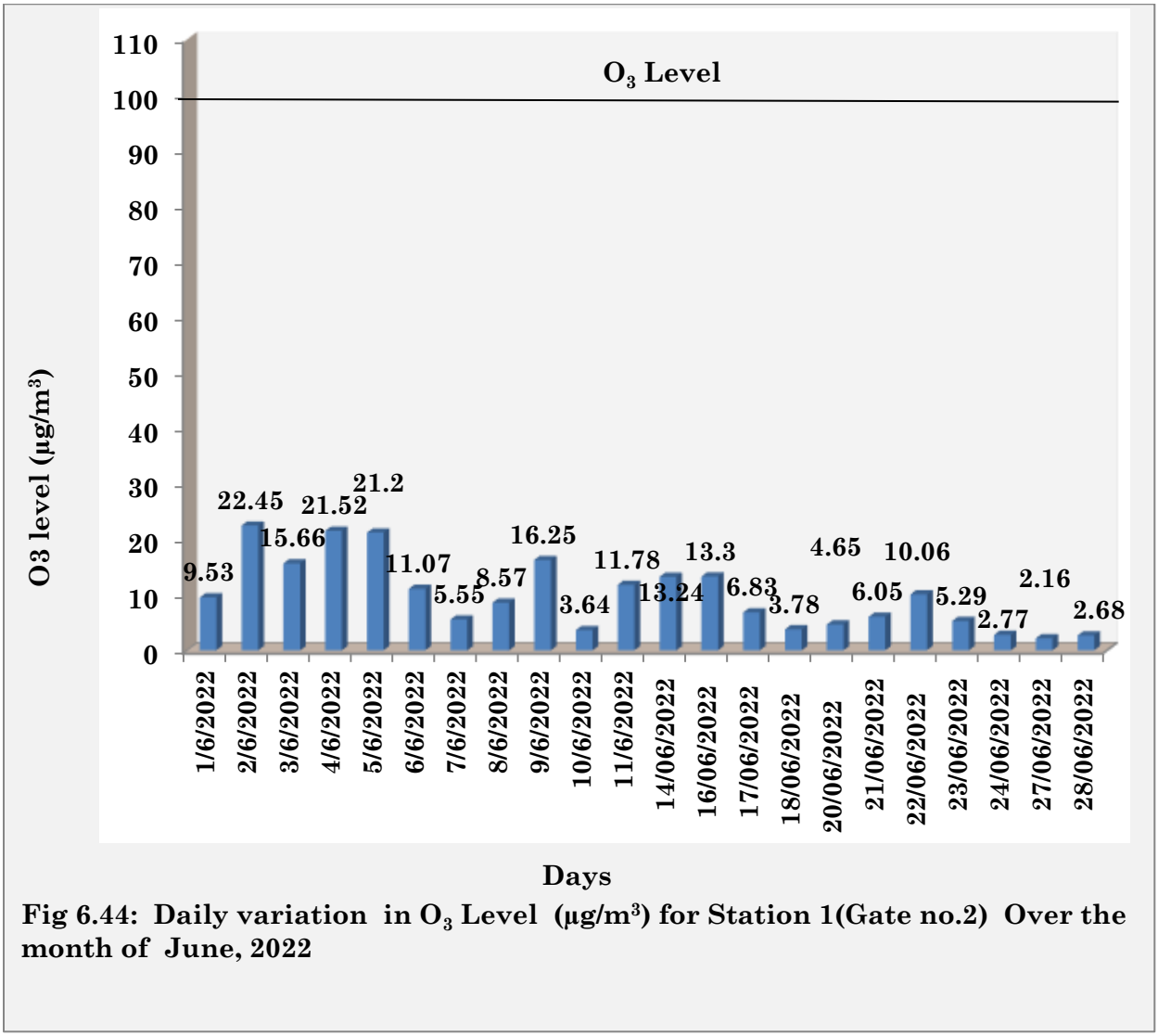


Fig 6.44: Daily variation in O_3 Level (µg/m³) for Station 1(Gate no.2) Over the month of June, 2022

The daily variation in O_3 level at the Station 1 over the month of June, 2022 is shown in the Fig. 6.44. The maximum pollutant concentration is found to be 22.45 µg/m³ on 2nd June 2022 and the minimum concentration of 2.16 µg/m³ is observed on 27thJune 2022. Average O_3 concentration for the month of June at Station 1 is found to be 35.6 µg/m³. The range of O_3 concentration (2.16 – 22.45 µg/m³) observed for station1 over the month of June lied well below the 8 hourly permissible limits of 100.0 µg/m³

❖ **Station 2 (KTTP Township)**

Status of PM_{10} concentration

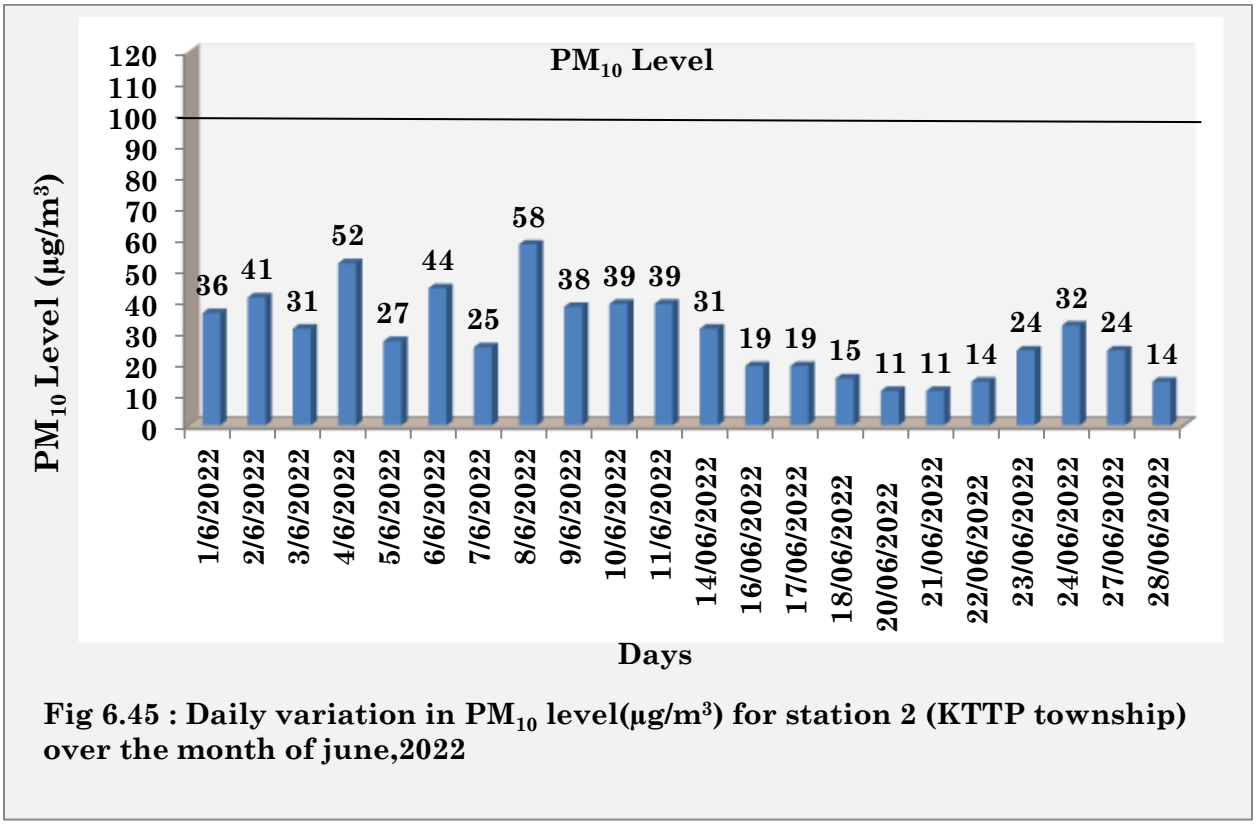


Fig 6.45 : Daily variation in PM_{10} level(µg/m³) for station 2 (KTTP township) over the month of june,2022

The daily variation in PM_{10} level at the Station 2 over the month of June, 2022 is shown in the Fig. 6.45. The maximum pollutant concentration is found to be 58.0 µg/m³ on 8th June 2022 and the minimum concentration of 11 µg/m³ is observed on 20th and 21st June 2022. Average PM_{10} concentration for the month of May at Station 2 is found to be 29.27 µg/m³. The range of PM_{10} concentration (11 – 58 µg/m³) observed for station 2 over the month of June lied well below the 24-hourly permissible limit of 100 µg/m³.

Status of $PM_{2.5}$ concentration

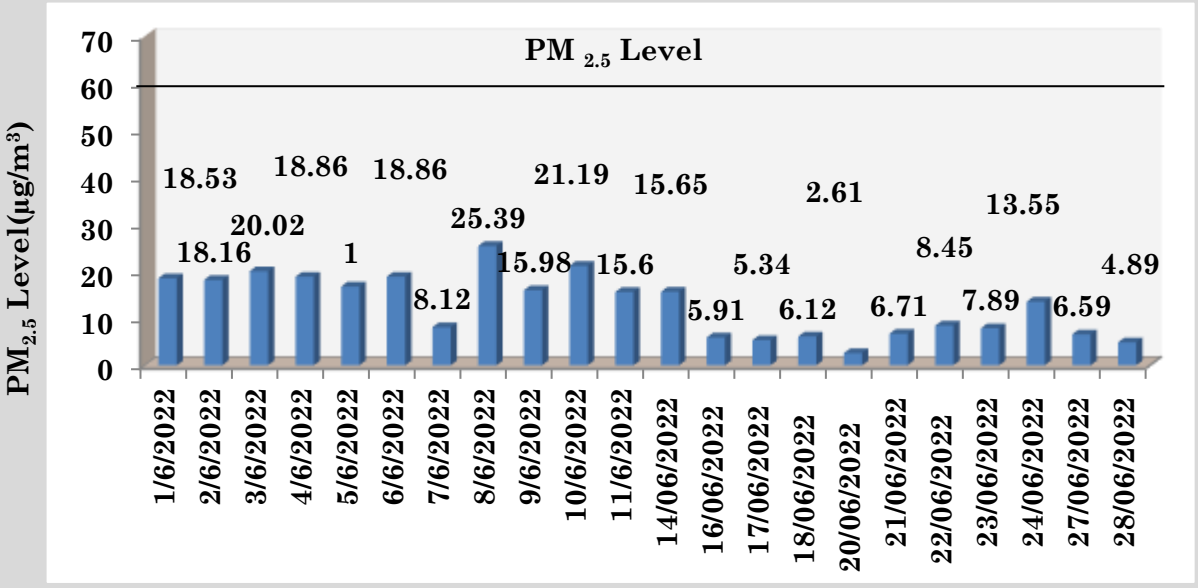


Fig 6.46: Daily varition in $PM_{2.5}$ level (µg/m³) for station 2 (KTTP township) over the month of June,2022

The daily variation in $PM_{2.5}$ level at the Station 2 over the month of June, 2022 is shown in the Fig. 6.46. The maximum pollutant concentration is found to be 20.02 µg/m³ on 3rd June 2022 and the minimum concentration of 2.6 µg/m³ is observed on 20th June 2022. Average $PM_{2.5}$ concentration for the month of June at Station 2 is found to be 12.78 µg/m³. The range of $PM_{2.5}$ concentration (2.6 – 20.02 µg/m³) observed for station 2 over the month of May lied well below the 24-hourly permissible limit of 60 µg/m³

Status of SO_2 concentration

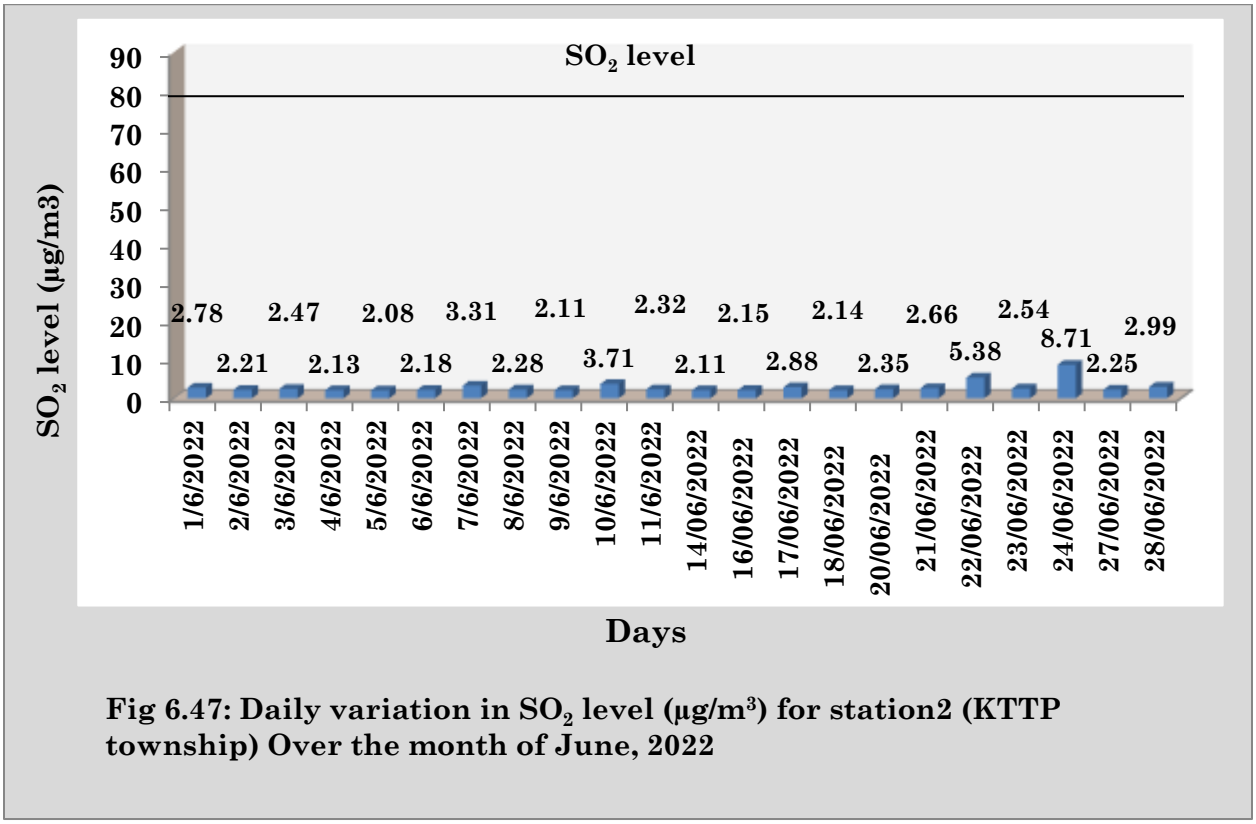


Fig 6.47: Daily variation in SO_2 level (µg/m^3) for station2 (KTTP township) Over the month of June, 2022

The daily variation in SO_2 level at the Station 2 over the month of June, 2022 is shown in the Fig. 6.47. The maximum pollutant concentration is found to be 8.71 µg/m^3 on 24th June 2022 and the minimum concentration of 2.08 µg/m^3 is observed on 8th June 2022. Average SO_2 concentration for the month of June at Station 2 is found to be 2.89 µg/m^3. The range of SO_2 concentration (2.08 – 8.71 µg/m^3) observed for station 2 over the month of June lied well below the 24-hourly permissible limit of 80 µg/m^3.

Status of NOx concentration

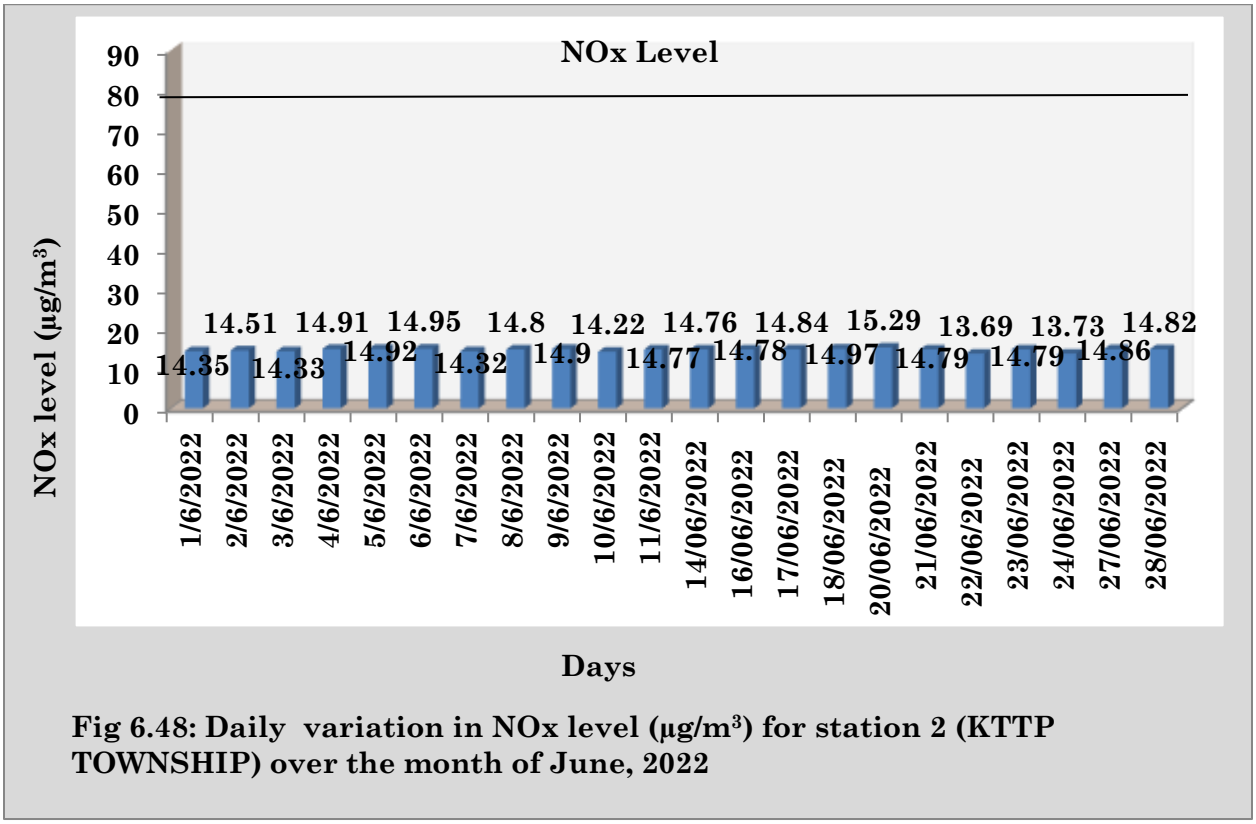


Fig 6.48: Daily variation in NOx level (µg/m³) for station 2 (KTTP TOWNSHIP) over the month of June, 2022

The daily variation in NOx level at the Station 2 over the month of June, 2022 is shown in the Fig. 6.48. The maximum pollutant concentration is found to be 15.29 µg/m^3 on 20th June 2022 and the minimum concentration of 14.22 µg/m^3 is observed on 10th June 2022. Average NOx concentration for the month of June at Station 2 is found to be 14.65 µg/m^3. The range of NOx concentration (14.22 – 15.29 µg/m^3) observed for station 2 over the month of June lied well below the 24-hourly permissible limit of 80 µg/m^3.

Status of CO concentration

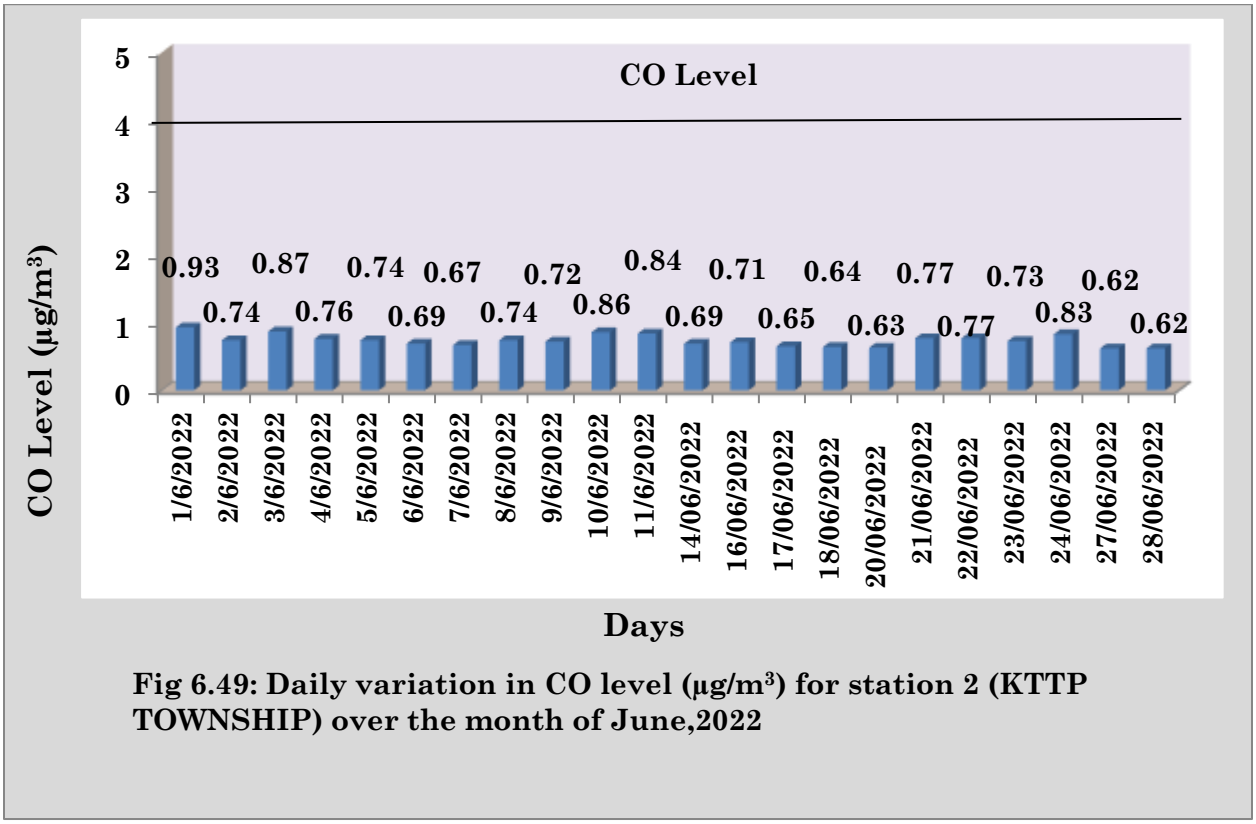


Fig 6.49: Daily variation in CO level (µg/m³) for station 2 (KTTP TOWNSHIP) over the month of June,2022

The daily variation in CO level at the Station 2 over the month of June, 2022 is shown in the Fig. 6.49. The maximum pollutant concentration is found to be 0.93 µg/m^3 on 1st June 2022 and the minimum concentration of 0.62 µg/m^3 is observed on 27th and 28th June 2022. Average CO concentration for the month of June at Station 2 is found to be 0.74 µg/m^3. The range of CO concentration (0.62 - 0.93 µg/m^3) observed for station 2 over the month of June lied well below the 24-hourly permissible limit of 4.0 µg/m^3

Status of O_3 concentration

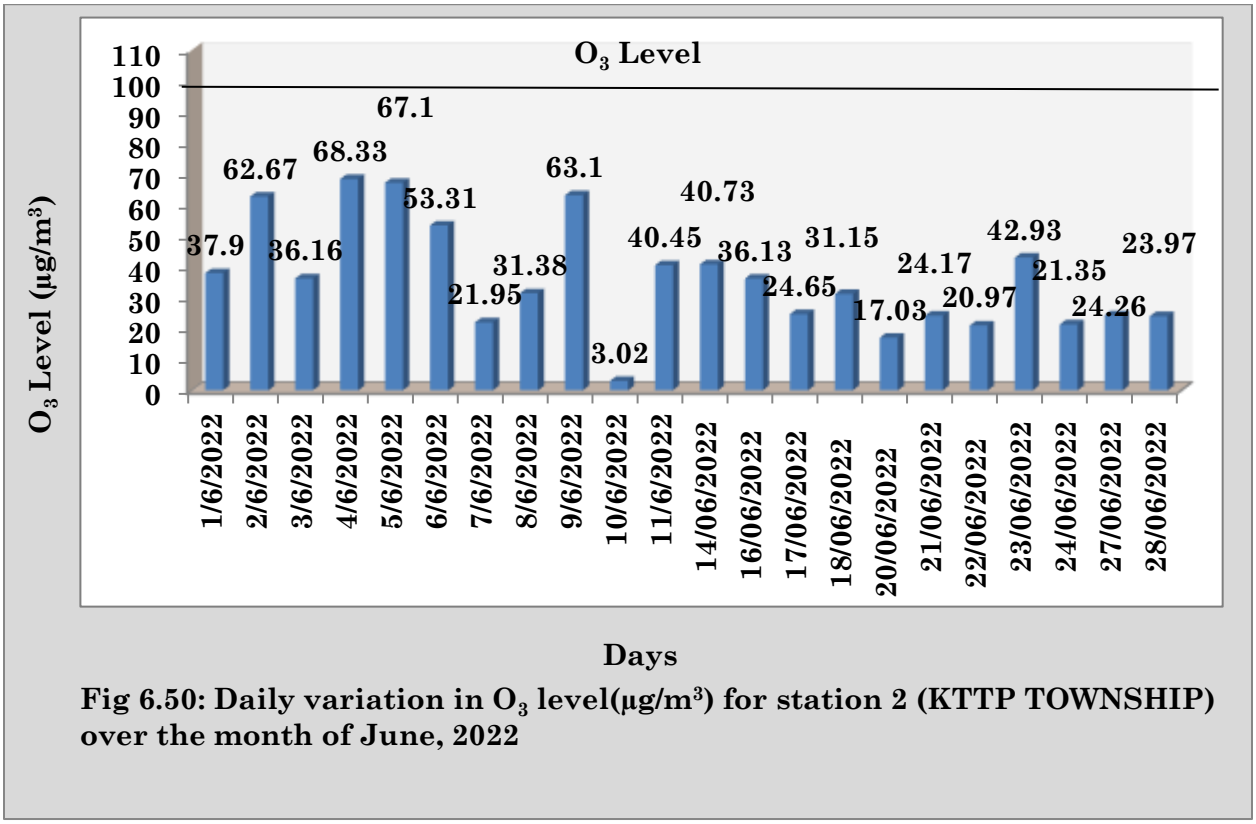


Fig 6.50: Daily variation in O_3 level(µg/m^3) for station 2 (KTTP TOWNSHIP) over the month of June, 2022

The daily variation in O_3 level at the Station 2 over the month of June, 2022 is shown in the Fig. 6.50. The maximum pollutant concentration is found to be 68.33 µg/m^3 on 4th June 2022 and the minimum concentration of 3.02 µg/m^3 is observed on 10th June 2022. Average O_3 concentration for the month of June at Station 2 is found to be 36.03 µg/m^3. The range of O_3 concentration (3.02 – 68.33 µg/m^3) observed for station 2 over the month of June lied well below the 8 hourly permissible limits of 100.0 µg/m^3

❖ **Station 3 (Intake Pump house)**

Status of PM_{10} concentration

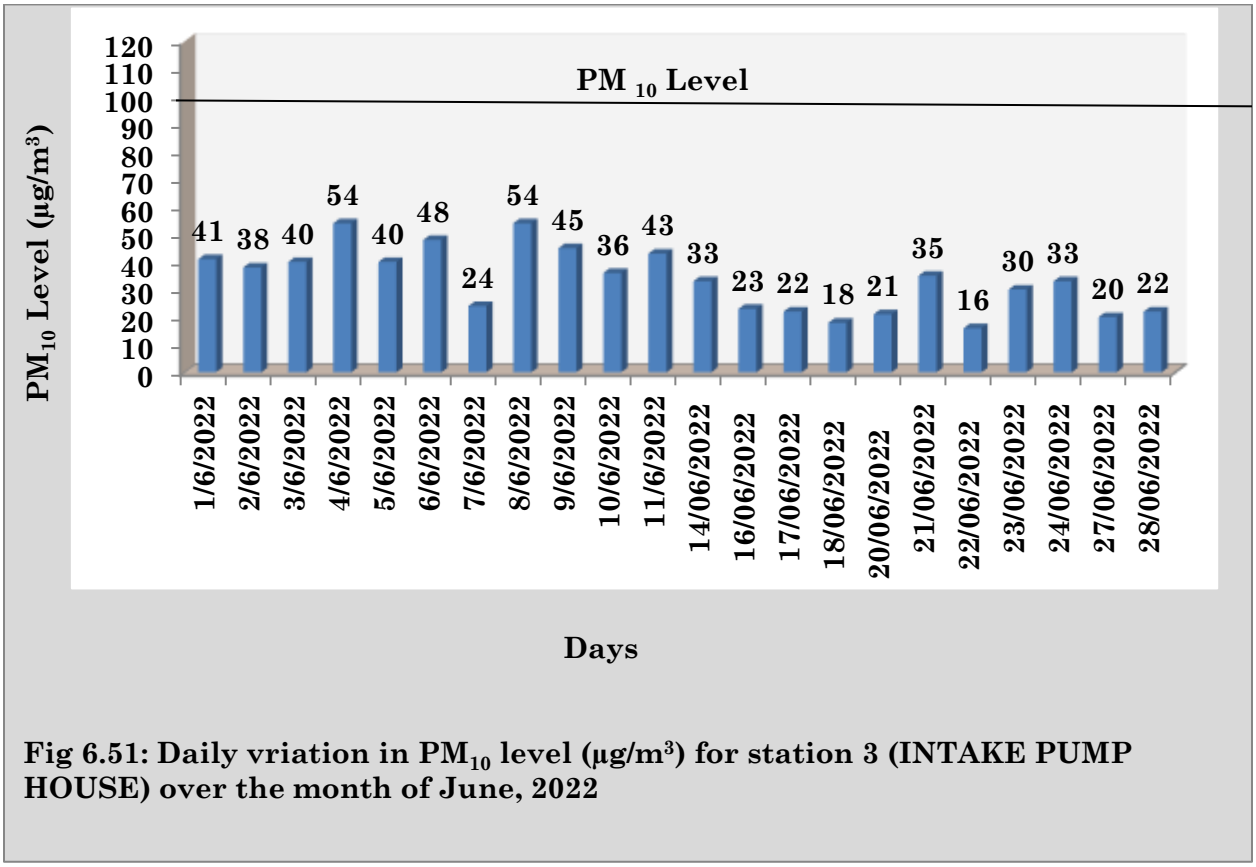


Fig 6.51: Daily vriation in PM_{10} level (µg/m³) for station 3 (INTAKE PUMP HOUSE) over the month of June, 2022

The daily variation in PM_{10} level at the Station 3 over the month of June, 2022 is shown in the Fig. 6.51. The maximum pollutant concentration is found to be 54.0 µg/m³ on 4th and 8th June 2022 and the minimum concentration of 16 µg/m³ is observed on 22nd June 2022. Average PM_{10} concentration for the month of June at Station 3 is found to be 33.45 µg/m³. The range of PM_{10} concentration (16 – 54 µg/m³) observed for station 3 over the month of June lied well below the 24-hourly permissible limit of 100 µg/m³.

Status of $PM_{2.5}$ concentration

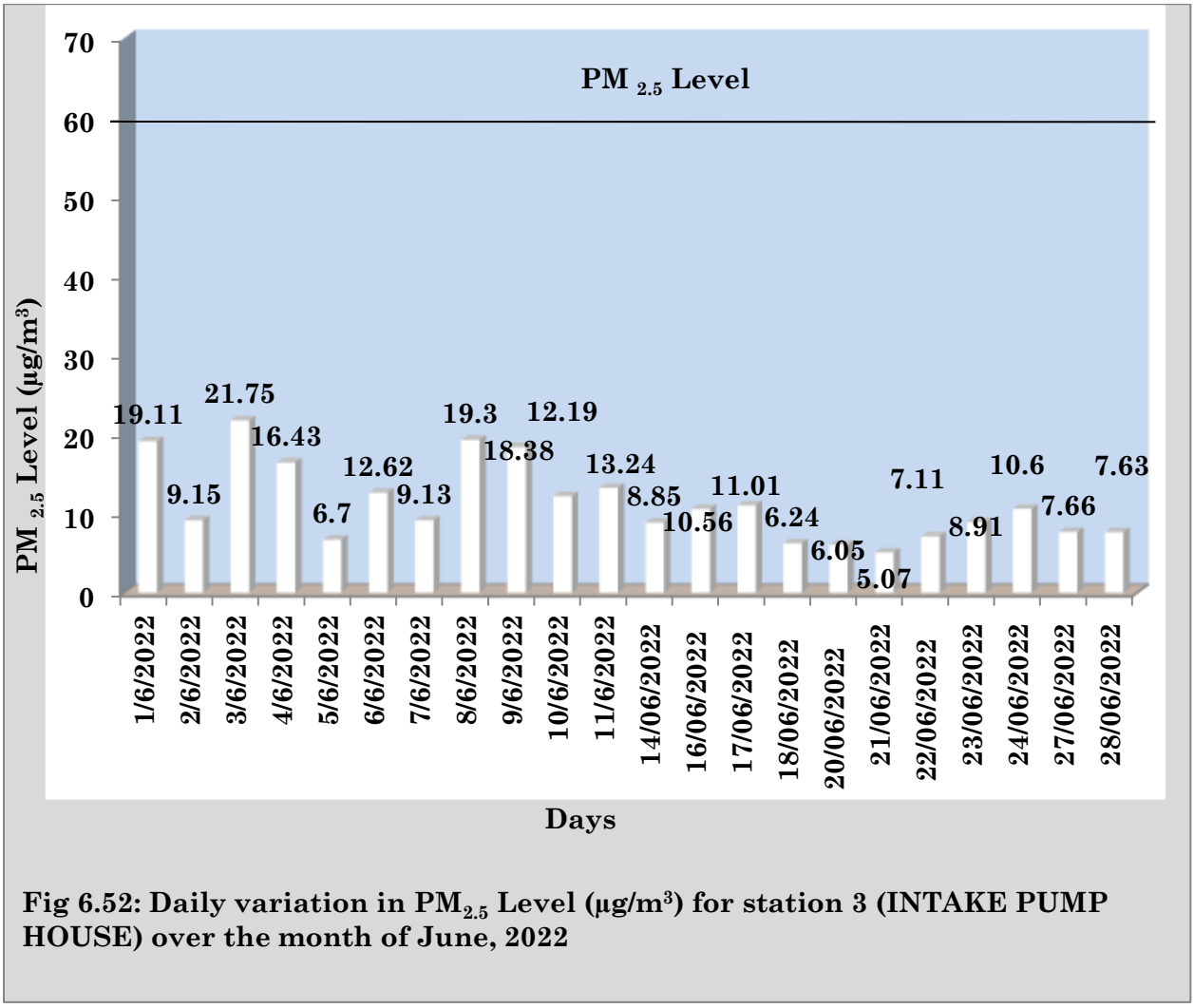


Fig 6.52: Daily variation in $PM_{2.5}$ Level (µg/m³) for station 3 (INTAKE PUMP HOUSE) over the month of June, 2022

The daily variation in $PM_{2.5}$ level at the Station 3 over the month of June, 2022 is shown in the Fig. 6.52. The maximum pollutant concentration is found to be 21.75 µg/m³ on 3rd June 2022 and the minimum concentration of 5.07 µg/m³ is observed on 21st June 2022. Average $PM_{2.5}$ concentration for the month of June at Station 3 is found to be 11.23 µg/m³. The range of $PM_{2.5}$ concentration (5.07 – 21.75 µg/m³) observed for station 3 over the month of May lied well below the 24-hourly permissible limit of 60 µg/m³

Status of SO_2 concentration

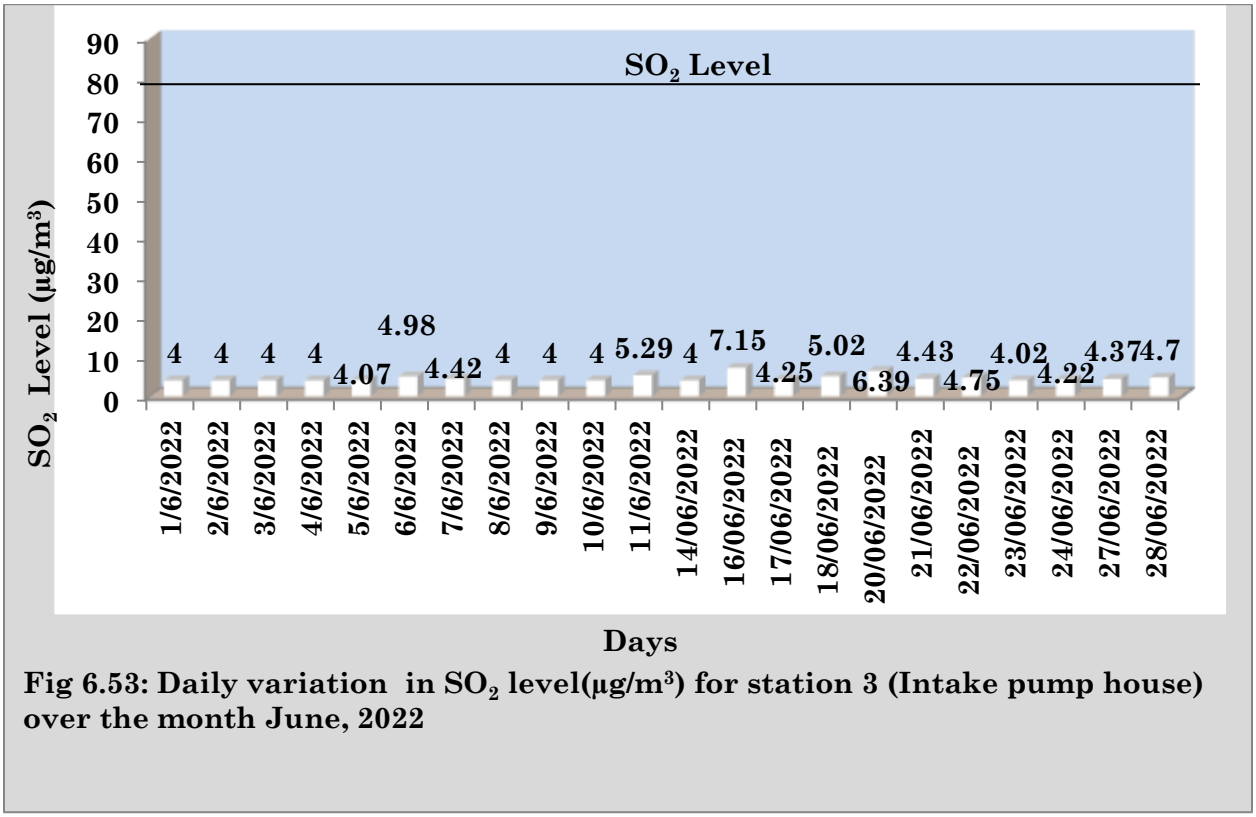


Fig 6.53: Daily variation in SO_2 level(µg/m³) for station 3 (Intake pump house) over the month June, 2022

The daily variation in SO_2 level at the Station 3 over the month of June, 2022 is shown in the Fig. 6.53. The maximum pollutant concentration is found to be 7.15 µg/m³ on 16th June 2022 and the minimum concentration of 4.0 µg/m³ is observed on 1st 2nd 3rd 4th 8th 9th 10th and14th June 2022. Average SO_2 concentration for the month of June at Station 3 is found to be 6.2 µg/m³. The range of SO_2 concentration (4.0 – 7.15 µg/m³) observed for station 3 over the month of June lied well below the 24-hourly permissible limit of 80 µg/m³

Status of NOx concentration

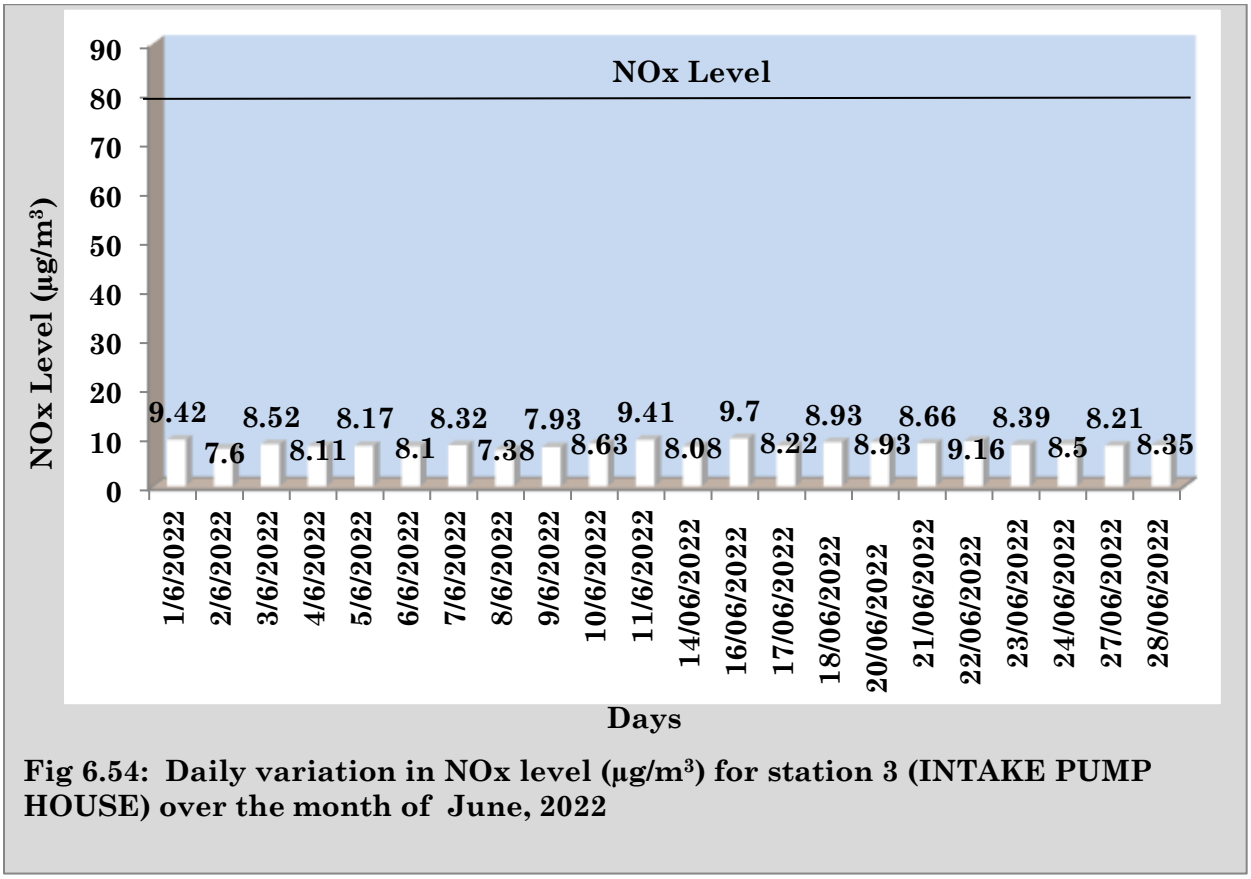


Fig 6.54: Daily variation in NOx level (µg/m³) for station 3 (INTAKE PUMP HOUSE) over the month of June, 2022

The daily variation in NOx level at the Station 3 over the month of June, 2022 is shown in the Fig. 6.54. The maximum pollutant concentration is found to be 9.42 µg/m³ on 1st June 2022 and the minimum concentration of 7.38 µg/m³ is observed on 8th June 2022. Average NOx concentration for the month of June at Station 3 is found to be 8.5 µg/m³. The range of NOx concentration (7.38 – 9.42 µg/m³) observed for station 3 over the month of June lied well below the 24-hourly permissible limit of 80 µg/m³.

Status of CO concentration

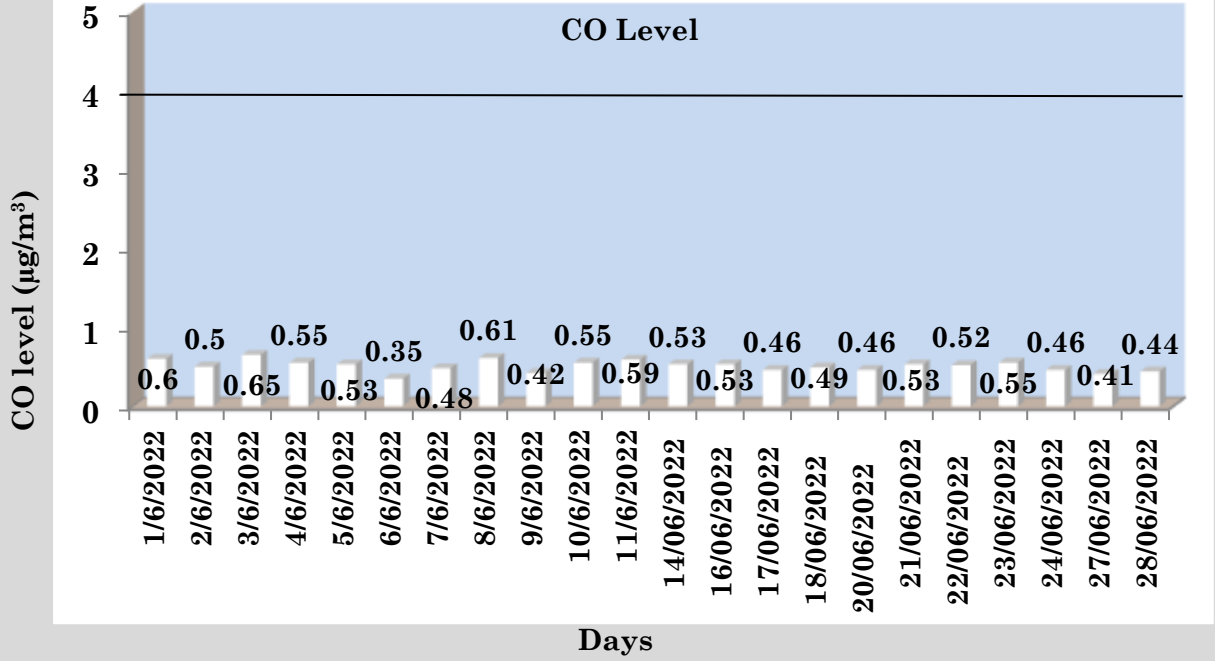


Fig 6.55: Daily variation in CO level (µg/m³) for station3 (intake pump house) over the month of June, 2022

The daily variation in CO level at the Station over the month of June, 2022 is shown in the Fig. 6.55. The maximum pollutant concentration is found to be 0.65 µg/m³ on 3rd June 2022 and the minimum concentration of 0.35 µg/m³ is observed on 6th June 2022. Average CO concentration for the month of June at Station 3 is found to be 0.51 µg/m³. The range of CO concentration (0.35 - 0.65 µg/m³) observed for station 3 over the month of June lied well below the 24-hourly permissible limit of 4.0 µg/m³

Status of O_3 concentration

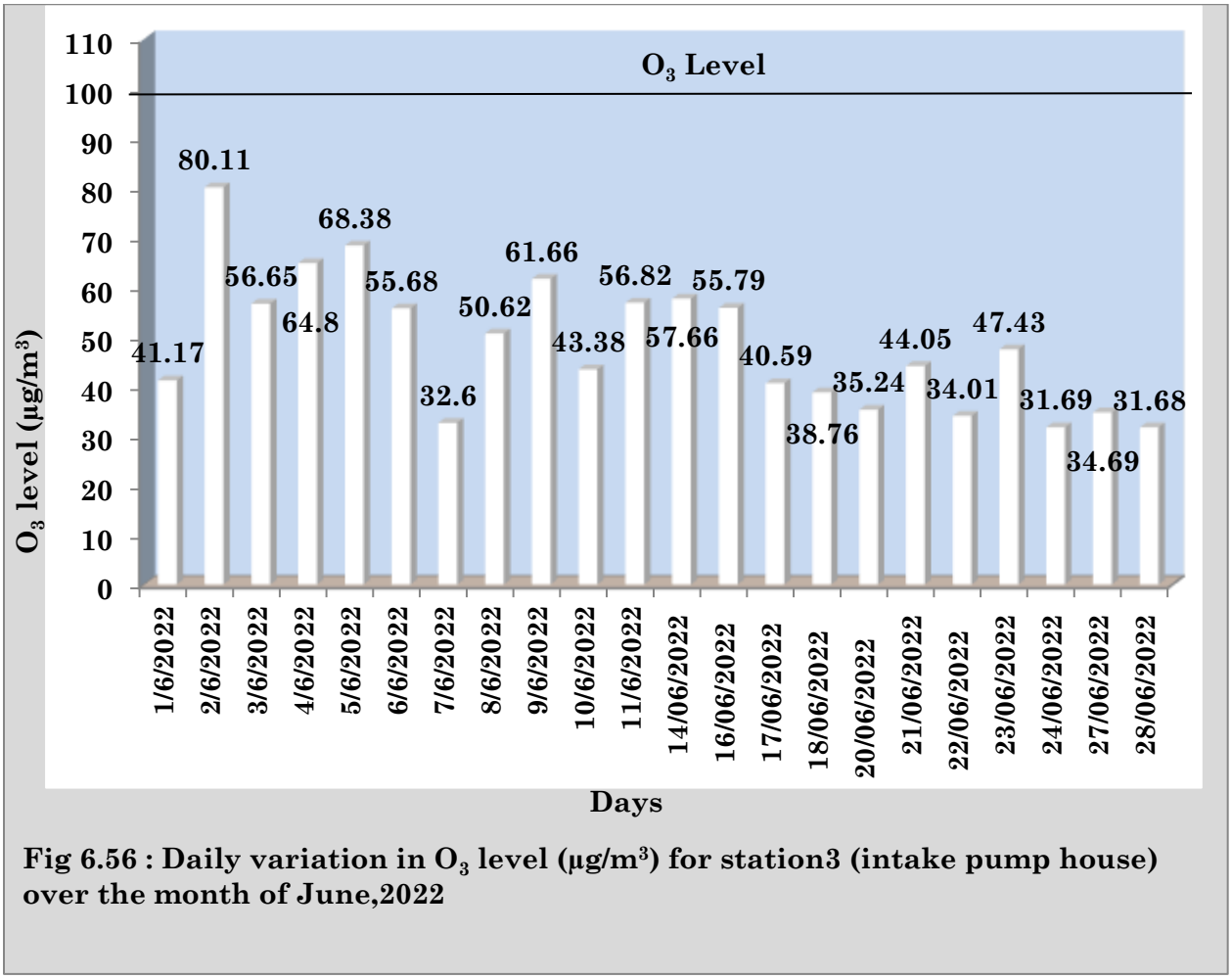


Fig 6.56 : Daily variation in O_3 level (µg/m³) for station3 (intake pump house) over the month of June,2022

The daily variation in O_3 level at the Station 3 over the month of June, 2022 is shown in the Fig. 6.56. The maximum pollutant concentration is found to be 80.11 µg/m³ on 2nd June 2022 and the minimum concentration of 31.68 µg/m³ is observed on 28th June 2022. Average O_3 concentration for the month of May at Station 3 is found to be 48.3 µg/m³. The range of O_3 concentration (31.68 – 80.11 µg/m³) observed for station 3 over the month of June lied well below the 8 hourly permissible limits of 100.0 µg/m³

6.3.1 Conclusion of concentration level for the month of June in the three stations

The summary of mean pollutant concentration prevailing at three monitoring stations over the month of June, 2022 for six criteria air pollutants is furnished in the Table 6.5

Table 6.5: Mean pollutant concentration of the pollutants over the month of June, 2022

Pollutants	Concentration level (µg/m^3)		
	Station 1	**Station 2**	**Station 3**
PM_{10}	1.227	29.272	33.454
$PM_{2.5}$	15.309	12.780	11.258
SO_2	3.58	2.89	4.548
NOx	14.825	14.65	8.487
CO	0.723	0.737	0.509
O_3	9.910	36.032	48.339

- Graphical plotting of the above data are as follows

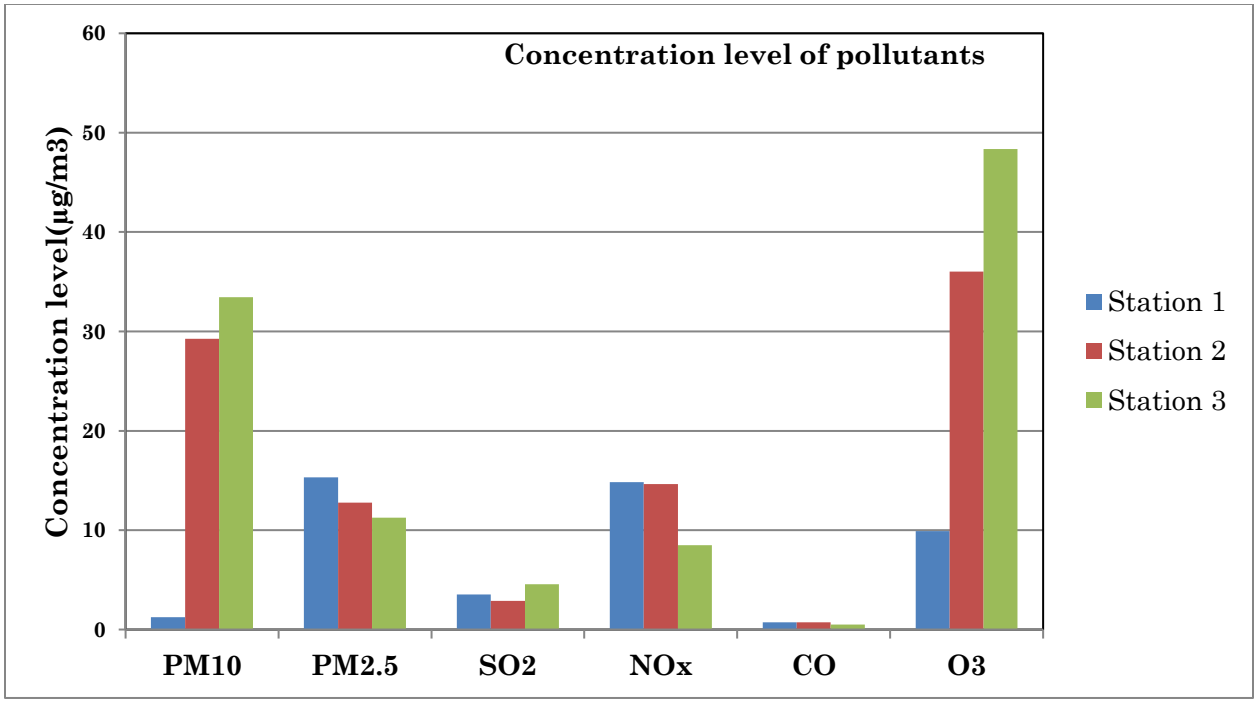


Fig 6.57: Variation in pollutant concentrations for three stations for the month of June, 2022

6.4 Monthly variation of the pollutant concentrations for three monitoring stations

The monthly variation in the mean concentration of six criteria air pollutants over the period of April, 2022 to June, 2022 for three monitoring stations are shown in the Fig 6.58 to Fig 6.63 below.

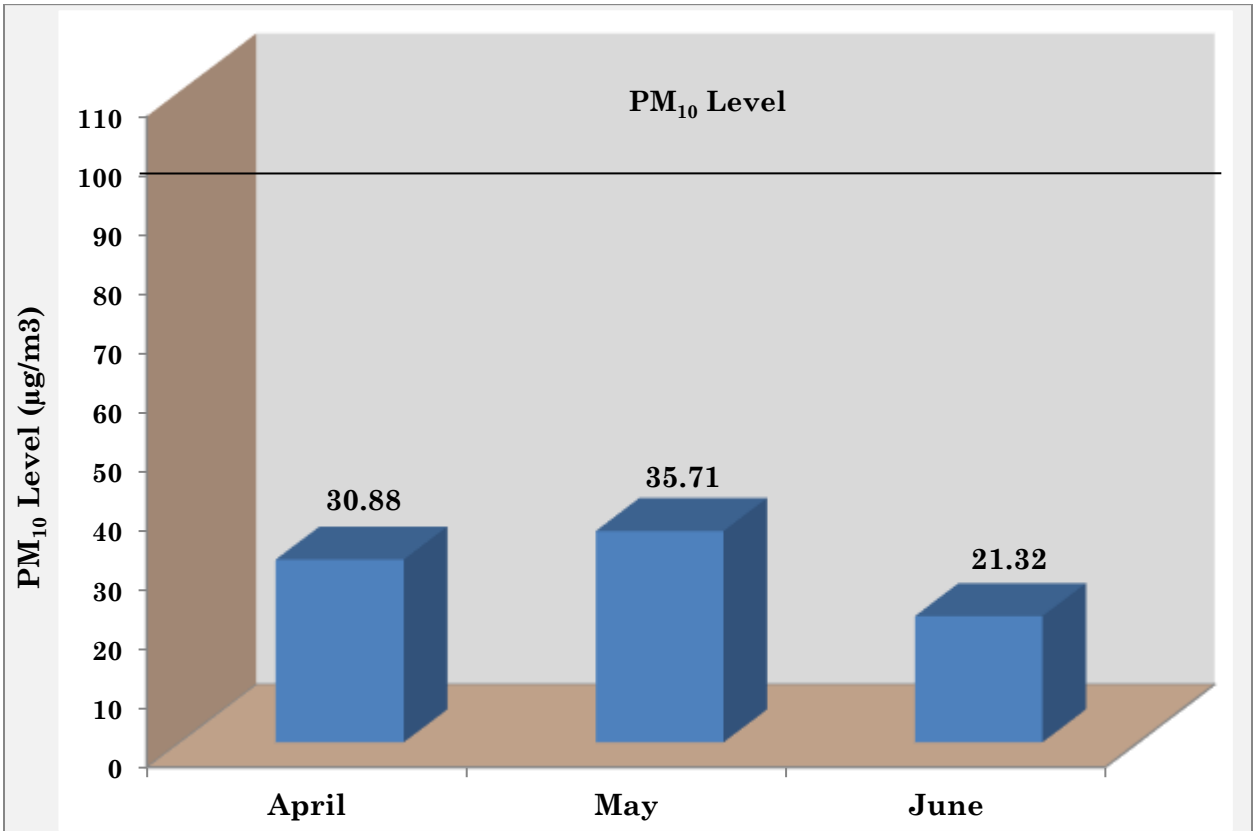


Fig 6.58: Month of the Year- 2022

The maximum concentration level of PM_{10} was obtained as 35.71 µg/m^3 in the month of May while the minimum concentration level of 21.32 µg/m^3 was obtained in the month of June. The decrease in the PM_{10} level could be attributed to the effect of rainfall during the month of June, 2022.

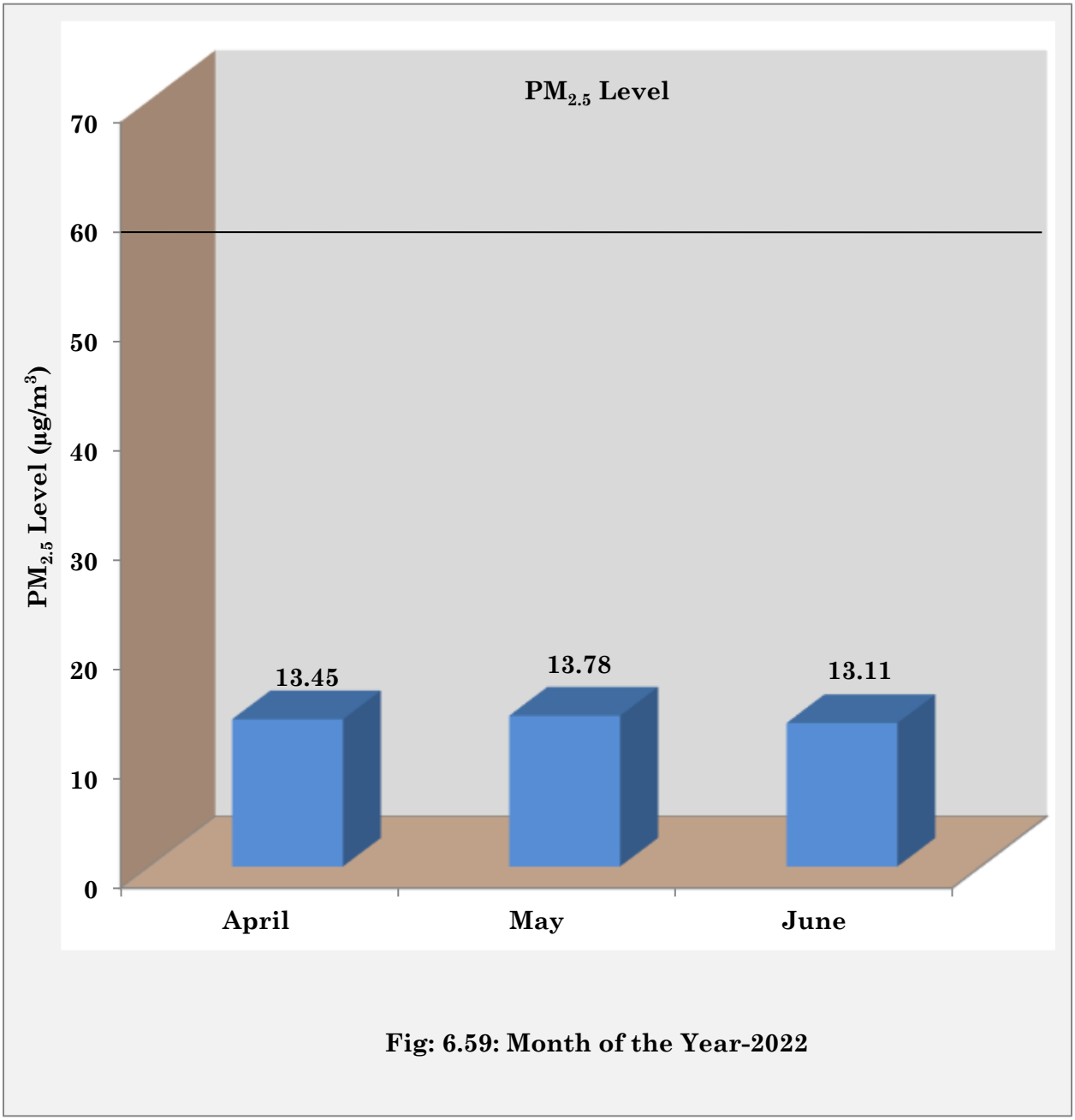


Fig: 6.59: Month of the Year-2022

The concentration level of $PM_{2.5}$ in the respective months as shown in the graph is somewhat similar, that is 13.45µg/m^3 in the month of April, 13.78µg/m^3 in the month of May and 13.11µg/m^3 in the month of June.

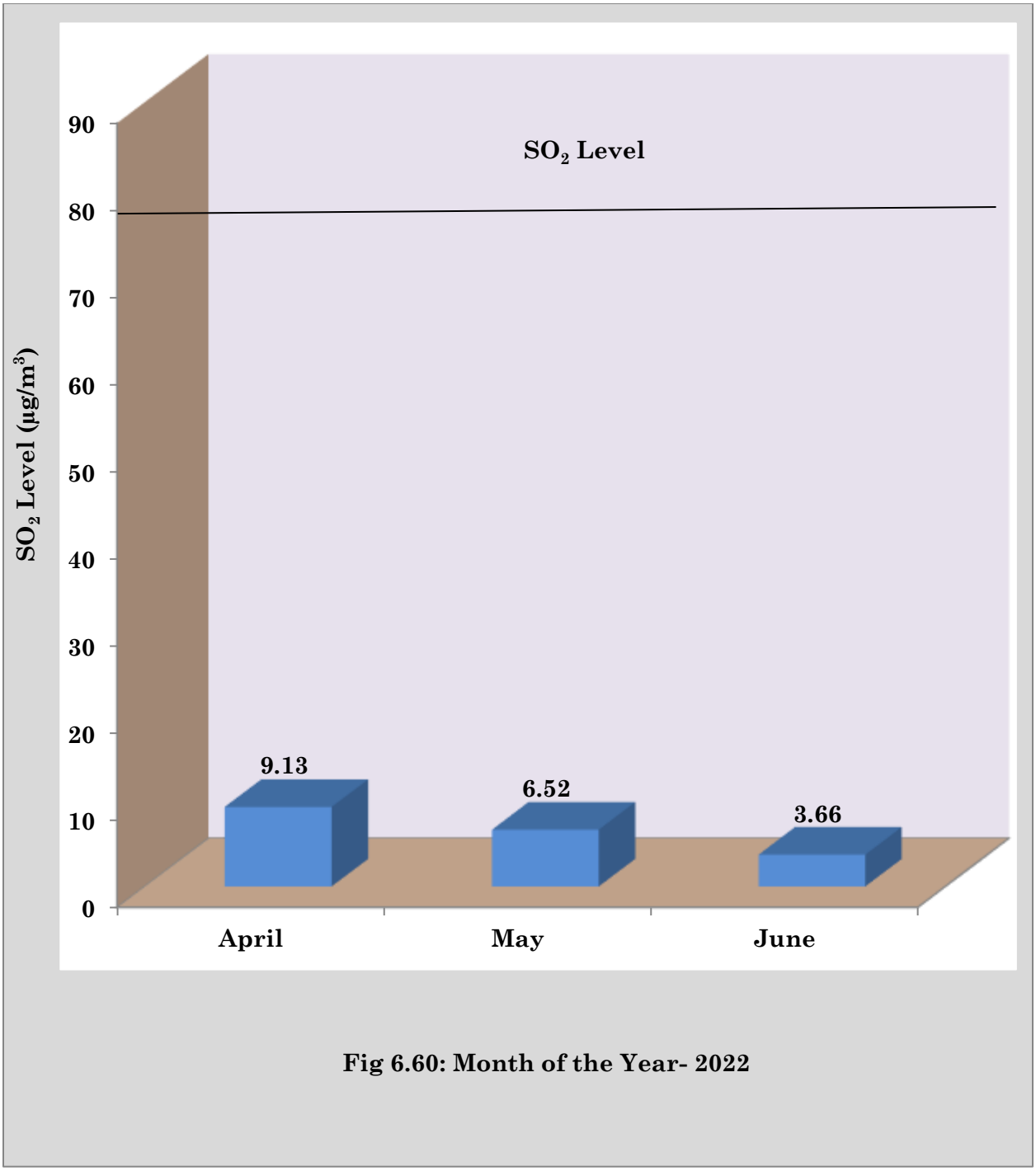


Fig 6.60: Month of the Year- 2022

The concentration level of SO_2 is maximum in the month of April that is 9.13 µg/m^3, minimum in the month of June that is 3.66µg/m^3 and in the month of May is 6.52µg/m^3.

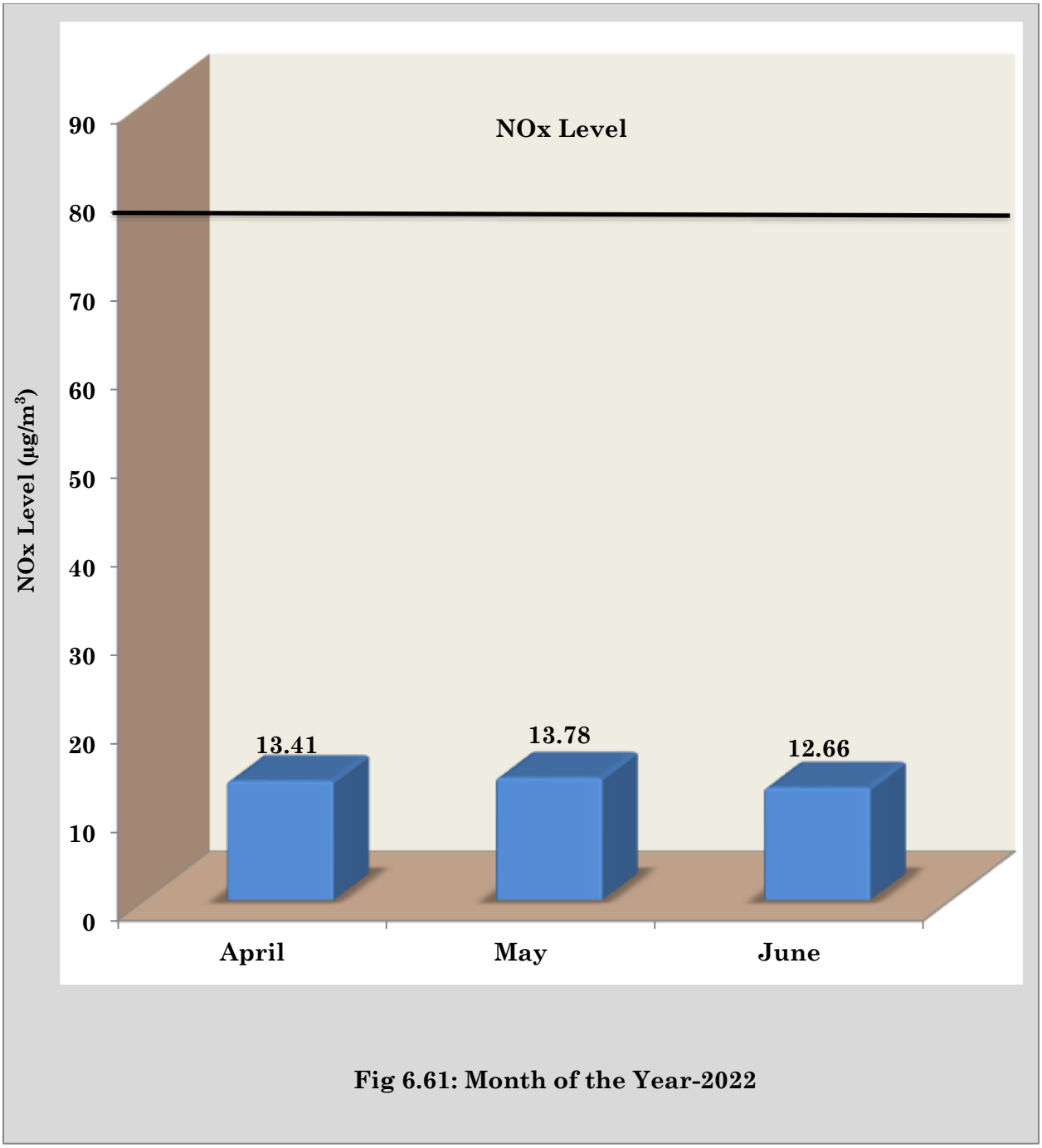


Fig 6.61: Month of the Year-2022

The concentration of NOx level is similar in the three months, that is in the month of April is 13.41µg/m^3, in the month of May is 13.78 µg/m^3 and in the month of June is 12.66 µg/m^3.

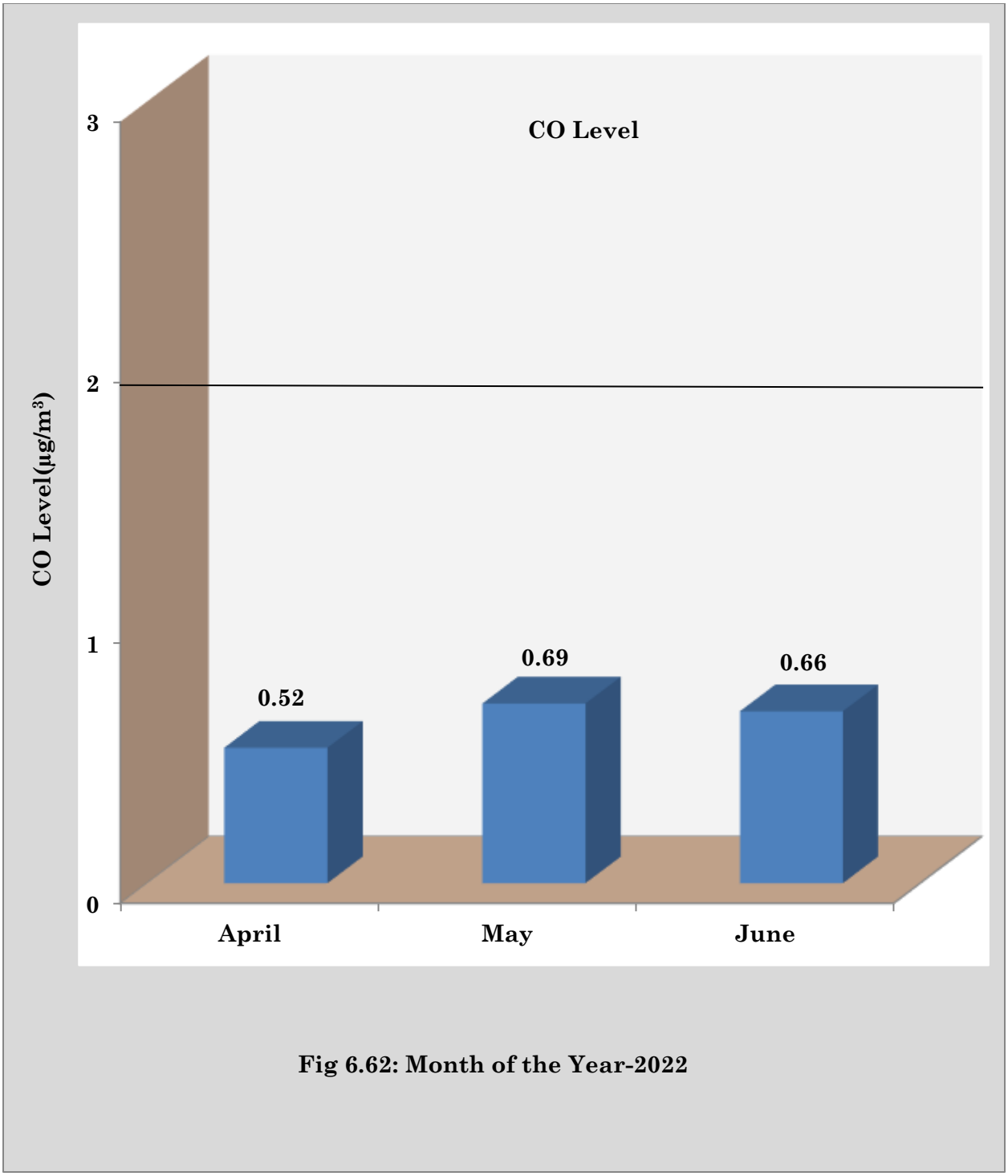


Fig 6.62: Month of the Year-2022

The concentration level of CO in the month of April is 0.52 µg/m^3, in the month of May is 0.69µg/m^3 and in the month of June is 0.66 µg/m^3.

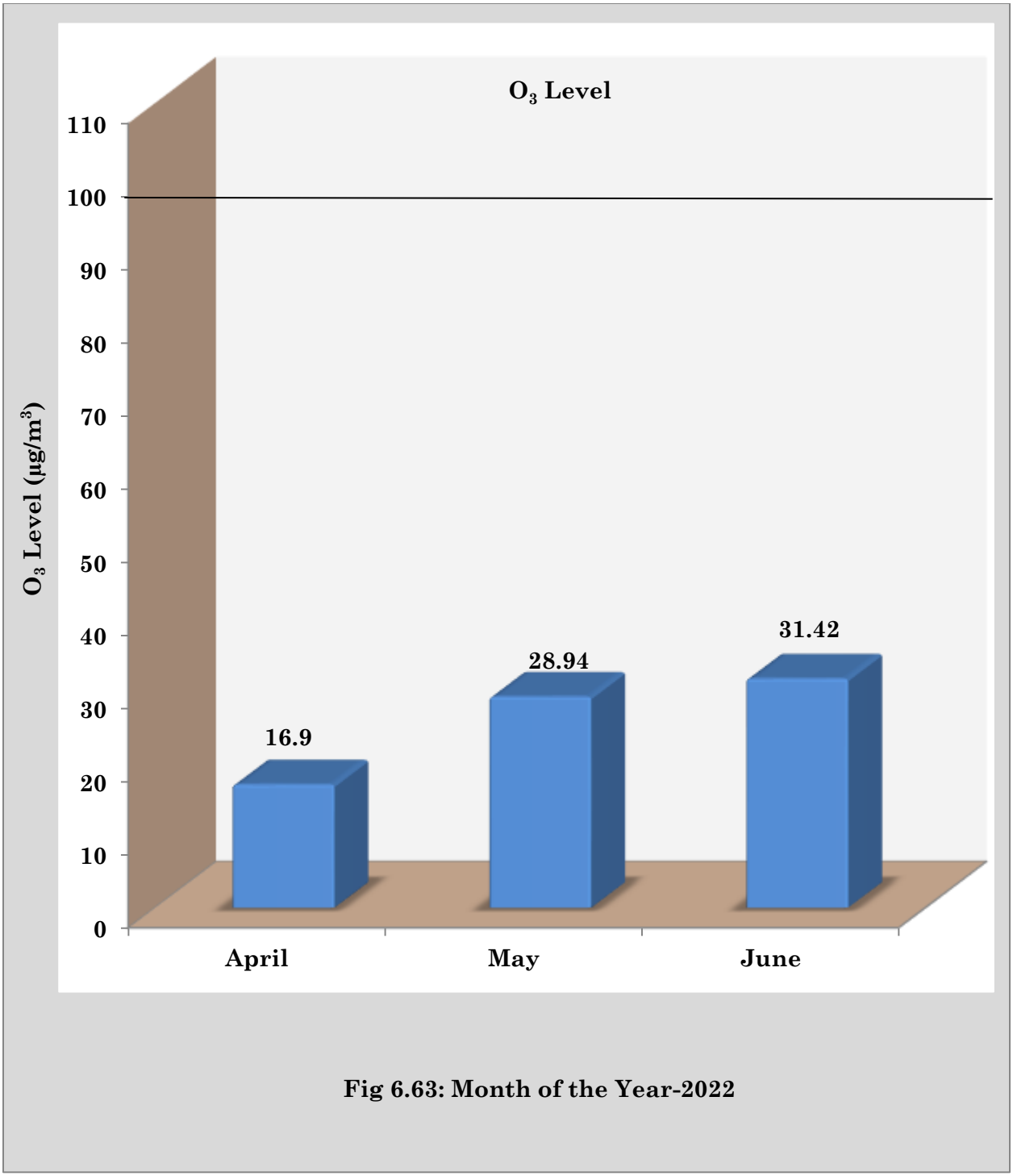


Fig 6.63: Month of the Year-2022

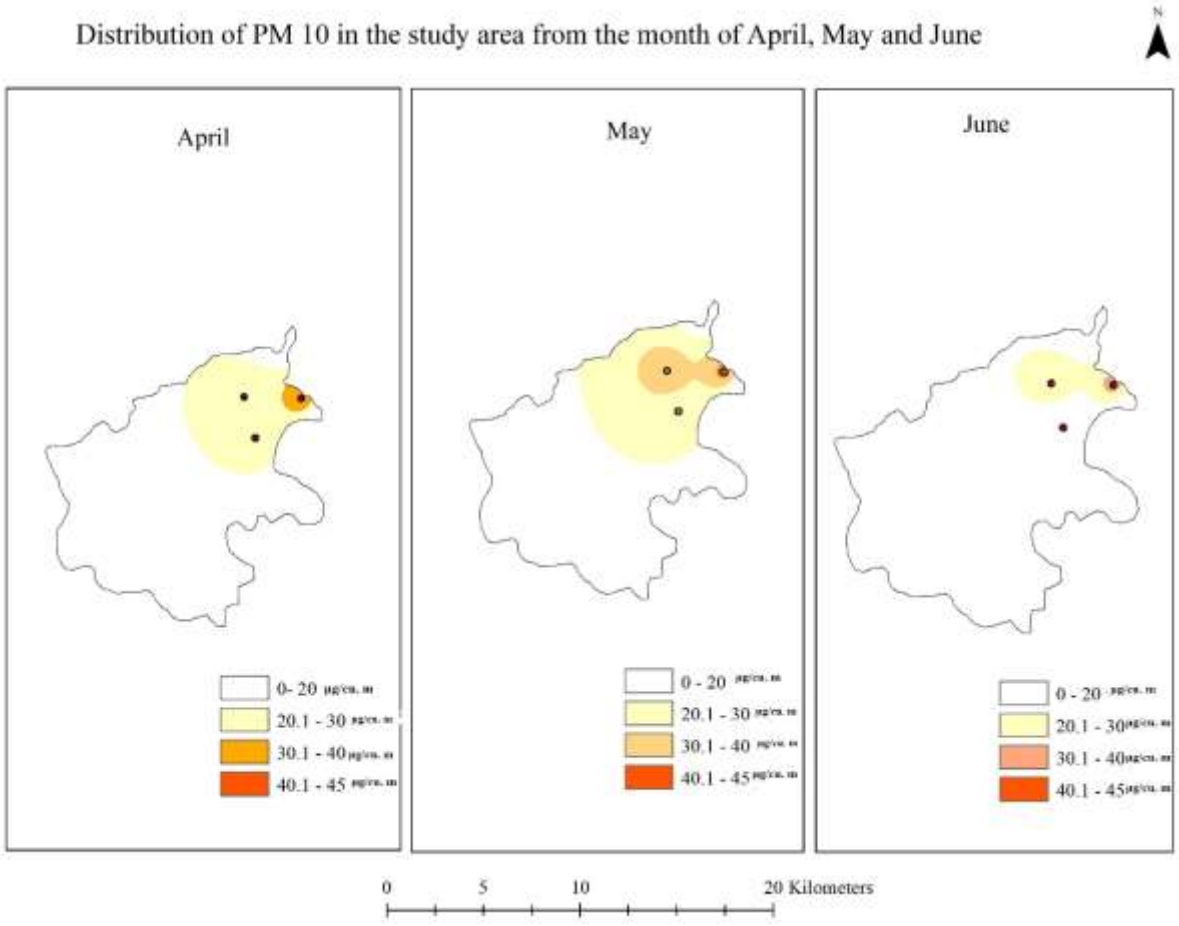
The concentration level of O_3 in the month of April is 16.9µg/m^3, in the month of May is 28.94 µg/m^3 and in the month of June is 31.42 µg/m^3.

6.5 Spatial distribution of the pollutants

- Spatial variations of the pollutants

In this section the spatial distribution of concentration level of the pollutants in the vicinity of the three stations for is shown for the month of April, May and June, 2022. The discussion are as follows:

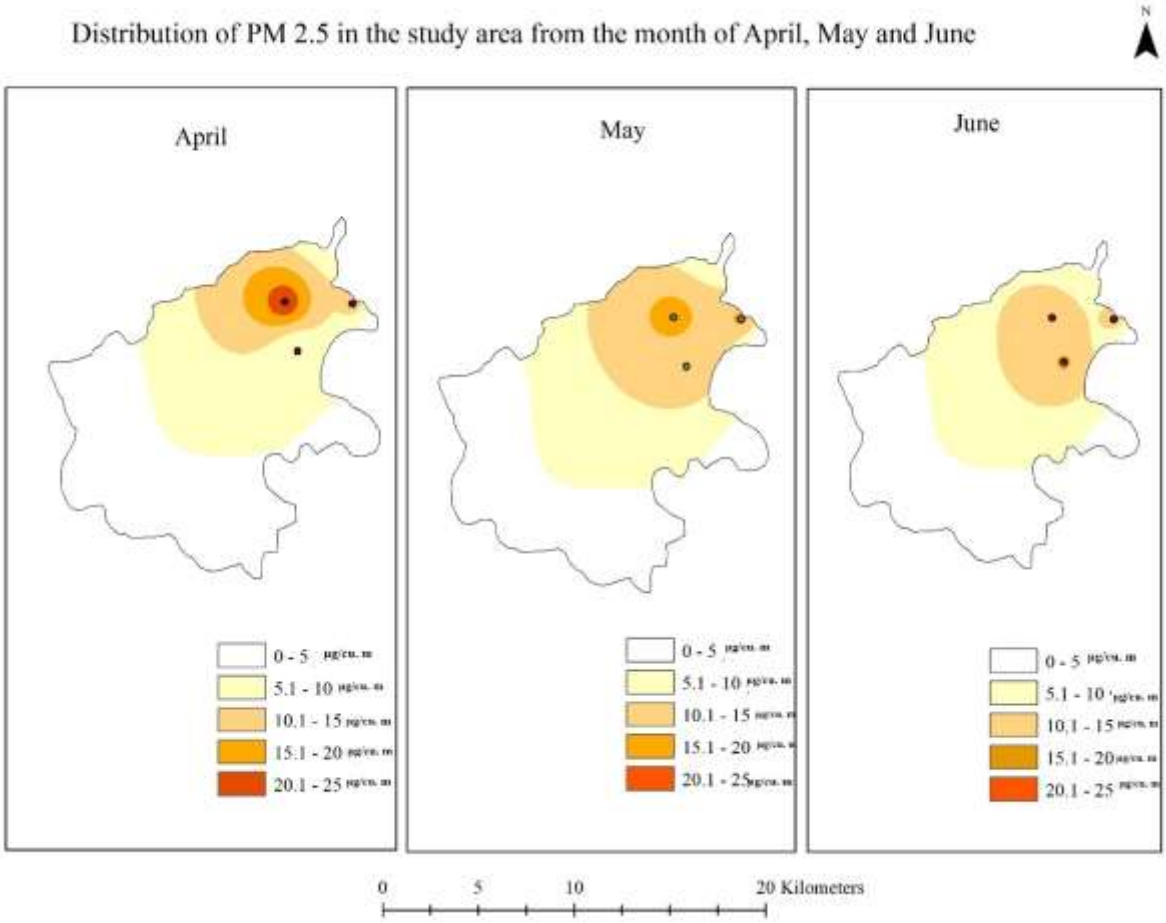
For PM_{10} Level



- The figure above shows the distribution of concentration of PM_{10}. From the picture it is obvious that the concentration level is much higher in station 3 as compared to station 1 and 2. If the average concentration level is considered, the month May represents the highest and the month June shows the minimum. The reason for these variations arises due to the seasonal variations, and the monsoon season starts in the region in month of June. This pattern of concentration distribution is somewhat similar in case of the $PM_{2.5}$ level.

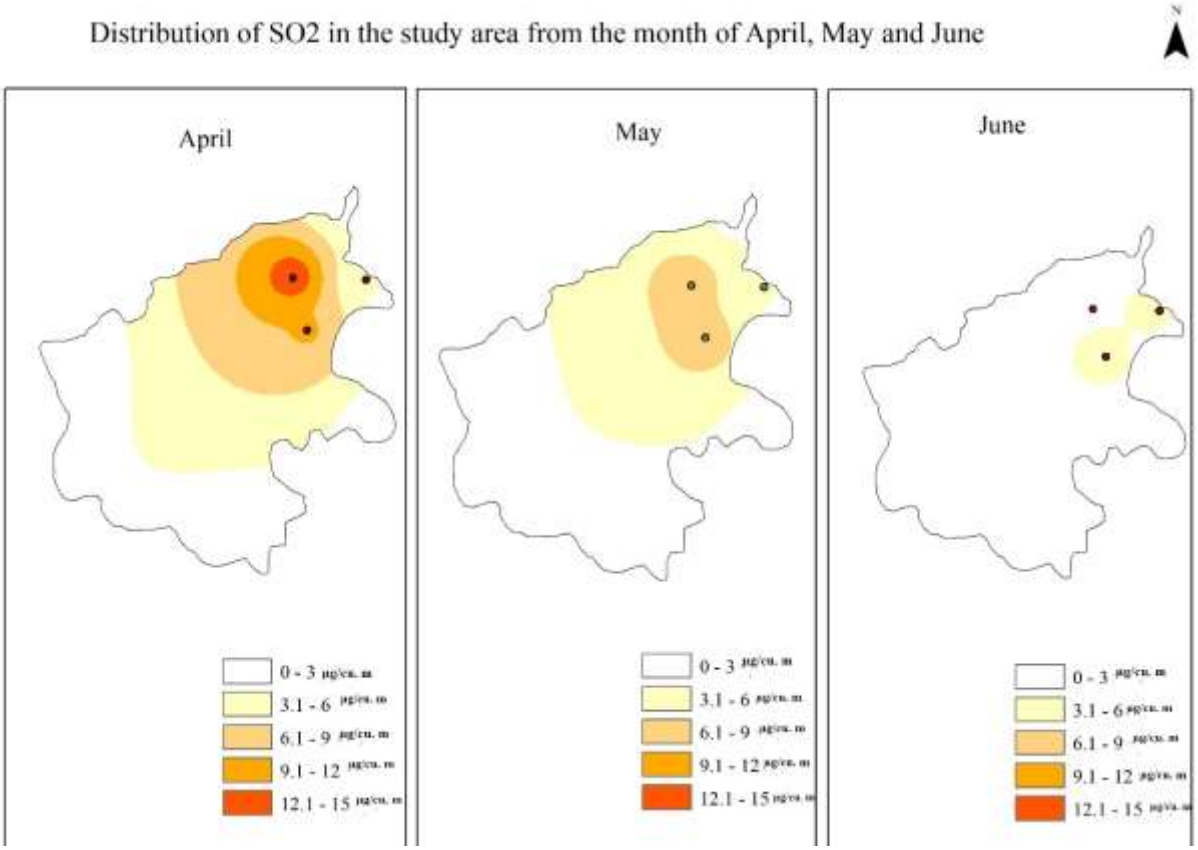
PM2.5 Level

- The following picture shows the spatial distribution of $PM_{2.5}$ level



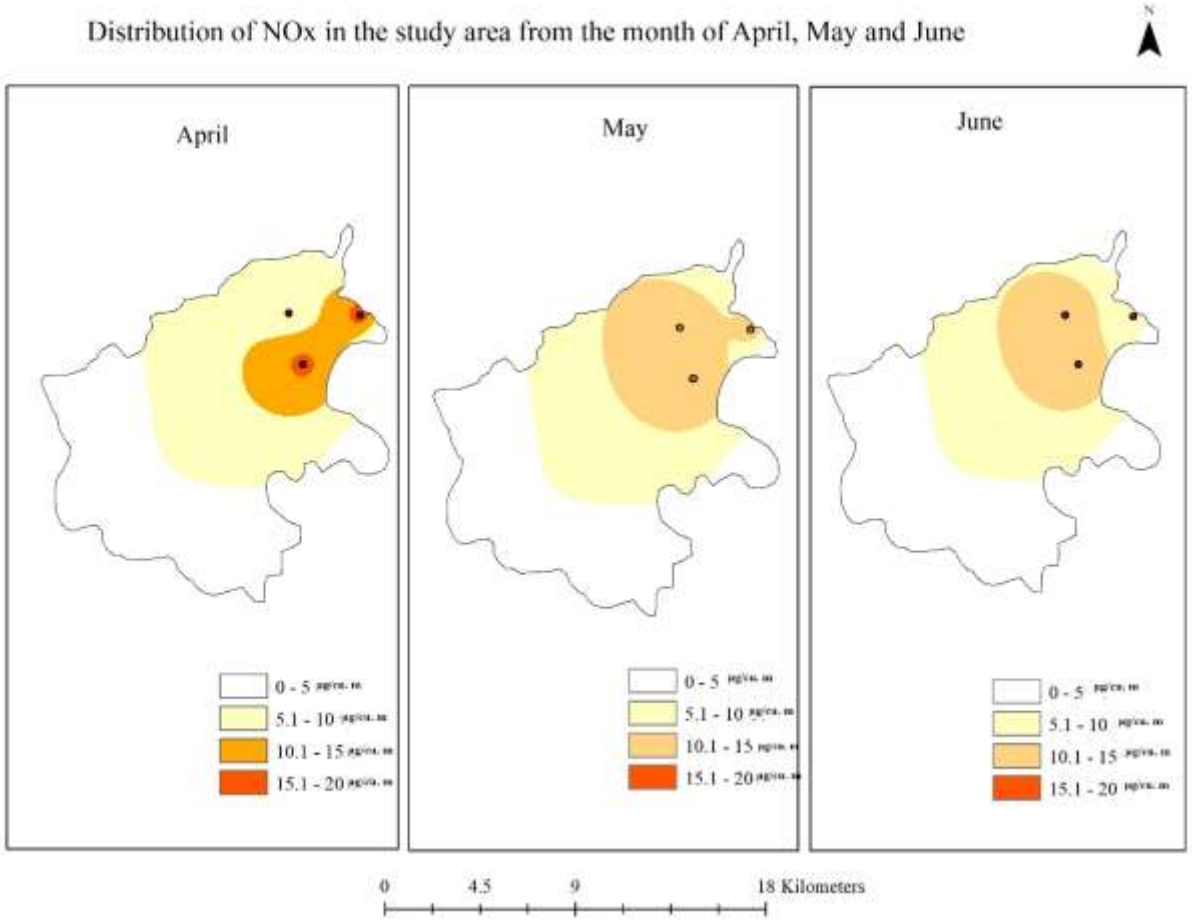
- The concentration level of $PM_{2.5}$ for the month of April is the highest, while it is minimum for the month of June, the reason is discussed in the above paragraph of PM_{10}.

For SO_2 Level



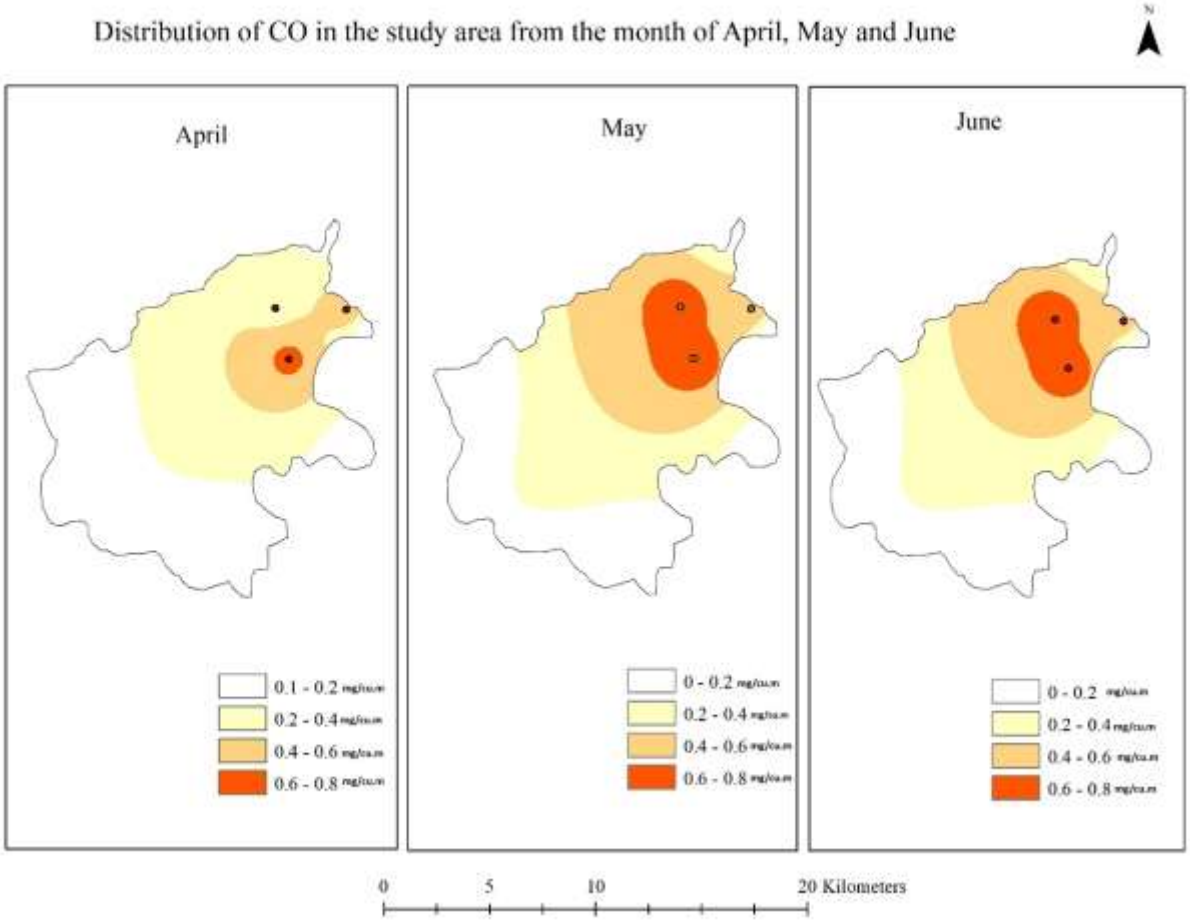
- The above diagram shows the spatial distribution of SO_2 level and it is shows that the concentration was maximum in the month of April and it decreased in the order of April, May, and June, 2022.

For NOx Level



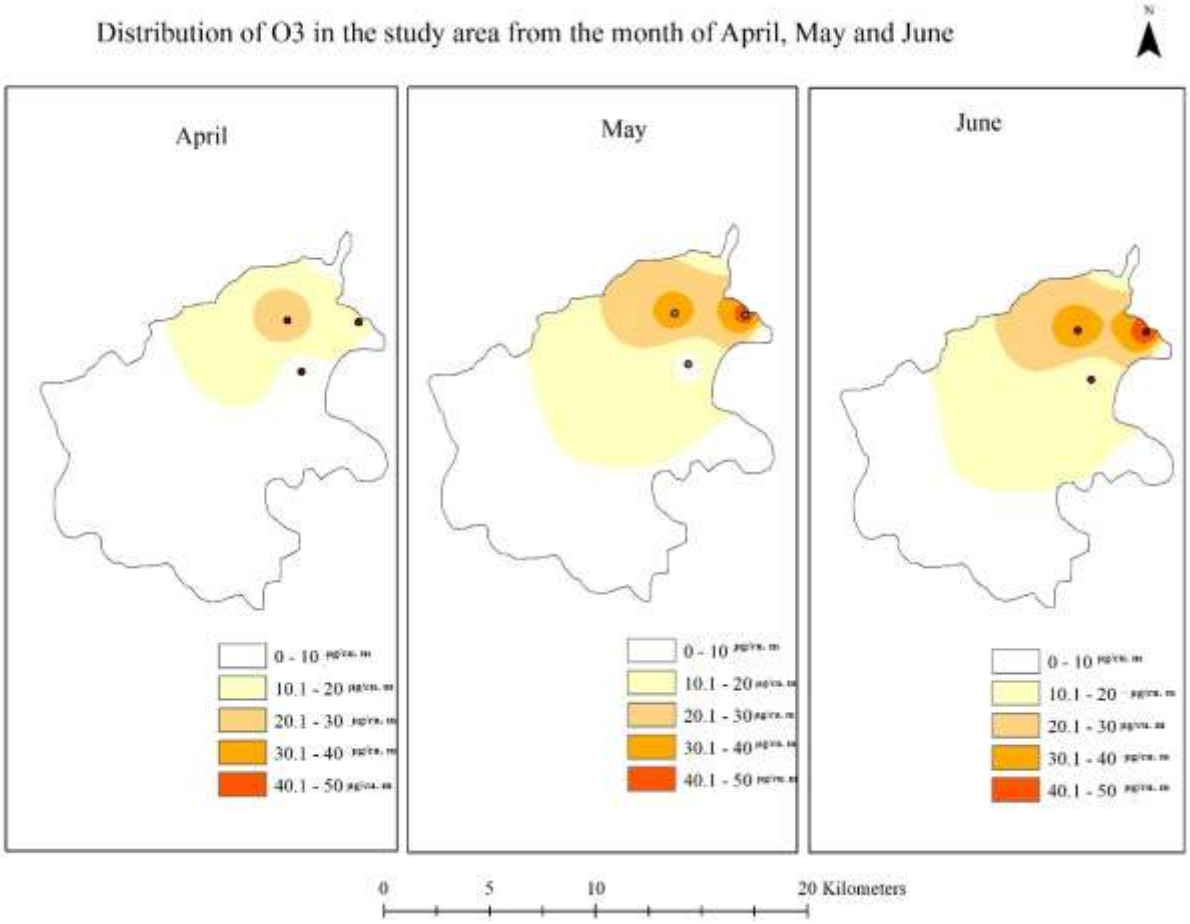
- The above figures show that the concentration level of NOx decreased in the order of April, May, and June. It is also observed that in the month of April Station 1 and Station 3 are the most polluted compared to the other months.

For CO Level



- It seems from the above figures that in the month of April Station 1 is most polluted, but in case of May and June, Station 1, 2 and their adjacent areas were found to be worst affected.

For O_3 Level



- In this figure if the comparison is done with respect to CO level, the ozone (O_3) is somewhat less concentrated. And, from the prediction idea concentration level is decreased in the order of June, May and April.

Chapter-7

Conclusion and Future Scope of Work

In the present study an insight was made to assess the air quality parameters within a Coal Based Thermal Power Plant. The air quality data has been analyzed for this thesis work from the Continuous Air Quality Monitoring Stations of a Coal Based Thermal Power Plant (KTPS).

- From the analysis of the data, it is found that the concentration levels of the air quality parameters are within the permissible limit as per National Ambient Air Quality Standards (NAAQS-2009) of India.
- Air quality parameters in three different locations have been observed and analyzed. Concentrations of the Pollutants decreased with the increase in distance of receptors from the source.
- Concentration of the pollutants also decreased significantly due to the effect of rainfall.
- During the changeover of different units in thermal power plants, consumption of coal varies leading to the change in the concentrations of the air quality parameters.

Future scope of work

- The scope of the work can be expanded on long term scale to understand more accurately the trend of air quality parameters concentrations within and outside of thermal power plants.
- An epidemiological study may be conducted to explore the relationship between exposures to particulate air pollution with cardiovascular, respiratory etc. health of the commuters.
- A comparative study with different power plants can be carried out with respect to the air quality parameters.
- The monitoring stations which are located on the vicinity of highway and power plant, for that source apportionment study can be carried out for conclusive views.

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Annexure

Station 1 (Gate No.02)

April	PM_{10}	$PM_{2.5}$	SO_2	NOx	CO	O_3
	Limit:100(µg/m3)	Limit:60(µg/m3)	Limit:80(µg/m3)	Limit:80(µg/m3)	Limit:2.0(µg/m3)	Limit:100(µg/m3)
01/04/2022	32.9	11.4	5.43	14.05	0.79	21.69
02/04/2022	30.3	7.3	5.3	18.26	0.49	11.09
05/04/2022	25	7.2	8.74	15.58	0.66	5.09
06/04/2022	24.5	7	10.53	16.75	0.69	8.33
07/04/2022	38.7	8	9.66	15.68	0.49	10.63
08/04/2022	25.2	10.6	13.52	16.37	0.46	1.98
09/04/2022	15.5	1.6	11.94	16.64	0.7	0.36
11/04/2022	21	2.1	13.33	15.11	0.64	3.74
12/04/2022	18.6	2.1	4.82	15.37	0.50	3.09
13/04/2022	17.4	6.1	8.32	15.11	0.69	5.43
16/04/2022	26.2	3.4	7.94	17.02	0.7	6.79
18/04/2022	34.4	8.2	11.29	15.28	0.64	16.67
19/04/2022	21.7	7.2	8.16	14.49	0.5	6.11
20/04/2022	20.3	5	11.39	16.45	0.69	8.98
21/04/2022	24.7	3.4	7.06	16.51	0.52	5.95
22/04/2022	24.1	6.6	7.42	12.94	0.71	1.46
23/04/2022	32.5	5.2	9.38	15.26	0.63	14.26
25/04/2022	44.3	11.8	13.02	16.86	0.74	10.5
26/04/2022	12	4.3	5.82	16.27	0.74	10.44
27/04/2022	10	5.9	10.66	16.96	0.77	6.24
28/04/2022	Unavailable	4.1	9.92	16.01	0.79	0.19
29/04/2022	Unavailable	7.5	10.82	15.1	0.69	3.95

Station 1 (Gate No.02)

May	PM_{10}	$PM_{2.5}$	SO_2	NOx	CO	O_3
	Limit:100(µg/m3)	Limit:60(µg/m3)	Limit:80(µg/m3)	Limit:80(µg/m3)	Limit:2.0(µg/m3)	Limit:100(µg/m3)
02/05/2022	Unavailable	5.5	12.04	16.2	0.59	1.65
04/05/2022	Unavailable	12.1	11.91	15.59	0.86	13.29
05/05/2022	Unavailable	9.2	9.36	16.93	0.78	6.42
06/05/2022	Unavailable	6.5	10.77	15.29	0.67	6.69
07/05/2022	Unavailable	9	7.12	15.56	0.81	12.08
09/05/2022	Unavailable	2	10.39	13.61	0.91	9.11
10/05/2022	Unavailable	4	12.32	16.71	0.7	9.53
11/05/2022	Unavailable	2.4	6.68	15.27	0.78	9.12
12/05/2022	Unavailable	16.8	11.09	13.36	0.66	12.72
13/05/2022	Unavailable	8.6	6.89	13.91	0.75	13.26
14/05/2022	Unavailable	9.9	9.33	12.95	0.69	4.18
17/05/2022	Unavailable	7.2	11.39	16.58	0.65	4.92
18/05/2022	Unavailable	4.1	6.85	15.24	0.73	9.75
19/05/2022	Unavailable	1.8	7.86	15.03	0.68	6.87
20/05/2022	Unavailable	Unavailable	2.86	14.74	0.64	0.08
21/05/2022	20	9.9	3.71	13.77	0.71	2.38
23/05/2022	36.7	19.2	2.92	16.63	0.92	9.69
24/05/2022	26.2	14.8	5.26	15.26	0.82	3.19
26/05/2022	35.6	35.6	5.6	15.62	0.76	6.3
27/05/2022	17.6	33.2	2.97	15.03	0.9	13.5
30/05/2022	35.3	34.9	2.42	14.01	0.62	9.45

Station 1 (Gate No.02)

June	PM_{10}	$PM_{2.5}$	SO_2	NOx	CO	O_3
	Limit:100(µg/m3)	Limit:60(µg/m3)	Limit:80(µg/m3)	Limit:80(µg/m3)	Limit:2.0(µg/m3)	Limit:100(µg/m3)
01/06/2022	1.6	28.6	7.32	14.79	0.91	9.53
02/06/2022	1.1	23.4	3.21	14.25	0.81	22.45
03/06/2022	1.5	19.2	5.01	15.99	0.76	15.66
04/06/2022	0.6	30.6	3.93	15.02	0.69	21.52
06/06/2022	1.8	28.7	2.63	14.28	0.8	11.07
07/06/2022	2.2	18.5	2.89	14.31	0.69	21.2
08/06/2022	2	29.5	2.02	14.52	0.83	8.57
09/06/2022	4.6	28.4	1	13.87	0.63	16.25
10/06/2022	1.1	25.1	2.61	14.6	0.75	3.64
11/06/2022	1.8	23.1	2.96	14.09	0.65	11.78
14/06/2022	0.8	16.2	1.97	14.71	0.53	13.24
16/06/2022	0.8	14	3.4	13.96	0.5	13.3
17/06/2022	0.8	6.4	6.11	13.66	0.65	6.83
18/06/2022	0.7	8.5	5.25	14.36	0.91	3.78
20/06/2022	0.7	1.5	0.54	15.5	0.67	4.65
21/06/2022	0.7	3	2.35	14.75	0.94	6.05
22/06/2022	0.7	7.5	3	14.21	0.82	10.06
23/06/2022	0.7	4	4.94	16.05	0.74	5.29
24/06/2022	0.7	8	3.44	16.21	0.68	2.77
27/06/2022	0.7	3.9	4.2	15.3	0.71	2.16
28/06/2022	0.7	2.2	4.46	15.19	0.55	2.68
30/06/2022	0.7	6.5	4.2	16.54	0.7	5.55

Station 2 (KTTP Township)

April	PM_{10}	$PM_{2.5}$	SO_2	NOx	CO	O_3
	Limit:100(µg/m3)	Limit:60(µg/m3)	Limit:80(µg/m3)	Limit:80(µg/m3)	Limit:2.0(µg/m3)	Limit:100(µg/m3)
01/04/2022	30	32.14	9.01	8	0.42	43.52
02/04/2022	24	17.91	89.73	8.08	0.42	27.65
05/04/2022	19	15.58	8.93	8.03	0.33	19.93
06/04/2022	24	11.64	8.93	8	0.43	30.03
07/04/2022	40	16.58	9.68	8	0.43	35.91
08/04/2022	24	9.7	9.2	8.08	0.38	33.41
09/04/2022	14	10.89	9.27	8	0.39	23.15
11/04/2022	23	5.35	10.15	8.02	Unavailable	34.91
12/04/2022	19	17.47	9.77	8	0.27	23.67
13/04/2022	23	9.23	9.87	6	0.27	26.3
16/04/2022	27	19.37	10.67	8	0.27	27.55
18/04/2022	31	31.54	11.48	8.03	0.35	32.52
19/04/2022	28	18.3	11.07	8.01	0.27	25.95
20/04/2022	25	12.49	11.4	8	0.27	29.13
21/04/2022	28	11.09	11.48	8	0.34	23.7
22/04/2022	23	182.28	11.78	8	0.34	11
23/04/2022	35	15.64	12.39	8.08	0.27	53.73
26/04/2022	29	10.19	Unavailable	8.01	0.27	24.94
27/04/2022	33	11.52	8.32	8	0.47	25.61
28/04/2022	27	7.37	8.21	8	0.47	15.94
29/04/2022	41	13.66	8.01	8.02	0.47	11.21

Station 2 (KTTP Township)

May	PM_{10}	$PM_{2.5}$	SO_2	NOx	CO	O_3
	Limit:100(µg/m3)	Limit:60(µg/m3)	Limit:80(µg/m3)	Limit:80(µg/m3)	Limit:2.0(µg/m3)	Limit:100(µg/m3)
02/05/2022	21	12.23	20.87	8.06	0.53	30.37
04/05/2022	37	14.63	12.02	8	0.47	53.61
05/05/2022	36	19.69	10.14	8.01	0.47	17.48
06/05/2022	26	21.75	11.91	8.07	0.47	83.75
07/05/2022	34	17.23	10.99	13.64	0.76	50.41
10/05/2022	25	15.32	11.24	23.11	0.79	12.41
11/05/2022	31	15.96	10.3	26.88	0.81	20.91
12/05/2022	43	18.21	1.72	Unavailable	0.66	37.51
13/05/2022	43	19.74	7.9	Unavailable	0.7	39.81
14/05/2022	32	13.7	7.45	Unavailable	0.71	18.75
17/05/2022	23	9.78	7.82	18.53	0.63	22.43
19/05/2022	21	8.58	8.03	19.2	0.66	15.7
20/05/2022	23	8.99	2.26	14.86	0.74	34.45
21/05/2022	41	15.24	2.25	14.83	0.76	36.4
23/05/2022	59	25.85	2.92	14.23	0.95	25.59
24/05/2022	35	13.17	2.5	14.54	0.87	28.56
26/05/2022	45	25.34	2.27	14.72	0.84	35.45
27/05/2022	74	33.98	2.29	14.68	0.95	57.53

Station 2 (KTTP Township)

June	PM_{10}	$PM_{2.5}$	SO_2	NOx	CO	O_3
	Limit:100(µg/m3)	Limit:60(µg/m3)	Limit:80(µg/m3)	Limit:80(µg/m3)	Limit:2.0(µg/m3)	Limit:100(µg/m3)
01/06/2022	36	18.53	2.78	14.35	0.93	37.9
02/06/2022	41	18.16	2.21	14.51	0.74	62.67
03/06/2022	31	20.02	2.47	14.33	0.87	36.16
04/06/2022	52	18.86	2.13	14.91	0.76	68.33
06/06/2022	44	18.86	2.18	14.95	0.69	53.31
07/06/2022	27	16.75	2.08	14.92	0.74	67.1
08/06/2022	58	25.39	2.28	14.8	0.74	31.38
09/06/2022	38	15.98	2.11	14.9	0.72	63.1
10/06/2022	39	21.19	3.71	14.22	0.86	3.02
11/06/2022	39	15.6	2.32	14.77	0.84	40.45
14/06/2022	31	15.65	2.11	14.76	0.69	40.73
16/06/2022	19	5.91	2.15	14.78	0.71	36.13
17/06/2022	19	5.34	2.88	14.84	0.65	24.65
18/06/2022	15	6.12	2.14	14.97	0.64	31.15
20/06/2022	11	2.61	2.35	15.29	0.63	17.03
21/06/2022	11	6.71	2.66	14.79	0.77	24.17
22/06/2022	14	8.45	5.38	13.69	0.77	20.97
23/06/2022	24	7.89	2.54	14.79	0.73	42.93
24/06/2022	32	13.55	8.71	13.73	0.83	21.35
27/06/2022	24	6.59	2.25	14.86	0.62	24.26
28/06/2022	14	4.89	2.99	14.82	0.62	23.97
30/06/2022	25	8.12	3.31	14.32	0.67	21.95

Station 3 (Intake pump house)

April	PM_{10}	$PM_{2.5}$	SO_2	NOx	CO	O_3
	Limit:100(µg/m3)	Limit:60(µg/m3)	Limit:80(µg/m3)	Limit:80(µg/m3)	Limit:2.0(µg/m3)	Limit:100(µg/m3)
01/04/2022	46	14.33	4.25	16.78	0.54	16.66
02/04/2022	38	11.28	4.49	16.49	0.48	16.36
04/04/2022	37	10.73	4.96	16.58	0.49	15.8
07/04/2022	52	15.66	4.06	16.61	0.48	14.44
08/04/2022	41	13.43	4.81	16.45	0.52	16.4
09/04/2022	32	5.56	3.5	16.59	0.54	16.5
11/04/2022	31	5.46	4.91	16.56	0.53	15.46
12/04/2022	35	7.84	4.26	16.24	0.55	15.53
13/04/2022	32	7.77	3.86	16.42	0.47	16.38
16/04/2022	37	10.97	3.84	16.65	0.54	15.05
18/04/2022	57	11.46	3.75	16.49	0.49	15.13
19/04/2022	32	12.59	4.01	16.26	0.43	15.48
20/04/2022	28	6.25	3.86	16.55	0.47	16.41
21/04/2022	33	10.71	4.42	16.51	0.47	14.81
22/04/2022	34	6.39	4.82	16.46	0.61	15.2
23/04/2022	39	13.96	4.56	16.28	0.62	15.22
25/04/2022	62	21.32	3.98	16.46	0.72	15.87
26/04/2022	49	14.12	3.18	16.58	0.51	16.32
27/04/2022	48	13.34	4.08	16.04	0.8	15.76
28/04/2022	49	10.13	3.93	16.77	0.5	15.32
29/04/2022	42	14.28	3.59	16.53	0.59	15.67

Station 3 (Intake pump house)

May	PM_{10}	$PM_{2.5}$	SO_2	NOx	CO	O_3
	Limit:100(µg/m3)	Limit:60(µg/m3)	Limit:80(µg/m3)	Limit:80(µg/m3)	Limit:2.0(µg/m3)	Limit:100(µg/m3)
02/05/2022						
04/05/2022	35	21.46	5.48	16.84	0.63	Unavailable
05/05/2022	33	14.76	4.26	16.67	0.56	48.18
06/05/2022	23	13.43	5.24	16.46	0.62	71.96
19/05/2022	18	5.22	3.84	12.64	0.54	29.9
20/05/2022	27	5.9	4.01	8.34	0.48	44.75
21/05/2022	37	10.22	4	8.19	0.54	51.21
23/05/2022	62	24.77	5.88	9.76	0.78	58.53
24/05/2022	48	12.36	4	8.74	0.72	47.76
26/05/2022	52	22.78	4	8.35		
27/05/2022	90	25.24	4	8.63	Unavailable	3.43

Station 3 (Intake pump house)

June	PM_{10}	$PM_{2.5}$	SO_2	NOx	CO	O_3
	Limit:100(µg/m3)	Limit:60(µg/m3)	Limit:80(µg/m3)	Limit:80(µg/m3)	Limit:2.0(µg/m3)	Limit:100(µg/m3)
01/06/2022	41	19.11	4	9.42	0.6	41.17
02/06/2022	38	9.15	4	7.6	0.5	80.11
03/06/2022	40	21.75	4	8.52	0.65	56.65
04/06/2022	54	16.43	4	8.11	0.55	64.8
06/06/2022	48	12.62	4.98	8.1	0.35	55.68
07/06/2022	40	6.7	4.07	8.17	0.53	68.38
08/06/2022	54	19.3	4	7.38	0.61	50.62
09/06/2022	45	18.38	4	7.93	0.42	61.66
10/06/2022	36	12.19	4	8.63	0.55	43.38
11/06/2022	43	13.24	5.29	9.41	0.59	56.82
14/06/2022	33	8.85	4	8.08	0.53	57.66
16/06/2022	23	10.56	7.15	9.7	0.53	55.79
17/06/2022	22	11.01	4.25	8.22	0.46	40.59
18/06/2022	18	6.24	5.02	8.93	0.49	38.76
20/06/2022	21	6.05	6.39	8.93	0.46	35.24
21/06/2022	35	5.07	4.43	8.66	0.53	44.05
22/06/2022	16	7.11	4.75	9.16	0.52	34.01
23/06/2022	30	8.91	4.02	8.39	0.55	47.43
24/06/2022	33	10.6	4.22	8.5	0.46	31.69
27/06/2022	20	7.66	4.37	8.21	0.41	34.69
28/06/2022	22	7.63	4.7	8.35	0.44	31.68
30/06/2022	24	9.13	4.42	8.32	0.48	32.6