# Statistical analysis of air pollution status in various urban areas of Odisha

*A Thesis submitted to the*
*Odisha University of Agriculture and Technology*
*In Partial fulfilment of the requirement for the degree of*
*Master of Science in Agriculture*
*(Agricultural Statistics)*

**By**


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# CERTIFICATE-I

This is to certify that the thesis entitled **"Statistical analysis of air pollution status in various urban areas of Odisha"** submitted in partial fulfilment of the requirements for the award of the Degree of **MASTER OF SCIENCE IN AGRICULTURE (AGRICULTURAL STATISTICS)** of the Odisha University of Agriculture and Technology, Bhubaneswar is an authentic record of *bona fide* research work carried out by **HITESH KUMAR** under my guidance and supervision. No part of this thesis has been submitted for any other degree or diploma.

It is further certified that the evidence and help obtained by him from various sources during the course of investigation has been duly acknowledged.

Pradhan

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# CERTIFICATE -II

This is to certify that the thesis entitled **"Statistical analysis of air pollution status in various urban areas of Odisha"** submitted by **HITESH KUMAR, Adm. No. 191221411** to the Odisha university of Agriculture and Technology, Bhubaneswar in partial fulfilment of the requirements for the degree of **MASTER OF SCIENCE IN AGRICULTURE (AGRICULTURAL STATISTICS)** has been approved by the students' Advisory committee and the external examiner.

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# ABBREVATIONS USED

| | | |
|---|---|---|
| % | : | percentage |
| $\mu g/m^3$ | : | Microgram per cubic meter |
| AQI | : | Air Quality Index |
| EPA | : | Environmental Protection Agency |
| WHO | : | World Health Organisation |
| NAARS | : | National Ambient Air Quality Standards |
| VOCs | : | Volatile Organic Compounds |
| PM | : | Particulate Matter |
| $PM_{10}$ | : | Particulate matter (diameter 10 mm and less) |
| $PM_{2.5}$ | : | Particulate matter (diameter 2.5 mm and less) |
| $SO_2$ | : | Sulphur Dioxide |
| $NO_2$ | : | Nitrogen Dioxide |
| $O_3$ | : | Ozone |

# ABSTRACT

Air pollution is a major concern of new civilized world, which has a serious toxicological impact on agriculture, environment and human health. It has a number of different emission sources, but motor vehicles and industrial processes contribute the major part of air pollution. According to the World health organisation, major air pollutants include particle pollution, ground level ozone, sulphur dioxide and nitrogen oxide.

Air pollutants have a negative impact on plant growth primarily through interfering with resource accumulation which affect metabolic function of the leaves and interfere with the net carbon fixation by the plant canopy. Long and short-term exposure to air suspended toxicants has a different toxicological impact on human including respiratory and cardiovascular disease, neuropsychiatric complications, eye irritation, skin diseases and long-term chronic disease such as cancer. In this present study, data from the year 2016 to 2020 is collected from the State Pollution Control Board website over eight monitored stations across Odisha. The eight monitored stations have been grouped into three divisions namely northern division, central division and southern division on the basis of RDC. The objective of this thesis is to discuss the status of four air pollutants viz., $PM_{2.5}$, $PM_{10}$, $NO_2$, $SO_2$ in the above eight monitored stations using descriptive statistics such as mean, median, range, standard deviation, correlation, etc., also draws trendlines of the air pollutants over monitored stations. Besides this, effects of four air pollutants on human health and agriculture are studied.

# CHAPTER-1

# INTRODUCTION

# INTRODUCTION

Air pollution refers to pollutants in the atmosphere that are detrimental to humans and other living things, as well as causing climate change. There are various sorts of air contaminants, including carbon monoxide, sulphur dioxide, nitrous oxides, methane and chlorofluorocarbons.

## Major air pollutants

The following are some of the most frequent and dangerous pollutants found outdoors:

- Particulate matter ($PM_{2.5}$ and $PM_{10}$)
- Nitrogen dioxide ($NO_2$)
- Ground-level Ozone ($O_3$)
- Sulphur dioxide ($SO_2$)

### 1.1.1 Particulate matter (PM)

Particulate matter is a mixture of solids and liquids suspended in the air that includes carbon, complex organic chemicals, sulphates, nitrates, mineral dust, and water. PM comes in a variety of sizes. $PM_{10}$ denotes particles with a diameter of less than 10 microns or 100 times the diameter of a millimetre. Fine particles are defined as particles having a diameter less than 2.5 microns which are referred to as $PM_{2.5}$.

### 1.1.2 Nitrogen dioxide ($NO_2$)

Nitrogen dioxide is a gas that contributes significantly to urban air pollution. Vehicles, power plants, and heating are all man-made sources of nitrogen oxides, including nitrogen dioxide. In metropolitan areas, diesel cars are a big cause.

### 1.1.3 Ground-level Ozone ($O_3$)

Ozone is a gas made up of three oxygen atoms. It absorbs harmful UV light at the highest levels of the Earth's atmosphere. Ozone is created near the ground by a chemical reaction involving the sun's rays, organic gases, and nitrogen oxides released by autos, power plants, chemical plants and other sources.

### 1.1.4 Sulphur dioxide ($SO_2$)

Sulphur dioxide is a colourless gas with a stifling, unpleasant odour. It's made when sulphur-containing fuels like coal and oil are burned. This covers transportation, energy generation, and heating. Electric industries that burn fossil fuels, as well as petrol refineries and cement manufacture produce the majority of sulphur dioxide.

## 1.2 Effects of air pollutants on human health

On a daily basis, enormous amounts of air pollutants are emitted. It should come as no surprise that such emissions pollute the air and pose a major hazard to human health. You inhale millions of air pollutants with every breath you take. A few detrimental impacts of air pollution on the human body are listed below.

- High Risk of Hypertension in Women
- Cardiovascular and Heart Problems
- Neurological and Birth Problems

## 1.3 Effects of air pollutants on agriculture

Agricultural crops are affected by air pollutants. Some of the most important air pollutants currently causing direct damage to crops are Sulphur dioxide ($SO_2$), Nitrogen oxide ($NO_x$), Ozone ($O_3$), Suspended particulate matter (SPM).

Due to higher concentration of various air pollutants, agricultural crops are affected. Injury ranges from visible markings on the foliage, reduced growth and yield, and premature death of the plant. The severity and development of the injury depend on pollutant concentration and a number of other external factors. These factors include a length of exposure to the plant, plant species, and its stage of development, as well as other environmental factors conducive to a build-up of the pollutant and to the preconditioning of the plant which make it either susceptible or resistant to injury.

## 1.4 Air Quality Index (AQI)

The term "air quality" refers to the condition of the air around us. The term "good quality" refers to air that is clean, clear, and unpolluted. Consider the AQI as a scale of 0 to 500. The higher the AQI value, the greater the level of air pollution and the greater the health risk. For example, an AQI of 50 or less indicates healthy air quality, while an AQI of 300 or above indicates harmful air pollution.

There are six categories in the AQI. Each category represents a different amount of risk to one's health. Each category has its own colour scheme. People may immediately identify whether the air quality in their neighbourhood has reached an unsafe level by using colour.

## 1.5 Effects of air pollution on urbanization

Cities have been built by humans for thousands of years, but the global move from rural to urban living has been a defining trend over the last century or so. Even though the extent and velocity of current urbanisation - in terms of the combination of demographic, economic, and ecological changes that make cities what they are - is unprecedented. More than half of us now live in cities, and the number of urban people will increase by three billion by the end of the century. Although megacities with tens of millions of people are frequently in the spotlight, the majority of urban growth is predicted to occur in small and medium-sized cities with populations of a million or less. According to a recently released study, the main sources of particulate matter contributing to city air pollution include transportation (25%), combustion and agricultural (22%), home fuel burning (20%), natural dust and salt (18%), and industrial activities (15%).

Odisha State is the 25th most urbanised and 5th least urbanised state in India, according to 2001 Census urbanisation trends, with 14.97 percent of the population living in cities. During the last decade (1991-2001), urban decadal growth was massive, with a growth rate of around 30.28 percent, almost matching the country's urban decadal growth rate of 32.60 percent. Odisha's urban population of 5517238 people (as per the 2001 census) is dispersed throughout 138 towns and cities. It is worth noting that Odisha's population has expanded by roughly 14% in the last decade, whereas the urban population has grown at about double the rate.

In this thesis, the following objectives have been taken to study the status of air pollution of eight monitored stations in various urban areas of Odisha using the secondary of year 2016 to 2020.

- To study the status of air pollutants in various urban areas of Odisha using multiple statistical tools from 2016 to 2020
- To study the trend lines of four air pollutants in the selected urban areas of Odisha using the data of the last five years
- To study the effects of air pollution on human health and agriculture
- To study the combined effects of four air pollutants on air pollution using appropriate statistical tools

# CHAPTER 2

# REVIEW OF LITERATURE

# REVIEW OF LITERATURE

In this chapter, we are briefly highlighting the research work carried out by different researchers in different time periods relevant to our research. Selection of appropriate analytical procedures is also strengthened through a review of pertinent literature. Moreover, it helps the researcher to formulate objectives and develop a hypothesis.

Ilangovan and Vivekanandan (1991) studied that as a result of continuous aqueous effluent irrigation in about 25 acres of a crop field, an oil compound infiltrated up to 50 cm depth of the soil. In oil-polluted soil, respiration was always higher than that the uncontaminated soil. The total hydrocarbon content of the polluted soil was quantified by infrared spectrophotometric technique. A significant correlation was observed between oil concentration (total hydrogen) in the upper layer of the soil (0-25 cm) and air temperature. Seed germination, percentage of seedling emergence, number of root nodules/plants, leghaemoglobin content in root nodules, total soluble sugars, total soluble protein, free amino acid, total chlorophyll and carotenoids, and the nucleic seed of the lives of vigana mungo (L) pepper grown in the polluted soil decrease significantly due to persistence of hydrocarbon. The total phenol content of the leaves in the polluted plant increased significantly.

M. R. Ashmore (1991) studied that air pollution was a primary problem of urban and industrial regions. In the last three decades, changes in the dispersal of pollutants and increases in motor vehicle emissions have led to greater pollutant impacts in more remote rural areas. On a national scale in North America and Western Europe, current losses of agricultural production due to air pollutants are small relative to other factors, but local impacts on sensitive crops may be substantial. Current international trends suggest that now, and in the near future, the greatest concern should be over impacts on agriculture in newly industrialized and developing countries, rather than in those countries where most research effort is currently concentrated.

Ashmore *et al.* in the year 1995 studied Open-top chambers ventilated with ambient or charcoal-filtered air were used to assess the impact of air pollution on the yield of local cultivars of wheat and rice, at a site on the outskirts of Lahore. At this location, 6-h mean $O_3$ concentrations reach 60 ppb in certain months, and annual mean $NO_2$ concentrations are 20–25 ppb. The experiments showed significant yield reduction in two successive seasons which ranged from 33% to 46% in wheat and from 37% to 51% in rice. The major yield parameter affected was the number of ears or panicles per plant, although there was also evidence of small effects on 1000 grain weight and the number of grains per ear/panicle. These results have significance in terms of the maintenance of agricultural yields as pollution emissions rise in the south and south-east Asia.

Mukherjee *et al.* (2003) studied that Anugul - Talcher belt in Central Orissa, having a number of industries contributes to a great extent of deterioration in the air quality of the surrounding villages. Previous reports showed higher SPM, $SO_2$, NO, levels in air and prevalence of respiratory illness, skin and teeth disorders among village population. Higher ground water fluoride, urine and serum fluoride among the cattle were also reported in some villages. Present study reports SPM, $SO_2$, $NO_x$ and Fluorides (gaseous and Particulate) in ambient air around aluminium smelter during February and August 1996. High volume sampling technique for SPM and the standard colorimetric methods (BIS) for analyses of $SO_2$ and $NO_x$ were adopted. Fluoride in air and water were estimated by standard fluoride ion selective electrode method. Higher SPM, $SO_2$ and $NO_x$ values than prescribed CPCB standard were obtained in February. Gaseous fluoride in village air were varied between 1.66 - 7.64 mg/m3 in February and 1.11 - 22.75 mg/m3 in August, whereas particulate fluoride ranged between, 0.054 - 19.61 mg/m3. Water sources of the villages near the smelter showed fluoride values above permissible limit. The study indicated higher fluoride pollution in air and water of the surrounding villages.

Kampa & Castanas (2008) observed through the data that due to air pollution human health also gets affected. Hazardous chemicals escape to the environment by a number of natural and/or anthropogenic activities and may cause adverse effects on human health. Air pollution has both acute and chronic effects on human health, affecting a number of different systems and organs. It ranges from minor upper respiratory irritation to chronic respiratory and heart disease, lung cancer, acute respiratory infections in children, and chronic bronchitis in adults, aggravating pre-existing heart and lung disease, or asthmatic attacks.

Mina, Singh, & Chakrabarti (2013) observed that problem of air pollution has attracted special attention in India due to the tremendous increase in the size of population, industrialization, and urbanization since the last few decades. Air pollutants emitted in varying forms adversely affect the growth and yield of crops. In comparison climatic change is estimated to cause global crop losses totalling approximately just US $5 billion per year.

Chaudhari *et al.* in the year 2014 studied the Mann-Kendall trend of pollutants, temperature and humidity over an urban station of Kolkata with forecast verification using different ARIMA models. They reported the trend of atmospheric pollutants and meteorological parameters with Mann-Kendall trend analysis reveals a seasonal and monthly variability over an urban station of Kolkata. The relationship between aerosol concentration and distribution of anthropogenic pollution were examined. They also reported that the ARIMA model of the order (0,2,2) is found to be best to fit the time series which is used to forecast the daily concentration of different atmospheric pollutants and meteorological parameter.

Puri *et al.* in the year 2017 observed that the increase in air pollution over the years has had major effects on the human skin. Exposure to ultraviolet radiation has been associated with extrinsic skin aging and skin cancers. Cigarette smoke contributes to premature aging and an increase in the incidence of psoriasis, acne and skin cancers. It is also implicated in allergic skin conditions such as atopic dermatitis and eczema. Polyromantic hydrocarbons are associated with extrinsic skin aging, pigmentation, cancers and acneiform eruptions. Volatile organic compounds have been associated with atopic dermatitis. Given the increasing levels of air pollution and its detrimental effects on the skin, it is advisable to use strategies to decrease air pollution.

Kumar and Dash (2018) studied about different methods that have been designed to calculate the air quality index in form of mathematical formula. But the formula designed by Central Pollution Control Board in 2014 is more robust to find out the air quality category. The index has been calculated based upon four parameters like particulate matters ($PM_{10}$, $PM_{2.5}$), sulphur oxide and nitrogen oxide. The study area was affected by different sources like point, line and volume. In the present research, monitoring of ambient air quality has been carried out for a period from March 2013 to February 2016 for three years. It has been revealed from the study that the air quality status of the area has been declining i.e. 78.9 to 157.8 in summer, 49.4 to 84.3 in monsoon and 86.9 to 183.9 in winter season. It has also been found that, $PM_{10}$ and $PM_{2.5}$ were responsible for maximum sub-index as well as air quality index. During the study period 2015-16, out of the eight stations most comes under moderately polluted category especially in winter season followed by summer season. Statistical and Duncan's multiple range tests has been applied to the results with two-way and one-way analysis of variance based on different seasons and stations. In two-way analysis of variance, F-value was computed to be 30.105 based on seasons and stations and one-way analysis of variance test shows the F-values as 186.07 and 18.97 based on seasons and stations respectively which is found to be significant ($P<0.01$). The research is important to assess the environmental quality of a mining- industrial complex area and can be a reference for similar study in other areas.

Tiwari and Khilnani (2018) review describes the current status of air pollution in India, summarizes recent research on adverse health effects of ambient and household air pollution, and outlines the ongoing efforts and future actions required to improve air quality and reduce morbidity and mortality because of air pollution in India. Global burden of disease data analysis reveals more than one million premature deaths attributable to ambient air pollution in 2015 in India. More than one million additional deaths can be attributed to household air pollution. Particulate matter with a diameter of 2.5 μm or less has been causatively linked with most premature deaths. Acute respiratory tract infections, asthma, chronic obstructive pulmonary disease, exacerbations of pre-existing obstructive airway disease, and lung cancer are proven adverse respiratory effects of air pollution. Targeting air quality standards laid by WHO can significantly reduce morbidity and mortality because of air pollution in India.

Bashir *et al.* in the year 2020 studied Spearman and Kendall correlation tests to analyse significant correlation with the COVID-19 epidemic and normal condition and evaluated the correlation between environmental pollution determinants and the COVID-19 outbreak in California by using the secondary published data from the Centres for Disease Control and the Environmental Pollution Agency (EPA) Spearman and Kendall correlation tests have been employed to analyse the association of $PM_{2.5}$, $PM_{10}$, $SO_2$, $NO_2$, Pb, VOC, and CO with COVID-19 cases in California. Our findings indicate that environmental pollutants such as $PM_{10}$, $PM_{2.5}$, $SO_2$, $NO_2$, and CO have a significant correlation with the COVID-19 epidemic in California.

# CHAPTER- 3
# MATERIAL AND METHODS

# MATERIAL AND METHODS

## 3.1 Period of study

The study period spans five years, from 2016 to 2020, and the data gathered includes air pollutants such as $SO_2$, $NO_2$, $PM_{2.5}$, and $PM_{10}$ for the study.

## 3.2 Sources of data collection

Secondary data has been collected from Odisha State Pollution Control Board, Bhubaneswar (OSPCB) website to study the status of air pollution of eight monitored stations of Odisha. These eight monitor stations have been grouped into three zones on the basis of Revenue Divisional Commissioners of Odisha. All of these data were collected year by year from the period of 2016-2020.

## 3.3 Monitored stations

- Kalinganagar (Jajpur)
- Bhubaneswar (Khorda)
- Paradeep (Jagatsinghpur)
- Jharsuguda (Jharsuguda)
- Rourkela (Sundargarh)
- Talcher (Anugul)
- Berhampur (Ganjam)
- Rayagada (Rayagada)

### 3.3.1 Information about monitored stations

**Kalinganagar:** Kalinganagar is located in Jajpur district of Odisha. Kalinganagar is a planned industrial and modern town in Jajpur district of coastal Odisha, India. It is rich in iron ore. Kalinganagar is a global steel hub of international business and commerce, and is also one of the best industrial complexes, with various manufacturing businesses and organisations, which contribute to the growth of India's economy. It is located at latitude 200 45’ N and longitude 850 50’ E. It has an average elevation of 51 m (167 ft) above mean sea level. According to Indian standards, the climate of Jajpur District is typical. The yearly rainfall is around

1014.5 millimetres. According to 2011 census of India, Total Kalinganagar population is 49,415 of which 25,061 are male and 24,354 are female. Jajpur District has the third best conditions for agricultural growth. Rice is cultivated in two distinct seasons: Kharif and Dalua. The most significant rice season is Kharif. The primary crop, Kharif rice, covers approximately 85 percent of the total rice acreage and is totally dependent on the southwest monsoon. It is planted in June and harvested in October–December, depending on the length of the cultivation and the field's terrain. The dalua (summer) crop grows throughout the dry season and is completely reliant on irrigation. The irrigation water comes from a tank. The dalua season runs from December to January and then again from April to May. During this season, farmers exclusively plant high–yielding cultivars.

**Bhubaneswar:** Bhubaneswar is the capital city of Odisha, which is located in Khordha district of Odisha. It is located along the axis of the Eastern Ghats Mountains on the eastern coastal lowlands. The city is 45 metres (148 feet) above sea level on average. Within the Mahanadi River's delta, it sits southwest of the Mahanadi River, which defines the northern limit of the Bhubaneswar metropolitan region. Bhubaneswar is bordered on the south by the Daya River and on the east by the Kuakhai River; the Chandaka Wildlife Sanctuary and Nandankanan Zoo are located in the city's western and northern sections, respectively. According to 2011statistics, the total population of Bhubaneswar region is 886,397. The male population of which is 468,577 while female population is 417,820. Topographically, Bhubaneshwar is split into two Terai regions: western upper and eastern Terai, with hills in the western and northern parts. Lake Kanjia, on the outskirts of town, is a nationally significant wetland with a diverse ecosystem. The soil of Bhubaneshwar is 65% percent laterite, 25% alluvial, and 10% sandstone. On a scale of I to V, the Bureau of Indian Standards places the city in Seismic Zone III, the most vulnerable to earthquakes. Winds and cyclones provide a "very high damage risk," according to the United Nations Development Program. The 1999 Odisha cyclone wreaked havoc on buildings and city infrastructure, as well as taking numerous lives. Flooding and water logging have become prevalent in low-lying areas due to unplanned construction.

**Paradeep:** Paradeep is located in Jagatsinghpur district of Odisha. It is India's most important maritime port for trade. It is located on the Bay of Bengal at a latitude

20° 55.44' N and a longitude 86°34.62' E. Paradeep is a hub of industrial activities. The city has a population of 73,633 where male constitute 58% of the population and female constitute 42% of the population. The hypnotic beauty of the sea, a great sea beach and sea drives, estuaries, and evergreen forests of the islands near the mouth of the Mahanadi River all contribute to this location's popularity as a tourist destination. The sea vessels and massive ore adds more to the tourist's enjoyment. The crops grown here in the Kharif season are rice, vegetables, fallow and spices. The crops grown in the rabi season are rice, pulses, fallow, oilseeds, vegetables and spices.

**Jharsuguda:** Jharsuguda is the district headquarters of Jharsuguda district which is one of Odisha's most industrially developed cities. It is surrounded by different mines. According to the 2011 census, Jharsuguda district had a population of 579,505. The district of Jharsuguda has a total size of 2,081 square kilometres. The district is located between the latitudes of 21.82 degrees north and 84.1 degrees east. Summers in the Jharsuguda district are hot and dry. In the month of May, the highest temperature is 42 degrees. The district's average rainfall is 1500 mm. The wind blows from the south and southwest from April to August, and from September to October, the wind blows from the northwest. A radish stony soil covers the majority of the land area in the mountainous region. Plains with brownish black soil are ideal for paddy and vegetable cultivation. The soil along the riverbanks and in the delta area is sandy, making it ideal for growing rice, sugarcane, and groundnuts. Some areas of the Lakhanpur block are noted for its ginger growing, which they export in large quantities to other nations.

**Rourkela:** Rourkela, an industrial township in Odisha, is often recognised as the state's commercial centre. It is located in the district of Sundergarh. Iron and steel production is a large part of the city's economy. Steel Authority of India Limited (SAIL), one of the country's major steel mills, is located here. The city has a population of 4, 84,292 people according to the 2001 India census. In the same year, there were 835 females for every 1000 males. Summers are quite hot, with maximum temperatures reaching 45 °C, while winters are very chilly due to the impact of the sea. Rainfall occurs throughout the monsoon season, which lasts from June to September. The weather is typically hot and humid. Rourkela has a tropical climate with heavy rains during the Southwest monsoon (June–September) and the receding

Northeast monsoon (December–January). Rainfall averages between 160 and 200 cm each year. During the coldest and hottest months, the minimum and maximum temperatures vary from 5 to 49.7 degrees Celsius, with a mean minimum and maximum temperature range of 12.0 to 31.5 degrees Celsius. Semi-evergreen or tropical dry deciduous forest covers 36 percent of the district's geographical area.

**Talcher:** Talcher, popularly known as Odisha's Coal City, is one of the state's fastest developing industrial and coal centres. The city has been ranked among the highest in terms of GDP in Odisha due to its vast coal deposits. It comes under Anugul district of Odisha. As of 2011 India census, Talcher had a population of 40,841. Males constitute 55% of the population and females 45%. The city is bordered by MCL (Mahanadi Coalfields Limited) coalfields and has two mega power plants, NTPC and TTPS. Anugul district has a wide range of climate conditions. The district's average annual rainfall is 1421 mm and it varies greatly from year to year. Rainfall in the district has varied between 896 mm and 1744 mm over the previous ten years. Winter is the ideal time to visit this region. Agriculture, according to the 2001 India census, plays a significant role in the economy of Anugul district, providing direct and indirect employment to around 70% of the district's total workforce. This district's entire cultivable land is 216403 hectares, or 32.7 percent of the overall geographical area. The major crops of Kharif season are paddy, maize, ragi, oilseeds, pulses, small millets and vegetables etc. Wheat, Maize, Pea, Sunflower, Garlic, Ginger, Potato, Onion, Tobacco, Sugarcane and Coriander etc are the major Rabi crops.

**Berhampur:** Berhampur is a city in the state of Odisha, located on the eastern shore of Ganjam district. Berhampur, popularly known as the "Silk City”. Berhampur is located around 169 kilometres south of Bhubaneswar, the state capital of Odisha. According to 2011 census, the city has a population of 355,823 making it the state's fourth most populated metropolitan metropolis. Ganjam district is located between 19.4 and 20.17 north latitude and 84.7 and 85.12 east longitude. It has an area of 8070.60 square kilometres. The coastal lowlands in the east and the hills and tablelands in the west divide the region roughly in half. The Eastern Ghats stretch along the district's western border. Ganjam's climate is characterised by consistent temperatures throughout the year, especially around the shore. From December to

February, the area has cold weather, followed by hot weather from March to May. Agriculture has long been a traditional vocation and way of life for the people of Ganjam. The rich soil and agricultural output of the area are well-known. Paddy, groundnuts, sugarcane, oilseeds, ragi, moong, beeri, and other crops are cultivated here. Due to its agro-climatic conditions, Ganjam is classified as an agricultural district.

**Rayagada:** Rayagada is the city located in the district of Rayagada which is the most well-known region in the state because of its lengthy human history. It possesses magnificent historical documents from copper plates, rock inscriptions, and different coins, all of which plainly show that the region was a popular tourist destination throughout history. According to the 2011 census, the population of Rayagada town is 71,208 people, with 36,036 men and 35,172 women. The climate of Rayagada is tropical. The summers here have a good deal of rainfall, while the winters have very little. The average annual temperature in Rayagada is 25.5 °C. The annual rainfall is 1527 mm. It was ruled by the Kalinga Empire in the 3rd century BCE, under the reign of Ashoka the Great. the mountainous territory between the Languli River and the Prachi language, such as Banasdhara and Nagabali, was known for spices. Rayagada district comes under North Eastern Ghat Zone characterized by hot, moist and sub-humid climate and consists of brown forest, lateritic, Red alluvial, Black and mixed Red Soil groups. Over 10,000 farmers in the region grow short duration paddy during monsoon and 33 varieties of millets, pulses, sorghums, maize, niger, sesame, tubers, spices and vegetables on the upland.

## 3.4 Selection of data

According to the Revenue Divisional Commissioner, the state has been split into three divisions. From this three RDC zones, eight monitored stations are selected purposefully. The data has been collected year by year for the period of 2016-2020 from Odisha State Pollution Control Board, Bhubaneswar (OSPCB) website pertains to four primary pollutants i.e., $PM_{2.5}$, $PM_{10}$, $SO_2$, $NO_2$.

## 3.5 Descriptive statistics:

The basic characteristics of the data in a study are described using descriptive statistics. They give quick summaries of samples and measurements. They are the foundation of almost every quantitative data analysis, along with simple graphics analysis. Inferential statistics and descriptive statistics are usually distinguished. One can simply state what the data is or show it with descriptive statistics. With approximate data, attempt can be made to draw conclusions for the data that go beyond hand. For example, we use inference statistics to try to infer what a population might think based on sample data, we use estimation data to judge the probability that the observed difference between groups is a confounding one or one that would have occurred by chance in this study. As such, we use inferential statistics to make estimates from our data under more normal circumstances; we use descriptive statistics only to describe what is happening in the given data.

### 3.5.1 Measures of Central Tendency

One of the most important objectives of statistical analysis is to get one single value that describes the characteristic of the entire mass of unwieldy data. Such a value is called the central value is very commonly used in day-to-day conversation. For example, we often talk of average boys in a class, average height or life of an Indian, average income, etc. There are three major types of estimates of central tendency:

- Mean
- Median
- Mode

The most common method for describing central tendency is the mean average. Its value is obtained by adding together all the item and by dividing this total by the number of items. The median by definition refer to the middle value in a distribution. In case of median one-half of the item in the distribution have a value the size of the median value or smaller and one-half have a value the size of the median value or larger.

The median is useful for distributions containing open-end interval since these do not enter its computation. Also since the median is effected by the number rather than size of item, it is frequently used instead of the mean as a measure of central tendency in cases where such values are likely to distort the mean.

## 3.5.2 Measures of Dispersion

The various measures of central value give us one single figure that represents the entire data. But the average alone cannot adequately describe a set of observations, unless all the observations are the same. It is necessary to describe the variability or dispersion of the observation. Since measures of dispersion give an average of the differences of various items from an average, they are also called averages of the second order

### 3.5.2.1 Range

Range is the simplest method of studying dispersion. It is defined as the difference between the value of the largest and the value of the smallest included in the distribution.

$$Range = Maximum\ value - Minimum\ value\ in\ the\ series$$

### 3.5.2.2 Standard deviation

Standard deviation tells how the data is spread in a distribution. It is a measure of how far each observed value is from the mean. In any distribution, about 95% of values will be within 2 standard deviations of the mean.

It can, however, be done using the formula below, where x represents a value in a data set, μ represents the mean of the data set and N represents the number of values in the data set.

$$SD(\sigma) = \sqrt{\frac{\sum_{i=1}^{N}(x_i - \bar{x})^2}{N}}$$

Take enough samples from a population, the means will be arranged into a distribution around the true population mean. The standard deviation of this distribution, i.e., the standard deviation of sample means, is called the standard error. The standard error tells you how accurate the mean of any given sample from that population is likely to be compared to the true population mean. When the standard error increases, i.e., the means are more spread out, it becomes more likely that any given mean is an inaccurate representation of the true population mean. Standard error can be calculated using the formula below, where σ represents standard deviation and n represents sample size.

$$SE = \frac{\sigma}{\sqrt{n}}$$

Standard error increases when standard deviation, i.e., the variance of the population, increases. Standard error decreases when sample size increases – as the sample size gets closer to the true size of the population, the sample means cluster more and more around the true population mean.

### 3.5.2.3 Variance

The average of the square of the deviations taken from mean is called variance. The population variance is generally denoted by $\sigma^2$ and its estimate (sample variance) by $s^2$. For N population values $X_1$, $X_2$,…. $X_N$ having the population mean is the population variance. As estimate of $\sigma^2$ is based on n sample value $x_1$, $x_2$,…$x_n$ the sample variance

$$(s^2) = \frac{1}{n-1}\sum_{i=1}^{n}(x_i - \bar{x})^2$$

$$(\sigma^2) = \frac{1}{N}\sum_{i=1}^{N}(x_i - \mu)^2$$

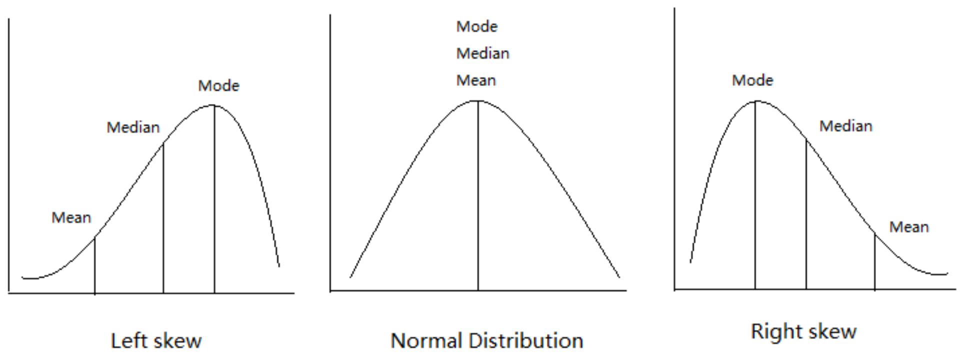
Where $\mu = \sum_{i=1}^{N} x_i/N$

## 3.6 Skewness

Skewness is the measure of asymmetry in a probability distribution. It might be either positive, negative, or undefined. Positive Skew occurs when the right side of the curve's tail is larger than the left side. The mean is bigger than the mode in these distributions. Negative Skew occurs when the curve's tail on the left side is larger than the curve's tail on the right. The mean is smaller than the mode in these distributions.

The most commonly used method of calculating Skewness is

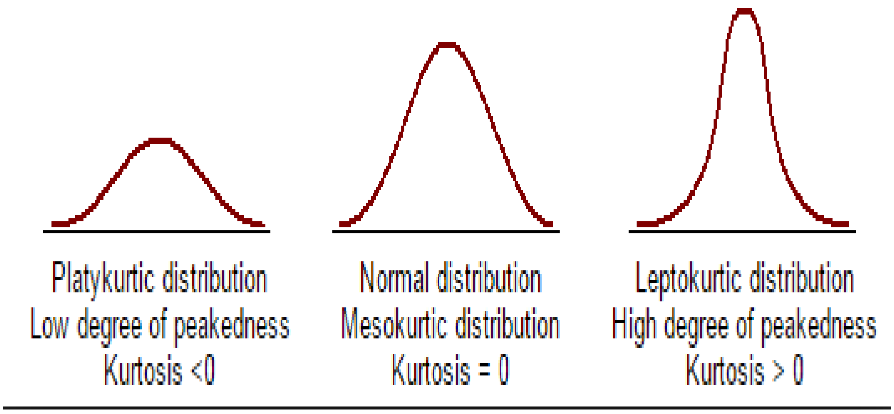
$$Skewness = \frac{3(Mean - Median)}{standard\ deviation}$$




## 3.7 Kurtosis

When compared to a Normal distribution, Kurtosis describes whether the data is less peaked or more peaked. Kurtosis is divided into three types:

- Mesokurtic- Similar to normal distributions, this is the case when the kurtosis is zero.
- Leptokurtic-When the curve is more peaked and when the kurtosis is higher than the normal distribution, the distribution is said to be leptokurtic.
- Platykurtic- When the curve is less peaked and the kurtosis is lower than the normal distribution, the distribution is said to be platykurtic.




## 3.8 Correlation

The linear relationship or association between two series X and Y is measured by calculating a coefficient, which is called the coefficient of correlation, usually denoted by the symbol r. This coefficient is a pure number and is free from the unit of measurement of both unit measurement of both the variables.

Karl Pearson in 1890 defined measures of relationship given by the formula

$$r_{xy} = \frac{E(x-\bar{x})E(y-\bar{y})}{\sqrt{E(x-\bar{x})^2E(y-\bar{y})^2}}$$

$$= \frac{Cov\ (x,y)}{\sqrt{Var(x)Var(y)}}$$

# CHAPTER 4

# RESULTS AND DISCUSSION

# RESULTS AND DISCUSSSION

In this section of the study, pollutant data are collected from various monitored stations and are analysed using various statistical tools, graphs, and tables to investigate the status of pollutants in various divisions.

**Table 4.1:** List of monitored stations on revenue division and districts

| Northern Division | Central Division | Southern Division |
|---|---|---|
| 1. Bhubaneswar (Khorda)<br>2. Paradeep (Jagatsinghpur)<br>3. Kalinganagar (Jajpur) | 1. Rourkela (Sundargarh)<br>2. Talcher (Anugul)<br>3. Jharsuguda (Jharsuguda) | 1. Rayagada (Rayagada)<br>2. Berhampur (Ganjam) |

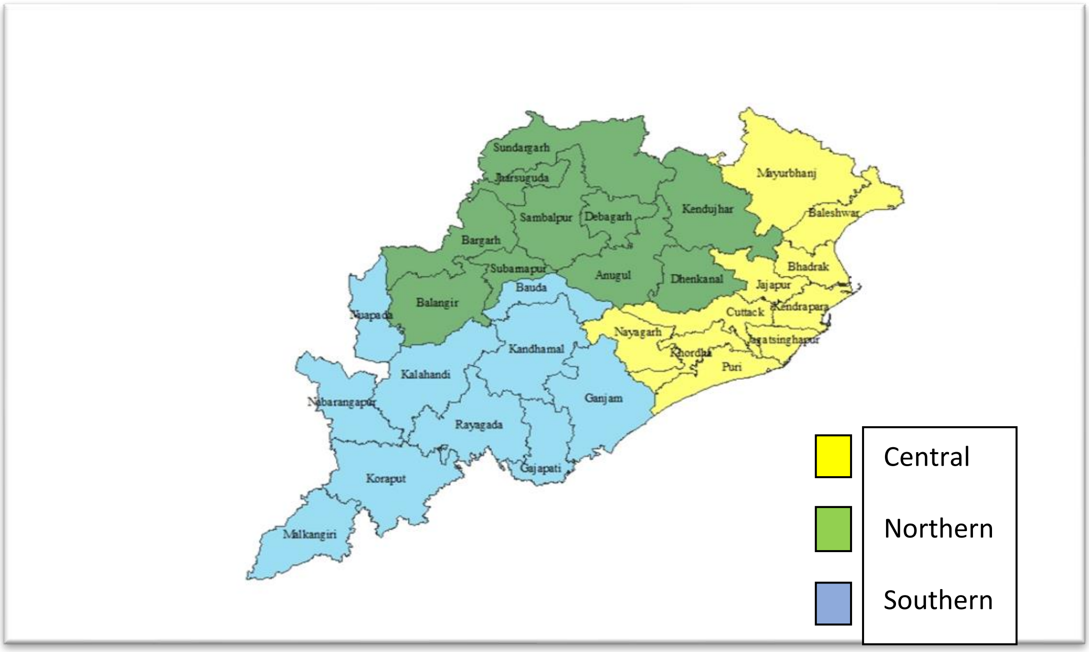



**Figure 4.1:** Map of Odisha as per Revenue Divisional Commissioner (RDC)

**Table 4.2:** Data of $NO_2$ (μg/$m^3$) recorded at various monitored stations representing annual average urban areas (2016–20)

| Monitored stations/Year | 2016 | 2017 | 2018 | 2019 | 2020 |
|---|---|---|---|---|---|
| **Talcher** | 30 | 38 | 35 | 35 | 27.1 |
| **Berhampur** | 24 | 24 | 24 | 24 | 16.5 |
| **Bhubaneswar** | 24 | 23 | 21 | 20 | 14.3 |
| **Jharsuguda** | 25 | 21 | 20 | 18 | 11.7 |
| **Kalinganagar** | 6 | 6 | 13 | 21 | 17.7 |
| **Paradeep** | 17 | 18 | 14 | 12 | 11.5 |
| **Rayagada** | 26 | 24 | 23 | 21 | 15.1 |
| **Rourkela** | 15 | 17 | 18 | 17 | 11 |

**Table 4.3:** Parametric values of $NO_2$ for monitoring stations (2016-20)

| Monitored Stations/Year | Talcher | Berhampur | Bhubaneswar | Jharsuguda | Kalinganagar | Paradeep | Rayagada | Rourkela |
|---|---|---|---|---|---|---|---|---|
| **Mean** | 33.02 | 22.50 | 20.46 | 19.14 | 12.74 | 14.50 | 21.82 | 15.60 |
| **Median** | 35.00 | 24.00 | 21.00 | 20.00 | 13.00 | 14.00 | 23.00 | 17.00 |
| **Minimum** | 27.10 | 16.50 | 14.30 | 11.70 | 6.00 | 11.50 | 15.10 | 11.00 |
| **Maximum** | 38.00 | 24.00 | 24.00 | 25.00 | 21.00 | 18.00 | 26.00 | 18.00 |
| **Range** | 10.90 | 7.50 | 9.70 | 13.30 | 15.00 | 6.50 | 10.90 | 7.00 |
| **Standard Deviation** | 4.38 | 3.35 | 3.79 | 4.88 | 6.78 | 2.92 | 4.17 | 2.79 |
| **Skewness** | -0.48 | -2.24 | -1.32 | -0.74 | 0.10 | 0.26 | -1.26 | -1.50 |
| **Kurtosis** | -1.36 | 5.00 | 1.94 | 1.40 | -2.44 | -2.65 | 1.83 | 2.04 |

a) It is observed from above table that mean value (33.02µg/m$^3$) of concentration of nitrogen oxide of Talcher is highest, while Kalinganagar exhibits lowest (12.74µg/m$^3$).

b) It is noticed that concentration of nitrogen oxide in Kalinganagar shows more scattered (6.78) than other stations.

c) Table 4.3 shows that out of 8 monitored stations, Kalinganagar has lowest emission (6µg/m$^3$).

d) It is observed that in table 4.3, Talcher (38µg/m$^3$) has the highest nitrogen oxide measurement out of the 8 monitored stations.

e) It is noticed from table 4.3 that out of 8 monitored stations, 5 monitored stations are highly or moderately skewed and only 3 monitored stations are approximately symmetric.

1. **Pie Chart:** Out of the eight monitored station Talcher has produce maximum emission during year 2016 to 2020 for that purpose we have constructed a pie chart over the year 2016 to 2020 present below:

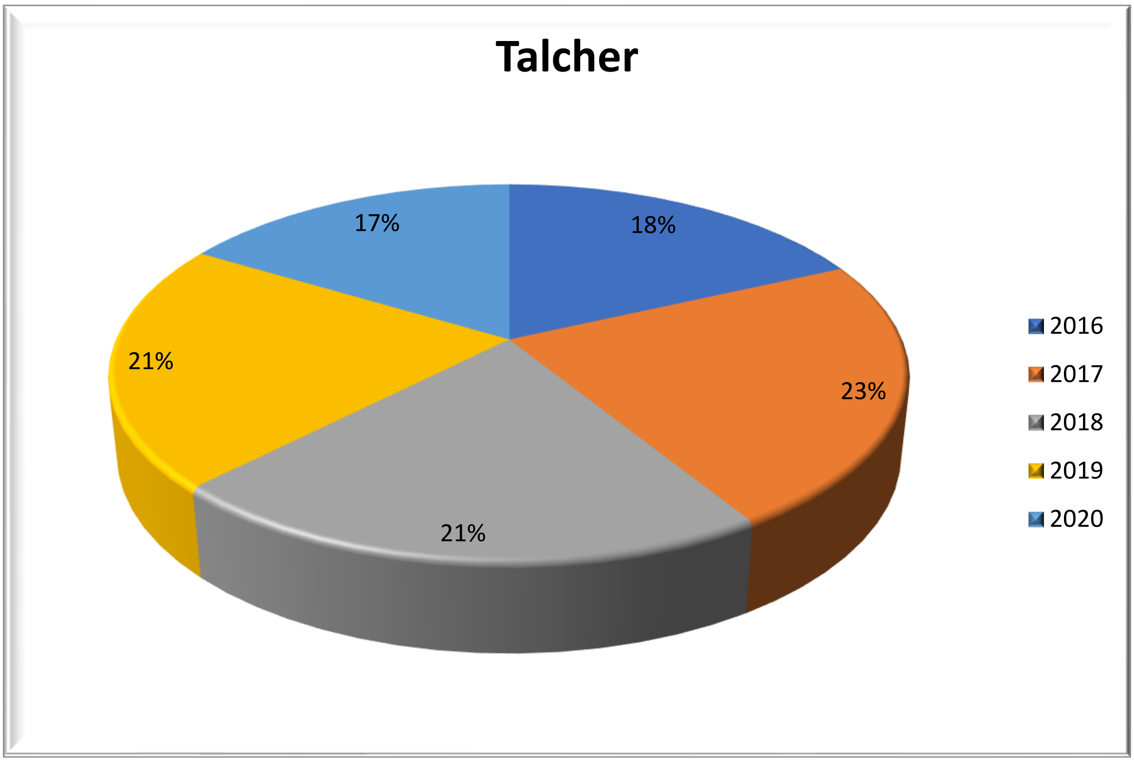



**Figure 4.2:** Distribution of $NO_2$ (2016-2020)

It is seen from figure 4.2 that in the year 2017 has maximum emission in Talcher and minimum emission in 2016.

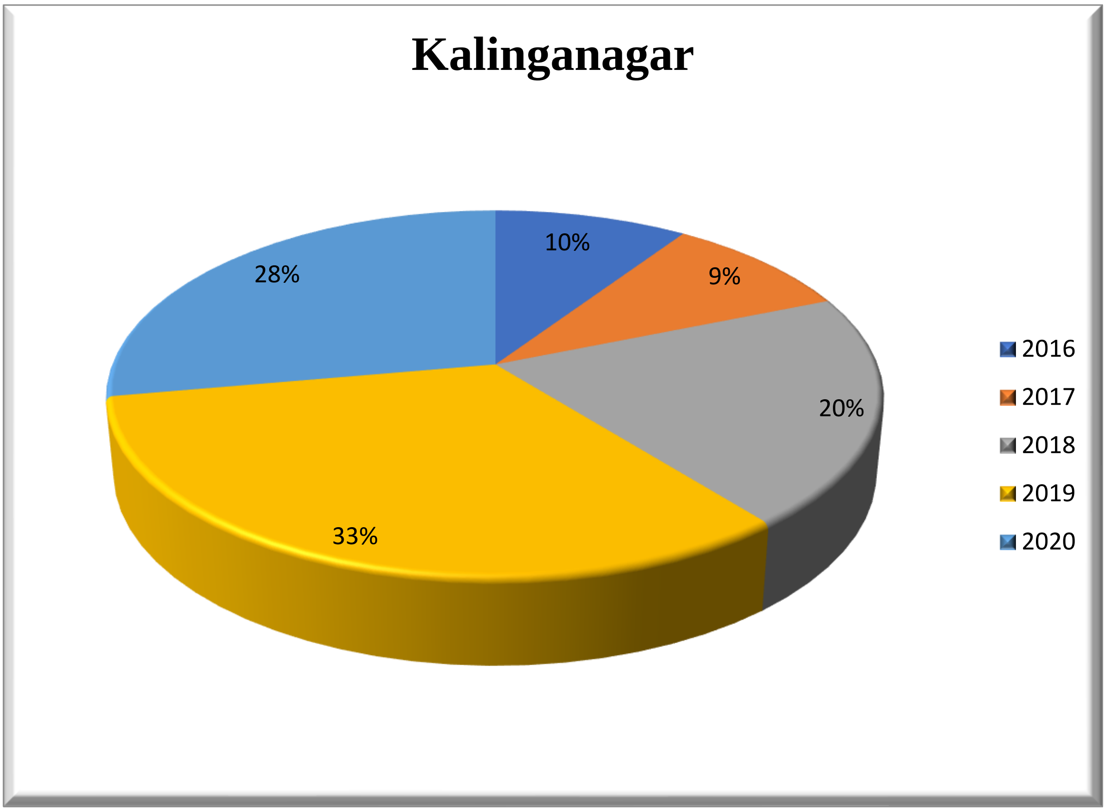



**Figure 4.3:** Distribution of $NO_2$ (2016-2020)

It is seen from the figure 4.3 that in the year 2019 has maximum emission in Kalinganagar while in 2017 has minimum emission of nitrogen oxide.

**2. Correlation:** To study the association between Talcher and Kalinganagar we have computed correlation coefficient which is presented below;

**Table 4.4:** Correlation between Talcher and Kalinganagar

| **Monitored stations** | ***Talcher*** | ***Kalinganagar*** |
|---|---|---|
| Talcher | 1 | |
| Kalinganagar | **-0.23** | 1 |

It is found from the table 4.4 that there is poor negative correlation between Talcher and Kalinganagar which is -0.23.

## 3. Multiple bar diagram:

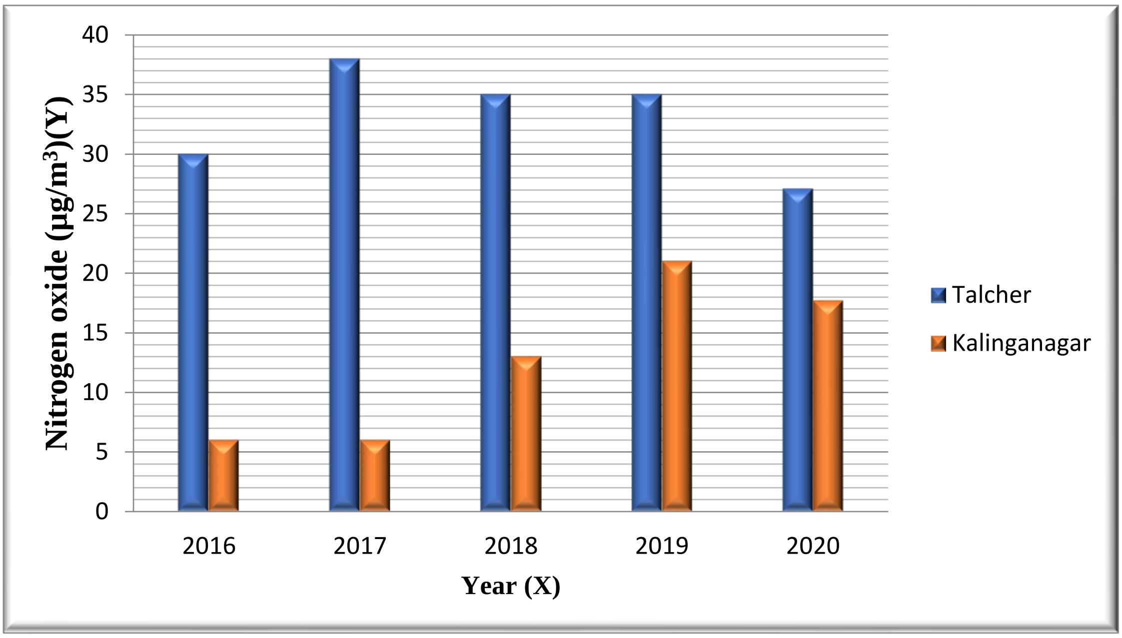



**Fig 4.4:** Status of $NO_2$ (2016-2020)

It is clearly seen from the figure 4.4 that in the year 2017 Talcher produce maximum emission while in 2020 having minimum emission.

## 4. Line diagram:

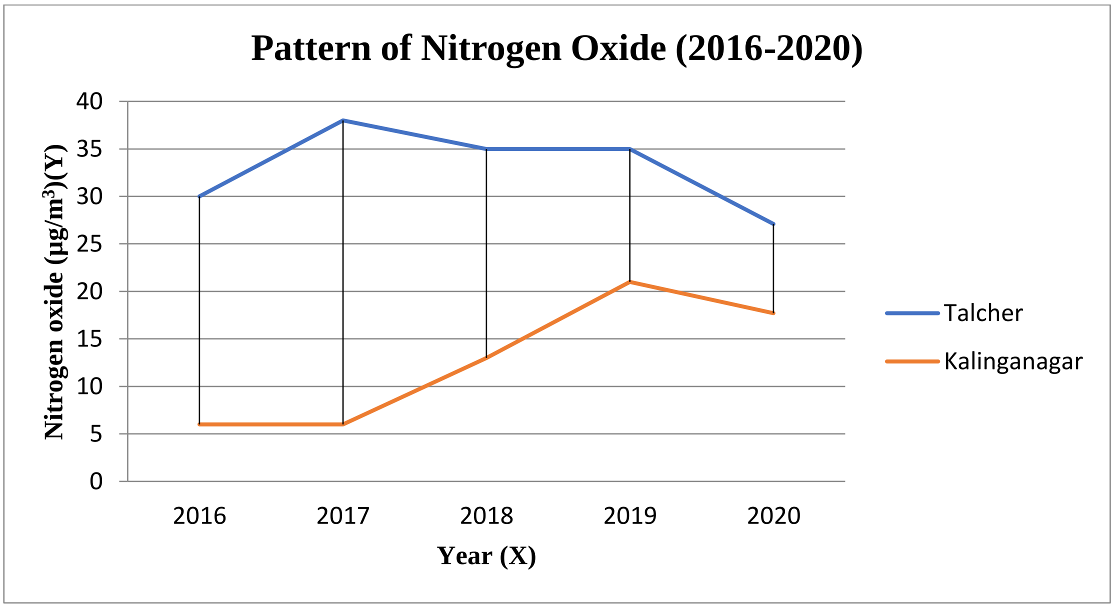



**Figure 4.5**: Pattern of Nitrogen Oxide (2016-2020)

Period 2016-2017, concentration of $NO_2$ is increasing and in the subsequent years 2017 to 2020, it is decreasing of $NO_2$ is increasing during the period 2016 to 20219 and due to lockdown concentration is decreasing.

**Table 4.5:** Data of $SO_2$ ($\mu g/m^3$) recorded at various monitored stations representing annual average urban areas (2016–20)

| Monitored stations/year | 2016 | 2017 | 2018 | 2019 | 2020 |
|---|---|---|---|---|---|
| **Talcher** | 12 | 12 | 12 | 13 | 10 |
| **Berhampur** | 3 | 3 | 3 | 3 | 6.9 |
| **Bhubaneswar** | 3 | 3 | 3 | 3 | 4.2 |
| **Jharsuguda** | 16 | 12 | 10 | 9 | 7.1 |
| **Kalinganagar** | 3 | 3 | 3 | 3 | |
| **Paradeep** | 28 | 24 | 23 | 23 | 16.8 |
| **Rayagada** | 3 | 3 | 3 | 3 | 7.7 |
| **Rourkela** | 5 | 11 | 11 | 10 | 6 |

**Table 4.6:** Parametric values of $SO_2$ for monitoring stations (2016-20)

| Monitored Stations | Talcher | Berhampur | Bhubaneswar | Jharsuguda | Kalinganagar | Paradeep | Rayagada | Rourkela |
|---|---|---|---|---|---|---|---|---|
| **Mean** | 11.80 | 3.78 | 3.24 | 10.82 | 3.00 | 22.96 | 3.94 | 8.60 |
| **Median** | 12.00 | 3.00 | 3.00 | 10.00 | 3.00 | 23.00 | 3.00 | 10.00 |
| **Standard Deviation** | 1.10 | 1.74 | 0.54 | 3.39 | 0.00 | 4.01 | 2.10 | 2.88 |
| **Maximum** | 13.00 | 6.90 | 4.20 | 16.00 | 3.00 | 28.00 | 7.70 | 11.00 |
| **Minimum** | 10.00 | 3.00 | 3.00 | 7.10 | 3.00 | 16.80 | 3.00 | 5.00 |
| **Range** | 3.00 | 3.90 | 1.20 | 8.90 | 0.00 | 11.20 | 4.70 | 6.00 |
| **Skewness** | -1.29 | 2.24 | 2.24 | 0.88 | | -0.67 | 2.24 | -0.59 |
| **Kurtosis** | 2.92 | 5.00 | 5.00 | 0.72 | | 2.05 | 5.00 | -2.85 |

a) Table 4.6 shows that the mean value in Paradeep is the highest, while in Kalinganagar it is the lowest.

b) As shown in table 4.6, the maximum deviation from the mean is in Paradeep.

c) Table 4.5 shows that in the year 2016, Paradeep had the highest value (28µg/m3).

d) Table 4.5 shows that Berhampur, Bhubaneswar, Kalinganagar, and Rayagada had the lowest $SO_2$ levels in 2016, 2017, 2018, and 2019, respectively.

e) The maximum range of $SO_2$ is shown in table 6 by Paradeep.

**1. Pie Chart:** Out of eight monitored stations, Paradeep has produced highest amount of emissions from 2016 to 2020 which is, reflected through pie chart:

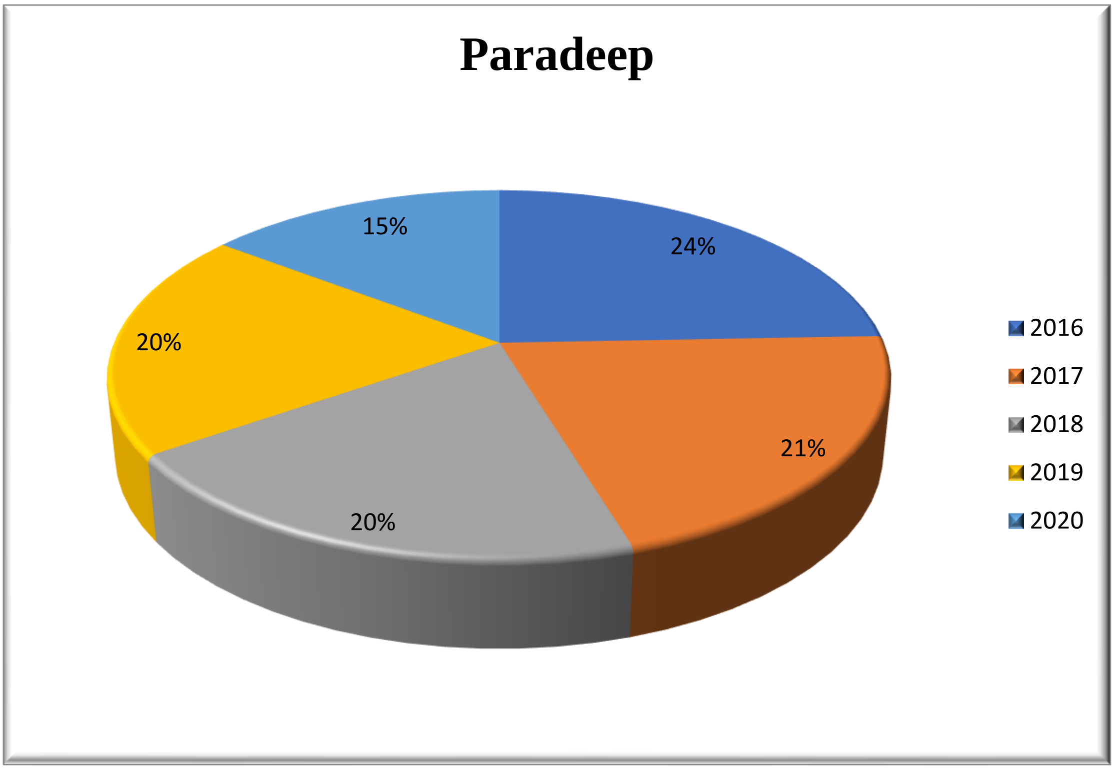



**Figure 4.6:** Distribution of $SO_2$ (2016-2020)

As can be seen from the figure 4.6, the year 2016 has the highest $SO_2$ emissions, while the year 2020 has the lowest $SO_2$ emissions.

It is noticed from fig. 4.6 that Paradeep, monitored station under northern division has highest emission in $SO_2$ in the year 2016 while 2020, its contribution is less in comparison to other year.

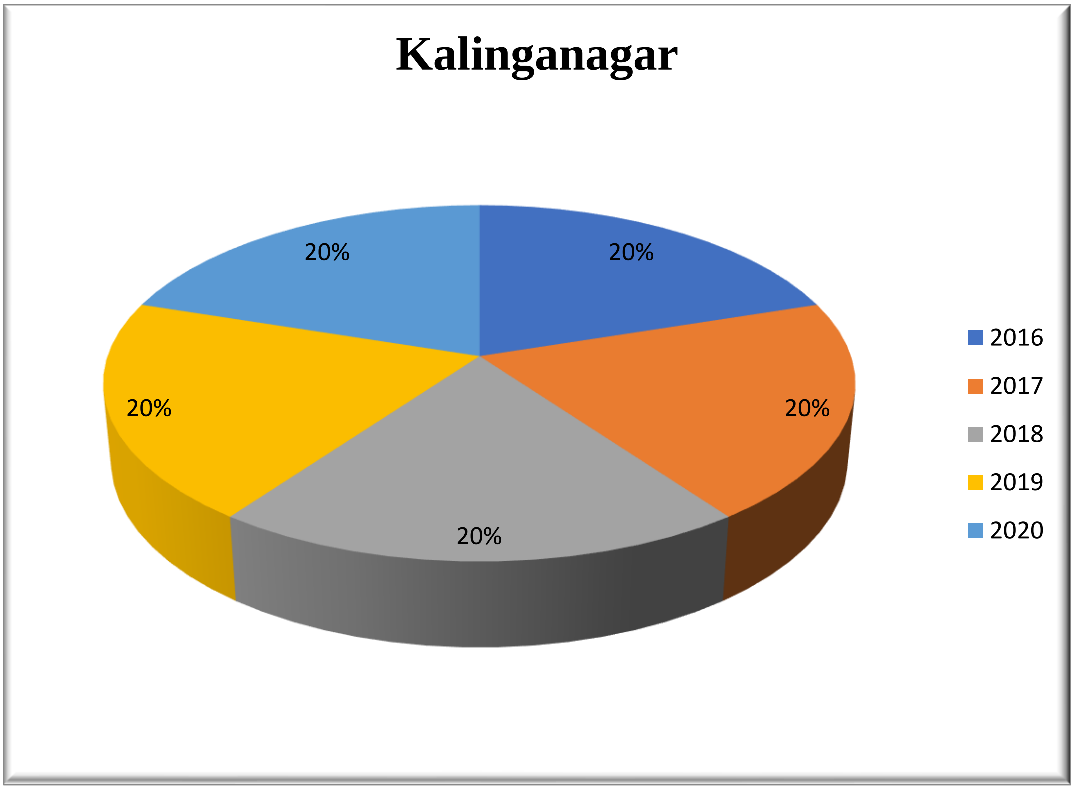



**Figure 4.7:** Distribution of $SO_2$ (2016-2020)

It is noticed from fig. 4.6 that $SO_2$ emissions at Kalinganagar, a monitored station in the central division, remained stable.

## 2. Multiple bar diagram:

We have also utilized of multiple bar diagram to represent the numerical figure for comparison between Paradeep and Kalinganagar from the year 2016 to 2020 as:

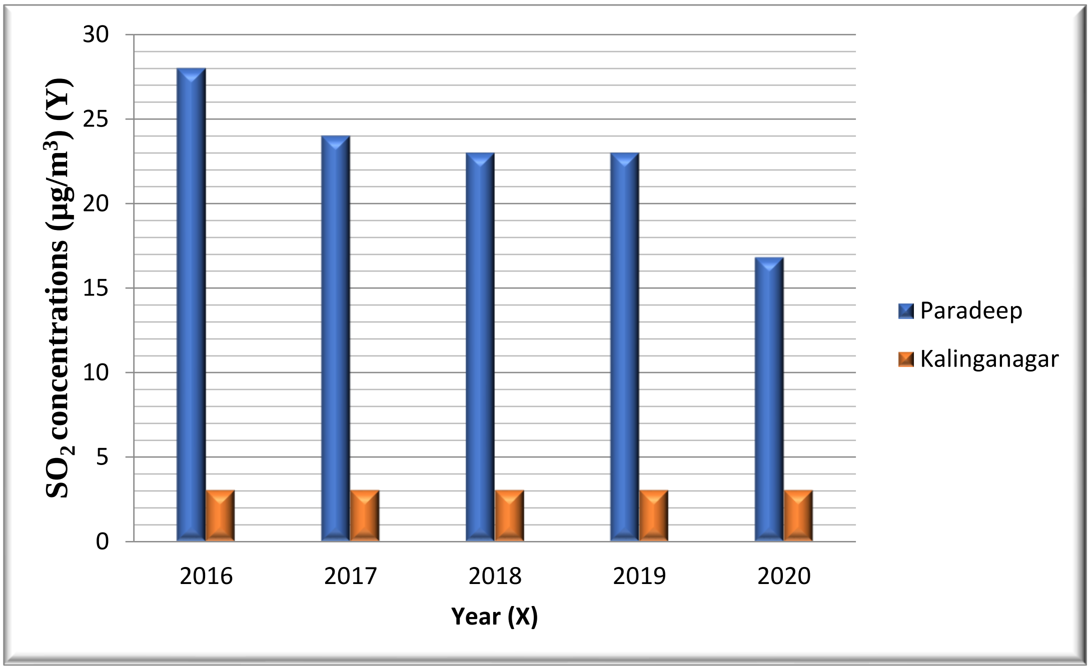



**Figure 4.8:** Status of $SO_2$ (2016-2020)

The figure 4.8 clearly shows that in 2016, Paradeep produced the highest amount of emissions, while in 2020, it produced the least amount and sulphur dioxide emission in Kalinganagar remains constant throughout the year from 2016 to 2020.

## 4. Line diagram:

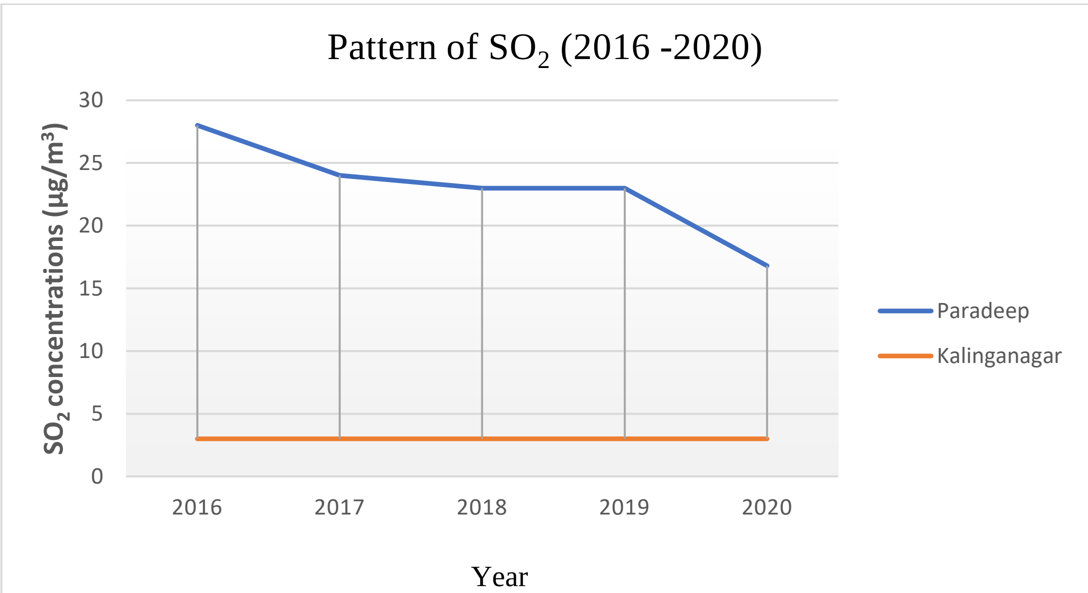



**Figure 4.9**: Pattern of $SO_2$ (2016-2020)

During the years 2016-2017, the concentration of $SO_2$ in Paradeep has been steadily decreasing from 2016 to 2020, while it has remained constant in Kalinganagar.

**Table 4.7:** Data of $PM_{2.5}$ (μg/$m^3$) recorded at various monitored stations representing annual average urban areas (2016–20)

| Monitored stations/year | 2016 | 2017 | 2018 | 2019 | 2020 |
|---|---|---|---|---|---|
| Talcher | 85 | 77 | 83 | 77 | 38 |
| Berhampur | 60 | 57 | 55 | 43 | 23 |
| Bhubaneswar | 62 | 57 | 52 | 48 | 31 |
| Jharsuguda | 80 | 78 | 93 | 75 | 45 |
| Kalinganagar | 78 | 93 | 98 | | 65 |
| Paradeep | 65 | 65 | 80 | 90 | 78 |
| Rayagada | 59 | 57 | 66 | 55 | 30 |
| Rourkela | 70 | 80 | 77 | 78 | 31 |

**Table 4.8:** Parametric values of $PM_{2.5}$ for monitoring stations (2016-20

| Monitored Stations | Talcher | Berhampur | Bhubaneswar | Jharsuguda | Kalinganagar | Paradeep | Rayagada | Rourkela |
|---|---|---|---|---|---|---|---|---|
| **Mean** | 72.00 | 47.60 | 50.00 | 74.20 | 83.50 | 75.60 | 53.40 | 67.20 |
| **Median** | 77.00 | 55.00 | 52.00 | 78.00 | 85.50 | 78.00 | 57.00 | 77.00 |
| **Standard Deviation** | 19.34 | 15.19 | 11.85 | 17.71 | 14.98 | 10.69 | 13.72 | 20.58 |
| **Maximum** | 85.00 | 60.00 | 62.00 | 93.00 | 98.00 | 90.00 | 66.00 | 80.00 |
| **Minimum** | 38.00 | 23.00 | 31.00 | 45.00 | 65.00 | 65.00 | 30.00 | 31.00 |
| **Range** | 47.00 | 37.00 | 31.00 | 48.00 | 33.00 | 25.00 | 36.00 | 49.00 |
| **Skewness** | -2.05 | -1.41 | -1.20 | -1.35 | -0.51 | 0.24 | -1.71 | -2.06 |
| **Kurtosis** | 4.34 | 1.41 | 1.72 | 2.84 | -2.21 | -1.43 | 3.50 | 4.30 |

a) Table 4.8 shows that the mean value in Kalinganagar is the highest, while in Berhampur it is the lowest.

b) As shown in table 4.8, the maximum deviation from the mean is in Rourkela.

c) Table 4.7 shows that Paradeep had the highest value (98µg/m3) in the year 2018.

d) Table 4.7 shows that Berhampur had the lowest $PM_{2.5}$ value in the year 2020.

e) Rourkela's maximum $PM_{2.5}$ range is shown in table 4.8.

**1. Pie Chart:** Out of the eight monitored stations, one stands out. Kalinganagar has produced the highest amount of emissions from 2016 to 2020, so we've created a pie chart showing the results from 2016 to 2020:

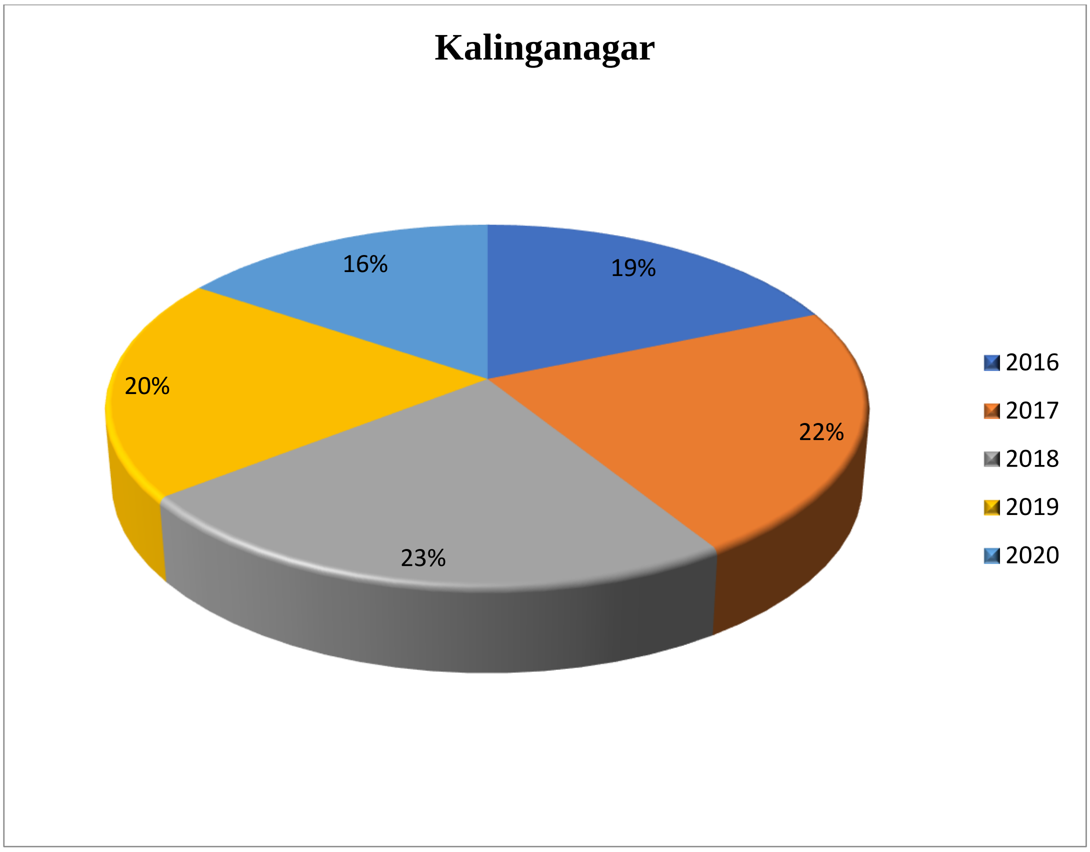



**Figure 4.10:** Distribution of $PM_{2.5}$ (2016-2020)

Figure 4.10 show that the year 2018 has the highest emission in Kalinganagar, while the year 2020 has the lowest emission of $PM_{2.5}$.

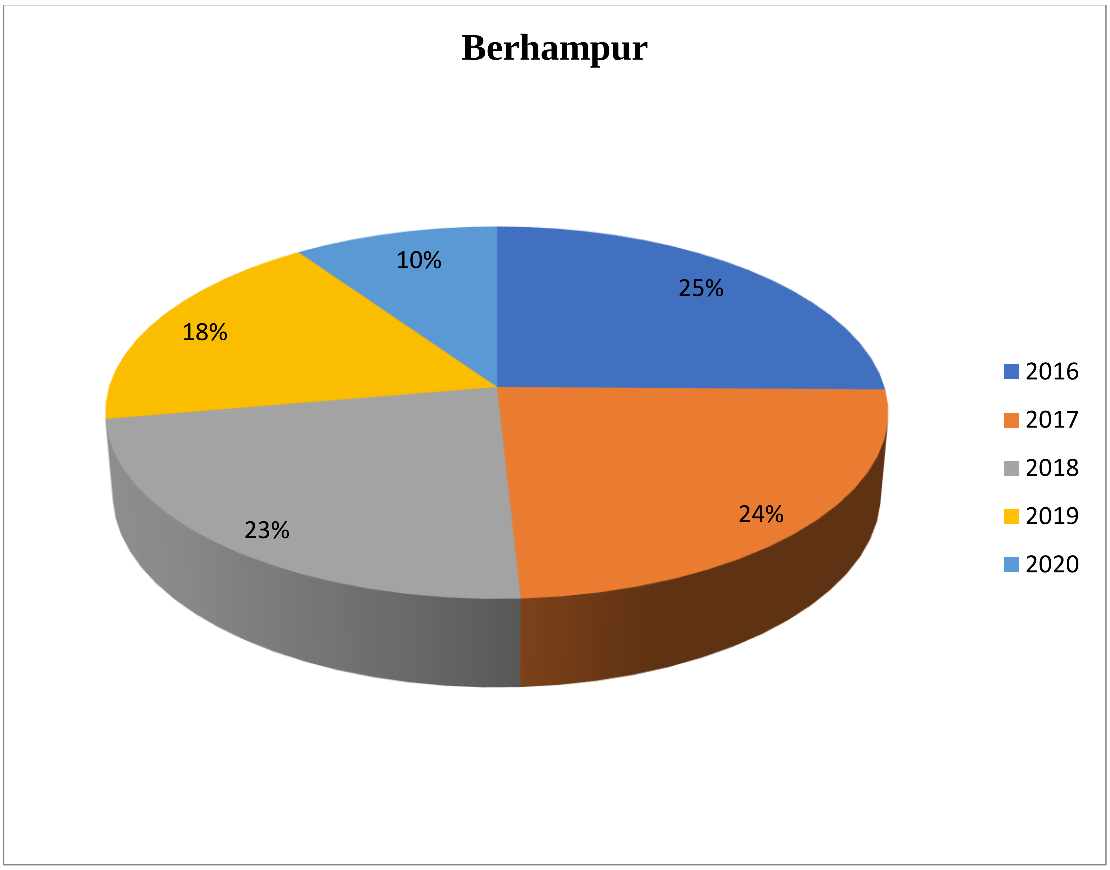



**Figure 4.11:** Distribution of $PM_{2.5}$ (2016-2020)

It is noticed from fig. 4.11 that Berhampur, monitored station under southern division has highest emission in $PM_{2.5}$ in the year 2016 while 2020, its contribution is less in comparison to other year. Above figure exhibits the rising of $PM_{2.5}$ emissions in 2016 and the rapid fall in 2020

**3. Correlation:** To investigate the relationship between Paradeep and Kalinganagar, we calculated a correlation coefficient, which is shown below;

**Table 4. 9:** Correlation between Kalinganagar and Berhampur

| Monitored Stations | Kalinganagar | Berhampur |
|---|---|---|
| Kalinganagar | 1 | |
| Berhampur | 0.743069 | 1 |

It is found from the table 4.9 that there is positive correlation between Kalinganagar and Berhampur which is 0.74.

## 4. Multiple bar diagram:

We have also utilized of multiple bar diagram to represent the numerical figure for comparison between Kalinganagar and Berhampur from the year 2016 to 2020 as:

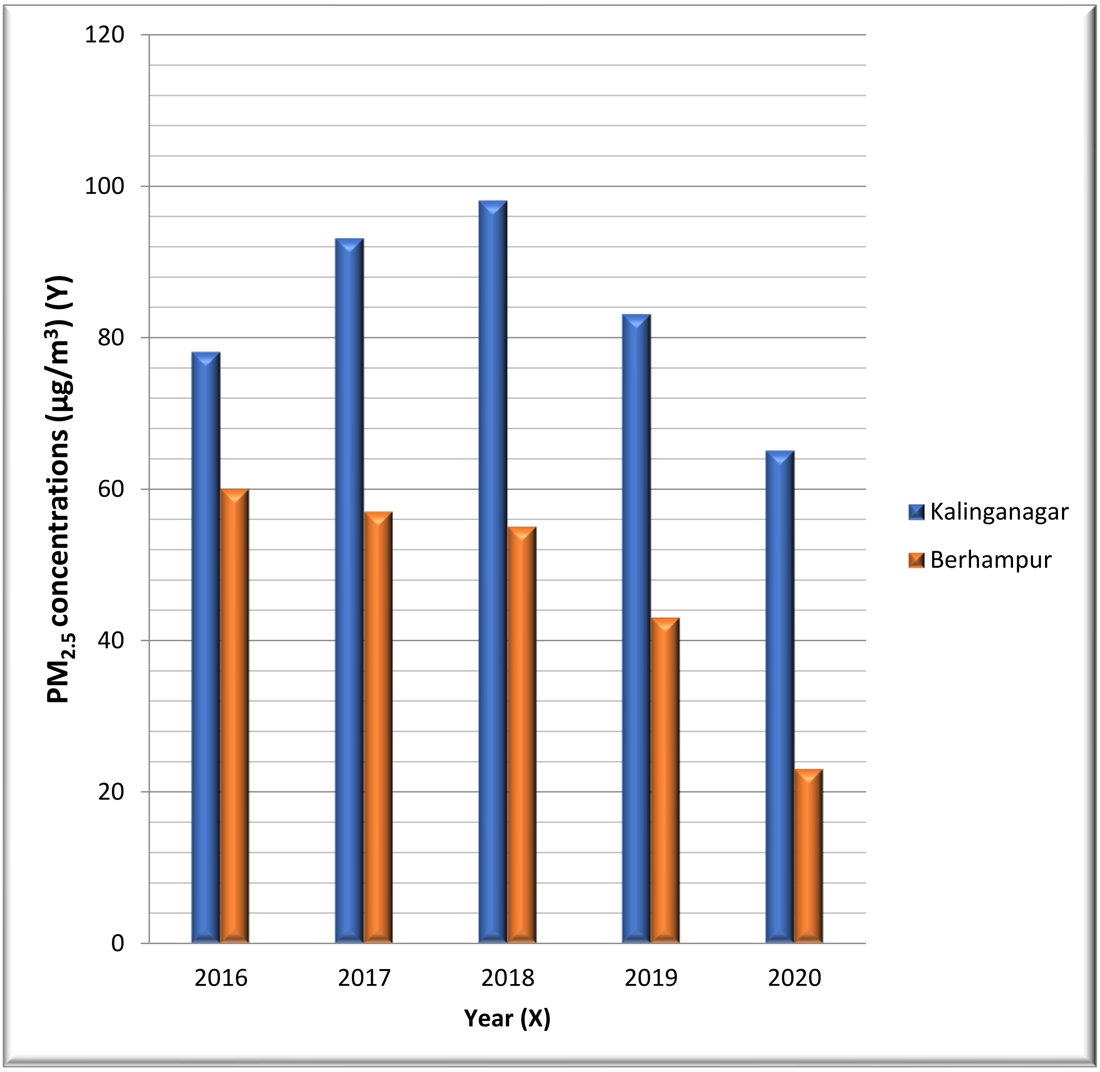



**Figure 4.12:** Status of $PM_{2.5}$ (2016-2020)

The figure 4.12 clearly shows that in 2016, Kalinganagar produced the highest amount of emissions, while in 2018, it produced the least amount and $PM_{2.5}$ in the year 2020 while emission in Berhampur constantly decreasing from the year from 2016 to 2020.

## 4. Line diagram:

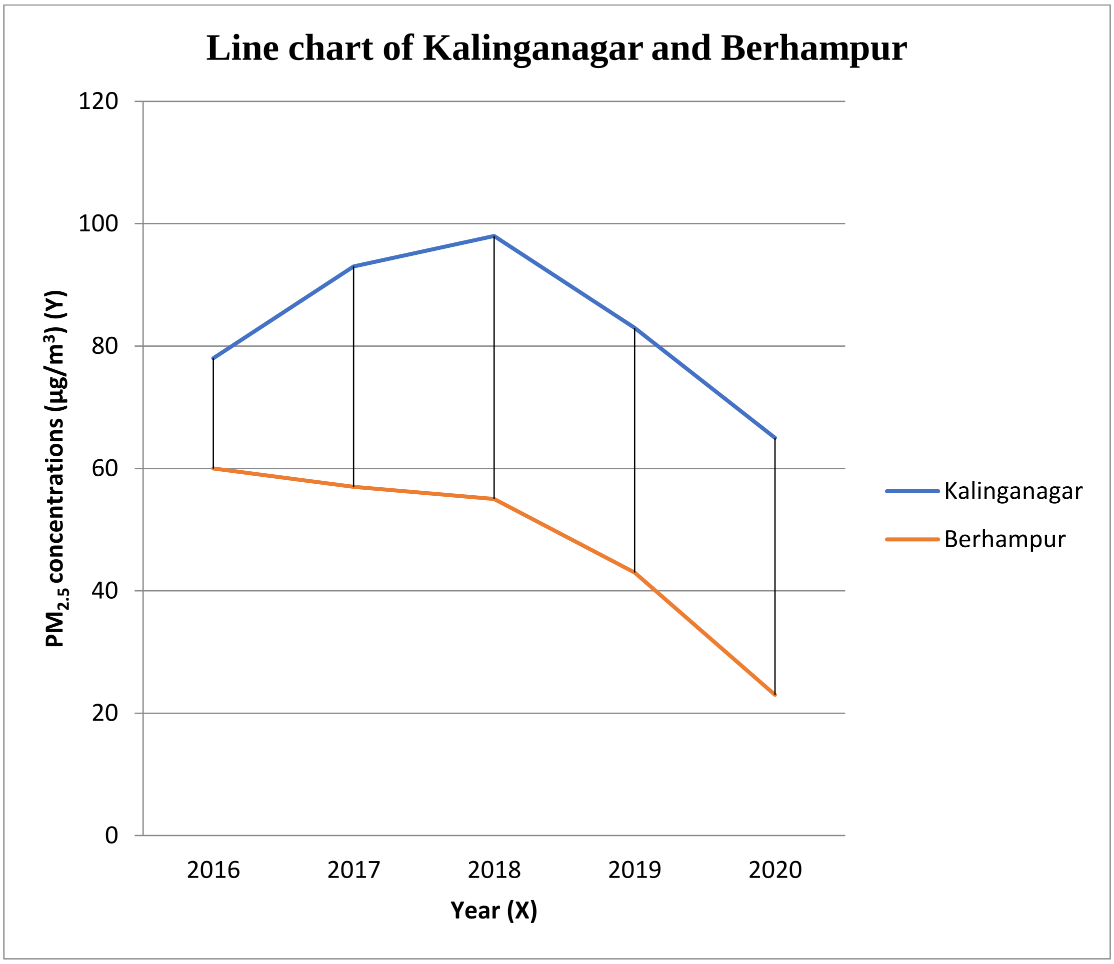



**Figure 4.13**: Pattern of $PM_{2.5}$ (2016-2020)

$PM_{2.5}$ emissions decreased at both monitored stations after 2018, as shown by the trend line. It had the lowest value in 2020 due to the lockdown. Kalinganagar comes under central division whereas Berhampur comes under Berhampur comes under Southern division.

**Table 4.10:** Data of $PM_{10}$ ($\mu g/m^3$) recorded at various monitored stations representing annual average urban areas (2016–20)

| Monitored stations/year | 2016 | 2017 | 2018 | 2019 | 2020 |
|---|---|---|---|---|---|
| Talcher | 103 | 98 | 106 | 102 | 88 |
| Berhampur | 58 | 60 | 64 | 64 | 52 |
| Bhubaneswar | 101 | 94 | 94 | 97 | 92 |
| Jharsuguda | 87 | 91 | 104 | 102 | 79 |
| Kalinganagar | 109 | 116 | 122 | 102 | 112 |
| Paradeep | 106 | 104 | 113 | 128 | 126 |
| Rayagada | 60 | 58 | 63 | 64 | 62 |
| Rourkela | 90 | 111 | 106 | 113 | 75 |

**Table 4.11:** Parametric values of $PM_{10}$ for monitoring stations (2016-20)

| Monitored Stations | Talcher | Berhampur | Bhubaneswar | Jharsuguda | Kalinganagar | Paradeep | Rayagada | Rourkela |
|---|---|---|---|---|---|---|---|---|
| **Mean** | 99.40 | 59.60 | 95.60 | 92.60 | 112.20 | 115.40 | 61.40 | 99.00 |
| **Median** | 102.00 | 60.00 | 94.00 | 91.00 | 112.00 | 113.00 | 62.00 | 106.00 |
| **Standard Deviation** | 6.99 | 4.98 | 3.51 | 10.45 | 7.50 | 11.13 | 2.41 | 16.17 |
| **Maximum** | 106.00 | 64.00 | 101.00 | 104.00 | 122.00 | 128.00 | 64.00 | 113.00 |
| **Minimum** | 88.00 | 52.00 | 92.00 | 79.00 | 102.00 | 104.00 | 58.00 | 75.00 |
| **Range** | 18.00 | 12.00 | 9.00 | 25.00 | 20.00 | 24.00 | 6.00 | 38.00 |
| **Skewness** | -1.38 | -0.92 | 1.02 | -0.14 | -0.10 | 0.26 | -0.60 | -0.96 |
| **Kurtosis** | 1.98 | 0.32 | 0.55 | -1.73 | 0.06 | -2.90 | -0.95 | -0.69 |

a) Table 4.11 shows that the mean value in Kalinganagar is the highest, while in Berhampur it is the lowest.

b) As shown in table 4.11, the maximum deviation from the mean is in Rourkela.

c) Table 4.10 shows that Paradeep has the highest value (128µg/m3) in the year 2019.

d) As can be seen from table 4.10, Berhampur had the lowest $PM_{10}$ value in 2016.

e) From table 4.11, it can be seen that Rourkela has the highest $PM_{10}$ range.

**1. Pie Chart:** Out of the eight monitored stations, one stands out. Paradeep has produced the most emissions from 2016 to 2020, so we've created a pie chart for the period from 2016 to 2020, which you can see below:

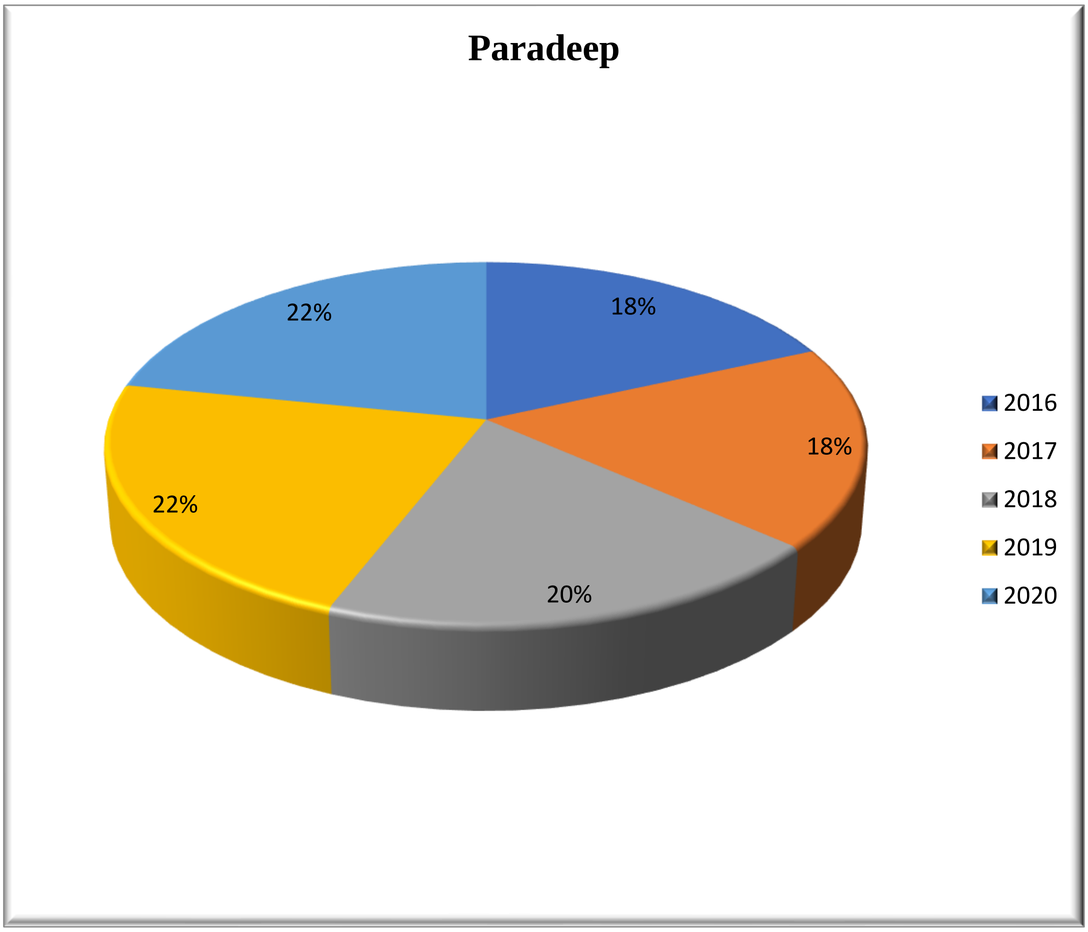



**Figure 4.14:** Distribution of $PM_{10}$ (2016-2020)

Figure 4.14 shows that the maximum emission in Paradeep occurs in the years 2019 and 2020, while the lowest emission of $PM_{10}$ occurs in the years 2016 and 2017.

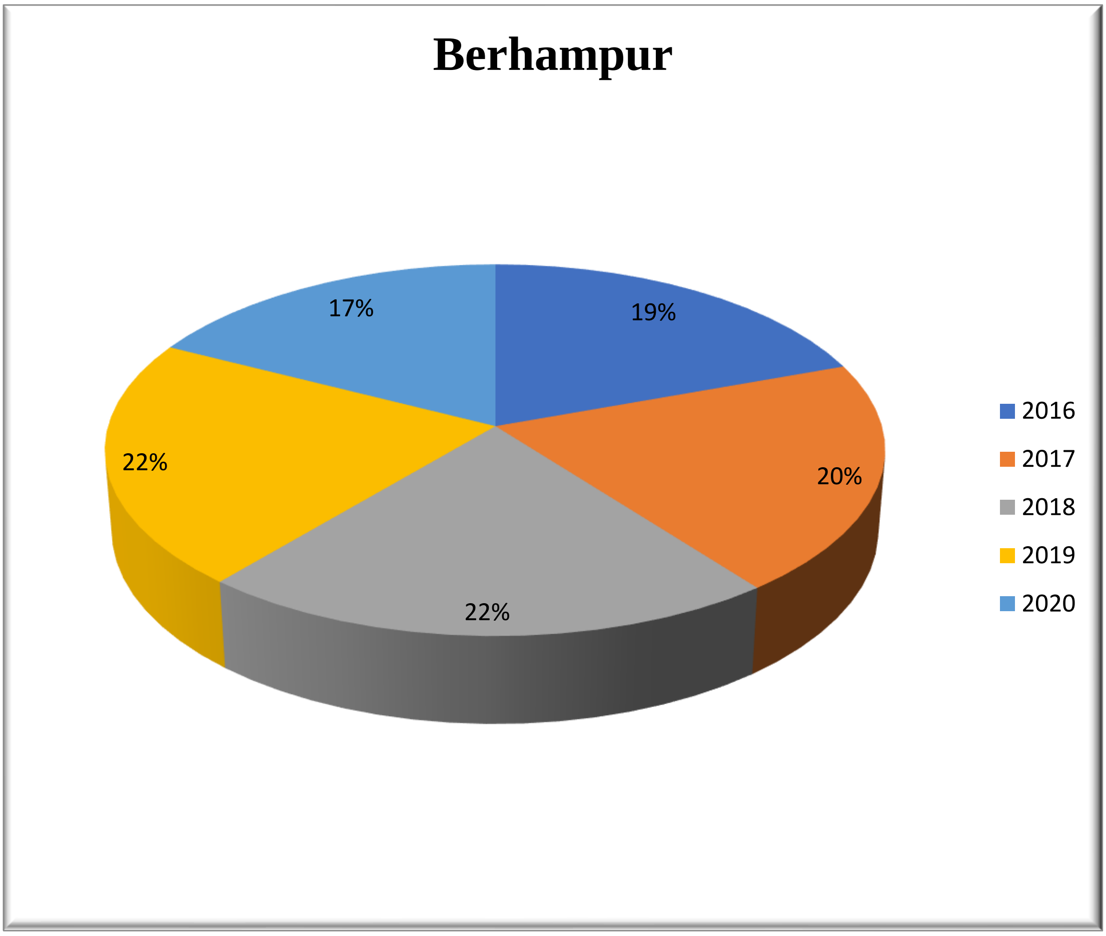



**Figure 4.15:** Distribution of $PM_{10}$ (2016-2020)

It is noticed from fig. 4.15 that Berhampur, monitored station under southern division has highest emission in $PM_{10}$ in year 2018 and 2019 while 2020, its contribution is less in comparison to other year.

**5. Correlation:** To investigate the relationship between Paradeep and Berhampur, we calculated a correlation coefficient, which is shown below:

**Table 4.12: C**orrelation between Paradeep and Berhampur

| Monitored station | Paradeep | Berhampur |
|---|---|---|
| Paradeep | 1 | |
| Berhampur | 0.743069 | 1 |

Table points the fact that there is positive correlation between Paradeep and Kalinganagar

## 3. Multiple bar diagram:

We have also utilized of multiple bar diagram to represent the numerical figure for comparison between Paradeep and Berhampur from the year 2016 to 2020 as:

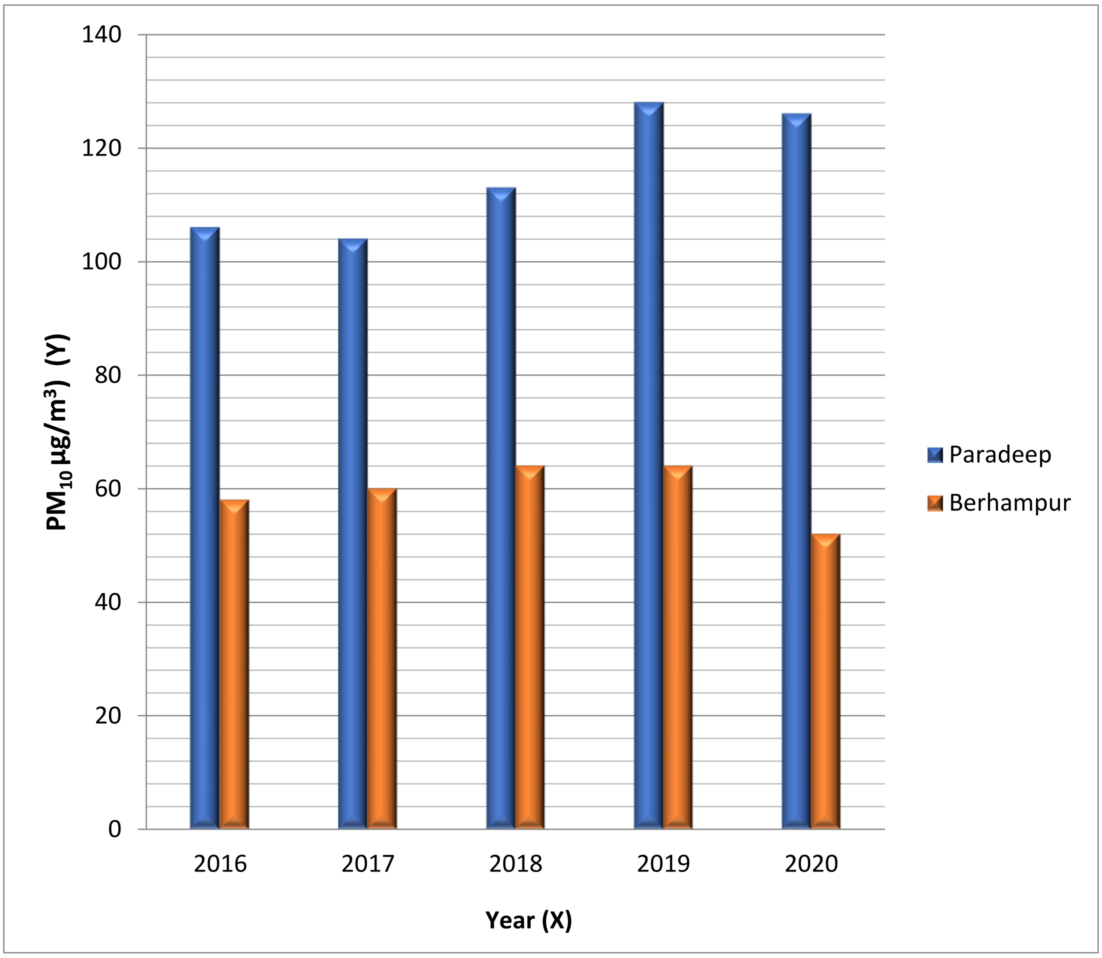



**Figure 4.16:** Status of $PM_{10}$ (2016-2020)

The figure 4.16 clearly shows that in 2016, Paradeep produced the highest amount of emissions, while in 2019, it produced the least amount and $PM_{10}$ in the year 2017 while emission in Berhampur highest in year 2018 and 2019 lowest in the year 2020.

## 4. Line diagram:

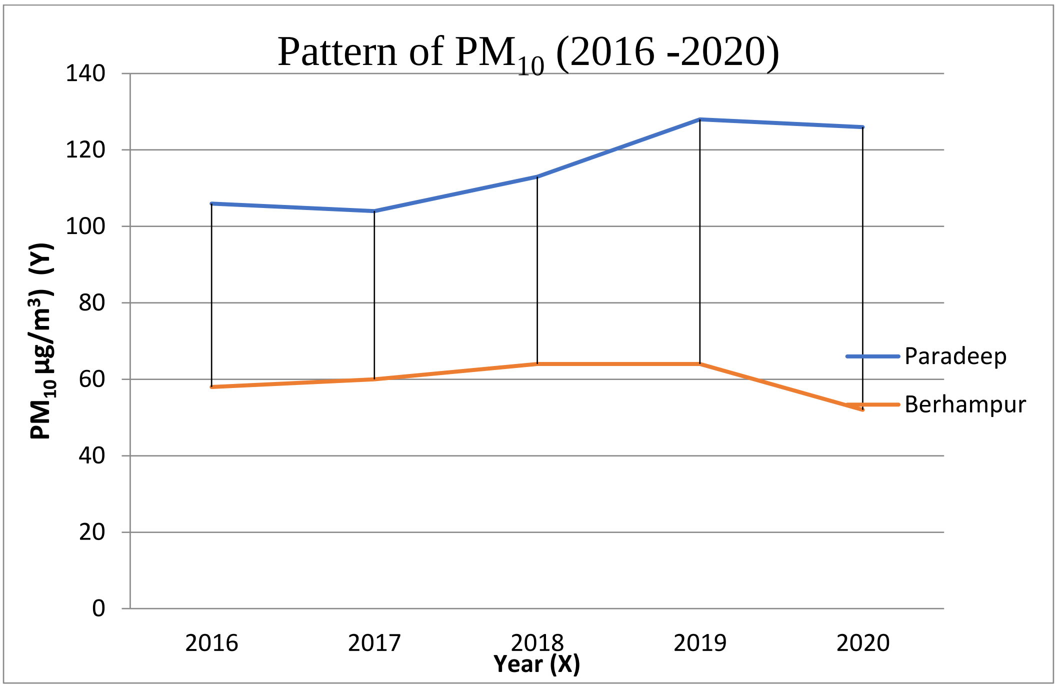


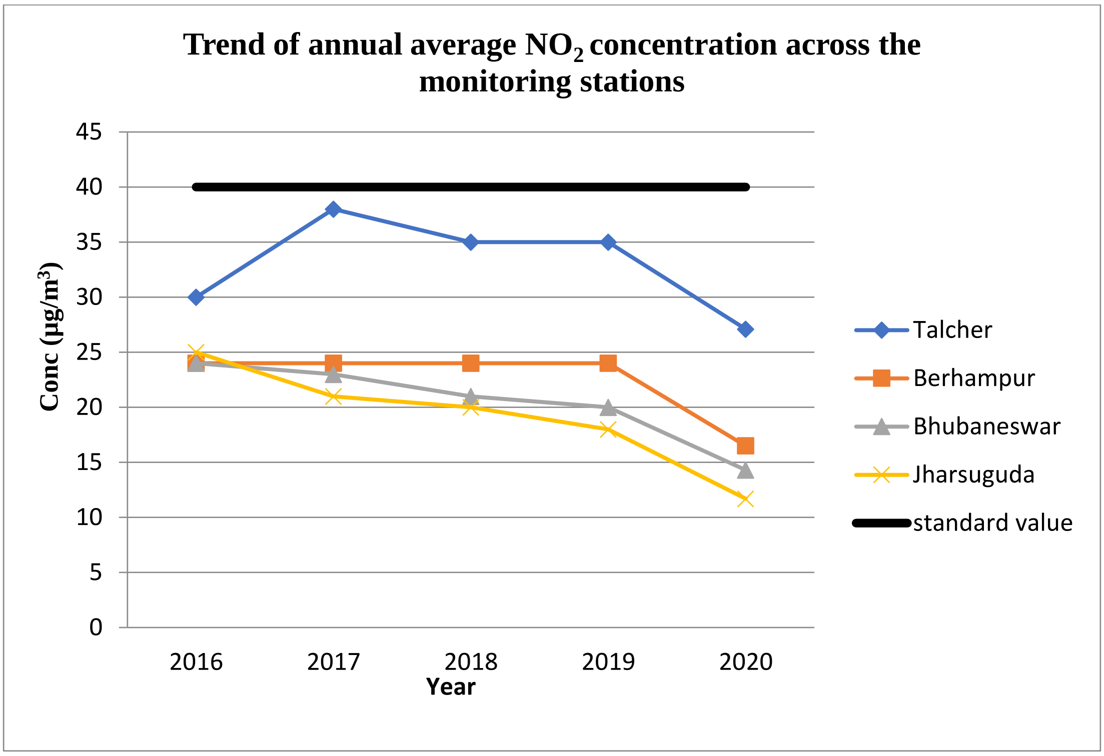

**Figure 4.17**: Pattern of $PM_{10}$ (2016-2020)

As demonstrated in the trend line above, both monitored stations have been falling since 2019, with Paradeep showing a minor decrease and Berhampur having the lowest value of all the years in 2020 due to lockdown.

**Table 4.13:** National Air Quality Index of India

| AQI category (range) | $PM_{10}$ 24- hour | $PM_{2.5}$ 24- hour | $NO_2$ 24- hour | $SO_2$ 24-hour |
|---|---|---|---|---|
| Good (0–50) | 0-50 | 0-30 | 0-40 | 0-40 |
| Satisfactory (51–100) | 51-100 | 31-60 | 41-80 | 41-80 |
| Moderately polluted (101–200) | 101– 250 | 61–90 | 81–180 | 81-380 |
| Poor (201–300) | 251– 350 | 91–120 | 181– 280 | 381–800 |
| Very poor (301–400) | 351-430 | 121– 250 | 281– 400 | 801– 1,600 |
| Severe (401–500) | 430+ | 250+ | 400+ | 1,600+ |

Note: Ambient concentration values of all regulated pollutants are compared with corresponding standards, and an exceedance factor is used for qualitative assessment of air quality.



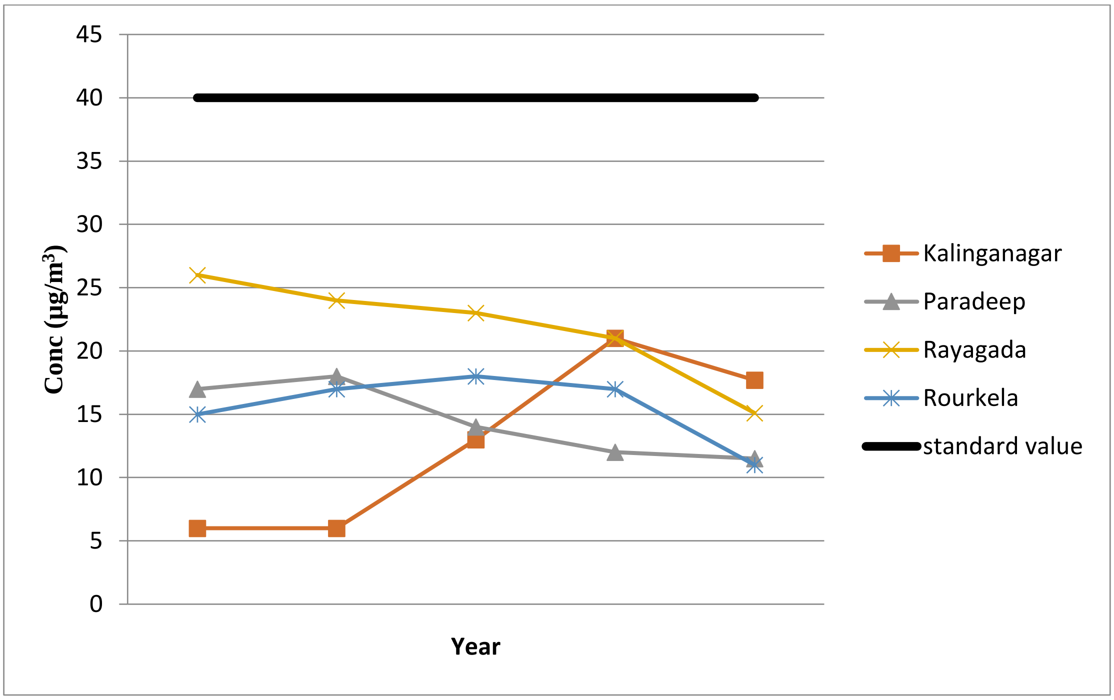




**Figure 4.18:** Trend of annual average $NO_2$ concentration across the monitoring stations

$NO_2$ concentrations at monitored stations were below the yearly standard in all of the stations, as shown in Figure 4.18. In comparison to other monitored stations, Talcher has routinely recorded relatively high $NO_2$ values.

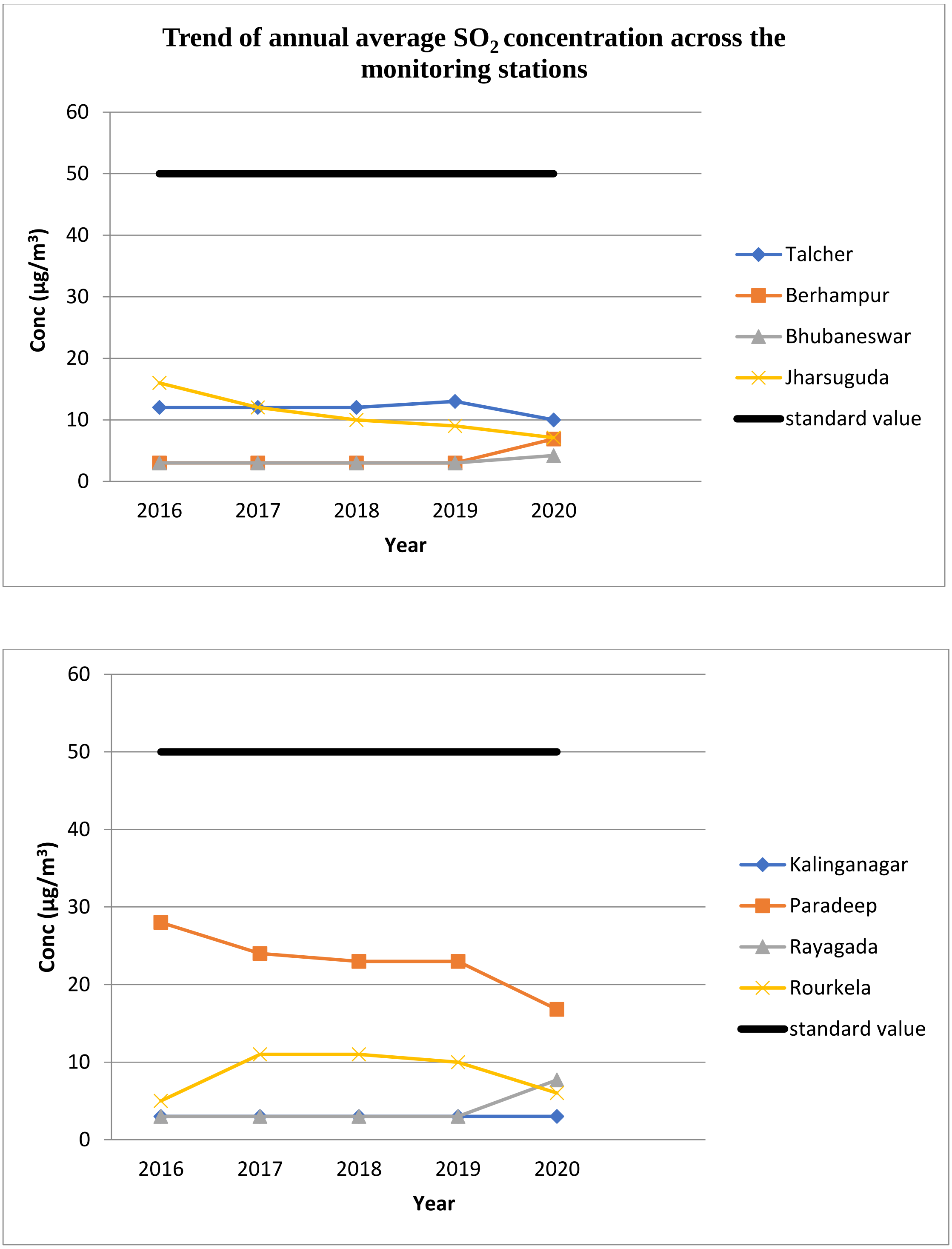
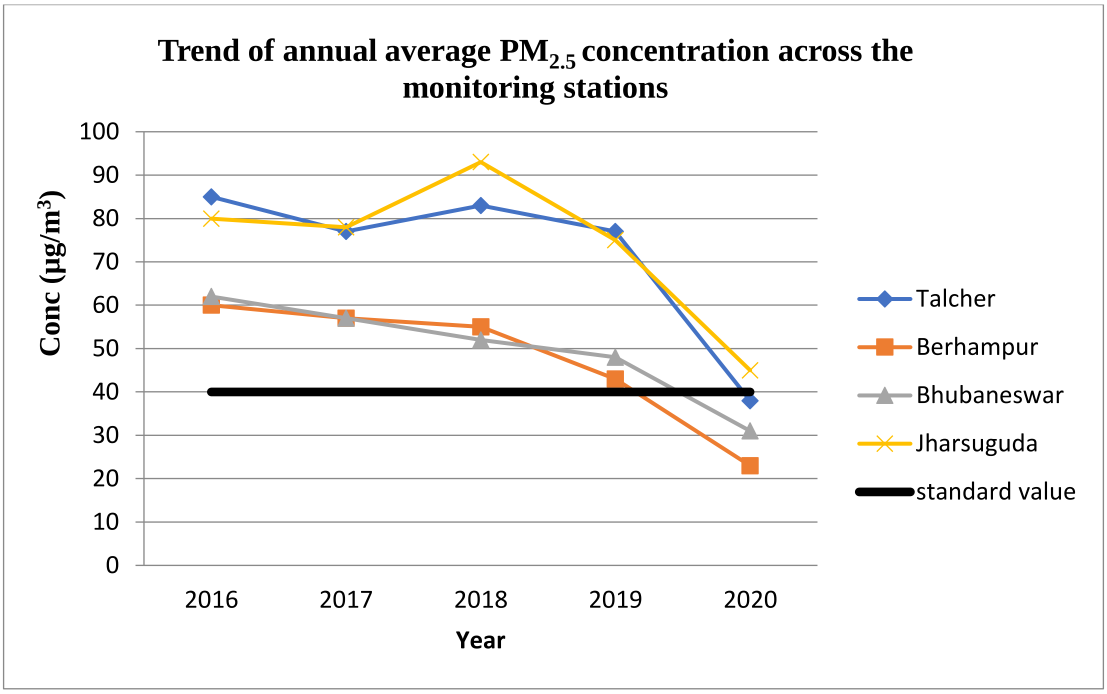



**Figure 4.19:** Trend of annual average $SO_2$ concentration across the monitoring stations

$SO_2$ concentrations at monitored stations were below the yearly standard in all of the stations, as shown in Figure 4.19. In comparison to other monitored stations, Paradeep has routinely recorded relatively high $SO_2$ values.



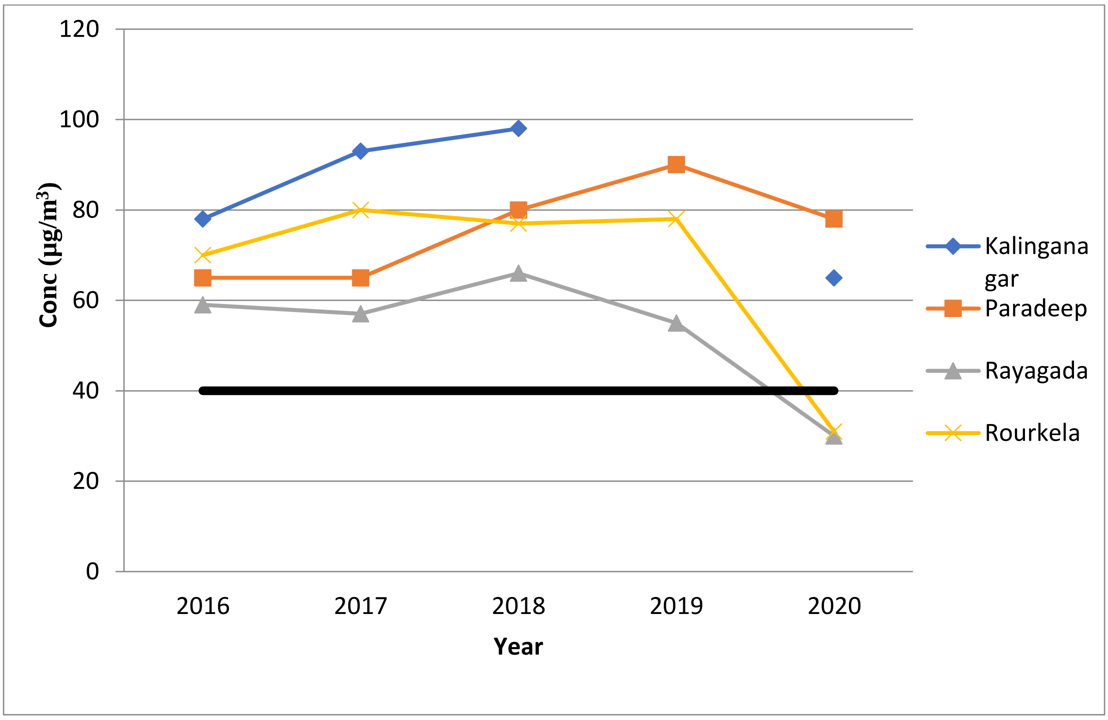
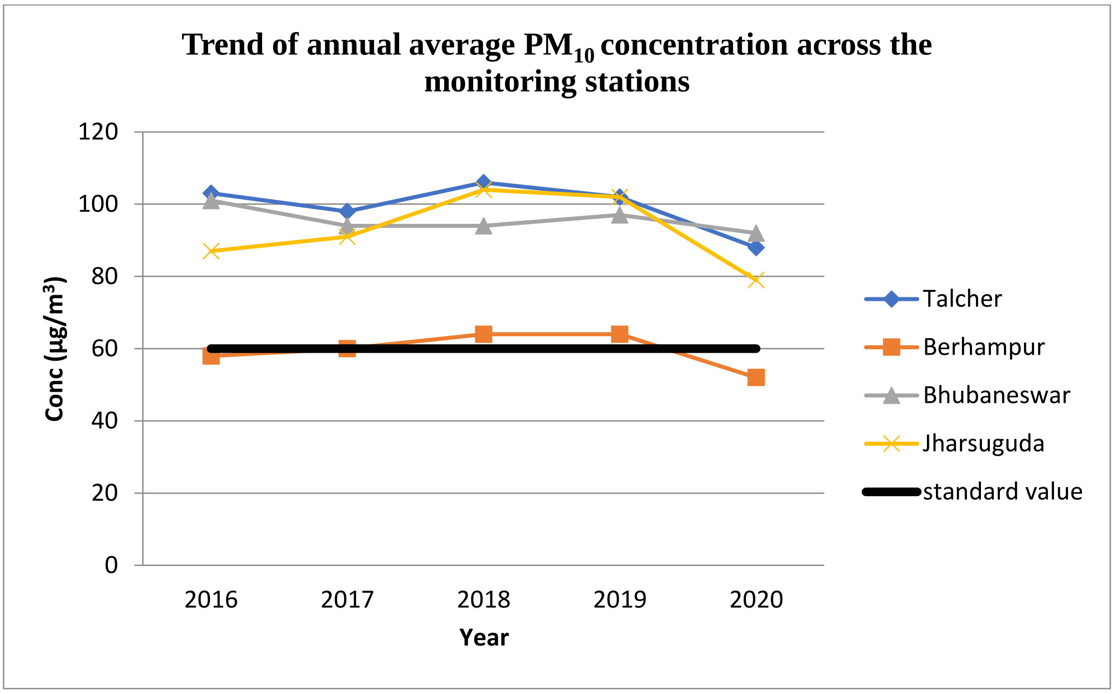




**Figure 4.20:** Trend of annual average $PM_{2.5}$ concentration across the monitoring stations

Figure 4.20 shows that $PM_{2.5}$ concentrations at monitored stations were higher than the yearly standard in all of the stations. Paradeep has consistently observed high $PM_{2.5}$ levels when compared to other monitoring stations.



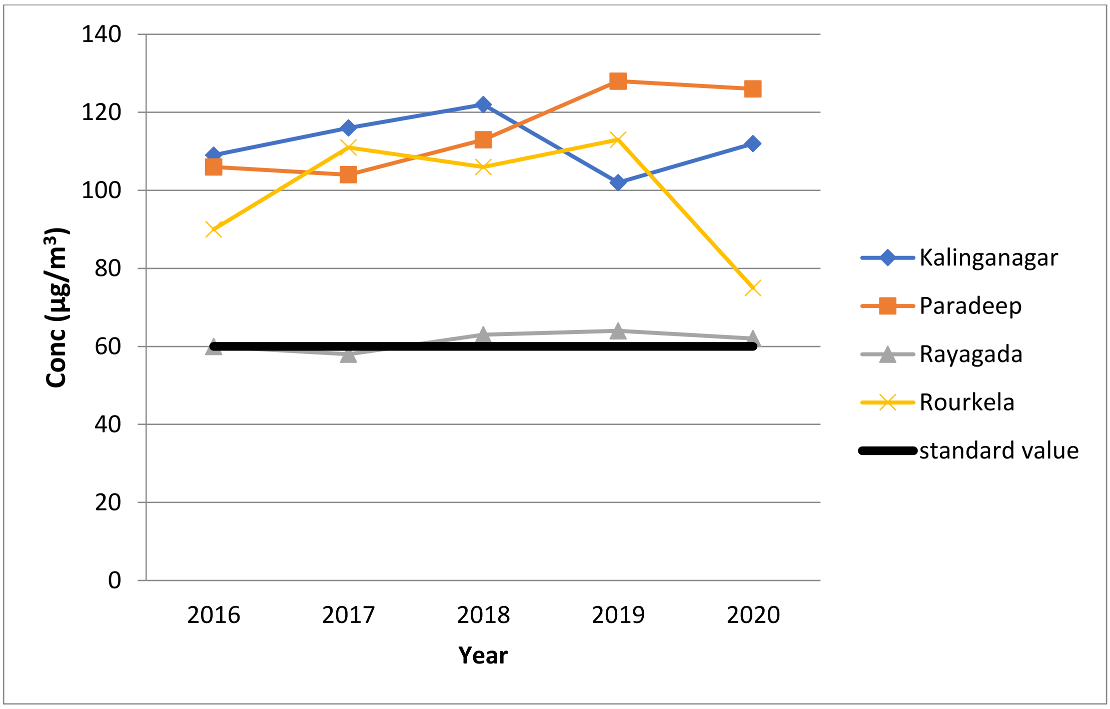




**Figure 4.21:** Trend of annual average $PM_{10}$ concentration across the monitoring stations

Figure 4.21 shows that $PM_{10}$ concentrations at monitored stations were higher than the yearly standard in all of the stations. Paradeep has consistently observed high $PM_{10}$ levels when compared to other monitoring stations.

Agricultural crops can be injured when exposed to high concentrations of various air pollutants. Injury ranges from visible markings on the foliage, to reduced growth and yield, to premature death of the plant. The development and severity of the injury depends not only on the concentration of the particular pollutant, but also on a number of other factors. These include the length of exposure to the pollutant, the plant species and its stage of development as well as the environmental factors conducive to a build-up of the pollutant and to the preconditioning of the plant, which make it either susceptible or resistant to injury.

## Effects of Air Pollution on Plants

Air pollution injury to plants can be evident in several ways. Injury to foliage may be visible in a short time and appear as necrotic lesions (dead tissue), or it can develop slowly as a yellowing or chlorosis of the leaf. There may be a reduction in growth of various portions of a plant. Plants may be killed outright, but they usually do not succumb until they have suffered recurrent injury.

## Oxidants

Ozone is the main pollutant in the oxidant smog complex. Its effect on plants was first observed in the Los Angeles area in 1944. Since then, ozone injury to vegetation has been reported and documented in many areas throughout North America, including the south western and central regions of Ontario. Throughout the growing season, particularly July and August, ozone levels vary significantly. Periods of high ozone are associated with regional southerly air flows that are carried across the lower Great Lakes after passing over many urban and industrialised areas of the United States. Localized, domestic ozone levels also contribute to the already high background levels. Injury levels vary annually and white bean, which are particularly sensitive, are often used as an indicator of damage. Other sensitive species include cucumber, grape, green bean, lettuce, onion, potato, radish, rutabagas, spinach, sweet corn, tobacco and tomato. Resistant species include endive, pear and apricot.

Ozone symptoms characteristically occur on the upper surface of affected leaves and appear as a flecking, bronzing or bleaching of the leaf tissues. Although yield reductions are usually with visible foliar injury, crop loss can also occur without any sign of pollutant stress. Conversely, some crops can sustain visible foliar injury without any adverse effect on yield.

Susceptibility to ozone injury is influenced by many environmental and plant growth factors. High relative humidity, optimum soil-nitrogen levels and water availability increase susceptibility. Injury development on broad leaves also is influenced by the stage of maturity. The youngest leaves are resistant. With expansion, they become successively susceptible at middle and basal portions. The leaves become resistant again at complete maturation.

**Sulphur Dioxide:**

Major sources of sulphur dioxide are coal-burning operations, especially those providing electric power and space heating. Sulphur dioxide emissions can also result from the burning of petroleum and the smelting of sulphur containing ores.

Sulphur dioxide enters the leaves mainly through the stomata (microscopic openings) and the resultant injury is classified as either acute or chronic. Acute injury is caused by absorption of high concentrations of sulphur dioxide in a relatively short time. The symptoms appear as 2-sided (bifacial) lesions that usually occur between the veins and occasionally along the margins of the leaves. The colour of the necrotic area can vary from a light tan or near white to an orange-red or brown depending on the time of year, the plant species affected and weather conditions. Recently expanded leaves usually are the most sensitive to acute sulphur dioxide injury, the very youngest and oldest being somewhat more resistant.

It is studied from the trend line and also from descriptive statistics, Sulphur dioxide is under control in all the eight monitored stations (below 50 microgram per cubic meter) as per NAAQS-2009 wherein Paradeep monitored station is relatively producing highest emissions in comparison to other monitored stations due to one port and number of industrial units. It may be suggested to timely checking of coal-burning operations, especially those providing electric power and space heating under control to of increasing trend line of Paradeep under northern zone f urban areas of Odisha.

**Particulate Matter ($PM_{2.5}$)**

Particulate matter such as cement dust, magnesium-lime dust and carbon soot deposited on vegetation can inhibit the normal respiration and photosynthesis mechanisms within the leaf. Cement dust may cause chlorosis and death of leaf tissue by the combination of a thick crust and alkaline toxicity produced in wet weather. The dust coating also may affect the normal action of pesticides and other agricultural chemicals applied as sprays to foliage. In addition, accumulation of alkaline dusts in the soil can increase soil pH to levels adverse to crop growth.

It is observed from the trend line and also from descriptive statistics, particulate meter is under control in all the eight monitored stations (below 60 microgram per cubic meter) as per NAAQS-2009 wherein Paradeep monitored station is relatively producing highest emissions in comparison to other monitored stations due to one port and number of industrial units. It may be suggested to timely checking of coal-burning operations, especially those providing electric power and space heating under control to of increasing trend line of Paradeep under central zone of urban areas of Odisha.

**Effect of $PM_{10}$**

As a significant air pollutant $PM_{10}$ has negative relationship with air quality, as $PM_{10}$ increases in air, air quality worsens. It is found from the figure 4.21 one that $PM_{10}$concentration values for all the stations are above the NAAQS (60 $\mu g/m^3$) during the period under study. All station has shown in increasing trend during last four year except the last year. The declined value for the year 2020 may be due to covid-19 pandemic situation Paradeep shows the highest increase trend with average concentration of 11 2.20 ($\mu g/m^3$) which may be due to the dust of the port and combination of the industry. The range of the mean value of all the stations is in the range 55 to 154 ($\mu g/m^3$), so it shows condition of $PM_{10}$ is moderate.

Technically there is not a safe level of $PM_{10}$ as any amount of particulate matter in air is not a good thing. Keeping or exposure to $PM_{10}$ concentration below 54.0 $\mu g/m^3$ in the best way to prevent any short or long-term health effect for developing.

Exposure to high concentration of $PM_{10}$ can result in a number of health impact recognise from coughing and wheezing to asthma attack and bronchitis to high blood pressure heart attack strokes and premature death. Further most of the effect of $PM_{10}$ particles on plants include the potential to block and damage the stomata such that photosynthesis and respiration are affected.

**Effect of $NO_2$**

In the presence of sunlight, the oxides of nitrogen react with the unburned hydrocarbons to form photochemical smog which causes damage to plant and is also so determinate to human health. It is observed from the figure 4.18 that the value of $NO_2$ concentration in air for all the situation are below the NAAQS (40 µg/$m^3$).

Again, in comparison to other monitored station Talcher has continuous recorded high$NO_2$ values due to a number of mines thermal plants and a big aluminium plant (NALCO) and running of large number of commercial and transport vehicles.

Elevated levels of nitrogen dioxide can cause damage to the human respiratory track and increase a person’s vulnerability to, and the 7:30 of respiratory infection and asthma. Long-term exposure to high level of nitrogen dioxide can cause chronic lung disease for other at high concentration level nitrogen dioxide is potentially toxic to plant, can injured leaves and produce growth and yield. In combination with ozone ($O_3$) or sulphur dioxide ($SO_2$) nitrogen dioxide may cause injury at even lower concentrations level.

**Effect of air pollutant on human health:**

Air pollution is a major concern of new civilized world, which has a serious toxicological impact on agriculture, environment and human health. It has a number of different emission sources, but motor vehicles and industrial processes contribute the major part of air pollution. According to the World health organisation, major air pollutants include particle pollution, ground level ozone, sulphur dioxide and nitrogen oxide. Impacts of four major pollutants on human health are briefly discussed hereunder:

$PM_{2.5}$ is one of the major air pollutants produced from motor engines, industrial activities; smokes have high health impact on respiratory and cardiovascular diseases, CNS and reproductive dysfunctions and cancer.

$PM_{10}$ is another of the major air pollutants produced from vehicular exhaust, industrial activities have high health impact on respiratory and cardiovascular dysfunctions and eye irritation.

Sulphur dioxide which is produced from fuel combustion and burning coal has health impact on respiratory and CNS involvement, eye irritation.

Nitrogen dioxide is produced from fuel-burning and vehicular exhaust has high impact on damage to liver, lung, spleen, and blood.

# CHAPTER 5
# SUMMARY AND CONCLUSION

# SUMMARY AND CONCLUSION

In this section we have briefly discussed about the status of air pollutants viz. Nitrogen oxide ($NO_2$), Sulphur dioxide ($SO_2$) and particulate matter ($PM_{2.5}$ and $PM_{10}$) over eight monitored station that is i.e. Kalinganagar (Jajpur), Bhubaneswar (Khurda), Paradeep (Jagatsinghpur), Jharsuguda (Jharsuguda), Rourkela (Sundargarh), Talcher (Anugul), Berhampur (Ganjam) and Rayagada (Rayagada) utilising the five-year data ranging from the year 2016 to 2020. Here we also group eight monitored stations into three revenue division's viz. Northern division, Central division and Southern division.

Bhubaneswar, Paradeep and Kalinganagar are chosen under Northern division similarly Rourkela, Talcher and Jharsuguda comes under Central division and the rest two monitored stations i.e., Rayagada and Berhampur are under South division.

To fulfil our objectives, we have exploited multiple statistical tool i.e., mean, median, standard deviation and range to study the status of air pollutants. We also constructed pie chart, multiple bar diagram, line diagram and trend line for pictorial representation on and of the above study.

We have found from table 4.3 that mean value 32.0 ($\mu g/m^3$) of nitrogen oxide of Talcher is highest while Kalinganagar shows lowest 12.7 ($\mu g/m^3$) and concentration of nitrogen oxide in Kalinganagar shows more scattered 6.78 ($\mu g/m^3$) than other monitored stations. We also studied from the table 4.3 that Kalinganagar has lowest emission 6 ($\mu g/m^3$) while Talcher has contributed highest nitrogen oxide ($NO_2$). It is also very interesting fact that five monitor stations i.e., Berhampur, Bhubaneswar, Jharsuguda, Rayagada and Rourkela are highly or moderately skewed while three monitored stations viz., Kalinganagar, Paradeep and Talcher are approximately symmetric.

It is also here to mention that only monitor station i.e,. Kalinganagar (Jajpur) under Northern division produces lowest nitrogen oxide 12.74 ($\mu g/m^3$) in comparison then Bhubaneswar (Khurda) and Paradeep (Jagatsinghpur).

Similarly Talcher (Anugul) which comes under Central division contribute highest nitrogen oxide 33.02 (µg/m$^3$) very interesting fact that Rayagada and Berhampur (Ganjam) under the southern division receive less nitrogen oxide ($NO_2$) in comparison to other divisions.

We have also computed correlation coefficient between the highest producing monitored station Talcher and Kalinganagar found that they are poorly negatively correlated i.e. – 0.23._From the figure 4.18 in chapter IV that annual average concentration nitrogen oxide ($NO_2$) stands below the yearly standard which is 40 (µg/m$^3$) and also found that Talcher successively recorded relatively high concentration and $NO_2$ in comparison to other monitored stations.

We have found from table 4.6 that mean value 22.96 (µg/m$^3$) of sulphur dioxide of Paradeep is highest while Kalinganagar shows lowest 3.00 (µg/m$^3$) and concentration of sulphur dioxide in Paradeep shows more scattered 4.01 (µg/m$^3$) than other monitored stations. We also studied from the table 4.6 that Kalinganagar has lowest emission 3 (µg/m$^3$) while Paradeep has contributed highest sulphur dioxide ($SO_2$). It is also very interesting fact that 7 monitored stations i.e., Berhampur, Bhubaneswar, Jharsuguda, Rayagada, Rourkela, Paradeep and Talcher are highly or moderately skewed while Kalinganagar have no variation in its values.

It is also here to mention that only monitor station i.e., Kalinganagar (Jajpur) under Northern division produces lowest sulphur dioxide 3.00 (µg/m$^3$) in comparison then Bhubaneswar (Khurda) and Paradeep (Jagatsinghpur).

Similarly, Paradeep (Jagatsinghpur), which comes under Northern division contribute highest sulphur dioxide 28.00 (µg/m$^3$) very interesting fact that Rayagada and Berhampur (Ganjam) under the southern division receive less sulphur dioxide ($SO_2$) in comparison to other divisions.

From the figure 4.18 in chapter IV that annual average concentration sulphur dioxide ($SO_2$) stands below the yearly standard which is 50 (µg/m$^3$) and also found that Paradeep successively recorded relatively high concentration and $SO_2$ in comparison to other monitored stations.

We have found from table 4.8 that mean value 83.50 (µg/$m^3$) of Particulate matter of Kalinganagar is highest while Berhampur shows lowest 47.60 (µg/$m^3$) and concentration of particulate matter in Rourkela shows more scattered 67.20 (µg/$m^3$) than other monitored stations. We also studied from the table 4.8 that Berhampur has lowest emission 23.00 (µg/$m^3$) while Kalinganagar has contributed highest Particulate matter ($PM_{2.5}$). It is also very interesting fact that two monitor stations i.e., Kalinganagar and Paradeep are approximately symmetric while six monitored stations viz., Berhampur, Bhubaneswar, Jharsuguda, Rayagada, Rourkela and Talcher are highly or moderately skewed.

It is also here to mention that only monitor station i.e., Kalinganagar (Jajpur) under Northern division produces highest 83.50 (µg/$m^3$) in comparison then Bhubaneswar (Khurda) and Paradeep (Jagatsinghpur).

Similarly, Talcher (Anugul) which comes under Central division contribute $PM_{2.5}$ 72.00 (µg/$m^3$) very interesting fact that Rayagada and Berhampur (Ganjam) under the southern division receive less particulate matter ($PM_{2.5}$).

We have also computed correlation coefficient between the highest producing monitored station Kalinganagar and Berhampur found that they are positively correlated i.e., 0.73. From the figure 4.20 in chapter IV that annual average concentration particulate matter ($PM_{2.5}$) stands above the yearly standard which is 40 (µg/$m^3$) and also found that Kalinganagar successively recorded relatively high concentration and $PM_{2.5}$ in comparison to other monitored stations.

We have found from table 4.11 that mean value 112.20 (µg/$m^3$) of Particulate matter of Paradeep is highest while Berhampur shows lowest 59.60 (µg/$m^3$) and concentration of particulate matter in Paradeep shows more scattered 11.13 (µg/$m^3$) than other monitored stations. We also studied from the table 4.11 that Berhampur has lowest emission 52.00 (µg/$m^3$) while Paradeep has contributed highest Particulate matter ($PM_{10}$). It is also very interesting fact that four monitor stations i.e., Kalinganagar, Berhampur, Jharsuguda and Paradeep are approximately symmetric while four monitored stations viz., Bhubaneswar, Rayagada, Rourkela and Talcher are highly or moderately skewed.

It is also here to mention that monitor station i.e., Kalinganagar (Jajpur) and Paradeep (Jagatsinghpur) under Northern division produces highest 122.00 and 128.00 (μg/$m^3$) respectively in comparison then all of the monitored stations.

Similarly, Talcher (Anugul) which comes under Central division contribute $PM_{10}$ 99.40 (μg/$m^3$) very interesting fact that Rayagada and Berhampur (Ganjam) under the southern division receive less particulate matter ($PM_{10}$).

We have also computed correlation coefficient between the highest producing monitored station Paradeep and Berhampur found that they are positively correlated i.e., 0.74. From the figure 4.21 in chapter IV that annual average concentration particulate matter ($PM_{10}$) stands above the yearly standard which is 60 (μg/$m^3$) and also found that Paradeep successively recorded relatively high concentration and $PM_{10}$ in comparison to other monitored stations.

Susceptibility to ozone injury is influenced by many environmental and plant growth factors. High relative humidity, optimum soil-nitrogen levels and water availability increase susceptibility. Injury development on broad leaves also is influenced by the stage of maturity. The youngest leaves are resistant. With expansion, they become successively susceptible at middle and basal portions. The leaves become resistant again at complete maturation.

It is studied from the trend line and also from descriptive statistics, Sulphur dioxide is under control in all the eight monitored stations (below 50 microgram per cubic meter) as per NAAQS-2009 wherein Paradeep monitored station is relatively producing highest emissions in comparison to other monitored stations due to one port and number of industrial units. It may be suggested to timely checking of coal-burning operations, especially those providing electric power and space heating under control to of increasing trend line of Paradeep under northern zone f urban areas of Odisha.

Elevated levels of nitrogen dioxide can cause damage to the human respiratory track and increase a person's vulnerability to, and the 7:30 of respiratory infection and asthma. Long-term exposure to high level of nitrogen dioxide can cause chronic lung disease for other at high concentration level nitrogen dioxide is potentially toxic to plant, can injured leaves and produce growth and yield. In combination with ozone ($O_3$) or sulphur dioxide ($SO_2$) nitrogen dioxide may cause injury at even lower concentrations level.

It is observed from the trend line and also from descriptive statistics, particulate meter ($PM_{2.5}$) is under control in all the eight monitored stations (below 60 microgram per cubic meter) as per NAAQS-2009 wherein Paradeep monitored station is relatively producing highest emissions in comparison to other monitored stations due to one port and number of industrial units. It may be suggested to timely checking of coal-burning operations, especially those providing electric power and space heating under control to of increasing trend line of Paradeep under central zone of urban areas of Odisha.

Exposure to high concentration of $PM_{10}$ can result in a number of health impact recognise from coughing and wheezing to asthma attack and bronchitis to high blood pressure heart attack strokes and premature death. Further most of the effect of $PM_{10}$ particles on plants include the potential to block and damage the stomata such that photosynthesis and respiration are affected.

It is studied from the empirical findings that Sulfur Dioxide and Nitrogen Oxide's concentration is under control as per the NAAQS-2009 in all eight monitored stations of three zones. Though all the monitored stations are under control but the monitored station namely Paradeep (high concentration in Sulfur Dioxide) and Talcher (high concentration in Nitrogen Oxide) of urban areas of Odisha are showing increasing trend. Practical measures of prevention may be taken up to control the increasing trend of the two above-said alarming monitored stations.

Two air pollutants viz., $PM_{10}$ and $PM_{2.5}$ concentration are above the normal standard as per the NAAQS-2009 in all the years starting from 2016 to 2019 except the year 2020. Due to Covid-19, year 2020 is showing downward trend.

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