

AIR QUALITY MONITORING OF ROORKEE TOWN

A DISSERTATION

*Submitted in partial fulfilment of the
requirements for the award of the degree*

of

MASTER OF ENGINEERING

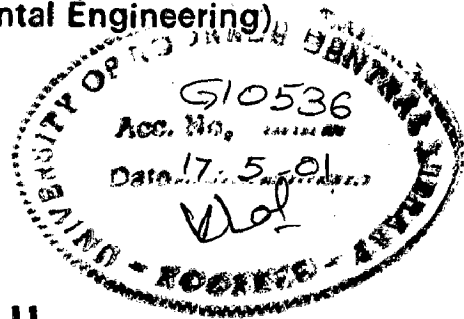
in

CIVIL ENGINEERING

(With Specialization in Environmental Engineering)

By

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CANDIDATE'S DECLARATION

I hereby declare that the work which is being presented in the dissertation entitled "AIR QUALITY MONITORING OF ROORKEE TOWN" in partial fulfillment of the requirements for the award of the degree of **Master of Engineering** in Civil Engineering with specialization in Environmental Engineering submitted in the **Department of Civil Engineering, University of Roorkee**, is an authentic record of my own work carried out for a period of about six months from September 2000 to February 2001 under the supervision of **Dr. Renu Bhargava**, Professor, Environmental Engineering Section and **Dr. M. Parida**, Assistant Professor, Transportation Engineering Section, Department of Civil Engineering, University of Roorkee, India.

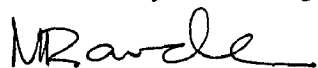
The matter embodied in this dissertation has not been submitted by me for the award of any other degree.

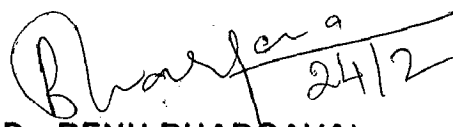
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ABSTRACT

Adequate knowledge of a situation is a prerequisite for any effective intervention aiming at its modification for achieving certain goals. This is true even in air pollution studies since the ambient air quality plays a vital role in assessment of the extent of pollution levels especially in urban, semi-urban and in rural areas. The concern for quality of urban, semi-urban, rural air quality is being felt due to tremendous increase in anthropogenic activities resulting in deterioration of air quality at a faster rate. As a result, these activities cause environmental pollution and lead to many problems like health effects, visual problems.

In India also, much of the interest has been shown and much of the work has been done for maintaining air quality. Recognizing the importance of this, Acts have been passed in the last 20 years. Concentrations of pollutants vary over an area due to combined effects of source configuration and meteorological and topographical features of the area. Thus with the objective of knowing the status of air quality and its probable effects on human, "Roorkee" town a semi urban area was selected as the study area for the present study. Primary pollutants (SPM, SO₂, Nox) were monitored in the study area at nine stations. CO, HC were also monitored in Bus Stand on the day of Kumbh Mela. The sampling was done in all the stations for eight hour interval. The air quality index was also evaluated for observed results.

After observing the results the concentration of SPM was observed at high levels. In remaining parameters SO₂, NO₂ were well below permissible value, except NO₂ concentration at bus stand was observed above permissible limits. The concentration of CO was also observed at higher than permissible limits. The air quality index at various locations were calculated and the results say that except bus stand, old Roorkee the remaining stations were observed very clean.

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CHAPTER 1

INTRODUCTION

1.1 IMPORTANCE OF AIR QUALITY

Earth can be described as a living planet. The gaseous envelop i.e., atmosphere is held to it as cover upto a height of approximately 10000 km. The composition of atmosphere is uniform up to 80 km where bulk of atmosphere lies and contains life-sustaining gases. Air is thus a priceless gift of nature without which life cannot be sustained for more than a few minutes. Humanity has now realized that their existence would be in danger if this gift is not maintained in a proper way. Human activities like industrial production, motor transport and domestic burning of fuels are adding large amounts of harmful pollutants to the atmosphere triggering off a host of global and regional environmental problems. Earth atmosphere has a limited capacity to assimilate these problems. Even with present day scientific knowledge human understanding on sinks is unclear, but there should be absolutely no doubt that this ability is limited. At local levels, pollutants include various gases, smoke, unburnt hydrogen carbide and dust. These reduce visibility, irritate and impair health or affect vegetation and materials.

1.2 INDIAN SCENE

World Health Organization (WHO) in late 1972 initiated its first ever-global air quality-monitoring project at pre-selected stations. These become operational in 1973. In India however, a National Air Monitoring

Program has been taken up by NEERI (National Environment Engineering Research Institute), Nagpur in accordance with the WHO suggestions to assess air quality within the framework of selected parameters. Ahmedabad, Bombay, Calcutta, Cochin, Delhi, Hyderabad, Jaipur, Kanpur and Madras were the centers chosen for this purpose. Four parameters were chosen for monitoring, suspended particles, Sulphur Dioxide, Sulphation rate and dust fall.

In Indian scenario, air pollution came to national focus in 1972 when Government of India decided to set up a large oil refinery at Mathura, 40 Km upwind of (Tajmahal) at Agra. The extent of pollution even in cities having populations of more than a million has not been studied. However, it is apparent from the limited data available that levels of SO₂ are increasing in all most all cities and they exceed the limits specified by Indian Standard Institution (ISI). In metropolitan cities, levels of SPM are also found considerably more than cities of Europe and North America. In fact, Indian cities and towns generally have lot of smoke. Further since India is a tropical country, atmosphere contains greater amounts of dust particles even if there is no human activity. Hence it is absolutely necessary to control pollutants being emitted by anthropogenic activities.

1.3 STUDY AREA

Roorkee is a medium sized town comprising of Municipal and Cantonment board. The Ganga canal office and Thomason College of Engineering are the institutions that were established before independence. After independence it became a center of academic and research activities. University of Roorkee, Central Building Research Institute, Bengal Sappers,

Irrigation Research Institute and National Institute of Hydrology are the institutions located in this region. Presently 80% of the industrial units are manufacturing engineering and scientific instruments.

Roorkee lies at 29°51' N latitude and 77°53' E longitude. It is situated on the right bank of River Solani . Upper Ganga Canal divides the city into two parts. Old part of the city is situated along the right bank, whereas the institutional sector of the city mostly falls along the left bank of the canal. It is situated on National Highway 58 (Roorkee-Haridwar-Rishikesh road). The natural boundaries of Roorkee are Himalayas on the north side, Ganges River on the east side and Yamuna River on the west side. Presently Roorkee is in Haridwar district of Uttaranchal state which has been created on November 9, 2000.

Roorkee experiences long winters which starts from the month of November and continues up to the month of February. Summer season starts from March and the maximum temperature generally goes around 40°C. September is the general duration in which intense rains are most prominent. The average annual rainfall is 1068 mm. The average wind speed is 4.9 m/s.

1.4 OBJECTIVES OF PRESENT STUDY

The metropolitan cities have received lot of attention w.r.t. air pollution and usually small urban centres are kept beyond the scope of study assuming that they open a pollution free environment. Roorkee is a typical small town without any large scale of industrial activity but exposed to nuisances of two national highways, i.e., NH-58, NH-73. In Roorkee, not much work has been carried out in air quality monitoring. This is because Roorkee is a sub urban

area where industrialization is less. The present study has been carried out to monitor different air quality parameters at various locations in Roorkee.

The objectives of the present study are to assess the extent & potential of air pollution in Roorkee.

- To observe concentration of SO₂, NO₂ and SPM in Roorkee atmosphere.
- To observe concentration of CO, HC in Bus stand area.
- Calculation of Air Quality Index at all monitoring points.

1.5 ORGANISATION OF THE THESIS

Chapter 2 deals with the sources and effects of various air quality parameters, Acts and Standards for these parameters, Ambient air quality in different cities

Chapter 3 deals with the Study area.

Chapter 4 includes various instruments and methodologies used for the evaluation of various air quality parameters.

Chapter 5 deals with Results and Discussion.

Chapter 6 deals with the conclusions and future scope of the study.

CHAPTER 2

LITERATURE REVIEW

2.1 GENERAL

This chapter deals with the relevant literature review i.e. atmospheric pollutants their sources and their effects, ambient air quality at different cities and past work done in Roorkee town.

2.2 AIR QUALITY PARAMETERS, SOURCES AND THEIR EFFECTS

Atmospheric pollutants affect human health and vegetation in many ways. Some of the atmospheric pollutants that affect human beings directly and indirectly, are listed below.

2.2.1 Suspended particulate matter (SPM)

Particulates may be classified according to their physical, chemical and biological characteristics. Physical characteristics includes size and mode of formation. Chemical characteristics includes organic components like phenols, organic acids & alcohols, inorganic components like nitrates, sulphates and metals such as iron, lead, manganese, zinc and vanadium. Biological characteristics include bacteria, viruses, spores and pollens. Combustion generated pollution is one of the principal sources of air pollution where particulate exists in different degrees. The main single or point sources are steel mills, thermal power plants, oil refineries and pulp and paper mills. Exhausts from railway engines and other vehicles are also responsible for its formation [3, 4].

Effects on Humans : At high concentrations suspended particulate matter poses health hazards to human, particularly those susceptible to respiratory illness. Pollens and spores are the cause of allergic reactions in sensitive persons. Finely powdered industrial materials can also cause allergic reactions in sensitive persons.

Effects on Plants : Dry cement and kiln dust damages the plants if deposited on a leaf surface, yet in presence of moisture such dust impacts damage and consequential growth inhibition to plant tissues. Animals, who eat plants coated with particles containing fluorides, arsenic are affected.

Effects on Metals : Particulates corrode metals (at relative humidity > 75%), corroding building surfaces and discoloring and destroying painted surfaces.

2.2.2 Sulphur dioxide (SO₂)

Sulphur dioxide is a colorless, non-flammable and non-explosive gas with a suffocating odour. It has a taste threshold of 784 $\mu\text{g}/\text{m}^3$ (0.3 ppm) and an odour threshold of 1306 $\mu\text{g}/\text{m}^3$ (0.5 ppm). Sulphur dioxide is highly soluble in water (11.3 g/100 ml at 20°C), has a molecular weight of 64.06 and is about twice as heavy as air. It is estimated that Sulphur dioxide remains air borne for 2 to 4 days during which time, it may be transported as far as thousand kilometers depending upon meteorological factors. Thus the problem of sulphur dioxide pollution can become an international one. The sources of sulphur dioxide are transportation, fuel combustion, industries and solid waste disposal [3, 4].

Effects on Human Beings : Sulphuric acid, Sulphur dioxide and Sulphate salts tend to irritate the mucous membranes of the respiratory tract and foster the development of chronic respiratory diseases, particularly bronchitis and pulmonary diseases. Apart from these, tightness in chest, choking of lungs, nose bleeding and digestive tracts are also affected.

Effects on Plants : Injury to vegetation can be classified as acute or chronic. The sulphur dioxide concentration in acute exposure is high for a short period, resulting in damage characterized by clearly marked dead tissue between the veins or on the margin of the leaves. Chronic injury comes from exposure to low concentrations for long period of time, which causes brownish-red or bleached white area on the blade of the leaf. Plants are particularly sensitive to Sulphur dioxide during periods of intense light, high relative humidity, adequate moisture, moderate temperature and during their growing season, regardless of climatic conditions.

Effects on Metals : Sulphuric acid aerosols will readily attack building materials, especially those containing carbonates such as marble limestone, roofing slate and mortar. Many of our historical monuments (Taj mahal), public buildings, cathedrals and sulphates have deteriorated from exposure to sulphur dioxides. Excess exposure to sulphur dioxide accelerates corrosion rates for many metals such as iron, steel, zinc, copper and nickel especially at relative humidity over 70 %. Corrosion rates are found to be 1.5 to 15 times greater in polluted urban areas than in clean air areas.

2.2.3 Oxides of nitrogen

Out of seven varieties of oxides of Nitrogen, Nitrogen dioxide is found to be injurious to human health. Nitrogen dioxide is a reddish brown gas is quite visible in sufficient amounts. A concentration of 1 ppm of Nitrogen dioxide probably would be detected by eye. Nitrogen dioxide is heavier than air and is readily soluble in water in the form of Nitrous acid. Nitrogen dioxide mainly originates into atmosphere from automobile exhausts, incineration plants, furnace smoke etc. and it is caused by the combustion of organic matter [3, 4].

Effects : Nitrogen dioxide irritates the alveoli of the lungs. Eye and nasal irritations are the common problems caused by about 28 mg/m³ (15 ppm) of Nitrogen dioxide. Respiratory discomfort may occur even with brief exposure, when its concentration rises to about 47 mg/m³ (25 ppm). Many deaths were reported to have occurred in a fire in a clinic in Cleveland in United States of America in May 1929, due to evolution of Nitrogen dioxide from the burning of X-ray films.

2.2.4 Carbon monoxide (CO)

It is a colourless, tasteless and odourless gas and is chemically inert under normal conditions. The estimated atmospheric mean life of carbon monoxide is about 2 ½ months. Carbon monoxide sources are both natural, like decay of vegetation and anthropogenic like the traffic. Another source of its formation is human metabolism i.e., exhalations of a resting person. Major source of CO is automobile exhaust. Another source of CO is solid waste disposal, forest fire, structural fires, coal refuse and agricultural burnings [3, 4].

Effects on Human Beings : CO possesses about 200 times affinity for blood hemoglobin (Hb) than oxygen. Eventually when inhaled CO replaces oxygen from hemoglobin and forms what is known as Carboxy Hemoglobin (COHb). COHb is of no use for respiratory purposes and hence when about half of the hemoglobin of the blood is used up in forming COHb, death becomes a certainty. Persons dying of CO inhalation exhibit characteristics bright pink colour of the flesh due to presence of pink coloured (COHb) in their blood. CO also affects the central nervous system and causes heart attacks.

2.2.5 Hydrocarbons

Organic compounds containing only carbon and hydrogen are classified as hydrocarbons. Most of the major chemicals in gasoline and other petroleum products are hydrocarbons, which are divided into two major classifications. The aliphatic hydrocarbons include alkanes (methane), alkenes (olefines), and alkynes. Out of these three Only alkenes (olefines) have been found to be highly reactive in atmosphere through photochemical reactions. Alkanes are simply inert hydrocarbons and do not react photochemically. But alkynes, though quite reactive are generally not found in atmosphere and hence are of no importance to us in the air pollution studies [3, 4].

Hydrocarbons are chiefly released into the atmosphere by automobile exhaust. Hydrocarbons are also released into the atmosphere by smokes of incinerators, through fumes of oil refineries, by evaporation of gasoline at service stations and solid waste disposal.

Effects on Human Beings : Experimental tests on humans and animals with aliphatic hydrocarbon concentrations of 326.5 mg/m^3 produce no harmful effects. Some aromatic hydrocarbons (benzene) are found to cause body cancers. Substances like formaldehyde cause irritations of eyes, skins and lungs and hence may be quite injurious to health.

Effects on Plants : Ethelene is among the few hydrocarbons that can cause plant damage. Exposure of orchids to $342 \text{ } \mu\text{g/m}^3$ for one hour produces adverse affects.

2.3 ACTS AND STANDARDS

In India, in the beginning of this century, some local authorities adopted legislation in the form of "SMOKE NUISANCE ACT". These came into existence for Calcutta in 1905, for Bombay in 1912 and Kanpur in 1958 (CENTER FOR SCIENCE AND ENVIRONMENT, 1986). However, at national level, the act for prevention and control of air pollution came in existence only in 1981. Unlike the "WATER POLLUTION CONTROL ACT", this act is applicable throughout the country. The act provides an integrated approach for tackling environment problems relating to pollution. Pollution of air or that of water cannot be dealt in isolation. Recognizing more seriousness of interactions, Government of India passed another act in May 1986. "THE ENVIRONMENT PROTECTION ACT". This act is to serve the purpose of protecting and improving the quality of the environment and preventing, controlling and abating environmental pollution.

As per the provisions of section 16(h) of air act, the state pollution control boards have categorized parts of India into:

1. Industrial and mixed used areas
2. Residential and rural areas
3. Sensitive areas

Based on land use pattern and sensitivity of the realm category (1) is the area which is marked industrial development or where main land use is industrialization. Category (2) includes all areas not specially included in categories (1) and (3). Sensitive areas will cover hill stations, tourists' resorts, health resorts and other such areas where the nation would wish to conserve its clean environment even if that implies some curbs on economic activities and development efforts. Table 2.1 gives Indian ambient air quality standards prescribed by Central Pollution Control Board (CPCB), when monitored uniformly over a year with frequency of not less than once in a week with a sampling time of 8 hours. The monitoring is to be done according to procedure specified by the CPCB, and concentration shall be 95% of the time within the limits prescribed, whereas table 2.2 gives the limits for ambient air quality prescribed by the Indian Standard Institution.

TABLE 2.1: Indian Ambient Air Quality Standards (CPCB) [14]

Category	area	concentration ($\mu\text{g}/\text{m}^3$)			
		SPM	SO ₂	NO ₂	CO
A	industrial and mixed	500 (8hrs)	120(8 hrs)	120(8hrs)	5000
		360(24 hrs)	80(24 hrs)	90 (24 hrs)	
B	residential and rural	200 (8 hrs)	80(8 hrs)	80 (8 hrs)	2000
		140(24 hrs)	60(24 hrs)	60 (24 hrs)	
C	sensitive	100(8 hrs)	30(8 hrs)	30(8 hrs)	1000
		70(24 hrs)	20(24 hrs)	20 (24 hrs)	

In 1979, World Health Organization (WHO) published exposure limits for SO₂ and SPM (1984) measured as smoke or determined gravimetrically to limit the effects of both acute and long-term exposures. For long-term exposures and the related risks to public health, reference is made to the annual average pollutant concentrations in air.

Table 2.2 gives the air quality standards adopted by the Environment Protection Agency (EPA).

TABLE 2.2: Air Quality Standards (EPA) [11]

S.No.	Parameter	Concentration $\mu\text{g}/\text{m}^3$	PPM	Remarks
1.	SPM	75	--	Annual geometric mean 24 hours
		260	--	
2	SO ₂	80	0.83	Annual mean 24 hours
		365	0.14	
3.	Oxides of Nitrogen	100	0.05	24 hours
4.	Carbon Monoxide	10,000	9	8 hours not more than once in a year 1 hours not more than once in a year
		40,000	35	
5.	Non-methane Hydrocarbons	160	0.24	6-9 hours. Annual mean not more than once in a year.
6.	Ozone	235	0.12	1 hour daily max. not more than once in a year.
7.	Lead	1.5	--	3 months average.

2.4 AIR QUALITY INDEX

The concentration expressed for various parameters are difficult to be understood by a common man. In addition air quality standard for a particular parameter gives maximum permissible limit considering possible effects on man, material and vegetation. When, two or more pollutants are present the effect could be synergistic. These problems can be sorted out by representing quality of air by a single number known as "AIR QUALITY INDEX (AQI)". There are various methods to find AQI. The method given by Tiwari and Ali [198] is presumed to be good, since this is based on the geometric mean principle [14].

Air quality categories

On assumption that, the cumulative effect of an parameters is more severe than that of the effect of individual pollutant, and further, that all the pollution parameters are of equal importance, Mudri (1990) classified AQI into 7 categories as listed in Table 2.3.

TABLE 2.3: Air Quality Categories Based on AQI [13]

Category	AQI	Ambient air quality
I	< 10	Very clean
II	10-25	Clean
III	25-50	Fairly clean
IV	50-75	Moderately polluted
V	75-100	Polluted
VI	100-125	Heavily polluted
VII	>125	Severely polluted

2.5 AMBIENT AIR QUALITY IN DIFFERENT CITIES

The ambient air quality for various Indian cities is being monitored by the different agencies and research workers and is published for time to time. These have been received in the following paragraphs.

2.5.1 Ambient Air Quality in Delhi

Ambient air quality in Delhi was monitored regularly at 9 locations. C.P.C.B. monitored six locations namely, Nizamuddin, Ashok Vihar, Shahazadabagh, Shahdara, Janakpuri and Siri Fort while Environmental Research Institute (NEERI) monitored at 3 locations namely at Netaji Nagar, Najafgarh and town hall. The parameters monitored were SO₂, NO₂, SPM. CO was also monitored at selected locations by Centre Pollution Control Board (CPCB) [19].

The SPM values in Delhi found to be varying between 360 to 430 $\mu\text{g}/\text{m}^3$ during summer season. During pre-monsoon season, these values ranged between 200 to 400 $\mu\text{g}/\text{m}^3$. During post-monsoon season, the SPM values were observed between 360 to 600 $\mu\text{g}/\text{m}^3$. In the winter season, the SPM levels were observed to be ranging between 260 to 380 $\mu\text{g}/\text{m}^3$.

The sulphur dioxide levels were found to be varying between 10 to 21 $\mu\text{g}/\text{m}^3$ during summer season. During pre-monsoon season, sulphur dioxide values were varying between 14 to 22 $\mu\text{g}/\text{m}^3$ over the city. In the past monsoon season, the sulphur dioxide values were very high ranging between 14 to 38 $\mu\text{g}/\text{m}^3$. The SO₂ values in winter season were also observed to be considerable high ranging between 12 to 32 $\mu\text{g}/\text{m}^3$.

The oxides of Nitrogen (NO_2) were observed to be varying between 14 and $34 \mu\text{g}/\text{m}^3$ in summer season. During pre-monsoon season the nitrogen values were observed to be varying between 25 to $35 \mu\text{g}/\text{m}^3$ over the city. In the post-monsoon season, the values were observed to be high varying with values ranging between 26 to $52 \mu\text{g}/\text{m}^3$. In winter season these were also observed to be varying between 27 to $47 \mu\text{g}/\text{m}^3$.

2.5.2 Ambient Air Quality in Lucknow

Pandey et. al reported air quality of Lucknow city in their research paper. Air quality parameters SO_2 , NO_2 , SPM were monitored at 13 locations in the city. Only SPM concentrations were found to be on higher side. Maximum SPM concentrations were observed at Alambagh $3450 \mu\text{g}/\text{m}^3$. Maximum sulphur dioxide and Nitrogen dioxide were observed at University Road (29 ppb), Charbagh Bus stands (69 ppb). SPM levels exceeded air quality standards at all sites except at Kulkarni spot. SO_2 concentration was well below threshold limit. Concentration of NO_2 was also below threshold level except at 3 sites where it was very high [15].

2.5.3 Ambient Air Quality in Hyderabad

Air quality parameters SO_2 , NO_2 , SPM was calculated at 15 locations in the city. SPM values were found to be between 180 to $420 \mu\text{g}/\text{m}^3$. Nitrogen dioxide values were ranged from 5 to $20 \mu\text{g}/\text{m}^3$. Sulphur dioxide values were ranged from 4 to $18 \mu\text{g}/\text{m}^3$ [14].

2.6 PAST WORK DONE IN ROORKEE

Srivastava (1995) carried out the air quality studies in reference of traffic flow on Delhi - Haridwar highway and the values observed are listed in Table 2.4.

TABLE 2.4: Air Quality Parameters in Roorkee Bus Stand [20]

Parameters	Time	Concentration ($\mu\text{g}/\text{m}^3$)
NO ₂	8 A.M. - 4 P.M.	106.47
SPM	8 A.M. - 4 P.M.	566.2
CO	10 A.M. - 11 A.M.	1810
CO	11 A.M. - 12 P.M.	1970
CO	3 P.M. - 4 P.M.	1698
HC	10 A.M. - 11 A.M.	392
HC	11 A.M. - 12 P.M.	306
HC	3 P.M. - 4 P.M.	379

Raturi, (1983) determined the SPM in Roorkee atmosphere due to vehicular traffic on Delhi – Hardwar Road which is presented below.

TABLE 2.5: Particulate matter concentrations [17]

Sampling station No.	Location of the sampling station	Avg. conc. of SPM in $\mu\text{g}/\text{m}^3$ (8 hrs.)
1.	Near canal office towards Solani bridge	925
2.	Near Savera hotel	991.67
3.	Near Bengal Sweet Comer	1366.66
4.	Bus Stand	833.33
5.	Petrol near pump near court	1670
6.	Over bridge on railway line towards Delhi	1075
7.	Roorkee bakery near Azad Wing	170
8.	At Centenary gate	230
9.	At Jawahar Bhawan	50

From the literature review, it is seen that air monitoring has not been carried out in Roorkee.

CHAPTER 3

METHODOLOGY

3.1 GENERAL

This chapter deals with the various instruments and the method of analysis used.

3.2 INSTRUMENTS

For measuring various air quality parameters following instruments have been used. They are discussed in sections 3.2.1 to 3.2.4.

3.2.1 High Volume Air Sampler

A high volume air sampler model HVAS 1500 used as main instrument for monitoring the air pollutants SO_2 , NO_2 , SPM in the field is as shown in the plate 3.1. The main parts of the high volume sampler are manometers, timer, and blower. Main function of the impinger is to collect SO_2 , NO_2 samples into the known concentration of SO_2 , NO_2 that is already filled in the impingers. Diameter of the impinger is 1.3 mm. The manometer gives the differential pressure that is proportional to flow rate. The flow rate is known from the calibration curve that has been shown in Fig. 3.1. The timer is to adjust the time for the desire duration. The timer will switch off the unit as per the program. The parts of HVAS is shown in Fig. 3.2 [5].

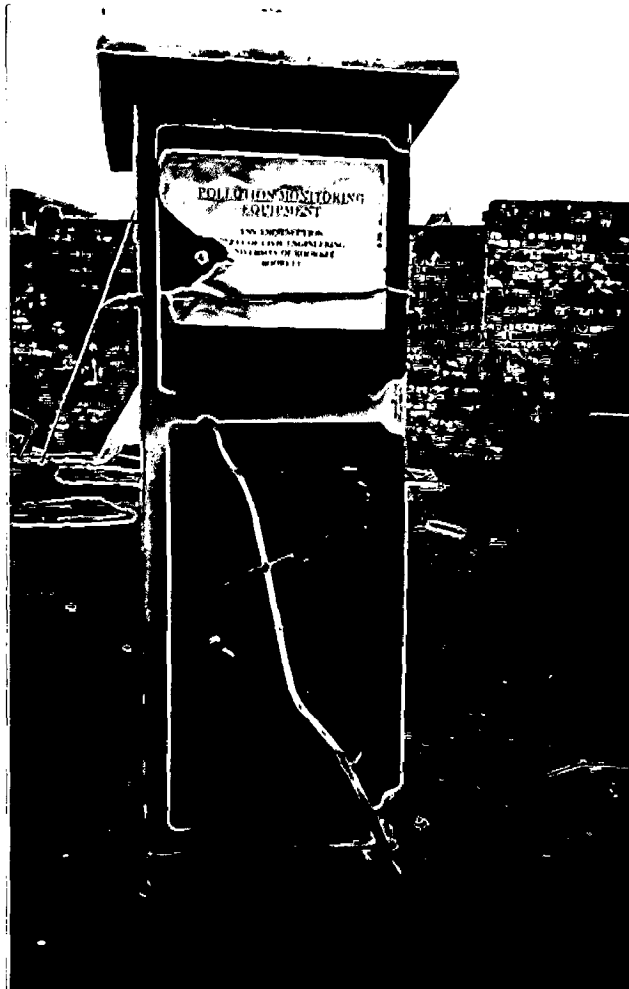


Plate 3.1: High Volume Air Sampler

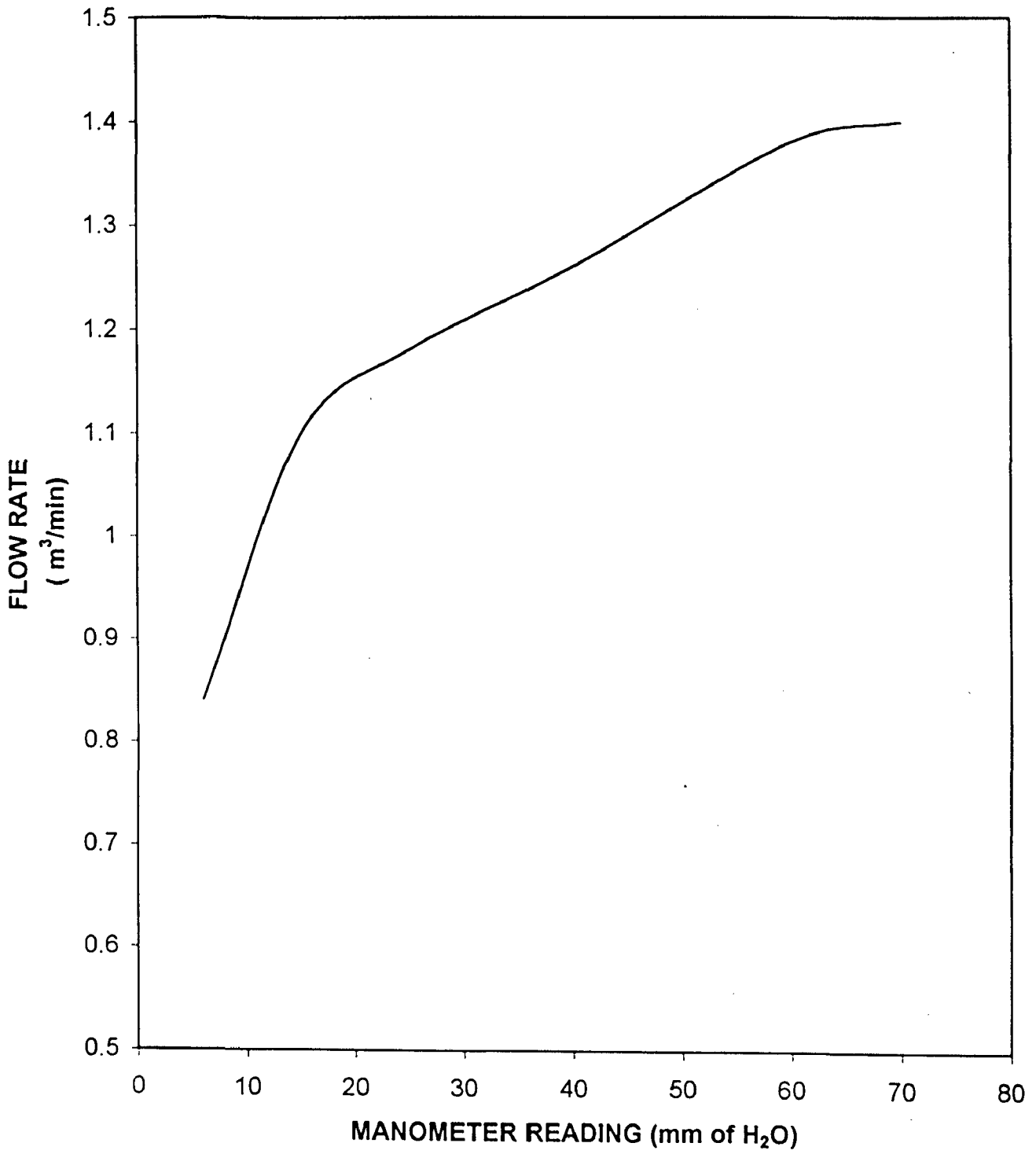
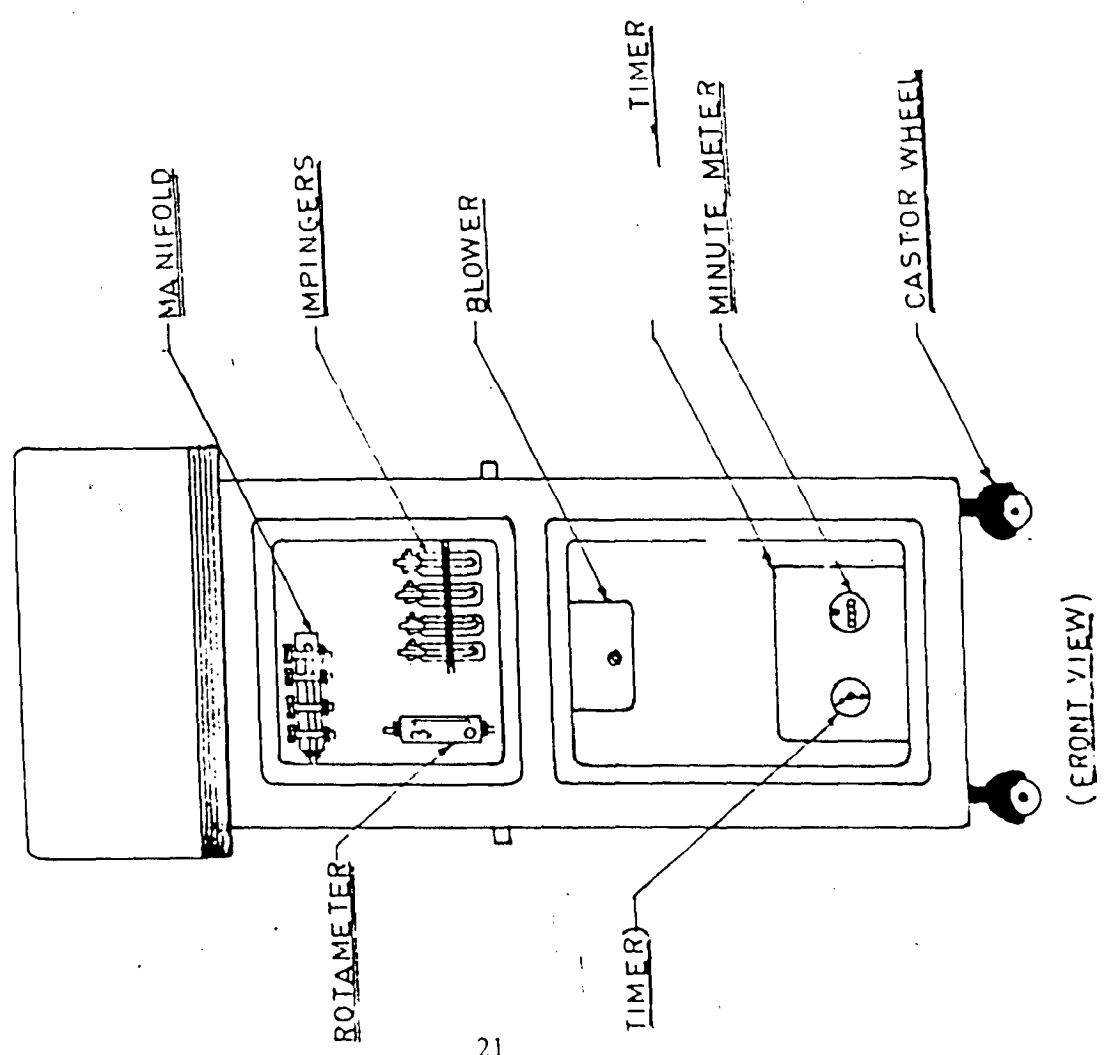
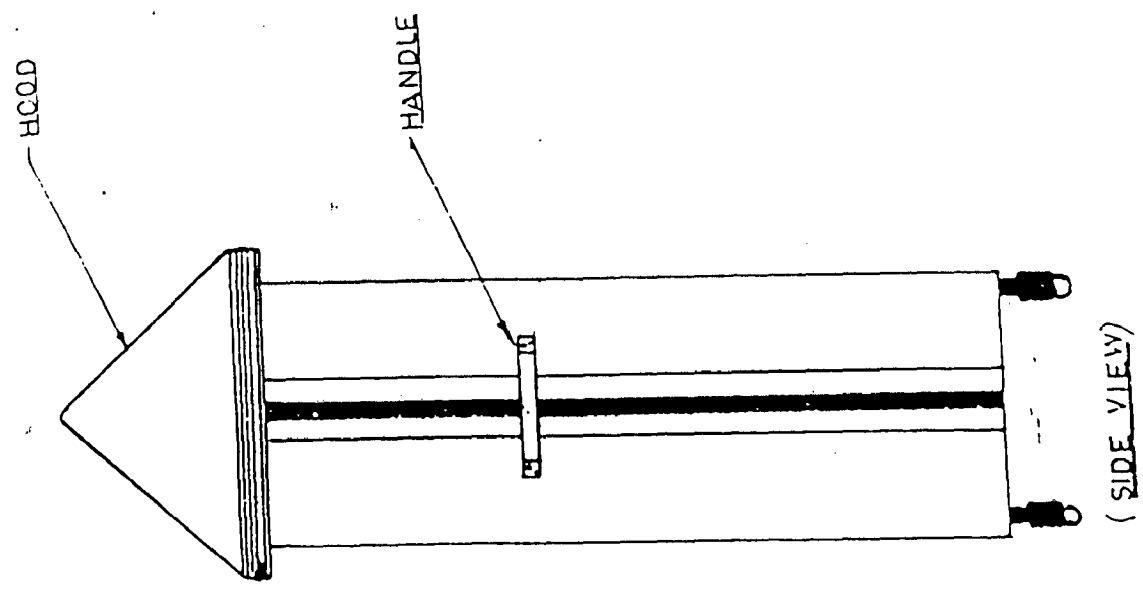
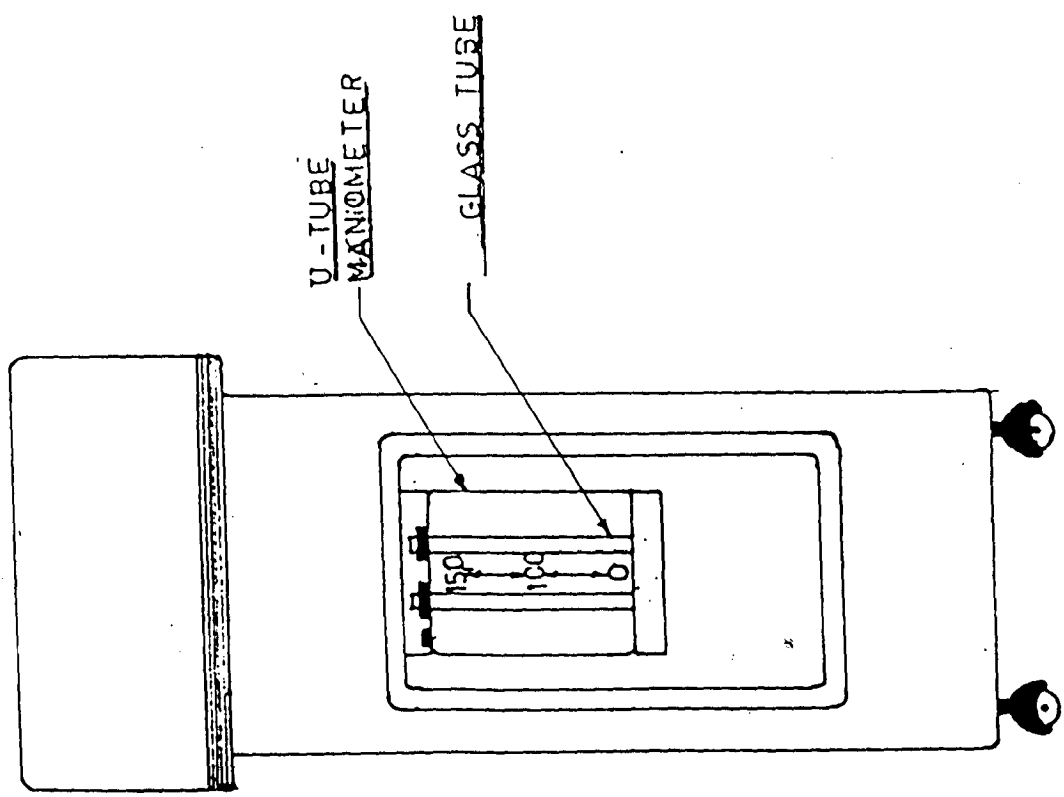
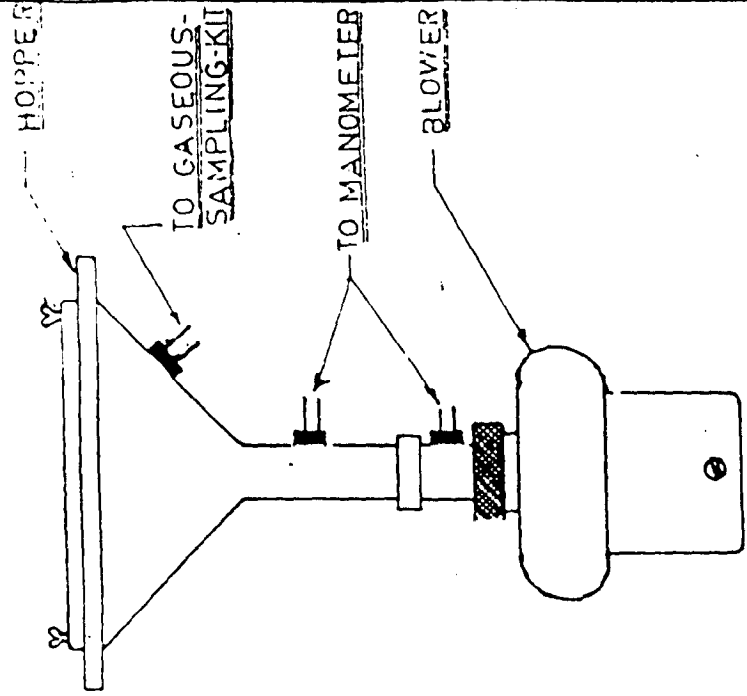


Fig: 3.1 CALIBRATION GRAPH FOR HVAS 1500

Fig. 3.2: (HIGH VOLUME AIR SAMPLER)



(HIGH VOLUME AIR SAMPLER)



BACK VIEW

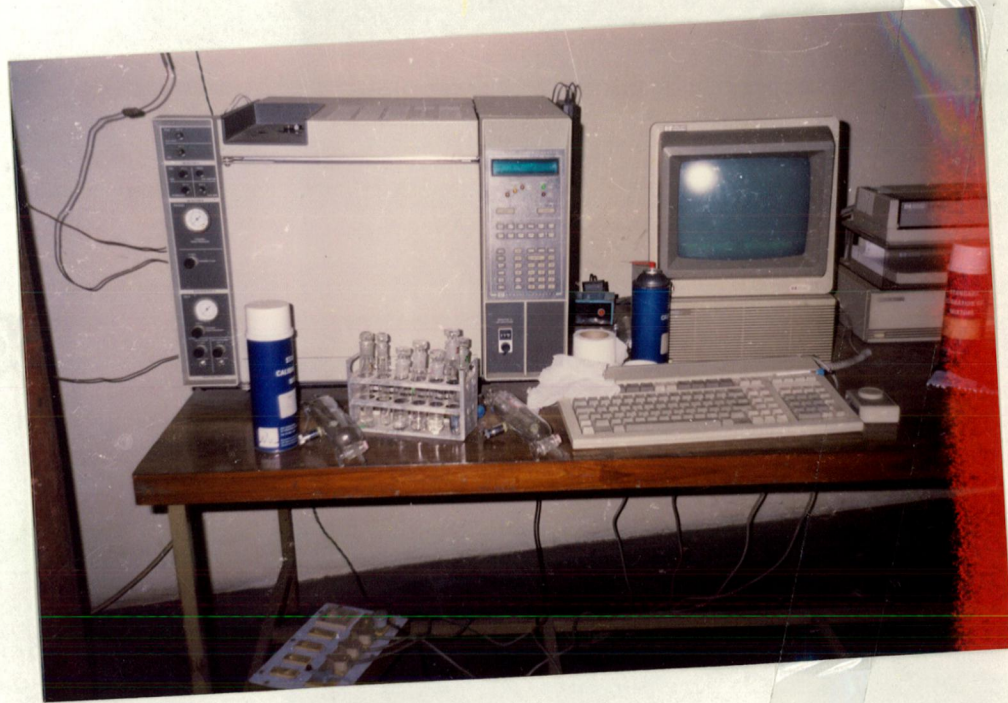


Plate 3.2: Gas Chromatography

3.2.2 Gas chromatograph

Gas chromatograph (model HEWLETT PACKARD 5890, USA.) available in University Science Instrumentation Center (USIC), Roorkee University was used for the analysis of air samples CO and hydrocarbons. A view of gas chromatograph is shown in the plate 3.2.

3.2.3 Spectrophotometer

Spectrophotometer (model ELICO INDIA SL 159 UV VIS) was used for the measurement of absorbance of collected sample solutions.

3.3 METHODOLOGY

In the present work, Roorkee town has been selected as study area. A reconnaissance survey was done to select the monitoring points. The site selection was selected in such a way that it covers all the important points of Roorkee town. Air quality parameters such as SO₂, NO₂, SPM were monitored at nine stations with an average of 8 hours interval. Carbon monoxide and hydrocarbons were monitored in the Bus Stand in the morning, afternoon and evening. The selected monitoring stations along with measured air quality parameters are li .1 and also shown in Fig. 3.3.

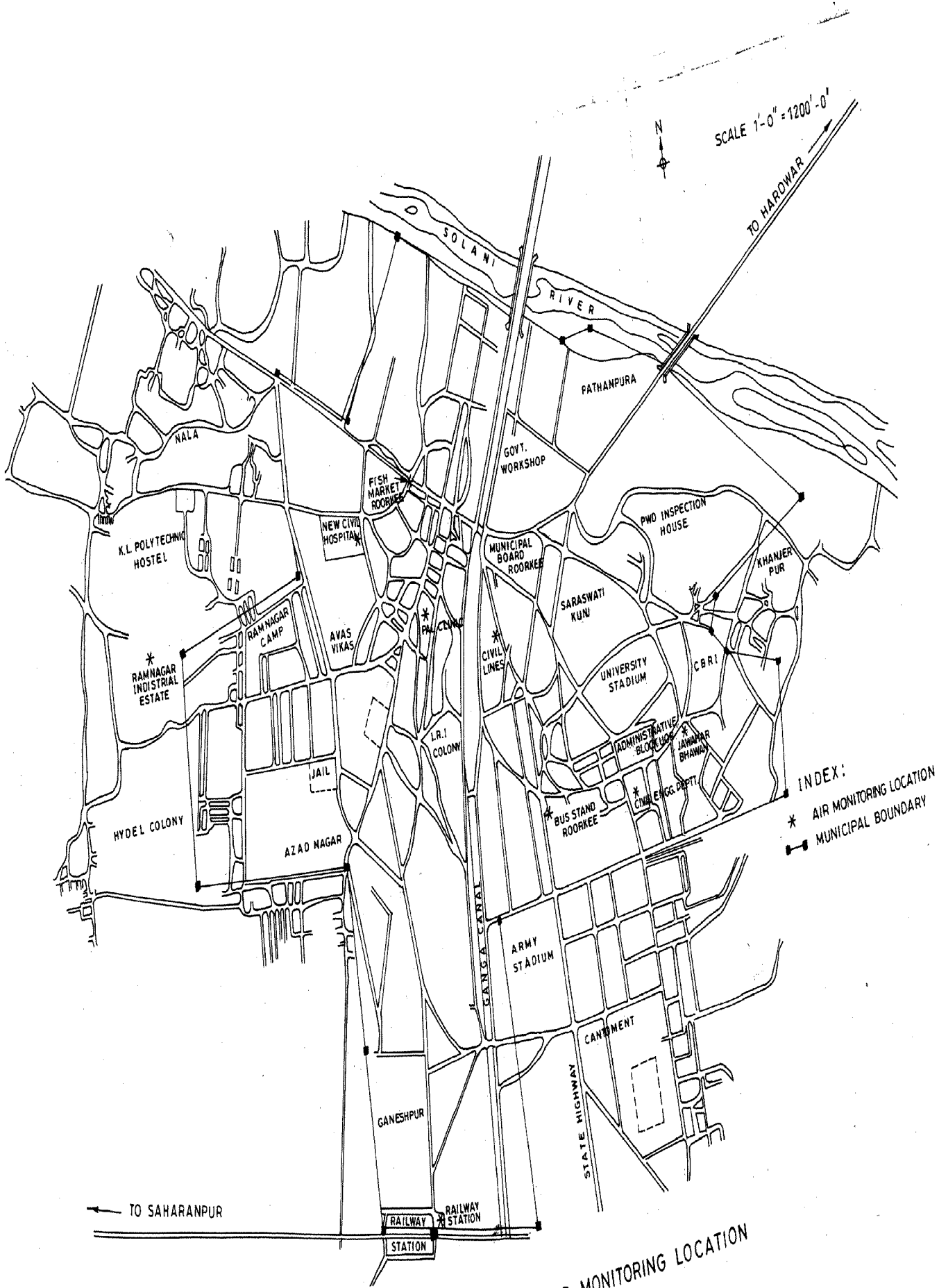


FIG. 3-3 MAP OF ROORKEE TOWNSHIP SHOWING AIR MONITORING LOCATION

TABLE 3.1: Monitoring stations and observed air quality parameters

Sl. no.	Station	SO ₂	NO ₂	SPM	CO	HC
1.	Bus stand (BS)	Y	Y	Y	Y	Y
2.	Civil Engg. Dept. (CED)	Y	Y	Y	N	N
3.	Civil lines (CL), near Mosque	Y	Y	Y	N	N
4.	Industrial area Ramnagar (IA)	Y	Y	Y	N	N
5.	New Civil Hospital (NCH)	Y	Y	Y	N	N
6.	Old Roorkee (OR) (Near fish Market)	Y	Y	Y	N	N
7.	Paul Clinic (PC), (Near Nehru Stadium)	Y	Y	Y	N	N
8.	P.G. Club (PG), (Jawahar Bhawan,U.O.R.)	Y	Y	Y	N	N
9.	Railway Station (RS)	Y	Y	Y	N	N

Y : Observed.

N: Not observed.

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3.3.1 Monitoring of Suspended Particulate Matter (SPM)

In HVAS air passes at a rate of 1 to 1.3 m³/min through a high efficiency filter paper, which retains the particles. The instrument measures the volume of sampled air which is actually recorded through manometer. The amount of particles collected on the filter paper is determined by measuring the change in the weight of filter paper as a consequence of sampling process. The paper is dried before placing it in HVAS. The passage for air reaching in the filter is designed to prevent heavier settleable dust particles from reaching the filter. Hence, high volume sampler measures only the concentration of SPM in the ambient air. In the present study, "WATMAN'S GF/A" grade filter paper was used and the sampler was operated for eight hours [7].

Calculation:

After sampling process is over, the filter paper is dried carefully in oven and weighed, ensuring that no other dust particles are further added to or blown away from the filter paper during drying and weighing.

Average hourly flow rate (V) in cubic meter per minute was calculated.

Then the average concentration of SPM can be calculated as :

$$C \text{ SPM} = (W/VT) \times 10^6 \mu\text{g}/\text{m}^3$$

where, C SPM = average concentration of SPM in

W = weight of dust (gm)

T = total period of sampling time in minutes

V = average flow rate (m³/min)

3.3.2 Monitoring of sulphur dioxide

For measuring the concentration of Sulphur dioxide in air two methods are available.

1. Hydrogen peroxide method.
2. Sodium tetra chloro mercurate method (also known as west and Gacke method).

For the present work, West and Gacke method was used. In this method sulphur dioxide from the air stream was absorbed in a Sodium tetra chloro mercurate solution. The amount of SO₂ was then estimated by measuring the color produced on addition of P-rosaniline hydrochloride to it. Using spectrophotometer, the color was estimated for which the calibration curve was prepared as given in the following para [6].

3.3.2.1 Preparation of calibration curve

2 ml of standard sulphite solution was pipetted in a 100-ml volumetric flask and dilute to mark with absorbing reagent. This final solution contains 3 ml of Sulphur dioxide per ml. Now 0.5, 1.0, 1.5, 2.0 ml portions of the dilute standard sulphite solution was added to a series of 10-ml volumetric flasks and the mark is diluted with absorbing reagent. To the resulting solution 1 ml of p-rosaniline solution and 1.0 ml of formaldehyde solution was added thoroughly. 10 ml portion of sodium tetra chloro mercurate solution was treated in the same manner to be used as the blank. After 20 minutes, absorbance at 560 nm was measured with blank as reference. Plot the absorbance as the ordinate against the μ l of SO₂/ml absorbing solution on rectangular

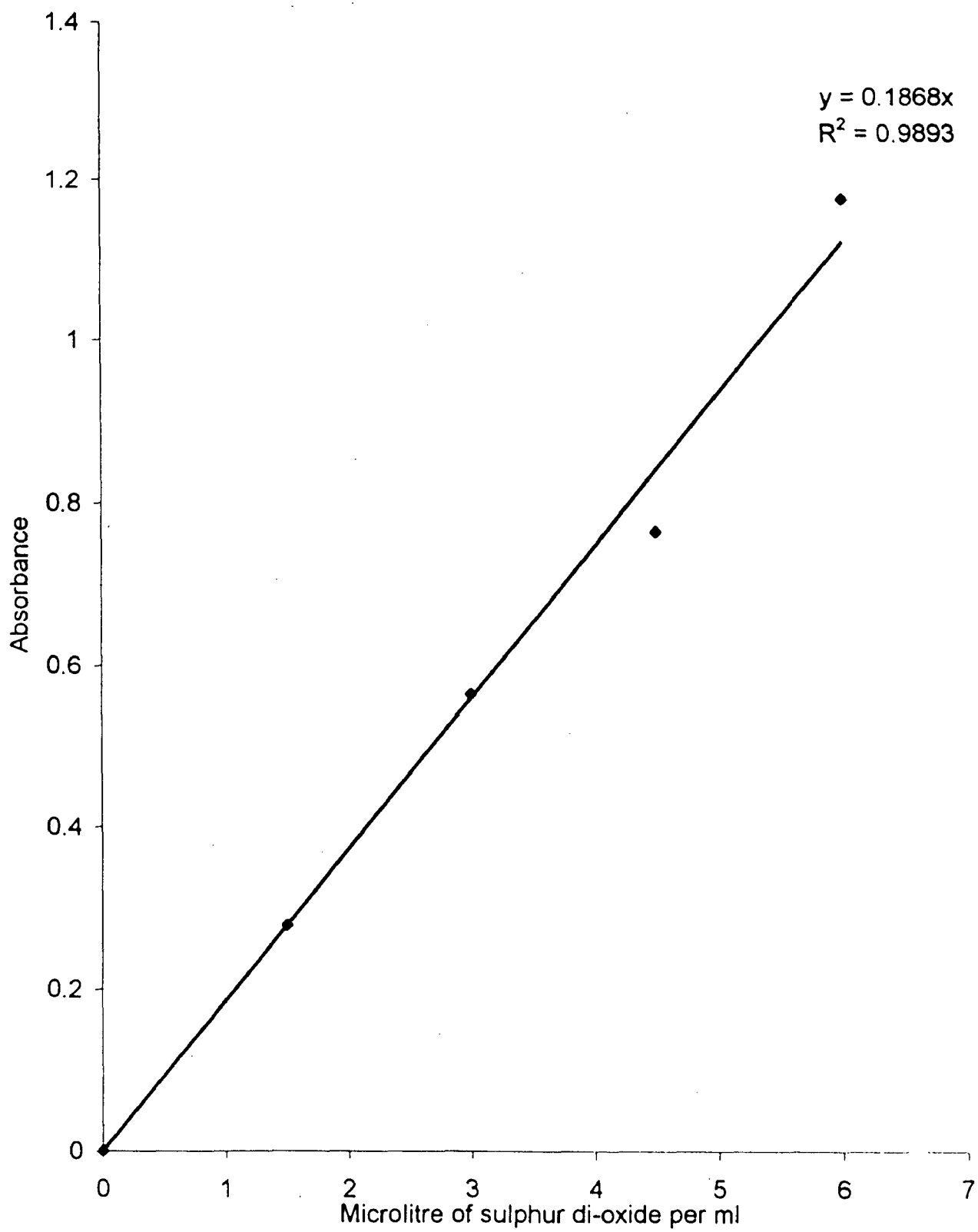


Fig - 3.4 Calibration Curve for Sulphur di-oxide

coordinate paper and the slope of best fit line was measured. The developed calibration curve is shown in Fig. 3.4.

3.3.2.2 Analytical procedure

Exactly 10 ml of absorbing reagent was taken into impinger. The air sample was passed through the absorber at a rate of 1 lpm. At the end of sampling time, pump was stopped and the new readings of the gas meter was recorded. The absorber was taken to laboratory for titration. Sample adjusted to 10 ml with distilled water to compensate evaporation losses. 1 ml of p-rosaniline solution and 1.0 ml of formaldehyde solution was added and well mixed. 10 ml portion of unexposed Sodium tetrachloro mercurate solution was processed in the same manner as a blank. The absorbance was recorded with blank as reference.

Calculation

$\mu\text{l of SO}_2 = \text{absorbance} / \text{slope of calibrated curve.}$

$\text{SO}_2, \text{ ppm by volume} = \mu\text{l of SO}_2 / V_s$

Where V_s = volume of air in liters at standard temperature and pressure (temp 25°C and pressure 760 mm of mercury).

To convert the volume of air sampled at STP

$$V_s = V \times \frac{(P - P_m)}{760} \times \frac{298.2}{(t + 273.2)}$$

Where V = volume of air as measured by flow meter

P = barometric pressure in mm Hg.

P_m = suction of meter in mm of Hg.

T = temperature of sampled air in degrees Celsius.

$\text{SO}_2 (\mu\text{g}/\text{m}^3) = \text{ppm of SO}_2 \text{ by volume} \times 2615.447$

3.3.3 Monitoring of oxides of nitrogen (NO₂)

Nitrogen oxides as Nitrogen dioxide were collected by bubbling air through a sodium hydroxide solution to form a stable solution of sodium nitrate. The nitrate ion produced during sampling was determined calorimetrically by adding phosphoric acid, Sulphanilamide solution, and N (1-Naphthyl) Ethylene diamine dihydro chloride to the exposed absorbing reagent [8].

3.3.3.1 Preparation of calibration curve

5 ml of 1000 microgram Nitrogen dioxide per ml solution was diluted to 200 ml with absorbing reagent. This solution contained 25 microgram Nitrogen dioxide per ml. Now 1, 2, 5, 15 ml of 25 microgram Nitrogen dioxide per ml solution was poured into 50, 50, 100, 250 ml volumetric flask and diluted to the mark with the absorbing reagent. This solution contains 0.5, 1.0, 1.25, 1.5 microgram Nitrogen dioxide per ml respectively. 10 ml of solution from each flask (of known NO₂ concentration) was taken in different test tubes. The color was developed by mixing the reagents as described above and the absorbance value for each solution was determined at 540 nm. Now a calibration graph was plotted between absorbance and concentration of Nitrogen dioxide taking absorbance on ordinate. The developed calibration curve is shown in fig. 3.5.

3.3.3.2 Analytical procedure

30 ml of sodium tetrachloro mercurate solution was taken in the impinger. After completion of the sampling period, the exposed absorbent was poured in a clean dry small plastic container and brought to laboratory for analysis. Any water lost by evaporation during the sampling was replaced by

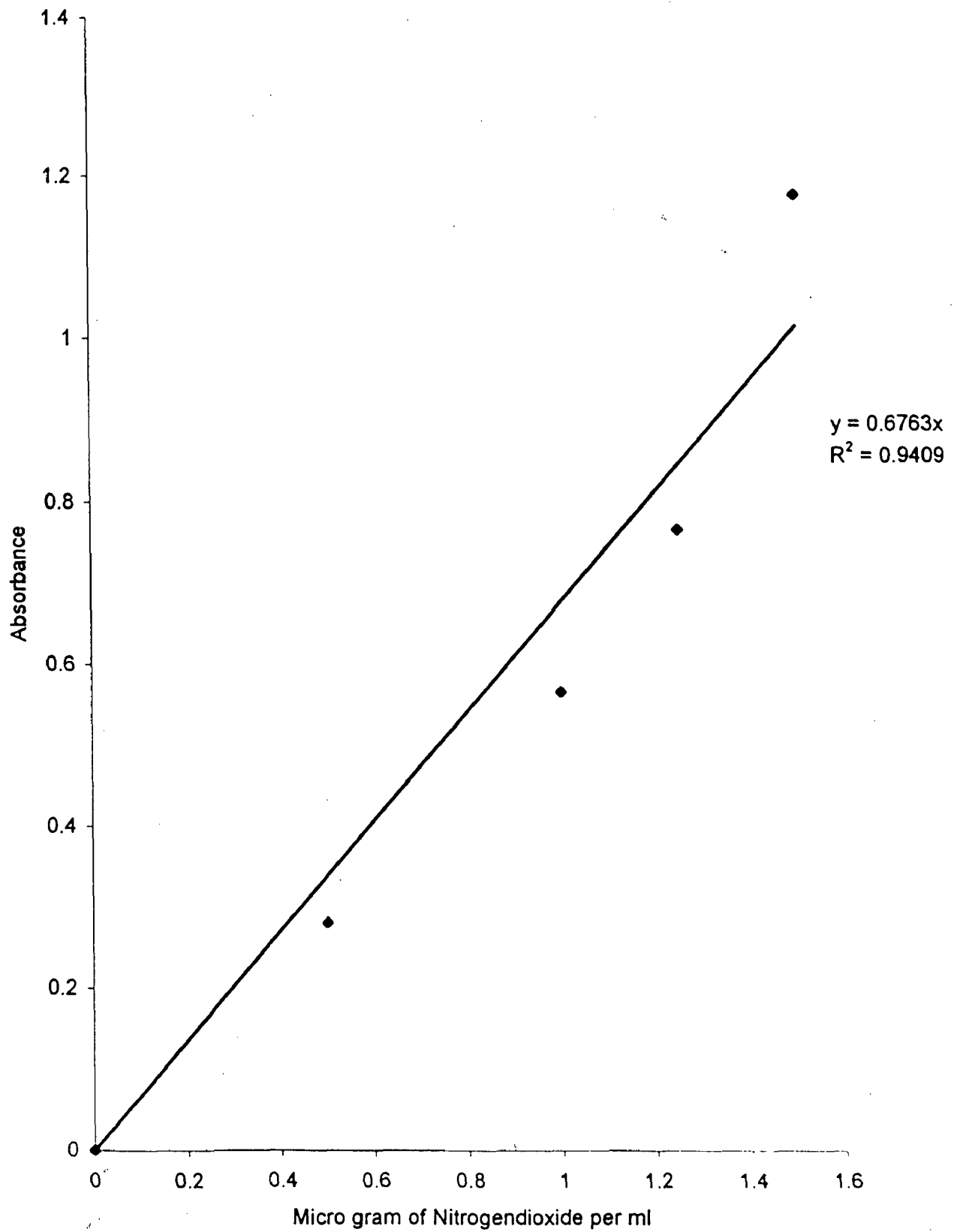


Fig - 3.5 Calibration curve for Nitrogen dioxide

distilled water to make the volume exactly 30 ml. For analysis 10 ml of collected samples was taken in the test tube. To it 1 ml of hydrogen peroxide solution, 10 ml of sulphanilamide solution and 1.4 ml of NEDA solution was added and mixed. Light pink to dark red color was developed depending upon the concentration of Nitrogen dioxide in the sample. The absorbance was measured and the value of NO₂ in µg/ml was read from the calibration curve.

Calculation

$$C \text{ NO}_2 = \mu\text{g/ ml of NO}_2 \times 10^3 / (r \times t \times k)$$

Where, C NO₂ = average concentration of nitrogen dioxide in µg/ m³

r = sampling rate

t = total sampling time in minutes

k = overall efficiency factor = 0.33

3.3.4 Monitoring of carbon monoxide and hydrocarbons

The following methods for monitoring the ambient CO and HC concentrations are used.

1. Iodine pentoxide method.
2. Gas chromatograph method.

In the present study gas chromatograph method was used.

The ambient air samples were collected in glass air sample Collection tubes by water replacement method. The knobs of the sample collection tubes were tightly closed and these tubes were brought to laboratory for testing through gas chromatograph [9, 10].

Procedure

A sample of air containing carbon monoxide and Hydrocarbons is injected into the air chromatograph where it is carried from one end of the columns to the other. During its movement, the constituents of the sample undergo distribution at different rates and ultimately get separated from one another. The separated constituents emerge from the end of the column one after the other and are detected by suitable means whose response is related to the amount of specific components leaving the column. The concentration of different constituents was plotted in the form of an inverted "V" shape curve (S) one after the other by the recorder and the peak of the curve depends on concentration of different gases detected by the instrument. Concentration of constituents were calculated on the basis of the peak areas on the chromatograph obtained with known amount of constituents namely CO, HC etc, using the same apparatus under identical conditions.

Sampling conditions

The air samples were tested at the following conditions of the instrument.

- Helium was used as the carrier flow at 30 CC/min.
- Thermal conductivity detector temperature was 200 degree Celsius.
- Injection temperature was 150 degree Celsius.
- Column temperature was 100 degree Celsius.
- Column used was PORA PACK Q.

3.4 CALCULATION OF AIR QUALITY INDEX

There are methods to find air quality indices based on arithmetic mean, weighted arithmetic mean etc. of the various methods proposed, the one suggested by Tiwari and Ale [1987] is presumed to be good, since this is based on the geometric mean principle. In arriving at AQI, an assumption is made that all pollutant parameters are of equal importance. The procedure of calculation for air quality index is as given below [14].

$$\text{Quality rating for each parameter } q_i = 100 \times \frac{V_i}{V_s}$$

where V_i = observed parameter value

V_s standard value recommended for the parameter

If n number of parameters are considered the geometric mean of these n number of quality ratings is found out and this is known as air quality index.

CHAPTER 4

RESULTS AND DISCUSSION

4.1 GENERAL

In the present study the air quality parameters (SPM, SO₂, NO₂, CO, HC) were measured for different stations as given in table 3.1. The results of these air quality parameters are listed in this chapter from Table 4.2 to Table 4.5.

4.2 SPM

The concentration of SPM at different monitoring stations at different atmospheric conditions, temperature is shown in table 4.1. The pictorial representation of the SPM have been shown in fig. 4.1.

TABLE 4.1: CONCENTRATION OF SUSPENDED PARTICULATE MATTER

Sl.no	Monitoring Station	Conc. Of SPM ($\mu\text{g}/\text{m}^3$)	Temp. In $^{\circ}\text{c}$	Wind Velocity (Km/hr)	Atmospheric Conditions
1	Bus-stand Roorkee	685.38	10	1.2	Foggy
2	Civil Engg. Dept.	74.25	15	0.0	Clear
3	Civil lines, Near Mosque	196.256	11	0.8	Foggy
4	Industrial area, Ramnagar	150.96	13	0.0	Clear
5	Civil hospital	75.48	16	1.4	Clear
6	Old Roorkee, near fish market	1343.59	11	0.0	Clear
7	Paul Clinic	175.22	13	0.0	Cloudy
8	P.G club, near Jawahar Bhawan	60.38	14	1.0	Clear
9	Railway station	286.83	11	0.0	Cloudy

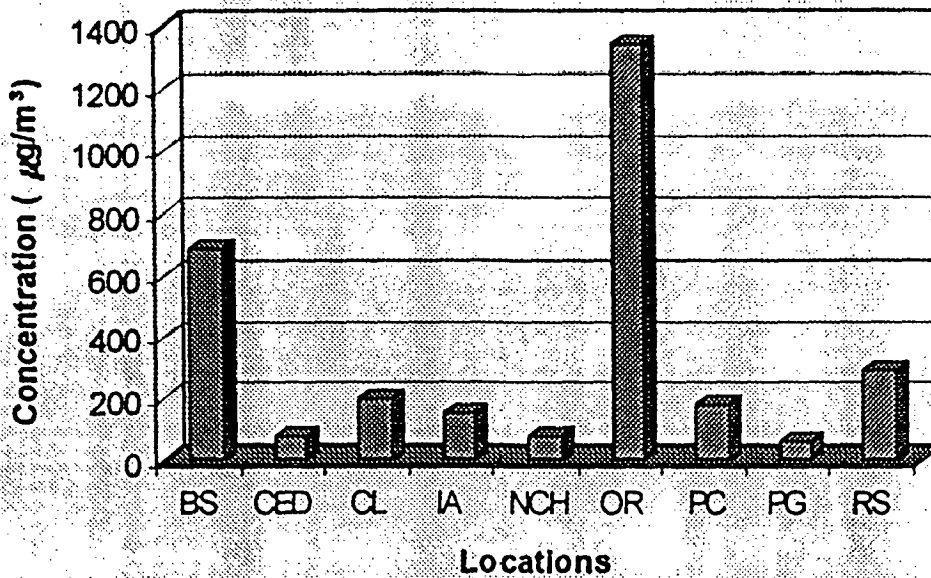


Figure 4.1 : SPM Concentration at Different Locations in Roorkee

SPM was found to be on very higher side particularly at old Roorkee ($1343.59 \mu\text{g}/\text{m}^3$), and bus stand ($685.38 \mu\text{g}/\text{m}^3$) which is above permissible value. The sampling at bus stand was done on kumbh mela to determine its value at high traffic movement condition. The value is about 20% higher in comparison with Srivastava's [20] observations,. Hence, it can be conferred that the SPM value has not changed significantly since 1995 while it is 20% less than the value obtained by Raturi [17] in 1983. At railway station a concentration of $286.83 \mu\text{g}/\text{m}^3$ was observed which is between the permissible limits for residential & rural and industrial given by CPCB in table 2.1. At remaining stations the concentration of SPM was observed to be below the permissible limits. Hence the traffic should be diverted to maintain SPM below the permissible limits.

4.3 SULPHUR DIOXIDE

The concentration of Sulphur dioxide at different monitoring stations are shown in table 4.2, while the pictorial representation of the concentration sulphur dioxide have been shown in fig. 4.2.

TABLE 4.2: CONCENTRATIONS OF SULPHUR DIOXIDE

Sl.no	Monitoring Station	Conc. Of SO ₂ (µg/m ³)	Temp. In °c	Wind Velocity (Km/hr)	Atmospheric Conditions
1	Bus-stand Roorkee	14.4877	10	1.2	Foggy
2	Civil Engg. Dept.	1.12	15	0.0	Clear
3	Civil lines, Near Mosque	2.5010	11	0.8	Foggy
4	Industrial area, Ramnagar	0.279	13	0.0	Clear
5	Civil hospital	0.0568	16	1.4	Clear
6	Old Roorkee, near fish market	11.59	11	0.0	Clear
7	Paul Clinic	1.12	13	0.0	Cloudy
8	P.G club, near Jawahar Bhawan	0.0218	14	1.0	Clear
9	Railway station	286.935 0.5618	11	0.0	Cloudy

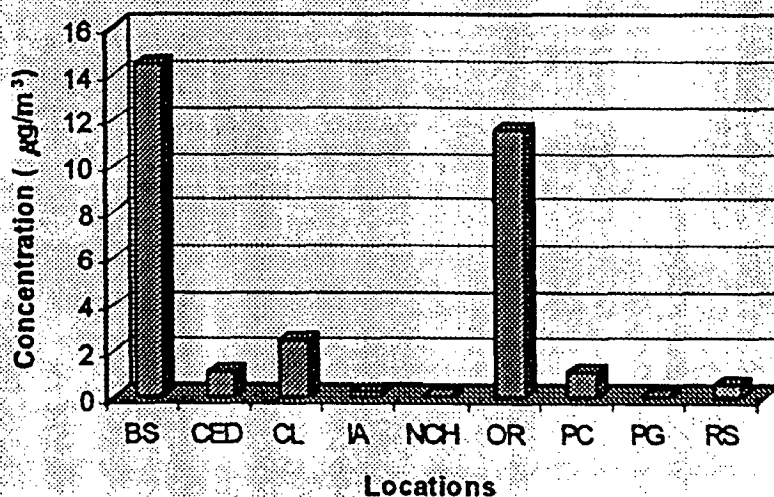


Figure 4.2 : SO₂ Concentration at Different Locations in Roorkee

It was found out that the concentration of sulphur dioxide at all the station were below the permissible limits. A concentration of $14.48 \mu\text{g}/\text{m}^3$, $11.59 \mu\text{g}/\text{m}^3$ was observed at bus stand, old Roorkee respectively. The lowest concentration was observed at PG club (Jawahar Bhawan).

4.4 OXIDES OF NITROGEN

The concentration of nitrogen dioxide at different monitoring stations at different atmospheric conditions, temperature have been shown in table 4.3.

The pictorial representation of the NO_2 have been shown in fig. 4.3.

TABLE 4.3: CONCENTRATIONS OF NITROGEN OXIDES

Sl.no	Monitoring Station	Conc. Of NO_2 ($\mu\text{g}/\text{m}^3$)	Temp. In $^{\circ}\text{C}$	Wind Velocity (Km/hr)	Atmospheric Conditions
1	Bus-stand Roorkee	145.22	10	1.2	Foggy
2	Civil Engg. Dept.	3.34	15	0.0	Clear
3	Civil lines, Near Mosque	22.443	11	0.8	Foggy
4	Industrial area, Ramnagar	2.64	13	0.0	Clear
5	Civil hospital	4.60	16	1.4	Clear
6	Old Roorkee, near fish market	40.928	11	0.0	Clear
7	Paul Clinic	3.34	13	0.0	Cloudy
8	P.G club, near Jawahar Bhawan	1.32	14	1.0	Clear
9	Railway station	29.044	11	0.0	Cloudy

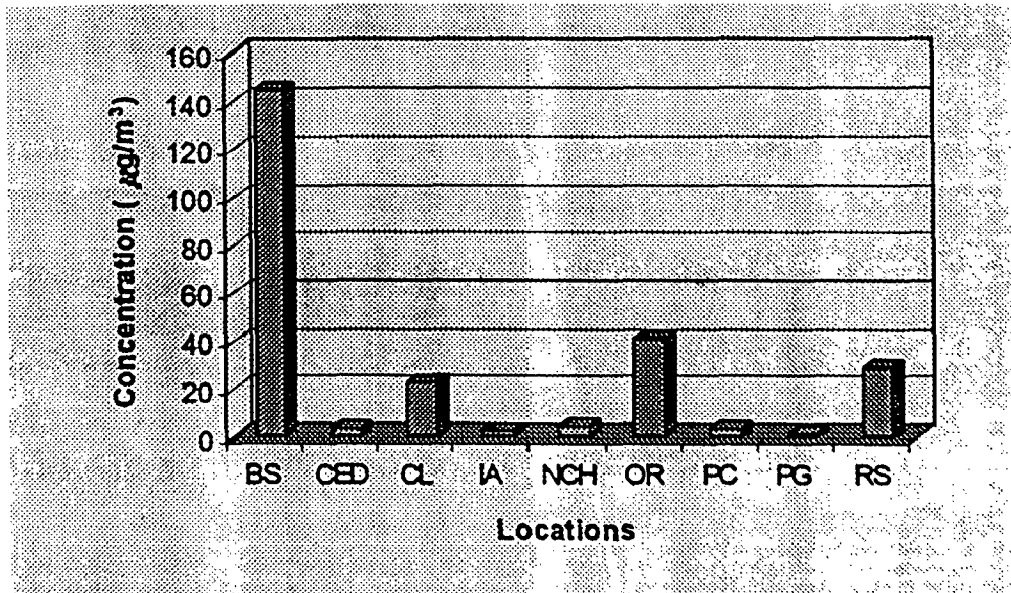


Figure 4.3 : NO₂ Concentration at Different Locations in Roorkee

It was found that the concentration of the NO₂ at all stations were below their permissible limits except at bus stand. At bus stand a concentration of 145.22 µg/m³ was observed which is higher than the permissible limits. The high concentration of the NO₂ at bus stand was attributed to heavy traffic on Kumbh Mela which is also confirmed by comparing the results of Srivastava [20]. However a concentration of 40.9 µg/m³ was observed in old Roorkee. A low concentration was observed at PG club.

4.5 CARBON MONOXIDE AND HYDROCARBONS

The concentration of CO and HC are given in table 4.4, while the pictorial representation of the concentration CO and HC are shown in fig. 4.4.

TABLE 4.4: CONCENTRATION OF CARBON MONOXIDE & HYDROCORBONS

Sl. No.	Location	Parameter	Concentration ($\mu\text{g}/\text{m}^3$)		
			Morning	Afternoon	Evening
1	Bus-stand, Roorkee	Carbon monoxide	2120	2800	2780
2	Bus-stand, Roorkee	Hydrocarbons (Non Methane)	352	260	385

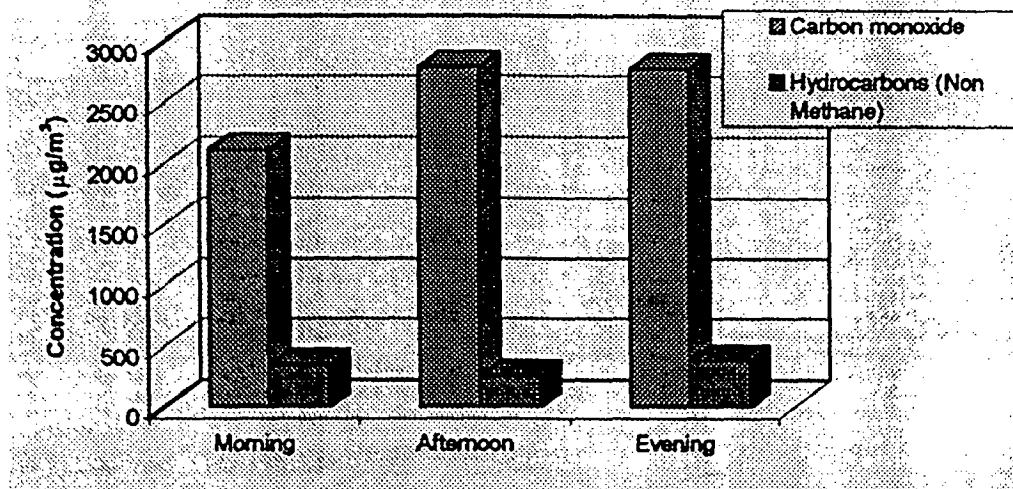


Fig. 4.4 : Concentration of CO and HC in Bus Stand

From the table and figure it is seen that CO concentration is higher than the permissible limits. The concentration at all the times is more than the permissible limits. However a maximum of $2800 \mu\text{g}/\text{m}^3$ was observed at afternoon. CO concentration is marginally higher during morning as compared to Srivastava's [20] observation. HC are found to be less and this is because of the use of catalytic converter in the vehicles. As far as HC are concerned a concentration of $385 \mu\text{g}/\text{m}^3$ was observed at evening. For HC no limits are prescribed in India.

4.6 AQI FOR STUDY AREA

In the present study air quality was assessed taking three primary pollutants, i.e. SPM, SO₂ and NO_x. Standard values as specified by Central Pollution Control Board were used for computation of AQI. The calculated AQI values for different stations and categories of air quality at different stations are shown in table 4.5.

TABLE 4.5: AMBIENT AIR QUALITY AT DIFFERENT STATIONS

Sl. No.	Station	Quality rating			AQI	AAQ
		SPM	SO ₂	NO ₂		
1.	Bus-stand	342.69	18.11	181.525	104.05	Heavily polluted
2.	Civil Engg. Deptt.	37.125	1.4	4.175	6.009	Very clean
3.	Civil lines	98.128	3.126	28.054	20.492	Clean
4.	New Civil Hospital	37.74	0.071	5.75	2.488	Very clean
5.	Industrial area (Ramnagar)	75.48	0.3475	3.3	4.42	Very clean
6.	Old Roorkee (near fish market)	671.795	14.497	51.163	79.275	Polluted
7.	Paul Clinic	87.61	1.4	4.175	8.00	Very clean
8.	PG club (Jawahar Bhawan)	30.193	0.0272	1.65	1.107	Very clean
9.	Railway station	143.42	0.7023	36.315	15.406	Clean

Results indicate that a greater geometric mean air quality index value were observed in the location of bus stand, old Roorkee.

CHAPTER 5

CONCLUSIONS

The following conclusions are drawn on the basis of present study.

1. The clear impact of catalytic converter on ambient air quality is clearly seen from the observation at the bus-stand.
2. Roorkee town is generally free from air pollution, except in some parts of the interior old town.
3. At Bus stand the values of SPM observed are quite low as compared to 1983, which shows the improvement in air quality.
4. Regular monitoring at the Bus stand is required for future planning

RECOMMENDATIONS:

There should be attempt to study the correlation of land use activity with air quality zonation, which will be useful in air quality improvement in the core area older portion of cities.

REFERENCES

1. American Public Health Association, "Methods of Air Sampling and Analysis", Edited by Katz, Second Edition, 1977.
2. Chitranshi, U.B., Raturi, V.D., Deepak, D., "Study of particulates in Roorkee atmosphere due to vehicular traffic on Delhi-Haridwar road" Asia pacific symposium on Wind Engineering, December 5-7, 1985, UOR, Roorkee.
3. Garg, S.K., "Sewage disposal and Air Pollution Engineering" Environmental Engineering" Vol. 2, tenth edition, 1996.
4. Howard, Peavy. S., Donald R. Rowe, Tchobanoglous George, "Environmental Engineering", International Edition, 1985.
5. Instruction manual, "high volume air sampler", Environmental Engineering Inc., NEERI, Nagpur, 25-09-90.
6. IS:5182 (part-II)-1969, "Indian Standards Methods for Measurement of Air Pollution, Sulphur di oxide".
7. IS:5182 (part-IV)-173, "Indian Standard Methods for Measurement of Air Pollution, Suspended Particulate Matter".
8. IS:5182 (part-VI)-1975, "Indian Standard Methods for Measurement of Air Pollution, Nitrogen Oxides".
9. IS : (part-X)-1976, "Indian Standard Methods for Measurement of Air Pollution, Carbon monoxide".
10. IS : (part-XIV)-1979, "Indian Standard Methods for Measurement C₁ to C₅ hydrocarbons in air by gas chromatography".
11. IS:10193 (part-I)-1982, "Limits for Ambient Air quality".

12. Kenneth, Wark and Warner, C.F., "Air Pollution and its Origin and Control", II Edition, Harper and Row, New York, 1981.
13. Mudri, S. S., Ali, "Categorization of Ambient Air Quality on the Basis of Air Quality Index", *Indian Journal of Environmental Protection*, Vol. 10, No. 6, 1990.
14. Mudri, S.S., Rao Venkat, D., Rao Rammohan, I., Shankar Ravi, V., Rao Vittal, M., Aggarwal, A.L., "Status of Ambient air quality at Hyderabad – A metropolitian cities, *Indian Journal of Environmental Protection*, Vol. 11, No. 8, pp. 561 to 567, (1991).
15. Pandey, V., Kumar, A., Pal, A., Singh, N., Youhus, M., "Status of Ambient Air Quality in Lucknow City", *Indian Journal of Environmental Protection*, Vol. 19, No. 31, pp. 181 to 184.
16. Parviz, A., Koushik, "Carbon monoxide from traffic in Riyadh", A.S.C.E, Vol 114, No. 3, pp. 704, 1988.
17. Raturi, V. D., "Study of Particulates in Roorkee Atmosphere due to Vehicular Traffic on Delhi-Hardwar Road", M. E. Thesis, University of Roorkee, Roorkee, 1983.
18. Shanigarhi, A.S., Sharma, R.C., Agarwal, K.M., "State of Art of Air Pollution Monitoring in India", *Indian Journal of Environmental Protection*, Vol. 18, No. 8, p. 561-567, 1975.
19. Srinivas, D.S.R.K., "Spatial pattern of Air Pollution in Delhi", *Indian Journal of Environmental Protection*, Vol. 19, No. 3, pp. 172 to 180, 1999.
20. Srivastava, J. B., "Traffic Flow and Environmental Impact Analysis of a Highway Corridor", Ph.D. Thesis, University of Roorkee, Roorkee, 1995.