REPORT OF THE EXPERT COMMITTEE ON THE ENVIRONMENTAL IMPACT OF MATHURA REFINERY

MINISTRY OF PETROLEUM CHEMICALS AND FERTILIZERS
DEPARTMENT OF PETROLEUM
GOVERNMENT OF INDIA, NEW DELHI—1978

REPORT OF THE EXPERT COMMITTEE ON THE ENVIRONMENTAL IMPACT OF MATHURA REFINERY

DECEMBER—1977

EXPERT COMMITTEE ON ENVIRONMENTAL IMPACT OF MATHURA REFINERY

MEMBERS

CHAIRMAN :

Dr S Varadarajan
Chairman & MD, Indian Petro-chemicals Corporation Ltd.

MEMBER-SECRETARY :

— Indian Oil Corporation Ltd. (R & P Division)
Shri RN Bhatnagar, Managing Director (Up to April 1977)
Shri SK Nayak, General Manager (From May 1977)

MEMBERS :

— Ministry of Petroleum, Government of India
Shri M Kurien, Adviser (R) (Up to January 1977)
Shri TS Nayar, Adviser (R) (From February 1977)

— National Environmental Engineering Research Institute
Shri JM Dave, Scientist (Up to September 1977)
Dr BB Sunderesan Director (From October 1977)

— National Committee on Environmental Planning & Co-ordination, (Deptt. of Science & Technology)
Dr Ashok Khosla, Sr Specialist (Up to April 1976)
Shri Thomas Mathew, Sr Environmental Specialist (From May 1976)

— Indian Institute of Petroleum
Shri HK Mulchandani, Head, Projects Division

— India Meteorological Department, Ministry of Tourism & Civil Aviation
Dr. AK Mukherjee, Director, Regional Met. Centre, Bombay (Up to March 1977)
Dr. B. Padmanabha Murthy, Meteorologist (From April 1977)

— Government of Uttar Pradesh
Dr SD Shukla, Director, Harcourt Butler Technological Institute, Kanpur
Shri AB Malik, Resident Commissioner, New Delhi
Shri Desh Raj Singh, Additional Resident Commissioner, New Delhi.

— Archaeological Survey of India, Govt. of India
Shri R. Sengupta, Director (Conservation) (From December 1975)

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CHAPTER I

INTRODUCTION

1.1 The Government of India announced its decision to set up a large oil refinery in the Mathura region to meet the growing petroleum products demand of the North west region This decision was based on techno economic studies which has established the need to locate the refinery at Mathura for the following principal considerations

(i) Mathura is located centrally within the demand area, and

(ii) It has both BG and MG lines and also is on National Highway No 2

1.2 Subsequent to this decision, some apprehensions were raised about the possible adverse effects on the monuments in the Agra-Mathura region as a result of gaseous effluents to be discharged from the refinery. Since this was a matter of great concern, the then Minister of Petroleum & Chemicals, Shri D. K Barooah, immediately took a meeting with the senior officers of Ministry of Petroleum & Chemicals, National Committee on Environmental Planning & Coordination, Planning Commission Bhabha Atomic Research Centre and IOC in September, 1973 The consensus of opinion during this meeting was that technological processes were available for containing pollutants in gaseous effluent to desirable limits as required from the point of view of preservation of monuments The Hon'ble Minister had then directed IOC to take necessary precautionary measures to ensure that the effluents discharged in the atmosphere from the refinery will not have any adverse effect on the monuments at Mathura and Agra

1.3 It was agreed that no effort should be spared for protecting the monuments, particularly, the Taj Mahal. Subsequently, the Government of India constituted an Expert Committee *vide* Government of India, Ministry of Petroleum & Chemicals Memo No. IS-46011/10/73-OR-I dated 16th July 1974 given at Annexure I, to advise the project authorities on the measures to be taken for keeping the pollution effect to the absolute minimum The Committee was not only to guide Mathura Refinery Project in planning and implementing effective pollution measures, but also to advise the Ministry on the pollution aspects of other ancillary and downstream units The Committee was to work on a continuous basis The Committee consisted of the following

Chairman

(1) Dr S Varadarajan, Chairman, IPCL

Members

(2) Shri M Kurien, Adviser (R), Ministry of Petroleum & Chemicals

(3) Representative of the National Environmental Engineering Research Institute, Nagpur

(4) Representative from the Office of the National Committee on Environmental Planning & Coordination, Department of Science & Technology, New Delhi.

(5) Representative from the Indian Institute of Petroleum, Dehra Dun

(6) Representative from the Meteorological Department, Ministry of Tourism & Civil Aviation

(7) Representative of the Government of Uttar Pradesh.

Member-Secretary

(8) Managing Director, Indian Oil Corporation Limited (R&P Division), New Delhi

Subsequently a representative from Archaeological Survey of India was also nominated as a member.

1.4 The Government *vide* Ministry of Petroleum's letter No. IS-36012/4/76-OR-I dated 4th April 1977 asked the Committee to also cover the aspect of effect of pollutants on the birds in the Bharatpur Sanctuary. Copy of the letter is given at Annexure II.

1.5 This Report of the Committee covers, in brief, the activities of the Committee so far and its findings and recommendations.

CHAPTER 2

ACTIVITIES OF THE COMMITTEE

2.1 Since the formation of the Committee so far it had held eleven meetings as per details given below:

	Date	Place
1st Meeting	. 8th Aug., 1974	In the Chamber of the then Minister for P&C, Shri D K Barooah, New Delhi
2nd Meeting	. 7th Oct, 1974	Indianoil Bhavan, New Delhi
3rd Meeting	. 9th Jan, 1975	Do.
4th Meeting	. 1st Oct., 1975	Do.
5th Meeting	. 27th Nov., 1975	Do.
6th Meeting	. 1st May, 1976	Sikandara Guest House, Agra.
7th Meeting	. 13th Jan., 1977	Indianoil Bhavan, New Delhi
8th Meeting	. 12th Jul., 1977	Do
9th Meeting	. 23rd Nov., 1977	Do.
10th Meeting	. 2nd Dec, 1977	Do.
11th Meeting	6th Dec, 1977	Do.

The names of the participants in each of the above meetings are given in Annexure—III.

At the sixth, eight, ninth, tenth and eleventh meetings, Shri M. N. Deshpande, Director-General, Archaeological Survey of India was present by special invitation to assist the Committee.

At the fifth meeting, Shri Y. P. Rao, Director-General, India Meteorological Department and Prof. N. Majumder, Director, NEERI, were special invitees. Shri S Haider, Director (SP), Prime Minister's Secretariat, was specially invited to attend the fourth and sixth meetings.

At the sixth meeting, representatives from the U.P. State Electricity Board, U.P. State Industries Department and Central Railway were present at the request from the Chairman.

At the ninth meeting, Prof. T. Shivaji Rao, Professor in Environmental Engg., Andhra University, was present

Dr B. B. Lal (Retired Chief Chemist, Archaeological Survey of India) who at the instance of the Committee had been appointed Consultant assisted the Committee in its deliberations and attended Committee meetings.

The List of agenda items considered by the Committee in its various meetings are given in Annexure—IV.

2.2 The Committee initiated a number of studies which were considered essential by it in coming to conclusions and recommendations. These studies were:

(a) *Existing levels of pollutants in the Agra region*—These were conducted by National Environmental Engineering Research Institute for the period from 19th November, 1975 to March, 1977 covering a period of 15 months which included two winters and one summer.

(b) *Studies on the Dispersal of Pollutants from the Refinery*—These studies were entrusted to India Meteorological Department and Teeneco of Italy. The studies involved determination of the concentration of sulphur dioxide at various distances from the Refinery under different meteorological conditions. As initially meteorological data for Mathura was not available, the data available for Delhi and Agra were utilised in the studies. Subsequently, IMD established at the instance of the Committee, first class meteorological stations at Mathura, Agra and Bharatpur. Meteorological observation for more than one year has been collected at the Mathura and Agra observatories.

(c) *Present status of the Monuments*—With a view to ascertain the present status of the monuments the Committee entrusted to Teeneco of Italy, investigation covering physical, chemical and biological analyses of the monuments.

(d) *Studies in respect of the effects of the effluents of the Refinery on Bharatpur Bird Sanctuary*—At the instance of the Committee, discussion were held with Dr Salim Ali on the effect of the refinery on the Bharatpur Bird Sanctuary. Assistance was also obtained from the Nature Conservancy Council, the Royal Society for the Protection of Birds and the Wild Fowl Trust, all of U.K.

(e) *Indigenous capabilities for studies*—The Committee collected information on the facilities available for studies in regard to effect of pollutants on monuments in India. Laboratories and Institutes such as National Aeronautical Laboratory, Bangalore; National Physical Labora tory, New Delhi; Physical Research Laboratory, Ahmedabad; Indian Agricultural Research Institute. New Delhi; Central Building Research Institute, Roorkee etc.

2.3 *Advice to IOC*—The Committee obtained from IOC particulars of various effluents from the refinery and advised IOC on the measures to be taken and technology to be used for minimising environmental pollution from the refinery.

CHAPTER 3

OBSERVATIONS BY THE COMMITTEE

Based on the various studies initiated by it and information furnished to it, the Committee has the following observations to make:

3.1 *Studies by NEERI*

3.1.1 NEERI were entrusted with the work of measuring the existing air quality of Agra region with particular reference to the levels of pollutants at Agra for 15 months covering two winters and one summer. They commenced the studies on 19th November 1975 and completed the same in March 1977. They had established 5 air monitoring stations, one each at Taj Mahal, Agra Fort, Sikandara, Itmat-Ud-Daulah and Nagar Mahapalika. The main pollutants monitored were sulphur dioxide, suspended particulate matter and oxides of nitrogen. The wind speed and direction measurements were also simultaneously taken. On the basis of this it has been observed that there is substantial sulphur dioxide pollution existing at Agra, the long term concentration level being in the region of 15 to 20 micrograms per cubic metre. NEERI have been submitting periodic reports of their investigations. The reports are given in Annexure—V.

Summary of their reports is given hereafter:

3.1.2 The report for the period from 19th November, 1975 to 29th February, 1976 indicates that 24-hourly mean value for sulphur dioxide is around 20 micrograms per cubic metre at most of the stations except at the Agra Fort. The Agra Fort value reaches the level of 40 micrograms per cubic metre. The concentration of nitrogen oxides at different stations most of the time were found to be close to the lowest detectable level. It may, therefore, be concluded that the nitrogen oxide is negligible. The results of 24-hourly sampling for suspended particulate matter ranges from 450 micrograms per cubic metre in November and December to 250 micrograms per cubic metre in January and February. All the five sites have more or less recorded the same level of particulate matter.

3.1.3 NEERI's second quarterly report for the period March, April & May 1976 shows that monthly average 24-hourly mean value for sulphur dioxide is around 10 micrograms per cubic metre at most of the stations except for Agra Fort where the value has gone to 34 micrograms per cubic metre in April 1976. Sulphur dioxide level in summer season is low compared to winter season because of high temperature conditions of the summer when the pollutants are diffused upward convectionally with active winds. Oxides of nitrogen levels were not measurable as the normal concentration is considerably low during this period. Suspended particulate level is measured on 24-hour basis and observed to be higher than those recorded during winter. The summer values are found to be in the order of 350-500 microgramms per cubic metre. These higher values are attributable to the stormy and dusty weather which prevails in this area.

3.1.4 NEERI's third quarterly report gives monsoon and post-monsoon data collected for the period June to October 1976. Sulphur dioxide level was very low during monsoons (June to September 1976). The recorded values are below 10 micrograms per cubic metre. The month of October (post-monsoon) showed a rise in sulphur dioxide level. The 24-hour average values recorded ranged from 15 to 26 micrograms per cubic metre.

3.1.5 NEERI's fourth quarterly report gives winter data collected for the period November 1976 to January 1977. Sulphur dioxide concentration (24-hour average value) varied from 11 micrograms per cubic metre at Sikandara to 56 micrograms per cubic metre at Agra Fort. Suspended particulate matter concentration varied from 170 to 400 micrograms per cubic metre.

3.1.6 NEERI's fifth quarterly report covering the period February and March 1977 records sulphur dioxide concentration (24-hour average) between 9 to 29 micrograms per cubic metre. Suspended particulate matter was varying from 174 to 388 micrograms per cubic metre (24-hourly average).

3.1.7 Air quality data at Taj Mahal during the period from November 1975 to March 1977 indicate that sulphur dioxide concentration ranges from 7 to 42 micrograms per cubic metre (24-hour average) and the 2 hour maximum values range from 20 to 160 micrograms per cubic metre. Suspended particulate matter ranges from 66 to 448 micrograms per cubic metre (24-hour average) and 24-hour maximum range from 106 to 803 micrograms per cubic metre. The annual average sulphur dioxide level ranges from 15 to 20 micrograms per cubic metre.

3.2 *Comparison of existing sulphur dioxide levels at different cities*

3.2.1 Over the last few years the annual average sulphur dioxide levels at various cities of the world have been observed to be of the order of:

City	*Sulphur dioxide in micrograms / cubic metre*
Copenhagen	60
Stockolm	70

City	Sulphur dioxide in micrograms per cubic metre
Amsterdam	80
Liege	130
Brussels	170
Paris	110
London, city	250
London, greater	150
Milan	600
Venice, industrial area	130
Venice, city	70
New York—Manhattan	110
New York—Richmond	50
Los Angeles	70
Toronto, city	170
Toronto, residential	30

3.3 *Possible sources of Pollution at Agra*

3.3.1 From NEERI's studies it has been established that there is substantial amount of pollution both sulphur dioxides and particulate matter in the Agra region particularly near the Agra Fort and the Taj Mahal. The possible sources of this pollution are:

(a) Two Power Plants—one near the Agra Fort and the other at Itmat-Ud-Daulah both of nominal capacity 10 MW each. The power plant at Agra Fort has been in operation for the last 50 years and is considered to be of very old and uneconomic design. Approximately one rake of coal (about 1100 tonnes) is being used by these power plants daily.

(b) Industries including about 250 foundries around Agra. Most of these industries are situated north-west of the monuments with the result that the carry over of pollutants from them is normally in the direction of the monuments. These foundries are using mostly coal of the order of 200 to 300 tonnes daily.

(c) Railway Shunting Yard—which is very close to the Agra Fort. This marshalling yard uses approximately 40 to 50 tonnes of coal every day.

3.4 *Pollution Abatement Measures at the Refinery*

3.4.1 At the instance of the Expert Committee, IOC has taken various steps to minimise the pollution effect from the refinery. A brief description of the refinery and the effluent treatment facilities provided are given in Annexure-VI

3.4.2 Originally in 1973 the refinery was designed o process 6 million tonnes per annum (MTPA) of crude oil imported from the Middle East containing about 2.0 per cent sulphur and the emissions from the refinery stacks would have amounted to approximately 5 tonnes per hour. Subsequently, with the prospects of Bombay High Crude being available, the refinery is now being designed to process 3 MTPA of imported crude and 3 MTPA of Bombay High. Bombay High crude is a low-sulphur crude with a sulphur content of 0.05 per cent. At the instance of the Committee, IOC have taken measures to minimise the emission of sulphur dioxide from the refinery stacks. This is being achieved by using low sulphur fuel oil and gas in the furnaces of the refinery and by installing a plant for removal and recovery of sulphur from the fuel gases. With this it will be possible to limit the sulphur dioxide emission from the refinery to a maximum of one tonne per hour. Low sulphur fuel oil will be available through processing of Bombay High Crude at Mathura Refinery If for any reason low sulphur fuel oil is not available at the refinery, such fuels can be obtained from either Gujarat or Barauni Refinery where low sulphur fuels are readily available

3.4.3 For better dispersal of the sulphur dioxide emission from the stacks, the stack design has been changed from the generally self-supporting stacks of 40 meters height to separate concrete stacks of 80 meters height minimum. Instruments will be provided to continuously monitor emission of sulphur dioxide from the various stacks. Calculations on the bassis of which the total sulphur dioxide emission figure has been arrived at have been submitted by IOC and the same have been verified by the representative of the Ministry of Petroleum IOC also proposes to have fixed as well as mobile monitoring stations for determining the sulphur dioxide ground level concentration at various distances from the refinery. Since it has been established that the existing level of sulphur dioxide at Sikandara is very low and no major industries are located between Sikandara and the refinery (about 30 KM), it should be possible to monitor the actual contribution of sulphur dioxide from the refinery to the area If instead of coal, low sulphur fuel is permitted to be burnt in the power plant, sulphur dioxide emission can be reduced to 0.8 tonnes per hour The sulphur dioxide emission can be further reduced to 0.4 tonnes per hour by installation of a flue gas desulphurisation unit Adequate provision has been made in the design to permit the installation of flue gas desulphurisation unit at a future date when a proven process technology can be selected

3.4.4 In order to minimise the emission of particulate matter from the refinery, (which will be mainly from the power plant when it uses coal as fuel) the refinery authorities shall be installing electro-static precipitators Messrs Bharat Heavy Electricals Ltd., (BHEL) who have been entrusted with supply and installation of these precipitators have confirmed that latest technology will be used in designing these precipitators which will have much more than 95 per cent efficiency for particulate matter removal At the refinery, it is proposed to have two separate chains of electro static precipitators, each chain having three sections. It will be possible to attend to any one section without upsetting the power plant operation. Thus it would be possible to attend to the maintenance requirements of the electrostatic precipitators with a view to keep their efficiency at the design level. IOC have, however, confirmed that the power plant is being designed for the use of fuel oil and gas also and it would be possible for it to switch over to these fuels in case of any problem with the use of coal.

3 4 5 All the waters that are likely to be contaminated will be separately collected and sent to the Effluent Treatment Plant where adequate arrangement will be provided for physical, chemical and biological treatment The treated effluents will meet the specifications laid down by the Indian Standard Institution and State statutory authorities in respect of discharge of effluent into inland surface waters. The treated effluent is proposed to be discharged into Yamuna river at a point downstream of Brahmand ghat, approximately 40 KM upstream of the Agra Municipal Water Works, through an open channel. An inspection road will be provided along the channel with points for collection of samples. Sufficient flow exists in the river for adequate dilution of the treated effluents. However, IOC shall make necessary arrangements for proper dilution of the treated effluent with fresh water, if required. IOC has obtained consent from the Chief Inspector of Factories and Effluent Board, U.P. and also from the U.P. State Water Pollution (Prevention & Control) Board for discharging the treated effluent into the Yamuna river.

3.4.6 IOC has confirmed that there is suffcient expertise for design, construction and operation available in the country for treatment of the effluent in order to obtain desired level of purity of the final effluent Similar facilities provided at the existing IOC refineries are working satisfactorily.

3.4.7 IOC has studied the various natural water courses in the region and it has been firmly established that at no time the effluent from the refinery is likely to contaminate any of the water courses at Bharatpur.

3.4.8 Adequate facilities are being provided by IOC for disposal of ash from the power plant in an area of about 200 acres which would be sufficient for disposal of ash from the power plant for about 15 years. Since the ash will be dumped in the form of slurry. no adverse air pollution problems are anticipated

3 4 9 The approximate additional cost on account of providing the above extra facilities has been estimated at about Rs 8 crores including the cost of various studies undertaken in respect of the Environmental Impact of Mathura Refinery as per details given in Annexure VII.

3.5 *Studies on the Dispersal of Pollutants from the Refinery*

3.5 1 On the basis of meteorological data available for Delhi and Agra and using methods that are generally employed, IMD made an exhaustive study of the dispersal of pollutants from the refinery stack. On the basis that emission of sulphur dioxide from the refinery stacks would be limited to one tonne per hour, the report indicated that the increase in the long-term concentration of sulphur dioxide at Agra on account of the refinery would be one microgram per cubic metre. A copy of the IMD Report is given at Annexure VIII.

3.5.2 Tecneco of Italy, using meteorological data for the last ten years for Delhi and on the basis of dispersion model have also predicted that the contribution on sulphur dioxide from the refinery to the Agra region would be in the region of 1.7 micrograms per cubic metre. A summary of their report is given at Annexure IX NEERI have also made sample calculations and have arrived at nearly similar results.

3.5.3 Although it was generally felt that there would not be much difference between the meteorological data of Mathura and Delhi, with a view to improve upon the studies already made by IMD, at the instance of the Committee, IMD set up three first class meteorological observatories for collecting data at the refinery site, at Agra and at Bharatpur. Using meteorological data collected for more than one year at the observatory at the refinery site, IMD have indicated that the long term seasonal contribution of sulphur dioxide from the refinery would be of the order of 1.0 microgram per cubic metre at Agra and 0.3 microgram per cubic metre at Bharatpur. The short term maximum peak concentration (1 hour) is estimated to be about 65 micrograms per cubic metre at Agra and Bharatpur. However, such concentrations are likely to occur only during stable atmospheric conditions. From an analysis of the meteorological data available, IMD have indicated that frequency for the atmosphere to be stable towards Agra and Bharatpur is in the region of 2 0 to 4 0 per cent and 0 to 1 0 per cent respectively. Only under such stable conditions the maximum short term concentration (1 hour) of sulphur dioxide is of the order of 65 micrograms per cubic metre. Details are given in Annexure X.

3.5.4 IMD have recognised that one of the shortcoming of the dispersal studies in general is the effect of the accuracy of studies due to use of different empirical coefficients in the model. They have, therefore, in their report taken into account the effects of assuming different values for the empirical coefficients on the accuracy of estimates of concentration. IMD have stated that although variation in empirical coefficients will have considerable effect on the estimated concentration at distances close to the refinery, it would not have any appreciable effect for estimates of concentrations for distances beyond 10 KM and particularly for estimates at a distance of 40 KM. According to IMD at the most the error could be of the order of 50 per cent for estimates of concentration for such long distances. IMD, therefore, concluded that the long term seasonal contribution of sulphur dioxide from the refinery to the Agra region can be assumed with reasonable accuracy to be of the order of one to two micrograms per cubic metre.

3.6 *Study of the Present State of Preservation of Monuments (Studies by Tecneco)*

3.6.1 As far as the monuments in Agra are concerned, the outward appearance indicated that they are in good state of preservation, particularly, the white marble. No visual deterioration due to atmospheric pollution can be detected. The Committee, however, felt that this further needed to be verified and studied in a scientific manner. Further, there is no exact or straight-forward method of conducting laboratory tests to indicate or arrive at any realistic rate of deterioration with different levels of pollutants. This is primarily because the actual deterioration of monuments could be and is due to diverse factors such as water, humidity, quality of stone, pollutants in atmosphere etc. and it is not possible to simulate in the laboratory, the exact conditions to which the monuments are subjected to. It was therefore necessary to know the present condition of the monuments before the refinery goes into operation and their condition after few years of refinery's operation to determine the extent of deterioration, if any, and analyse the cause for the same. This would permit adoption of further protective measures that need to be taken in case of necessity. With the approval of the Committee initially such a study was entrusted to Tecneco of Italy.

3.6.2 In connection with the above studies entrusted to Tecneco, their specialists visited the monuments twice and collected samples from different places from various monuments. Pieces of old marble and stone removed from the monuments during previous maintenance work were also used by Tecneco in this study. Tecneco's team had collected samples of marble and sandstone from the original quarries at Makrana and Jaipur. A summary of Tecneco's report is given in Annexure XI.

3.6.3 Tecneco's report covers methodology adopted for collection of samples, results of the petrographic, chemical, physical, biological parameters and air quality in the monuments zone, discussion on the results and conclusions

3.6.4 Tecneco have stated in their Report that:

"As far as the marble is concerned, on the whole the alterations are limited to only a few zones.

On the contrary, the alterations of the sandstone are present nearly everywhere

Therefore, in conclusion, the marble results as being well conserved in all three monuments and its state of aging can be considered initial while the sandstone is generally in a bad condition.

Since the concentration levels of pollutants taken into consideration are very low, it can be taken for granted that the atmospheric pollution actually present in the Agra zone does not constitute a prevailing cause of alteration such as to notably increase the natural aging of the stone.

The levels of SO concentrations in the Agra zone due to the refinery (from 1.5 to 2 micrograms/m^3 as an annual average) form an objective increase of present levels, however the concentration levels at Agra zone, increasing from 6 micrograms/m^3 to 7.5—8 micrograms/^{8} as an annual average, will remain as very low absolute values.

For this reason, although keeping in mind the previous considerations on the state of conservation of the stones and on the accumulation effect, it can be considered that the foreseen pollution levels will not form one of the main causes of deterioration of the monuments.

It is necessary to remember that the annual increase of 1.5—2 micrograms/m^3 is the result of theoretical calculations which, although carried out with due care, have necessarily large margins of uncertainty connected to the schematization taken for the meteorological parameters.

As already referred in our comments on page 15 of our First and Second Report it should be noted that in their calculations SO is considered chemically and physically inert. This means that physical or chemical removal processes of SO, are not taken into consideration

This assumption does not affect very much the short term concentrations while overestimates the long term concentrations

The model assumes a stationary meteorological conditions, that is speed and direction of wind and atmospheric stability are considered constant during the transport of pollutants."

3.7 *Studies in respect of effect of the Refinery Effluents on Bharatpur Bird Sanctuary*

3.7.1 Based on the information gathered from Nature Conservancy Council, the Royal Society for the Protection of Birds and the Wild Fowl Trust and the discussions with Dr. Salim Ali, it has been established that sulphur dioxide from the refinery would generally not have any adverse effect either on bird life or vegetation. Relevant correspondence in this respect is given in Annexure XII.

3.7.2 In any case since the wind direction is such that it is generally away from Bharatpur most of the time, the increase in sulphur dioxide levels at Bharatpur on account of the refinery would be negligible. IMD has estimated that the long term concentration would be of the order of 0.3 micrograms per cubic metre. As far as surface effluents are concerned, all these will be collected separately and after adequate treatment discharged into the Yamuna river and therefore it will not affect the Bharatpur water course. Further, since the terrain is such that there are no changes of the refinery's effluent ever coming in contact with water courses around the Bharatpur Bird Sanctuary even during floods or by accidents.

3.8 *Indigenous capabilities for Studies*

3.8.1 During its deliberations the Committee felt the need for periodically determining the present status of the monuments. Although, the First such study had been entrusted to Tecneco, there was need to develope expertise within India for future studies of similar nature. The Committee, based on the data collected by it, feels that such studies can be conducted in future through the use of expertise and the facilities available with following institutions among others:

1. National Aeronautical Laboratory, Bangalore;
2. National Physical Laboratory, New Delhi;
3. Physical Research Laboratory, Ahmedabad;
4. Bhabha Atomic Research Centre, Bombay;
5. Raman Research Institute, Bangalore;
6. Geological Survey of India, Calcutta;
7. Central Building Research Institute, Roorkee;
8. Environmental Division of the Department of Science & Technology, New Delhi;
9. Indian Institute of Science, Bangalore;
10. National Environmental Engineering Research Institute, Nagpur;
11. India Meteorological Department, (Ministry of Tourism & Civil Aviation) New Delhi.

CHAPTER 4

CONCLUSIONS

Based on the data made available to the Committee as well as the results of the studies and investigations undertaken, the following conclusions are made.

4.1 There is substantial level of pollution of sulphur dioxide and particulate matter in the Agra region. The possible sources are all coal users consisting of two Power Plants, a number of small industries mainly foundries (approximately 250) and a Railway Shunting Yard. As far as suspended particulate matters are concerned, because of use of coal, contribution will be substantial. Even though the total amount of emission of sulphur dioxide from these sources may be small, on account of their proximity to the monuments, their contribution to the air quality of the zone will be considerably high.

4.2 IOC have estimated that total emission of sulphur dioxide from the refinery would be limited to, one tonne per hour and these estimates have been confirmed by the representative of the Ministry of Petroleum. Since basically low sulphur fuel will be used in the furnaces and modern instruments are available for proper measurement of emissions, it would be possible to ensure that the actual emission is limited to one tonne per hour. IOC have also assured that modern technology will be used for electro-static precipitators of the power plant so that particulate emission from the stack is effectively controlled.

4.3. Based on the dispersal studies made by IMD and the investigations conducted by Tecneco and NEERI it has been estimated that the contribution from the refinery to the long term concentration of sulphur dioxide at Agra would be of the order of one to two micrograms per cubic metre compared to the existing level of 15 to 20 micrograms per cubic metre. Short term (one hour) peak concentration of the order of 65 micrograms per cubic metre could be expected under worst meteorological conditions in winter and the frequency for such occurrences are 2.0—4.0 per cent for Agra region* and 0—1.0 per cent for Bharatpur region.

4.4 Adequate facilities are being provided for treatment of water effluents to meet the required specifications laid down by the Indian Standard Institution and the U.P. Government. Arrangement will be made for ensuring proper dilution of the treated effluents on occasions when enough water is not available in the river for dilution. Adequate expertise and proven technology is available indigenously for such treatment plants. IOC are operating similar plants in their existing refineries satisfactorily.

4.5 So far as the effect on the Bharatpur Bird Sanctuary is concerned, it has been established that there is no likelihood of any adverse effect either on the birds or the plant life at Bharatpur on account of the refinery.

4.6 Effective steps need to be taken quickly to reduce the existing level of pollution in Agra.

4.7 It will be necessary to ensure that the actual long term contribution to the sulphur dioxide levels at Agra as a result of the refinery is not more than two micrograms per cubic metre.

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*Winter refers to the 90 days period from the beginning of December to end of February When the temperature profile in the atmosphere is such that it prevents a parcel of air to rise above a certain height, the atmosphere is said to be stable. Usually, stable condition mean that a rising parcel of air can rise upto a height of 100 to 500 metres, but its further ascent is prevented by an adverse temperature profile. The adverse temperature gradient is referred to as an "inversion" in meteorological literature. Meteorological data indicate that the frequency of wind direction towards Agra during the winter months varies from 14 to 28 per cent during the winter. Out of this percentage, the frequency of conditions which prevent the dispersal of pollutants due to stable conditions is approximately 2.0 to 4.0 per cent for Agra. This implies that the probability of joint conditions of favourable northwesterly winds towards Agra, and stable atmospheric conditions in winter, is likely to be small.

CHAPTER 5

RECOMMENDATIONS

Although primarily the Committee has been formed to advise the project authorities on the measures to be taken for keeping the pollution effect to the absolute minimum, conscious of the great responsibility entrusted to the Committee and its deep concern for the preservation of the priceless monuments at Agra and particularly the Taj Mahal, the Committee considers it of utmost importance that the following recommendations be considered by the Government for urgent and expeditious implementation in order to reduce substantially the existing pollution levels at Agra and to forestall creation of any future sources of pollution.

5.1 Efforts should be made immediately to minimise the existing pollution from sources close to the monuments in the Agra zone. The U.P State Electricity Board has given indications that the old thermal power station (nominal 10 MW capacity) near the Agra Fort would be dismantled as soon as the grid for power supply to Agra is ready and the other power station (10 MW capacity) at Itmat-Ud-Daulah which is in good condition will be shut down and used only as a stand-by in emergencies. Closing down of these two power plants is expected to make a significant reduction in the existing levels of sulphur dioxide and particulate matter at Agra. It is recommended that early steps are taken to close down these two power plants.

5.2 Railways may be advised to replace the present coal-based locomotives with diesel-based locomotives at the marshalling yard at Agra. Since the marshalling yard is very close to the Agra Fort, this measure is expected to reduce the sulphur dioxide and particulate matter levels significantly.

5.3 Steps may be taken to ensure that no new industry including small industries or other units which can cause pollution are located north-west of the Taj Mahal.

5.4 Efforts may be made to relocate the existing small industries, particularly the foundries, in an area south east of Agra beyond the Taj Mahal so that emissions from these industries will not be in the direction of the monuments.

5.5 Similar considerations may apply to large industries such as Fertilizer & Petrochemicals. Such industries which are likely to cause environmental pollution may not be located in the neighbourhood of the refinery. The Committee further recommends that no large industry in the Agra region and its neighbourhood be established without conducting appropriate detailed studies to assess the environmental effect of such industries on the monuments. Location should be so chosen as to exclude any increase in environmental pollution in the area.

5.6 The Committee wishes to record its deep concern regarding the existing level of pollution in Agra. It recommends that an appropriate authority be created which could monitor emissions by industries as well as the air quality at Agra on a continuous basis. This authority should be vested with powers to direct industries causing pollution to limit the level of emission and specify such measures as are necessary to reduce the emission whenever the pollutant level at the monuments exceeds acceptable limits. The Committee particularly desires that the recommendations made in regard to reduction of existing pollution levels at Agra should be converted to a time-bound programme and should be implemented with utmost speed.

5.7 The Committee recognises that there is urgent need for continuous study and investigations to ensure that the monuments at Agra are not exposed to further threats from the pollutants or from any cause. Therefore, it recommends that such studies should be periodically conducted with a view to determine whether any deterioration has occurred and if so, scientifically analyse the cause/s for the same to enable taking suitable measures for prevention of such deterioration. Since the Archaeological Survey of India are in charge of preservation of the monuments, it is logical that they should be entrusted with the responsibility for getting such continuous studies made. For this purpose, ASI may have adequately staffed cell which can carry out studies and additionally utilise the services of other organisations such as National Environmental Engineering Research Institute, India Meteorological Department, National Physical Laboratory, Bhabha Atomic Research Centre, National Aeronautical Laboratory etc., for determining the status of the monuments and also the effects of pollutants thereon Adequate funds should be made available to ASI for these investigations.

5.8 The Committee also recommends that studies should be undertaken by competent agencies to explore the possibility of protecting the monuments by measures such as provision of a green belt around Agra in the region between Mathura and Agra.

5.9 Even though assurances have been obtained from IOC that adequate precautions would be taken to contain the pollution on account of using coal in the power plant, the Committee is of the opinion that till such time this problem is studied in depth and suitable technologies have been found to be satisfactorily in use elsewhere, the use of coal in the refinery power plant should be deferred

5.10 In order to ensure that the emissions from the refinery and their dispersion towards Agra are in accordance with estimates made and assurances given, a minimum of 3 monitoring stations beyond 10 KM from the refinery in the direction of Agra at suitable intervals may be established. These should be operated well before the commissioning of the refinery and operated continuously thereafter. The agency proposed earlier under para 5.7 shall audit these measurements.

5.11 The Committee recommends that the Government should establish facilities and expertise in organisations such as India Meteorological Department, National Environmental Engineering Research Institute, Bhabha Atomic Research Centre, Environmental Division of Dept. of Science & Technology, National Aeronautical Laboratory, Physical Research Laboratory and Raman Research Institute for developing dispersion models suitable for conditions as are actually obtainable in different parts of the country. This is essential for studies as the one entrusted to this Committee.

ANNEXURE I

No. IS-46011/10/73-OR I

Government of India

MINISTRY OF PETROLEUM AND CHEMICALS

(Department of Petroleum)

New Delhi, the 16th July, 1974

MEMORANDUM

SUBJECT—*Environmental Impact of Mathura Refinery—appointment of an Expert Committee to advise on*

A petroleum refinery with a capacity of 6 Million Tonnes is being set up by the Indian Oil Corporation near Mathura in Uttar Pradesh. The environmental impact of Mathura Refinery and other ancillary and down stream units particularly the possibilities of gaseous effluents affecting the Taj Mahal and other historical monuments in Agra and Mathura has been engaging the attention of the Government for sometime The Project authorities have been taking some steps to incorporate anti-pollution measures in the refinery. To advise the Project authorities on the measures to be taken for keeping the pollution effect to the absolute minimum, it has been decided to set up an Expert Committee consisting of the following experts

1. Dr. S Varadarajan, Chairman, IPCL—Chairman
2. Shri M Kurien, Adviser (R), Ministry of Pet & Chemicals—Member
3. Representative of the National Environmental Engg. Research Instt. Nagpur—Member
4. Representative from the Office of the Environmental Planning and Coordination, Deptt. of S&T, New Delhi—Member
5. Representative from the Indian Institute of Petroleum Dehra Dun—Member
6. Representative from the Meteorological Deptt. Min. of Tourism & Civil Aviation—Member
7. Representative of the Government of Uttar Pradesh—Member
8. Managing Director, Indian Oil Corpn. Ltd. (R&P Div.), New Delhi—Member-Secretary

2. Representatives of other concerned organisations such as Department of Archaeology, Indian Standards Institution etc. will be invited to the Committee as and when considered necessary.

3. The Expert Committee will review the steps being taken by the Project authorities for prevention of the pollution and advise them of the additional measures to be taken. The Committee will also take into account the considerable progress made in different parts of the world in devising technical solution to the pollution problems of refineries and particularly to air pollution and examine whether these solutions are proven and can be incorporated in Mathura Refinery The Committee will not only guide Mathura Refinery Management in planning and implementing effective pollution control measures but will also advise Ministry on the pollution aspects of other ancillary and down Stream units.

4. The Committee will meet as often as necessary and will work on a continuing basis. All secretariat assistance required by the Committee will be rendered by the Indian Oil Corporation. No remuneration etc. will be payable to them members of the Committee TA/DA etc. of the Members of attending the meetings of the Committee will be borne by their respective organisations.

5 The Committee will also keep the Government informed of their deliberations from time to time.

Sd/-

(C. VENKATARAMANI)
Joint Secretary to the Govt. of India

To

All concerned.

ANNEXURE II

Government of India

MINISTRY OF PETROLEUM

No. IS-36012/4/76-OR-I

New Delhi, the 4th April, 1977

To

Shri R. N. Bhatnagar
Managing Director, IOC (R&P Div.) and
Member-Secretary, Expert Committee on
Environmental Impact of Mathura Refinery,
Indian Oil Bhavan, Janpath,
NEW DELHI

SUBJECT.—*Environmental impact of Mathura Refinery*

Sir,

I am directed to refer to your letter No. MRG/6/6 dated the 31st March, 1977 forwarding the First Report of the Expert Committee on Environmental Impact of Mathura Refinery and to say that as you are aware, it was decided in the meeting of the Steering Committee held on 15th March, 1977 that the Committee could also advise Government on the effect of pollutants on the birds in the Bharatpur sanctuary. A copy of the minutes of the said meeting has already been sent to you separately. I am to request that this aspect also may please be covered by the Committee and a report sent to this Ministry as quickly as possible.

Yours faithfully,

Sd/-

(K. CHANDRACHOODAN)
Deputy Secretary to the Govt. of India.
(Tel. No. 389096)

ANNEXURE III

LIST OF PARTICIPANTS

Meeting Number	Date	Venue	Members	Special Invitees & other participants
1	2	3	4	5
1.	8-8-1974	Chamber of Hon'ble Minister of Petroleum, New Delhi.	Dr. S. Varadarajan Shri M. Kurien Shri J.M. Dave Shri H.K Mulchandani Dr. Ashok Khosla Dr. A K. Mukherjee Dr. S D. Shukla Shri R N. Bhatnagar	Shri C R Das Gupta Chairman, IOC Shri V V Sarma—IMD
2.	7-10-1974	Indian Oil Bhavan, New Delhi	Dr. S. Varadarajan Dr. Ashok Khosla Dr. A.K. Mukherjee Shri R.N. Bhatnagar	Shri V.V. Sarma—IMD Shri S.K. Nayak—IOC
3.	19-1-1975	Indian Oil Bhavan, New Delhi	Dr. S. Varadarajan Dr. A K Mukherjee Shri H.K. Mulchandani Shri J.M. Dave Shri R.N. Bhatnagar	Shri S. K. Nayak—IOC
4.	1-10-1975	Indian Oil Bhavan, New Delhi	Dr. S. Varadarajan Shri M. Kurien Shri H K. Mulchandani Dr. Ashok Khosla Dr. A K. Mukherjee Shri R N. Bhatnagar Dr. S D Shukla	Shri S Haidar, Prime Minister's Secretariat Shri R P Misra—NEERI Shri S.K. Nayak—IOC
5.	27-11-1975	Indian Oil Bhavan, New Delhi	Dr S Varadarajan Dr. Ashok Khosla Shri R Sengupta Shri R.N. Bhatnagar	Shri Y P Rao, D G (IMD) Prof N Majumadar, Director NEERI Shri V.V Sarma (IMD) Shri P. K Yennawar (NEERI) Shri S K Nayak Dr B B. Lal Shri V S. More — IOC Shri C.S Sharma (IIP)
6.	1-5-1976	Sikandra Guest House, Agra	Dr. S. Varadarajan Shri H.K. Mulchandani Shri R Sengupta Shri R.N. Bhatnagar	Shri S. Haider PM's Secretariat Shri M N Deshpande, DG, ASI. Shri A M Qureshi Chief Engineer Shri Rajendra Prasad Shri U.K. Agarwal Shri B.S. Sinha — UPSEB Shri Nirankar Singh ADO, Industries Deptt, Agra. Shri V.S Mathur Shri D Sankaralingam Shri B.P. Varma — Central Railway. Dr. S C. Roy (ASI) Dr. P P Murthy (IMD) Shri B M. Chabra (IMD) Shri P.K. Yennawar, NEERI Shri S K. Nayak Dr. B B Lal Shri V.S. More — IOC Shri D.K. Biswas (NCEPC)

1	2	3	4	5
7.	13-1-1977	Indian Oil Bhavan, New Delhi	Dr. S. Varadarajan Shri J.M. Dave Dr. S.D. Shukla Shri R.N. Bhatnagar	Dr. P.K. Das Dr. B. Padanabmhamurthy } IMD Shri R.N. Gupta Shri C.R. Subramaniam (ASI) Shri G.C. Joshi } IIP Shri C.S. Sharma Shri S.K. Nayak } IOC Shri V.S. More
8.	12-7-1977	Indian Oil Bhavan, New Delhi	Dr. S. Varadarajan Shri T.S. Nayar Shri H.K. Mulchandani Shri J.M. Dave Shri S.K. Nayak	Shri M.N. Deshpande, DG, ASI Shri K. Chandrachudan Min. of Pet. Shri R N. Gupta } IMD Dr. P.K. Das Shri V.S. More, IOC
9.	23-11-1977	Indian Oil Bhavan, New Delhi	Dr. S. Varadarajan Shri T.S. Nayar Shri R. Sen gupta Dr. S.D Shukla Shri H.K. Mulchandani Shri Thomas Mathew Dr. B.B. Sundresan Shri S.K. Nayak	Shri M.N. Deshpande } ASI Prof. T. Shivaji Rao Dr. P. K. Das } IMD Shri R.N. Gupta Shri V.S. More, IOC
10.	2-12-1977	Indian Oil Bhavan, New Delhi	Dr. S. Varadarajan Shri T.S. Nayar Shri R. Sen gupta Shri H K. Mulchandani Shri Thomas Mathew Shri Desh Raj Singh Shri S.K. Nayak	Shri M.N. Dehspande ASI, DG Dr. P. K. Das } IMD Shri R N. Gupta Shri V.S. More, IOC
11.	6-12-1977	Indian Oil Bhavan, New Delhi	Dr. S. Varadarajan Shri T S Nayar Shri R Sen gupta Shri H K. Mulchandani Shri Thomas Mathew Shri Desh Raj Singh Dr. Padmanabha Murthy Shri S.K. Nayak	Shri M N Desphande DG, ASI Dr P K Das } IMD Shri R N Gupta Shri V S. More, IOC

ANNEXURE IV

LIST OF AGENDA ITEMS CONSIDERED BY THE COMMITTEE

1st Meeting held on the 8th August, 1974 :

1. Salient Features of the proposed Mathura Refinery.
2. A Brief Note on Anti-Pollution Measures in respect of the proposed Mathura Refinery.
3. A note on Pollution Abatement Installations at IROM Refinery at PORTO MARGHERE (Venice, Italy).
4. Production Facilities and relevant Gaseous Effluent Treatment Units.

2nd Meeting held on 7th October 1974:

1. Review of the Minutes of the First Meeting held on 8th August, 1974.
2. Consideration of the Record Note of Discussion IOC had with M/s. TECNECO in Rome on 23rd Aug., '74.
3. Deputation of a team from IOC for studying the pollution control in Italy.

Supplementary Papers for the 2nd Meeting:

1. A Brief Description of Shell Flue Gas Desulphurisation Process.
2. A Brief Description of IFP Flue Gas Desulphurisation and Sulphur Recovery Process.

3rd Meeting held on 9th January, 1975:

1. Consideration of the Minutes of the Second Meeting held on 7th October, 1974.
2. Consideration of letter from EIL dated 8th October, 1974 suggesting EIL's association in the Committee.
3. Consideration of letter from Shri J. M. Dave, Deputy Director, NEERI, Nagpur to Shri R. N. Bhatnagar, Member-Secretary.

4th Meeting held on 1st October, 1975:

1. Tecneco's Proposal
2. Report submitted by NEERI to Archaeological Survey of India on Air Pollution Survey around Taj Mahal and other National Monuments at Agra.
3. Report submitted by IMD.

5th Meeting held on 27th November, 1975:

1. Minutes of the 4th Meeting of the Expert Committee held on 1st October. 1975
2. The proposal from NEERI for continuous monitoring of Pollutants levels for a period of 15 months.
3. The proposal from IMD for setting up two first class observatories at Mathura and Agra.
4. The proposal from ASI for setting up of a cell in the Survey for Investigation and studies for the preservation of monuments from Environmental pollution.
5. Report from Dr. B. B. Lal, Consultant, IOC.

6th Meeting held on 1st May, 1976:

1. Minutes of the 5th Meeting held on 27th Nov., 1975.
2. Interim Report from National Environmental Engineering Research Institute on Base Line Air Quality Survey at Agra.
3. Notes from Dr. B. B. Lal, Consultant, IOC, on organisation for laboratory study of weathering and degradation of stone monuments.
4. Correspondence exchanged between IOC and Prof T. Shivaji Rao of Andhra University.
5. Monitoring Stations set up by NEERI & Tecneco.

7th Meeting held on 13th January, 1977:

1. Approval of the Minutes of the 6th Meeting of the Expert Committee held on 1st May, 1976, at Sikandara Guest House at Agra.
2. Draft of the First Report from the Expert Committee to be submitted to the Government of India.
3. Report from the Indian Meteorological Department on the "Dispersal of Pollutants from a Refinery Stack."
4. First & Second Report from M/s. Tecneco, Italy.
5. Extension of services of Dr B. B. Lal as a consultant to IOC beyond 31st October, 1976.
6. Note prepared by Dr B. B. Lal on the scope and facilities for environmental degradation studies of stones at National Aeronautical Laboratory, Bangalore.
7. Request from the Ministry of Works & Housing for their representation in the Expert Committee.

8th Meeting held on 12th July, 1977:

1. Approval of the minutes of the 7th meeting held on 13th January, 1977.
2. Draft of the First Report from the Expert Committee
3. Third & Final Report from M/s Tecneco, Italy.

4. Effluent Treatment and Disposal Facilities to be provided at Mathura Refinery.

5. Problems arising from the use of coal for steam/ power generation in Mathura Refinery.

6. Effect of the Refinery on the Bharatpur Bird Sanctuary.

7. Letter from the General Manager, Central Railway on the subject of dieselisation at Agra marshalling yard.

9th Meeting held on 23rd November, 1977:

1. Approval of the minutes of the 8th meeting held on 12th July, 1977.

2. NEERI's comments on IMD's report on Dispersal of Pollutants from Refinery's stacks, and IMD's clarifications on the same.

3. ASI's comments on Tecneco's third and final report and note by Shri R. Sengupta, ASI on his discussions with Dr. G. Torraca, Assistant Director, International Centre for Conservation, Rome.

4. Letter from Dr. Torraca to Member Secretary.

5. Note on estimated sulphur dioxide emission from the Refinery.

6. Problems arising from the use of coal in Power Plant-Letter from M/s. BHEL assuring the performance of Electrostatic Precipitators.

7. Bharatpur Bird Sanctuary—Discussions with Dr. Salim Ali.

10th Meeting held on 2nd December, 1977:

1. Finalisation of the draft of summary of the first Report—comments from NEERI, IMD, ASI.

2. Letter from M/s Tecneco giving their view point on the comments from Dr. Torraca.

11th Meeting held on 6th December, 1977:

1. Minutes of the meetings held on 23rd November, 1977 and 2nd December 1977.

2. Finalisation of the draft of the Report from the Expert Committee.

ANNEXURE V

BASELINE AIR QUALITY SURVEY AT AGRA

SPONSOR : INDIAN OIL CORPORATION LIMITED
(Refineries & Pipelines Division), New Delhi

REPORT BY
NATIONAL ENVIRONMENTAL ENGINEERING RESEARCH INSTITUTE
NAGPUR—20

- First Quarterly Report (19-11-1975 to 29-2-1976)
- Second Quarterly Report (1976—Summer Dataa)
- Third Quarterly R'port (Monsoon and Post—Moonsoon Data, 1976)
- Fourth Quartely Report(Winter Season 1976-77 Data)

BASELINE AIR QUALITY SURVEY AT AGRA

FIRST QUARTERLY REPORT

(19 NOVEMBER 1975 TO 29 FEBRUARY 1976)

Introduction

On the recommendations of the Expert Committee to advise on the environmental impact of Mathura Refinery, the National Environmental Engineering Research Institute, Nagpur was awarded the work of conducting air quality survey around the national monuments at Agra by the Indian Oil Corporation The object of the study was to set up a baseline of pollution around national monuments at Agra before the proposed refinery at Mathura is established. As per the expert committee's opinion it was felt necessary to conduct air quality study for a period of 12 to 15 months which will cover at least two winter seasons so that observations would be of more confirmative nature A work programme and financial proposal by NEERI was submitted to the Indian Oil Corporation and in order not to miss the first available winter of 1975 the sampling work was immediately started on 19th November 1975 at the Taj Mahal and subsequently at four other sites for the survey

Air quality survey programme has been satisfactorily progressing since its inception with the kind cooperation of the Indian Oil Corporation, the Archaeological Survey of India, the District Magistrate of Agra and the Nagar Mahapalika. A small laboratory cell has been established in the Officers Hostel Building located in the Circuit House premises. A space for laboratory was made available with the kind cooperation and help of the Commissioner of Agra region and the District Magistrate. This accommodation is ideally suited for the survey work.

The Office of the Superintending Archaeologist, Northern Circle, Agra, have been extending their all time cooperation in locating air monitoring stations at different monument-sites, permitting entries in the monuments and in the security of the air sampling instruments left at these places. Nagar Mahapalika authorities have kindly permitted to locate the monitoring station on the Mahapalika building. This is the first quarterly report of the work done by NEERI covering the period from November 1975 to February 1976.

2. *Air Monitoring Sampling Stations*

In Agra, the most important monument is Taj Mahal The other ones being Red Fort, Sikendra and Itamat-ud-Daulah where study on air quality data is a must It was also felt necessary that general city air pollution level should be obtained for comparison purpose This means five stations are the minimum required for the survey Therefore, five air sampling stations are fixed at the following site (Fig 1).

	Sampling site	*Date of sampling and frequency*
I	Taj Mahal .	. Every alternate days started from 19 Nov. 1975.
II	Agra Fort (Red Fort) .	. Every forurth day started from 22 Nov. 1975.
III	Itamat-ud-Daulah	. Every forurth day stared from 12 Dec 1975
IV.	Sikendra . .	. Every fourth day from middle of Dec. 1975.
V	Nagar Mahapalika	. Every fourth day started from middle of Dec 1975

The above air sampling stations were located taking into consideration the monumental importance. The city station at Nagar Mahapalika is the additional one to get the general air quality pattern of the city as it represents typical commercial and residential area.

3. ***Pollution Parameters***

As per the work done in other countries, the common pollutants that affect the monumental construction materials like marble, sand stone and plaster are sulphur dioxide and particulate soot as primary pollutants to cause damaging effects. These are also index of average pollution carried by fossil fuel like coal, oil etc. and other industrial activities. NO is also a common pollutant of secondary importance as it gives an index of high temperature combustion for other photochemical activity. Therefore, sulphur dioxide, suspended particulate matter, NOx (as NO_2) and sulphation rate were selected as pollution parameters.

Wind data with respect to direction and speed are also collected. This is a vital tool to interpret the pollution data of the air pollution survey Though the airport at Agra records the climatological data, it was felt necessary to collect micro-meteorological data near Taj Mahal site by setting independent meteorological station at the Officers Hostel building in the Cricuit House premises

4. *Sampling Programme*

Air sampling programme is designed as follows. At Taj Mahal the frequency of sampling is on every alternate day and therefore each day of the week is covered twice in a month. At other places seven sampling days per station are fixed for every month as shown in Table 1. These seven days cover all the seven days of the week (*i.e.* Monday, Tuesday—— ——Saturday & Sunday). A sampling day comprises 24 hours period and normally the sampling gets started by about 10.00 hours in the morning and continues till the next day up to 10.00 hrs. This completes the sampling of the day. On that basis effort are being made to follow up the sampling frequenc as described in 2 as above.

The tentative schedule of sampling is shown in the following table.

TABLE 1

A SCHEDULE OF SAMPLING AT MONITORING STATIONS

1st week							2nd week							3rd week							4th week						
M	T	W	Th	F	S	Sn	M	T	W	Th	F	S	Sn	M	T	W	Th	F	S	Sn	M	T	W	Th	F	S	Sn
a	b	a		a	b	a		a	b	a		a	b	a		a	b	a		a	b	a		a	b	a	
c	d		c	e	d		c	e	d		c	e	d		c	e	d		c	e	d		c	e	d		c

a—Taj Mahal;
b—Agra Fort,
c—Itmat-ud-Daulah;
d—Sikendra;
e—City centre.

Gaseous samples are collected normally on 2-hourly basis for 24 hours continuously. This gives twelve samples per site per sampling day. Suspended particulate matter is collected on single 24 hrs. basis Sulphation rate is measured by exposing lead peroxide candle for 30 days on a calendar month basis.

5. *Observations*

This report limits its observations only for a period starting from middle of November 1975 till the end of February 1976. This period can be classified as winter period and the observations made can be attributed to the winter conditions at Agra. Presence of sulphur dioxide and particulate matter are the main features of the observations made on air quality survey. Other parameters, namely, sulphation rate and NOx are found to be considerably low during this survey period. These are discussed below.

5.1 *General Pattern of SO_2 Levels*

Figure 2 illustrates the general pattern of SO_2 levels. Taj Mahal, Red Fort and Itmat-ud-Daulah show comparatively higher levels than the other two monitoring sites, namely, Sikendra and Nagar Mahapalika. November, December and January data show Similar pattern of SO_2 level whereas February data indicates the receding trends. Three bars for each station show three different features of SO_2 level for that particular month. An open bar in the figure represents a maximum single 2-hour value recorded in that month. This value signifies the possibility of pollution reaching the monitoring site from the neighbouring or a distant sources. This high value is only for a short interval of time (2 hours). The middle bar with slanting line-represents the calculated 24-hours maximum average value observed on a particular day in a month. The third bar with dark blue column represents the calculated means value of sulphur dioxide for 24-hours or monthly basis.

The 24 mean value for sulphur dioxide is almost near about 20 micrograms/M^3 at most of the stations except at the Red Fort. The Red Fort value reaches the level of 40 micrograms/M^3. At Sikendra the SO_2 level is minimum in comparison to the other stations. The Taj Mahal monitoring site stand second in the order of SO_2 level after Red Fort, Itmat-ud-Daulah comes in third position Table 2 gives the evaluation summary of sulphur dioxide levels at different stations. The last column of the table depicting 2 hour maximum value recorded during the survey shows the instance of pollution level up to the mark of about 100 to 200 micrograms/M^3. This is, however, for a short interval of time say, 2 hours. Such situation can be repeated in a month more than once. This confirms that there is a significant source of pollution in the neighbourhood. The high values recorded though for a short interval are at the Red Fort and the Taj Mahal which are vulnerable to the effect of pollution.

5.2 *Diurnal Pattern of Sulphur Dioxide Level*

Figure 3 represents the variation in sulphur dioxide level for different periods of the day.

The normal trend in the diurnal variation is depression in the level during the afternoon hour say from 12.00 to 16.00 hrs. The pollution seems to get started rising during evening hours and maintain throughout the night and after the sun gets brighter and hotter the pollution starts receding This can be explained by calm condition in the morning and night and windy ones in the afternoon. Also ground level diurnal inversion prevents dispersal of pollutants at night

Figure 3 gives the illustration of the diurnal pattern for Taj Mahal, Red Fort, Itmat-ud-Daulah Sulphur dioxide level at Taj Mahal could be soon ranging between 20 and 30 micrograms/M^3 with a depression of its level below 10 microgrammes/M^3 during afternoon hours. At the Red Fort sulphur dioxide levels are slightly higher than those at Taj Mahal The values ranging between 30 and 35 with a depression of 14 micrograms/M^3, in the afternoon Similarly, levels at Itmat-ud-Daulah were also seen in the range of 30 to 40 microgramms/M^3 with a slight depression during night (15 to 20 micrograms/M^3). Itmat-ud-Daulah also records only 10 micrograms/M^3 level at the afternoon period.

Since Nagar Mahapalika and Sikendra monitoring sites were having almost negligible variations these sites have not been illustrated in the figure.

TABLE 2

DIURNAL VARIATION IN SO_2 LEVELS AT AGRA

(Micrograms/M^3, 4-hr average)

Station	Month	Time of the Day						No of days	24 hr.* Avge	24 hr.* Max.	2 hr.* Max.
		04—08	08—12	12—16	16—20	20—24	00—04				
Taj Mahal	Nov 75	19	18	8	23	30	28	5	22	35	77
	Dec. 75†	25	26	11	29	31	24	14	24	50	122
	Jan. 76†	22	26	7	17	26	18	10	17	58	160
	Feb. 76	19	21	6	11	14	20	10	15	32	102
Red Fort	Nov. 75	44	54	13	35	43	38	4	38	62	140
	Dec. 75†	39	46	17	43	49	31	8	39	93	188
	Jan. 76†	20	12	10	15	22	39	6	24	50	188
	Feb. 76	36	14	11	11	14	18	5	17	21	58
Sikendra	Dec 75	11	15	6	8	13	10	3	10	16	22
	Jan 76	11	10	6	10	16	28	4	12	18	56
	Feb 76	6	6	6	6	8	10	5	7	10	30
Itmat-ud Daulah	Dec 75†	17	33	12	16	32	20	8	26	64	134
	Jan 76†	16	26	10	35	36	18	6	24	43	110
	Feb 76	16	18	6	24	23	10	7	17	25	78
Nagar-Mahapalika	Dec. 75	15	19	6	19	31	22	2	20	30	64
	Jan 76	13	13	7	19	29	15	6	16	27	74
	Feb. 76	10	10	7	16	21	19	7	14	27	70

*Refer to Figure 2

†See also Figure 3

5.3 *Sulphation Rate Measurements*

Sulphation rate measurement though started from the month of December. the values of December and January could not be obtained due to technical difficulties. February values are reported as follows:

TABLE 3

Sulphation Rate Measurment at Agra

Name of the Station	*Sulphation rate in February 1976*
Taj Mahal	0 33
Red Fort	0 51
Sikendra	0 49
Itmat-ud-Daulah	0 47
Nagar Mahapalika	0 37

Sulphation rate measurements will be continued regularly till the end of the survey and the values will be more conclusive after the collection of one year data

5.4 NO_x *Levels*

Normally the levels for NO_x (as NO_2) were measured at all the different stations and are found to be very close to the lowest detectable levels. Most of the time the values for NO_x are found in traces and therefore could be said negligible. In order to collect more volume of air the sampling programme for NO_x was prolonged from 2 hours to 4 hours in a single impinger and the values are almost all the same magnitude *i e*, under traces about 20 micrograms/M^3 or below.

5.5 *Suspended Particulate Matter in the Air at Agra*

24 hour samples for the suspended particulate matter record the particulate levels in the air ranging from 450 micrograms/m^3 in November and December whereas 250 micrograms/M^3 in January and February (Figure 4) all the monitoring sites have recorded similar trend of particulates with a little variation depending on the local activities.

Particulate matter at all the monitoring stations except Sikendra are identical. Red Fort site being slightly higher than other because of neighbourhood activities of the power station and transport.

Sikendra site which is identified as control station in relation to sulphur dioxide levels also holds good in this respect. The exceptionally high value during the month of February (at Sikendra) was due to dust storm on one particular day of sampling. Normally the average value at Sikendra is about 150 micrograms/M^3 The general pattern of suspended particulate level has been illustrated in Figure 4.

5.6 *Wind Pattern*

Winds are recorded from the Officers Hostel Building at the Circuit House compound. Exposure of the wind instrument observed to be ideal and could be a representative for the Taj Mahal and Red Fort area.

Monthly wind roses are drawn for December 1975 and January-February 1976, (Figure 5). Special feature of the wind for the winter season (December to February) seems to be with prevailing calm conditions. About 25 to 30 per cent time the winds are calm. However, weak winds with a velocity range of 0 to 5 km/hr was also recorded during December and January. February winds seems to have been little more active and the winds were rising occasionally in the velocity range of 6 to 10 km/hr.

5.7 *Directional Pattern of the Wind*

Calm conditions prevail most of the time in December and occasionally south-westerly winds were recorded. In January the magnitude of the wind speed remain unchanged. However, the direction pattern was observed north-westerly as that of January with little more active winds in the movement. This explains the different levels of pollutants at Red Fort, Taj Mahal and Itmat-ud-Daulah during December-January.

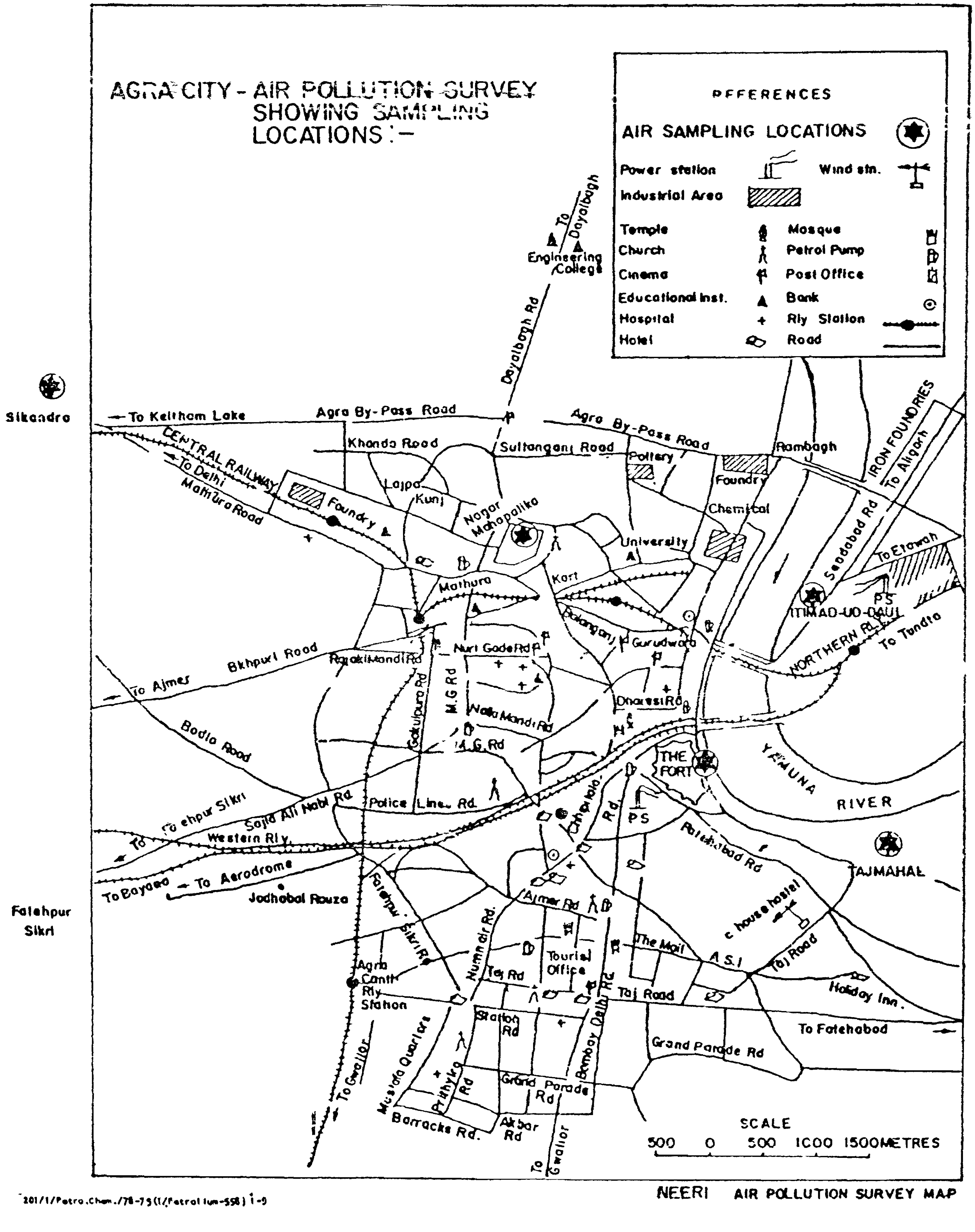
5.8 *Temperature and Humidity*

The temperature during three months survey was about with maximum 78°F and minimum 55°F and humidity about 40 per cent during the day time and 80 to 90 per cent in the night.

5. *General Remarks*

The data presented in this report is a factual data without conclusive interpretation. More data covering various aspects of meteorology, pollution etc. are required for conclusive interpretation in future. The survey is being continued on those lines. However, this will be discussed in the final report after completing the studies of the whole year.

FIG. I



NEERI AIR POLLUTION SURVEY MAP

BASELINE AIR-QUALITY SURVEY AT AGRA

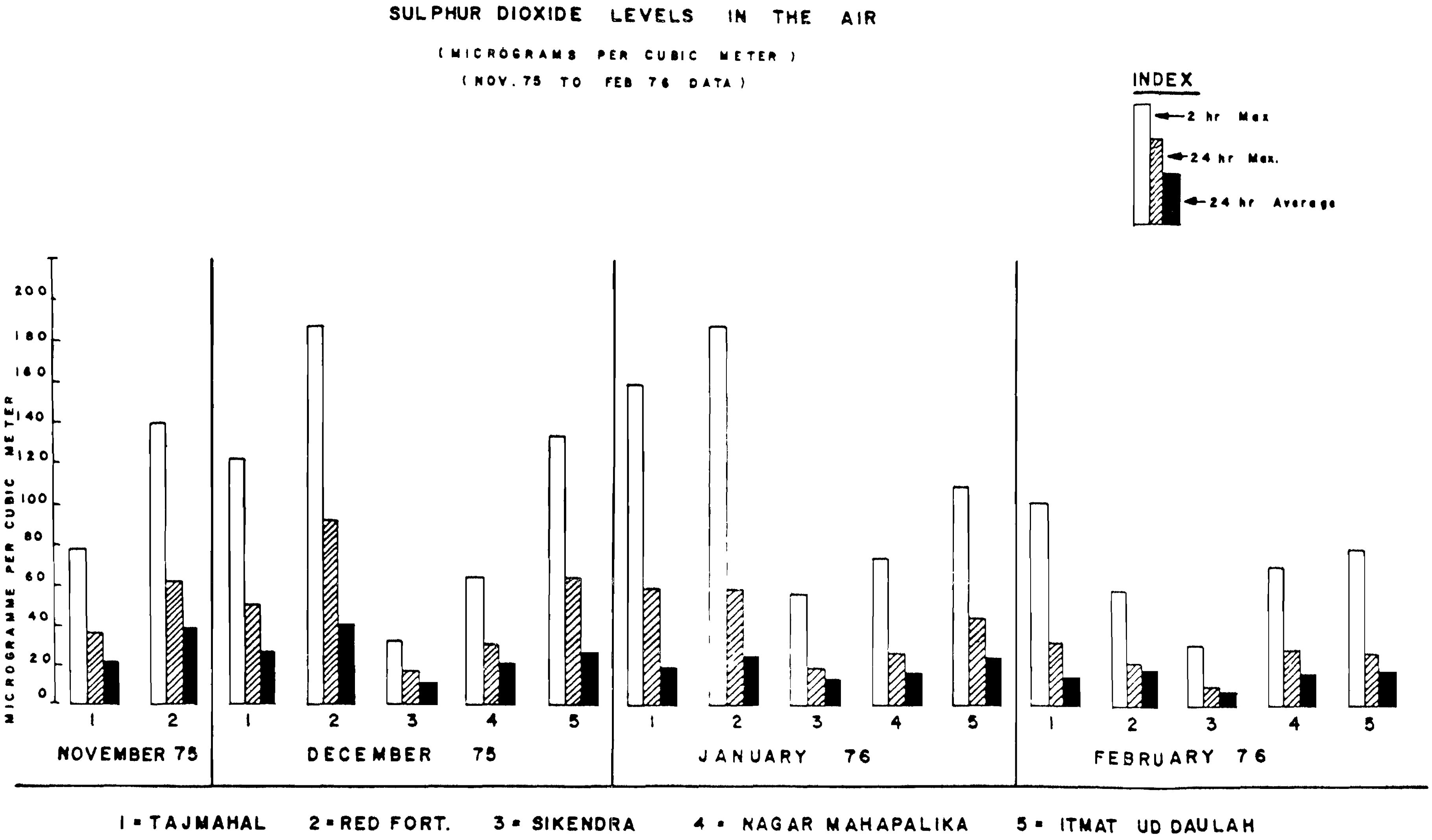


FIG. 2

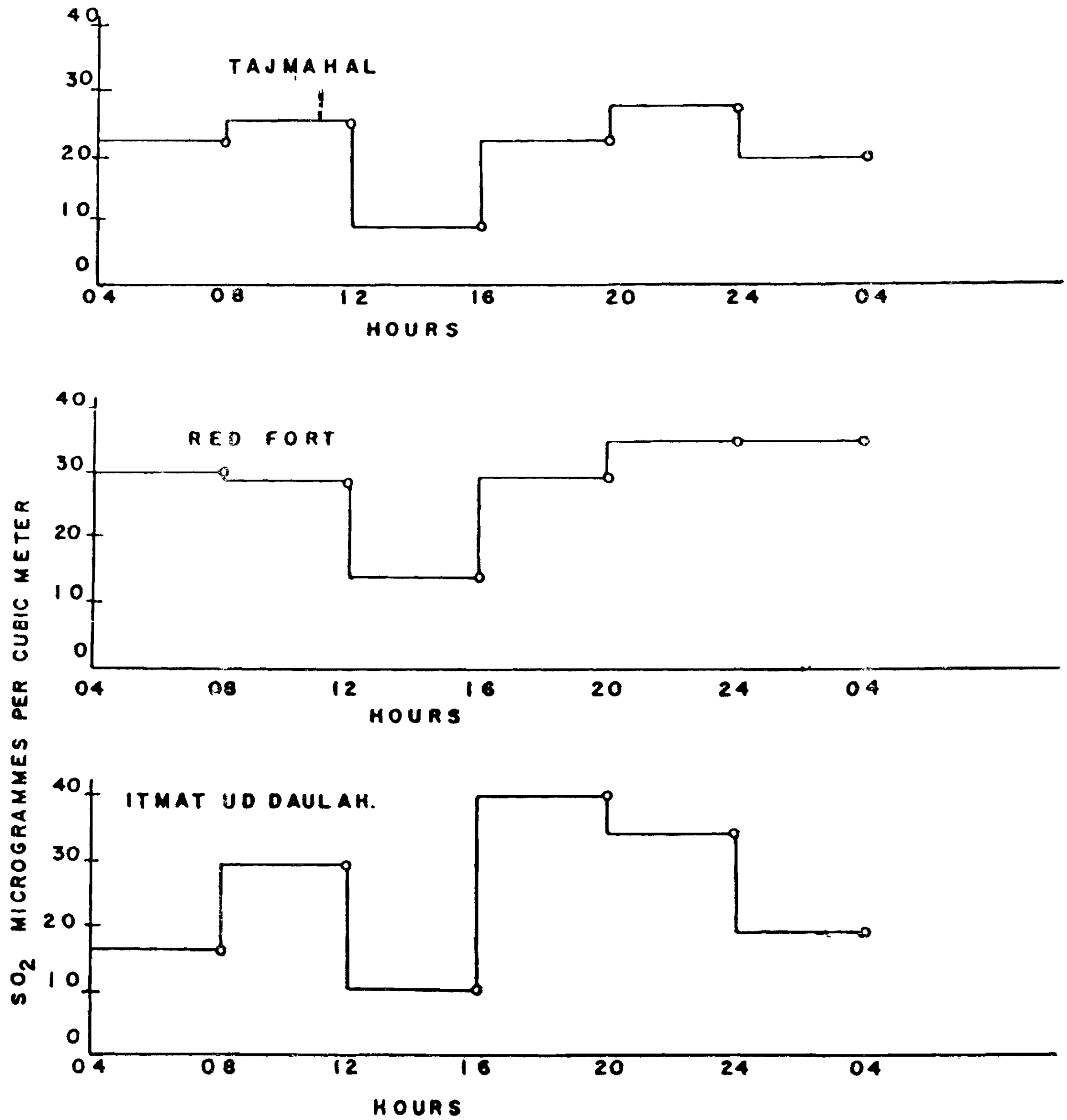
(NEERI SURVEY DATA)

BASELINE AIR-QUALITY SURVEY AT AGRA.

DIURNAL VARIATIONS IN SO_2 LEVELS

(DEC. 75 & JAN 76 DATA

WINTER PERIOD



PERIOD OF THE DAY —— (ON 24 HOURS CLOCK)

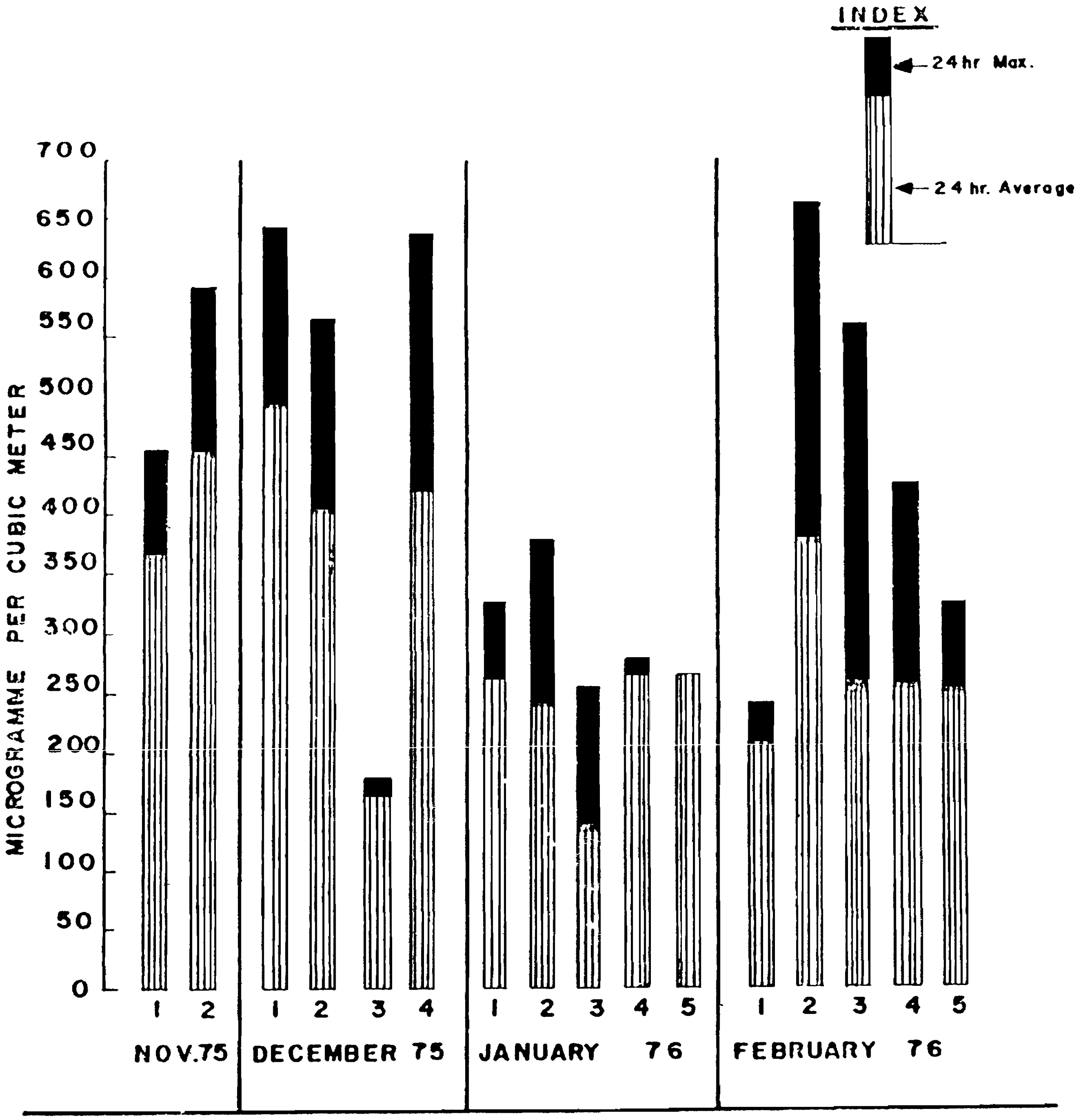
FIG.3

(NEERI SURVEY DATA)

BASELINE AIR-QUALITY SURVEY AT AGRA

LEVELS OF SUSPENDED PARTICULATE MATTER IN THE AIR

(NOV. 75 TO FEB. 76 DATA)



1 = TAJMAHAL, 2 = RED FORT, 3 = SIKENDRA,
4 = ITMAT UD DAULAH, 5 = NAGAR MAHAPALIKA.

FIG. 4

(NEERI SURVEY DATA)

BASE LINE AIRQUALITY SURVEY AT AGRA

WIND PATTERN

DEC. 75 - FEB. 76

DATA

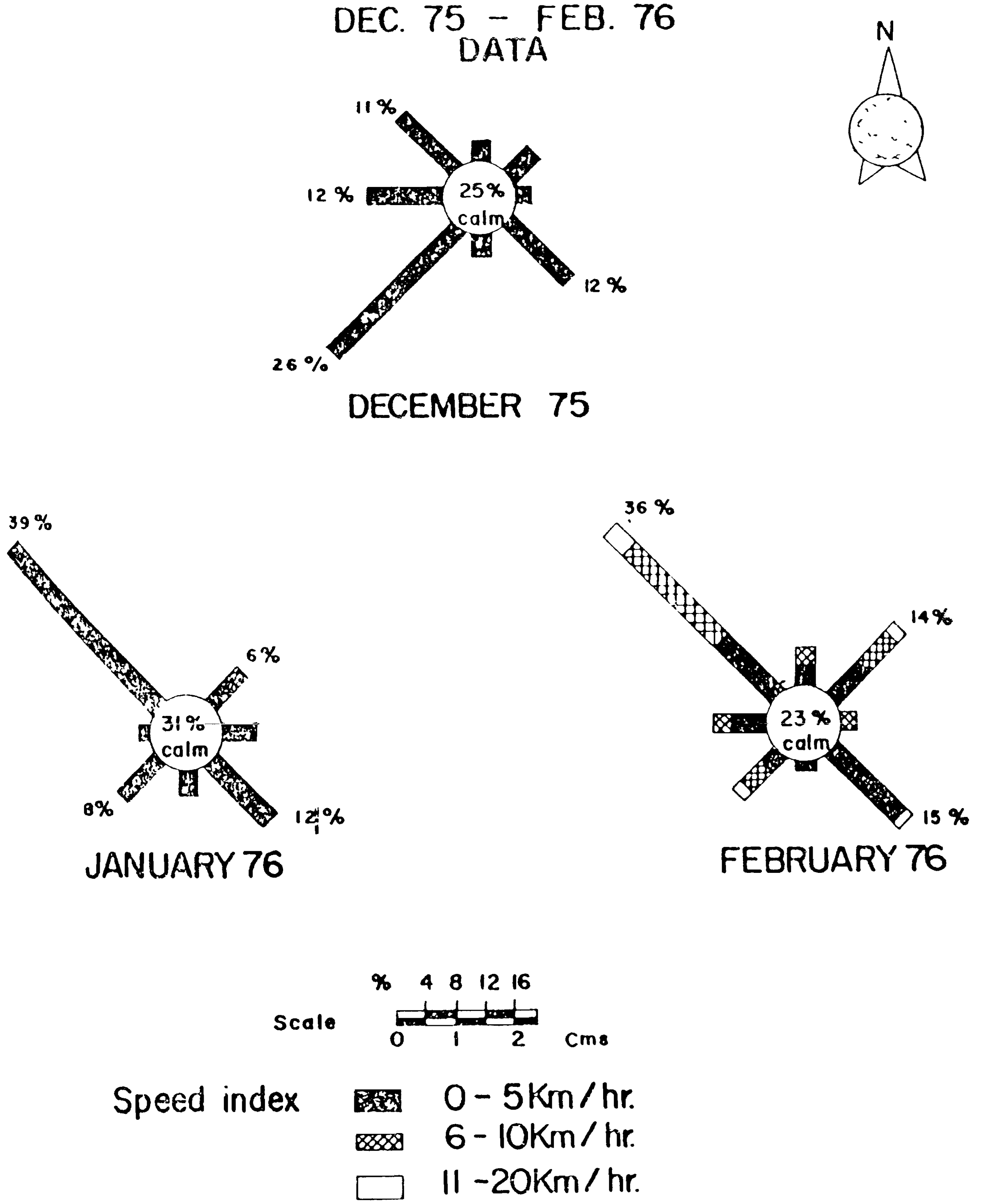


FIG. 5

[NEERI DATA]

BASELINE AIR QUALITY STUDY AT AGRA

SECOND QUARTERLY REPORT

(1976 SUMMER DATA)

1. Air quality data on the project work for the last winter months (November 1975 to February 1976) was reported earlier in the first quarterly report This report comprises the summer data for a period starting from March to May 1976, a total period of three months.

2. *Air Sampling Programme*—The sampling schedule was continued to be of the same design without any specific change in the programme. Sulphur dioxide, oxides of nitrogen and suspended (dust) particulate matter is being sampled on every fourth day at each of the monitoring sites. Sulphation rate measurements are also regularly carried out at all the five locations, namely, the Taj Mahal, Red Fort, Itmat-ud-Daulah, Sikandara and Nagar Mahapalika.

3. Wind data regarding speed and direction is being recorded at one site Temperature and humidity measurements are also made on the sampling sites and on sampling days

4. *Summer Observations*—Table-1 summarises the diurnal pattern of sulphur dioxide levels for the individual months (March, April & May) of summer. 2-hourly sampling was carried out and the data being computed for 4-hourly and 24-hourly period from these observations. The monthly average (24 hour) of sulphur dioxide levels was below 15 micrograms/m³, the maximum that was recorded being 34 micrograms/m³ at the Agra Fort in April. 2-hourly maximum value of 87 micrograms/m³ was recorded at Itmat-ud-Daulah in March. Earlier, during winter, monthly average (24-hour) value was recorded up to 39 micrograms/m³ with maximum value of 93 micrograms/m³ at Agra Fort, 2-hourly maximum being 188 micrograms/m³ at the same place. Thus the levels of sulphur dioxide in summer were considerably lesser in comparison with those recorded during winter.

5. Oxides of nitrogen (NOx as NO_2) levels were measured on 8-hourly basis since the values below this period was not measurable as the normal concentration is considerably low. These levels are also recorded below 31 micrograms/m³ (Table-1) for 24 hours average.

6. Suspended particulate level is measured on 24-hour basis and the levels were observed to be of higher than those recorded during winter The winter values are reported in the range of 250—450 micrograms/m³ whereas the summer values are found to be in the order of 350 to 500 micrograms/m³ The stormy and dusty weather which normally prevails in this area is the main cause for the higher values The particulate levels are given in Table-1.

7 *Sulphation Rate Measurements*.—Sulphation rates for the summer months are found considerably low in comparison with the winter observations. Summer values are tabulated below:

Name of site	Sulphation rate (Milligrams SO_3/100 sq cm²/day)		
	March 76	April 76	May 76
Taj Mahal	0 08	0 07	0 05
Red Fort	0 17	0 12	0 08
Itmat Ud--Daulah . . .	0 12	0 13	0 09
Sikandra	*	0 05	†
Fatehpur Sikri . . .	†	†	0 01

*Sampling missing

†Fatehpur Sikri location started newly from May 76.

8 *Temperature and humidity*.—The general pattern of temperature and humidity during the sampling at Taj Mahal is recorded in Table-2.

TABLE 2

Temperature and humidity—Taj Mahal (Observation at sampling days)

Month	Temperature (°C)			Relative humidity (%)	
	Average	Highest on month	Lowest on month	Max 6 am	Min 3 pm
March . .	22·7	36	14	71	16
April . .	35·4	43	14	74	18
May . .	29·4	46	21	56	10

9 *Wind Pattern*.—The normal wind pattern during summer months was little more active than the winter months The wind velocities were low mostly in range of 0 to 5 km/hr and sometimes increasing up to 10 to 20 km/hr Calm conditions were less frequent 12 to 23 per cent of time when compared to winter which was 23 to 31 per cent of time.

The wind direction as can be seen from Fig. 1 is more or less westerly and north-westerly.

10. *Remarks.*—Sulphur dioxide levels at all the sampling sites were considerably low (less than 34 micrograms/m³) except a few individual 2-hourly samples which were observed at Red Fort and Itmat-ud-Daulah. The general trend of the low level of SO_2 can be explained on the basis of high temperature conditions of the summer when the pollutants are diffused upward conventionally and active winds.

Because of low levels of SO_2 sulphation measurements are also proportionately low.

High increase in the suspended particulate matter is because of natural dust in summer months transported from Rajasthan Desert.

11. *Follow up.*—The same programme of work will be continued for the rainy season and the report on the data for June—August will follow in the third quarterly report.

TABLE 1:

AIR QUALITY DATA—AGRA

March to May, 1976

(Summer Data)

Diurnal Pattern of $SO_2/\mu g/m^3$									$SO_2/\mu g/m^3$		$NOx/\mu g/m^3$		$SPM/\mu g/m^3$	
Station	No. of days	04—08	08—12	12—16	16—20	20—24	00—04	2hours maximum once in a month	Monthly avg.	Monthly max. (24-hr value)	Monthly avg.	Monthly max. (24-hr value)	Monthly. avg	Monthly. max (24-hr value)
1. *TAJ MAHAL*														
March	10	11	9	7	10	12	10	34	10	20	9	24	315	547
April	12	14	11	7	11	11	12	34	11	22	13	26	355	655
May	12	7	6	6	7	9	8	25	7	11	8	17	448	803
2. *AGRA FORT*														
March	4	11	10	9	14	11	18	34	12	17	14	19	449	720
April	9	17	14	8	9	15	12	63	12	34	17	31	511	1461
May	7	18	16	14	10	17	15	58	15	30	16	26	463	903
3. *ITMAT-UD-DAULAH*														
March	3	11	16	8	12	27	10	87	14	21	11	13	363	731
April	— POWER LINE DISLOCATED. NO SAMPLING FOR ALL OVER THE MONTH—													
May	5	10	7	6	8	18	10	58	11	14	11	15	556	
4. *NAGAR MAHAPALIKA*														
March	5	10	11	8	8	15	8	42	10	16	22	37	295	375
April	7	14	15	9	9	12	11	37	11	20	15	32	464	728
May	7	7	6	6	6	7	6	20	6	8	10	15	638	1483
5. *SIKANDARA*														
March	5	9	7	6	7	10	11	25	9	13	6	13	181	195
April	7	8	7	6	8	7	9	20	7	12	6	17	287	493
May	5	6	11	10	6	12	11	27	11	25	10	15	328	458

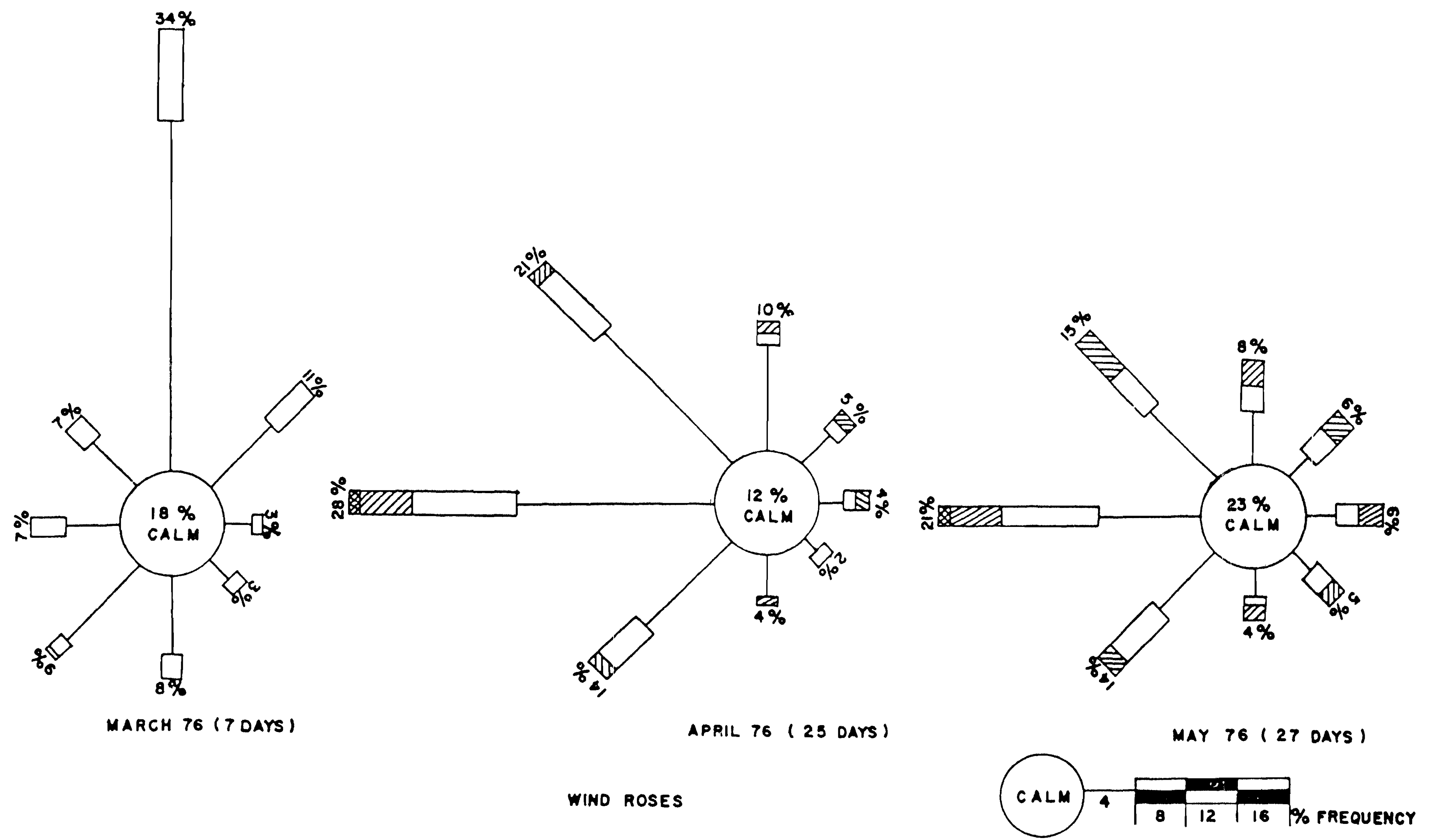


FIG. 1 AGRA AIR POLLUTION SURVEY MARCH TO MAY 1976

BASELINE AIR QUALITY STUDY AT AGRA

THIRD QUARTERLY REPORT

(MONSOON AND POST-MONSOON DATA, 1976)

1. Air quality data on the project work for the last summer months (March—May 1976) was reported earlier in the Second Quarterly Report. This report consists of the monsoon and post-monsoon data for a period starting from June to October 1976 for a total period of five months.

2. *Air sampling programme*.—The sampling schedule was continued to be of the same order without any changes in the original programme. Sulphur dioxide, oxides of nitrogen, suspended particulate matter is being sampled on every fourth day at each of the monitoring sites. Only monitoring site at Taj Mahal being surveyed on every alternate days. Sulphation rate measurements are also carried out at all the five locations, namely, the Taj, Red Fort, Itmat-ud-Daulah, Sikandara and Nagar Mahapalika. Other two sites have been added for sulphation measurements one of which is at Fatehpur Sikri,—Guest House, and the other at Circuit House in Agra.

3. Wind data regarding speed and direction are recorded at the Circuit House premises from the Officers Hostel Building Roof.

4. *Observations*.—Table-1 summarises the values of pollutants observed during June to October 1976. The monthly average is worked out on 24 hour basis by computing 2 hourly values. Sulphur dioxide level was very low during monsoons, (June to Sept. 1976). The recorded values are of the order below 10 micrograms/m^3 However, there appeared a casual increase in the levels of sulphur dioxide for a short interval The maximum level observed on 2 hourly sampling schedule ranged from 20 to 70 micrograms/m^3 at different monitoring sites Such an observation was only once or twice in a total period of the calendar month. The month of October (post-monsoon period), showed a rise in the sulphur dioxide level and the values recorded ranged from 15 to 26 micrograms/m^3 (on the 24 hourly basis). Table-1 shows the statistics of the compiled observations from which it is clearly seen that the rise in levels took place only in the month of October while the rainy season months recorded very low values.

5. As regards oxides of nitrogen levels, similar pattern as observed in case of sulphur dioxide was noted. Recorded values are in the range of 10—15 micrograms/m^3.

6. Suspended particulate levels were observed lower than those recorded during summer. Summer observations recorded the dust concentration level in the range of 350 to 500 micrograms/m^3 whereas monsoon values were found in the order of 50 to 150 micrograms/m^3. Only October values showed sudden increase in the order of 200 to 380 micrograms/m^3 (Table-1).

TABLE I

AIR QUALITY DATA—AGRA

Period of Observations : June to October, 1976

(Monsoon & Post-Monsoon)

Station Month	No. of days	$SO_2/\mu g/m^3$ 24 hr avg	24 hr Max	24 hr Max.	$NO_2/\mu g/m$ 24 hr avg.	8 hr Max.	$SPM/\mu g/m^3$ 24 hr avg.	24 hr Max.	Sulphation Rate Mg, SO_3 100 cm^2/day
1	2	3	4	5	6	7	8	9	10
Taj Mahal									
June	14	7	12	[illegible]0	11	37	210	472	0·035
July	12	7	17	34	7	21	121	384	—
August	12	8	16	38	7	18	66	106	Spoiled
September	14	7	10	30	10	47	105	201	0·13
October	13	15	32	80	13	28	286	407	0·248
Agra Fort									
June	7	7	10	22	13	33	321	726	0·271
July	5	7	8	17	12	19	194	413	0·12
August	4	7	10	36	6	17	48	64	0·19
September	6	15	31	71	18	50	156	321	0·20
October	6	24	72	208	16	56	314	440	Spoiled

1	2	3	4	5	6	7	8	9	10
Itmat-ud-Daulah									
June	7	9	17	34	17	49	354	562	0·059
July	4	6	7	12	12	31	256	501	0·065
August	7	11	24	56	7	18	91	186	0·065
September	6	10	14	44	12	31	159	238	0·170
October	7	26	54	151	15	89	377	515	0·468
Nagar Mahapalika									
June	6	6	8	20	12	24	194	384	..
July	6	8	15	30	111	17	166	327	0·037
August	5	8	18	42	10	16	117	176	0·054
September	6	6	7	13	13	36	166	315	0·170
October	6	13	24	75	15	49	313	487	0·217
Sikandara									
June	6	6	6	6	13	35	183	375	0·099
July	5	6	7	16	4	6	141	239	0·098
August	5	7	8	16	6	13	74	87	0 098
September	6	6	6	8	6	15	102	161	0 110
October	6	10	16	40	7	19	201	220	0 281
Fatehpur Sikri									
June	..	..	..	..	..	..	..	..	0·033
July	..	..	..	..	..	..	..	..	0·19
August	..	..	..	..	..	..	..	..	0·037
September	..	..	..	..	..	..	..	..	0 06
October	..	..	..	..	..	..	..	..	0 108
Officers Hostel (Circuit House)									
June	..	..	..	..	..	..	..	..	0·11
July	..	..	..	..	..	..	..	..	0·054
August	..	..	..	..	..	..	..	..	0·12
September	..	..	..	..	..	..	..	..	0·22
October	..	..	..	..	..	..	..	..	0 262

7. *Sulphation Rate*.—Sulphation rate values for monsoon were similar to summer observations. These values are recorded in Table-1.

8. *Temperature*.—The temperature recorded at the Circuit House site are given below. The values have been computed from the recording charts.

Month	Average° C	Maximum	Minimum
June . . .	29·6	40	21
July . . .	24·7	41	17
August . .	23·6	37	17
September . .	26·7	46	19
October . .	24·6	41	14

9. *Wind Pattern*.—From the collected data at the Circuit House, the wind pattern for the region is shown as below:

Months	Directions%								
	N	NE	E	SE	S	SW	W	NW	Calm
June . . .	2	8	2	5	2	32	7	11	31
July . . .	2	10	6	8	5	20	2	2	45
September . .	1	7	3	2	—	27	18	19	23
October . . .	—	—	1	1	1	14	8	7	68

During monsoon period the calm conditions were in the range of 40 to 60 per cent and the prevailing direction for the wind was southwest and west.

10. *Remarks*.—The general trend of the pollution level for sulphur dioxide was found to be similar to that recorded during the summer months. The levels were considerably low (less than 10 micrograms/m^3) except during October when the values were little higher. However, few individual two hourly samples which were observed at Red Fort and Itmat-ud-Daulah were little higher. The general trend of the low levels of sulphur dioxide, sulphation rate and suspended dust are due to rainy weather.

11. *Follow-up Programme*.—The same programme of work will be continued for the coming winter season and the report on the data for November to January will follow in the fourth quarterly report.

BASELINE AIR QUALITY STUDY AT AGRA

FOURTH QUARTERLY REPORT

(WINTER SEASON 1976-77 DATA)

1. Air quality data on the project work for the last monsoon months (June-October 1976) was reported earlier in the Third Quarterly Report. This report consists of the winter season data for a period starting from November 1976 to January 1977.

2. *Air Sampling Programme.*—The sampling schedule was continued to be of the same order without any changes in the original programme. Sulphur dioxide, oxides of nitrogen, suspended particulate matter is being sampled on every fourth day at each of the monitoring sites. Only monitoring site at Taj Mahal being surveyed on every alternate days. Sulphation rate measurements are also carried out at all the five locations, namely, the Taj, Red Fort, Itmat-ud-Daulah, Sikandra and Nagar Mahapalika. Other two sites have been added for sulphation measurements one of which is at Fatehpur Sikri Guest House, and the other at Circuit House in Agra.

3. Wind data regarding speed and direction are recorded at the Circuit House premises from the Officers Hostel Building Roof.

4. *Observations.*—Table 1 summarises the variations in sulphur dioxide levels during 24 hours for three different months. There is a remarkable rise in levels as compared to previous observations for summer and rainy season, particularly at the monitoring sites at Taj Mahal, Agra Fort and Itmat-ud-Daulah. Maximum trend was observed during December, the levels of sulphur dioxide being 40 to 50 /ug/m^3 on 24 hours average.

Table 2 give further details with respect to all the pollution parameters under study. The maximum 2 hourly values of sulphur dioxide are recorded as high as 100 to 200 /ug/m^3 but once in a month during nights.

Nitrogen dioxide also shows a significant rise from the summer and rainy season observations. Eight hourly maximum values recorded for nitrogen dioxide are around 60-90/ug/m^3 or even more at all the stations except Sikandra. The higher levels are recorded during nights.

Suspended particulate matter levels are also quite high during all three months of winter ranging between 300 to 400 /ug/m^3 at all sites including Sikandra which is away from the city. Winter values are comparable with those observed during summer.

Sulphation rate measurements are also proportionately on increase as per the expectations (Table 2).

5. *Temperature.*—The temperature recorded at the Circuit House site are given below. The values have been computed from the recording charts.

Month	Average C°	Maximum	Minimum
November	19·8	34	9
December	22·5	30	5
January	13·0	25	4

6. *Wind pattern.*—From the collected data at the Circuit House, the wind pattern for the region is shown as below:

Month	Directions %								
	N	NE	E	SE	S	SW	W	NW	Calm
November	1·5	1	1	3	4	7	9	7·5	66
December	0·40	4·0	2·9	2·3	0·7	4·2	7·5	9·2	68·8
January	10	2	10	7	1	2	12	13	43

Calm conditions are prevalent during winter months. The prevailing wind direction was north-west and west.

During monsoon period the calm conditions were in the range of 40 to 60 per cent and the prevailing direction of the wind was southwest and west.

7. *Remarks.*—The general trend of pollution parameters is on the increase with respect to all parameters under study. This trend is significantly different from that observed in summer and rainy season.

Winter data is available for last three years from 1974 to 1976 and will be studied and compiled in the final report.

8. *Follow-up-programme.*—The last phase of the survey is in progress. The field survey will conclude on March 31, 1977. This report will follow a final report on the survey project by June end 1977.

TABLE I

AIR QUALITY DATA—AGRA

Sulphur Dioxide Diurnal Pattern

(Winter Data)

Period of Observation . November, 1976 to January, 1977.

Station Month	00—4	04—08	08—12	12—16	16—20	20—00
Taj Mahal						
Nov. '76	15	10	13	8	20	19
Dec. '76	46	41	35	18	42	66
Jan. '77	26	16	17	9	15	34
Agra Fort						
Nov. '76	22	15	19	9	17	28
Dec. '76	43	52	52	44	65	66
Jan. '77	34	34	28	21	41	37
Itmat-ul-Daulah						
Nov. '76	12	14	17	10	44	35
Dec. '76	21	23	29	24	48	42
Jan. '77	44	49	40	41	52	58
Nagar Mahapalika						
Nov. '76	8	6	7	6	10	9
Dec. '76	37	43	14	10	29	28
Jan. '77	18	20	15	9	21	34
Sikandra						
Nov. '76	12	10	10	10	10	11
Dec. '76	12	15	8	6	12	21
Jan. '77	12	8	8	7	13	17

TABLE 2

AIR QUALITY DATA—AGRA

(Winter Season)

Period of Observation : November 1976 to January 1977

Station Month	No. of days	$SO_2/\mu g/m^3$			$NO_2/\mu g/m^3$		$SPM/\mu g/m^3$		Sulphation rate
		24 hr average	24 hr Max	2 hr Max	24 hr average	8 hr Max	24 hr average	24 hr Max	Mg/SO_3 100 cm^2 day
Taj Mahal									
Nov.	14	15	35	76	23	67	298	503	0·4398
Dec.	15	42	81	147	33	85	300	394	0·353
Jan.	14	20	42	100	25	87	283	559	0·149
Agra Fort									
Nov.	6	24	40	86	19	40	244	355	0·2871
Dec.	6	56	116	204	34	91	322	391	0·386
Jan.	7	33	68	112	29	69	360	653	0·224
Itamat-ud-Daulah									
Nov.	7	22	46	152	21	47	366	476	0·3126
Dec.	7	30	46	117	32	75	400	508	0·309
Jan.	6	48	120	200	36	124	358	445	Spoiled
Nagar Mahapalika									
Nov.	7	8	14	26	19	68	274	484	0·2241
Dec.	7	30	41	157	41	176	318	597	0·276
Jan.	8	20	42	168	27	90	328	436	0·198
Sikandra									
Nov.	6	11	15	50	7	20	170	228	0·1826
Dec.	5	12	19	56	19	50	205	288	0·198
Jan.	7	11	22	54	15	55	187	290	0·134
Fatehpur Sickri									
Nov.	—	—	—	—	—	—	—	—	0·03576
Dec.	—	—	—	—	—	—	—	—	0·242
Jan.	—	—	—	—	—	—	—	—	NIL
Officers Hostel (*Circuit House*)									
Nov.	—	—	—	—	—	—	—	—	Spoiled
Dec.	—	—	—	—	—	—	—	—	0·276
Jan.	—	—	—	—	—	—	—	—	0·160

TABLE I

5th Report from Neeri Covering Period

February and March, 77.

AIR QUALITY DATA—AGRA

Sulphur Dioxide Diurnal Pattern

(February & March, 1977)

Station	00—04	04—08	08—12	12—16	16—20	20—20
Taj Mahal	21	20	18	8	17	24
	36	36	18	6	13	32
Agra Fort	21	27	16	18	26	33
	45	51	25	14	26	51
Itmat-ul-Daulah	26	20	18	12	30	26
	30	35	23	6	25	53
Nagar Mahapalika	19	14	11	7	12	28
	8	8	6	6	8	25
Sikandara	11	16	12	6	6	13
	18	9	7	6	6	8

sd/-

Survey Incharge,
(Air Quality Study Programme)
National Environmental Engg. Research Institute

TABLE 2

5th Report from Neeri Covering Period Feb. and March, 77

Period of Observation: February and March 1977

Station	Month	No. of days	$SO_2/\mu g/m^3$		$NO_2/\mu g/m^3$			$SPM/\mu g/m^3$		Sulphate on Rate mg SO_3 100 cm²/day
			24 hr Average	24 hr Max	2 hr Max	24 hr Average	8 hr Max	24 hr Average	24 hr Max	
Taj Mahal .	Feb	14	18	32	106	19	67	265	447	0·253
	March	10	23	48	108	20	81	290	366	0·231
Agra Fort . . .	Feb	7	23	53	78	18	50	280	411	0·236
	March	5	35	48	140	24	74	388	565	0·311
Itmat-ul-Daulah .	Feb	7	23	43	91	17	46	300	448	0·182
	March	4	29	44	90	26	54	359	462	0·113
Nagar Mahapalika .	Feb	7	15	26	76	23	93	302	477	0·141
	March	4	13	25	90	16	56	268	466	0·113
Sikandara . . .	Feb	7	10	15	44	10	26	174	322	0·139
	March	4	9	15	52	11	22	207	267	0·105
Fatehpur Sikri . .	Feb	—	—	—	—	—	—	—	—	0·058
	March	—	—	—	—	—	—	—	—	0·039
Officer's Hostel . .	Feb	—	—	—	—	—	—	—	—	0·179
	March	—	—	—	—	—	—	—	—	0·196

sd/-

Survey Incharge,
(Air Quality Study Programme)
National Envi onmental Engg. Research Institute.

AIR QUALITY DATA AT TAJ MAHAL

(Nov. 1975—March, 1977)

Month	No. of days	Sulphur Dioxide 24 hr Average	Sulphur Dioxide 2 hr Max	Suspended Particulate 24 hr Average	Suspended Particulate 24 hr Max
November 1975	5	22	77	362	455
December	14	24	122	490	640
January 1976	10	17	160	262	325
February	10	15	102	167	237
March	10	10	34	315	547
April	12	11	34	355	655
May	12	7	25	448	803
June	14	7	20	210	472
July	12	7	34	121	384
August	12	8	38	66	106
September	14	7	30	105	201
October	13	15	80	286	407
November	14	15	76	298	503
December 1976	15	42	147	300	394
January 1977	14	20	100	283	559
February	14	18	106	265	447
March	10	23	108	290	366

NEERI DATA

ANNEXURE VI

NOTE ON SALIENT FEATURES OF THE PROPOSED MATHURA REFINERY, EFFLUENTS AND THEIR TREATMENT

1. *Introduction*

The Government of India has taken a decision to set up a large oil refinery at Mathura to meet the growing petroleum products demand of the North-West region. The techno-economic Studies have established the need to locate the refinery at Mathura. The principal considerations that have prompted this decision are: the fact that Mathura is centrally located within the demand area; proximity to both Broad Gauge and Metre Gauge railway lines and national highway; and availability of land.

2. *Site*

As directed by the Government, Indian Oil Corporation constituted a Site Selection Committee comprising representatives from the Railways, Government of Uttar Pradesh, Ministry of Petroleum & Chemicals and Indian Oil Corporation for selecting a suitable site for the refinery. After ascertaining the merits and demerits of a number of sites, the Committee finally recommended a site situated on the west of the national highway between Bad Station on one side and village Dhana Teja on the other. This area is marked in the location map No. 1800-C-73022, copy attached. The area recommended for location of the township is also marked.

3. *Brief Description of the Refinery*

3.1 The proposed refinery will have a nominal capacity of processing 6 million tonnes per annum and is designed for processing Middle East crudes in the gravity range of 32—36· API with sulphur content less than 2 per cent. With the prospects of increased availability of indigenous crudes it is expected that this refinery may also process Bombay High crude to the extent of 3 million tonnes per annum, the balance 3 million tonnes will be imported crude.

The main process units are as follows:

Unit	*Capacity in '000 tonnes per annum*
Atmospheric Distillation Unit with Desalter	6000/7000
LPG Treating Units	215
Naphtha Treating Units	350
Naphtha Caustic Wash	750
Kerosene Treating Unit	1500
Visbreaker	1000
Vacuum Unit	2300
Fluid Catalytic Cracking Unit	1000
Sulphur Recovery Unit	10
Bitumen Unit	500

3.2 In addition to these process units, the Refinery will have the following facilities:

(1) Crude & Product Storage Tanks
(2) Product Despatch Facilities by Pipeline, Rail & Road.
(3) LPG Bottling Facilities
(4) Bitumen Drumming Facilities
(5) TEL Blending Facilities
(6) Thermal Power Station 37.5 MW Capacity.
(7) Effluent Collection & Treatment Facilities
(8) Water Treatment Facilities
(9) Other auxiliary facilities such as:
  — Pump Stations,
  — Laboratory,
  — Warehouses,
  — Workshop etc.

3.3. The estimated products from the refinery are as follows:

Products	*Qty. in '000 tonnes/Year*
LPG	197
MS	350
Naphtha	809
ATF	480
SK	658
HSD	2043
LDO	36

Products	Qty in '000 tonnes/Year
FO (Reg)	84
Fertilizer Feed	640
Bitumen	300
Sulphur	6

3.4 It is also proposed to build a township of approximately 800 houses for the refinery. The township will be provided with facilities such as schools, medical treatment, shops and recreation facilities.

3.5 *Employment Potential.*—The total requirement of personnel for the refinery is estimated at 1100. Apart from the direct employment opportunities commissioning of the refinery will provide indirect employment opportunities to small-scale and other industries in the area in the form of maintenance jobs, provision of stores etc.

4. *Effluents from the Refinery and their Treatment*

4.1 Effluents from the refinery can be divided into two categories, *viz.* those to be discharged to the surface and those discharged to the atmosphere. Effluents that will be discharged to the surface will be mainly treated waste water from the refinery and coal ash from the refinery thermal power plant. Effluents that will be discharged to the atmosphere will be due to evaporation of petroleum products during storage, catalyst particles, flue gases from the furnaces and particulate matter from the power plant stack.

4.2 *Effluents to be discharged to the Surface*

4.2.1 The estimated quantity of treated waste water that will be discharged from the refinery is of the order of 3 million gallons per day. The refinery will have an elaborate system for collection of all waste water that needs treatment before discharge which include:

(i) Oily Storm water from tank farm;
(ii) Oily & Chemical waste water;
(iii) Contaminated rain water;
(iv) Cooling tower blow down;
(v) Sanitary sewage; and
(vi) Spent caustic.

In other words, during normal conditions any water that is likely to be contaminated is collected for treatment before its discharge.

4.2.2 The facilities for the treatment of these have been given in the attached Block Diagram No. 1217-65-SKB-045-A.

4.2.3 The usual contaminants are oil, phenol and sulphides. The facilities provided will ensure that the contaminants will be reduced to the limits specified by the current Indian Standard Specifications for industrial effluents to be discharged into inland river waters. Adequate know-how and manufacturing capabilities exist within the country for providing these treatment facilities.

4.2.4 The ash from the thermal power plant is proposed to be dumped into a specific area admeasuring approximately 200 acres, which will be used as a burrow pit for construction earth requirements. (Please refer to Drawing No. 1800-C-7302) The area is considered to be adequate for dumping ash for ten to fifteen years. The ash will be transported in the form of slurry. Adequate bunds will be provided so that the water, after separation will have sufficient time to settle before it is discharged into the natural drainage of the area. Reuse of this water is also being examined. In any case, the water that will be discharged will conform to the relevant Indian Standard Specifications. Since the ash will be wet, local dust nuisance will be prevented.

4.2.5 The treated waste water will be discharged into the Yamuna river at a suitable point downstream of Brahmandghat *via* an open channel from the refinery to the discharge point. (Please refer to drawing No. 1800-C-73022). An inspection road will also be provided along the channel. Adequate arrangement for proper mixing of the treated waste water with the river water will be provided at the point of discharge. It has been ascertained that the extent of dilution of the waste water even when there is minimum flow of the river is more than 1 : 10 and the river water will be suitable for human consumption after usual municipal treatment. As per information provided by the State Government officials, there is no habitation for about 15 to 20 KMs from the point of discharge. This point is about 40 KMs from the Agra water supply works.

4.2.6 As a normal routine measure considerable attention is given to the collection, treatment and discharge of the effluent in a refinery. Checks and balances are provided to ensure that only water of acceptable quality is discharged into the channel. Samples from the channel as well as from the river will also be periodically collected and checked.

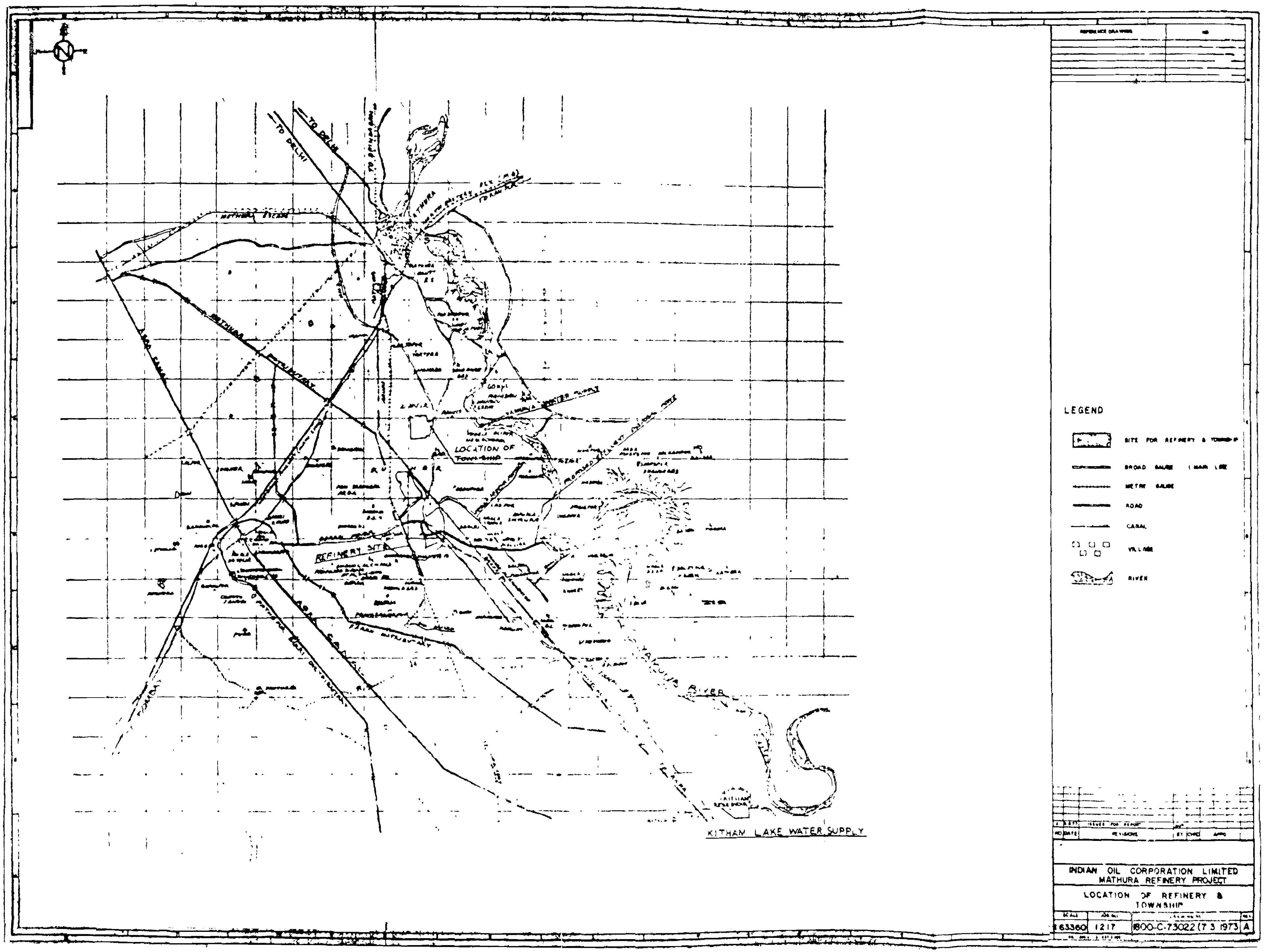
4.3 *Effluents to be Discharged to the Atmosphere*

4.3.1 The catalyst fines which is an inert material is discharged from the stack of the Catalytic Cracking Unit. The approximate quantity of discharge is one tonne per day. The size of the particles is of the order of 50 microns or less. No adverse effect is caused by this discharge.

4.3.2 Another particulate matter that will be discharged to the atmosphere will be from the thermal power plant stack. Here also facilities will be provided so that the particles that will be discharged to the atmosphere will be of less than 50 microns.

4.3.3 Evaporation losses are minimum since most of the products which are volatile are Stored in tanks with floating roofs for reasons of safety as well as to reduce product losses.

4.3.4 The main source of contamination in the effluents to be discharged to the atmosphere is sulphur dioxide contained in the flue gases from the furnaces and FCC stacks. The sulphur dioxide in the flue gases come from sulphur contained in the fuels. With


TO DELHI
TO DELHI
MATHURA
REFINERY SITE
LOCATION OF TOWNSHIP
YAMUNA RIVER
AGRA CANAL
KITHAM LAKE WATER SUPPLY
LEGEND
SITE FOR REFINERY & TOWNSHIP
BROAD GAUGE (MAIN LINE
METRE GAUGE
ROAD
CANAL
VILLAGE
RIVER
REFERENCE DRAWINGS
ISSUED FOR REPORT
NO DATE
REVISIONS
BY CHKD APPD
INDIAN OIL CORPORATION LIMITED
MATHURA REFINERY PROJECT
LOCATION OF REFINERY & TOWNSHIP
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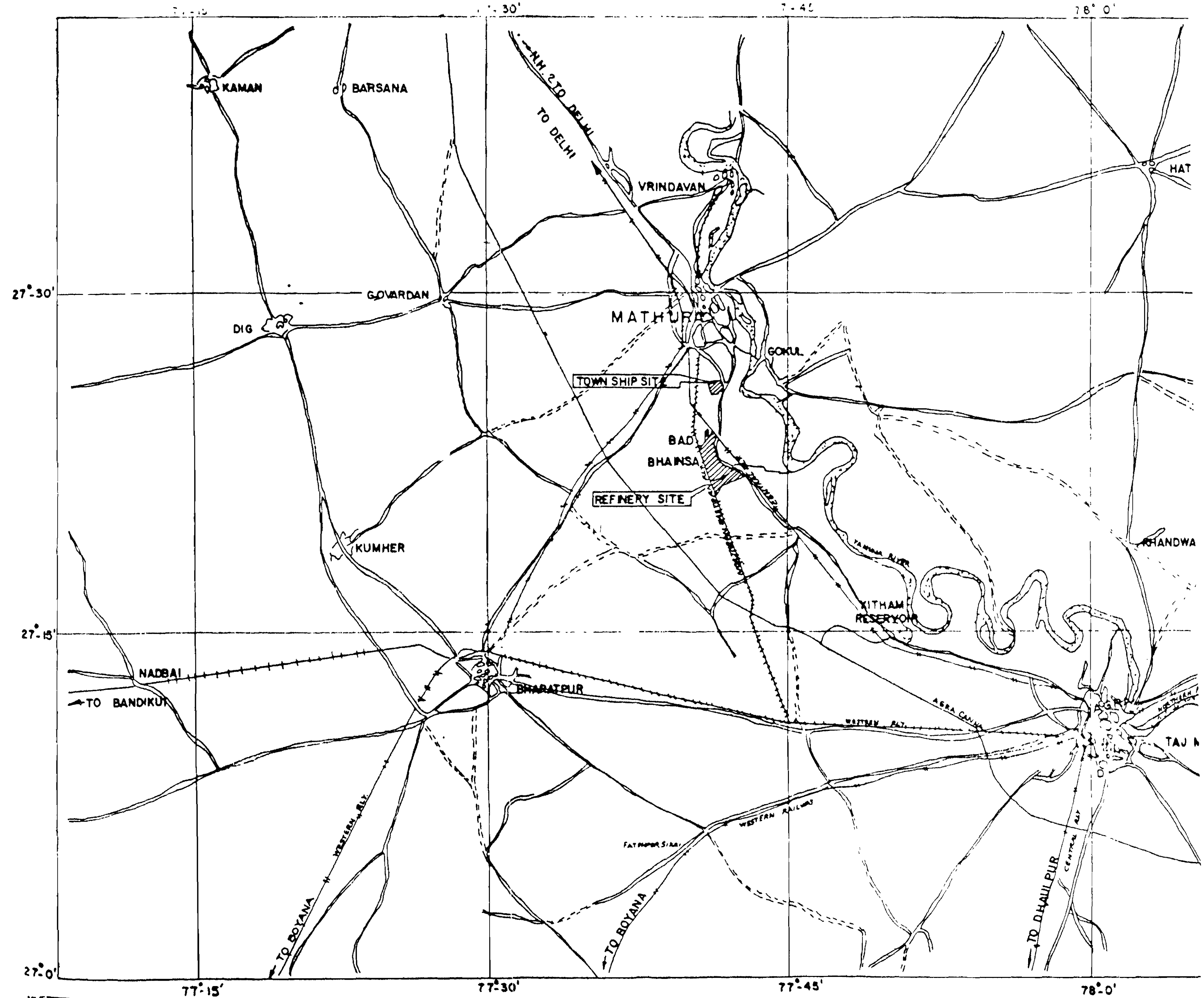

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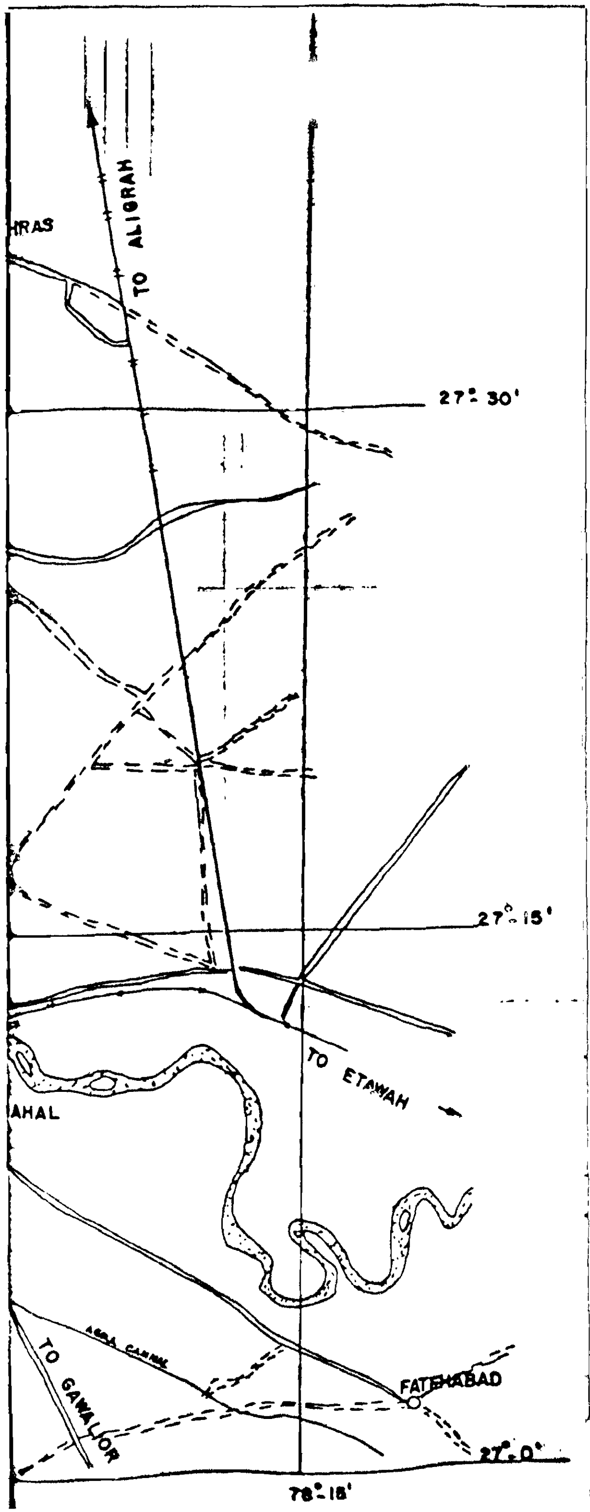
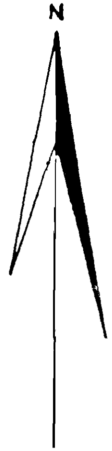
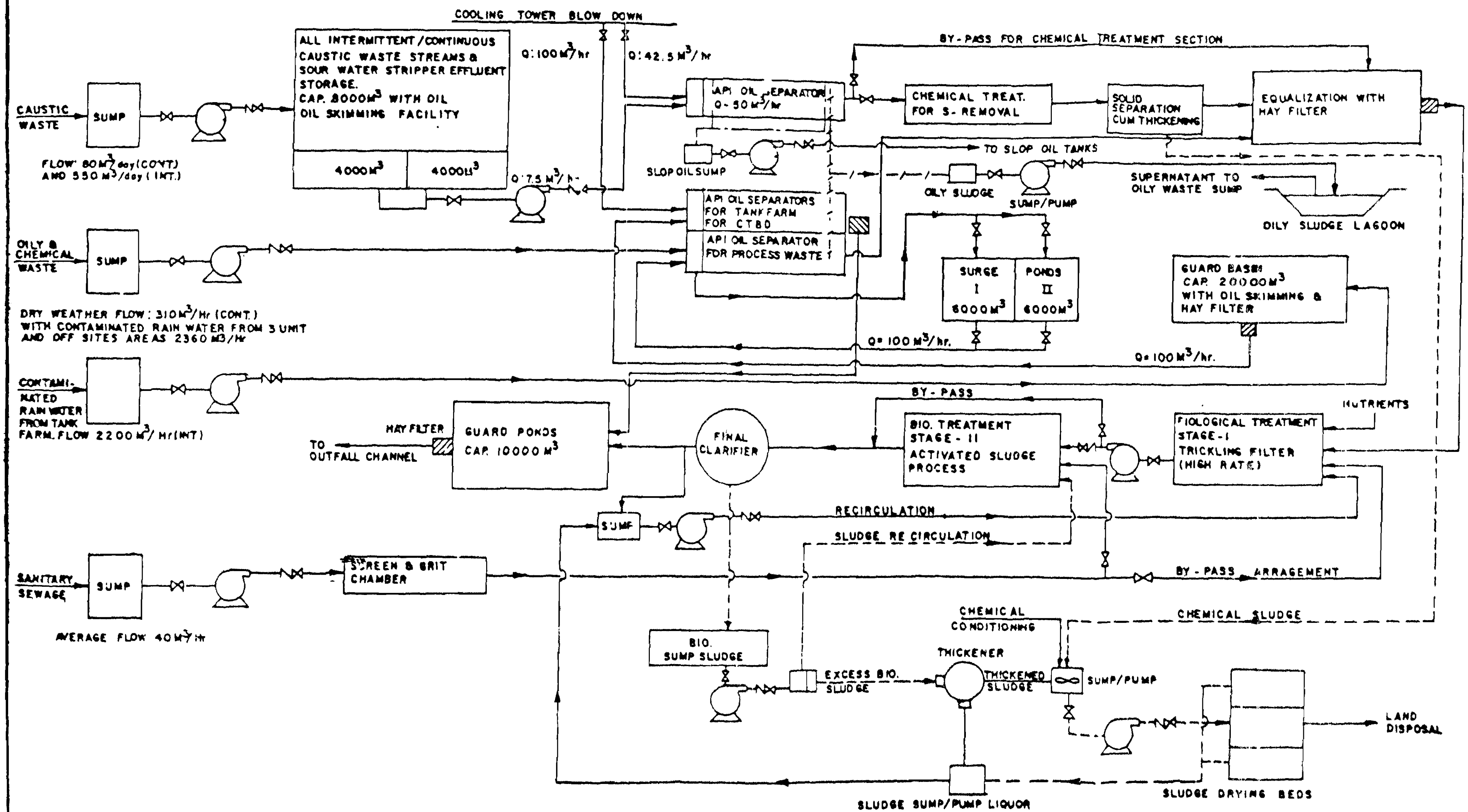




LEGEND

- ROADS
- BROAD GAUGE RLY LINE
- OTHER GAUGE RLY LINE
- AGRA CANNEL
- RIVER (YAMUNA)
- KITHAM RESERVOIR
- METALLED ROAD

INDIAN OIL CORPORATION LIMITED (REFINERIES DIVISION) MATHURA REFINERY PROJECT	
REF DWG.	
DRN	MATHURA REFINERY & ITS SURROUNDINGS
CKD	
APPD	
SCALE 1 inch to 4 miles	
DATE	DWG.NO 1800-C - 75070



EXCLUSIONS: GUARD PONDS, GUARD BASIN, RISING MAIN TO SLOP OIL TANKS

DWG NO	REF DRAWING	I.O.C MATHURA REFINERY	NO	DATE	REVISION	BY	CH	APPD	SCHEMATIC FLOW DIAGRAM FOR WASTE WATER TREATMENT PLANT	1217	65-SKB-045	REV

the decision to use low sulphur coal as fuel for the thermal power plant and the prospects of processing about 3 million metric tons per annum of Bombay High crude in the refinery, the estimated quantum of sulphur dioxide that will be emitted from the refinery stacks will be less than one metric ton per hour. All the major stacks would be of a height not less than 80 metres to ensure proper dispersal of the fuel gases.

4.3.5 Even in case, for various reasons, it does become necessary to process only imported sulpherous crude in the refinery, the emission of sulphur dioxide from the refinery would be less than 3 tonnes per hour. However, measures can be taken to reduce this to less than one tonne per hour by adopting suitable flue gas treatment facilities. There are at present a few flue gas treatment processes which have been in commercial operation for a short period. It is expected that by the time the refinery goes into stream, fully commercially proven processes will be available and therefore provision is being made in the refinery scheme so that these can be installed at a later date, if required. In the intervening period should it be required, it will be ensured that the sulphur dioxide emission is limited to less than one tonne per hour by using low sulphur fuel which is fortunately available from the Barauni and Koyali Refineries. It will thus be seen that in all cases, the Refinery will be operated to ensure that the SO_2 emission is less than one tonne per hour.

* * *

Encl : Drawing No. 1800-C-73022
(Location Map)

Block Diagram No. 1217-65-SKB-045-A.

ANNEXURE VII

DETAILS OF ADDITIONAL COST ON ACCOUNT OF POLLUTION ABATEMENT MEASURES ADOPTED BY IOC

On the specific advice of the Expert Committee to advise on the Environmental Implact of Mathura Refinery, Indian Oil Corporation has taken various measures for effective control of pollution in the Mathura Refinery Project. Some of these measures and their financial implications are given below briefly.

(1) *Effluents to be discharged to the Atmosphere*

(1) *To lim't the sulpuhr dioxide emission to the atmosphere to one tonner per hour.*

	Rs. lakhs
(a) For this purpose all liquids fuels that will be burnt in the refinery furaances will be low sulphur fuels obtained either by processing Bombay High Crude or obtained from other refineries where indigenous crudes are processed, such as the Barauni Refinery and Gujarat Refinery. Additional tankage, pumps and provision for unloading low sulphur fuels will be provided as and when necessary. Approximate cost towards the above is . .	7
(b) All excess gas available from the refinery furnaces will be amine washed to remove H_2S to make it sulphur-free. For this purpose, apart from amine washing facilities, a sulphur recovery unit is also being provided. The total estimated cost towards this is of the order of	300
(c) Provision has been made for concrete stacks of 80 metres height instead of the normally used self-supporting steel stacks of 40 metres height for all the furnaces excepting for units where only sulphur-free gases are burnt. Approximate increase in cost on account of this is	8
(d) Provision has been kept for flue gas treatment facilities at a future date, if required. The additional cost for provision of extra ducting for future interconnection is approximately etc. (Cost of flue gas treatment plant not includded)	5

(2) *Particulate Matter*

	Rs. lakhs
(a) Provision of electro-static precipitators for particulate matters from the power plant is estimated to cost approximately . .	50
(b) Provision of cyclone separtoras for particulate matters from the FCC unit is estimated to cost	12

(B) *Effluents to be discharged to the Surface*

(1) *Effluent Water*

	Rs lakhs
(a) Cost of special measures such as provision of mechanical seals instead of conventional stuffing box type, hydraulic seals etc., in order tominimise oil spillage and consequent oil contamination	6
(b) Cost of sour water stripper system and surface condensors etc., to minimise contamination of water	36
(c) Special collection systems for ensuring that any water that is likely to be contaminated is separately collected and taken to the effluent treatment plant	25
(d) Effluent Treatment Plant (inclusive of chemical and bio-chemical treatment) so as to ensure that the treated effluent meets the specifications laid down by the Indian Standard Institution and the UP State Water Pollution (Prevention & Control) Board .	90
(e) Special channel and inspection road from the refinery for the discharge of treated effluent into the Yamuna river [Permission of the UP State Water Pollution (Prevention & Control) Board already obtain]. . .	55

(2) *Ash handling and Disposal Facilities*

(a) Cost of ash handling and disposal facilities including land for the same . . .	93

(C) *Cost of various studies undertaken at the instance of the Expert Committee* :

	Rs. lakhs	Rs. lakhs
Studies by :		
(a) IMD .	18	
(b) NEERI .	6	
(c) TECNECO	20	
(d) Misc. . .	5	49
(D) Cost of various special equipment and instruments for monitoring purposes . .		11
Total		748
SAY :		Rs. 8 crores
Total Project Cost .		195·31 crores

ANNEXURE VIII

REPORT ON

THE DISPERSAL OF POLLUTANTS FROM A REFINERY STACK

BY

P. K. DAS, R. K. DUTTA & B. M. CHHABRA

OF

INDIA METEOROLOGICAL DEPARTMENT

LODI ROAD, NEW DELHI-110 003

The Dispersal of Pollutants from a Refinery Stack

by

PK Das, RK Datta & BM Chhabra
Meteorological Office, New Delhi-3

ABSTRACT

There is proposal to establish a refinery near Mathura during the late Fifth Plan or early Sixth Plan. Mathura is about 40 KM from Agra, where one of the major tourist attraction in India - The Taj Mahal is located. The designers of refinery are, as a consequence, concerned about whether the quantum of sulphur dioxide released from the refinery stacks would damage the Taj Mahal.

To meet this requirement, we have computed the concentration of sulphur dioxide at different distances downstream from a refinery stack assuming Gaussian distribution of the pollutants. Delhi wind data have been used for the computations, the same have been discussed here. In particular, we present quantitative estimate of the impact of errors in vertical diffusion coefficients, the plume rise and meteorological data. A comparison has been made of concentration values obtained with a limited number of Agra winds with the estimates based on Delhi wind data. Computations have also been for the refinery in Madras, so that the model could be tested against field data in the vicinity of the Madras Refinery. We also show the use of power-law to define vertical wind profile. It reduces the concentration estimates without it by a factor of approximately ½.

THE DISPERSAL OF POLLUTANTS FROM A REFINERY STACK

by

PK Das, RK Dutta & BM Chhabra

Meteorological Office, Lodi Road, New Delhi-3

1. INTRODUCTION

It has been proposed to establish a refinery near Mathura during the late Fifth Plan or early Sixth Plan. Mathura is about 40 Km from Agra, where one of the major tourist attraction in India - The Taj Mahal - is located. The designers of the refinery are, as a consequence, concerned about whether the quantum of sulphur dioxide released from the refinery stacks would damage the Taj Mahal. Sulphur dioxide is a toxic gas which, in combination with water vapour in the atmosphere, produces sulphuric acid. The long term effect of this on marble, and other monuments, would be to corrode them. To have an idea of the possible quantum of pollutants and their effect on Taj Mahal some preliminary computations have been made. This is a preliminary report and here an attempt has been made to present computations of sulphur dioxide concentrations at different distances downstream from a refinery stack under different meteorological conditions. We have assumed that sulphur dioxide emanating from the stack spreads out in the form of a Gaussian plume. Earlier work of Sutton (1953) and Pasquill(1962) forms the basis of this study.

There are some uncertainties in our computations because of a number of variables used on which very little field data are available. The main uncertainties are on account of (a) empirical values of diffusion co-efficients, (b) the mechanics of plume rise, (c) empirical wind profiles in the lowest 100 m above the ground. Here an attempt has also been made to estimate the order of errors in the computations of sulphur dioxide concentrations due to these causes.

2. SYMBOLS

The following symbols not defined in the text have been used in this paper.

χ	:	Short period (1 hour) ground concentrations in $(\mu g/M^3)$
Q	:	Emission rate $(\mu g/sec)$
$\theta, \frac{\partial\theta}{\partial\theta}$	:	Potential temperature (^{o}k) and its vertical gradient (^{o}k/m);

T_s	:	Ambient air temperature;
S	:	Atmospheric stability $\left(\frac{g}{T_s}\ \frac{\partial\theta}{\partial Z}\right)$
U	:	Mean wind speed (m/sec);
g	:	Acceleration due to gravity (m sec^{-2}) ;
x,y	:	Distances down wind (x) and cross wind (y) from the stack;
z	:	Vertical distance from the ground;
H	.	Physical height of the stack (m);
Δh	:	Plume rise (m) ;
h	:	Effective stack height ($H + \Delta h$);
σ_y , σ_z	:	Standard deviations (m) of plume concentration along y and z.

3. <u>BASIC EQUATIONS</u>

The ground level concentrations from an elevated source are provided by the Gaussian distribution. The short term concentrations (1 hour) at the ground are,

$$\chi = \frac{Q}{\pi U \sigma_y \sigma_z} \exp\left[-\frac{1}{2}\left(\frac{y^2}{\sigma_y^2} + \frac{h^2}{\sigma_z^2}\right)\right] \qquad (3.1)$$

In this expression we assume that there is no diffusion downwind in the x direction. This is a reasonable assumption for large sampling periods.

To obtain 3 and 24 hour concentrations, the 1 hour values were multiplied by 0.84 and 0.59 respectively. These factors were obtained on empirical considerations. Turner (1970) suggested an expression of the form.

$$\chi_s = \chi_k \left(\frac{t_k}{t_s}\right)^p \qquad (3.2)$$

to relate the concentration for two different sampling periods. Thus, in (3.2) χ_s is the desired estimate for a period t_s while χ_k is the estimate for the shorter sampling period t_k

Considering

$$p \simeq 0.17$$

We find

$$\chi_3 = 0.83\,\chi_1$$
$$\chi_{24} = 0.58\,\chi_1$$

where the suffixes denote 1, 3 and 24 hour concentrations. The multiplicative factors are thus in good agreement with the empirical values used in our computations.

For seasonal or annual average concentrations, (3.1) is averaged over a circular region. When this is done, the cross wind components are eliminated (Pasquill, 1962). The average concentration is then expressed by

$$\chi = \left(\frac{2}{\pi}\right)^{1/2} \sum_{i=1}^{I} \sum_{j=1}^{J} \frac{f(U_i, S_j, \theta_k)}{U_i} \times \frac{\theta}{2\pi x/N} \times \frac{1}{\sigma_z} \times \exp -\frac{1}{2}\frac{h^2}{\sigma_z^2} \qquad (3.3)$$

From hourly observations of wind speed and direction, the wind record was divided into a number of categories. In (3.3) the suffixes i and j refer to wind speed and change in wind direction, while k refers to the mean wind direction and N is the total number of wind direction categories. The relative frequency of the ith wind speed, ~~i th direction~~ j th direction change and k th mean direction is represented by $f(U_i, S_j, \theta_k)$

The categorisation of 1 hour changes in wind direction is a measure of the turbulent structure of the atmosphere. The three classes that were used are

(i) $\Delta\theta > 45^\circ$

(ii) $22.5^\circ \leqslant \Delta\theta \leqslant 45^\circ$

(iii) $\Delta\theta < 22.5^\circ$

where $\Delta\theta$ is the change in wind direction between the current observation and the previous hour.

For wind speed ($m\ sec^{-1}$) three classes were used. The are :

(i) $U < 3\cdot0$

(ii) $3\cdot0 \leqslant U < 4\cdot2$

(iii) $4\cdot2 \leqslant U < 7\cdot0$

The classification for mean wind direction was for the eight points of the compass.

Relative frequencies were evaluated with the above scheme from Dines anemograph records of Delhi for four representative months. These are given in Appendix I.

To estimate the impact of uncertainties in input data on sulphur dioxide concentration, it is convenient to introduce the variable.

$$\Psi = \frac{\sigma_z}{h} \tag{3.4}$$

Whence we write (3 . 3) as

$$\chi = C \times \frac{G(\Psi)}{h} , \tag{3.5}$$

where

$$C = \left(\frac{2}{\pi}\right)^{1/2} \sum_{i=1}^{I} \sum_{j=1}^{J} \frac{f(\mu_i, S_j, \theta_k)}{\mu_i} \times \frac{Q}{2\pi x/N} \tag{3.6}$$

and

$$G(\Psi) = \frac{1}{\Psi} \exp\left(-\frac{1}{2\Psi^2}\right) \tag{3.7}$$

This enables us to consider, in turn, the impact of errors in (a) meteorological data and stack characteristics, and (b) in σ_z and h . Thus, it will be observed that the variable C is largely dependent on meteorological data and stack characteristics (Q) , while $G(\Psi)$ is a function of σ_z and h. If we assume that variations of h are small compared to those of C and G (Ψ), then we have from (3.5)

$$\frac{\Delta \chi}{\chi} = \frac{\Delta C}{C} + \frac{\Delta G(\Psi)}{G \Psi} \tag{3.8}$$

Values of G (Ψ) have been tabulated by Bohac, Derrick and Sosebee (1974) from which we can compute $\Delta G(\Psi)$ In the subsequent sections we shall present estimates of the two terms on the right hand of (3.8)

4. DISCUSSION OF ERRORS

4.1 Diffusion coefficients

A large number of meteorological and physical features influence σ_y and σ_z . The turbulent structure of the atmosphere, the height of the stack above the ground, surface roughness, sampling time, wind speed and downwind distances are the main factors which determine σ_y and σ_z . It is difficult to derive a single expression which will include the effect of all these factors. In general, a sampling time of 10 minutes is assumed, and a relatively open land is considered for this purpose. Here we have used McElroy's (1969) expressions for σ_y and σ_z . They were

$$\sigma_y = b\chi^p \tag{4.1}$$

$$\sigma_z = a\chi^k \tag{4.2}$$

where a, b, p and k are constants. The numerical value of these constants for three categories of atmospheric stability are given in Table 1.

TABLE - 1

Numerical values of a, b. p, k

	Stability	a	k	b	p
1.	Unstable	.00724	1.510	1.400	0.719
2.	Neutral	.11000	0.934	1.140	0.698
3.	Stable	.47800	0.655	0.945	0.648

Numerous studies of diffusion coefficients have been made in recent years. This is perhaps the most uncertain parameter in diffusion studies, because there is very little information on its value for large distances down wind from the stack. Turner (1970) tabulated values of σ_z for seven classes of atmospheric stability, and five categories of wind speed. These categories are shown in table 2.

TABLE - 2

Stabilities and wind speed categories (Turner, 1970)

Surface wind speed (at 10m) m sec $^{-1}$	Day: incoming solar radiation			Night	
	Strong	Moderate	Slight	Thinly Overcast or 4/8 low cloud	3/8 Cloud
2	A	A-B	B		
2 - 3	A-B	B	C	E	F
3 - 5	B	B-C	C	D	E
5 - 6	C	C-D	D	D	D
6	C	D	D	D	D

The correspondence with the classification used by us in this report is, approximately, as below :

	Mc Elory (1969)	Turner (1970)
(a)	Unstable	A, B
(b)	Neutral	C
(c)	Stable	D, E, F

Figure 1 shows a comparison between the values of McElory and Turner for σ_z. The lower values of σ_z for a very stable atmosphere are of interest, because they would tend to make our computations slightly over-estimate the sulphur dioxide concentration.

Very little is known about the accuracy of these values. Turner (1970) states : "In the stable and unstable cases several fold errors in the estimate of σ_z can occur for the longer travel distances. In some cases, σ_z may be expected to be correct within a factor of 2. These are : (i) all stabilities for a distance of travel out to a few hundred metres; (ii) unstable conditions in the lowest 1000 metres of atmosphere with a marked inversion above for distances out to 10 km or more."

In view of our lack of knowledge about the accuracy of σ_z we decided to use (4.2) to express σ_z, but with assumed errors in the coefficients a and k. Three possibilities have been explored.

(i) Treat a as correct, and alter k by $\pm$ 10, 15 and 20% ;

(ii) Treat k as correct, but alter a by $\pm$ 10, 15 and 20% ;

(iii) Alter both a and k by $\pm$ 10, 15 and 20%.

The resultant changes in concentration estimates are presented in the next section of this paper.

4.2 PLUME RISE

The effective stack height is the sum of the physical height of the stack and the plume rise. The latter is a function of (a) velocity of gases at the point of exit from stack ; (b) atmospheric stability and (c) The buoyancy of the effluent gases.

The rise on account of momentum has been neglected in our computations. This assumption is not likely to reduce the accuracy of our result beyond a downwind distance of a few stack heights (500 m) from the source of emission. For hot plumes, buovancy is by far the more dominant factor.

We expressed the effect of buovancy by a parameter F, which combined the physical characteristics of the stack with the temperature of the exhaust gas. F was related to the energy output from the stack by

$$F = \frac{g\,Q}{\pi C_p \rho T} \qquad (4.3)$$

where Q is The emission of heat in Cal/sec. C_p is the specific heat of air, ρ is the density and T is the environmental temperature. The heat emission (Q) is

$$Q = (\rho C_p T)_e \times QV \qquad (4.4)$$

where the suffix e denotes the density, specific heat and temperature of the exhaust gas and Q is the flow rate ($m^3\ sec^{-1}$) of the effluent.

Putting (4.4) in (4.3) we have

$$F = \left(\frac{g}{\pi C_p T \rho}\right) \times (\rho C_p T)_e \times QV ,$$

or $$F = 3.7 \times 10^{-5} \times (\rho C_p T)_e \times QV \qquad (4.5)$$

when the numerical values of C_p, ρ and T for dry air are inserted, F is expressed in (4.5) in units of $m^4\ sec^{-3}$. If we use the following representative values

$$QV = 1.7 \times 10^5\ m^3\ hr^{-1}$$
$$\rho_e = 1180\ \ gm/m^3$$
$$(C_p)_e = 0.2418\ cal.\ gm^{-1}\,{}^{o}k^{-1}\ \text{and}$$
$$T_e = 450\ {}^{o}k$$

we observe,

$$F = 224.3\ m^4\ sec^{-3}$$

There is not much scope for the changes in the numerical value of F, unless we consider moist environmental air or use different stack characteristics.

The buoyancy parameter is closely related to the plume rise. For short distances downwind, we have

$$\Delta h = 1.6 \times \frac{F^{1/3}}{U} \times x^{2/3} \qquad (4.6)$$

Briggs (1971) used 1.6 for the numerical value of the constant in (4.6), but some authors have used 1.32 (Perkins, 1974). In our computations we have used 1.6 for the constant; but the results are not likely to be substantially altered by using 1.32 instead of 1.6.

There is divergence of opinion about the plume rise at large (greater than 1 km) distances from the stack. In neutral and unstable equilibrium, it is generally agreed that the stability parameter (s) is no longer an important variable only F and U need be considered for large distances. In this report, we have used a formulation due to Briggs (1969) in which equation (4.6) is used upto a critical distance x1, but subsequently the downstream distances were weighted by a constant factor. The critical distance is approximately ten times the stack height. As we are mainly interested in estimating the heighest concentration of sulphur dioxide in the worst meteorological conditions, we will be hereafter concerned with only a stable atmosphere.

Under stable conditions, the plume rise for large distance is

$$\Delta h = 2.9 \left(\frac{F}{US}\right)^{1/3} \quad (4.7)$$

There is again divergence of opinion on the value of the numerical constant. A value of 2.3 instead of 2.9 is often preferred (Perkins, loc. cit), but the difference in sulphur dioxide concentrations on this account is not large.

But considerable differences from the present computations can arise if we consider a very stable atmosphere with little or no wind. Under these circumstances there will be no bending of the plume, it will rise to a certain height until the buoyancy force is completely dissipated by mixing with the environment. A relation developed by Morton, Taylor and Turner (1956) for such conditions is

$$\Delta h = 5.0 \frac{F^{1/4}}{S^{3/8}} \quad (4.8)$$

A comparison of the plume rise evaluated by (4.7) and (4.8) is presented below for a wind speed (U) of 3 m sec^{-1}.

TABLE - 3

COMPUTATIONS OF PLUME RISE (Δ h)

		Plume rise (m)	
$\frac{\partial \theta}{\partial z}$	$S \times 10^3$ (sec^{-2})	Briggs (1969)	Morton et al (1956)
.020	.68	115.2	298.7
.015	.51	126.7	332.8
.010	.34	145.1	387.4

The values obtained by (4.8) are greater by a factor of about 2.5. Thus (4.8) provides lower values of the concentration downstream from the stack.

It is not clear up to what distances equation (4.8) could be reasonably expected to hold; but in the next section we shall present a comparison with both the sets of plume rise data shown in Table 3.

4.3 Wind data

In this report, a mean value of the wind speed U has been used in equations (3.1) and (3.3). An improvement on this would be to use a time averaged wind speed at the stack height.

Unfortunately, this value can at best be estimated if we assume a vertical profile of wind speed. On using a power law, we have

$$u = u_0 \left(\frac{H}{Z_0}\right)^n \tag{4.9}$$

Where Uo is the wind speed measured at the anemometer level (Zo), usually 10 m above ground level. Opinions differ on the appropriate value of n, but n = 0.25 for unstable and n = 0.50 for stable conditions have been recommended (Perkins loc. cit). Numerical computations to assess the vertical variation of the wind speed are presented in the next section.

The computations in this study are based on the surface winds of Delhi which is 140 km away from the site of the proposed refinery site. Unfortunately, Dines anemographs of Agra were available to us for only one year. They were not of the same standard of reliability as Delhi. However, to compare our results with those of Agra, We used the one year Agra Data to compute the relative frequencies.

We also present in the next section concentration estimates with the wind data of Madras, where a refinery already exists. The object of these computations is to verify, at a future date, the concentrations computed for a Gaussian plume with actual field measurements. This could provide an idea of the validity, or otherwise of the present computations, although such a verification programme would be vitiated to some extent by the humid environment, and different wind regime of Madras.

5. NUMERICAL RESULTS:

5.1 Diffusion Coefficient

In Table 4 we present values of σ_z obtained by altering the constants (a, k) in McElroy's formulation.

TABLE - 4

Changes in constants (a, k)
Values of σ_z (m)

Distance (x) (Km)	McElroy (1969)	Variation in 'k' (%)			Variation in 'a' (%)			Variation in 'a'& 'k' (%)		
		10	15	20	10	15	20	10	15	20
0.5	28	42	52	63	31	32	34	46	59	76
1	44	69	87	109	49	51	53	76	100	131
5	127	221	292	386	139	146	152	243	336	464
10	199	364	493	666	219	229	239	401	566	799
20	314	600	830	1148	345	360	377	660	955	1378
30	409	804	1127	1579	450	471	491	884	1296	1895
40	494	989	1399	1980	544	568	593	1088	1609	2376
50	572	1162	1656	2360	629	658	686	1184	1904	2831

The table illustrates the sensitivity of σ_z to errors in a and k. As expected, the response to errors in k is much more predominant. A 20% positive error in k, for example, at 40 km downwind will cause a four-fold error in σ_z. Even a small error of 10% in k at 40 km will be reflected by a two-fold error in σ_z. At smaller distances from the stack the response to error in a and k is smaller, but by no means negligible. If we considered the errors to be negative, the value would be correspondingly reduced.

5.2 Plume rise

In table 3 we had presented the difference in plume rise arising out of the work of Briggs (1969) and Morton et al(1956). The values of Morton et al for no wind and stable conditions were greater by a factor of 2.5 than the values for a stable atmosphere with light winds.

But, as we have seen earlier, the errors in concentration are not measured by errors in σ_z, or h; but by errors in the ration σ_z/f_1 which is defined by ψ. As indicated by equation 3.5, we are mainly concerned with variations in $G(\psi)$.

In Appendix II we have tabulated values of $\frac{\Delta\psi}{\psi}$ and $\frac{\Delta G(\psi)}{G(\psi)}$. This is an extension of the earlier values of Bohac et al (loc. cit). The computations in Appendix II were made by centered differences. Thus

$$\left(\frac{\Delta\psi}{\psi}\right)_n = \frac{1}{2}\left[\frac{\psi_{n+1} - \psi_{n-1}}{\psi_n}\right]$$

with a similar expression for $\Delta G(\psi)/G(\psi)$

It will be noted from Appendix II that large errors in $G(\psi)$ could result from small errors in ψ, especially when small values of ψ are considered. Thus, for $\psi \rightarrow 0.5$, a 20% error in would cause a 56% error in $G(\psi)$. But, the interesting point is that for large values of ψ, the error in $G(\psi)$ is small. Thus, for $\psi > 1.0$, a 10% error in ψ would cause only 2-4% error in $G(\psi)$.

We had earlier observed that moderate errors in the coefficients a, k often change σ_z by a factor of 4. If, therefore, the effect of increasing σ_z is to raise the value of Ψ beyond the range $0 < \Psi < 1.0$, then the error in $G(\Psi)$ or our concentration values need not be large, But, if errors in a, k decrease

σ_z, so that $0 < \Psi < 0.5$, then there would be large errors in $G(\Psi)$ and the concentration estimates could be out by several orders of magnitude. The crucial point is, therefore, to determine the range of Ψ in which we are interested.

Unfortunately, it is difficult to determine this range with much precision, but we could attempt an estimate of the worst possible conditions. As we can see from Appendix II this will happen for the lowest values of Ψ_o. This implies a minimum value for σ_z and a maximum h.

Let us assume that 20% negative error in a, k reduces σ_z to, approximately, a fourth of its value 40 km downstream from the stack. From Table 4, we observe that this will make

$$\sigma_z \simeq 494/4 \simeq 124$$

We also assume an approximate stack height of 100 m. From Table 3, we then find that the largest values of effective stack height are,

$$h = 145.1 + 100 \simeq 245$$

and

$$h = 387.4 + 100 \simeq 487$$

depending on whether we consider the plume rise by Briggs or by Morton et al. This yields,

$$\Psi \simeq \frac{124}{245} \simeq 0.5$$

and

$$\Psi \simeq \frac{124}{487} \simeq 0.3$$

From Appendix II we find that for the above values of Ψ, the error in concentration estimates would be 56% if $\Psi = 0.5$, but 426% if $\Psi = 0.3$. There is no strong ground, however, to believe that the latter would invariably be the case, because Morton's formulation is only valid for every stable atmosphere with no wind. Such conditions cannot be expected to predominate.

On the other hand, if the 20% error in k was positive then σ_z would be increased four-fold and Ψ would exceed

1.0. Such an event would make our concentration estimates fairly good. From these simple computations, it appears to us reasonable to infer that on most occasions the concentration estimates would be reasonable, especially when $\psi \gg 1.0$ But, on a comparatively few number of occasions, when $\psi \ll 1.0$ the estimates could be out by 50-60% at a distance 40 km downstream from the stack.

5.3 Wind Data

(a) Power Law

As indicated in equation (4.9), a power law was used to determine the wind (U) at the level of the stack height. We were mainly concerned with ascertaining the effect for worst meteorological conditions. Consequently, we used $n = 0.50$ in (4.9) to represent stable conditions. The computations show that the use of the power law decreased the concentration values. The numerical value of the ratios.

(A) Concentration (40 km) downwind with power law + Concentration (40 km) without power law; and

(B) Peak concentration with power law + Peak Concentration without power law;

is fairly constant. A statistical analysis revealed very small variation of A and B from one season to another.

In table 5 we present the average values of A and B from two stack heights. These values were obtained using the wind data of Delhi.

TABLE - 5
Values of 'A' & 'B'

	Stack height (m)	A	B
1.	80	.36	.60
2.	60	.41	.70

Table 5 indicates that the concentration values without a power law should be multiplied by a factor of about 0.4 to obtained the concentration at 40 km and by a factor of about 0.65 to obtain the corresponding peak concentration. The use of a power law would thus diminish the concentration values by approximately a factor of ½ for stack heights between 60 and 80 m.

In figures 2 and 3 we have shown the short term concentration with and without the use of a power law. The values obtained with the power law are lower.

In Appendix 3 we have also presented values of the long term concentration with the help of a power law and without power law for a very stable atmosphere to simulate the worst meteorological conditions. The maximum peak concentration is 28.1 $\mu g/m^3$ at a distance of 2 km from a stack height of 40 m. This occurs with a power law for northwesterly winds in January. Without a power law the corresponding value is 37.1 μ If the stack height is raised to 80 m, the maximum peak concentration is reduced to 10.3 $\mu g/m^3$ for north-westerly winds in January.

The maximum concentration at a distance 40 km downstream is 1.3 $\mu g/m^3$ for northwesterly winds in January without a power law. If we use a power law however, the maximum concentration 40 km downwind is reduced to 0.6 $\mu g/m^3$ for a stack height of 40 m. For higher stack (80 m) this is reduced to 0.4 $\mu g/m^3$.

b AGRA WINDS

The study is mainly based on the wind data of Delhi which is 140 km away from the site of the refinery. Ideally wind data of Mathura should be used for the purpose of these computations. But, as such data were not available, the Delhi data were used. A few comparative checks were made between Delhi and Agra and wind data. Agra is nearer to Mathura than Delhi. These checks suggest that a large difference in the final results would not be caused by the use of Delhi winds.

It must be emphasized, however, that the quality of the data for Agra was not as reliable as that of Delhi and the records were available for only one year. In order to become more confident about the accuracy of our sulphur-dioxide estimates, an observatory has been established at the site of Mathura Refinery and another will be set up at Agra near the Taj Maha

C. MADRAS WIND DATA

As we had mentioned earlier, computations were made with the wind data of Madras. It was felt that these estimates of concentration could be checked, if necessary, against field observations. This would provide a check on the reliability of our model.

The following characteristics were assumed for the Madras Refinery :

Density of the exhaust gas	=	1180 gm/m^3
Specific heat	=	0.24 $cal/gm/^{o}k$
Temperature	=	$450^{o}k$
Q_v	=	$1.7 \times 10^5\ m^3\ hr^{-1}$
Emission rate (Q)	=	4000 kg hr^{-1}
Stack heights	=	25, 35 and 45 m.

The long term concentration values for the above three stack heights are given in Appendix IV. As it will be observed from the values in Appendix IV, the peak concentrations are observed in January and August at an approximate distance of 2 km from the stack. The values of the peak concentration are 122.8 and 97.4 $\mu g/m^3$ respectively for January and August. At a distance of 40 km downwind the concentration values are 3.9 and 3.5 $\mu g/m^3$ respectively for January and August. The prevailing wind is predominently northeasterly in January, while in August the winds are largely westerly. In the computations shown in Appendix IV, mean winds of Madras for a 5-year period (1968-72) were used. We did not use a power law for these computations. If a power law had been used, lower concentrations could be expected.

6. BACKGROUND AND PERMISSIBLE LEVELS OF SULPHUR DIOXIDE

6.1 The global background level of Sulphur-dioxide in the atmosphere varies from 2.6 to 5.2 $\mu g/m^3$. Thus, we can reasonably assume that the level of sulphur-dioxide already in the air in Agra would be of the order of 5 $\mu g/m^3$ or more due to local industries. NEERI is actually analysing the air samples to have realistic estimates of the present sulphur-dioxide at Agra. This background estimates of sulphur dioxide will have to be added to our estimates of sulphur-dioxide from Mathura Refinery to have the realistic estimates.

6.2 The prescribed standards for sulphur-dioxide in different countries express the concentration of this gas as averages over periods of time ranging from 1 hour to 1 year. In general, the tolerable concentration for 1 hour period could be fairly high, but when averaged over one year the level is substantially reduced.

6.3 Published literature on the subject suggested that:

a) Acute injury to vegetation (leaves, tree and shrubs) would be caused if the concentration exceeds 0.5 ppm (1320 $\mu g/m^3$) for a 1 hour period. The same type of damage could be caused if the annual (yearly) average level exceeds 0.01 ppm (26 $\mu g/m^3$).

b) There is risk of pulmonary diseases in human beings if the short-term (1 hour) concentration exceeds 0.4 ppm (1056 $\mu g/m^3$), or if the yearly average exceeds 26 $\mu g/m^3$. High concentrations for periods of short duration (1 hour) are possible very near a source of emission.

c) Corrosion of hard metals such as steel, sets in when the annual mean concentration is 0.02 ppm (52 $\mu g/m^3$). Very little information is available on the tolerable level for marble, or other types of building material. On empirical considerations, we may assume this to be atleast one-half the level for steel (i.e. 26 $\mu g/m^3$). But, we cannot be certain of this figure without a detailed chemical test on corrosion effects. This involves a study of surface films and requires sophisticated equipment.

6.4 To sum up, it appears reasonable at this stage to assume the following permissible levels of sulphur-dioxide.

	Concentration ($\mu g/m^3$)	
	1 hour (short term)	Annual (long term)
i) Vegetation	1320	26
ii) Human beings	1056	26
iii) Building material	-	26

7. SUMMARY AND CONCLUSIONS

It must be emphasized that the present study is handicapped by lack of field data under Indian conditions. We have used formulations for the diffusion coefficients, and the power law for wind profiles, which are used in extra-tropical latitudes. It is not clear how far these values would be applicable in India, without further field experiments. Despite this limitation, the main conclusions of the study may be summarised as follows :

(i) The vertical diffusion coefficient (σ_z) could be changed by a factor of 4 by 20% error in 'a', 'k' the coefficients used by McElroy (loc.cit) to express the dependence of σ_z on downwind distance.

(ii) If the ratio σ_z/h exceeds 1.0, then the error in concentration estimates, purely on account of errors in σ_z or h, would be small. On the other hand, for very small values of this ratio ($\leq$ 0.5), a small error in σ_z or h could create very large error in concentration values. An examination of typical values suggest that errors in σ_z, could generate an average error of about 50% in our estimates of concentration.

(iii) If the wind profile is expressed by a power law, then (a) the estimates of peak concentration, and (b) the concentration 40 km downwind would be reduced approximately by a factor of 1/2. Some doubt exists, however, on the appropriate value of the exponent to be used in the power law. A value of n = 0.5 was used in the present study. The use of this wind profile suggests a maximum long term concentration of 28.1 $\mu g/m^3$ in January at 2 km from the stack. At a distance 40 km. downwind, the maximum concentration is 0.44 in January for a 80 m stack.

(iv) More reliable Dines Anemograph data are needed at the site of the refinery to improve our calculations which are based on Delhi wind observations. To overcome this, a meteorological observatory has been established at the site of Mathura Refinery and another will be located near Taj Mahal at Agra.

(v) Long term concentrations of sulphur dioxide from the refinery in Madras have been computed and presented in Appendix IV. They could be used to test the results of this mathematical model.

(vi) The present computations assume a single source. An assessment of the effect of multiple stacks will improve the results.

(vii) To avoid acute injury to vegetation, the risk of pulmonary diseases in human beings and corrosion of building material, the permissible lavel of sulphur-dioxide would be approximately, 1000 $\mu g/m^3$ for short term (1 hour) and 10-20 $\mu g/m^3$ for long term (annual concentration).

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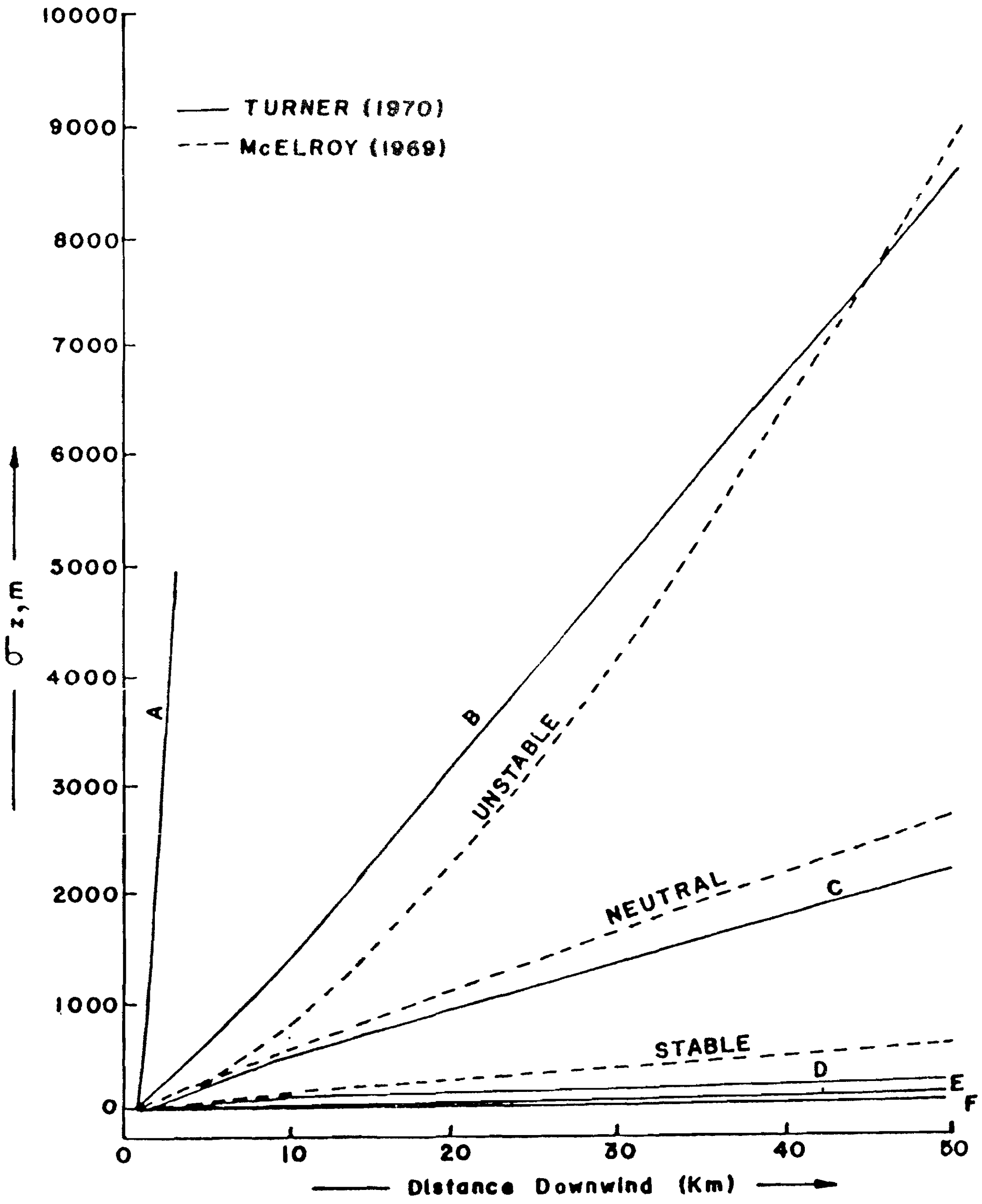

FIG. I VERTICAL DISPERSION COEFFICIENT AS A FUNCTION OF DOWNWIND DISTANCE FROM THE SOURCE.

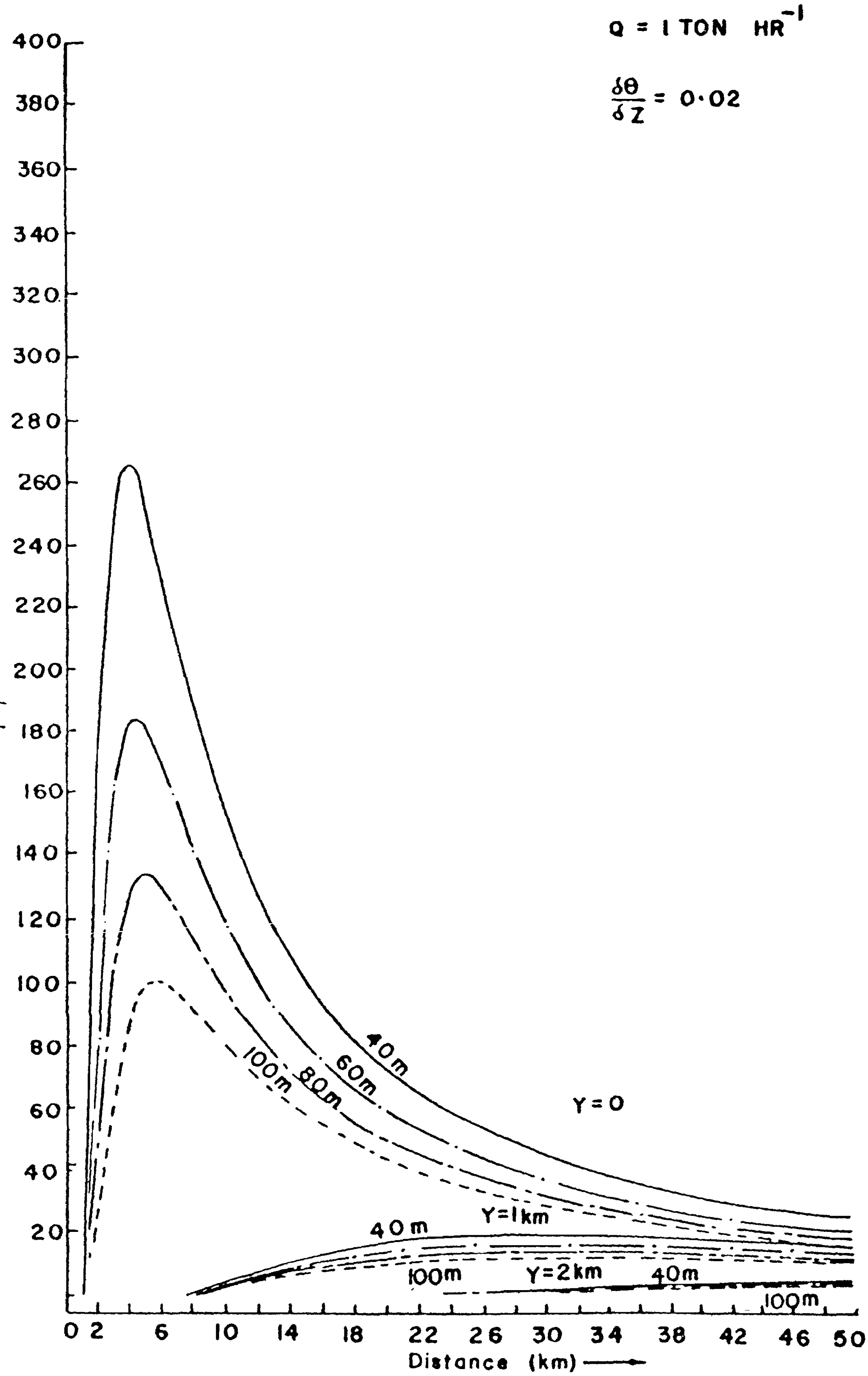

FIG.2 SHORT TERM CONCENTRATION OF SULPHUR DIOXIDE ($\mu g/m^3$) VERSUS DISTANCE FOR STACK HEIGHTS USING POWER LAW.

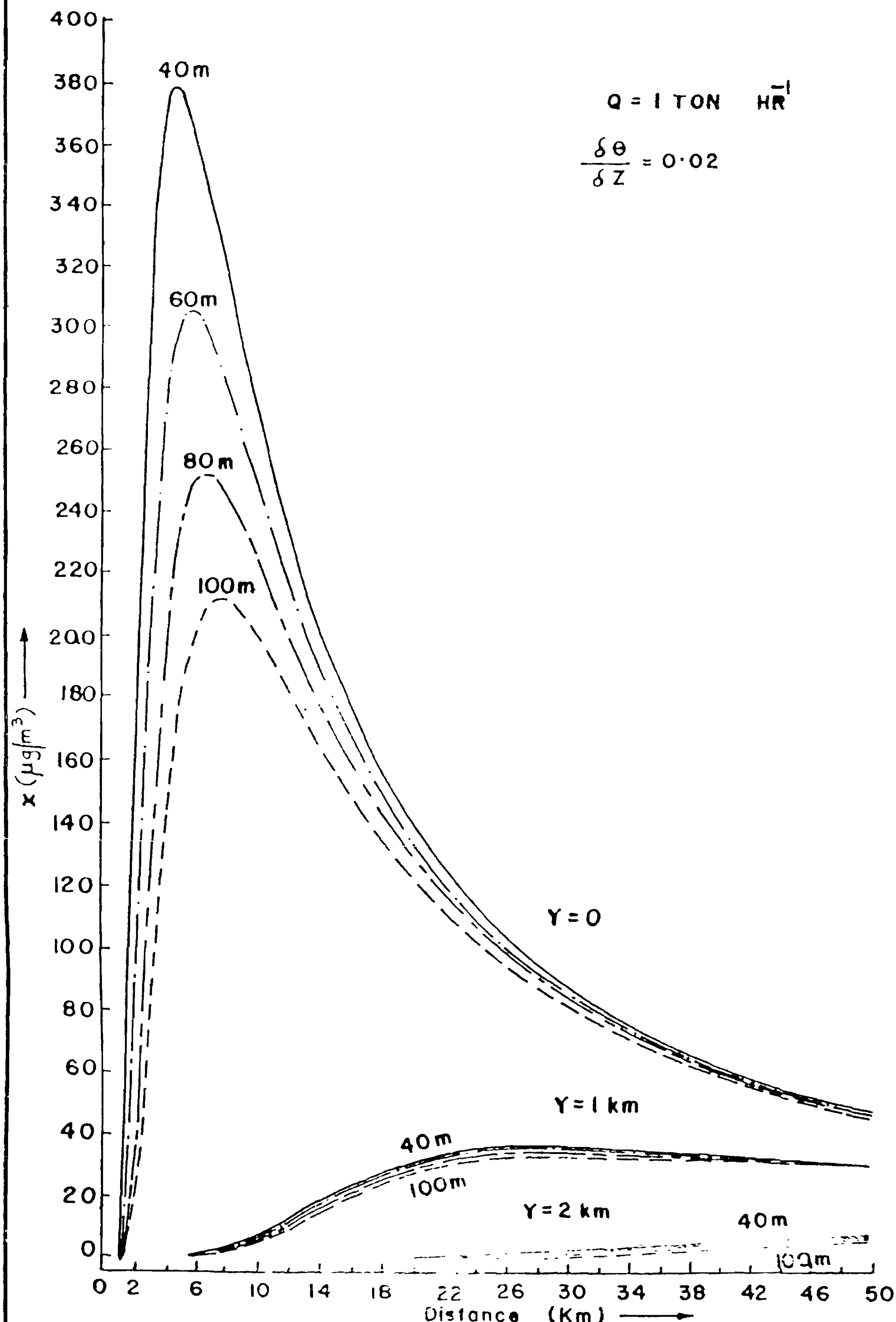

FIG. 3. SHORT TERM CONCENTRATION OF SULPHUR DIOXIDE ($\mu g\ m^{-3}$) VERSUS DISTANCE FOR STACK HEIGHTS WITHOUT POWER LAW.

APPENDIX - 1

TABLE - 1

Relative Frequencies, January
(x 10^3)

Wind Direction	Stability	U (m Sec^{-1}) 3.0	4.2	7.0
W	Unstable	9.4	0.3	0.3
	Neutral	21.5	3.0	2.2
	Stable	151.8	23.1	23.7
N	Unstable	12.1	0.3	0
	Neutral	4.8	0.3	0.3
	Stable	48.5	8.1	4.6
NE	Unstable	9.2	0	0
	Neutral	8.1	0.5	0.5
	Stable	23.7	1.1	1.1
NW	Unstable	7.3	0	0.3
	Neutral	22.6	2.4	1.3
	Stable	196.0	47.1	94.5
E	Unstable	9.7	0.5	0.8
	Neutral	7.5	0	1.1
	Stable	68.9	7.3	11.0
S	Unstable	9.4	0	0.3
	Neutral	3.0	0	0.3
	Stable	15.1	0.8	2.4
SE	Unstable	5.7	0.8	1.1
	Neutral	8.9	1.1	1.1
	Stable	44.7	8.9	8.3
SW	Unstable	13.5	0.3	1.1
	Neutral	5.9	0	0
	Stable	26.1	0.8	4.0

APPENDIX - I

TABLE - II

Relative Frequencies, March

(x 10^3)

Wind Direction	Stability	U (m Sec^{-1}) 3.0	4.2	7.0
W	Unstable	7.5	1.3	0.3
	Neutral	7.8	3.5	4.6
	Stable	78.1	25.6	19.4
N	Unstable	10.8	1.1	1.6
	Neutral	8.9	2.4	3.2
	Stable	77.3	22.1	50.1
NE	Unstable	9.4	0.5	0.8
	Neutral	8.1	0.8	0.3
	Stable	36.3	3.2	6.7
NW	Unstable	6.5	0.5	1.6
	Neutral	15.1	1.6	3.0
	Stable	132.7	70.8	164.2
E	Unstable	8.1	0.8	1.1
	Neutral	9.4	0.3	0.3
	Stable	53.0	4.3	16.2
S	Unstable	3.2	0	0.8
	Neutral	3.0	0.5	0.5
	Stable	11.0	1.1	6.5
SE	Unstable	5.7	0.5	0.5
	Neutral	3.2	0.3	0.5
	Stable	29.3	5.4	7.3
SW	Unstable	4.6	1.3	1.6
	Neutral	3.8	0.3	0.8
	Stable	18.0	4.0	4.8

APPENDIX - I

TABLE - III

Relative Frequencies, August

(x 10^3)

Wind Direction	Stability	U(m Sec^{-1}) 3.0	4.2	7.0
W	Unstable	2.4	0	0.3
	Neutral	4.3	1.1	1.1
	Stable	35.1	19.4	69.9
N	Unstable	7.0	0	0
	Neutral	2.7	0.3	0.5
	Stable	27.8	3.5	6.7
NE	Unstable	6.5	0.5	1.1
	Neutral	4.9	0	0.8
	Stable	45.9	5.9	5.7
NW	Unstable	11.1	0.3	1.3
	Neutral	5.7	0.8	0.5
	Stable	41.0	11.9	38.8
E	Unstable	8.6	0.5	1.1
	Neutral	10.0	1.3	1.9
	Stable	187.8	36.4	57.7
S	Unstable	8.6	0.5	1.1
	Neutral	7.3	0.3	0
	Stable	47.2	5.1	8.4
SE	Unstable	9.2	0.8	1.1
	Neutral	9.4	1.3	0.8
	Stable	96.0	4.5	25.6
SW	Unstable	8.4	1.6	0.5
	Neutral	5.4	0.3	0.3
	Stable	46.7	10.0	9.4

APPENDIX - I

TABLE - IV

Relative frequencies, October

(x 10^3)

Wind Direction	Stability	U (m Sec^{-1}) 3.0	4.2	7.0
W	Unstable	3.3	0	0
	Neutral	9.5	1.1	0.8
	Stable	92.8	15.5	24.4
N	Unstable	23.1	0.3	0.8
	Neutral	22.8	0.8	0.8
	Stable	85.5	6.5	11.1
NE	Unstable	19.8	0	0.3
	Neutral	14.4	0.5	0.8
	Stable	63.8	2.2	9.2
NW	Unstable	14.7	0.3	0.3
	Neutral	22.0	0.5	0
	Stable	112.3	22.3	36.1
E	Unstable	8.7	0	0.3
	Neutral	14.9	0	0.5
	Stable	114.0	4.9	3.0
S	Unstable	14.4	2.2	0.3
	Neutral	3.8	0.8	0.3
	Stable	29.3	4.9	3.0
SE	Unstable	8.7	0.5	0.5
	Neutral	10.0	0.8	0.3
	Stable	86.0	10.9	3.8
SW	Unstable	6.0	0.5	0.8
	Neutral	4.3	0.5	0.3
	Stable	37.2	3.5	1.6

APPENDIX - II

Values of $\Delta G(\Psi) / G(\Psi)$

1	2	3	4
	$G(\Psi)$	$\Delta\Psi/\Psi$	$\Delta G(\Psi) / G(\Psi)$
0.1	$.19287\times10^{-20}$	-	-
0.2	$.18633\times10^{-4}$	.50	345.79
0.3	$.12886\times10^{-1}$	.33	4.26
0.4	.10984	.25	1.17
0.5	.27067	.20	.56
0.6	.41559	.17	.29
0.7	.51493	.14	.15
0.8	.57229	.13	.07
0.9	.59934	.11	.03
1.0	.60653	.10	.00
1.1	.60138	.09	-.02
1.2	.58887	.08	-.02
1.3	.57223	.08	-0.03
1.4	.55346	.07	-.04
1.5	.53383	.07	-.04
1.6	.51411	.06	-.04
1.7	.49478	.06	-.04
1.8	.47611	.06	-.04
1.9	.45824	.05	-.04
2.0	.44125	.05	-.04
2.1	.42515	.05	-.04
2.2	.40993	.05	-.04
2.3	.39557	.04	-.04
2.4	.38202	.04	-.03

Appendix-II contd.

1	2	3	4
2.5	.36925	.04	-.03
2.6	.35719	.04	-.03
2.7	.34582	.04	-.03
2.8	.33508	.04	-.03
2.9	.32492	.04	-.03
3.0	.31532	.03	-.03
3.1	.30622	.03	-.03
3.2	.29761	.03	-.03
3.3	.28943	.03	-.03
3.4	.28167	.03	-.03
3.5	.27429	.03	-.03
3.6	.26727	.03	-.03
3.7	.26058	.03	-.03
3.8	.25420	.03	-.03
3.9	.24812	.03	-.02
4.0	.24231	.03	-.02
4.1	.23676	.02	-.02

APPENDIX - III : TABLE - 1 DELHI

LONG TERM CONCENTRATION 40 Km DOWN WIND ($\mu g/m^3$) USING POWER LAW

$Q = 1$ ton/hr $\frac{\partial \theta}{\partial z} = 0.02$

Month	Wind Direction	$\mu g/m^3$ 40 m	60 m	80 m	100 m	Month	Wind Direction	$\mu g/m^3$ 40 m	60 m	80 m	100 m
WINTER (JANUARY)	W	0.42	0.34	0.30	0.26	MONSOON (AUGUST)	W	0.18	0.16	0.14	0.12
	N	0.14	0.10	0.10	0.28		N	0.08	0.06	0.06	0.04
	NE	0.06	0.06	0.04	0.04		NE	0.12	0.10	0.08	0.08
	NW	0.64	0.52	C.44	0.40		NW	0.16	0.12	0.12	0.10
	E	0.18	0.16	0.14	0.12		E	0.56	0.46	0.38	0.34
	S	0.04	0.04	0.02	0.02		S	0.14	0.10	0.10	0.08
	SE	0.14	0.10	0.10	0.08		SE	0.03	0.24	0.20	0.18
	SW	0.06	0.06	0.04	0.04		SW	0.14	0.12	0.10	0.08
PRE-MONSOON (MARCH)	W	0.26	0.20	0.18	0.16	POST-MONSOON (OCTOBER)	W	0.26	0.22	0.18	0.16
	N	0.28	0.22	0.20	0.16		N	0.24	0.18	0.16	0.14
	NE	00.10	0.08	0.08	0.06		NE	0.16	0.14	0.12	00.10
	NW	0.60	0.48	0.42	0.36		NW	0.34	0.28	0.24	0.22
	E	0.16	0.12	0.10	0.10		E	0.28	0.24	0.20	0.18
	S	0.04	0.02	0.02	0.02		S	0.08	0.06	0.06	0.06
	SE	0.08	0.08	0.06	0.06		SE	0.22	0.18	0.16	0.14
	SW	0.06	0.04	0.04	0.04		SW	0.10	0.08	0.06	0.06

APPENDIX - III : TABLE - II

DELHI

Long Term Peak Concentration ($\mu g/m^3$) and corresponding distance in Km (in paranthesis) with a power law Q = 1 ton/hr. $\frac{\partial \theta}{\partial z}$ = 0.02

Month	Wind Dir.	$\mu g/m^3$ 40 m	60 m	80 m	100 m	Month	Wind Dir.	$\mu g/m^3$ 40 m	60 m	80 m	100 m
WINTER (JANUARY)	W	19.30 (2)	11.54 (7)	7706 (3)	4.78 (3)	MONSOON (AUGUST)	W	8.74 (2)	5.06 (2)	3.12 (3)	2.06 (3)
	N	6.08 (1)	3.70 (1)	2.48 (1)	1.82 (1)		N	3.61 (1)	2.20 (1)	1.43 (1)	1.08 (1)
	NE	5.78 (1)	3.78 (1)	2.58 (1)	1.80 (1)		NE	5.48 (2)	3.26 (2)	2.00 (3)	1.34 (3)
	NW	28.14 (2)	16.44 (2)	10.28 (3)	6,86 (3)		NW	7.54 (2)	4.50 (2)	2.78 (1)	1.96 (1)
	E	8.26 (2)	4.90 (2)	3.02 (3)	2.04 (3)		E	22.86 (2)	13.08 (2)	8.46 (3)	5.54 (3)
	S	3.46 (1)	2.36 (1)	1.72 (1)	1.32 (1)		S	6.34 (1)	3.86 (1)	2.50 (1)	1.74 ((1)
	SE	7.00 (1)	4.18 (1)	2.60 (1)	1.70 (1)		SE	12.82 (2)	7.52 (2)	4.70 (3)	3.14 (3)
	SW	5.70 (1)	3.84 (1)	2.74 (1)	2.06 (1)		SW	6.18 (2)	3.68 (2)	2.24 (3)	1.62 (1)
PRE-MONSOON (MARCH)	W	11.32 (2)	6.74 (2)	4.12 (3)	2.78 (3)	POST-MONSOON (OCTOBER)	W	11.62 (2)	6.78 (2)	4.28 (3)	2.86 (3)
	N	12.66 (2)	7.52 (2)	4.56 (3)	3.06 (3)		N	16.38 (1)	10.42 (1)	5.14 (2)	4.76 (1)
	NE	6.58 (1)	4.16 (1)	2.76 (1)	1.94 (1)		NE	11.62 (1)	7.46 (1)	5.04 (1)	3.58 (1)
	NW	27.08 (2)	15.68 (2)	9.76 (3)	6.46 (3)		NW	16.48 (2)	9.98 (2)	6.16 (2)	4.08 (3)
	E	7.46 (1)	4.50 (1)	2.86 (1)	1.92 (1)		E	12.38 (2)	7.38 (2)	4.58 (3)	3.10 (3)
	S	2.58 (1)	1.64 (1)	1.08 (1)	0.74 (1)		S	5.82 (1)	3.88 (1)	2.80 (1)	2.16 (1)
	SE	3.90 (2)	2.34 (2)	1.42 (3)	1.04 (1)		SE	9.90 (2)	5.88 (2)	3.64 (3)	2.46 (3)
	DE	3.62 (1)	2.30 (1)	1.54 (1)	1.10 (1)		SW	4.40 (1)	2.62 (1)	1.70 (1)	1.20 (1)

DELHI

APPENDIX - III : TABLE - III

Long Term Concentration 40 Km downwind ($\mu g/m^3$) without using POWER Power Law $Q = 1$ ton/hr $\frac{\partial \theta}{\partial z} = 0.02$

Month	Wind Dir.	$\mu g/m^3$ 40 m	60 m	80 m	100 m	Month	Wind Dir.	$\mu g/m^3$ 40 m	60 m	80 m	100 m
WINTER (JANUARY)	W	0.86	0.84	0.82	0.82	MONSOON (AUGUST)	W	0.38	0.36	0.36	0.36
	N	0.26	0.26	0.26	0.26		N	0.16	0.16	0.16	0.14
	NE	0.12	0.12	0.12	0.12		NE	0.24	0.24	0.24	0.24
	NW	1.26	1.26	1.24	1.22		NW	0.32	0.30	0.30	0.30
	E	0.36	0.36	0.36	0.36		E	1.10	1.10	1.03	1.06
	S	0.08	0.08	0.08	0.08		S	0.26	0.26	0.26	0.24
	SE	0.26	0.26	0.26	0.26		SE	0.58	0.58	0.58	0.56
	SW	0.14	0.14	0.14	0.14		SW	0.28	0.26	0.26	0.26
PRE-MONSOON (MARCH)	W	0.50	0.48	0.48	0.48	POST-MONSOON (OCTOBER)	W	0.53	0.54	0.52	0.52
	N	0.54	0.54	0.52	0.52		N	0.46	0.46	0.46	0.44
	NE	00.20	0.20	0.20	0.20		NE	0.34	0.34	0.32	0.32
	NW	1.18	1.18	1.16	1.14		NW	0.68	0.68	0.66	0.66
	E	0.30	0.30	0.30	0.28		E	0.56	0.56	0.54	0.54
	S	0.08	0.08	0.06	0.06		S	0.16	0.16	0.16	0.16
	SE	1.18	0.16	0.16	0.16		SE	0.46	0.46	0.44	0.44
	SW	0.12	0.12	0.10	0.10		SW	0.18	0.18	0.18	0.18

APPENDIX -III : TABLE - IV

Long Term Peak Concentration ($\mu g/m^3$) and corresponding distance in Km (in paranthesis) without using power law. Q = 1 ton/hr. $\frac{\delta\sigma}{\delta z}$ = 0.02

Month	Wind Dir.	$\mu g/m^3$ 40 m	60 m	80 m	100 m	Month	Wing Dir.	$\mu g/m^3$ 40 m	60 m	80 m	100 m
WINTER (JANUARY)	W	25.04 (2)	18.04 (3)	12.94 (4)	9.96 (4)	MONSOON (AUGUST)	W	12.04 (2)	8.32 (3)	5.90 (3)	4.48 (4)
	N	7.90 (2)	5.54 (3)	3.98 (3)	3.12 (1)		N	4.78 (2)	3.34 (3)	2.40 (3)	1.80 (1)
	NE	5.00 (2)	3.52 (2)	2.76 (1)	2.38 (1)		NE	7.22 (2)	5.14 (3)	3.70 (4)	2.82 (4)
	NW	37.14 (2)	26.66 (3)	19.14 (4)	14.58 (4)		NW	10.36 (2)	7.06 (3)	5.10 (4)	3.84 (4)
	E	10.86 (2)	7.74 (3)	5.56 (4)	4.24 (4)		E	30.38 (2)	21.94 (3)	15.92 (4)	11.96 (4)
	S	3.80 (1)	3.88 (1)	2.68 (1)	2.40 (1)		S	8.06 (2)	5.64 (3)	4.08 (3)	3.10 (4)
	SE	8.60 (2)	5.96 (3)	4.36 (3)	3.30 (4)		SE	16.94 (2)	12.12 (3)	8.72 (4)	6.64 (4)
	SW	5.74 (1)	4.58 (1)	3.98 (1)	3.56 (1)		SW	8.20 (2)	5.78 (3)	4.14 (3)	3.16 (4)
PRE-MONSOON (MARCH)	W	15.22 (2)	10.68 (3)	7.66 (3)	5.84 (4)	POST-MONSOON (OCTOBER)	W	15.18 (2)	11.02 (3)	7.96 (4)	6.04 (4)
	N	17.20 (2)	11.92 (3)	8.56 (3)	6.50 (4)		N	16.58 (2)	11.22 (3)	8.40 (3)	6.26 (4)
	NE	7.00 (2)	4.74 (3)	3.52 (3)	2.66 (1)		NE	11.82 (2)	7.98 (3)	5.96 (3)	4.42 (4)
	NW	36.74 (2)	25.82 (3)	18.36 (4)	13.98 (4)		NW	21.76 (2)	15.28 (3)	11.06 (3)	8.40 (4)
	E	9.62 (2)	6.70 (3)	4.86 (3)	3.68 (3)		E	15.94 (2)	11.58 (3)	8.36 (4)	6.40 (4)
	S	7.72 (2)	1.86 (2)	1.34 (3)	1.00 (1)		S	5.68 (2)	5.32 (1)	4.62 (1)	4.12 (1)
	SE	5.22 (2)	3.66 (3)	2.62 (3)	2.00 (4)		SE	12.88 (2)	9.28 (3)	6.70 (4)	5.12 (4)
	SW	3.92 (2)	2.62 (3)	2.02 (1)	11.74 (1)		SW	5.70 (2)	4.02 (3)	2.90 (3)	2.22 (4)

APPENDIX - IV : TABLE - I

MADRAS

Long-term (Peak) Concentration ($\mu g/m^3$) and corresponding distance in Km (in paranthesis)

$\frac{\partial \theta}{\partial z} = 0.02$, $Q = 4$ tons/hr.

Month	Wind Dir	$\mu g/m^3$ 25 m	35 m	45 m	Month	Wind Dir.	$\mu g/m^3$ 25 m	35 m	45 m
WINTER (JANUARY)	W	5.9 (2)	4.8 (2)	4.1 (1)	MONSOON (AUGUST)	W	152.5 (2)	122.7 (2)	97.4 (2)
	N	108.1 (2)	87.1 (2)	69.2 (2)		N	8.4 (1)	7.2 (1)	6.2 (1)
	NE	191.5 (2)	154.7 (2)	122.8 (2)		NE	20.0 (1)	9.8 (1)	8.8 (1)
	NW	33.9 (2)	27.4 (2)	21.9 (2)		NW	25.5 (1)	19.9 (1)	15.9 (1)
	E	97.1 (2)	77.8 (2)	61.4 (2)		E	18.2 (1)	15.4 (1)	13.3 (1)
	S	21.1 (2)	17.2 (2)	13.8 (2)		S	125.9 (2)	102.9 (2)	82.1 (2)
	SE	41.6 (2)	33.0 (2)	27.0 (3)		SE	41.6 (2)	33.9 (2)	27.3 (2)
	SW	5.3 (2)	4.3 (2)	3.4 (2)		SW	142.5 (2)	114.6 (2)	90.9 (2)
PRE-MONSOON (MARCH)	W	42.4 (2)	34.8 (2)	28.4 (2)	POST-MONSOON (OCTOBER)	W	70.4 (2)	56.7 (2)	45.4 (3)
	N	19.3 (2)	15.7 (2)	12.6 (2)		N	60.6 (2)	49.5 (2)	40.0 (2)
	NE	32.1 (2)	25.9 (2)	20.5 (2)		NE	94.1 (2)	76.7 (2)	61.5 (2)
	NW	25.5 (2)	20.9 (2)	17.0 (2)		NW	74.5 (2)	60.2 (2)	48.1 (2)
	E	56.0 (2)	44.4 (2)	34.5 (2)		E	48.4 (2)	39.1 (2)	31.3 (2)
	S	133.7 (2)	108.4 (2)	86.4 (2)		S	54.6 (2)	44.4 (2)	35.7 (2)
	SE	100.4 (2)	80.6 (2)	63.6 (2)		SE	53.6 (2)	43.8 (2)	35.4 (2)
	SW	94.6 (2)	77.2 (2)	60.2 (2)		SW	68.1 (2)	55.4 (2)	24.6 (2)

MADRAS

APPENDIX - IV TABLE - II

LONG TERM CONCENTRATION ($\mu g/m^3$) AT 40 Km DOWN WIND

$\frac{\partial \sigma}{\partial z} = 0.02$ Q = 4 tons/hr

Month	Wind Dir.	$\mu g/m^3$ 25 m	35 m	45 m	Month	Wind Dir	$\mu g/m^3$ 25 m	35 m	45 m
WINTER (JANUARY)	W	0.15	0.15	0.15	MONSOON (AUGUST)	W	3.50	3.48	3.46
	N	2.44	2.43	2.42		N	0.09	0.09	0.09
	NE	3.89	3.88	3.86		NE	1.10	0.10	0.10
	NW	0.82	0.82	0.82		NW	0.39	0.39	0.38
	E	2.24	2.23	2.22		E	0.19	0.19	0.19
	S	0.42	0.42	0.41		S	2.56	2.55	2.54
	SE	1.06	1.06	1.05		SE	0.92	0.92	0.91
	SW	0.12	0.12	0.12		SW	3.29	3.27	3.25
PRE-MONSOON (MARCH)	W	0.93	0.93	0.92	POST-MONSOON (OCTOBER)	W	1.70	1.69	1.68
	N	0.43	0.42	0.42		N	1.27	1.26	1.26
	NE	0.68	0.68	0.68		NE	1.88	1.87	1.86
	NW	0.58	0.57	0.57		NW	1.74	1.73	1.72
	E	1.41	1.41	1.40		E	1.12	1.11	1.11
	S	2.68	2.66	2.65		S	1.15	1.14	1.13
	SE	2.24	2.23	2.22		SE	1.12	1.12	1.11
	SW	1.87	1.86	1.85		SW	1.49	1.48	1.47

ANNEXURE IX

SUMMARY OF THE FIRST AND SECOND REPORT ON THE STUDIES FOR THE PRESERVATION OF MONUMENTS FROM MATHURA REFINERY AIR POLLUTION MADE BY M/s. TECNECO

Messrs Tecneco of Italy were entrusted by IOC to undertake studies for:

(1) Determination of typical meteorological conditions in the Mathura-Agra region and calculation of long term ground level concentrations of effluents (particularly SO_2) at Agra on account of emission from the Mathura Refinery.

(2) Determination of the existing level of pollutants in the Agra zone.

(3) The present status of preservation of monuments and studies for determining permissible concentration of effluents from the point of view of preservation of monuments.

M/s. Tecneco have submitted the 'First & Second Report' covering the studies at (i) above. A brief summary of this report is given hereinafter.

The Report is based on the following data given by IOC:

(1) Direction and wind speed at all times of the day from 1965 to 1974.

(2) Maximum and minimum temp. and humidity.

(3) Degree of cloudiness and global solar radiation.

(4) Radiosonde data of New Delhi for the period 1965—1974.

(5) Average monthly rainfall in mm for last 10 years.

(6) Map showing zone Agra, Mathura and location of Refinery and monuments

(7) Emission data for each chimney for each operating conditions and height and diameter of chimney.

Based on the studies using the above data, the Report covers the following aspects:

The month with highest speed is June and lowest is November. The frequency of 36 km/hr speed is highest in the month of June (1.2%).

Wind Steadiness

Only for West-North-West direction the wind steadiness data at New Delhi have been studied. Steadiness more than six hours occurs only for wind speed more than 28 km/hr. The most frequent wind speed is 4 km/hr for the steadiness of 2 hours.

Atmospheric Stability (Based on cloudiness, solar radiation and wind data)

The frequency of unstable and stable conditions is higher compared to that of neutral conditions. In Winter and Post-Monsoon period strongly stable conditions are more frequent while in Pre-Monsoon and monsoon periods unstable conditions are more frequent.

Joint Steadiness of wind speed

Highest value of frequency is for steadiness till 2 hours only.

Ground level Concentration of SO_2 Discharged by Refinery

Dispersion Model used to calculate the short term ground level concentration of SO_2 is Gaussian Plume Model. SO2 concentration from each single source are considered additive. SO_2 is considered chemically and physically inert i.e. physical and chemical removal processes of SO_2 are not considered. The model assumes stationary meteorological conditions with respect to wind speer, direction and atmospheric stability.

Meteorological Conditions used for calculating short term SO_2 Concentrations.

(i) Wind Direction . . .	Mathura to Agra within West-North West Sector.
(ii) Wind Speed . . .	6 to 36 km/hr.
(iii) Air Temperature . . .	34·5°C (Corresponding to maximum value of average monthly temperature at Agra.

Assumptions Made

(i) Flat Terrain.

(ii) Wind Speed less than 6 km/hr is excluded (The distance of 40 km from Agra to Refinery implies that wind speed below 6 km/hr will not effect monuments and it requires several hours to reach the monument zones. As per data, available from 1965 to 1974).

(iii) Meteorological parameters measured at New Delhi are representative of Mathura and Agra.

(iv) **Vertical profiles of winds and temperature are assumed constant for short term calculations.**

(v) Wind steadiness: (Which of course is not very true).

Short Term Concentration of SO_2

Short term concentrations between refinery and Agra as well as near the monuments have been calculated for various meteorological conditions. A summary of the frequency of these values is given below:

Frequency of short term ground level concentrations of SO_2

Concentration of SO_2 micro-grams/M^3	Around Taj		Between Refinery & Agra	
	Monsoon	Post Monsoon	Monsoon	Post Monsoon
Undefined	14.88	26.13	14.88	26.13
100	83.75	72.84	79.25	66.49
100	1.37	1.03	5.87	7.38
TOTAL	100.00	100.00	100.00	100.00

It should be noted that according to Tecneco, based on their experience, calculated short term value of SO_2 concentrations are about 10 to 25 times higher than actual measured ones. This is essentially due to the assumption that wind speeds and directions will remain unchanged for long periods whereas in actual practice steadiness of wind even in stable conditions is limited to 2 hours in the Mathura case.

Long term Ground level Concentrations of SO_2

Calculations have been done to obtain daily and seasonal average concentrations. These are given in the following tables:

Maximum daily average Lon Term Ground level Concentration of SO_2

NEAR TAJ MAHAL

Month	Maximum daily average Micro-grams/M^3
Jan.	6·75
Feb.	3·80
Mar.	5·90
Apr.	2·50
May	3·50
June	2·25
Jul.	1·00
Aug.	0·80
Sept.	2.00
Oct.	2·25
Nov.	5·75
Dec...	7·00

Seasonal Long term ground level Concentrations of SO_2

Season	Near Taj Micro-grams/M^3	Maximum Concentration Micro-grams/M^3	Distance from the Refinery (KM) at which max. concentration occurs
Premonsoon	1·5	2·5	20
Monsoon	0·5	6	2
Post Monsoon	2	6	1·5
Winter	3	7	1·5

ANNEXURE X

RESULTS OF IMD STUDY ON DISPERSAL OF POLLUTANTS FROM THE REFINERY USING METEOROLOGICAL DATA COLLECTED AT THE MATHURA OBSERVATORY

TABLE 1

Short-term concentration (1-hour) at ground for emission rate of (1 tonne/hr.) from Mathura

Month	Maximum value of the short-term concentration in $\mu g/m^3$* Agra	Bharatpur
January	47·2	47·2
February	65·2	62·9
March	65·3	65·2
April	65·2	5·6
May	65·2	42·7
June	65·2	65·0
July	65·1	65·0
August	65·2	65·2
September	65·2	46·8
October	65·1	53·1
November	65·2	62·9
December	47·3	11·1

NOTE : *$\mu g/M^3$ -Micrograms of Sulphur-dioxide per cubic metre.

TABLE 2(a)

Long-term concentration (Mg/m^3) at ground for emission rate of (1 tonne/hr.) from Mathura

Month	Agra	Bharatpur
January	0·7	0·3
February	0·8	0·4
March	..	..
April	..	..
May	0·7	0·07
June	0·2	0·04
July	1·4	0·07
August	0·1	0·20
September	—	—
October	0·6	0·08
November	1·2	0·30
December	1·5	0·20

TABLE 2 (b)

Long-term concentration (Mg/m^3) at ground for emission rate of (1 tonne/hr.) from Mathura.

Season	Agra	Bharatpur
Winter	1·0	0·30
Summer	0·7	0·07
Monsoon	0·6	0·10
Post-Monsoon	0·9	0·20

TABLE 3

Percentage frequency for wind direction towards Agra and Bharatpur

Month	Agra	Bharatpur
January	14	2
February	28	3
March	13	4
April	6	0
May	23	4
June	19	6
July	10	4
August	3	7
September	3	4
October	13	1
November	8	1
December	16	1

TABLE 4

Percentage frequency for the atmosphere to be stable towards Agra and Bharatpur

Month	Agra	Bharatpur
January	3	0
February	4	1
March	3	1
April	1	0
May	2	0
June	2	0
July	1	1
August	0	1
September	1	1
October	2	0
November	2	0
December	2	0

ANNEXURE XI

SUMMARY OF THE THIRD AND FINAL REPORT MADE BY M/s. TECNECO ON THE STUDIES FOR THE PRESERVATION OF MONUMENTS IN AGRA FROM MATHURA REFINERY AIR POLLUTION

1. *Introduction*

1.1 M/s. Tecneco of Italy were entrusted by IOC to undertake studies for:

(a) Determination of typical meteorological conditions in the Mathura-Agra region and calculation of long-term ground level concentrations of effluents (particularly SO_2) at Agra on account of emission from the Mathura Refinery.

(b) Determination of the existing level of pollutants in the Agra Zone.

(c) The present status of preservation of monuments and studies for determining permissible concentration of effluents from the point of view of preservation of monuments.

1.2 M/s. Tecneco had already submitted their First and Second Report covering the studies at (a) above. Summary of these two reports were circulated to Members on 30-12-76. Their third and final report covering the studies (b) and (c) above has also been received.

1.3 M/s. Tecneco's third report includes following Chapters:

(i) Introduction.

(ii) Collection of samples: Criteria and Methods.

(iii) Petrographic, Chemical and Physical Analyses.

(iv) Biological Analyses.

(v) Discussion of the results of the Chemical, Physical and Biological Analyses.

(vi) Determination of Meteorological Parameters and Air Quality in the Monument Zone.

(vii) Conclusions.

(viii) Appendix I—Glossary of Biological Terms.

(ix) Appendix II—Deterioration of Stone Monuments: Chemicals, Physical, Mechanical and Biological causes: Effects of Atmospheric Pollution.

(x) Bibliography.

1.4 The report also gives various Tables, Drawings, Figures and Photographs as per the details given below:

Chapter	Tables	Drawings	Figures	Photos
2	2	3	..	4
3	12	2	8	103
4	10	..	..	9
6	29	17	..	..
9	3	..	..	..

2. *Summary of the Report*

2.1 *Present Status of Preservation of Monuments*

Chapter 1 of the report gives a brief introduction of the work carried out by M/s. Tecneco. This third and final report completes the studies carried out by M/s. Tecneco for the preservation of monuments in Agra from Mathura Refinery Air-Pollution. To carry out the studies M/s. Tecneco had secured the help of Scientists and Specialists from some of the Research Organisations in Italy and particularly Institute Centrale del Restauro in Rome. This is probably the first time that such types of studies are carried out and as such no previous reference was available to correlate concentration of pollutants and the degree of degradation of the stone monuments. The studies, therefore, were carried out using the basic knowledge available.

2.2 *Collection of Samples* (Chapter 2 of the Report)

2.2.1 In order to establish the present status of preservation of the monuments, M/s. Tecneco had collected stone and dust samples from the monuments. Two on the site inspections were made to select the monuments to be examined in Agra Zone and to decide upon the samples required to be taken from each of the selected monuments. The first examination was made at the end of 1974 and the second in January 1976 just before the collection of the samples. As substantial uniformity was observed in Agra monuments, both from the point of view of quality of the building material and that of the state of conservation of the surface of the material, it was decided to limit the study to the three monuments namely, Taj Mahal, Agra Fort and Akbar Tomb.

2.2.2 Basically these monuments are constructed of only two types of stones, white marble coming from Makrana quarry and red sand stone coming from Tantpur and Paharpur quarries. During the inspections the following forms of alterations* were noticed:

For Marble

(i) More or less abundant deposit of yellow grey dust on the surface where rain cannot reach the stone. This dust can be easily removed by a brush.

(ii) A thin black hard layer or small black spots covering some projecting parts mostly on the north side, near the floor and on the upper parts where rain can easily reach.

*In Tecneco's Report the term 'alteration' is intended to cover changes that have occurred in the material due to factors such as aging, corrosion etc.

(iii) Some cracks on the slabs along the greyish veins, from where a visible algae growth is penetrating inside.

For Sandstone

(i) A heavy exfoliation of stone along the sedimentation planes.

(ii) In some places a white efflorescence is present on the detaching layers.

(iii) In some places large and black entrusted layers cover the surfaces.

(iv) In some places insects and weeds are present.

2.2.3 *Mode of collection of samples.*—Samples were collected to study in more details the following forms of alterations:—

— Earth dust (present on marble)
— Black spots (present on marble)
— Black spots (present on sand stone)
— White efflorescence (present on sand stone)

Samples were taken using sterile scalpel (spots and efflorescence) and with a sterile brush (dust). The material collected from every type of alteration from each monument was put in a sterile tube, closed with a rubber stopper wrapped in a sheet of aluminium and kept in a refrigerator (about 4°C) upto the time they were transported to Rome in portable refrigerated cases. The collection of samples was done during the period from 6th to 16th Jan, 1976. Some pieces of marble and sand stone detached from the three monuments during the previous maintenance work were given by the Archaeological Survey of India to be analysed and compared with the corresponding quarry stones.

2.3 *Petrographic, Chemical and Physical Analyses carried out on the Samples*

To establish the actual state of conservation of monuments two types of studies were made on the samples collected. One was of chemical and physical nature and the other of biological. Chapter 3 of the report discusses the studies carried out with Petrographic, Chemical and Physical Analyses—following methods were used:

2.3.1 *Petrographic Study.*—This was done to determine the lethe types and their characteristics. Phenomena of aging and of alterations in the building materials depend not only on external conditions but on their mineralogical composition and internal structure. For this reason microscopic and mineralogical microscopic observations were carried out on thin sections of the samples. Macroscopic observations were not possible for many of the monument samples because of their small sizes. The report discusses the observations made and also gives some photographs showing texture of the stones. (Summary of the findings is given in paras 2.5.1, 2.5.2 & 2.5.3).

2.3.2 *Porosimetric Characteristic.*—A knowledge of the Porosimetrical characteristics of the stone material, i.e. the volume of the Pores and their distribution in relation to the section, is important for classifying the stone according to its internal structure. The mechanical properties and the durability of the material depend upon the pore structure. A knowledge of the structural modification caused to lapideous material as a result of aging is also a help in the study of the causes of alteration and their mechanism. The measurement of the absorption of water is carried out to have an indication of the capacity of the stone to absorb water.

The Report gives details on the techniques and methods used for carrying out these studies. The results obtained are given in tabular forms and also in graphical forms. (Summary of the findings is given in paras 2.5.1, 2.5.2 and 2.5.3).

2.3.3 Superficial strata of the stone were subjected to the following tests for investigating the presence of soluble salts and mechanism of their action:

(a) X-ray diffraction: This technique helped in furnishing additional information on mineral constituents.

(b) Chemical analyses—qualitative and quantitative.

(c) Morphological examination by electronic scanning microscope, metallographic and mineralogic microscopes.

The Report discusses in detail the various observations made and also describes the techniques and methods employed for the analyses. (Summary of the findings is given in paras 2.5.1, 2.5.2 & 2.5.3).

2.4 *Biological Analyses*: (Chapter 4 of the Report)

2.4.1 The biological research was guided by the following objectives:

(a) A direct survey of the biological profile of each monument.

(b) The study of specific biological deteriorations.

(c) An indirect evaluation of the state of conservation by determination of the microbic charge of all types of alterations.

The objective (a) was carried out in situ with the verification of generic alterations and the presence or absence of alterations of biological origin.

The objective (b), which was carried out with laboratory tests, includes the survey of specific phenomena of bio-deterioration, their recognition, their morphological classification and the characterisation of the dominant biological agent.

For the third objective (c) using specific liquid and solid cultures, isolation was effected in the laboratory of those microbic groups which are considered on account of their metabolic characteristics, to play a part in the alteration of monuments. The report gives details of each of the tests and discusses the findings. (Summary of the findings is given under para 2.5.4).

2.5 *Findings of the hemical, Physical & Biological analyses*: (Chapter 5 of the Report)

2.5.1 The different types of analyses carried out on the samples from monuments and quarries showed considerable agreement. Materials used in these monuments are same and state of conservation is comparable. From the quantitative difference of soluble salts in the marble samples it can be presumed that there is slightly more attack at Agra Fort than that at Taj Mahal. Attack on Akbar's Tomb can be considered as the least.

2.5.2 *Observation on Marble.*—Marble is essentially constituted of calcite and dolomite. It is structurally compact and unaltered. It is quite resistant to climatic factors of aging as it is not porous and has low absorption of water. The superficial layers were analysed by X-ray diffraction, chemically, by electronic microscopy, and by X-ray microprobes. It was evident that major cause of alteration is biological as the presence of soluble salts was found to be extremely low. Among the soluble salts found, percentage of sulphates and chlorides were largo. In some samples from the zones where rain water does not reach, presence of some gypsum was observed. Accumulation of gypsum presents danger for good conservation. Dust samples collected from the marble showed presence of soluble salts. This also presents potential danger.

2.5.3 *Observation on sand Stone.*—Sand Stone used in the monuments is basically of one type only. It is essentially constituted of quartz and alkaline feldspar. The layer structure is such that flaking takes place according to the planes parallel to that of sedimentation. Flaking is a major form of alteration. The quarry stones have porosity comparable with that of other stones of similar type but absorb more water. This may be the reason for lesser resistance of the material to the atmospheric agents. Structural variations due to process of aging are (a) decrease in porosity and (b) increase in pores of smaller diameters. This is normally due to formation of clay materials as confirmed by diffractometric analyses. On external surfaces where black patina is present, alteration is mainly due to biological action and corrosion is limited to the surface. In this zone soluble salts are practically absent except for sulphates which are present in near about same amount, as observed in stone samples with white efflorescence. On samples with white efflorescence the degradation of superficial structure is due to presence of soluble salts, mainly chlorides and nitrates of sodium and potasium. Biological alteration is practically absent.

2.5.4 *Biological Investigations.*—Even though these investigations were limited to only one set of samples of stones and that too limited to as obtainable during one season, they furnished interesting information.

2.5.4.1 *Black Spots.*—Monuments examined were in a similar and sufficiently uniform state of conservation from a microbiological point of view. Both types of stones were similarly altered by black spots. This type of alteration is attributed to multiplication of microscopic algae which are also accompanied by decomposing micro-organisms or at least using their organic and inorganic remains (sulphur bacteria-predominantly oxidising type, ammonifying and heterotrophic bacteria, fungi and actinomy cetes). Algae responsible for black spots (both on marble and sand stone) are generally blue green algae i.e. cynophiceae. This indicates the presence of humidity, a little mould and of saline nutrients (bird excrement). Since this type of algae have pigments such as phycobilin, they can survive even in low light conditions. This explains their presence in all the cardinal points and also in zones in shadow. The major portion of the algae determined is of covering and corrosive type because of action of their constituents like exalic and muramic acids. Some forms (e.g.) cocoals can cause dis-integration and perforations on the stone. Other forms (chroococcus, cloocapsa lyngbya) are able to fix atmospheric nitrogen to produce nitrogen compounds, these compounds are used by nitro bacteria thus causing further corrosion attack. This type of attack, however, is not noticed at this stage.

It was observed that cyanophyceae algae was present in great number. Sulphur bacteria was present in very small number, less than patelogic, heterotrophic and ammonifying bacteria, actinomycetes and microscopic fungi. All these were present in small amount indicating their development is in stages due to the algae.

2.5.4.2 *White Efflorescence, on Sand Stone.*—White efflorescence, which causes accumulation of salts and is quite damaging to stone, has a microbic charge consisting of nitrosifying, ammonifying, sulphur-oxidising heterotrophic bacteria and fungi. These are however present in very insignificant amount. This much amount is normally found in every surface exposed to air.

2.5.4.3 *Earth dust from marble.*—Reddish grey or brown or yellowish dust recovered from the surface of marble, contained not only salts but also a number of micro-organisms both heterotrophic bacteria, actinomycetes, fungi and chemiosynthetic autotrophic (sulphur oxidising and reducing). The origin can be attributed from the surrounding earth.

2.6 *Air quality in monument zone and Meteorological Parameters* (Chapter 6 of the Report)

2.6.1 For determining the existing level of pollutants in the Agra Zone M/s. Tecneco had installed some instruments in Agra. One continuous Analyser for SO2 was installed near Taj Mahal and one sampler giving 24 hours average SO_2 Concentration was located at the same place. Continuous SO2 Analyser was installed for determining the maximum values while sampler was installed to have a reliable daily average values. It has been found that for most part of the survey graphs, the values were very near to zero. From continuous analyser readings, hourly average readings and daily average readings were computed. Hourly average readings were related with wind speed & direction results. Hourly concentrations have been higher than 150 micrograms/M^3 for 4 times and higher than 200 micrograms/M^3 for 2 times only. All these situations occur during calm conditions when wind velocities are low Daily average concentration results are less than 60 micrograms/M^3. The daily average concentration vary invariably and do not form any particular pattern.

2.6.2 M/s Tecneco had positioned some huts at different locations in the monuments. Filters treated with K_2CO_3 were suspended in these huts for the measurement of acidic compounds in the atmosphere.

After exposing these filters to a period of about 2 weeks they were regularly sent to Italy for further analyses.

K_2CO_3 filters exposed to Agra atmosphere were tested for sulphur, nitrates and chlorides. The chlorides were found negligible. Average values for sulphur and nitrates for 3 monuments are as under:

	Milli-grams of NO_3/cm^2 day	Milli-grams of 'S'/cm^2 day
Agra Fort	0·039	0·17
Taj Mahal	0·028	0·12
Akbar's Tomb . . .	0·027	0·06

The average figures given above for Sulphur compounds can generally be related to Sulphur-dioxide as it is the major pollutant normally present in the atmosphere.

2.6.3 *Meteorological Parameters*

(i) *Air Temperature inside & outside monuments.*—Values measured outside Taj & outside Akbar's Tomb are similar. Area covered thus shows homogenity as regards air temperature.

Outside temperature variations over a day range above $10^{\circ}C$ and at some points of the order of 20—22·C. Maximum value was observed in the beginning of June i.e. $43^{\circ}C$. Minimum value was observed in Jan. i.e. $5^{\circ}C$.

(ii) *Surface temperature of monuments.*—In order to estimate the possibility of condensation phenomenon, the surface temperature of the stones and temperature of air at 1/2 meter distance from stone were measured. The dew point was calculated considering humidity records.

Only in 0.38 per cent of cases examined condensing conditions were present. These conditions occured more frequently at Taj.

(iii) *Wind Speed and Direction.*—The continuous measurement of wind speed and direction was carried out at Taj. These readings were converted to obtain the hourly average speeds and direction from which the frequency of each direction and speed was calculated.

There is considerable agreement between Delhi results (as reported in Reports 1 & 2) and Agra results for the months of Jan., Feb., & March.

For the months April, May, June & July the Wind data for Delhi and Agra differ. The difference is difficult to explain.

The lowest level of wind speed at Agra as recorded is 2 k.m./hr. and at Delhi it is 1 k.m./hr. This is attributed to the difference in the sensitivity of the instruments.

7 *Conclusions*

Chapter 7 of the Report giving conclusions is reproduced hereunder.

CONCLUSIONS

As a reference parameter of the state of atmospheric pollution in the Agra Zone, the concentration of SO_2 in the atmosphere has been taken into consideration. This is above all because SO_2 is the atmospheric pollutant emitted by the Mathura Refinery in the highest concentration and which can reach Agra, even if the levels of concentrations result very low on the basis of the theoretical calculations carried out in "First and Second Report". The surveys of this parameter, carried out at the Taj Mahal from January to July 1976, led to the conclusion that the Agra zone has a very low index of atmospheric pollution.

In fact the daily level of concentration of SO_2 measured is usually only a few micrograms/m^3. Only on some days does it reach values of 10—20 micrograms/m^3 and in very exceptional cases higher values (60 micrograms/m^3).

During the whole period, there is a total average of about 6 micrograms/m^3).

The primary standards of the Environmental Protection Agency U.S.A. for the quality of the air concerning sulphur oxides (sulphur dioxide) are:

— 80 micrograms/m^3 as an annual average
— 365 micrograms/m^3 as an average over 24 hours not to be exceeded more than once in a year.

Various nations in Europe have established as a target a maximum monthly concentration of 150 micrograms/m^3 and a maximum annual concentration of 100 micrograms/m^3.

The World Health Organisation recommends as a target, for SO_2 and suspended particulates measured in conjunction:

— SO_2 annual average 60 micrograms/m^3 98 per cent of observation below 200 micrograms/m^3.
— *Suspended particulates* annual average 40 micrograms/m^3; 98 per cent of observation below 120 micrograms/m^3.

Over the last years, average annual levels of SO_2 have been observed as follow:

	(micrograms/m^3)
Copenhagen	60
Stockholm	70
Amsterdam	80
Liege	130
Brussels	170
Paris	110
London, city	250
London, greater	150
Milan	600
Venice, industrial area	130
Venice, city	70
New York—Manhattan	110
New York—Richmond	50
Los Angeles	70
Toronto, city	170
Toronto, residential	30

With monthly average included among some tens of micrograms/m^3 and:

Copenhagen	120
Stockholm	130
Amsterdam	130
Liege	250
Brussels	300
Paris	250
London, city	400
Milan	1400
Venice, city	150
Venice, industrial area	200
New York—Manhattan	130
New York—Richmond	70

(see bibliography).

SO_2 has been taken as a parameter to evaluate the increase in atmospheric pollution in the Agra zone caused by the Mathura Refinery. This is because, as has been previously pointed out, SO_2 is the alone polluting substance emitted by the refinery which can reach Agra and even if it does, only in very small concentrations.

The concentrations of SO emitted by the refinery which can reach Agra have been estimated using a mathematical model of Gaussian type, taking into consideration the anemological data of New Delhi relative to the ten-years period 1965—1974 and the emission characteristics supplied by the Indian Oil Corporation.

In consideration of the great distance between Mathura and Agra, the calculated values should be considered even more valid the longer the period to which they refer. This means that the most valid are the annual averages less valid the seasonal averages and even less significative the short term averages.

The average annual theoretical concentrations of SO, in Agra caused by the Mathura Refinery result as being very much reduced; *i.e.* 1.5—2 micrograms/m^3: analogously, the seasonal averages, which go from 0.5—1 micrograms/m^3 (monsoon period) to 3 micrograms/m^3 (winter). Therefore, it can be affirmed that the atmospheric pollution caused by the refinery does not constitute, except for very improbable high levels of concentrations due to exceptionally bad meteorological conditions, a modifying element of the atmospheric situation of Agra because of its extremely low levels of concentration which it could add to the already existing low levels. Petrographic and mineralogical analyses, X-Ray diffractometry, chemical analyses, micro-scopic analyses with X-rays, morphological examinations with optical and electronic scanning microscopes and biological analyses were carried out on samples of marble and sandstone taken from Agra Fort, Akbar's Tomb, the Taj Mahal and from the quarries and on dust samples taken from the three monuments so as to be able to define their state of conservation. On the basis of the results obtained, the following can be affirmed:

MARBLE On the basis of the results obtained, it can be affirmed that the state of conservation of the marble is still good. The optical microscopic and electronic scanning micro-scopic examinations as well as the biological analyses reveal that the prevailing form of alteration is due to the superficial corrosion by algae, which for the most part of the cases is not deeper than some tons of microns on the material.

On the other hand, in the earth dust samples and in the TM filter (put at a few tons of meters from the ground) the presence of chlorides, sulphates and nitrates was found.

The chemical and diffractometric analyses show the presence of insignificant quantities of soluble salts and the porosimetric measurements show that in the worst case, the internal structure of the material compared to marble from the quarry has only an initial alteration. In the marble smaples taken from near those in which dust samples were taken, these salts were in lesser quantities than in the dust and such as not yet to have caused any remarkable alteration. However, it is evident that their presence represents a potential danger for the good conservation of the marble.

SANDSTONE the sandstone doesn't appear in a good condition mainly because the nature of the material (chemical-mineralogical composition, structure and porosity).

Over and above the alterations of biological origin, mainly due to the algae which have an analogous action as that already explained on the marble, there is also peeling and scaling due to the strata structure of the stone.

This caling forms the most obvious and common alteration. The variation in porosity of the stone of the monuments, compared to the quarry stone, shows a more obvious aging phenomenon than in the case of marble. Some areas of the sandstone present serious forms of alterations caused by the presence of white efflorescence formed by soluble salts (mainly chlorides and nitrates) the origin of which can be connected with atmospheric pollution phenomena. The presence of these soluble salts induce, in the porous structure of the stone, a series of phenomena connected with processes as dissolution—crystallisation and hydration—dehydration which cause considerable degradation, taking in account the structure and texture of the stone.

The determination of the surface tempratures of the monuments together with the air temperatures and relative humidity has demonstrated that, at least during the period being considered, the probability that condensation phenomena on the stones occur is rather small.

This situation means that the attack of atmospheric SO_2 on the stones is more difficult.

On the other hand, it should be considered that the deterioration phenomena are not linear but exponential.

This means that the more a stone is altered, the more it will be sensitive to the action of any alteration agent.

From this point of view, the bad conservation of sandstone makes this stone more sensitive to the action of any degradation agent including atmospheric pollution.

Another consideration concerns the accumulation phenomena consisting in the fact that eventual chemical attacks on a stone, even if low in absolute values, induce an irreversible modification on the stone itself which is added to the others, even if slight, which preceded it and which will follow.

However, it is evident that, if such modifications are slight in absolute values, they become secondary compared to those more important induced by other alteration agents.

Excluding some fragments of stone taken from substitutions carried out during maintenance work, all the other marble and sandstone samples were taken from the surface of the various deteriorated zones of the three monuments.

As far as the marble is concerned, on the whole the alterations are limited to only a few zones.

On the contrary, the alterations of the sandstone are present nearly everywhere.

Therefore, in conclusion, the marble results as being well conserved in all three monuments and its state of aging can be considered initial while the sandstone is generally in a bad condition.

Since the concentration levels of pollutants taken into consideration are very low, it can be taken for granted that the atmospheric pollution actually present in the Agra zone does not constitute a prevailing cause of alteration such as to notably increase the natural aging of the stone.

The levels of SO_2 concentrations in the Agra Zone due to the refinery (from 1.5 to 2 micrograms/m^3 as an annual average) form an objective increase of present levels; however the concentration levels at Agra Zone, increasing from 6 micrograms/m^3 to 7.5—8 micrograms/m^3 as an annual average will remain as very low absolute values*.

For this reason, although keeping in mind the precious considerations on the state of conservation of the stones and on the accumulation effect, it can be considered that the foreseen pollution levels will not form one of the main causes of deterioration of the monuments. It is necessary to remember that the annual increase of SO_2 of 1.5—2 micrograms/m^3 is the result of theoretical calculations which, although carried out with due care, have necessarily large margins of uncertainty connected to the schematization taken for the meteorological parameters.

As already referred in our comments on page 15 of our First and Second Report it should be noted that in their calculations SO_2 is considered chemically and physically inert. This means that physical or chemical removal processes of SO_2 are not taken into consideration. This assumption does not affect very much the short term concentrations whilo overestimates the long term concentrations.

The model assumes a stationary meteorological condition, that is speed and direction of wind and atmospheric stability are considered constant during the transport of pollutants.

2.8 *Glossary of Biological Terms*

Appendix—I gives Glossary of Principal Biological terms used.

2.9 *Deterioration of Stone Monuments*

In Appendix—II. M/s. Tecneco have described in detail the various aspects of the deterioration of stone monuments and the factors, causing the deterioration, such as chemical, physical, mechanical and biological and also the effects of atmospheric pollution based on available published literature.

2.10 *Bibliography*

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*) Note:

It was already said in chap. 6, the value 6 micrograms/m^3 really represent the average during the 6 months of measurement, from 12th July, 1976. But we can sonsider that the annual average concentration would not be higher than 6 micrograms/m^3 because during the other 6 months, in which the measurements were not made, there are three months affected by monsoons.

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ANNEXURE XII

BHARATPUR BIRD SANCTUARY CORRESPONDENCE EXCHANGE

COPY OF:

LETTERS FROM MEMBER-SECRETARY No. MRG/6/6 DATED 18TH APRIL '77 AND 12TH JUNE '77 TO MESSRS NATURE CONSERVANCY COUNCIL, THE ROYAL SOCIETY FOR PROTECTION OF BIRDS AND THE WILD FOWL TRUST, ALL OF U.K.

As you are perhaps aware, construction work on a large oil refinery of a capacity of processing six million metric tons of crude per annum has commenced at a place near Mathura, which is situated at about 150 KM South East of New Delhi. The refinery will have the normal process units, storage tanks, despatch facilities and would also include a power plant. It is expected to be commissioned by early 1980.

As a measure of limiting emission of pollutants from the refinery, a decision has been taken to use only low sulphur fuels so that the total emission of sulphur dioxide from the refinery would not be more than one tonne per hour. This was primarily from point of view of conservation of monuments such as the Taj Mahal and the Agra Fort.

Subsequent to the decision to locate the refinery at Mathura some apprehensions have been raised about its possible adverse effects on the Bird Sanctuary situated at Bharatpur, approximately 30 KM south west of the refinery. This Sanctuary used to be the famed duck shooting preserve of the rulers of the former State of Bharatpur. It consists of a natural depression, sparesely covered with medium sized trees and shrubs It is one of the best breeding places of water birds. They assemble in large numbers during the month of July and August and breeding takes place until October, when the young birds are usually big enough to fly away. Prominent among these birds are the open-bill, painted stork, spoonbill and grey heron, egrets, darter or snake-bird and white ibis.

We understand that you have considerable data on the effects of plants such as the refinery on birds. We would, therefore, like to have your guidance on the steps to be taken to assess the effect of the Mathura Refinery on birds and the measures to be taken to ensure that there would be no adverse effect. We shall be grateful for your advice on the line of action that we could take for this purpose.

Should you desire for further details we can furnish the same after hearing from you.

Thanking you in anticipation of an early reply.

COPY OF:

REPLY RECEIVED FROM MESSRS THE ROYAL SOCIETY FOR THE PROTECTION OF BIRDS DATED 20TH MAY, 1977.

I am replying to your letter of 18th April seeking information about the effects of refineries on birds. It is difficult to comment with absolute confidence without more detailed information but it appears likely that the effect of the refinery on the birds will not be significant.

As the refinery is located some 30 kms. from the sanctuary we assume that there is no likelihood of effects arising from disturbance or from disposal of effluents into water courses and the only potential impact would arise from sulphur dioxide emissions and these are not known to effect birds. However, some plants are susceptible and there could, as a result, be a change in vegetation with consequent effects on the birds' food supply and habitat. This seems unlikely but if you wish to pursue it further, I would recommend that you contact Dr. Humphery Bowen of the Department of Chemistry at the University of Reading, Berkshire, England. I imagine that he would need to know the main plant species involved before being able to comment.

If after further consultation you feel that it is possible that there would be an effect from the refinery, it would be desirable to set up a biological monitoring programme so that once it is in operation any serious changes can be identified, correctly attributed to their cause and appropriate remedial action taken. This might involve undertaking seasonal counts of selected bird species and relating their natural fluctuations on their overall population levels, but it is more likely that the programme would be based on monitoring changes in the numbers and distribution of lower organisms or plants within the sanctuary area.

I am sorry that our advice cannot be more precise, but this is impossible without more detailed information; I hope that it will be of some help.

COPY OF:

LETTER RECEIVED FROM MESSRS NATURE CONSERVANCY COUNCIL DATED 24TH JUNE, 1977

I apologise for the delay in replying to your letter of 18th April but the problem of the possible effects pollution from the proposed Mathura Oil Refinery the Bharatpur Bird Sanctuary has necessitated sultation with advisers both within and outside organisation. The problem is best considered er several headings as follows:

phur

t is pleasing to learn of the decision to limit emis-s ot pollutants from the projected refinery by g only low sulphur fuels to conserve the Taj al and the Agra Fort. With reference to the ratpur Sanctuary and nature conservation inte-in general some plants, notably lichens, are very eptible to injurious effects of gaseous sulphur. vever, a case can be made out for sulphur as a efit to water birds. Sulphur dioxide emissions an acidic sulphur contribution to the environ-t but when neutralized act as a significant ferti-r. This tends to increase the protein content of tic and emergent plants as well as increasing kton and bottom invertebrate levels in what rwise might be relatively infertile waters. Pro-g this process is not overdone, and so lead to enrichment, the presence of some additional ur would not seem to be deleterious to the ratpur Sanctuary. The relationship between r-fowl density and sulphur abudance is illustra-by reference to the situation at the Canadian d of Ontario. In general only a sparse water population is supported but there are two areas e Shield, downwind from the smelters at Sudbury Wawa, that support populations of duck that comparable to high breeding duck densities else-A similar situation of benefit to water birds at Lake Myvatn in Iceland which has sulphur springs and geysers.

Pollutants

er pollutants will occur either as gaseous emis-or are water borne. There will be a substan-mission of hydro-carbons, phenols and other ns but although their pollution effect should not a problem it is dependent on local factors at nt unknown to me. These possible influential nknown factors will include:—

(a) The physical geography of the area including the effect of shadow of hills and prevailing wind. From this type of information it should be possible to construct isobars of expected pollution fall-out at ground level.

(b) Information on processing, such as the fields of origin of oil and therefore the type of crude being processed and its wax content, together with the height of the stack releasing the gaseous emission, would be further relevant factors in the matter.

(c) If the process was water-cooled rather than air-cooled the source of water obtained for the process, and in particular its release, would again be matters for attention. The effluent quality would be a problem if its release contaminated waters feeding the Bharatpur Sanctuary. It is certain that accidents will occur through human error or plant failure and any consequential pollution of water courses will undoubtedly cause concern.

Controls

I need hardly say that adherence of the strictest code of conduct, control and supervision in all activities aimed at keeping gaseous emission, only waste and general pollution down to a minimum will be the best safeguards.

Summary

From the evidence available to me it is thought unlikely that the Bharatpur Sanctuary will be at risk from the proposed refinery. The possible addition of sulphur may in fact be advantageous to the birds. The main danger is likely to arise from accident and in particular from pollution of the water sources of the Sanctuary.

I am sending under separate cover three booklets which may be of general interest to you. They are Pollution Research and the Research Councils (1977), Combustion—General Pollution (1976) and Effects of Airborne Sulphur Compounds on Forests and Freshwater (1976).

If there is any further help or information you may need please do not hesitate to contact me.

I am copying this letter and enclosures to the Scientific Counsellor to the Indian High Commission, London, and the letter to the London office of International Tanker Owners Pollution Federation Ltd. who have both been in touch with us on the matter.

COPY OF:

REPLY RECEIVED FROM MESSRS THE WILD FOWL TRUST DT. 30TH JUNE '77

Thank you for your letter of 13th June seeking advice regarding the likely effect of emission of sulphur dioxide from the Mathura Refinery on the Bird Sanctuary at Bharatpur.

We have already been consulted by our Nature Conservancy Council on this question and we have passed all the relevant data we have to them. I have checked that the NCC have recently despatched their reply to you and therefore I will not seek to duplicate it.

May I say how impressed we are with the environmental concern shown by your Corporation. If you feel there are any further points on which we can assist, when you have examined the NCC reply, do not hesitate to let us know.

COPY OF LETTER NO. MRG/6/6 DT. 12TH SEPT. '77 FROM MEMBER-SECRETARY TO DR. SALIM ALI, PRESIDENT, BOMBAY NATURAL HISTORY SOCIETY, BOMBAY

Permit me to draw your kind attention to the discussion with Dr. S. Varadarajan, Chairman of the Expert Committee on Environmental Impact of Mathura Refinery, during your visit to Delhi on 11th August. During this discussions you had kindly agreed to give us details of some of the bird sanctuaries abroad and the organisations responsible for their maintenance so that we could get in touch with them and find out about the precautions being taken for preservation of the sanctuaries. We had also requested you to give us an introductory letter to the officer in charge of the Bharatpur Sanctuary so that we could contact him and obtain various details of the sanctuary. May I request you kindly to furnish us this information at your earliest convenience?

I would also take this opportunity to express our sincere thanks for the keen interest you have shown in our activities.

Trusting that this will find you in good health and with kind regards.

P.S: I am sending herewith a brief note on the clarifications/information that was brought out during your discussion with the Chairman in respect of the anti-pollution measures that are being taken at Mathura Refinery, which, I trust, you will find useful.

Encl: As above.

COPY OF ANNEXURE:—

CLARIFICATONS/INFORMATION BROUGHT OUT DURING THE DISCUSSION WITH DR. S. VARADARAJAN, CHAIRMAN, EXPERT COMMITTEE ON ENVIRONMENTAL IMPACT OF MATHURA REFINERY ON 11TH AUGUST, 1977.

1. There is sufficient technological development and know-how available to ensure that the effluents discharged by the refinery to the atmosphere are within the limits stated by IOC, *viz.* SO_2 being less than one tonne per hour. Equipments are available and would be installed for monitoring discharge of wind pattern is such that it is away from Bharatpur effluents as well as for measuring the air quality at various distances from the Refinery. The general most of the time and therefore the carry over to SO_2 to this area will be negligible.

2. The Indian Standards Institution is considering a draft Standard for the air quality. As per this the annual long-term concentration of sulphur dioxide permitted for urban areas is of the order of 40 micrograms/M^3 as compared to 60 micrograms/M^3 as specified by W.H.O. It should, however, be noted that in industrially developed countries, although the limit has been specified as 60 micrograms/M^3, the actual concentration of sulphur dioxide is much higher as illustrated in the table given below:

Copenhagen	60
Stockholm	70
Amsterdam	80
Liegé	130
Brussels	170
Paris	110
London, City	250
London, greater	150
Milan	600
Venice, city	70
Venice, Industrial Area	130
New York-Manahattan	110
New York-Richmond	50
Los Angeles	70
Toronto, city	170
Toronto, residential	30

The actual concentration of sulphur dioxide at Agra and Bharatpur, even after taking into account the contribution from the refinery, is far lower than the figure of concentration being attempted at in other countries.

3. As mentioned by both the Nature Conservancy Council (UK) and the Royal Society for the Protection of Birds (UK) the effect of sulphur dioxide on birds will be nil. However, it has been stated that water effluents could effect the plant life and consequently effect the bird sanctuary. The water effluents from the refinery would be treated to meet the stringent specifications laid down by the Indian Standards Institution for discharge of treated effluents into inland waters which are being used for domestic consumption after usual municipal treatment. In any case, the effluent from the refinery will be discharged into the Yamuna river downstream of Brahmandghat and therefore there is no likelihood of the same reaching Bharatpur Sanctuary. None the less, a detailed study of the water courses around the refinery and Bharatpur will be made to ensure that there is no likelihood of the refinery's treated effluents reaching Bharatpur under any circumstances.

COPY OF THE REPLY RECEIVED FROM DR. SALIM ALI, PRESIDENT, BOMBAY NATURAL HISTORY SOCIETY, BOMBAY—DT. 14TH SEPT. '77

Thank you for your letter dated 12th September and the note on my recent discussion with the Chairman, Expert Committee on Environmental Impact of Mathura Refinery, on the Bird Sanctuary at Bharatpur. The best people to inform you about the steps taken in the U.K. to keep the waters of bird sanctuaries free from industrial wastes and chemical pollutants would be The Nature Conservancy Council and the Royal Society for the Protection of Birds, with whom you are already in touch. I am sure they would be only too glad to furnish all the relevant information. Another source for information and advice in this matter would be: Station Biologique La bour du Valat, Le Sambuc, 13200 Arles, France, if you will give the Director (Dr. Morgan) all the details of our problem. Mentioning my name would perhaps help.

Meanwhile it is good to be assured that it is unlikely for the effluent from the refinery to reach the Bharatpur Sanctuary. All the same, I feel it essential that the water in the Sanctuary should be kept under sustained monitoring, so that any untoward happening from this source is detected in good time. With the cooperation of your Department, we would like to set up a hydrobiological monitoring station in the Sanctuary, for which a site has been already gifted to us by the ex-Maharaja. Would it be possible for one of your experts to meet myself and Shri N. D. Jayal, Joint Secretary, Ministry of Agriculture (Forests & Wildlife) in Bharatpur on 7th October when we are there? Perhaps it would be a good idea if we could meet together with the Officer-in-Charge and brief him and discuss the various details required by you. If you think this would help, I suggest that you contact Shri Jayal and fix up details about the visit with him.

With kind regards to yourself and Dr. Varadarajan.

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