

**Report on the  
Immission / Ambient Air Quality Monitoring during Paus Mela  
adjacent to Visva Bharati University, Santinikatan, West Bengal**



**By**

**West Bengal Pollution Control Board**

*May 2004*

## **Report on the Immission / Ambient Air Quality Monitoring during Pous Mela adjacent to Visva Bharati University, Santinikatan, West Bengal**

### **Introduction:**

The Pous Mela (a fare held in the end of December) is held after the harvesting of rice crop. Pous is the ninth month of the Bengali calendar (from the middle of December to the middle of January). Pous Parbon, the festival of offering sweet pies etc., made of new rice on the last day of the month of Pous.

The Pous Mela (a fare) is held and sponsored by the Visva Bharati Mela Committee adjacent to the Visva Bharati University, the university founded by the noble laureate Rabindranath Tagore. The fare ground is more than two square kilometer where temporary shops are setup, the local village people bring their handworks, painting, etc., (cottage industry) for exhibition and sale, majority of the shops sell various food items cooked from the newly harvested rice. During the third week of December half a million people attend the festival (Pous Mela).

There was a need to study the air pollution generated during the fair vis-à-vis the rural environment and so an attempt had been made to study the air pollution during the fare under the guidance of Shri. Hirak Ghosh, IAS, the then Principal Secretary of the Department of Environment and the then Chairman of the West Bengal Pollution Control Board.

### **Scope of Study:**

The study of the air pollutants in the atmosphere during the largest village fare (pous mela) held in the winter season, the reason of the pollutants accumulating in the atmosphere and its dispersion. The hourly variation of the air pollutants in the atmosphere due to the village fare vis-à-vis location of the University, etc.

### **Methodology:           Annexure – ‘A’**

#### **Instrumentation:**

An automatic ambient air quality monitoring mobile van was procured under the JBIC project for immission monitoring.

The monitoring van consists of:

- Gas Sampling Probe located 0.3 meters above the roof of the van and at 4 meters from the ground level. The sampling probe also consists of peltier cooling and condenser system with excess flow of samples and directly discharged out of the van. The moisture free ambient gaseous samples are drawn by the measuring instruments directly from the sample manifold.
- Particulate sampling probe i.e. PM<sub><10</sub> probe with a built in heater system directly above the measuring instruments. The sampling probe located at about 0.5 meters above the roof and about 4 meters above the ground level.
- The inside temperature of the van (instrumentation chamber) maintained at 21° C by two air-conditioner for better stability of measuring instruments.
- Sulphur-dioxide monitors [ultraviolet radiant at 214 nm wavelength fluorescence irradiated (between 300 to 400 nm) measured by a photo-multiplier tube (PMT)].
- Carbon-monoxide monitor [correlation of the absorption of non-destructive infra-red light (NDIR).
- Oxides of Nitrogen [NO - NO<sub>2</sub> – NO<sub>x</sub> ] monitor [Gas Phase Chemiluminescence].
- Ozone monitor [absorption of ultraviolet radiation 253.7 nm].
- Respirable Suspended Particulate Matter [RSPM] monitor [Beta Ray C14 deflection with Geiger-Muller tube detector located on the same axis, particulate matter collected on filter paper].
- A computer for on line recording of all the gaseous measuring parameters, respirable particulate matter (RPM) alias respirable suspended particulate matter (RSPM) alias

particulate matter less than 10 µm size (PM<10µ), metrological parameters viz. ambient temperature, relative humidity of atmosphere, wind speed and wind direction

Calibration instruments in the van:

All the measuring instruments were calibrated before each measuring programme.

- Zero air generator.
- Gas calibrator.

Calibration gases:

- SO<sub>2</sub> – Permeation tube, built in permeation chamber in SO<sub>2</sub> analyser. The permeation rate for SO<sub>2</sub> gas is 190 nano-gram per minute ± 25% at 40 °C.
- CO – Nitrogen gas mixture cylinder. CO = 949.49 ppm and remaining Nitrogen.
- NO – Nitrogen gas mixture cylinder. NO = 72 ppm and remaining Nitrogen

Calibration of RSPM:

- Calibration foil of known value 886 ± 3 µg per cm<sup>2</sup>

Meteorological Parameters:

- Wind speed (anemometer cup type) [10 meters from ground level]
- Wind Direction [10 meters from ground level]
- Relative Humidity [3 meters from ground level]
- Ambient Temperature [3 meters from ground level]

### National Ambient Air Quality Standard

Pollutants	Time weighted average	Industrial Areas	Residential, Rural & other areas	Sensitive Areas
Sulphur-dioxide (SO <sub>2</sub> )	Annual Average	80 µg/m <sup>3</sup>	60 µg/m <sup>3</sup>	15 µg/m <sup>3</sup>
	24 hours average	120 µg/m <sup>3</sup>	80 µg/m <sup>3</sup>	30 µg/m <sup>3</sup>
Oxides of Nitrogen as NO <sub>2</sub>	Annual Average	80 µg/m <sup>3</sup>	60 µg/m <sup>3</sup>	15 µg/m <sup>3</sup>
	24 hours average	120 µg/m <sup>3</sup>	80 µg/m <sup>3</sup>	30 µg/m <sup>3</sup>
Suspended Particulate Matter (SPM)	Annual Average	360 µg/m <sup>3</sup>	140 µg/m <sup>3</sup>	70 µg/m <sup>3</sup>
	24 hours average	500 µg/m <sup>3</sup>	200 µg/m <sup>3</sup>	100 µg/m <sup>3</sup>
Respirable Particulate Matter (RPM) (size less than 10 micron)	Annual Average	120 µg/m <sup>3</sup>	60 µg/m <sup>3</sup>	50 µg/m <sup>3</sup>
	24 hours average	150 µg/m <sup>3</sup>	100 µg/m <sup>3</sup>	75 µg/m <sup>3</sup>
Carbon-monoxide (CO)	8 hours	5 mg/m <sup>3</sup>	2 mg/m <sup>3</sup>	1 mg/m <sup>3</sup>
	1 hour	10 mg/m <sup>3</sup>	4 mg/m <sup>3</sup>	2 mg/m <sup>3</sup>

Ozone [O<sub>3</sub>] USEPA Standard for 1-hour average is 120 ppb [parts per billion]

## Analysis of the Results / Observation:

The Maximum, mean and average value of the measured pollutants (hourly average) are given in the following table from which it can be observed that the average values of the pollutants were within the standard norms except the respirable particulate matter [RPM] i.e. PM less than 10 microns, which was due to the activity of the fare and proximity of the measuring instrument.

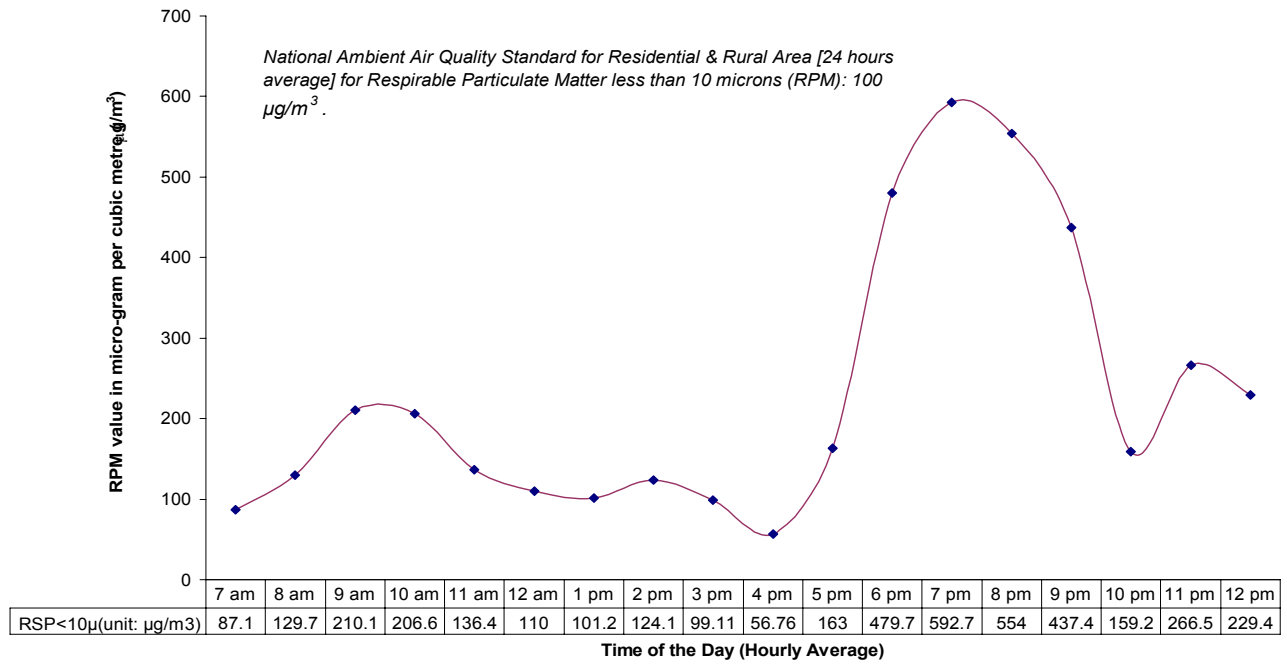
The basic fuel used by various fast food centers had been the coal and initial firing by wood. The value of Oxides of Nitrogen had been observed higher during the peak dinner time of 8 to 9 pm, which can be attributed to the fuel used by the fast food centers.

Parameters	Unit	98 Percentile	50 Percentile
Sulphur-dioxide [SO <sub>2</sub> ]	µg / m <sup>3</sup>	25.3	9.3
Carbon-monoxide [CO]	mg / m <sup>3</sup>	2.7	1.1
Nitric Oxide [NO]	µg / m <sup>3</sup>	4	2
Nitrogen-dioxide [NO <sub>2</sub> ]	µg / m <sup>3</sup>	64	11
Oxides of Nitrogen [NO <sub>x</sub> ]	µg / m <sup>3</sup>	66	12
Ozone [O <sub>3</sub> ]	ppb	34	16
Respirable Particulate Matter [PM<10]	µg / m <sup>3</sup>	838	199

Parameters	Unit	Range	26/12/03	25/12/03	24/12/03	23/12/03
SO <sub>2</sub>	µg / m <sup>3</sup>	Maximum	14.1	27.1	23	14
		Minimum	0.8	4.4	0.3	0.3
		Average	4.66	15.81	7.40	5.44
CO	mg / m <sup>3</sup>	Maximum	1.33	3.1	2.35	1.07
		Minimum	0.77	1.3	1.03	0.18
		Average	1.08	1.94	1.4	0.08
O <sub>3</sub>	ppb	Maximum	31.46	33.9	34.8	34
		Minimum	10	3.6	4.01	5.23
		Average	20	16	18	16
NO	µg / m <sup>3</sup>	Maximum	2	10.3	2.4	4.8
		Minimum	1.9	1.8	1.8	1
		Average	1.94	2.30	1.96	2.03
NO <sub>2</sub>	µg / m <sup>3</sup>	Maximum	20.1	84.8	55.4	33.8
		Minimum	5.5	4.8	4.2	10.7
		Average	9.01	23.76	14.09	18.82
NO <sub>x</sub>	µg / m <sup>3</sup>	Maximum	22.1	95.1	57.6	35.7
		Minimum	7.5	6.8	6.1	11.7
		Average	10.98	26.06	16.05	20.86
RPM	µg / m <sup>3</sup>	Maximum	325	855	770	592
		Minimum	93	103	11	56
		Average	221	390	270	212

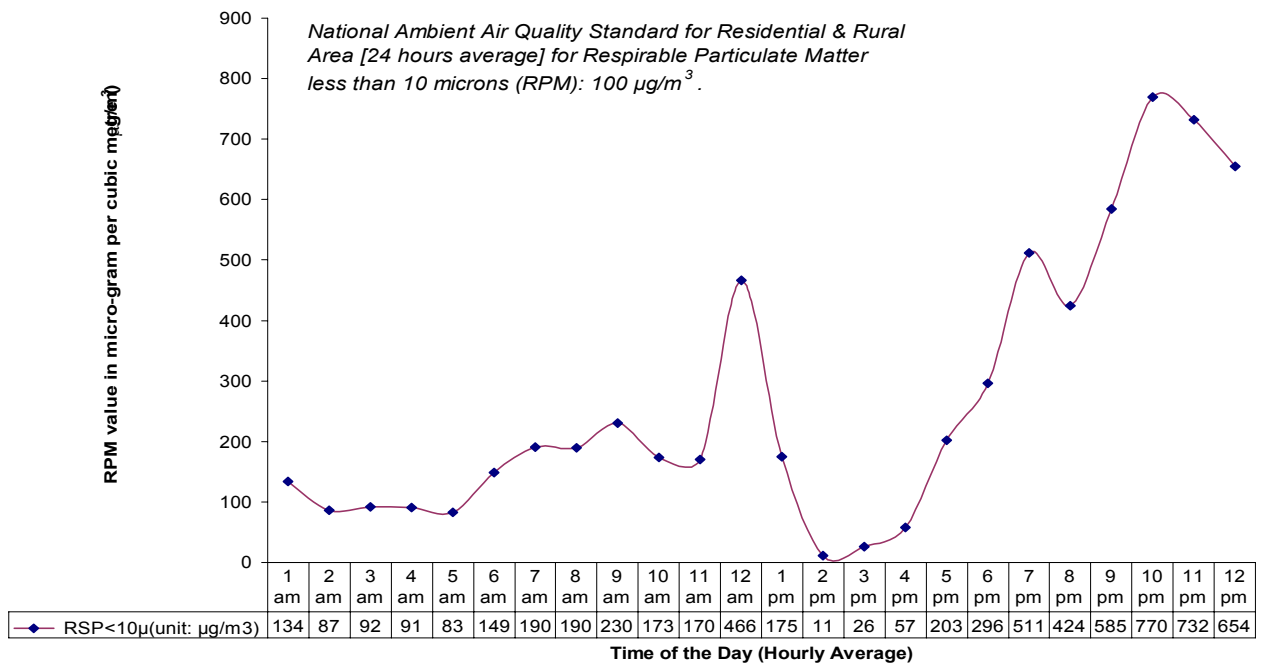
Graph – 1

**Ambient Air Quality / Immission Monitoring Values of Respirable Particulate Matter (RSP<10µm) (Hourly Average) at Pous Mela (fare), Santinikathan, West Bengal during 23<sup>rd</sup> December, 2003**



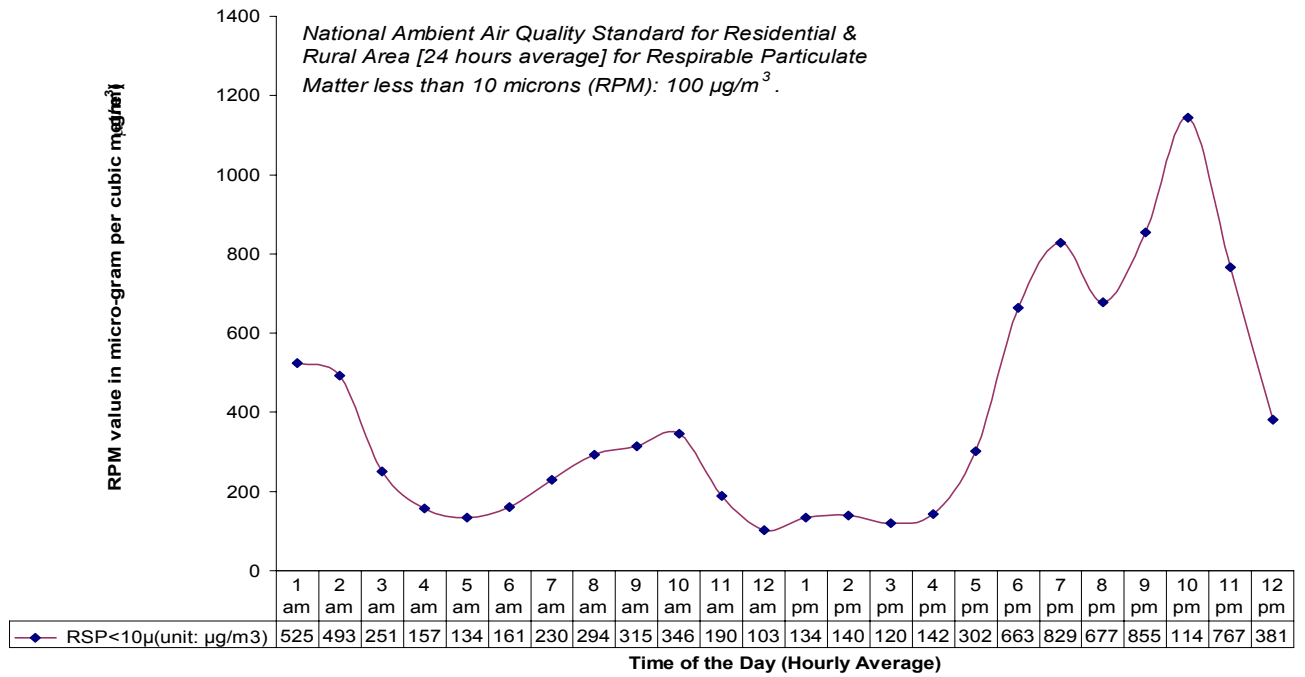
Graph – 2

**Ambient Air Quality / Immission Monitoring Values of Respirable Particulate Matter (RSP<10µm) (Hourly Average) at Pous Mela (fare), Santinikathan, West Bengal during 24<sup>th</sup> December, 2003**



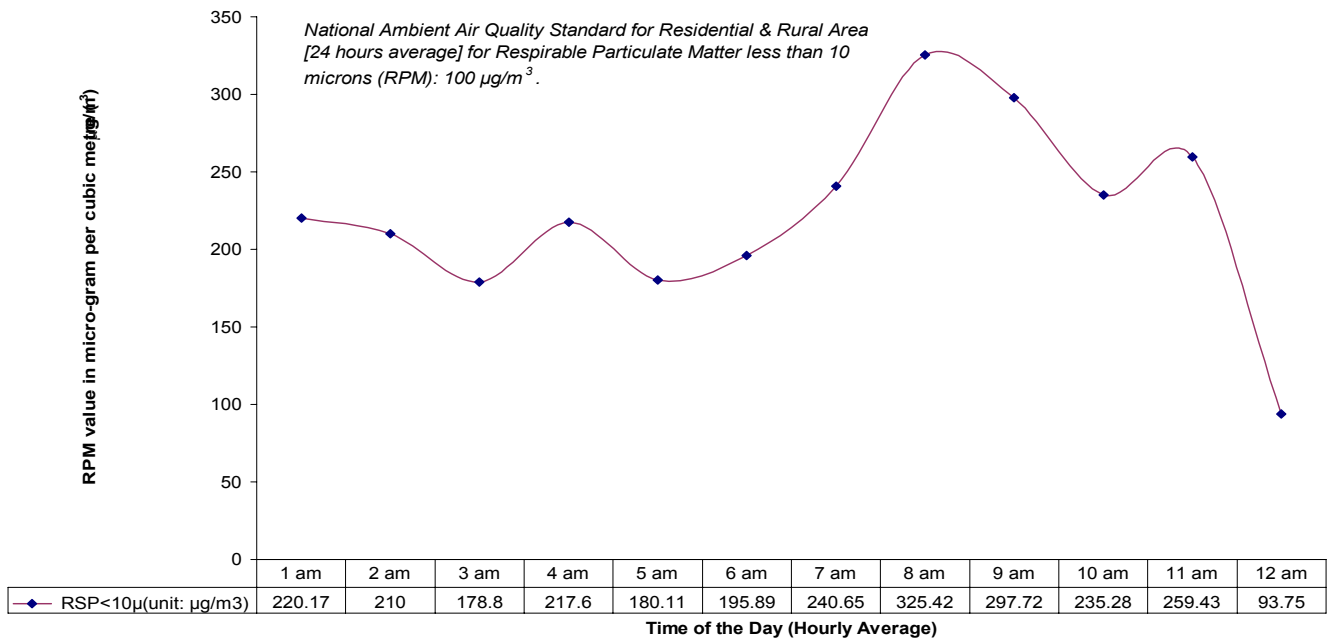
Graph – 3

**Ambient Air Quality / Immission Monitoring Values of Respirable Particulate Matter (RSP<10µm) (Hourly Average) at Pous Mela (fare), Santinikathan, West Bengal during 25<sup>th</sup> December, 2003**



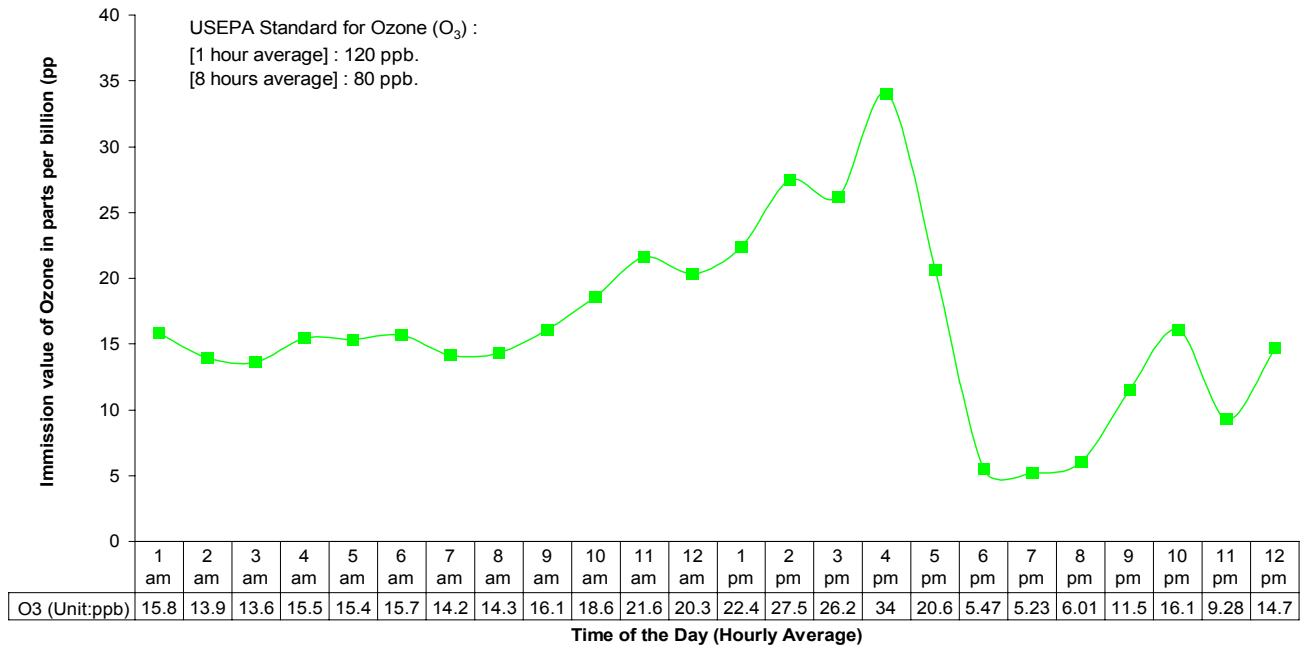
Graph – 4

**Ambient Air Quality / Immission Monitoring Values of Respirable Particulate Matter (RSP<10µm) (Hourly Average) at Pous Mela (fare), Santinikathan, West Bengal during 26<sup>th</sup> December, 2003**



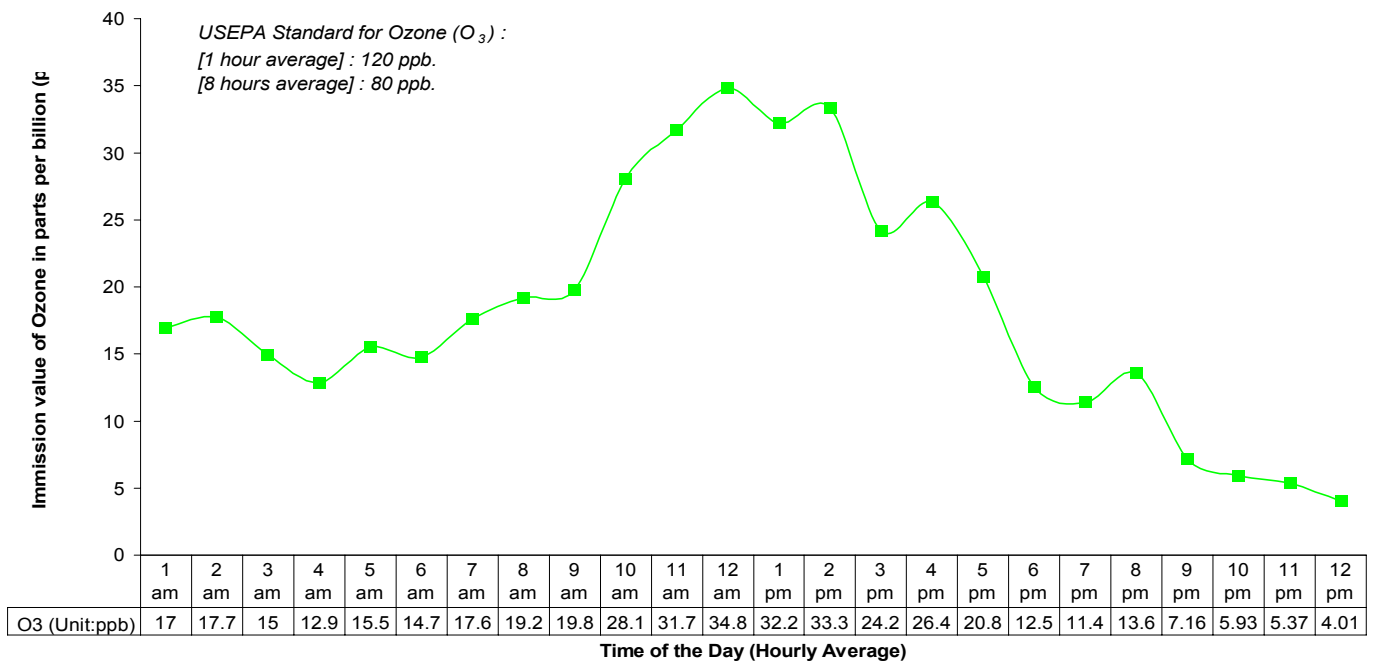
Graph – 5

**Ambient Air Quality / Immission Monitoring Values of Ozone (O<sub>3</sub>) (Hourly Average) at Pous Mela (fare), Santinkatan, West Bengal during 23<sup>rd</sup> December, 2003**



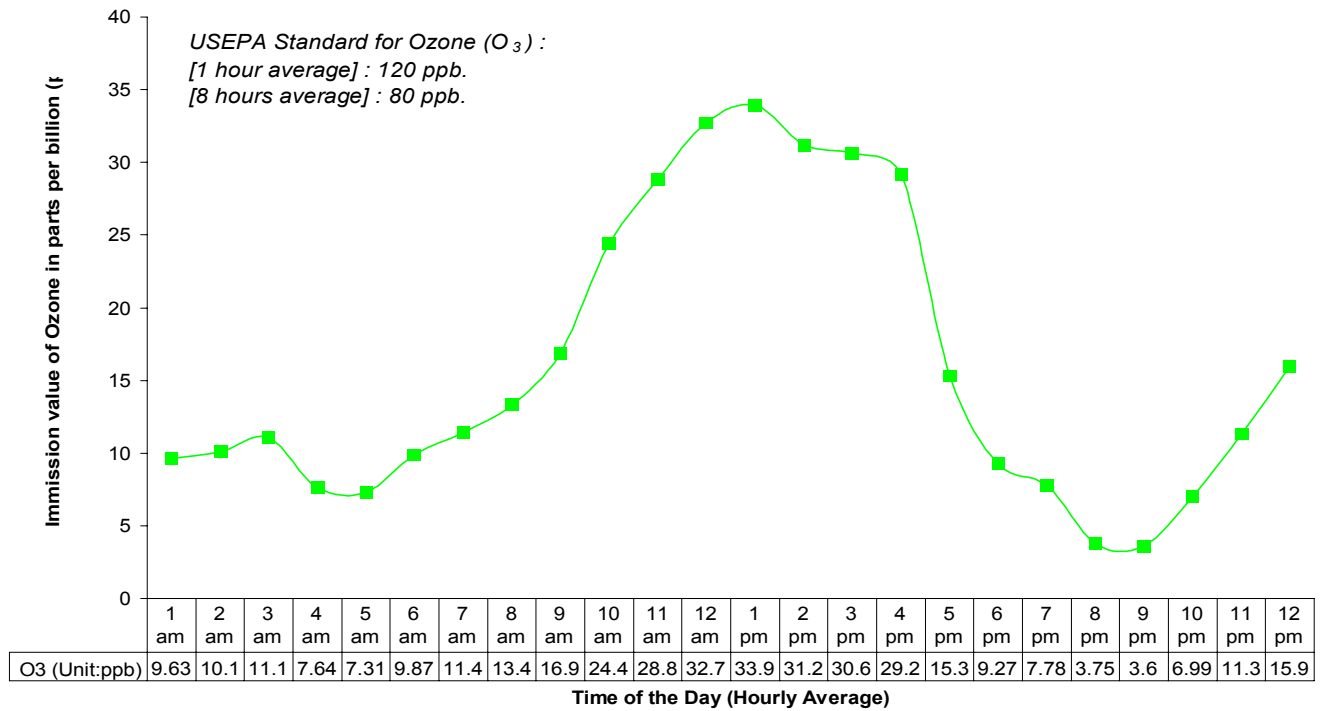
Graph – 6

**Ambient Air Quality / Immission Monitoring Values of Ozone (O<sub>3</sub>) (Hourly Average) at Pous Mela (fare), Santinkatan, West Bengal during 24<sup>th</sup> December, 2003**



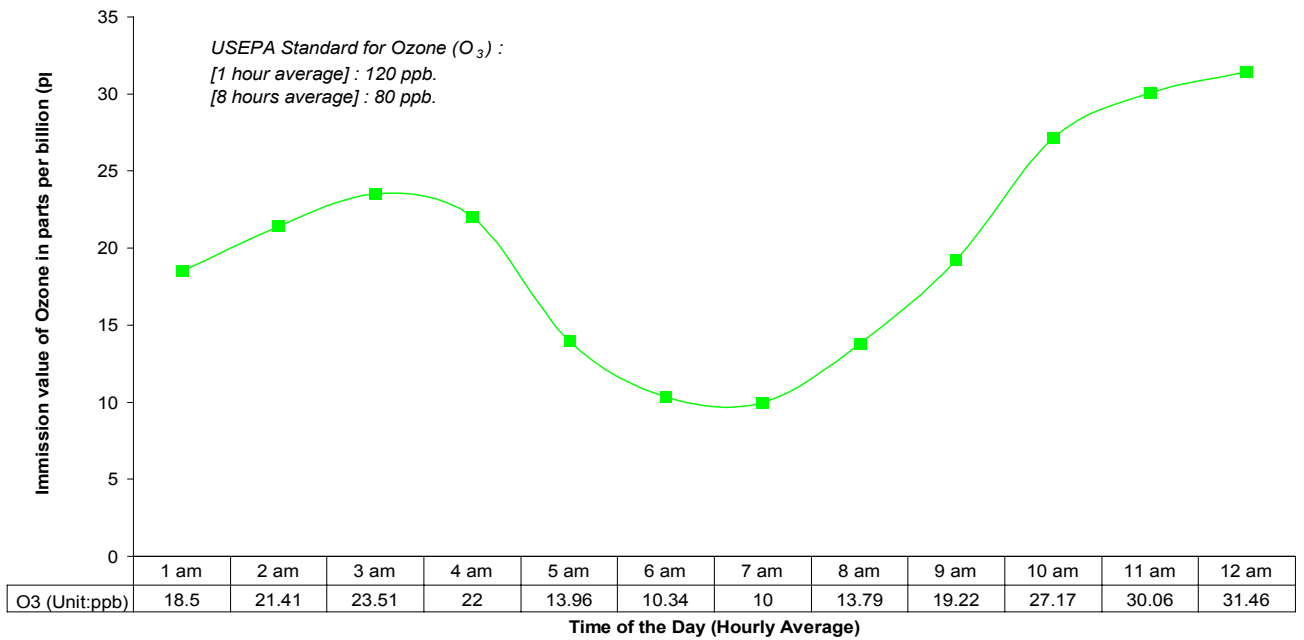
Graph - 7

**Ambient Air Quality / Immission Monitoring Values of Ozone (O<sub>3</sub>) (Hourly Average) at Pous Mela (fare), Santinkatan, West Bengal during 25<sup>th</sup> December, 2003**



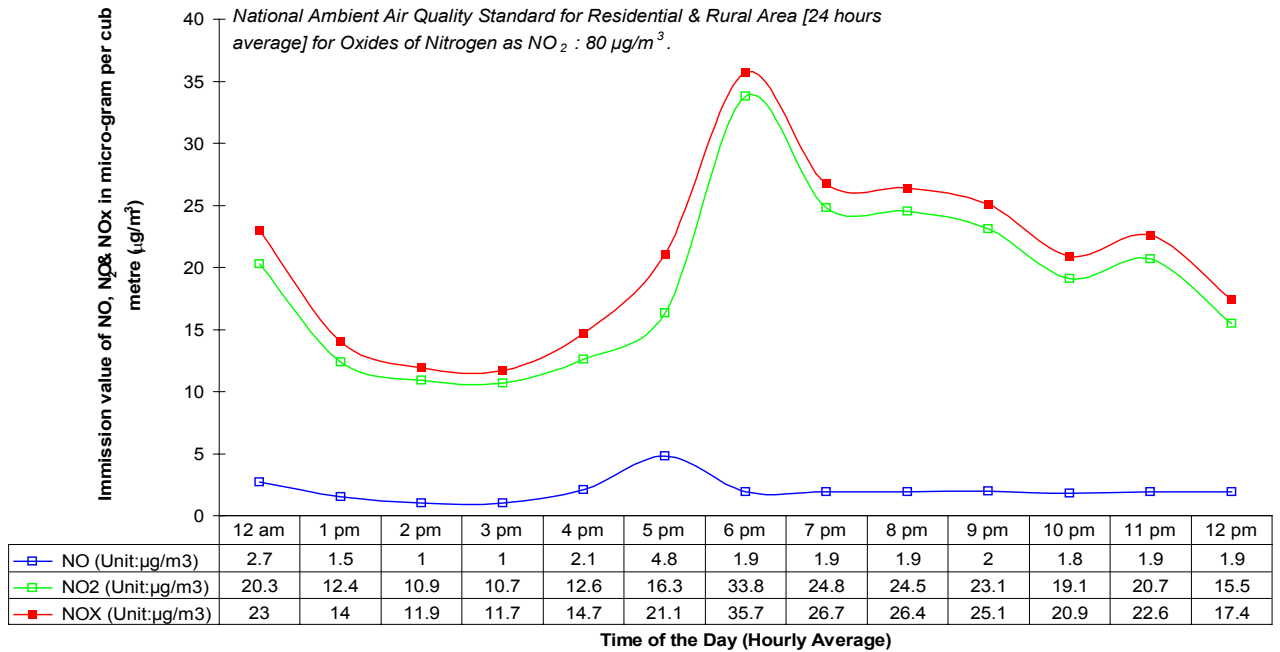
Graph - 8

**Ambient Air Quality / Immission Monitoring Values of Ozone (O<sub>3</sub>) (Hourly Average) at Pous Mela (fare), Santinkatan, West Bengal during 26<sup>th</sup> December, 2003**



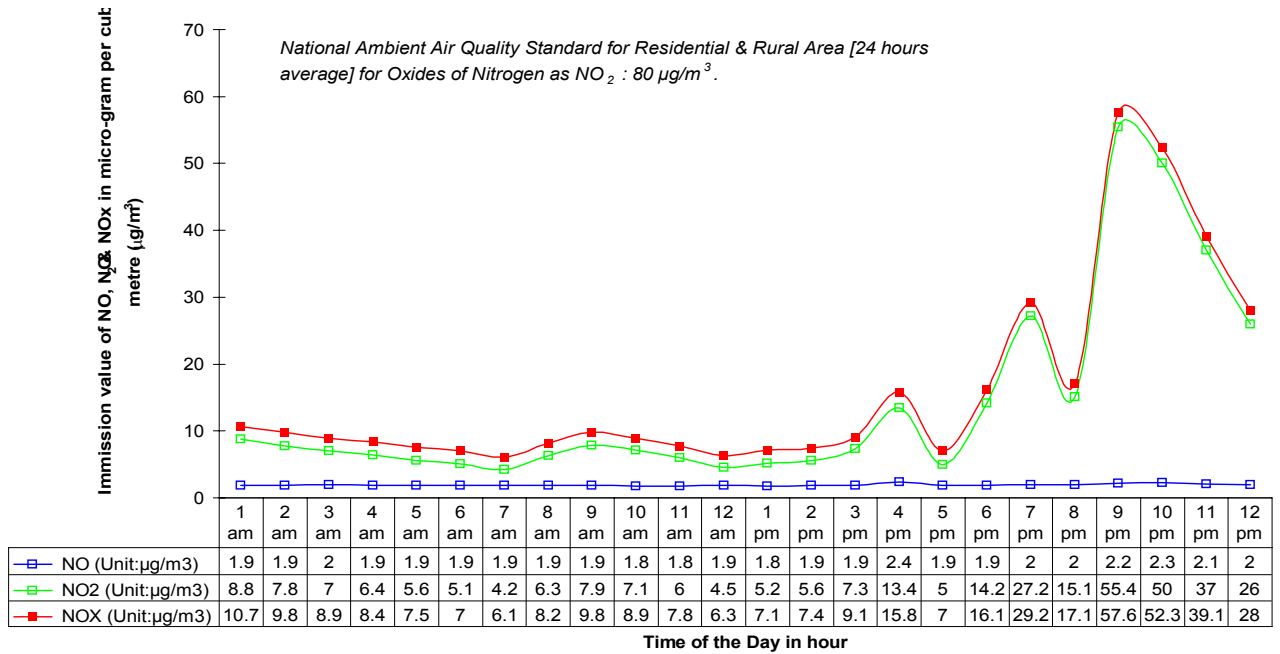
Graph – 9

**Ambient Air Quality / Immission Monitoring Values of Oxides of Nitrogen (Hourly Average) at Pous Mela (fare), Santinikatan, West Bengal during 23<sup>rd</sup> December, 2003**



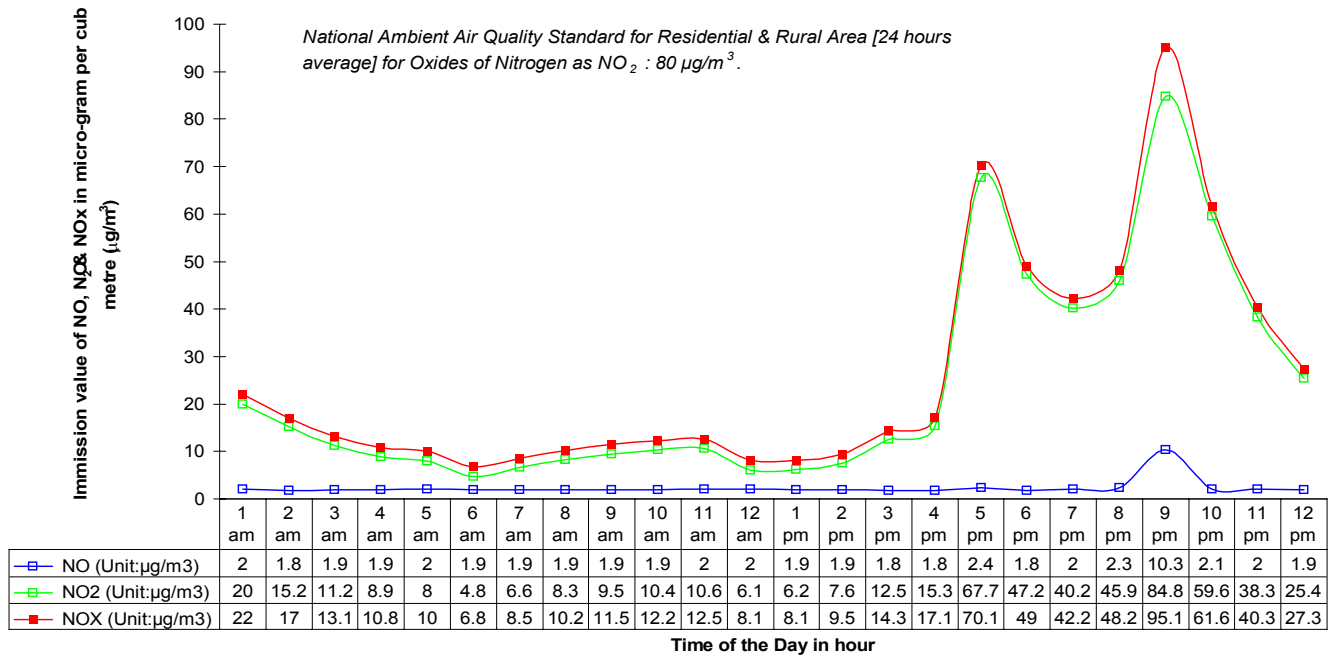
Graph – 10

**Ambient Air Quality / Immission Monitoring Values of Oxides of Nitrogen at Pous Mela (fare), Santinikatan, West Bengal during 24<sup>th</sup> December, 2003**



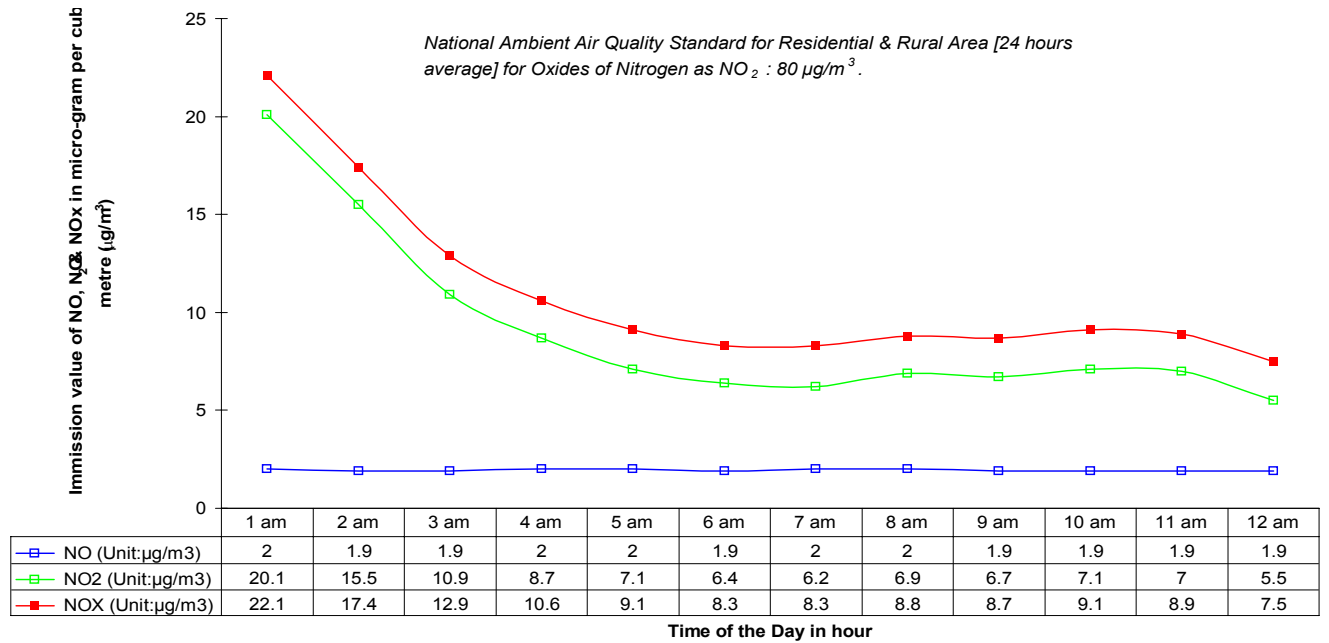
Graph - 11

**Ambient Air Quality / Immission Monitoring Values of Oxides of Nitrogen at Pous Mela (fare), Santinikatan, West Bengal during 25<sup>th</sup> December, 2003**



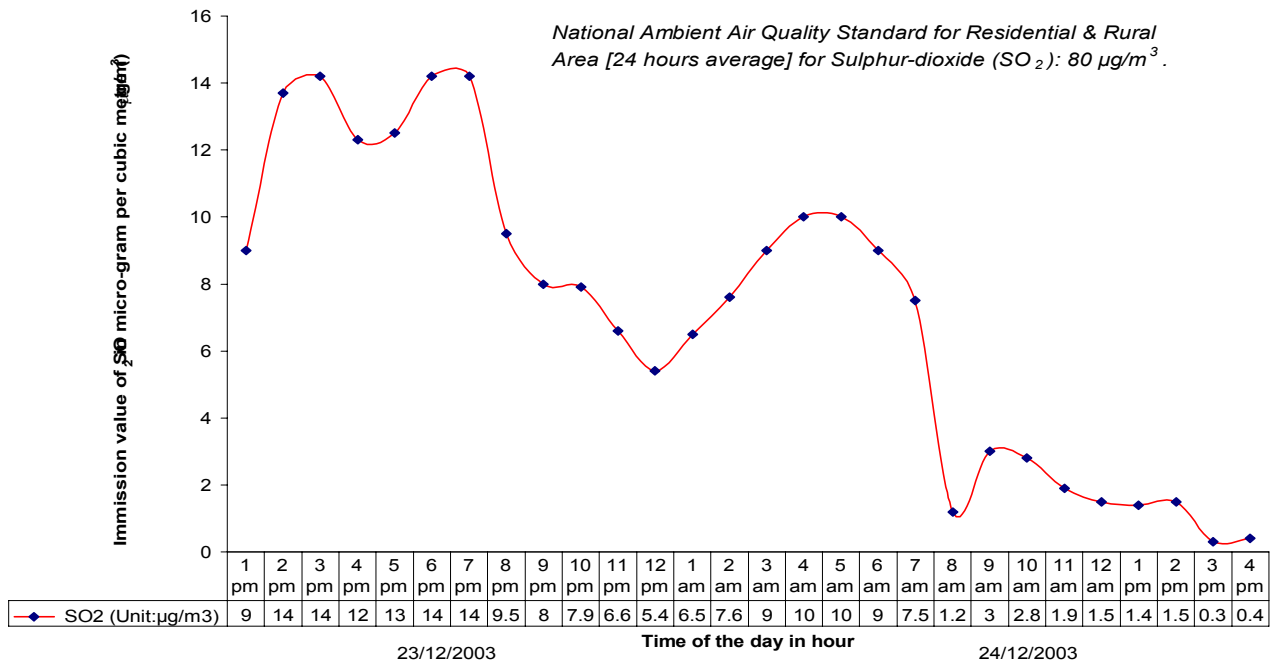
Graph -12

**Ambient Air Quality / Immission Monitoring Values of Oxides of Nitrogen at Pous Mela (fare), Santinikatan, West Bengal during 26<sup>th</sup> December, 2003**



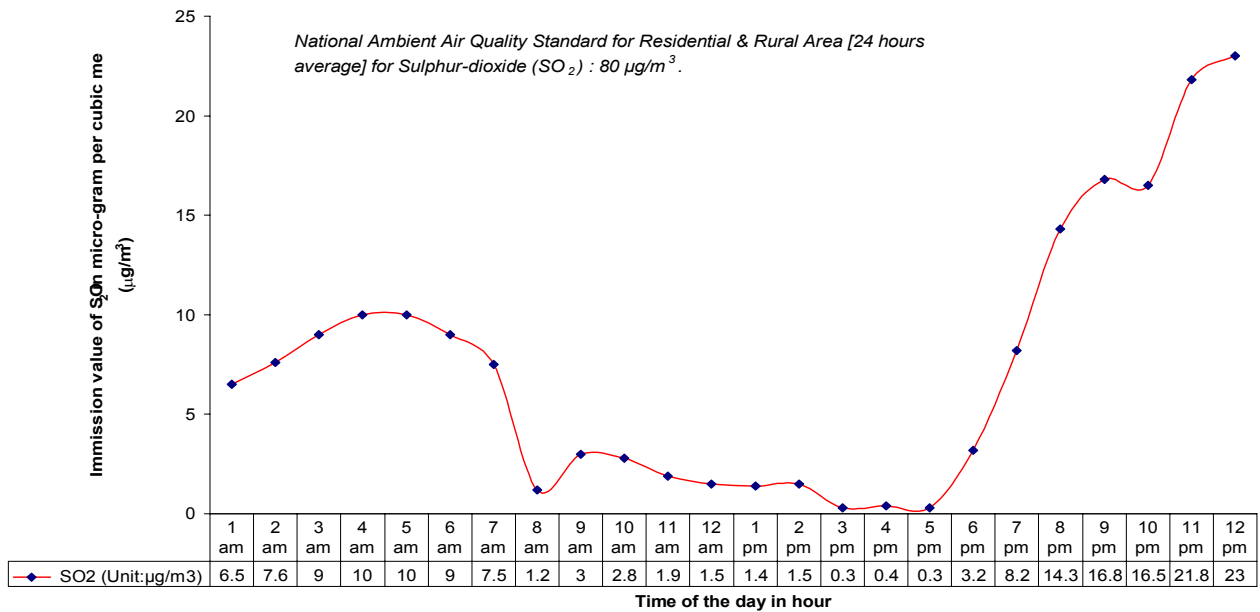
Graph - 13

**Ambient Air Quality / Immission Monitoring Values of Sulphur-dioxide at Pous Mela (fare), Santinikatan, West Bengal during 23rd & 24th December, 2003**



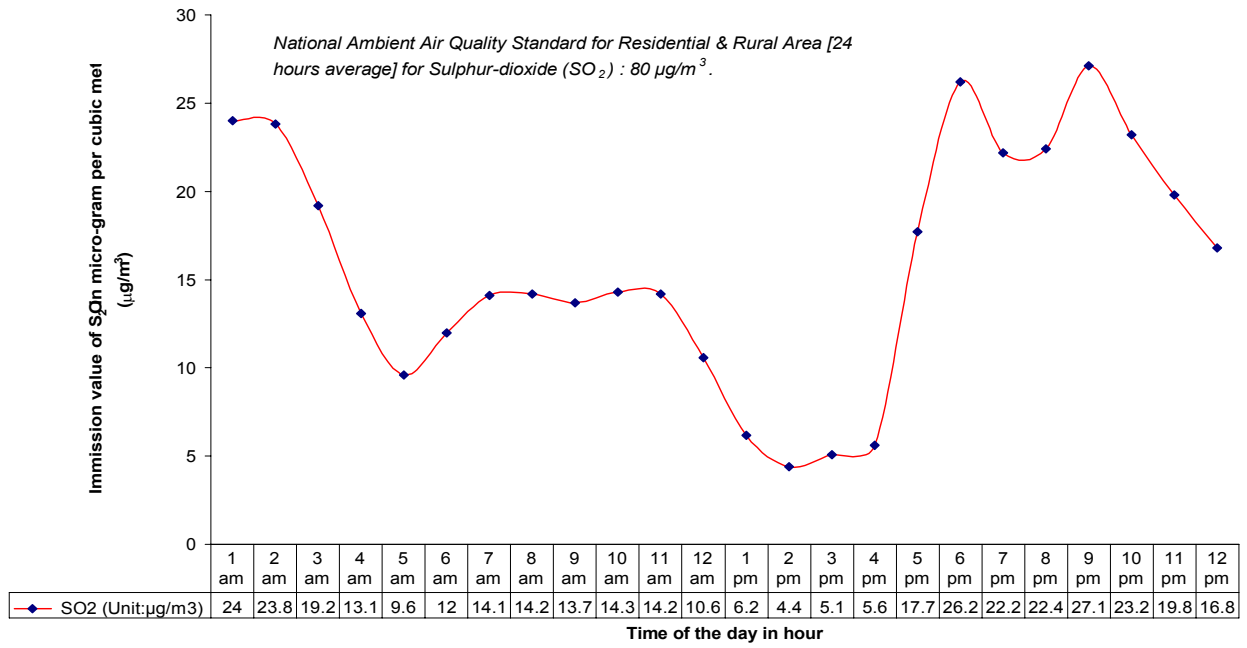
Graph – 14

**Ambient Air Quality / Immission Monitoring Values of Sulphur-dioxide at Pous Mela (fare), Santinikatan, West Bengal during 24<sup>th</sup> December, 2003**



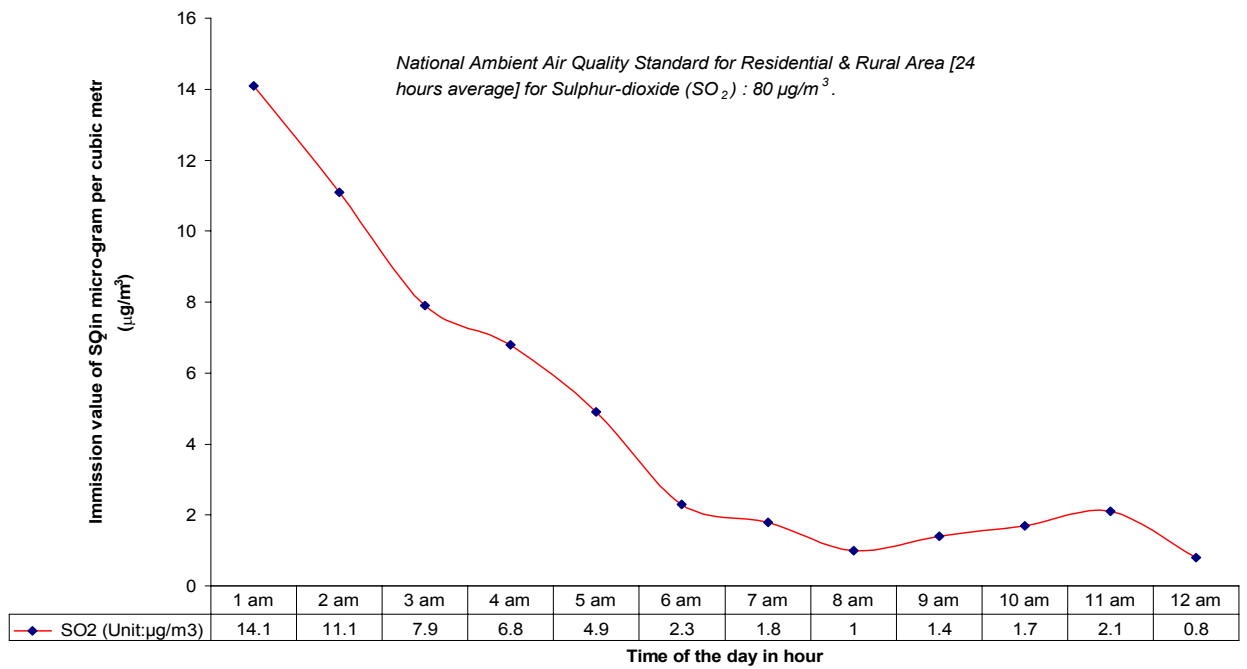
Graph – 15

**Ambient Air Quality / Immission Monitoring Values of Sulphur-dioxide at Pous Mela (fare),  
Santinikatan, West Bengal during 25<sup>th</sup> December, 2003**



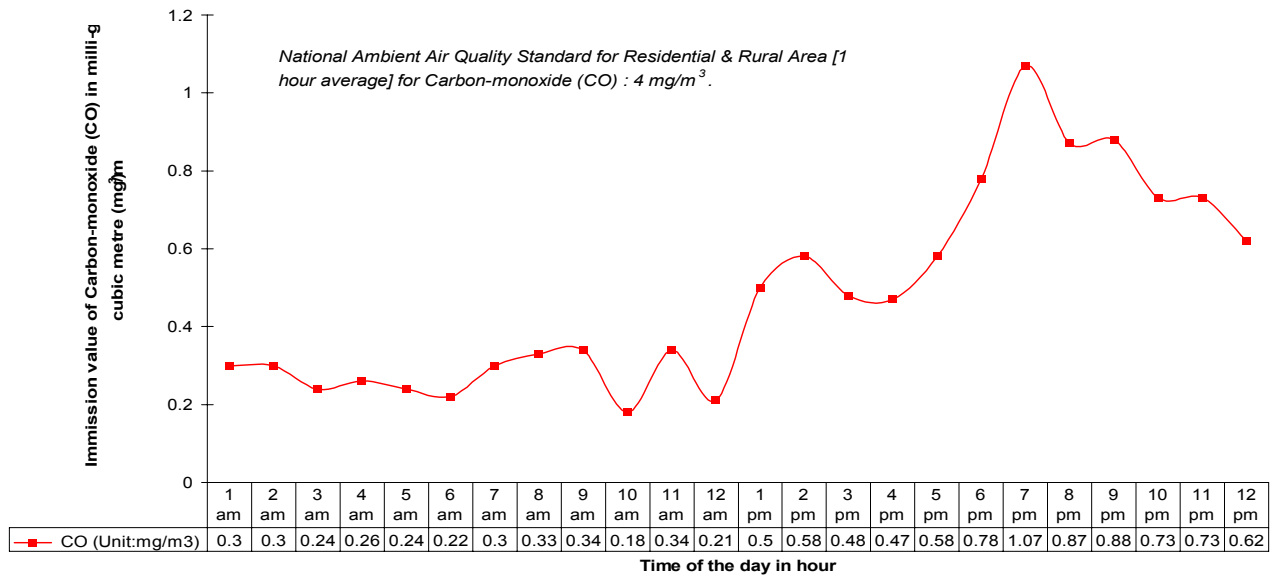
Graph – 16

**Ambient Air Quality / Immission Monitoring Values of Sulphur-dioxide at Pous Mela (fare),  
Santinikatan, West Bengal during 26<sup>th</sup> December, 2003**



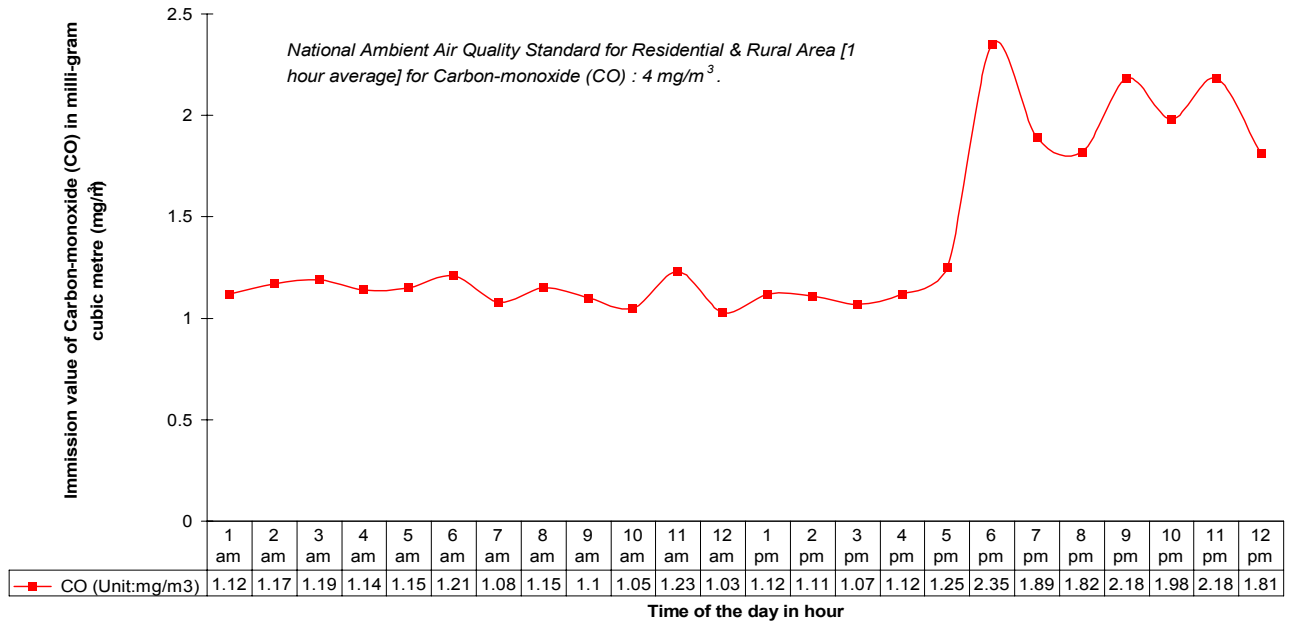
Graph – 17

**Ambient Air Quality / Immission Monitoring values of Carbon-monoxide (CO) at Pous Mela (fare),  
Santinikatan, West Bengal during 23<sup>rd</sup> December, 2003**



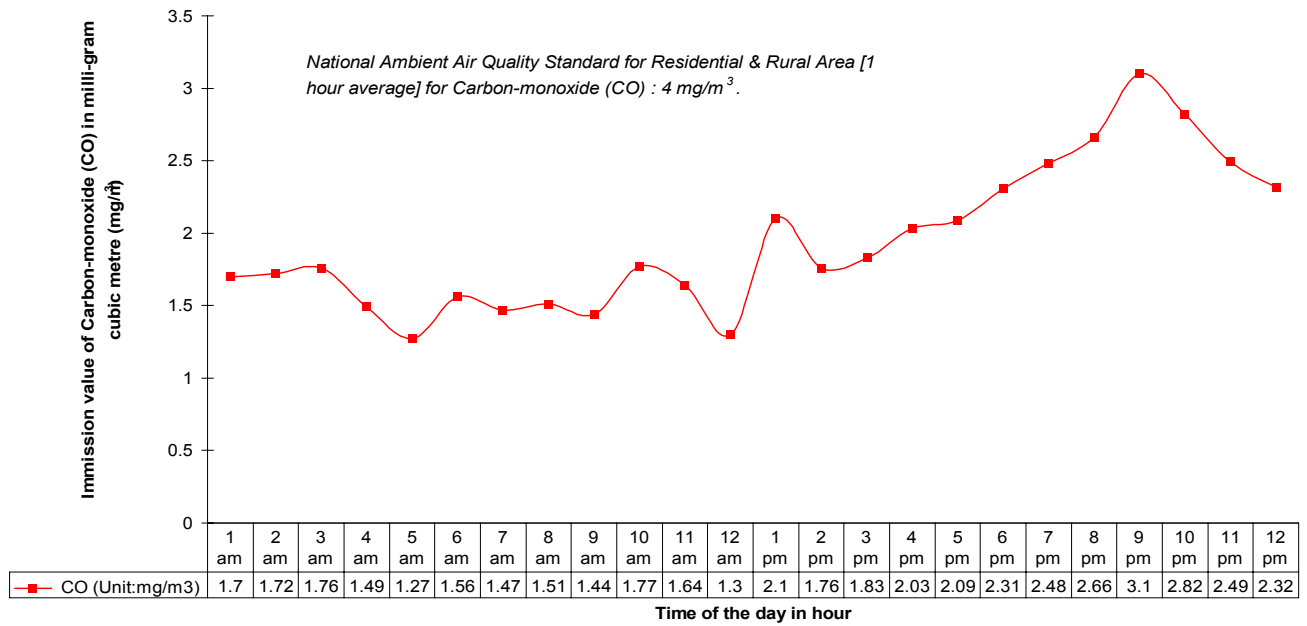
Graph - 18

**Ambient Air Quality / Immission Monitoring Values of Carbon-monoxide (CO) at Pous Mela (fare),  
Santinikatan, West Bengal during 24<sup>th</sup> December, 2003**



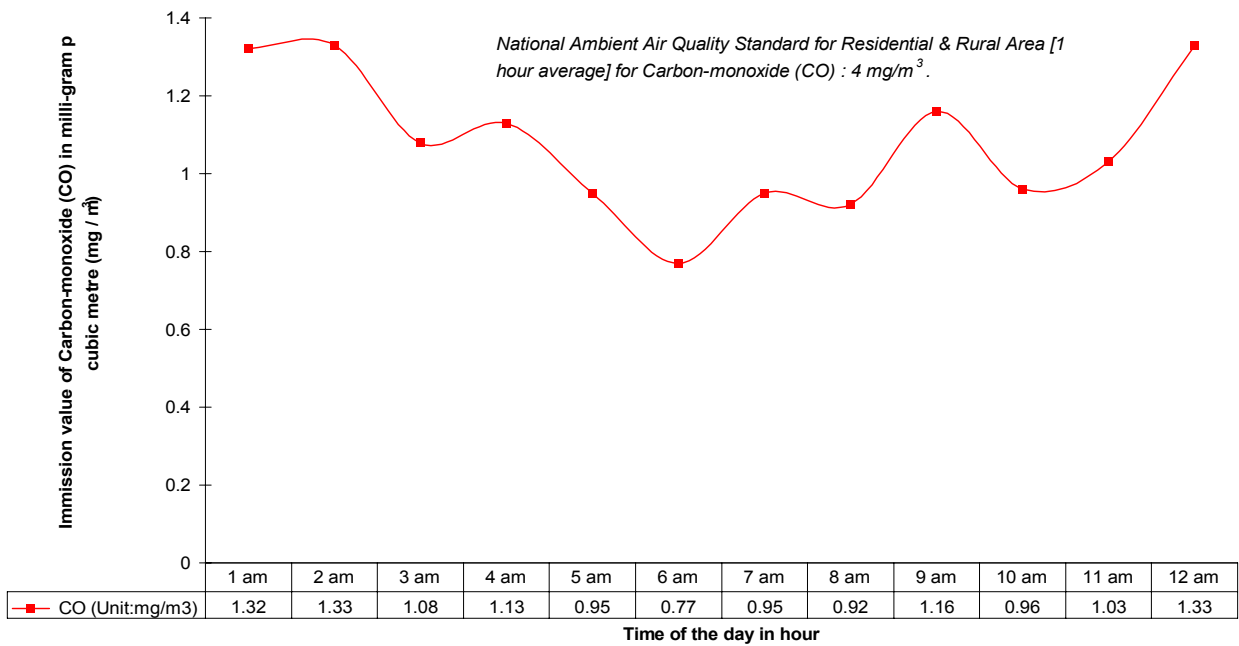
Graph – 19

**Ambient Air Quality / Immission Monitoring Values of Carbon-monoxide (CO) at Pous Mela (fare), Santinikatan, West Bengal during 25<sup>th</sup> December, 2003**



Graph – 20

**Ambient Air Quality / Immission Monitoring Values of Carbon-monoxide (CO) at Pous Mela (fare), Santinikatan, West Bengal during 26<sup>th</sup> December, 2003**



**Conclusion:**

1. The basic air pollutant affecting the ambient atmosphere of the fare (pous mela) is due to the respirable suspended particulate matter (PM<10) and oxides of nitrogen (NO<sub>x</sub>).
2. The respirable suspended particulate matter (RSPM) alias (RPM) alias (PM<10) had been observed during the evening hours when the movement of visitors were maximum and continued late night.
3. The respirable suspended particulate matter (PM<10) and oxides of nitrogen (NO<sub>x</sub>) had been observed due to the use of solid fuels in the various type of eateries within the fair ground.
4. The respirable suspended particulate matter (PM<10) and oxides of nitrogen (NO<sub>x</sub>) can be drastically reduced if the fair ground is sprinkled with water from time to time and complete restriction in the use of solid fuels / bio-mass in the various type of eateries within the fair ground.

**Methodology:**

A] Sulphur dioxide analyser:

a) Theory of operation:

Sulphur dioxide absorbs ultraviolet light in three primary range where it excites SO<sub>2</sub> molecules into higher energy states namely electronically spectrum (system of bands associated with an electronic transition); vibration – rotation spectrum (band associated with a vibration transition); and rotation spectrum (rays associated with a rotational transition).

<u>Region</u>	<u>Wavelength</u>
1	390 nm – 340 nm
2	320 nm – 250 nm
3	230 nm – 190 nm

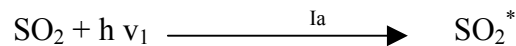
The first region is associated with weak absorption and heavy quenching of the fluorescent and so it has not been characterized accurately.

The second region is also associated with strong quenching of the fluorescent by oxygen and nitrogen in air.

The third region exhibits minimum quenching by air molecules and most other air pollutants molecules.

The low pressure zinc vapour lamp emits light of ultraviolet radiation at a wavelength  $\lambda = 213.9$  nm., the SO<sub>2</sub> in its fundamental state  $E_{e0}$ , the SO<sub>2</sub> molecules can only absorb energy photons to access the first excited state on electronic scale  $E_{e1}$ , producing electronically excited SO<sub>2</sub>\*. The energy quickly dissipates its vibration and rotation energy to remain on level  $E_{e1}$  a little longer i.e. a few nanoseconds.

As per the Einstein relation, the energy of a photon  $E = h\nu = h(c/\lambda)$  where  $\lambda$  is the radiation wave length output,  $h$  is the Plank's constant and  $c$  represent the speed of light in vacuum.



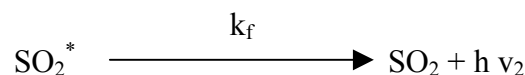
Here  $h\nu_1$  is the quantum of energy absorbed by the SO<sub>2</sub> molecules and  $I_a$  is the light intensity absorbed by the SO<sub>2</sub> molecules in terms of the incident light,  $I_0$ , i.e. the radiation intensity absorbed by Sulphur dioxide in an optical chamber of length  $x$  follows the Beer-Lambert law:

$$\text{then } I_a = I_0 [1 - e^{-\{a \times (\text{SO}_2)\}}]$$

Here,  $a$  – is the absorption coefficient of SO<sub>2</sub>,  $x$  – is the path length, and  $(\text{SO}_2)$  is the concentration of SO<sub>2</sub>.

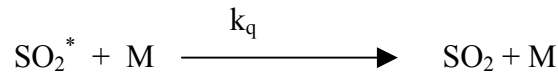
The radiation energy absorbed by the SO<sub>2</sub> molecules and being raised to an excited state then the excited SO<sub>2</sub> molecules will then release their excess energy and decay back toward the ground state using the following:

(i) decay by emitting the fluorescence light at a frequency  $\nu_2$  which is different from the absorbing frequency  $\nu_1$ , the reaction can be expressed as follows:



where  $\nu_1 = c/\lambda_1$  and  $\nu_2 = c/\lambda_2$  as  $\nu_2 < \nu_1$  then  $\lambda_2 > \lambda_1$ ,  $\lambda_2$  can be equal to one of the several values around an average length, thus the monitor observes photons emitted through a filter centered on 350 nm.

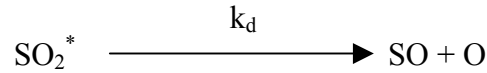
(ii) decay by quenching, where the background molecules collides with the excited SO<sub>2</sub> molecules and robbing some of the excess energy. The reaction can be expressed as follows:



Where M is the characteristic of background air.

(iii) decay by dissociation of the SO<sub>2</sub> molecule by actually splitting, the energy is sufficient to break the SO – O links.

The reaction can be expressed as follows:



Using the above reaction, an expression can be written representing the fluorescent intensity at a detector i.e. the fluorescence intensity received by the photo-multiplier tube (PMT):

$$F = \frac{G k_f I_0 [1 - e^{-[a \times (\text{SO}_2)]}]}{k_f + k_q [\text{M}] + k_d}$$

In the above equation,  $k_f$ ,  $k_q$ ,  $k_d$  denotes quantum or the rate constants of the respective process associated with each form of deactivation, and G represent the geometrical factor which is the function of the fluorescent chamber design, depends on the illuminated part of the chamber seen by the PMT.

When the SO<sub>2</sub> concentration is relatively low and the path length of exciting light is short, then in that case,  $a \times (\text{SO}_2) \ll 1$  and the

$$1 - e^{-a \times (\text{SO}_2)} \text{ can be developed to the first order } \cong + a \times (\text{SO}_2)$$

$$\text{The expression can be approximated as } F = \frac{G k_f I_0 a \times (\text{SO}_2)}{k_f + k_q [\text{M}] + k_d}$$

Since G and x depends upon the mechanical design of the fluorescent chamber and being constant, the radiation captured by the PMT is thus directly proportion to the SO<sub>2</sub> concentration

$$\text{i.e. } F = k (\text{SO}_2)$$

#### b) Interference:

The derivative given above did not take into consideration of the gaseous molecules that mimic the fluorescence activity of SO<sub>2</sub>, which are mainly the large organic molecules such as aromatic hydrocarbon.

An hydrocarbon kicker has been incorporated in flow system to remove the hydrocarbon from sampling gases. It works in the principal of permeation of the hydrocarbon through the special polymer (silicon) tube due to difference in the pressure of gas flow between the inner wall of the tube and outer wall of the said tube.

#### c) Calibration:

(i) The instrument has a provision for zero air generator by inbuilt Purafil / Charcoal internal zero filter for zero calibration of the instrument.

(ii) The instrument has the internal permeation bench and permeation tube for span calibration of the instrument.

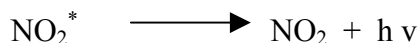
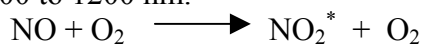
#### d) Analysis:

- (i) The sample to be analysed is free from dust particulate, soot's, hydrocarbon molecules HC before it is directed to the reaction chamber where it is irradiated by the ultra violet radiation at 214 nm which is the absorption wavelength of SO<sub>2</sub> molecules.
- (ii) A photodiode measures the ultra violet radiation generated by the UV lamp, through a mirror. This measurement is used during the signal processing in order to compensate for any variation of the UV energy.
- (iii) The molecules restore a specific fluorescence in the ultra violet range which is optically filtered between 300 and 400 nm at the out let in order to eliminate some interference gases. This fluorescence is measured by the photo-multiplier tube (PMT) placed at the side of the reaction chamber.
- (iv) At the start of each "zero-reference", a shutter is placed between the UV lamp and the reaction chamber inlet for 40 seconds. This electrical zero corresponds to the photo-multiplier tube darkness current and offset voltage of the preamplifier, incorporated into the signal processing. It eliminates the possibility of drifts with temperature and time.
- (v) The photo-multiplier tube signal is amplified and is converted into digital values for processing by the microprocessor that calculates the average of the measured values displayed on an alphanumeric display unit on the monitor and the said value is send to the station computer for record and further processing.

## B] Oxides of Nitrogen Analyser:

### a) Theory of operation:

Oxides of Nitrogen [NO - NO<sub>2</sub> - NO<sub>x</sub> ] monitor measures NO concentration in the sample gas stream. The NO molecules oxidized with O<sub>3</sub> molecules forming excited NO<sub>2</sub><sup>\*</sup> molecules for a fraction of seconds and which returns to a fundamental electronic states generating luminous radiation on a spectrum of wave length 600 to 1200 nm.



This energy can be lost by the process of quenching due to other molecules found with the sample air, so this is avoided by lowering the pressure in the reaction chamber and better luminous yield. The best luminous result at the reaction chamber is obtained at a vacuum pressure of 762 mm of Hg.

The ambient air sample is divided into two air sample steam, one of the air sample stream is drawn into the NO<sub>x</sub> measuring chamber of the instrument through NO converter (molybdenum converter) and the other air sample stream is directly drawn into the NO measuring chamber without NO converter. There is an ozone generator in the instrument, where the dry air is passed through a high voltage (4.5 kV) electrical current between two cylindrical, coaxial electrodes at its corona discharge operation generates ozone and the ozone so generated is proportion to the current passing between the electrodes. The inner electrode consists of stainless steel cylinder, the external electrode formed by a glass cylinder covered by a thin metal sheet and is connected to the ground. The principle of measurement is Chemiluminescence, the NO gas component in the sample gas reacts with Ozone (O<sub>3</sub>) under 30 inch vacuum producing NO<sub>2</sub> of higher orbit electronic configuration which is instantaneous for a fraction of second and returns to its lower stable electronic orbit configuration during this process light is emitted which is called chemiluminescent and is detected by the photomultiplier. The instruments have the inbuilt Ozone generator, driers, etc.

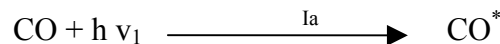
C] Carbon monoxide analyzer:

a) Theory of operation:

Carbon-monoxide monitor, measures CO concentration on the principle of correlation of the absorption of non-destructive infra-red light (NDIR). The CO has an absorption light spectrum of wave length between 4.67  $\mu\text{m}$  ( $2143\text{ cm}^{-1}$ ) to 4.72  $\mu\text{m}$  ( $2119\text{ cm}^{-1}$ ) in the infrared region of the spectrum.

The absorption spectrum is not continuous so a gaseous filter or the reference filter is associated to the optical bench or a known gas concentration of CO in the divided measuring chamber, this is known as the correlation system. The optical chopper wheel directs the infrared spectrum (i) opaque part of wheel, (ii) open part of wheel which let the filtered spectrum of 4.7  $\mu\text{m}$  into the measuring sample gas chamber, and (iii) a cell filled with known concentration of CO called the reference part of the wheel or in other type of instrument it guides the infrared spectrum of 4.7  $\mu\text{m}$  into a known gas concentration chamber of CO beside the measuring chamber.

As per the Einstein relation, the energy of a photon  $E = h\nu = h(c/\lambda)$  where  $\lambda$  is the radiation wave length output,  $h$  is the Plank's constant and  $c$  represent the speed of light in vacuum.



Here  $h\nu_1$  is the quantum of energy absorbed by the CO molecules and  $I_a$  is the light intensity absorbed by the CO molecules in terms of the incident light,  $I_0$ , i.e. the radiation intensity absorbed by Carbon monoxide gas molecule in an optical chamber of length 'x' follows the Beer-Lambert law:

$$\text{then } I_a = I_0 [1 - e^{-\{a \times (\text{CO})\}}]$$

Here,  $a$  – is the absorption coefficient of CO,  $x$  – is the optical path length, and  $(\text{CO})$  is the concentration of CO.

$$\text{Natural Log of this equation reduces to } I_a = I_0 [1 - e^{-\{a \times (\text{CO})\}}]$$

$$\text{Ln} \left[ \frac{I_a}{I_0} \right] = a \times (\text{CO}) \text{ at } P_0 \text{ and } T_0$$

The infrared spectrum when passing through reference known CO concentration cell, then

$$\text{Ln } I_a' - \text{Ln } I_0 = a \times (\text{CO})' \text{ at } P_0 \text{ and } T_0$$

The infrared spectrum when passing through unknown CO concentration cell, then

$$\text{Ln } I_a - \text{Ln } I_0 = a \times (\text{CO}) \text{ at } P_0 \text{ and } T_0$$

The above equation reduces to:

$$\frac{\text{Ln } I_a - \text{Ln } I_0}{\text{Ln } I_a' - \text{Ln } I_0} = \frac{(\text{CO})}{(\text{CO})'}$$

$$(\text{CO}) \text{ ppm} = 10^6 \left[ \frac{\text{Ln } (I_a / I_0)}{\text{Ln } (I_a' / I_0)} \right] (\text{CO})'$$

$$(\text{CO}) \text{ ppm} = 10^6 \left[ \text{Ln} \left( \frac{I_a}{I_a'} \right) \right] (\text{CO})'$$

Where:

$I_a$  = Filtered infrared spectrum energy passing through the reference cell containing known concentration of CO gas measuring cell and measured photometrical when sample does not contain carbon-monoxide gas molecules (passing through selective filter).

$I_a'$  = Filtered infrared energy passing through the measuring cell of the gas sample containing CO molecules and measured photometrical.

$(\text{CO})'$  = Is the know reference CO gas concentration.

$(\text{CO})$  = Is the unknown gas concentration containing CO molecules.

The sensitivity of the non-dispersive infrared technique is determined principally by electrical and optical noise and also the performance of the signal processing components, in most of the case it depends upon the amplifier gain.

Assumption of linearity in the scale proportion, introduces an error because of the logarithmic nature of the absorption.

b) Interference:

The inference may arise from gases that absorbs infrared spectrum radiation in band with overlapping that of CO, error due to this is relatively small for CO being hetero-nuclear diatomic gas, and its absorption peak at  $4.6 \mu\text{m}$  ( $2165 \text{ cm}^{-1}$ ), at this point the principal interference would be from water vapour ( $\text{H}_2\text{O}$ ) and carbon-dioxide ( $\text{CO}_2$ ), the positive interference from water vapour would be more likely in the range of 3 to 5 ppm. The inference from water vapour can be minimized by providing a means of drying the sample.

c) Calibration:

The instrument calibration is most important as precession and accuracy of the CO measuring, depends upon the accuracy of carbon-monoxide in the zero air and the span gas. Analyser's errors due to inaccuracy zero and span gas are more difficult to assess. Errors of  $\pm 2$  to 3 ppm are common with certified cylinder sources. Error in zero gas leads to greater relative inaccuracies in low concentration samples than due to error in span gas. If possible, a true Carbon-monoxide free zero gas to be used.

Assumption of linearity in the scale proportion, introduces an error because of the logarithmic nature of the absorption. For greater accuracy a calibration curve should be prepared from experimental data using variable span gas concentrations.

If a single concentration span gas is used for calibration, the value should be approximately  $2/3$  of the maximum expected concentration. This will minimize the mean error for the concentration frequency distribution expected in the air sample.

D] Ozone gas analyzer (UV Photometry):

a) Theory of operation:

Ozone monitor measures the  $\text{O}_3$  concentration in the ambient air on the principle of absorption of ultraviolet radiation and measurement by photometry. The difference in the photometry measurement of UV light absorbed by the sample gas gives the value of  $\text{O}_3$  concentration.

The ozone gas absorbs UV spectrum with a wave length range from 180 to 320 nm. The best absorption spectrum is to a wave length of 253.7 nanometer,

which corresponds to the main emission line of the low pressure mercury vapour lamp and the corresponding absorption coefficient for ozone is  $308 \text{ atm}^{-1} \cdot \text{cm}^{-1}$  at Pressure  $P_0 = 101.3 \text{ k Pa}$  and Temperature  $T_0 = 273 \text{ }^\circ \text{K}$  [ $0 \text{ }^\circ \text{C}$ ].

As per the Einstein relation, the energy of a photon  $E = h\nu = h(c/\lambda)$  where  $\lambda$  is the radiation wave length output,  $h$  is the Plank's constant and  $c$  represent the speed of light in vacuum.



Here  $h\nu$  is the quantum of energy absorbed by the  $\text{O}_3$  molecules and  $I_a$  is the light intensity absorbed by the  $\text{O}_3$  molecules in terms of the incident light,  $I_0$ , i.e. the radiation intensity absorbed by Ozone gas molecule in an optical chamber of length 'x' follows the Beer-Lambert law:

$$\text{then } I_a = I_0 [1 - e^{-\{a \times (\text{O}_3)\}}]$$

Here,  $a$  – is the absorption coefficient of  $\text{O}_3$ ,  $x$  – is the optical path length, and  $(\text{O}_3)$  is the concentration of  $\text{O}_3$ .

Natural Log of this equation reduces to  $I_a = I_0 [1 - e^{-\{a \times (\text{O}_3)\}}]$

$$\text{Ln} \left[ \frac{I_a}{I_0} \right] = a \times (\text{O}_3) \text{ at } P_0 \text{ and } T_0$$

$$(\text{O}_3) \text{ ppm} = \frac{10^6}{a \times x} \text{Ln} \left[ \frac{I_a}{I_0} \right] \cdot \frac{P_0}{P} \cdot \frac{T}{T_0}$$

Where:

$a \times x$  = instrument constant and is called the calibration coefficient.

$x$  = optical path length of the instrument which is  $73.5 \text{ cm}$

$a$  = the absorption coefficient of  $\text{O}_3$  which is  $308 \text{ atm}^{-1} \cdot \text{cm}^{-1}$

$I_0$  = UV energy passing through the measuring cell and measured photometrical when sample does not contain ozone gas molecules (passing through selective filter).

$I_a$  = UV energy passing through the measuring cell and measured photometrical when the sample contains ozone gas molecules (direct passage).

b) Calibration:

The instrument is calibrated with the known value of ozone generated by an ozone generator where the dry air is passed through a high voltage electrical current between two electrodes at its corona discharge operation generates ozone and the ozone so generated is proportion to the current passing between the electrodes. The system is enclosed in glass housing. The external of the house is coated with silver conductive paint. The ozone is formed when high voltage is applied to the internal electrode and discharge through the air to the outer electrode formed by the conductive paint. The analyser requires periodical multi-point calibration and subsequent zero / span checks.

Zero gas / purified air which is free from ozone ( $< 2 \text{ ppm}$ ) is used for zero calibration of the instrument.

c) Analysis:

(i) The air sample to be analysed is free from dust particulate, soots, before it is directed to the absorption cell / chamber, optical bench where it is irradiated by

the ultra violet radiation at 254 nm which is the absorption wavelength of O<sub>3</sub> molecules and detector.

- (ii) The sample air is circulate by a solenoid valve once through ozone scrubber / filter consisting of MnO<sub>2</sub> for 4 second then to the absorption cell and once directly into the absorption cell without the scrubber for 4 seconds. One complete cycle is approximately 10 seconds.
- (iii) The temperature sensor, flow sensor and pressure sensor with flow limiter and suction pump is the basic of gas flow system of the instrument with charcoal scrubber of ozone neutralization before sample air is discharged into the atmosphere.

E] Suspended Particulate Matter (Respirable Particulate Matter) (PM<10μ) analyzer:

a) Theory of operation:

Beta gauge dust measuring system consists of a carbon 14 radioactive source (14C) located in the source holder which can be positioned into two positions:

- Non measurement, storage position, when collecting particle by vacuum / suction pump or when the system is shut down.
- For measurements, aligned with Geiger counter.

A Geiger-Muller tube detector located on the same axis, downstream of the ribbon filter which collects the particle suspended in the air sample.

The ribbon filter is made of glass fiber with mass of 6.9 mg/cm<sup>3</sup> and collecting efficient of the particle size of 0.3 to 15 μm is better than 99.99%.

The low-energy Beta rays are absorbed by the matter consist of the dust deposited on the glass filter and the said filter material by collision with the electrons whose number is proportion to the density of dust collected on the glass filter and the filter material. The electron count during the blank filter is deducted from the electron count of the dust & filter material count which will give the electron count due to dust particle deposited on the filter only.

The absorption is governed by exponential law and is independent of the physical-chemical nature of the matter. The differential measurement is used to compensate for non-uniformity of the filter hen calculating the mass of the deposited dust, it also compensate for the variation in temperature of the weight of air knife.

a) Blank filter at start of cycle

$$N_1 = N_0 e^{-k(m_0 + m_1)}$$

Where

N<sub>0</sub> is electron count without absorbent.

N<sub>1</sub> is the electron counts per second on blank filter (air + filter)

m<sub>0</sub> is mass density of blank filter (mg / cm<sup>2</sup>)

m<sub>1</sub> is the mass density of air (mg / cm<sup>2</sup>) at temperature T<sub>1</sub>

$$\text{Then } m_1 = \rho_0 V / S = \rho_0 T_0 V / (T_1 \cdot S)$$

Where

$$T_0 = 273.15 \text{ K ; } \rho_0 = 1.293 \text{ g / l}$$

$$V = 1.8 \times 10^{-3} \text{ l ; } S = 2 \text{ cm}^2$$

b) Charged filter at the end of period or cycle

$$N_2 = N_0 e^{-k(m_0 + \Delta m + m_2)}$$

N<sub>2</sub> is the electronic counts per second through matter (filter + collected dust + air)

Δm is the density of particles deposited on the filter

m<sub>2</sub> is the density of air (mg / cm<sup>2</sup>) at temperature of T<sub>2</sub>

From the above two relation reduces to

$$(N_1 / N_2) = e^{-k(\Delta m + m_2 - m_1)}$$

and  $\Delta m + m_2 - m_1 = - (1/k) \text{Ln} [N_1 / N_2]$

$$\Delta m = (1/k) \text{Ln} [N_2 / N_1] + m_1 - m_2$$

$k' = (1/k)$  is the monitored calibration constant =  $[0.156 / 0.022]^{4/3}$   
The value  $[0.156 / 0.022]^{4/3}$  is expressed in  $\text{mg} / \text{cm}^3$  and is determined experimentally.