CONCENTRATION ESTIMATION OF DIFFERENT GASEOUS POLLUTANTS OF RAIPUR CITY

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ABSTRACT

The present study has been conducted at Collectorate and Shankar Nagar of Raipur city for a period of one year i.e., from April 2016 - March 2017 as well as at NIT and Science College Campus of Raipur city for a period of another one year i.e., from April 2017 - March 2018. The average mass concentration measurements from April 2016 - March 2017 of SO₂ at Shankar Nagar were found to be 28.0±11 µg/m³ while for NO₂ it was 23.0±14 µg/m³. At Collectorate, for SO₂ and NO₂, the yearly average mass concentration was found to be 28.7±11 µg/m³ and 23.1±15 µg/m³, respectively. Also, the yearly average mass concentration measurements from April 2017 - March 2018 of SO₂ at Science College Campus was found as 17.8±7 µg/m³ while for NO₂ it was 15.5±3 µg/m³. At NIT, for SO₂ and NO₂, the yearly average mass concentration was found to be 17.1±7 µg/m³ and 14.5±3 µg/m³ respectively. These average values are well within the NAAQS standards (50 µg/m³ for SO₂ and 40 µg/m³ for NO₂). The concentrations were higher in winters suggesting that industrial activities are one of the causes of the increase in the mass concentration of gaseous pollutants.

Keywords: Gaseous Pollutants, Mass Concentration, Seasonal Variation, Shankar Nagar, Collectorate Campus, Science College Campus, NIT Campus.

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INTRODUCTION

Air pollution involves those particles or chemicals in the air which degrades the quality of air and causes harmful effect to human health¹. The natural processes such as volcanic eruptions and wildfires may contaminate the air, however frequently; it is brought about by human activities like transportation, mechanical work, construction, mining, agriculture, smelting, etc. The air pollutants like Particulate Matter (PM), Black Carbon, Ozone, Nitrogen Oxides (NO_x), Sulphur Oxides (SO_x), Carbon Monoxide (CO), heavy metals and black smoke are often analyzed from the assessment of air quality.²⁻³

The mostly monitored air pollutants in the ambient air are Nitrogen dioxide (NO₂) and Sulphur dioxide (SO₂) due to their effects on the human respiratory system, their contribution to the ecosystem acidification, the acidifying of airborne particulate matter and its health effects and also the contribution of NO₂ in the photochemical oxidants formation⁴. They also cause visibility impact when converted into ambient aerosols. Anthropogenic emissions of nitrogen oxides mostly involve the result of combustion processes like combustion of fuel from vehicles⁵ and also coal, oil, natural gas from industrial processes. The nitrogen oxides are discharged from diesel engines as Nitrogen Dioxide (NO₂), is five times more toxic than Nitric Oxide (NO). Nitrogen dioxide, nitric oxide and different oxides of nitrogen are broadly known as NO_x⁶. Nitrogen oxides cause detrimental effects on public welfare and environment, involving global warming and stratospheric ozone depletion. NO_x reacts with water in the atmosphere to produce nitric acid which on precipitation with raised levels of hydrogen ions causes acid rain which affects the plants, animals and human and our infrastructure.⁷⁻⁸

SO₂ is used as an indicator for the large group gaseous Sulphur Oxides (SO_x)⁹. SO₂ is a prime component for acid rain precursor, and its oxidative product sulphate plays a significant role in climate radiative forcing¹⁰. Burning of fossil fuels by power plants and other industrial facilities are the main sources of

SO₂ in the atmosphere¹¹. Therefore, in this study, the SO₂ and NO₂ mass concentration measurement has been done at Shankar Nagar, Collectorate, Science College and NIT Campus of Raipur from April 2016 to March 2017 and April 2017 to March 2018, respectively.

EXPERIMENTAL

Study Area

Raipur city (latitude: 21° 13' N, longitude: 81° 37' E, altitude: ~290 m above sea level), the capital of Chhattisgarh is known as the business center place of surrounding cities and adjoining states. It is considered as a prominent center for education and business. As per 2011 census, the Raipur urban agglomeration has a population of about one million. It has a tropical wet and dry climate. Because of local industrial and human activities as well as regional transport, the city is exposed to high levels of gaseous pollution. The air quality of the city is deteriorating day by day which causes various health impacts and also environmental damage. All the measurements were done following the guidelines defined by the Central Pollution Control Board, New Delhi.

Sampling Site-1

Shankar Nagar (Latitude: 21.25° N and Longitude: 81.67° E), a residential site has been selected for the monitoring of the mass concentration of gaseous pollutants like SO₂, NO₂ for a period of one year i.e. from April 2016 to March 2017. For comparison purposes, we have also collected the same day/time gaseous pollutants data monitored at Collectorate Campus, a traffic interaction site which is an online ambient air monitoring station established by Chhattisgarh Environmental Conservation Board (CECB) (Figure 1) using UV Fluorescence (Model 100E, Teledyne Instruments) and Chemiluminescence method (Model 200E, Teledyne Instruments) for the measurement of sulphur dioxide and oxides of nitrogen in the ambient air respectively.

Sampling Site-2

Science College Campus (Latitude: 21.23° N and Longitude: 81.60° E), the residential and educational hub of Raipur city, has been selected for the monitoring of the mass concentration of gaseous pollutants like SO₂ and NO₂ for a period of one year i.e. from April 2017 to March 2018. For comparison purposes, we have also collected same day/time gaseous pollutants data at NIT campus which is an online ambient monitoring station established by Chhattisgarh Environmental Conservation board (CECB) (Figure 1) using Ultraviolet Fluorescence Method (APSA – 370) and Chemiluminescence method (APNA – 370) for the measurement of sulphur dioxide and oxides of nitrogen in the ambient air respectively. The various gaseous pollutants are measured by the following methods:

Measurement Principle of SO₂ (Online)

When the ultraviolet rays (215 nm) are irradiated over a sample, the SO₂ emits light of a distinct wavelength (peak: 320 nm, range: 240-420 nm) from that irradiated. The former irradiated light is the exciting light while the later emitted light is the fluorescence light. This method of deriving the concentrations of the samples by measuring the intensity of the fluorescence is known as the fluorescence method (Fig.-2,4). In this method, the fluorescence which is radiated in all the directions is generally observed at the right angles to the excitation light for preventing the interference by this excitation light¹².

Measurement Principle of NO₂ (Online):

When to the sample gas containing nitrogen oxide (NO_x), ozone is introduced; a part of the nitrogen monoxide (NO) in the sample gas gets oxidized to nitrogen dioxide (NO₂) while some of the generated nitrogen dioxides is in the excited state (NO₂^{*}) which emits the light in the de-excitation state. This present phenomenon of light emission is known as chemiluminescence¹².

The reaction is extremely fast thus involves only NO and so gets very little affected by the other coexistent gases. This reaction method which is used to measure NO concentration is called the chemiluminescence method (CLD method).

The sampled gas in the analyzer is divided into two flows: one is used for NO_x (NO + NO₂) concentration measurement by reducing NO₂ to NO with a NO_x converter while the other is used for direct NO concentration measurement. The sample gases after switching to the NO_x, NO and the reference gas are introduced to the reaction chamber (Figure 3,4). On the other hand, the open air is sucked, dried and used to form ozone in an ozonizer which is finally introduced in the reaction chamber. Here, the sample and the ozone react and the light emission in the reaction is detected by the photodiode.

This device calculates the NO, NO₂ as well as NO_x concentrations from the output obtained from the photodiode, those which are proportional to the NO₂ and NO concentrations and finally output the results as the continuous signals.

Fig.-1: Study Area of Raipur City (Latitude: 21°13'N, Longitude: 81°37'E, Altitude ~290 meters from the sea level)

Site-1: Shankar Nagar (Offline) and Collectorate (Online)

Site-2: Science College (Offline) and NIT (Online)

Measurement of Nitrogen Dioxide (NO₂) (Offline)

Ambient nitrogen dioxides were collected by bubbling known volume of air through a solution of sodium hydroxide and sodium arsenite⁹. The concentration of nitrite ion produced during sampling was determined calorimetrically by reacting the nitrite ion with phosphoric acid, sulphanilamide and N-(1-naphthyl)ethylenediamine dihydrochloride (NEDA) and measuring the absorbance of the highly colored azo-dye at $\lambda_{\max}$ 540 nm¹³. A blank sample, in the same manner, was prepared by un-exposed absorbing agent and concentration of NO₂ was determined from the calibration curve^{9,12}.

Measurement of Sulphur Dioxide (SO₂) (Offline)

The ambient air samples for sulphur dioxide were collected by absorbing SO₂ from a known volume of air absorbed in a solution of potassium Tetrachloromercurate (TCM). A stable dichloro sulphitomercurate complex formed was then made to react with pararosaniline and methyl sulphonic acid⁹. The absorbance of the colored solution was measured at $\lambda_{\max}$ 530 nm using spectrophotometer¹³. The concentration of sulphate ions formed in absorbent was calculated according to modified West & Gaeke Method^{9,12}.

Fig.-2: UV Fluorescence Method for Measurement of Sulphur Dioxide (SO₂) Fig.-3: Chemiluminescence Method for Measurement of Nitrogen Dioxide (NO₂)

Meteorological Parameters

The daily major meteorological parameters¹⁴ such as temperature, relative humidity, wind-speed, and wind direction of the study area during sampling period were collected from Indira Gandhi Agriculture University, Raipur to check the effect of local meteorology on pollution levels.

RESULTS AND DISCUSSION

Based on the adverse impact of these gaseous pollutants (SO₂, NO₂) on human health and environment, the CPCB has authorized the daily as well as the annual limit of SO₂ as 80 µg/m³ and 50 µg/m³, respectively, NO₂ as 80 µg/m³ and 40 µg/m³, respectively. The mass concentration measurements from April 2016 - March 2017 (Table-1a and 1b, Fig.-5a and 5b) of SO₂ at Shankar Nagar were in the range of 10.8±11 - 45.7±11 µg/m³ with an average 28.0±11 µg/m³ while for NO₂ it was in the range 4.3±14 -

$42.9 \pm 14 \mu\text{g}/\text{m}^3$ with an average of $23.0 \pm 14 \mu\text{g}/\text{m}^3$. At Collectorate, SO_2 ranges as $10.1 \pm 11 - 47.5 \pm 11 \mu\text{g}/\text{m}^3$ and NO_2 ranges as $3.6 \pm 15 - 45.1 \pm 15 \mu\text{g}/\text{m}^3$. Also for SO_2 and NO_2 , the average mass concentration was found to be $28.7 \pm 11 \mu\text{g}/\text{m}^3$ and $23.1 \pm 15 \mu\text{g}/\text{m}^3$, respectively. The mass concentrations were higher¹⁵ in winters followed by spring, summer and lowest in monsoon for SO_2 and for NO_2 , higher concentrations were found in spring followed by winters, monsoon and lowest in summer (Fig.-7).

Fig.-4: NO_2 and SO_2 Analysers at Collectorate Campus (Online)

Also, the mass concentration measurements from April 2017 - March 2018 (Table-2a and 2b, Fig.-6a and 6b) of SO_2 at Science College Campus were in the range of $8.6 \pm 7 - 27.2 \pm 7 \mu\text{g}/\text{m}^3$ with an average $17.8 \pm 7 \mu\text{g}/\text{m}^3$ while for NO_2 it was in the range of $13.3 \pm 3 - 23.7 \pm 3 \mu\text{g}/\text{m}^3$ with an average $15.5 \pm 3 \mu\text{g}/\text{m}^3$. At NIT, SO_2 ranges as $8.1 \pm 7 - 25.6 \pm 7 \mu\text{g}/\text{m}^3$ and NO_2 ranges as $11.8 \pm 3 - 22.7 \pm 3 \mu\text{g}/\text{m}^3$. Also for SO_2 and NO_2 , the average mass concentration was found to be $17.1 \pm 7 \mu\text{g}/\text{m}^3$ and $14.5 \pm 3 \mu\text{g}/\text{m}^3$ respectively. These average values are well within the NAAQS standards. The mass concentrations were higher in spring¹⁶ followed by winters, summer and lowest in monsoon¹⁶ for SO_2 and for NO_2 , higher concentrations were found in winters followed by spring, summer and lowest in monsoon (Fig.-8) which may be due to local burning activities, low wind speed, low temperature causes high loading in winter and spring months due to lower inversion layer caused by low mixing height that limits the dispersion. In winter, prevailing winds are mostly from North-East direction, i.e. from the industrial area of Raipur suggesting as one of the major contributors.

Table-1a: Average Monthly SO_2 and NO_2 Mass Concentrations as well as Meteorological Parameters (Temp. and RH) for Year April 2016 to March 2017

S. No.	Month and Year of Sampling	Mass Concentration (µg/m³)				Meteorological parameters	
		SO₂ (µg/m³)		NO₂ (µg/m³)			
		Online	Offline	Online	Offline	Temp. (°C)	RH (%)
1	April-16	21.16	20.10	10.11	10.91	33	27
2	May-16	21.32	20.51	07.61	08.37	30	48
3	June-16	23.73	22.78	07.62	08.76	30	63
4	July-16	19.96	20.56	03.58	04.26	26	86
5	Aug-16	10.12	10.83	18.39	20.05	26	86
6	Sep-16	18.28	18.09	12.47	13.72	26	84
7	Oct-16	31.79	29.56	23.82	23.58	24	67
8	Nov-16	42.92	39.74	36.15	35.43	20	55
9	Dec-16	47.45	45.65	39.25	37.29	18	56
10	Jan-17	38.54	40.47	33.14	32.48	18	57
11	Feb-17	34.92	34.75	45.11	42.85	21	47
12	March-17	34.32	33.36	39.78	38.39	26	36
13	Overall Average	28.71	28.03	23.09	23.00	25	59
14	Standard (24 hours)	80		80			
15	Standard (Annual)	50		40			

Table-1b: Seasonal and Annual Statistics of SO₂ and NO₂ Mass Concentrations and Meteorological Variations in Raipur from April 2016 to March 2017

Season	Mass Concentration (µg/m ³)				Meteorological parameters	
	SO ₂ (µg/m ³)		NO ₂ (µg/m ³)			
	Online	Offline	Online	Offline	Temp. (in °C)	RH (%)
	Mean±SD (Range) CV	Mean±SD (Range) CV	Mean±SD (Range) CV	Mean±SD (Range) CV	Mean±SD (Range) CV	Mean±SD (Range) CV
Spring	34.6±0.4 (34.3-34.9) 0.01	34.1±1.0 (33.4-34.8) 0.03	42.4±3.8 (39.8-45.1) 0.09	40.6±3.2 (38.4-42.9) 0.08	23.5±3.5 (21-26) 0.15	41.5±7.8 (36-47) 0.19
Summer	22.1±1.4 (21.2-23.7) 0.07	21.1±1.4 (20.1-22.8) 0.07	8.4±1.4 (7.6-10.1) 0.17	9.3±1.4 (8.4-10.9) 0.15	31±1.7 (30-33) 0.06	46±18.1 (27-63) 0.39
Monsoon	16.1±5.3 (10.1-19.9) 0.33	16.5±5.1 (10.8-20.6) 0.31	11.5±7.5 (3.6-18.4) 0.65	12.7±7.9 (4.3-20.1) 0.63	26.3±0.6 (26-27) 0.02	85.3±1.2 (84-86) 0.01
Winter	40.2±6.7 (31.8-47.5) 0.17	38.9±6.7 (29.6-45.7) 0.17	33.1±6.7 (23.8-39.3) 0.2	32.2±6.1 (23.6-37.3) 0.19	20±2.8 (18-24) 0.14	58.75±5.6 (55-67)
Annual	28.7±11.3 (10.1-47.5) 0.39	28±10.8 (10.8-45.7) 0.38	23.1±14.9 (3.6-45.1) 0.65	23±13.8 (4.3-42.9) 0.60	24.9±4.9 (18-33) 0.20	59.3±19.1 (27-86) 0.32

Table-2a: Average Monthly SO₂ and NO₂ Mass Concentrations as well as Meteorological Parameters (Temp. and RH) for Year April 2017 to March 2018

S. No.	Month and Year of Sampling	Mass Concentration (µg/m ³)				Meteorological parameters	
		SO ₂ (µg/m ³)		NO ₂ (µg/m ³)		Temp. (in °C)	RH (%)
		Online	Offline	Online	Offline		
1	Apr-17	18.86	20.37	22.74	23.65	35	24
2	May-17	12.38	13.74	13.58	15.07	36	33
3	June-17	08.10	08.56	12.82	13.97	31	64
4	July-17	08.19	09.42	13.06	14.37	28	81
5	Aug-17	08.94	09.21	12.50	13.25	28	82
6	Sep-17	12.10	13.19	12.70	13.72	29	76
7	Oct-17	19.10	18.91	16.80	18.65	29	68
8	Nov-17	20.10	20.70	16.65	16.57	26	57
9	Dec-17	25.63	27.17	14.14	14.28	24	48
10	Jan-18	24.07	23.83	13.45	14.66	23	40
11	Feb-18	25.56	25.05	13.40	14.07	27	41
12	Mar-18	22.37	23.49	11.76	13.29	32	29
13	Overall Average	17.12	17.80	14.47	15.46	29	54
14	Standard (24 hours)	80		80			
15	Standard (Annual)	50		40			

Table-2b: Seasonal and Annual Statistics of SO₂ and NO₂ Mass Concentrations and Meteorological Variations in Raipur from April 2017 to March 2018

Season	Mass Concentration (µg/m ³)				Meteorological parameters	
	SO ₂ (µg/m ³)		NO ₂ (µg/m ³)			
	Online	Offline	Online	Offline	Temp. (in °C)	RH (%)
	Mean±SD (Range) CV	Mean±SD (Range) CV	Mean±SD (Range) CV	Mean±SD (Range) CV	Mean±SD (Range) CV	Mean±SD (Range) CV
Spring	24.0±2.3 (22.3-25.6)	24.3±1.1 (23.5-25.1)	12.6±1.2 (11.8-13.4)	13.7±0.6 (13.3-14.1) 0.04	29.5±3.5 (27-32) 0.1	35±8.5 (29-41) 0.2

	0.09	0.05	0.09			
Summer	13.1±5.4 (8.1-18.9) 0.41	14.2±5.9 (8.6-20.4) 0.42	16.4±5.5 (12.8-22.7) 0.34	17.6±5.3 (14.0-23.7) 0.30	34±2.6 (31-36) 0.08	40.3±21.0 (24-64) 0.52
Monsoon	9.7±2.1 (8.2-12.1) 0.21	10.6±2.2 (9.2-13.2) 0.21	12.8±0.3 (12.5-13.1) 0.02	13.8±0.6 (13.3-14.4) 0.04	28.3±0.6 (28-29) 0.02	79.7±3.2 (76-82) 0.04
Winter	22.2±3.1 (19.1-25.6) 0.14	22.7±3.6 (18.9-27.2) 0.16	15.3±1.7 (13.5-16.8) 0.11	16.0±2.0 (14.3-18.7) 0.13	25.5±2.6 (23-29) 0.10	53.3±12.0 (40-68) 0.23
Annual	17.1±6.8 (8.1-25.6) 0.40	17.8±6.7 (8.6-27.2) 0.38	14.5±3.0 (11.8-22.7) 0.21	15.5±3.0 (13.3-23.7) 0.19	29±4.0 (23-36) 0.14	53.6±20.6 (24-82) 0.38

Fig.-5a: Monthly Variation in SO₂ Concentration at Shankar Nagar and Collectorate Campus from April 2016 to March 2017

Fig.-5b: Monthly Variation in NO₂ Concentration at Shankar Nagar and Collectorate Campus from April 2016 to March 2017

Fig.-6a: Monthly variation in SO₂ concentration at Science College and NIT Campus from April 2017 to March 2018

Fig.-6b: Monthly variation in NO₂ concentration at Science College and NIT Campus from April 2017 to March 2018

Fig.-7: Seasonal variation of Mass Concentrations of Pollutant Gases at Shankar Nagar (Offline) and Collectorate Sites (Online)

Fig.-8: Seasonal Variation of Mass Concentrations of Pollutant Gases at Science College Campus (offline) and NIT Campus (online)

CONCLUSION

The average mass concentration measurements from April 2016 - March 2017 of SO₂ at Shankar Nagar were found to be $28.0 \pm 11 \mu\text{g/m}^3$ while for NO₂ it was $23.0 \pm 14 \mu\text{g/m}^3$. At Collectorate, for SO₂ and NO₂, the yearly average mass concentration was found to be $28.7 \pm 11 \mu\text{g/m}^3$ and $23.1 \pm 15 \mu\text{g/m}^3$, respectively. Also, the yearly average mass concentration measurements from April 2017 - March 2018 of SO₂ at Science College Campus was found as $17.8 \pm 7 \mu\text{g/m}^3$ while for NO₂ it was $15.5 \pm 3 \mu\text{g/m}^3$. At NIT, for SO₂ and NO₂, the yearly average mass concentration was found to be $17.1 \pm 7 \mu\text{g/m}^3$ and $14.5 \pm 3 \mu\text{g/m}^3$ respectively. These average values are well within the NAAQS standards ($50 \mu\text{g/m}^3$ for SO₂ and $40 \mu\text{g/m}^3$ for NO₂). The concentrations were higher in winters since prevailing winds are mostly from North-East direction, i.e. from the industrial area of Raipur city suggesting that industrial activities are one of the major contributors to the increase in the mass concentration of gaseous pollutants.

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