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COMMUTERS EXPOSURE TO COMBINED AIR POLLUTANTS–A CASE STUDY IN JHARIA COAL FIELD

Keshav Kumar[1], Rajendra Kuamr Patel[2], Omprakash Thakare[2]
1. Research scholar, Department of health and safety, Shri Rawatpura sarkar University Raipur
2. Assistant Professor, Shri Rawatpura sarkar University Raipur

ARTICLE INFO **ABSTRACT** **ORIGINAL RESEARCH ARTICLE**

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Corresponding Author
***R. K. Agrawal**

The SPM and RPM level were found to be highest while moving between CFRI to CMRI which range from 821 to 1381 µg/m^3 and 450 to 743 µg/m^3 respectively which has the highest traffic density. SOx and NOx level were close to the national ambient air quality standards in between CFRI to CMRI. In between MM to BIT Sindri and mining areas of Jamadoba coalfield, the SOx and NOx levels were minimum in the range of 35-40 µg/m^3. The toxic heavy metals like cadmium, lead, arsenic, chromium and nickel were present in higher concentrations in the above stated routes while chromium and nickel were drastically higher (10 to 25 times) than the ambient air level. The overall of the present study in view of all the parameters chosen for study states that the commuters are exposed to higher concentrations for all the pollutants in the study area and the people living nearby road sides are also affected by the higher levels of the above stated parameters.

1. INTRODUCTION

The chance to live in a life supporting environment is a fundamental right for all the living beings including human. Environment addresses all the segments which support the life of an organism and the quality of environment decides its well-being. Earth from its formation onwards undergoes continuous change, and hence the change in environmental conditions became the decisive factors for the survival. Any unfavourable change in the quality of environmental segments termed as pollution and the causative agents for the same is termed as a pollutant.

Air pollution

Air is considered to be polluted when it contains certain substance in concentrations high enough and for duration long enough to cause harm to the living organisms including human and interfere with the comfortable enjoyment of life or property, health, repose and safety.

There has always been a balance between natural source and sinks to air pollution, but human and industrial activities have created pollution problems that have overburden the natural removal of pollutants and are getting accumulated in the environment. The places from which pollutants emanate are called ‘sources’ and the destinations to which pollutants reach are called ‘sinks’ (soil, vegetation, animals etc.). Receptors are inanimate as well as animate bodies that receive and are seriously affected by pollutants.

The atmospheric air pollutants are present in different forms in the atmosphere as

- Gaseous: SOx, NOx, COx, H2S and other toxic gases.

- Vaporous: H2SO4, HNO3, Aerosols and Halogens.
- Particulate: Metals, Dust, Soot, Asbestos, Organics.
- Radioactive: Radioactive wastes, Radon progeny, Radionuclide.

Gases like oxides of sulphur and nitrogen (SOx and NOx), carbon monoxide (CO), ozone (O3), hydrogen sulphide (H2S), hydrogen Fluoride (HF), Chlorine gas (Cl2), hydrogen chloride and aldehydes are the pollutant gases present in the atmosphere which are detrimental to the environment and human health. Besides these gases, aerosol particles are also present in the atmosphere as a pollutant.

Oxides of sulphur are major pollutant gas. About 99% of SOx in atmosphere comes from human sources like burning of fossil fuels like coal, petroleum product, and sulphur

2. LITERATURE REVIEW

Particulate matters are heterogeneous mixture of very small particles and liquid droplets suspended in the air. It can be classified as Suspended particulate matter and Respirable particulate matter based on their size distribution. The particles with aerodynamic diameter less than 10 µm are the Respirable fractions which get inhaled by living organisms and reaches the lungs while the particle size above 10 µm are the suspended particulate matter. The size of the particulate matter is indirectly related to their potential health hazards. Less is the particle size more is the penetration. Respirable fractions of particulate matters have higher penetration and thus have higher health risk on inhalation than the suspended particulate matters.

J.E. Gomez-Perales et al (2003) [1] carried out survey to measure commuters' exposure to PM2.5, CO, benzene, and the chemical composition of PM2.5 on different routes and modes of transport in Mexico City. PM2.5, CO and benzene are presented from morning (6:30–9:30) and evening (17:30–20:30) rush hours on minibuses, buses and Metro (underground or subway system). Minibuses had a slightly higher geometric mean PM2.5 concentration in the morning than other modes of transport, but the ranking of geometric mean PM2.5 by mode of transport is opposite in the evening and the variability within modes is approximately double the difference between modes. The highest single measurement was a concentration of 137µg/m3 on a bus during an evening rush hour.

S Latham, S Kpllamthodi, et al (2001) [2] carried out work primarily to determine the amount of nitrogen dioxide in total oxides of nitrogen from a range of vehicle types and to evaluate the importance of primary nitrogen dioxide emission in the influencing atmospheric concentrations near to roads. The modelling exercise shows that NO2 concentration might be underestimated as much as 30% if the primary emissions were ignored. Pham van Luong, Do Dang Quan, et al (2007) [3] conducted a pilot study to get preliminary estimates of personal exposure to particulate matter (PM10) and CO while travelling on four major roads in Hanoi, Vietnam and investigated the effect of few factors such as mode of transport, route, rush hour, and air conditioning on exposure levels. Lightweight portable real time measurement devices were used on buses, cars, mobikes and while walking. The result obtained suggested that rush hour level of PM10 and CO was higher than Non rush hour and significant fall in PM level was obtained (nearly 62%) but no change in CO level in air conditioned car.

Mrinal K. Ghose, et al (ISM Dhanbad, 2004) [4] examined the effect of vehicular emission on urban air quality and human health and focuses on the unique features of an Indian mega city regarding its air pollution. A fact-finding survey was conducted to evaluate the status of air pollution at traffic intersections and the problem arising out of vehicular emissions in the study area. All the key pollutants were in excess of permitted levels. Vulnerable analysis (VA) had been carried out to evaluate the air pollution stress at different locations within the study area. Pramod Kumar and N. C. Gupta (2013) [5] carried out field study to measure exposure of particle number to commuter on four major commuting modes (in cabin mode: Bus, Car

and Auto rickshaw; on roadway mode: motorcycle). The result clearly shows that the level of exposure was significantly influenced by the commuting modes, showing a higher fine no (more than 99%) than coarse (less than 1 %) on roadway mode. Higher average concentrations of total particulate number were observed in motorcycle compared to auto rickshaw, bus and car in morning and in evening the order being bus, motorcycle, auto rickshaw and car respectively.

Moniek Zuurbier, Gerard Hoek, et al (2010) [6] studied differences in commuters' exposure to traffic related air pollution to transport mode, route and fuel type. They measured particle number counts (PNCs) and concentrations of PM2.5, PM10, and soot in diesel and electric buses, gasoline and diesel fuelled cars, and along two bicycle routes with different traffic intensities in Arnhem, the Netherlands. In addition, each-day measurements were taken at an urban background location. They found that median PNC exposures were highest in diesel buses and for cyclists along the high-traffic intensity route and lowest in electric buses. Median PM10 exposure was highest from diesel buses and lowest along the high and low traffic bicycle routes. The median soot exposure was highest in gasoline-fuelled cars, diesel cars, and diesel buses and lowest along the low-traffic bicycle. They calculated the minute ventilation (volume of air per minute) of cyclists which estimated from measured heart rates, was twice the minute ventilation of car and bus passenger and calculated that the inhaled air pollution doses were highest for cyclists. With the exception of PM10, they found that inhaled air pollution doses were lowest for electric bus passengers.

3. METHODOLOGY

Sampling routes of study area on Map

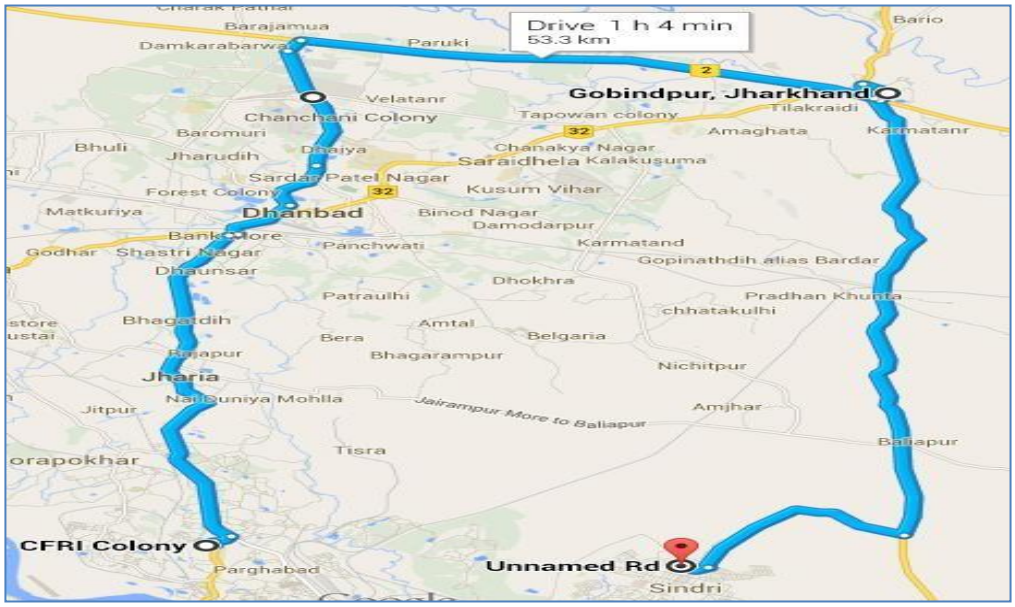

Fig 1: Sampling routes on map (CFRI-CMRI, CFRI-MM, and MM-BITS)

Study Area and Measurement Periods

This work is based on sample collection during winter season (November) and spring season (February) on four major roads of Jharia coal fields of Dhanbad district in Jharkhand. The four major routes selected were based on traffic density (i.e. most busy route and least busy route) and roads around coal mining areas. The sampling was done for three hours in morning time in between 10:00 am to 1:00

pm and 4:40 pm to 7:40 pm in evening time. For real time monitoring of pollutant exposure to commuters, the sampling instruments were installed on a moving vehicle and were run along the roads selected for sampling. The work was divided into (i) Sample Collection and (ii) Sample Analysis and the methodologies adopted for analysis were discussed below.

Sample collection

For collection of air samples, air was sucked using High Volume Sampler (HVS) and Respirable Dust Sampler (RDS). These two instruments were installed on a moving vehicle. SOx and NOx were collected in the impingers filled with their respective absorbing solutions. For collection of particulate matter, glass microfiber filters were used of different pore size. Respirable particulate matters were collected using Respirable dust sampler while suspended particulate matters were collected using High Volume Sampler.

Fig 2: High Volume Sampler

Fig 3: Respirable Dust Sampler

Pilot study was done to get the preliminary estimates of personal exposure to particulate matter (PM), SOx, NOx, PAH and heavy metals while travelling along the roads of Digwadih, Dhanbad, Govindpur, Jharia and Roads along the Coal Mining and coal washry areas in Jamadoba.

In order to get consistent and reproducible data, sampling was done in following manner.

- Sampling areas were divided into four sectors i.e. CFRI to CMRI, CFRI to Memco More, Memco More to BIT Sindri and roads in Jamadoba coal washry and mining areas.
- The vehicle was run all along the road maintaining a constant speed of 15-20 km/hr.
- Sampling was done in between 9:00 AM to 12:00 PM for morning peak hour and 4:00 PM to 8:00 PM for evening peak hour of each sector and three replicas were produced to get the consistent result.
- Memco more to BIT Sindri route was chosen as control with least traffic.

4. SAMPLE ANALYSIS

After each sampling, the absorbing solutions were collected in small bottles and final volume was noted for each sample. The SOx and NOx samples were analysed on the same day of sampling so that there would not be any loss in strength and result obtained would be accurate. The filter papers containing particulate matter were collected in plastic bags and were kept safe for further analysis. The sampling procedures of different parameters are described below.

SOx analysis:

The oxides of sulphur were analysed by preparing the sample for measuring the optical density using different chemical reagents. The optical density was measured using UV spectrophotometer at 540 nm.

Principle:

When the sulphur dioxide from the air stream is absorbed in a sodium

tetrachloromercurate solution, it forms a stable dichlorosulphito mercurate. The amount of sulphur dioxide is then estimated by the colour produced when p- rosaniline hydrochloride is added to the solution. The colour is estimated by a reading from an absorptimeter or spectrophotometer for which a calibration curve has already been produced.

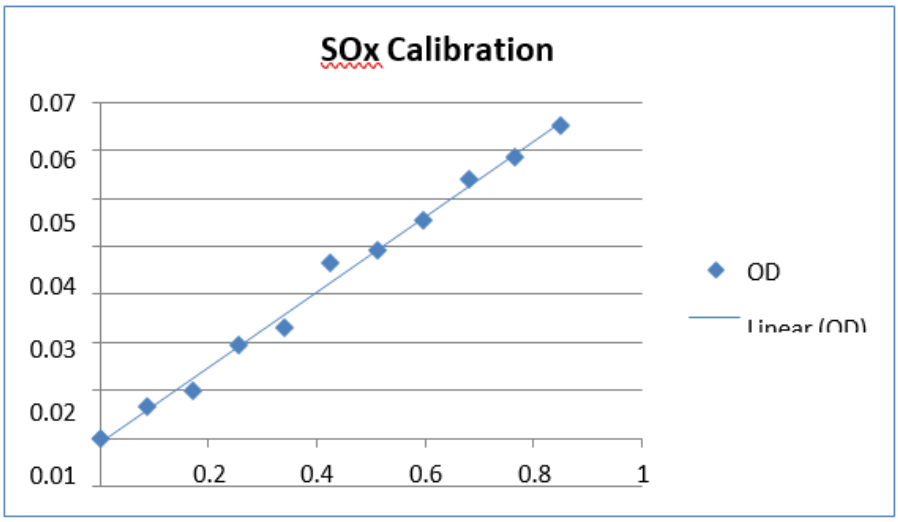

Fig 4. SOx calibration curve

X- axis: concentration of standard sulphite solution. Y- axis: Optical density of standard sulphite solution. From the equation of straight line,
m can be calculated as,

Y = mX + C
m = Y/X (Since, C=0)

m value obtained is 0.076 and calibration Factor (CF) = 1/m = 13.16

Analysis:
Concentration of SOx can be calculated in following steps

- Take 20 ml of sample solution in a 50 ml test tube.
- Add 1 ml of sulphanilic acid, 2 ml of formaldehyde solution, 2 ml of pararosaniline hydrochloride solution to it.
- Make up the final volume to 25 ml by adding absorbing solution.
- Treat a 10 ml portion of the unexposed sodium tetrachloromercurate solution in the same manner for use as the blank. If the collecting reagents remain exposed to the atmosphere during interval between sampling and analysis, the blank should be exposed in the same manner. After 20 min read the absorbance at 560 nm with the blank as reference.

Preparation of Standards:

Pipette 1, 2, 3, 4, 5, 6, 7, 8, 9, 10, 12, 15 and 20 ml of working standard solution in to 50 ml volumetric flask. Fill to 20 ml mark with absorbing solution. A reagent blank with 10 ml absorbing solution is also prepared. Add reagents to each volumetric flask as in the procedure for analysis. Read the absorbance of each standard and reagent blank against distilled water reference.

Standard Curve:

Plot a curve absorbance (Y axis) versus concentration (X axis). Draw a line of best fit and determine the slope. The reciprocal of slope gives the calibration factor (CF).

X	Y	m=Y/X
0	0	0
0.04	0.03	0.79
0.08	0.06	0.79

0.12	0.08	0.71
0.16	0.13	0.79
0.2	0.14	0.69
0.24	0.19	0.79
0.28	0.22	0.79
0.32	0.27	0.86
0.36	0.28	0.79
0.4	0.32	0.79
	Average	0.78

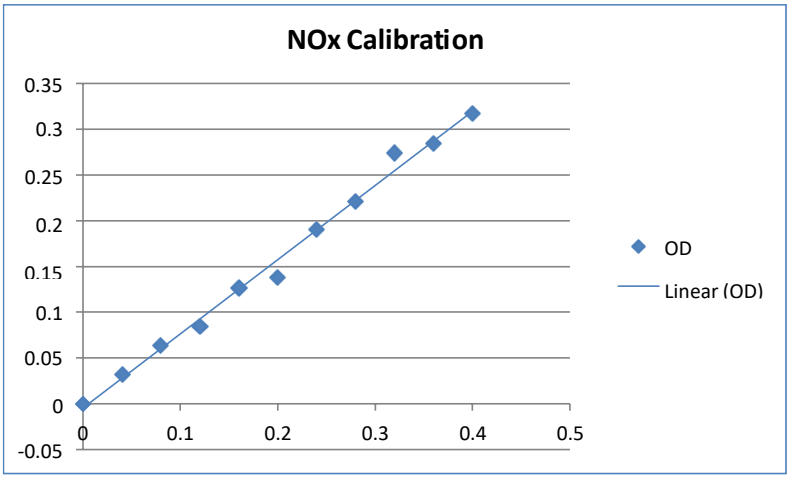

Fig 5. NOx Calibration Curve

Fig 6: Microwave Digester

Fig 7: Digested Samples of Heavy Metals

X- axis: concentration of standard solution. Y-axis: Optical density of standard solution. From the equation of straight line,

$Y = mX + C$

'm' can be calculated as,

$m = Y/X$ (Since, C=0)

'm' value obtained is 0.78 and Calibration Factor (CF) = 1/m = 1.28

Microwave Digester:

To perform an atomic absorption or atomic emission measurement the sample must be dissolved prior to analysis. It is often the case that the sample is not easily dissolved. In such situations fusion or acid digestion may be used, microwave digestion is a form of acid digestion. Microwave digestion usually involves placing a sample in an acid solution

and heating to high temperatures and pressures. These extreme conditions will dissolve most materials, but is potentially quite dangerous. The microwave oven has many safety features, all of which must be paid attention to when in use.

The ICP-OES is used to analyse the concentrations of heavy metals present in the digested samples obtained from the microwave digestion. It works on the principle of generation of specific wavelength from the heavy metals present in the sample followed by their detection through semiconductor photo detector such as charge coupled devices (CCDs). The torch present in the ICP-OES brings the sample in the plasma state with the help of radio frequency coil. The light intensity generated is measured with the photomultiplier tube to view the specific wavelengths and each intensity line is compared with the previously measured intensities of known concentrations of the elements, and their concentrations are then computed by interpolation along the calibration lines.

5. DISCUSSION

SOx and NOx are the gaseous pollutants produced mainly due to vehicular emissions and industrial activities. The permissible limit specified by the Indian standard for sensitive area, industrial area and residential areas are 30 µg/m3, 120 µg/m3, and 80 µg/m3 respectively during 24 hour sampling time. The results obtained through SOx and NOx analysis shows that SOx and NOx concentrations in the routes CFRI to CMRI and CFRI to MM was high and was nearly equal to the maximum permissible limit of their concentrations for residential area while in other routes SOx and NOx concentration ranges in between 30-40 µg/m3. The ambient air concentration of SOx and NOx were found to be 30-34 µg/m3 and 25-29 µg/m3 respectively. The SOx and NOx concentration in most busy route i.e. CFRI to CMRI were found to be in the range of 71- 80 µg/m3 and 65 - 74 µg/m3 respectively. This shows an elevated level of gaseous pollution in the above mentioned route.

Table 2: Variation in SOx and NOx over time and route.

S. No	Route	Time	SOx Range ($\mu g/m^3$)	NOx Range ($\mu g/m^3$)
1.	CFRI TO CMRI	10:00am to 1:00pm	71 – 79	65 – 72
		4:40pm to 7:40pm	74 – 80	68 – 74
2.	CFRI TO Memco Mod	10:00am to 1:00pm	68 - 75	59 – 65
		4:40pm to 7:40pm	70 – 78	60 – 67
3.	Memco Mod to BIT Sindri	10:00am to 1:00pm	33 – 38	28 – 34
		4:40pm to 7:40pm	33 – 39	30 – 35
4.	Jamadoba	10:00am to 1:00pm	36 – 39	32 – 35
		4:40pm to 7:40pm	38 – 42	32 – 37
5.	Residential Area	24 hour	30 – 34	25 - 29

6. CONCLUSION

The main conclusions regarding the second stated aim i.e. real time monitoring of basic air pollutants of the study area shows that:

 The SPM and RPM level in the most traffic route were found to be maximum in between CFRI to CMRI that range from 821 to 1381 µg/m3 and 450 to 743 µg/m3 respectively while that of ambient air concentration were around 145 µg/m3 and 90 µg/m3.This shows that commuters exposure to

SPM and RPM exposure were around 5-6 times higher as compared to ambient air level.

- In between MM and BITS, the SPM and RPM exposure level are comparable to the ambient air level.
- SOx and NOx level were found to be within the standard limit but were around twice as high as ambient air concentration in between CFRI to CMRI (70-80 µg/m3 SOx and 60-65 µg/m3 NOx). In between MM to BITS and Jamadoba Coal mining areas, SOx and NOx level were comparable to the ambient air quality.
- Polycyclic Aromatic Hydrocarbons being carcinogenic, mutagenic and teratogenic in nature is also a potential threat to human as it is very toxic even in nano grams. Their concentration were found to be 4.2 µg/m3, 3.7 µg/m3, 2.3 µg/m3, 2.3 µg/m3 and 2.2 µg/m3 in between CFRI-CMRI, CFRI-MM, MM-BITS, Jamadoba and Ambient air.
- The RPM fraction is also found to be very high in all the above routes.

The overall conclusion of the present study in view of all the parameters chosen for study states that the commuters are exposed to very high concentrations for all the pollutants in the study area and the people living nearby road sides are also affected by the higher levels of the above stated parameters.

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