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Silica Particulate Pollution in Central India

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Abstract

Asbestos exposure is known to cause asbestosis *i.e.* lung cancer (mesothelioma) with increased risk of diseases *i.e.* gastrointestinal, colorectal, throat, kidney, esophageal, and gallbladder cancer. Therefore, in the present work, the concentration of SiO_2 associated to the coarse and fine particulates in the ambient air of most industrialized area of central India *i.e.* Raipur city (capital of Chhattisgarh state) is described. The concentration of SiO_2 in ambient air associated to the PM_{10} and $PM_{2.5}$ was ranged from 6.6 to 102 and 0.2 to 15 μg/m^3 with mean value of 30.0 ± 6.0 and 4.3 ± 0.8 μg/m^3, respectively. The seasonal, spatial and temporal variations of SiO_2 in the air are described.

Keywords

Ambient Air, Particulate Matter, Silica, Trace Elements

1. Introduction

Silica is air toxics when inhaled or ingested during product use, demolition work, building or home maintenance, repair, remodeling, etc. [1]. Exposure to silica containing respirable particulates (<0.5 to 5.0 μm in diameter) over long time causes silicosis, lung cancer and airways diseases [1]-[4]. Some investigations of silica exposures were reported [5]-[20]. In the present work, the ambient exposure of silica associated to coarse and fine particulates in the most industrialized area of the central India (Raipur city, capital, Chhattisgarh state) is described.

2. Methods and Materials

2.1. Study Area

The Raipur city (latitude: 21˚24'N and longitude: 81˚63'E), capital of Chhattisgarh state, India, was selected for

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the present study due to running of several industries in this region. The population of city including suburb area is ≈2 million, and being an important regional commercial and industrial destination for the coal, power, steel and aluminum industries. Several steel and ferro-alloys industries are running in this city.

2.2. Particulate Collection

The Partisol Model 2300 Sequential speciation air sampler (Thermo Scientific, USA) was used for collection of the PM_{10} and $PM_{2.5}$ samples during period, June 2005 - May 2014. The PM_{10} and $PM_{2.5}$ samples were collected simultaneously on 47-mm teflon quoted PTVC filter (Whatmann) housed in molded filter cassettes. One sample blank was used for collection of PM_{10} and $PM_{2.5}$. The sampler was installed at the roof of the building, 3-m above from the ground level at residential site: Dagania (no. 2), Raipur, **Figure 1**. Similarly, PM collection was carried out in the commercial (Jaistambh, no. 3) and industrial area (Siltara, no. 1). The filter was prior heated up to 50˚C to reduce their blank value, and placed in clean polyethylene petri dish. The weighted filters were housed in the sampler and run for 24-hrs from 6.00 am - 6.00 am. The loaded filters were dismounted, brought to laboratory, transferred into the desicator, and finally weighted to record the particulate contents.

2.3. Analysis

The elemental analysis of the collected aerosol samples has been carried out by PIXE (Particle Induced X-ray

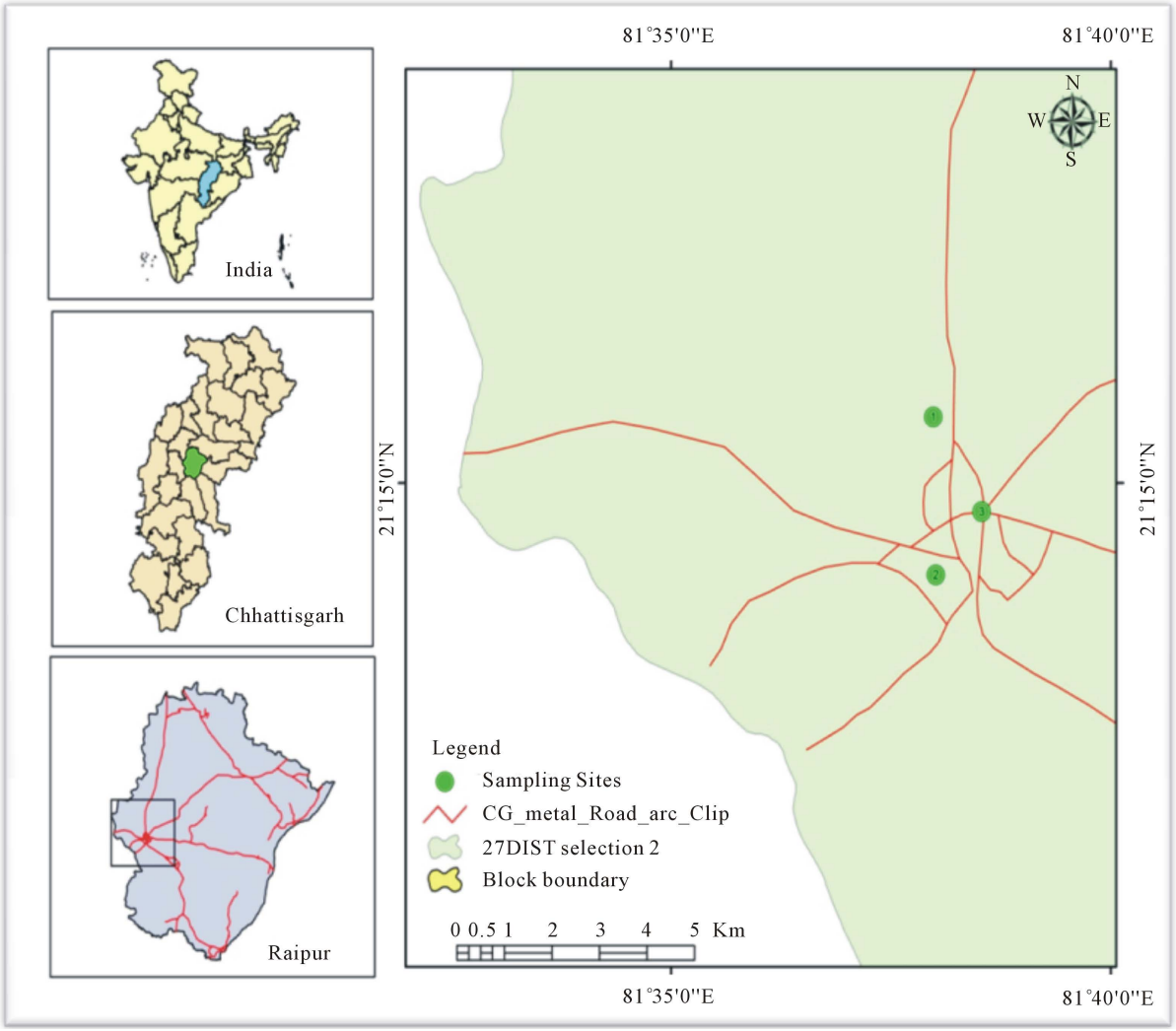

Figure 1. Sampling locations in Raipur city, CG, India.

Emission) technique, using the external beam set-up of the 3 MV Tandetron accelerator of the LABEC laboratory (INFN) in Florence, Italy.

3. Results and Discussion

3.1. Particulate Concentration

The annual (June 2005 - May 2006) mass concentrations of PM_{10} and $PM_{2.5}$ (n = 44) are in the range 37 - 501 μg/m^3 and 19 - 259 μg/m^3 with arithmetic mean value of 209 ± 38 μg/m^3 and 95 ± 18 μg/m^3, respectively, **Figure 2**. The annual mean ratio of [$PM_{2.5}$]/[PM_{10}] was found to be 0.46. The highest concentration of the PM_{10} and $PM_{2.5}$ was observed in the winter season (December - January), may be due to temperature inversion and lowest air mass speed. The lowest seasonal average concentration of PM_{10} and $PM_{2.5}$ observed was 50 and 20 μg/m^3, respectively, could be considered as background levels in Raipur city.

3.2. Elemental Concentration

The elements *i.e*. Na, K, Cl, Al, Si, S, Ca and Fe are main constituents of the PM. The annual mean concentration of Na, K, Cl, Al, Si, S, Ca and Fe in the ambient air associated to the PM_{10} was 1.0 ± 0.1, 3.4 ± 0.6, 1.9 ± 0.5, 6.6 ± 1.1, 15.9 ± 2.8, 3.4 ± 0.3, 9.8 ± 1.9 and 12.7 ± 2.5 μg/m^3, respectively, **Figure 3**. The concentration of Na, K, Cl, Al, Si, S, Ca and Fe in the air associated to the $PM_{2.5}$ was 0.5 ± 0.1, 1.5 ± 0.3, 0.8 ± 0.4, 1.0 ± 0.2, 2.0 ± 0.4, 3.1 ± 0.4, 0.9 ± 0.2 and 1.6 ± 0.4 μg/m^3, respectively. Silicon and sulfur showed the highest concentration in the PM_{10} and $PM_{2.5}$ mode, respectively, **Figure 3**.

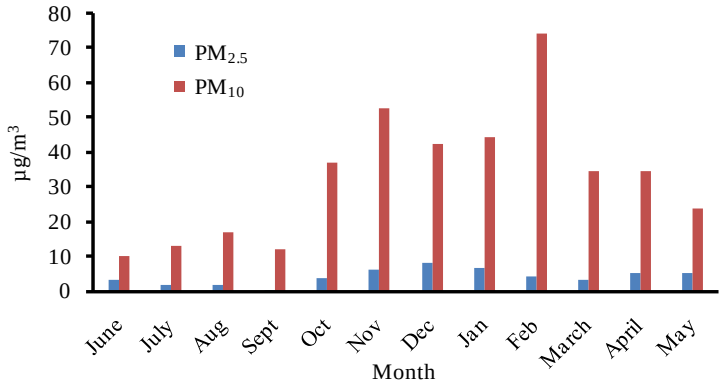

Figure 2. Distribution of PM_{10} and $PM_{2.5}$ in the ambient air of Raipur city at residential area during year, June 2005 - May 2006.

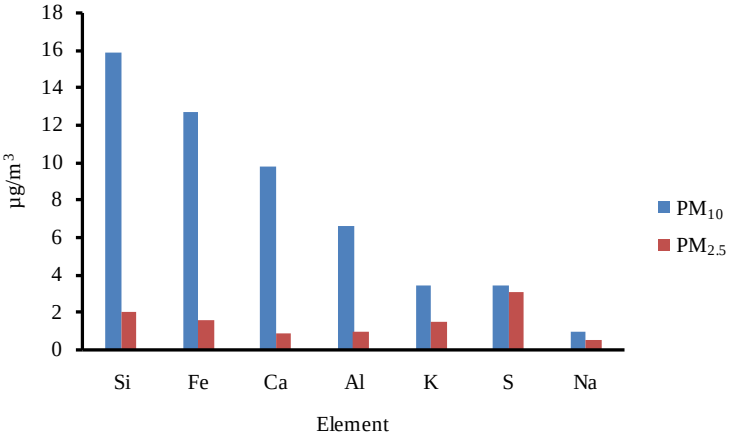

Figure 3. Annual mean concentration of major elements in ambient air associated to the PM_{10} and $PM_{2.5}$.

3.3. Silica Concentration

The existence of silicon in the particulates is assumed as silica, SiO_2, and a factor of 2.14 was used to compute SiO_2 concentration. The SiO_2 concentration associated to the PM_{10} and $PM_{2.5}$ was ranged from 6.6 - 102 and 0.3 - 15.1 µg/m^3 with mean value of 40 ± 6 and 4.5 ± 1.0 µg/m^3, respectively.

3.4. Seasonal, Spatial and Temporal Variations

The highest concentration of SiO_2 in the particulate phase was observed during month of February, 2006 mainly due to lowest wind speed (<2 km/hr) and higher temperature inversion, **Figure 4**. In turn, the lowest concentration of SiO_2 in the air was marked in the month of July due to the highest wind speed (>10 km/hr) and heavy rain fall (>50 cm/month). The SiO_2 concentration in the commercial area (CA) and industrial area (IA) was increased enormously, **Figure 5**. The temporal variation of SiO_2 was found to increase during year 2006 to 2009 due to vast industrialization, increase in vehicle numbers and unpaved nature of the road, **Figure 6**. Thereafter, the SiO_2 concentration was found to decrease may be due to use of control devices for industrial effluents and improving the road quality.

3.5. Silica Exposure

Exposure of silica beyond the threshold limit value (TLV) of 25 µg/m^3 in air causes respiratory diseases [6]. The annual mean value of silica exposed was 40 ± 6 µg/m^3, higher than the TLV value of 25 µg/m^3. The whole population is exposed with silica at elevated levels during period, October to April of a year.

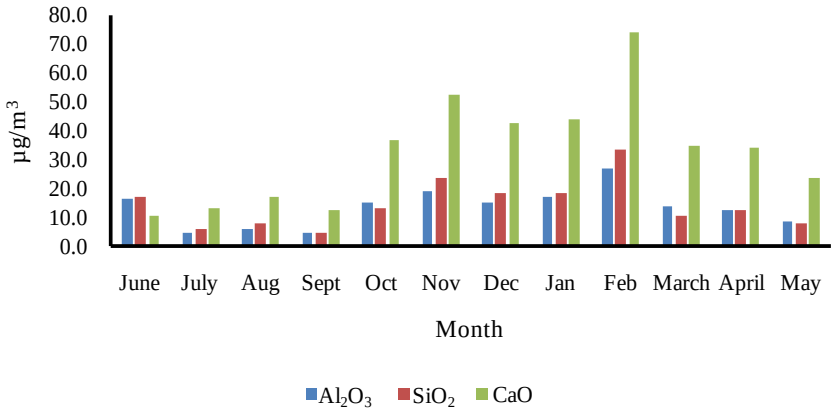

Figure 4. Seasonal variation of oxide of Al, Si and Ca.

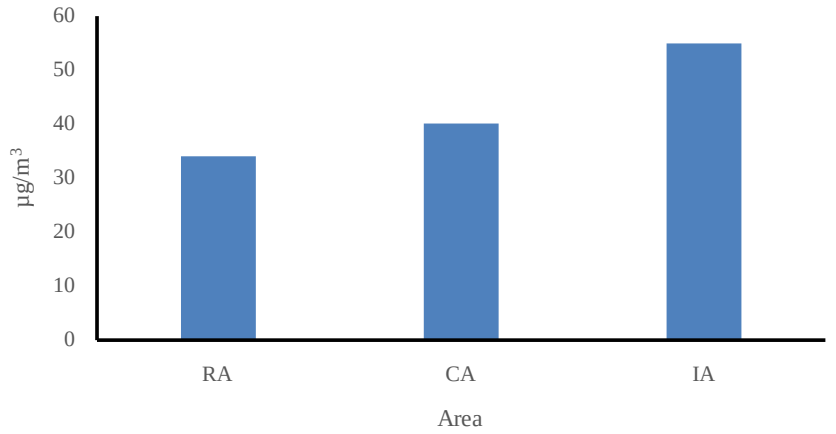

Figure 5. Spatial variation of SiO_2 in residential (RA), commercial (CA) and industrial area (IA) of Raipur city during February, 2006.

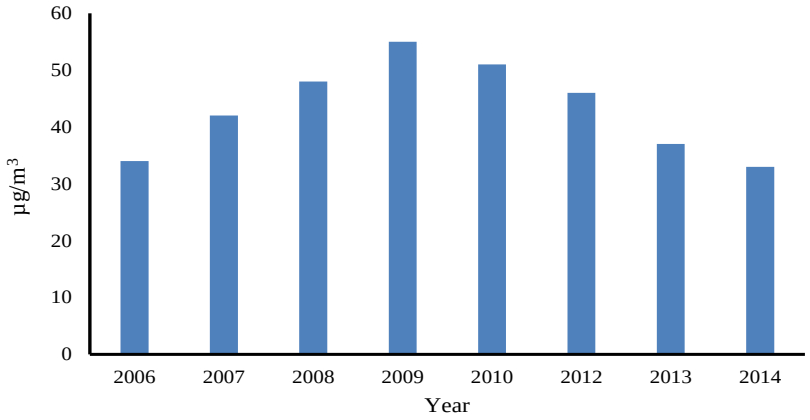

Figure 6. Temporal variation of SiO_2 in month of February at residential site of Raipur city.

4. Conclusion

The respirable aerosol concentration in the urban environment of India is found several folds higher than permissible limits during period, October - April of a year. They are associated with elevated levels of elements *i.e.* Si, Fe, Ca and Al. The concentration of silica in the ambient environment of Raipur city, central India was found to be higher than the permissible limit during period, October - April of a year. The mean silica concentration in the PM_{10} was observed to be 17.5% ± 1.7%.

Acknowledgements

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