5th International Conference on Fog, Fog Collection and Dew
Münster, Germany, 25–30 July 2010
FOGDEW2010-58

Fog chemistry in central India

K. S. Patel(1), B. Ambadey(1) and B. Blazhev(2)

(1)School of Studies in Chemistry, Pt. Ravishankar Shukla University, Raipur-492010, CG, India (patelks_55@hotmail.com)

(2)Central Laboratory for Chemical Testing and control, 1330-Saofia, Bulgaria

Abstract

The investigation of fog chemistry in the urban area is of great environmental and health hazard interests. In the present work, the fog chemistry in the most polluted area of central India, Raipur and its surrounding is described. Twenty two fog samples were collected in winter season, 2007-08 and their physiochemical properties were measured. The fog is yellowish in colour with neutral pH value except in coal burning site. The volume weighted concentration of species i.e. F^-, Cl^-, NO_3^-, SO_4^{2-}, NH_4^+, Na, K, Mg, Ca, Al, Mn, Fe, Cu, Zn, Pb and Hg is ranged from 1.7 – 2.4, 14.2 – 33.1, 11.4 – 23.8, 21.7 – 116, 2.8 – 8.2, 4.6 – 33.7, 4.8 – 22.4, 2.6 – 6.7, 8.5 – 18.5, 0.570 – 1.030, 1.100 – 1.640, 0.510 – 1.290, 0.080 – 0.117, 0.058 – 0.112 and 0.004 – 0.013 mg l^{-1} with mean value of 2.0±0.2, 23.6±7.0, 16.5±4.6, 46.9±28.2, 5.0±1.4, 12.2±8.7, 11.5±4.8, 4.8±1.3, 14.2±3.4, 0.875±0.120, 1.292±0.141, 0.759±0.155, 0.100±0.010, 0.087±0.014 and 0.008±0.002 mg l^{-1}, respectively. The variations, correlations and sources of the ions and metals in the fog water are discussed.

1. Introduction

Fogs are composed of fine droplets of water suspended in the air near the Earth's surface and formed a moist air mass when cooled to its saturation point (dew point). The presence of these droplets scatters the light and thus reduce the visibility near the ground. The fog droplets are approximately 100 times smaller than rain drops, highly concentrated with respect to the chemicals [1]. The smog, a soup of smoke with fog causes low visibility, health hazard and harm agricultural production [2]. The airborne particles burden over Asia are increased significantly due to rising of population, industrialization and urbanization. A major factor contributing to fog is the chemical composition of the aerosols and radiative forcing elements associated with the aerosols. Investigations of fog chemistry and physics have become very important as nutrients and pollutants from fog water exhibit strong influence on ecosystems [3]. In mountain forest ecosystems, fog water is an important source of ion deposition [4]. The chemical characterization of fog water in several parts of the World was carried out [5-12]. In the present work, the fog chemistry (i.e. load of F^-, Cl^-, NO_3^-, SO_4^{2-}, NH_4^+, Na^+, K^+, Mg^{2+}, Ca^{2+}, Al, Mn, Fe, Cu, Zn, Pb and Hg) in the most polluted region of the central India, Raipur region is described. The variations, scavenging ratio, enrichment, correlation and sources of the fog pollution in the central India are discussed.

1.1 Study area

Five cities i.e. Raipur, Korba, Bilaspure, Akaltara, Rajnangaon and Dongargargh of central India were selected for the proposed investigation, Figure 1. These sites were selected as representative of different geography, pollution source and pollution receptor - areas. The geographical characteristics of the sampling locations are summarized in Table 1. Raipur is a capital of Chhattisgarh state with population of ≈2 million inhabitants. Several steel, sponge iron and cement industries are running in Raipur. In Korba, the most of electricity of the state is generated by thermal plants using coal as source of energy.

2. Sample collection and analysis

A passive collector prescribed by Skar˙zy´nska et al. was used for the fog collection [13]. It consists of a 2 m tall collection, of two horizontal disks 20 cm in diameter, installed vertically on frames at a distance of 40 cm from each other. Nylon strings of 0.2 mm diameter between disks were stretched into two rows. After collection, the water was filtered and physical parameters i.e. pH, conductivity and TDS values were measured. The sample was divided into two portions. The first portion was used for analysis of anions and cations. The second portion was acidified with few drops of ultrapure nitric acid (E. Merck) and used for analysis of the metals. Total 22 fog water sample from five locations: Raipur, Bilaspur, Korba, Akaltara, Rajnandgaon and Dongargargh were collected in year 2007-08. The samples were kept in airtight 250-ml polyethylene bottles and refrigerated at 4 ^oC for further analysis.

The fluoride content was monitored with Metrohm ion meter-781 equipped with fluoride ion selective electrode and calomel electrode. The Dionex DX120 Ion Chromatograph (Dionex Corporation, Sunnyvale, CA, USA) equipped with anion separation column (AS9-HC, 250x4 mm), cation separation column (CS12A, 250x4 mm) and conductivity detector was used for analysis of the ions. The Varian Liberty AX Sequential ICP-AES and Varian AA280FS Atomic Absorption spectrophotometer equipped VGA-77 (plasma flow: 15 l min^{-1}, auxiliary flow: 1.5 l min^{-1}, power: 1KW, PMT voltage: 650 V) were used for analysis of the metals. The GBC AAS-935 equipped with HG-3000 was used for the analysis of Hg. The E. Merck multi elements standard solutions were used for preparation of the calibration curves.

4. Results and discussion

The pH, conductivity and TDS values (n=22) are ranged from 6.08 – 7.51, 148 – 224 µS and 78 – 128 mg l^{-1} with mean value of 7.07±0.40, 180±22 µS and 96±14 mg l^{-1}, respectively. The lowest pH value is observed in fog water of Korba city due to a huge coal burning, > 35 MT Yr^{-1}. The mean volume weighted concentration of ions i.e. F^-, Cl^-, NO_3^-, SO_4^{2-}, NH_4^+, Na^+, K^+, Mg^{2+} and Ca^{2+} is ranged from 1.7 – 2.4, 14.2 – 33.1, 11.4 – 23.8, 21.7 – 116, 2.8 – 8.2, 4.6 – 33.7, 4.8 – 22.4, 2.6 – 6.7 and 8.5 – 18.5 mg l^{-1} with mean value of 2.0±0.2, 23.6±7.0, 16.5±4.6, 46.9±28.2, 5.0±1.4, 12.2±8.7, 11.5±4.8, 4.8±1.3 and 14.2±3.4 mg l^{-1}, respectively. Among them, SO_4^{2-} shows the highest concentration, may be due to huge coal burning in this region. Their distribution pattern in decreasing order is: $SO_4^{2-} > Cl^- > NO_3^- > Ca^{2+} > Na^+ > K^+ > NH_4^+ \approx Mg^{2+}$. Several folds higher concentration of almost all ions is observed in Korba city, due to higher coal burning. The equivalent ratio of sum of the total anion to cation is ranged from 0.7 – 1.0 with mean value of 0.9±0.1. The mean volume weighted concentration of metals i.e. Al, Mn, Fe, Cu, Zn, Pb and Hg is ranged from 0.570 – 1.030, 1.100 – 1.640, 0.510 – 1.290, 0.080 – 0.117, 0.058 – 0.112 and 0.004 – 0.013 mg l^{-1} with mean value of 0.875±0.120, 1.292±0.141, 0.759±0.155, 0.100±0.010, 0.087±0.014 and 0.008±0.002 mg l^{-1}, respectively. Among them, Mn exhibits the highest concentration followed with Al and Fe. Similarly, almost all metals show the highest concentration in Korba city, due to a huge coal burning.

The mean concentration of species i.e. Cl^-, NO_3^-, SO_4^{2-}, NH_4^+, Na, K, Mg, Ca, Al, Mn, Fe, Cu, Zn, Pb and Hg in the aerosols of Raipur is 4.8, 6.4, 9.5, 1.6, 2.2, 2.1, 0.7, 7.1, 6.8, 0.8, 14.5, 0.8, 1.0 and 0.015 µg m^{-3}, respectively. The mean concentration of species i.e. Cl^-, NO_3^-, SO_4^{2-}, NH_4^+, Na, K, Mg, Ca, Al, Mn, Fe, Cu, Zn, Pb and Hg in the fog water of Raipur is 30, 16, 45, 5.3, 11.3, 11.7, 5.7, 16.1, 1.0, 1.5, 0.8. 0.01, 0.07 and 0.009 mg l^{-1}, respectively.

3. Figures

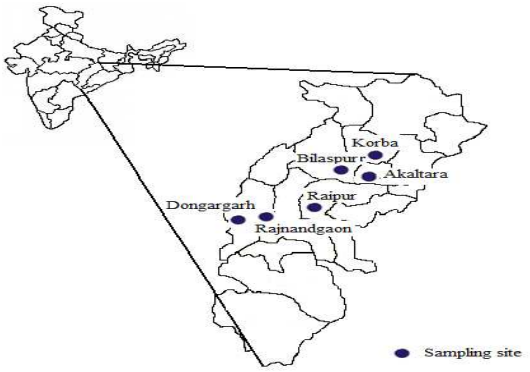

Figure 1. Representation of sampling sites

5. Tables

Table 1. Geographical characteristics of sampling locations

Site	Location	Altitude, m	Environment
Raipur	21° 13′ N, 81° 37′ E	298	Industrial and urban
Bilaspur	22° 5′ N, 82° 9′ E	346	Urban
Korba	22° 21′ N, 82° 40′ E	252	Industrial environment
Akaltara	22° 1′ N, 82° 25′ E	283	Cement plant
Rajnandgaon	21° 6′ N, 81° 1′ E	307	Urban
Dongargargh	21° 11′ N, 80° 45′ E	355	Hilly and urban

The scavenging ratio (SR) value for Cl^-, NO_3^-, SO_4^{2-}, NH_4^+, Na, K, Mg, Ca, Al, Mn, Fe, Cu, Zn, Pb and Hg is found to be 6000, 2500, 4540, 3310, 5130, 5570, 8140, 2300, 145, 1830, 56, 114, 76 and 6000, respectively. Sea salt particles i.e. Cl^-, Na^+, K^+ and Mg^{2+} exhibit the highest SR value due to most effectively scavenging out. The lower SR value of crustal metals i.e. Ca, Al, Mn and Fe is observed. The anthropogenic metals i.e. Zn, Pb and Hg show significant variation in their SR value, ranging from 76

– 6000. Calcium and aluminium are used as reference elements for evaluation of enrichment factors (EFs). Among them elements i.e. F^-, Cl^-, NO_3^-, SO_4^{2-}, NH_4^+, Na^+, K^+, $Mg^{2+}$and Ca^{2+} are highly enriched and expected to be contributed largely by anthropogenic sources i.e. coal burning, mineral roasting, industrial emissions, etc. While other elements i.e. Al, Mn, Fe, Cu, Zn, Pb and Hg are poorly to moderately enriched and more or less contributed by the dusts.

All anions and cations among themselves have fair to excellent correlation, suggesting their common origin in fog water. The Al and Fe content have fair positive correlation with Cl^- and Mn (r= 0.54-0.67). The content of three metals i.e. Zn, Pb and Hg have partial to good correlation with almost all ions and metals (except Al, Mn and Fe). The species i.e. Cl^-, NO_3^-, SO_4^{2-}, Mg^{2+} and Al with the ambient temperature have positive correlation unlikely to species F^-, NH_4^+, Na^+, Fe and Hg. All species (except F^-, NH_4^+, Al and Fe) show positive correlation with humidity. The vapour pressure and wind speed exhibit mixed correlations. Three species i.e. F^-, NH_4^+ and Fe have fair negative correlation with vapour pressure, unlikely to NO_3^-, SO_4^{2-}, Mg^{2+} and Hg. The wind speed has negative fair correlation with species i.e. Cl^-, NO_3^-, SO_4^{2-}, NH_4^+ and Mn unlikely Fe, Ca^{2+} and Al.

6. Summary and Conclusions

The chemical composition of fog water is an indicator for a lower tropospheric dust pollution of a given locations. The fog water of the central India is found to be contaminated with ions (i.e. Cl^-, NO_3^-, SO_4^{2-}, NH_4^+, Na^+, K^+, Mg^{2+} and Ca^{2+}) and metals (i.e. Al, Mn, Fe, Zn, Pb and Hg) at elevated levels due to industrial effluent emissions.

6. References

[1] Krupa S.V., Sampling and physic - chemical analysis of precipitation: a review, Environmental Pollution, 120, pp. 565 – 594, 2002.

[2] Biswas K.F., Ghauri B.M., Husain L., Gaseous and aerosol pollutants during fog and clear episodes in South Asian urban atmosphere, Atmospheric Environment, 42, pp. 7775 - 7785, 2008.

[3] Wen L., Yi Z., Hong L., Fan M., Yu L., Chang Ming W., Fog and rainwater chemistry in the tropical seasonal rain forest of Xishuangbanna Southwest China, Water Air and Soil Pollution, 167, pp. 295 - 309, 2005.

[4] Holder C.D., Rainfall interception and fog precipitation in a tropical montane cloud forest of Guatemala, Forest Ecology and Management, 190, pp. 373 - 384, 2004.

[5] Igawa M., Matsumura K., Okochi H., High frequency and large deposition of acid fog on high elevation forest, Environmental Science and Technology, 36, pp. 1 - 6, 2002.

[6] Wrzesinsky T., Klemm O., Summertime fog chemistry at a mountainous site in central Europe, Atmospheric Environment, 34, pp. 1487 - 1496, 2000.

[7] Bridges K.S., Jickells T.D., Davies T.D., Zeman Z., Hunova I., Aerosol precipitation and cloud water chemistry observations on the Czech Krusne Hory plateau adjacent 5 to a heavily industrialized valley, Atmospheric Environment, 2000, 36, 353 - 360.

[8] Fisak J., Tesar M., Rezacova D., Elias V., Weignerova V., Fottova D., Pollutant concentrations in fog and low cloud water at selected sites of the Czech Republic, Atmospheric Research, 64, pp. 75 - 87, 2002.

[9] Fišák J., Tesař M., Fotto vá D., Pollutant Concentrations in Rime and Fog Water, Soil Water Research, 3,pp. 68 - 73, 2008.

[10] Zapletal M., Kuňák D., Chroust P., Chemical Characterization of rain and fog water in the Cervenohorske Sedlo Hruby Jesenik Mountains Czech Republic, Water Air and Soil Pollution, 186, pp. 85 - 96, 2007.

[11] Lakhani A., Parmar R.S., Satsangi G.S., Prakash S., Chemistry of fogs at Agra India: influence of soil particulates and atmospheric gases, Environmental Monitoring and Assessment, 2007, 133, 435 - 445.

[12] Kulshrestha M.J., Sekar R., Krishna D., Hazarika A.K., Dey N.C., Rao P. G., Deposition fluxes of chemical components of fog water at a rural site in north-east India, Tellus B, 57, pp. 436 – 439, 2005.

[13] Skar˙zy´nska K., Polkowska Z., Namie´snik J., Sampling of atmospheric precipitation and deposits for analysis of atmospheric pollution, Journal of Automated Methods and Management in Chemistry, 26908, pp. 1 - 18, 2006.