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Research Article

Wet Deposition of Gaseous Pollutants in Dhanbad, India for Rain Water Quality

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Abstract

This research paper analyzes the quality of rain water collected at Dhanbad city (Jharkhand, India) by monitoring pH, conductivity, total hardness (TH), major anions (NO_2^-, NO_3^- and SO_4^{2-}), major cations (Ca^{2+}, Mg^{2+}, Na^+ and K^+), sodium absorption ratio (SAR), sodium percentage (Na%). The rain water has been analyzed at two different time period i.e, one during monsoon and second during winter to study the impact of air pollutant concentrations. The experimental result shows that pH value of rainwater samples ranges from 5.1 to 6.22 during monsoon while it ranges from 5.1 to 7.57 during winter indicating acidic nature. SO_4^{2-}/NO_3^- ratio 16.94 indicates that the increase in acidity of wet deposition has been attributed to the elevated SO_2 and NO_2 emissions from stationary and mobile pollution sources. TH of rainwater shows that rainwater is soft and can be used for drinking and domestic purposes. On average, the ion composition of the rainwater of studied region follows the sequence $SO_4^{2-} > NO_3^- > Na^+ > K^+ > Ca^{2+} > Mg^{2+} > NO_2^-$. The analytical result shows that average wet deposition rate of sulfate ion i.e. 243.70 mg/m^2/day which is higher than other ionic components.

Keywords: *Acid rain, Wet deposition, Rain water quality, Rain water characterization, Gaseous pollutants on rain water quality*

1. Introduction

Rainwater is the most appropriate scavenging factor for removing particulate and dissolved organic gaseous pollutants from the atmosphere. The scavenging of the atmospheric pollutants affects the chemical composition and the pH of the rainwater. The variation in physical and chemical characteristics of rainwater is one of the environmental problems worldwide (O. A. Khashman et al, 2005; D. Migliavacca et al, 2005; C. A. Ahiarakwem et al, 2012; S. J. Cobbina et al, 2013). The global ranges of pH from various studies reported that; pH ranges from 5.33 to 7.9 in South Jordan (O. A. Khashman et al, 2005) while in south Brazil, the average pH of rainwater was 5.4 (D. Migliavacca et al, 2004), Nigeria study has shown pH value 4.75 to 7.4 of the rainwater (C. A. Ahiarakwem et al., 2012) while in Ghana pH ranges between 5.02 to 9.

The acidity of rain water is determined by the presence of its acidic and basic components. The main acidic components are H2SO4 and HNO3 while main alkaline components are Ca^{2+}, Mg^{2+} and NH_4^+. Acid rain has a pH value lower than 5.6 (D. C. Parashar et al, 2001; A. K. Singh et al, 2008). The acidity value depends on the neutralization produced by certain rainwater components such as NH3, $CaCO_3$ and hydroxide (M. Flues et al, 2002; D. Migliavacca et al, 2005). Major contributors to acid rain are; use of fossil fuels, industrial activities and poor land use pattern (A. C. C. L. Tresmondi et al, 2003).

In the tropics, the atmosphere has high dust loading throughout the year except the coastal belt. Therefore, the dust is considered to be an important factor to influence the pH of precipitation (G. S. Varma et al, 1989). In India, the pH of rain water has been reported in the range of 6 to 7 (L. T. Khemani et al, 1992; D. C. Parashar et al, 1996; U. C. Kulshrestha et al, 1998). The extent of acidification or neutralization of precipitation, very much depends on the environment through which the rain drops travel. It is reported that the rain drops immediately coming out of the cloud possess relatively low pH, but when they reach the earth's surface, the pH is increased (L. T. Khemani et al, 1987). In India, a significant concentration of sulfate ion in soil has been reported (U. C. Kulshrestha et al, 2000).

The continuous emissions of CO_2, SO_x, NO_x gases into the atmosphere in industrialized urban area like Dhanbad may lead formation of acid rain (A. K. Singh et al, 2008). They have reported that pH value of rainwater ranges from 4.01 to 6.92 indicating acidic to alkaline nature of rainwater as compared to the reference level of 5.6 and found that pH of rainwater was above 5.6 during the non-monsoon and early phases of monsoon while during the late phase of monsoon pH tendency was towards acidity indicating the non - availability of proper neutralizer for acidic ions.

Rainwater is a serious threat to human environment, such as vegetation, soil, forestry, water bodies and corrosion of building materials. The groundwater quality is affected by rainwater because rainwater infiltrates through the soil into the flow system in underlying aquifer.

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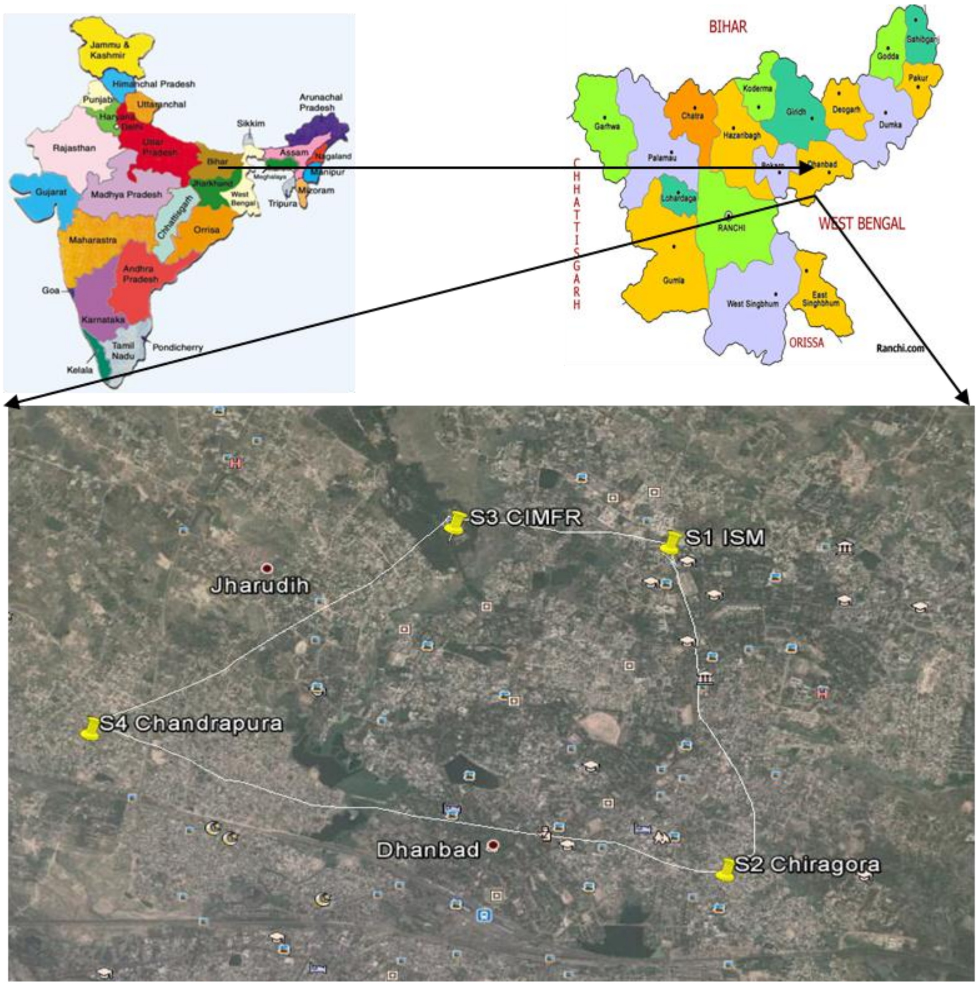

Figure 1: Geographical map of study area showing sampling locations (S1: ISM; S2: Chiragora; S3: CIMFR; S4: Chandrapura)

Acid rain and atmospheric aerosols are considered to be typical environmental pollution affecting human health, resulting in the deterioration of monuments and the acidification of lakes and soil and natural equilibrium (T. Spanos et al, 2002).

It is utmost necessary to analyze the quality of rainwater by measuring pH, conductivity, ion concentrations, sodium absorption ratio and sodium percentage to study its impacts on suitability for irrigation purpose, domestic use, rainwater harvesting, water bodies, living things, plants and materials. Therefore, in this research work rain water has been studied for its physical and chemical properties at various locations.

2. Experimental

2.1 Study Area

Dhanbad, known as coal city of India, lies in the eastern part of the Jharkhand state and actively associated with the mining activities for more than a century. There are many working and abandoned coalmines in and around Dhanbad city. Major activities in Dhanbad are associated with coalmines, steel production and power plants in these regions served the status of air quality. Besides these mining and industrial sources, ever increasing transport sector contributes more to air quality deterioration by means of elevated PM, CO_2, NO_x and unburnt hydrocarbons.

Dhanbad lies between 23037’ N and 2404’ N latitude and between 8606’ E and 86050’ E longitude. It has an average elevation of 222m (728 ft). Its geographical length, extending from North to South, is 43 miles and breadth, 47 miles, stretching across East to West. It shares its boundaries with West-Bengal in the Eastern and Southern part, Dumka & Giridih in the North Bokaro in the West.

The sampling locations of rain water are given in Figure 1. The identified sampling locations are Indian School of Mines (S1), Chiragora (S2), CIMFR (S3), and Chandarapura (S4), Dhanbad.

2.2 Climatic Conditions

The climate of Dhanbad is typical hot and tropical type with three distinct seasons i.e. summer, monsoon and winter. The summer season is hot and dry from March to mid June. Rainy season continues from mid June to mid October and is followed by cool and dry winter season from mid October to February. The lowest recorded temperature in the coalfield is 5°C to 7°C during December to January while the highest temperature is 46°C to 48°C during May to June. The average annual rainfall varies from 1,197 to 1,380 mm, out of which 95% occurred from mid June to September (A. K. Singh et al, 2008).

2.3 Materials and Methods

Rainwater samples were collected by polyethylene bucket at sampling locations in October, 2013 (late monsoon season) and January, 2014 (winter season) to understand the effect of season and frequency of rainfall occurrences. Meteorological data was taken by accuweather website (www.accuweather.com) and precipitation amount (in mm) reading was taken by rain gauge installed at the department of Environmental Science & Engineering, ISM. The buckets were placed at different height for each sampling locations to study the effect of particle size distribution. Rainwater samples were immediately transferred in plastic bottles separately on daily basis. The bottles were kept air tight and labeled properly for identification. Rainwater samples were taken to the laboratory within 24 hrs of collection and refrigerated at 40C for analysis. However, the physical parameters (pH, EC and TDS) of the rainwater samples were determined using digital portable pH-meter while the major constituent cations (Ca^{2+}, Mg^{2+}, Na^{+} and K^{+}) were determined by using flame photometer and anions (NO_2^-, NO_3^- and SO_4^{2-}) were determined by using ultraviolet/visible spectrophotometry (APHA 1995). To check the rainwater quality for the suitability of irrigation purpose and domestic use; SAR (Sodium Absorption Ratio), Na% (Sodium Percentage) and TH (Total Hardness) was calculated. SAR was estimated by the equation using the values obtained for, Ca^{2+}, Mg^{2+} and Na^{+} in meq/l; Na % was determined by the equation using the values obtained for Ca^{2+}, Mg^{2+}, Na^{+} and K^{+} in meq/l; TH was determined by the equation using the values obtained for Ca^{2+} and Mg^{2+} in mg/l or by titration method and wet deposition rate was determined by mathematical equations. SAR was determined using following equation 1 (C. A. Ahiarakwem et al, 2012):

$$\mathrm{SAR} = \frac{\mathrm{Na^+}}{\sqrt[2]{\frac{\mathrm{Ca^{2+} + Mg^{2+}}}{2}}} \qquad (1)$$

Where, the concentrations are reported in meq/l.
Sodium percentage was determined using equation 2 (T. Subramani et al, 2005) as given below:

$$\mathrm{Na\ \%} = \frac{(\mathrm{Na^+ + K^+})\times 100}{(\mathrm{Ca^{2+}+Mg^{2+}+Na^{+}+K^{+}})} \qquad (2)$$

Where, all the concentrations are expressed in meq/l.
TH of the rainwater was determined by the following equation 3 (APHA, 1995):

$$\mathrm{TH\ (mg/l)} = 2.5\ (\mathrm{Ca^{2+}}) + 4.1\ (\mathrm{Mg^{2+}}) \qquad (3)$$

Wet deposition for individual ionic components was calculated by equation 4 (Agrawal and Singh, 2005) as follows:

$$\text{Wet Deposition } (\mathrm{mg/\,m^2/day}) = \frac{\mathrm{IC\times P}}{\mathrm{day}} \qquad (4)$$

Where, IC is the ion concentration in mg/l and P is the precipitation amount in mm.

3. Results and discussion

The physico - chemical parameters, SAR, Na% and SO_4^{2-}/NO_3^- of rainwater were obtained by adopting the above stated methodologies to achieve the objectives of the study.

This section details out experimental outcome of the tested rainwater samples. The various physico - chemical parameters of this experiments are pH, EC, TDS, Ca^{2+}, Mg^{2+}, Na^{+}, K^{+}, NO_2^-, NO_3^-, SO_4^{2-} and TH. SO_4^{2-}/NO_3^- is estimated to quantify the sources of emissions that alters the chemistry of precipitation (Table 4). Wet deposition rate of individual ions are given in Table 6. To compare the results obtained in this study a summarized table of other researchers was prepared (Table 7).

The estimated SAR and Na % of rainwater samples are presented in Table 3, signify the quality of rainwater for irrigation and domestic purposes. Table 5 provides the standards for rainwater quality based on EC, TDS, SAR and Na%.

3.1 Physical Characterization of the Rainwater

The pH values for both seasons were presented in Figure 2 & 3. The pH value at ISM Teachers colony ranges from 5.1 to 6.0 with mean value 5.79 during October month while it ranges from 6.1 to 6.2 with mean value 6.15 during January month as shown in Table 1 & 2. The pH value at Chiragora is 5.7 while at CIMFR it ranges 5.1 to 5.3 and 5.1 to 6 in Chandrapura during January month. The above result shows that pH value varies on the basis of location. This shows that rainwater is not that of acid rain because pH value for acid rain is less than 5.6 (P. Primerano et al, 1998). There is very slight variation in pH values in respect of height at ISM, while pH values at Chandrapura and CIMFR are varied in context of height. The average pH values at ground level is 5.21 showing acid rain while at top of building it is 6 in Chandrapura. However, pH value of CIMFR sample at ground level is 5.9 while at top of the building its value is 5.1 which is acid rain. From the above results, the effect of altitude on wet deposition by pH is not clearly understood and it requires more monitoring with knowledge on gaseous pollutants variation.

EC of the rainwater varies from 17 μS/cm to 344 μS/cm during October 2013 while during January 2014 its values range between 14 μS/cm to 1290 μS/cm. TDS values vary from 14 mg/l to 255 mg/l during October 2013 while its values range between 11.6 mg/l to 914 mg/l during January 2014. These values conformed to the standard for safe drinking water (WHO, 2004 and IS: 10500, 2012). The TH of rainwater values varies from 1.21 to 12.18 mg/l indicating that the water is soft. The

Table1: Physical characteristics of rainwater (RW) during January, 2014

	pH	EC (μs/cm)	TDS (ppm)
RW1	6.1	22.7	16.8
RW2	6.1	32.2	23.0
RW3	6.2	51.1	37.4
RW4	6.2	14.5	11.6
RW5	6.3	67.8	48.4
RW6	6.2	72.5	52.0
RW7	6.3	255.0	175.0
RW8	6.6	71.0	49.2
RW9	6.1	211.0	154.0
RW10	6.4	1290.0	914.0
RW11	6.6	98.5	76.0
RW12	6.6	94.5	67.0
RW13	6.3	144.0	103.0
RW14	6.6	97.0	75.0
RW15	7.5	217.0	155.0
RW16	7.5	245.0	225.0
RW17	6.7	174.8	124.0
RW18	5.7	123.5	87.6
RW19	5.9	92.0	65.4
RW20	5.1	103.0	73.2
RW21	5.2	98.0	69.6
RW22	6.0	106.0	75.3
RW23	6.2	96.0	68.3
RW24	5.8	87.4	62.0
Average	6.25	167.03	121.35
Min	5.10	14.50	11.60
Max	7.57	1290.00	914.00

Table 2: Physical characteristics of rainwater (RW) during October, 2013

	pH	EC (μs/cm)	TDS (ppm)
RW1	5.1	344.00	255.00
RW2	5.3	121.67	85.00
RW3	6.1	110.17	78.60
RW4	6.2	21.00	16.00
RW5	6.2	17.40	14.00
Average	5.79	122.85	89.72
Min	5.10	17.40	14.00
Max	6.22	344.00	255.00

Table 3: Major ions concentration (mg/l), SAR values and sodium percentage of rainwater (RW) samples

		Ca^{2+}	Mg^{2+}	TH	Na^{+}	K^{+}	NO_2^-	NO_3^-	SO_4^{2-}	SAR	Na%
	1	0.14	0.21	1.21	1.52	0.71	0.02	3.22	41.54	0.601	77.68
RW1	2	1.15	1.27	8.08	1.71	0.78	0.08	4.54	43.56	0.262	36.86
	3	1.18	2.25	12.18	2.88	1.25	0.12	5.26	45.66	0.359	39.25
	1	0.88	0.63	4.78	1.05	1.24	0.01	2.3	30.8	0.209	44.74
RW2	2	0.95	1.25	7.50	2.6	1.88	0.04	3.5	32.1	0.413	51.81
	3	1.24	1.6	9.66	1.87	2.12	0.07	4.1	35.4	0.262	41.26
	1	0.84	0.41	3.78	1.26	0.65	0.01	2.21	49	0.282	48.59
RW3	2	0.95	0.47	4.30	2.12	1.2	0	3.11	56	0.444	58.83
	3	1.2	0.56	5.30	2.78	0.55	0.02	2.56	52	0.525	56.03
	1	0.36	0.36	2.38	0.56	0.15	0.02	0.31	30.21	0.158	37.24
RW4	2	0.45	0.45	2.97	1.43	0.23	0.03	0.35	31.5	0.361	53.41
	3	1.2	1.23	8.04	2.51	0.11	0.01	0.45	35.4	0.385	41.04
	1	0.52	0.33	2.65	0.61	0.33	0	0.5	28.13	0.163	39.74
RW5	2	0.78	0.42	3.67	0.69	0.35	0.02	0.61	30.1	0.157	34.67
	3	0.68	0.49	3.71	0.72	0.39	0.01	0.72	30.5	0.163	35.77
Median		0.88	0.49	4.30	1.52	0.65	0.02	2.3	35.4	0.316	46.46
Average		0.83	0.8	5.35	1.62	0.8	0.03	2.25	38.13	0.382	56.73
Percentile		1.21	1.8	10.41	2.81	1.95	0.09	4.76	53.2	0.548	64.49

hardness values make the rainwater suitable for washing purposes (although rainwater harvested for such purpose must be treated to correct the pH).

3.2 Major Cations and Anions

The statistical summary of major ions concentration (mg/l), SAR values and sodium percentage of rainwater samples (October month only) are given in Table 3. The average concentration of Ca^{2+} is 0.83 mg/l while that of Mg^{2+} is 0.8 mg/l; this indicates that both are having same concentration in rainwater. The average concentration of Na^+ is 1.62 mg/l i.e it is having 2.81 mg/l above 95 percentile (very less) while K^+ average value is 0.8 mg/l. The average concentration of NO_2^- is very less i.e 0.03 mg/l while NO_3^- is having 2.25 mg/l; while average concentration of SO_4^{2-} is 38.13 mg/l. the concentration of sulfate ion is higher than others ionic components. The results indicate that the concentrations of the constituent major cations and anions are generally low and this is typical of most rainwater resources in industrialized urban areas. The major constituent cations in decreasing order are: $Na^+ > Ca^{2+} >*(K^+, Mg^{2+})$ while that of the anions is: $SO_4^{2-} > NO_3^- > NO_2^-$. The concentrations of major cations and anions of the rainwater conform to the standard for safe drinking water (IS: 10500, 2012). The concentration of $SO_4^{2-}$was higher than those reported for Varanasi, Nigeria and Ghana (M. Agrawal et al, 2001; C. A. Ahiarakwem et al, 2012; S. J. Cobbina et al, 2013) while less compare to prior Dhanbad study (A. K. Singh et al, 2008).

3.3 SO_4^{2-}/NO_3^-

SO_4^{2-}/NO_3^- ratio quantifies the sources of emissions which affects the atmospheric precipitation. The calculated SO_4^{2-}/NO_3^- ratio is 16.94 as shown in Table 4 may indicates the anthropogenic sources in the atmospheric precipitation of industrial areas (D. Migliavacca et al, 2005). The results obtained in this study were compared to those from other sites as shown in Table 4. They show that the SO_4^{2-}/NO_3^- ratio was higher than ratios found in other studies such as Guaiba, Singapore, Spain and Italy. This is only due to the fact that the sites are located beside or in industrialized urban areas. Sulfate and nitrate ions are conventional acidic ions in rainwater, while the relative contribution of these ions to the acidity of rainwater is variable.

3.4 Rainwater Quality

SAR and Na% is an important parameter for determining the suitability of groundwater for irrigation because SAR is a measure of alkali/sodium hazard to crops while Na% displaces the calcium and magnesium ions by sodium in water. The ground water is mainly utilized for domestic needs and for irrigation purposes in Dhanbad city.

SAR of the rainwater as shown in Table 3 quantifies that it is excellent for irrigation purposes on the basis of quality of irrigation water given in Table 5 (T. Subramani et al, 2005), although it has to be treated to correct the pH. The SAR values range from 0.16 to 0.60 with an average value of 0.38 during October 2013. According to the SAR classification, 100% of rainwater falls in excellent category, which can be used for irrigation on almost all soils. As compared to other studies, this study is having less SAR value i.e. 0.38 (T. Subramani et al, 2005; N. S. Rao et al, 2006 and C. A. Ahiarakwem et al, 2012).

Table 4: SO_4^{2-}/NO_3^- comparison ratio at various sites in the World

Sites	SO_4^{2-}/NO_3^-	References
Italy	3.1	O. L. Bolloch et al, (1995)
Spain	2.22	A. Avila et al, (1999)
Singapore	5.3	R. Balasubramanian et al, (2001)
Guaiba	8.71	D. Migliavacca et al, (2005)
Dhanbad (India)	16.94	Present study

Table 5: Standards for quality of irrigation water (T. Subramani et al, 2005)

Water class	EC (µS/cm)	TDS (mg/l)	Sodium hazards	SAR	Na%
Excellent	< 250	250	Low	< 10	< 20
Good	250-750	250-500	Medium	10-18	20-40
Permissible	750-2000	500-1500	High	18-26	40-60
Doubtful	>2000	1500-3000	Very high	>26	60-80

The Na % indicates that the rainwater is permissible for irrigation purpose. Na% of rainwater samples ranges from 34.67 to 77.68 with an average value of 56.73 shows rainwater quality is permissible for irrigation. The Wilcox (1955) diagram relating sodium percentage in Table 5 shows that most of the rainwater sample falls in the field of good to permissible except a few samples falling in the fields of doubtful and unsuitable for irrigation. When the concentration of sodium is high in irrigation water, sodium ions tend to be absorbed by clay particles, displacing Mg^{2+} and Ca^{2+} ions. This exchange process of Na^+ in water for Ca^{2+} and Mg^{2+} in soil reduces the permeability and eventually results in soil with poor internal drainage. Hence, air and water circulation is restricted during wet conditions and such soils are usually hard when dry (R. Collins et al, 1996; A. Saleh et al, 1999).

All the parameters conform to the standards for safe drinking water except for pH, as shown in Table 7. The total hardness of rainwater is very low; therefore rainwater may be harvested for domestic purposes in Dhanbad locality and may be used for drinking water after treatment.

3.5 Wet Deposition Rate

In wet deposition, there are always some atmospheric

Table 6: Comparative analysis of the researchers outcome against wet deposition ionic components (mg/l)

Parameters	Present study	Dhanbad *(Singh & Mondal, 2008)*	Varanasi *(Agrawal, 2001)*	Nigeria *(Ahiarakwem, 2012)*	Ghana *(Cobbina, 2013)*	IS:10500 *(2012)* for Drinking water	WHO (2004)
pH	5.79	5.58	6.9	5	7.18	6.5-8.5	7.5-8.5
EC (μS/cm)	122.85	28.2	455	30.4	13.6	-	-
TDS	89.72	-	-	18	6.5	500-2000	500-2000
Ca^{2+}	0.83	96.1	1.13	0.5	2.38	75-200	75-200
Mg^{2+}	0.8	23.6	0.31	0.12	1.15	30-100	50-150
TH	5.35	-	-	1.78	-	300	100
K^+	0.8	9.1	0.25	8.78	0.1	-	-
Na^+	1.62	35.2	0.37	9.82	0.06	-	200
NO_2^-	0.03	-	-	-	-	-	-
NO_3^-	2.25	5.7	1.51	0.04	1.58	45	45
SO_4^{2-}	38.13	77.8	2.03	1.75	3.73	200-400	200-400
SAR	0.38	-	-	3.19	-	-	-

hydrometeors which scavenge aerosol particles. Wet deposition rate measures the deposition of ions in mg/m^2/day by considering ion concentration in the rainwater multiply by precipitation amount per day.

Total wet deposition rate of individuals ions at monitoring sites have been calculated by considering average volume weighted concentration and average daily rainfall data is shown in Table 6. The analytical result shows that wet deposition of Ca^{2+} varies from 1.35 to 21.14 mg/m^2/day; for Mg^{2+} it ranges from 2.1 to 14.66 mg/m^2/day; for Na^+ it ranges from 11.55 to 24.11 mg/m^2/day; for K^+ it ranges from 6.0 to 13.64 mg/m^2/day; for NO_2^- it ranges from 0.02 to 0.51 mg/m^2/day; for NO_3^- it ranges from 12.63 to 32.17 mg/m^2/day; for SO_4^{2-} it ranges from 338.84 to 1223.8 mg/m^2/day. Average wet deposition rate of sulfate ion i.e. 243.7 mg/m^2/day is higher than other ionic components.

Table 6: Wet deposition rate (mg/m^2/day) of major ions for rainwater at some sites worldwide

Parameters	Present study	Dhanbad *(A. K. Singh et al, 2008)*	Brazil *(L. B. L. S. Lara et al, 2001)*	Spain *(A. Alastuey et al, 1999)*
Ca^{2+}	3.76	98	0.31	5.64
Mg^{2+}	2.79	17	0.06	0.44
Na^+	5.88	46	0.22	1.03
K^+	3.16	19.5	0.44	1.68
NO_2^-	0.06	-	-	-
NO_3^-	7.68	12.4	3.12	2.7
SO_4^{2-}	243.70	278.4	2.63	8.83

The above result shows that all the ionic components are within the limit. Sulfate in rain arises mainly from anthropogenic emission, which is indicated by the above observations. Sulfate in rain water is contributed by soil in India (except some regions of acidic soils such as parts of Kerala and Orissa states) which is not responsible for acidity of the rain water (U. C. Kulshrestha et al, 2000).

4. Conclusion

The physical–chemical characterization of rainwater collected from the major coal-producing region of India i.e Dhanbad was carried out during October and January for the year 2013 and 2014 on rain event basis. The study reveals the following important chemical characteristics: The hydro-chemical analyses reveal that the water is kind of acidic in nature. The relative abundance of the constituent major cations and anions in decreasing order is $Na^+ > Ca^{2+} > K^+ > Mg^{2+}$ while that of the major anions is $SO_4^{2-} > NO_3^- > NO_2^-$. Rainwater is potable based on constituent major cations and anions. SO_4^{2-}/NO_3^- ratio indicates that Dhanbad is highly polluted area due to industrialization and urbanization. Total hardness and SAR is low in the rainwater indicates rainwater suitable for drinking, domestic and irrigation purpose. Na% value of the rainwater is within the permissible limit. Except for the pH, all other measured chemical parameters of the rainwater conform to the standard for safe drinking water (IS: 10500, 2012). The rainwater, if treated for pH, can be used for domestic and agricultural purposes (irrigation and livestock farming). If untreated, the rainwater can cause soil and water pollution as well as destruction vegetation; it can attack building roofs, monuments, sculptures and statues which constitute part of our cultural heritage. The pH of the rainwater can be corrected using sodium bicarbonate (soda ash). There is need for regular monitoring of air quality in the study area as well as proper disposal of waste. Scrubbers should be installed at industrial areas and waste disposal sites so as to reduce the quantity of gases released from these sources into the atmosphere. There is also the need to reduce the consumption of fossil fuels in the study area. The future scope of this study is to measure dry deposition rate. Dry deposition is the process by which atmospheric trace chemicals are transferred by air motions to the surface of the Earth in the absence of rain/snow. Gravitational settling affects deposition of particles, especially those larger than a few micrometers in diameter.

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