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MONSOON RAINWATER CHEMISTRY AND ITS POTABLE STATUS: A CASE STUDY FROM SOUTH-EAST COASTAL BELT OF BANGLADESH

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Abstract : Major ion chemistry of rain water from a selected area has been determined. The rainwater is slightly acidic as in the case with rain waters globally. All major cations and anions are present in delectable amount. HCO_3^- is the dominant anion in the study area and its concentration generally decreases subsequent showers. Such decrease in concentration also is noticed in case of other cations and anions. The influence of seawater in the chemistry of rain water is quite significant in the present study. Although at the beginning of the first rainfall event, bicarbonate ion predominates, its concentration gradually diminishes with the passage of time, but sometimes erratic values are noticed and even in the last fraction of a continuous rainfall. Most of the other cations and anions behave similarly to that of bicarbonate ion. Concentrations of various chemical constituents are not constant in local rainwater and it varies from rainfall event to event. It is also dependent on the various local meteorological parameters. Different calculated weight ratios such as $SO4^{2-}/Na^+$ etc. are compared with seawater. The results indicate the influence of southern seawater to a great extent. Moreover, non-marine origin from the onshore such as dust particles, automobile exhaust, smoke etc. also contribute significant amount of the dissolved constituents in the rainwater. A household survey was conducted to know about the water using pattern of the study area. However the calculated major cations and anions are below the potability status of DoE standard which is not viable for human health.

Key words: Monsoon, rainwater, rainwater chemistry, Bengal basin, Bangladesh.

Introduction

Bangladesh is a tropical monsoon country and receives heavy rainfall due to north-easterly winds during the rainy season. Rainwater can be a potential source of fresh water supply in Bangladesh. In the coastal districts, particularly in the S-E coastal belt rainwater has been used for drinking purposes traditionally at Patharghata Upazilla in Barguna District (22°3′N latitude and 89°58.6′E longitude), Bangladesh. The surface and subsurface water of the area is almost saline. Some pond waters are visible in the area which is not enough to fulfill the community demand (Ahmed and Jahan, 2000).

These protected ponds, annually replenished by rainwater serve as the main source of potable water in the coastal area. Unhygienic practices often pollute these ponds and rain water harvesting can be an alternative option for water supply. In some areas due to high salinity problem, ~36% of households have been found to harvest rain water in the rainy season for drinking purposes. But the collection, storages and usage pattern of rainwater are not in a organized manner and development through adoption of appropriate technologies. In Barguna district a local NGO

named SANGRAM is working with the rain water preservation system for few years financed by DANIDA and NGO Forum.

Ever since systematic analysis of rainwater was commend in the decayed of fifties (Barret and Bodin, 1955) with the views on acid rain problem and to identify the sources of the H^+ ion in rainwater. Angstrom and Hogberg (1952) investigated the content of nitrogen (NH_4-N and NO_3-N) in atmospheric precipitation. Gambell and Fisher (1964) identified the occurrence of sulfate and nitrate in rainwater. Handa (1969) was the first to attempt to identify the chemical composition of rain in Calcutta (a part of Bengal basin). Das (1988) advocated that the major, minor and trace elements monsoon rainfall over Calcutta had greater influence of marine inputs. Mukhopadhyay *et al.,* (1991) pointed out that the occurrence of acid rain is virtually absent over the Indian region. It is now believed that neutralization of acidic components in rainwater by calcareous aerosols species in the atmosphere acts as the main buffer mechanism against acid rain (Nanda, 1984; Mukherjee *et al*., 1985; Khemani *et al*., 1989).

In the Bengal basin due to the temperature effect, rain water expected to be near neutral (Mukherjee *et al*., 1985). Very little information towards chemical composition of rainwater is available in Bangladesh part. In the present study, the rainwater chemistry were analyzed to highlights its potability status.

Materials and Methods

Patharghata and *Kathaltali* unions in *Patharghata* Upazila of Barguna District are studied for their monsoon rainwater chemistry. The samples have collected from *Pathargata Sadar*, *Badurtala*, *Char Lathimara*, *Kathaltali*, *Taluk Kathaltali* and *Kalipur* villages during June-September, 2003 (Fig. 1).

Prior to data collection, a reconnaissance survey has been conducted in different regions of the study area. A household survey was conducted through personal interview during June-September, 2003 to know the water using pattern of the study area.

A wide mouthed stainless steel pot was used to collect the rainwater sample which was filtered through Whatman paper (no. 42) immediately after collection to remove any particulate matter if any. The sample was transferred to clean and dried plastic bottles. The pH, EC, and TDS were measured at the field. The bottle was rinsed with sampled water during the collection of samples and then securely sealed with proper leveling and preserved for chemical analysis.

The laboratory analyses were done in Environmental Science Discipline laboratory of Khulna University. Methods followed in the chemical analysis of water samples are presented briefly in Table 1.

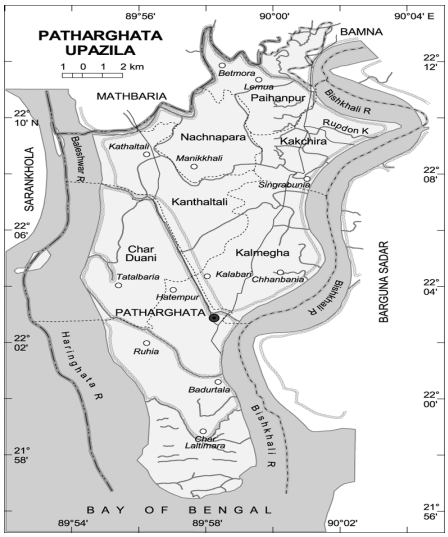

Fig.1. Location map of the study area.

Table 1. Methods and instruments used in rainwater analysis.

Parameters	Method/Instrument	Reference
pH	HANNA instruments, p^H 211 (Microprocessor p^H meter)	Instrument manual
EC	TDS meter (H1-9635, portable water proof Multirange Conductivity/TDS meter)	Instrument manual
TDS	TDS meter (H1-9635, portable water proof Multirange Conductivity/TDS meter)	Instrument manual

Na^+	Flame photometric method (Flame photometer- models PEP 7 and PEP 7/C)	Instrument manual
K^+	Flame photometric method (Flame photometer- models PEP 7 and PEP 7/C)	Instrument manual
NO_3^{2-}	Turbidimetric method (Thermo spectronic, UV-visible Spectrophotometers)	Ramesh and Anbu, 1996
SO_4^{2-}	Turbidimetric method (Thermo spectronic, UV-visible Spectrophotometers)	Ramesh and Anbu, 1996
HCO_3^-	Potential methods	Ramesh and Anbu, 1996

Results

Physico-chemical composition of Rainwater: The chemical analysis of rainwater sampled during June-September, 2003 from Patharghata is presented in Table 2. The temperature of rainwater of the study is in the DoE range but remaining parameters show very less amount comparing with DoE standard, which indicates that the rainwater of the study area is not feasible for human health.

Table 2. Major ion chemistry of rainwater (in mg/l except EC in µs/cm and pH).

Date	Station	pH	EC	TDS	HCO_3^-	Cl^-	SO_4^{2-}	NO_3^-	Na^+	K^+
June, 2003										
15	Patharghata	6.7	35.50	35.5	19	10	3.2	0.9	2.9	0.31
16	Patharghata	6.2	35.00	27.30	18	9.5	3.0	0.5	2.7	0.30
20	Badurtala	5.5	27.30	10	14	9.4	2.5	0.5	2.6	0.25
21	Badurtala	6.1	18.30	13.8	12	4.5	2.3	0.3	2.1	0.25
30	Char Lathimara	5.4	26.00	26	8	5.2	1.2	0.2	2.0	0.24
July, 2003										
01	Kathaltali	6.7	22.50	35	20	3.8	9.95	0.12	2.4	0.46
10	Kathaltali	5.8	13.00	22.5	10	2.2	5.1	0.10	2.4	0.40
11	Taluk	5.9	18.10	18.1	13	3.1	2.3	0.15	1.8	0.36
15	Kalipur	6.2	27.45	27.43	16	2.4	7.51	0.21	2.0	0.50
16	Kalipur	6.3	23.25	21	9.5	3.2	5.2	0.51	2.1	0.28
August, 2003										
02	Patharghata	7.1	18.10	25	18	4.5	3.21	0.28	0.13	0.84
15	Kalipur	6.1	22.50	27	18	3.8	3.51	0.21	0.12	0.41
18	Taluk	6.3	27.10	25	16	2.8	2.15	0.20	0.08	0.36
25	Char Lathimara	6.4	19.12	23	15	1.5	3.8	0.19	0.17	0.41
September, 2003										
08	Badurtala	6.5	18.00	19	12.5	4.2	3.5	0.28	0.09	0.42
12	Taluk	7.0	20.00	12	3.7	3.5	4.8	0.30	0.12	0.29
16	Char Lathimara	5.2	23.00	24	11	2.5	3.5	0.18	0.13	0.22
27	Kathaltali	6.8	28.10	21	8.9	1.8	2.8	0.08	0.18	0.18
	Average	6.2	23.46	22.92	13.47	4.32	3.86	0.29	1.33	0.36
	Max	7.1	35.5	35.5	20	10	9.95	0.9	2.9	0.84
	Min	5.2	13.0	10.0	3.7	1.5	1.2	0.08	0.08	0.18

The trend of pH values: The pH values occurring at all the stations between 5.2-7.1 averaging 6.23, indicates acidic in nature. pH of natural rain water should be 5.7 at 25°C which is the value for CO_2 in equilibrium with solution at the existing partial pressure (Das, 1988).

EC: EC is an indication of the total ionic concentration and thus represents the atmospheric status of both gaseous and particulate matter. The highest value of EC is occurring at Patharghata Sadar (35.5 µscm$^-$) and lowest value at Kathaltali (13 µscm$^-$).

Total Dissolved Solids (TDS): The amount of dissolved solids present in water is an important consideration in its suitability for domestic use. In general, water with a total solids content of less than 500 mgl$^-$is most desirable for such purposes. Water with higher solids content

Table 3. Comparison of the present studied data with DoE potability standard for selected water quality parameters in Bangladesh (ECA, 1997).

Parameters	Present study	DoE Standard (1997)
Temp. (°C)	26.2	20-30
pH	5.95	6.5-8.5
TDS (mg/l)	19.18	1000
SO_4^{--}(mg/l)	4.83	400
Na^+ (mg/l)	2.20	200

often has a laxative and sometimes the reverse effect upon people.

The TDS level in the study area is 10-35.5 mg/l. The lowest value obtained at Badurtala (10 mgl^-) and the highest value at Patharghata (35.5 mgl^-). The highest value is due to the presence of HCO_3^- and SO_4^{--} which is due to the anthropogenic contribution.

HCO_3 ion: It is a major constituent in all rainwater and highest concentration recorded the study areas is 20 mg l-1. Its concentration varies a good deal from shower to shower. This ion is produced by the reaction of the carbonic acid with alkaline earth bicarbonates present in soil, dust or otherwise in the atmosphere as a particulate matter. The average value to ions is around 13.47 mg l-1. Its concentration in the first shower of a particular day is relatively high which gradually decreases with time due to washing down of the soluble bicarbonates (Rao *et al.,* 1995).

SO_4^{--} ion : Sulfates occur in natural waters at concentration up to 50 mg l^{-1}. Concentration of 1000 mg l^{-1} can be found in water having contact with certain geological formations e. g. gypsum reserves, water from pyrite quarries. Sulfur is required in the synthesis of proteins and is released in their degradation. Rainwater has quite high concentration of sulfates particularly in areas with high atmospheric pollution. In humid region, sulfate is readily leached from the zone of weathering by infiltration-waters and surface run-off (Kotaiah and Swamy, 1994).

Sulfate concentration in rainwater of the study areas varies from 1.2 to 9.95 mg l^{-1} and the average concentration is 3.86 mg l^{-1}.

Na^+ ion: The source of Na ion in rainwater is likely to be both marine and non-marine in origin. Variation of this ion with progress of shower follows the same pattern as in the areas of other ions. Low Cl^- to Na^+ ratio compared with seawater indicates substantial loss of Cl^- ions from sea spray aerosols as they traced island.

Ratios of sea salt constituents ($SO4^{2-}/Na^+$): The low value of $SO4^{2-}/Na^+$ ratio in the study area points to the presence of marine conditions. The low values are due to the coastal upwelling. This however requires that H_2S (formed by the reduction of SO_4 in anaerobic waters) present in the upwelling water only be partially oxidized and they permit the H_2S to escape into the coastal atmosphere. It is therefore appears that these are physical process other than molecular diffusion which facilitate the escape of H_2S in coastal shallow water.

Rainwater harvesting and consumption pattern: SANGRAM (a local NGO) established 15 rainwater-harvesting plants following rooftop harvesting in Badurtala and Charlatimara sight. Each plant has the capacity of 100 liters and capable of supplying 25% water demand of community. People depend mostly on pond water, rain water (monsoon), tube well water (rare) for drinkable purpose. Ponds supply around 65% of drinking water resource in the area. Although rain is a seasonal phenomenon but it fulfils the major share of water demand. Whole of the year dwellers depend directly or indirectly on the rainwater.

Table 4. Drinking water pattern in the study area.

No.	Reservoir	Consumers (%)
1	Pond	65
2	Tube well	5
3	Rain	20
4	others	10
Total		100

Source: Field survey, 2003

Discussion

In the study area most of the samples are acidic in nature. The acidity of rainwater depends on the concentration of both anionic-cationic species. It may also be noted that rainwater contains both strong acid like H_2SO_4, HNO_3, HCl as well as the weak acids H_2CO_3, CH_3COOH (Likens *et al.,* 1976). Acidic pH reveals the presence of strong acids in rainwater while neutral or alkaline pH

indicates neutralization of acids by soil dust and ammonia. The pH of rainwater ranged 5.9 to 8 indicating slightly acidic-alkaline nature as compared to the reference level of 5.6 (Charlson and Rodhe, 1982). The highest pH value at Patharghata Sadar (7.1) is due to the urban growth in the study area and lowest value at Char Lathimara (5.2) is due to the influence of adjacent Sundarbans (Moody *et al.,* 1991). The relatively higher acidic nature with time- intensity is due to removal of alkaline species and higher presence of acidic precursors.

The electric conductivity that reported higher values in some samples is having ionic concentrations with the reflection of the total content most electrically significant ions (Cl^-, Na^+) that enter into rainwater.

The presence of dissolve solids concentrations demarcate whether the sample may have association either with natural or anthropogenic contribution. In the studied samples sometimes higher concentration of TDS values indicate anthropogenic contribution.

The HCO_3^- concentration of rain water decreases gradually with showering. The low value of $SO4^{2-}/Na^+$ ratio indicates marine influence in the rain water chemistry of the study area.

From the above study it can be concluded that consumption of rain water for a long period may cause health hazards.

Conclusion

The South Asian summer monsoon has a purely maritime origin and traverse with respect to India. In addition to bring an important source of moisture the monsoon winds also provide vast amount of sea salts which are well known cloud condensation nuclei. Admittedly, the present work is somewhat speculative in the context of Bangladesh. Much more research is needed to completely understand the complex nature of precipitation chemistry involved during the monsoon. From the chemical analysis of monsoon rainwater from the study area, the following conclusions can be drawn (i)Most of the rainwater has a tendency towards slightly acidic character (Av. pH 5.95) (ii) All major cations and anions are present in detectable amount. HCO^-_3, SO^{-2}_4 and Na^+ are the predominant anion and cations in the studied sample (iii) Although in the beginning of the first shower, bicarbonate ion predominates, its concentration gradually diminishes with passage of time but sometimes erratic values are also noticed and ever in the fraction of a continuous shower, high bicarbonate concentration is noticed (iv) Most of the other cations and anions behave similarly as bicarbonate ion (v) Weight ratios of Na^+/SO^{-2}_4 points out the unusual marine conditions (vi) The rainwater chemistry of the study area is below the range of a DoE standard. A concern over chemical point of view that acidic water as well as less natural quality is not suitable for human consumption. So it is an argent need to enrich the mineral constituents and alkali nature before advocating for drinking purpose.

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