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Chemistry of Pre-Monsoon and Monsoon Rain Water in Rajshahi City of Bangladesh

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Abstract*: This study assessed the physical and chemical properties of rainwater of Rajshahi city of Bangladesh. Rainwater samples were collected two time's pre-monsoon season and monsoon season per year with standard rain collection instruments in the period March, 2017 to October, 2019. The physicochemical characterization involved determination of pH, EC, major ions, and the metals of interest in the soluble fraction of rainwater. Precipitations had an acidic pH (6.40-6.66) and, compared to World Health Organization guidelines for drinking-water quality, samples were characterized by low EC (31-102 µS/cm), DO (2.77-5.80 m/L), TDS (15-49 mg/L), Acidity (9.49-18.55 m/L), dissolved CO_2 (8.35-16.32 mg/L), Alkalinity (17.4-20.8 mg/L), Hardness (25-38 mg/L), Ca^{2+} (9-15 mg/L), Mg^{2+} (6-9 mg/L), NO_3^-(3-6mg/L), and SO_4^{2-} (up to 6.0 mg/L) values. Metal ions (As, Cd, Cr, Pd and Hg) were found in below the detection limit (BDL) of AAS for these collected rainwater samples. Rain water quality during monsoon season was better than that of pre-monsoon season in Rajshahi city due to difference of dust in the air. pH, EC, TDS and DO of rainwater reflects the impact of atmospheric particulate matter on the precipitation chemistry.*

Keywords: *Rain water, acid rain, heavy metals, water quality, physicochemical properties.*

1. INTRODUCTION

Rajshahi is a metropolitan city, and a major urban, commercial and educational center of Bangladesh. It is also the administrative seat of eponymous division and district. Located on the north bank of the Padma River, near the Bangladesh-India border, the city has a population of over 763,952 residents [1]. Rajshahi is one of the most clean and green city in Bangladesh. Geographically Rajshahi is situated within Barind Tract, 23 m (75 ft) above sea level, and lies at 24°22′26″N 88°36′04″E. Under Köppen climate classification, Rajshahi has a tropical wet and dry climate. The climate of Rajshahi is generally marked with monsoons, high temperature, considerable humidity and moderate rainfall. The hot season commences early in March and continues till the middle of July. The maximum mean temperature observed is about 32 to 36 °C (90 to 97 °F) during the months of April, May, June and July and the minimum temperature recorded in January is about 7 to 16 °C (45 to 61 °F). The highest rainfall is observed during the months of monsoon. The annual rainfall in the district is about 1,448 millimeters (57.0 in) [2].

The water quality of the Rajshahi city was moderately contaminated with heavy metals and is threatening human health. It was revealed that the groundwater was not suitable for human consumption without adequate treatment, especially for Pb, Mn and As to ensure the quality required for safe drinking water [3]. There is lack of safe water for drinking and other purposes. So the people have to depend on different sources of water like groundwater, river water, stream water, pond water for their daily needs. More than 90 percent of rural households depend on water supply from ground water on their household and domestic usage. These sources of water are being polluted by human waste, animal waste, domestic waste, refuse dump, jute mills, textiles, sugar mills, tanneries, seepage from pit latrines, fertilizer. Arsenic Contamination of drinking water is

significant health problem in Bangladesh [4]. Due to disposal of different types of wastes in pond, pond transformed as sink for spreading harmful diseases and to create a polluted unhealthy living environment. Due to this incident of water borne diseases like diarrhoea, dysentery, typhoid, fever, jaundice, cholera etc. has increased in the recent year [5]. In many ways the water of Rajshahi city is being polluted day by day. Various kinds of bacteria, harmful germs, and toxic elements are present in the water of Rajshahi city. The water of Rajshahi city exhibits higher hardness than rest country. Ground water pollution has been found to be a critical problem in Rajshahi City and surrounding areas. The main problems relate to the high iron content which is the 0.4-3.5 mg/L in Rajshahi City Corporation area which exceeds the national drinking water standards for iron 0.3-1.0 mg/L. High levels of arsenic contamination were also in some areas. Average arsenic concentrations in local water drinking were 2–4 times the national average.

The wastewater, generated in the area of Rajshahi City Corporation considered, possesses a significant amount of contaminant. This domestic effluent dominated wastewater flow through the concrete drainage network and finally being disposed to the river Padma without any treatment continuously. During dry season the water from Padma accompanied by this wastewater is used for irrigation, but the quality of this discharge is not fully satisfactory for irrigation which may affect the yield of crop and fertility of the land. As a result, the aquatic life in Padma and the overall fertility of agricultural land around the river are affected potentially [6]. Rajshahi city householders are suffering from inadequate water supply as well as they suffer from various water related diseases. The concentration of iron and turbidity in RWASA (Rajshahi Water supply and Sewerage authority) point and household water of the study area were very high. Most of the area's water found to have an odor [7].

Safe drinking water is a basic need of every human being despite of any socioeconomic status. It is impossible to stop water pollution. Ground water, surface water or supplied water by RWASA has exceeded acceptable limit in some parameters especially arsenic and iron. Rain water is alternative source of drinking water. Harvesting of rain water can play important in agricultural purposes [8-9]. With the best of our knowledge no studies has been reported yet in assessment of physicochemical parameters of rain water of Rajshahi city. In this study we try to find out the physicochemical properties of rain water of Rajshahi city and assess the rainfall water whether it is acidic or not.

2. MATERIALS AND METHOD

2.1 Study area and sampling time

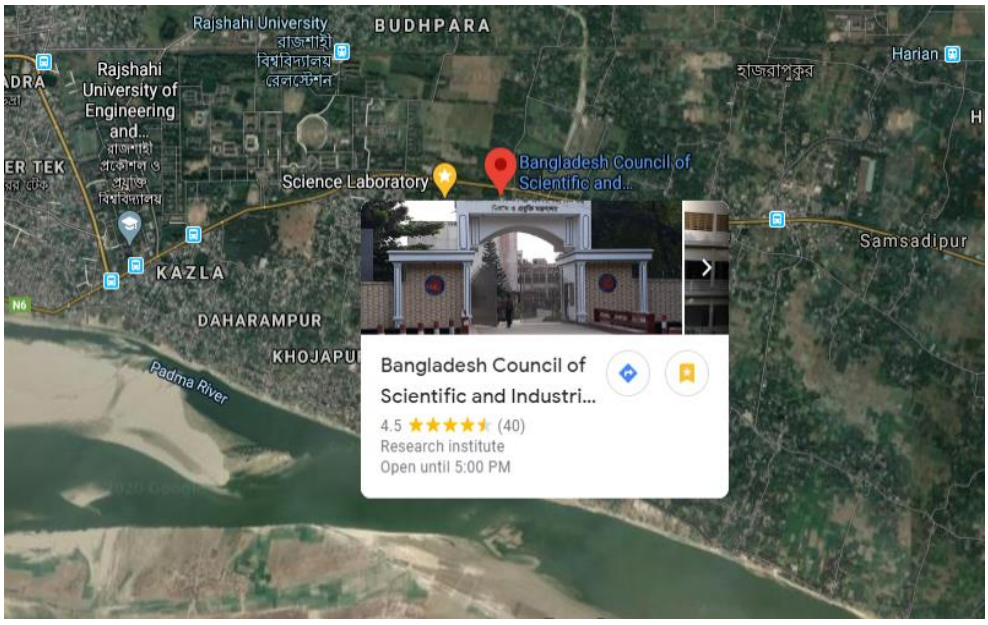

Figure 1. Sampling location for rain water

The samples were collected from Bangladesh Council of Scientific and Industrial Research (BCSIR) laboratories residential area, Rajshahi (24°22'00.2"N and 88°39'15.6"E), from the year 2017 to 2019 by the proper sampling procedure. Samples were collected twice (Pre-monsoon and monsoon season) in every year. Pre-monsoon season lasts from March through May month and monsoon season lasts from June through October month. Each sampling started at the time of the onset of each rainfall event.

2.2 Sample collection

In this study, for the analysis of physicochemical properties, samples were collected from sampling area's city dwellers houses. Rainwater samples were collected manually in an open space from a height of 8 ± 2 meters above ground level, in clean acid-washed polyethylene bottles using glass funnels. The sampling bottles were labeled with a unique identification no. (Table-1) for each sample, and stored at 4^0C prior to analysis. Five liters plastic bottles were used for collecting samples for physicochemical analysis. Prior to collection, the plastic bottles were cleaned by detergent solution and then, it was treated with 5% nitric acid overnight. They were finally washed with de-ionized water and dried in the air. During sampling the sample bottles were tightly screwed. The pH, electrical conductivity EC) and total dissolved solids (TDS) were measured at the site during sample collection. Then samples were kept in ice bag tied well. Then, it was carried to the laboratory and stored in the refrigerator for analysis.

Table1. Sample Identification number

Sample Identification no	Sampling Time
S-1701	Pre-monsoon season, 2017
S-1702	Monsoon season, 2017
S-1801	Pre-monsoon season, 2018
S-1802	Monsoon season, 2017
S-1901	Pre-monsoon season, 2019
S-1902	Monsoon season, 2019

2.3 Sample analysis

pH, Temperature and Electrical Conductivity were measured at the sampling point and the other parameter TDS, DO, heavy metals and anions of the samples were analyzed at the Institute of National Analytical Research and Service (INARS) of Bangladesh Council of Scientific and Industrial Research (BCSIR) by standard methods [10].The temperature of water was recorded with the help of a thermometer calibrated from Cali-lab, India. pH, EC and DO were measured by portable multi parameter meter (Senion^{TM}156, HACH, USA). TDS was determined gravimetrically by following standard methods [11-12]. A certain amount of samples were filtered by using Whatman 44 filter paper followed by drying at 180^0C in a calibrated oven for measuring TDS. Acidity and carbon dioxide was determined by NaOH titration method.

Analysis of metals such as Arsenic (As), Iron (Fe), Magnesium (Mg), Calcium (Ca), Lead (Pb), Mercury (Hg), Zinc (Zn) and Cadmium (Cd) were measured by atomic absorption spectrometry. 100 mL sample was digested in 5 mL HNO_3 on a hot plate in fume hood [13]. The sample was gently boiled to the lowest possible volume until digestion completed as shown by a light color, clear solution. After complete digestion, cool sample was transferred to 100 mL volumetric flask and diluted up to the mark. The sample was then filtered and analyzed by Atomic Absorption Spectrometer (Model: AA240FS, Varian, Australia) for metals content following the techniques described earlier. In case of high concentration, the sample was diluted by using de-ionized water [14].

Anions (F^-, Cl^-, Br^-, NO_2^-, NO_3^-, SO_4^{2-}) were measured using Ion Chromatograph (SIC10AVP, Shimadzu, Japan) following the procedure reported earlier. Samples were filtered through 0.22 micron filter to avoid dust

particles. 1.3 mM Sodium carbonate (Na_2CO_3) and 1.7 mM Sodium bi-carbonate ($NaHCO_3$) mixer was used as a mobile phase to separate ions in an ionic chromatographic column (HIC 10A super).

2.4 Calibration standards used for sample analysis

Zero solution (5% $NaSO_2$ solution), buffer solutions (pH=4.0, pH=7.0), 1000 µS/cm of NaCl solution were used to calibrate portable multi parameter meter for determining DO, pH & conductivity, respectively.1000 mg/L stock metals and anions standard (Scharlau, Spain) solutions were used to prepare calibration standards. The stock standards were diluted to certain concentration of calibration standards required to measure different metals by AAS.

3. RESULT AND DISCUSSION

Table 2. Physicochemical parameters of rain water

Sample ID	pH	DO (mg/L)	EC (µS/cm)	TDS (mg/L)
S-1701	6.50	2.77	47.2	23.9
S-1702	6.66	5.80	31.9	15.6
S-1801	6.44	2.55	58.5	27.5
S-1802	6.58	5.57	37.3	17.3
S-1901	6.40	2.54	101.4	48.7
S-1902	6.54	5.27	43.2	20.3
ECR-1997 [15]	6.5-8.5	6.0	--	1000
WHO (4^{th} edition) [16]	6.5-8.5	--	--	600

The pH value of all samples was within 6.40-6.66. The pH of rainwater during the pre-monsoon season was slightly less than that of monsoon season which is due to the lower concentrations of nitrate and sulphate [17]. It indicates that the rainwater is slightly acidic during pre-monsoon compared to monsoon."Clean" or unpolluted rain has an acidic pH, but usually no lower than 5.7, because carbon dioxide and water in the air react together to form carbonic acid, a weak acid according to the following reaction [18]:

$$H_2O\ (l) + CO_2\ (g) \rightleftharpoons H_2CO_3\ (aq)$$

But the rainwater of Rajshahi city was not acid rain. Dissolved oxygen (DO) of pre-monsoon samples was lower than that of monsoon samples. The dissolved oxygen content was found to be less than 3.0 mg/L during the period of pre-monsoon which was less than the desirable amount of dissolved oxygen in drinking water. The value of DO of pre-monsoon season is lower due to the excess of dust in the air. Electrical conductivity and Total dissolved solids of pre-monsoon samples were higher than that of monsoon samples. Electrical conductivity of rainwater reflects the impact of atmospheric particulate matter on the precipitation chemistry. Rainwater conductivity is mainly contributed by water-soluble ions, the value being related to the total sum of cations and anions in the rainwater. Low rainwater conductivity is an indicator of good atmospheric environmental quality.

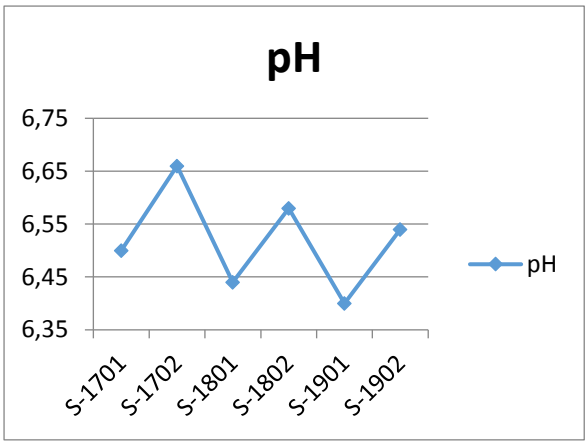

Figure 2. Variation in pH of rainwater

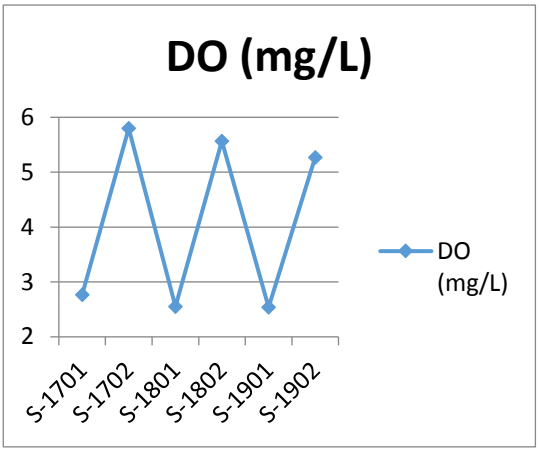

Figure 3. Variation in DO of rainwater

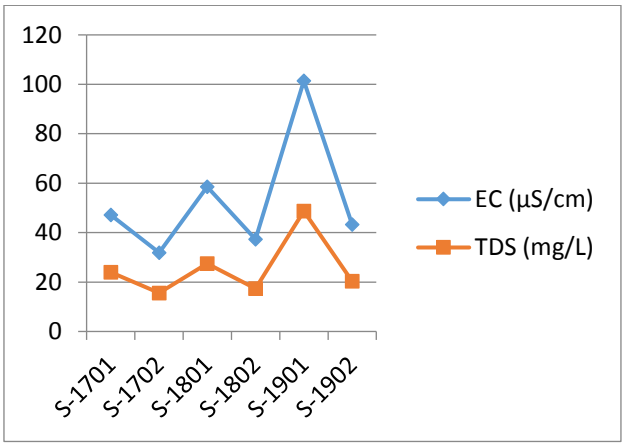

Figure 4. Variation in EC and TDS of rainwater

The total dissolved solids (TDS) in rainwater, originating from particulate matter suspended in the atmosphere usually range from 2 mg/l to 20 mg/L. However, the study disagreed with the finding since total dissolved solids concentration has gone beyond the 20 m/l limit and probably due to the high concentration of particulate matter in the atmospheric air.The value of collected samples pH, DO, EC and TDS was within acceptable limit of Environment Conservation Rules (ECR)-1997, Bangladesh.

Table 3: Physicochemical properties of rain water

Sample ID	Acidity (mg/L)	CO_2 (mg/L)	Alkalinity (mg/L)	Bi-Carbonate (mg/L)	Hardness (mg/L)	Ca (mg/L)	Mg (mg/L)
S-1701	12.33	10.85	18.6	22.69	33.3	13.32	7.94
S-1702	9.49	8.35	17.4	21.22	23.6	9.44	6.57
S-1801	15.32	13.48	19.9	24.27	36.4	14.56	8.74
S-1802	11.81	10.39	18.1	22.08	25.7	10.28	6.17
S-1901	18.55	16.32	20.8	25.37	38.6	15.44	9.27
S-1902	13.32	11.72	18.6	22.69	28.1	11.24	6.74
ECR-1997 [15]	--	--	--	--	200-500	75	30-65

WHO (4th edition) [16]	--	--	500	--	--	100	30

The acidity value of rain water was higher during the period of pre-monsoon compared to monsoon. Where acidity value was higher, there dissolved carbon-di-oxide value was higher. The low pH found in samples indicates high presence of CO_2 in the atmosphere as a result of excessive bush burning within the environs. The value of acidity and dissolved carbon-di-oxide was below of acceptable limit of drinking water. Alkalinity value of rain water was higher than that of acidity value. Bi-carbonate value was between 20-26 mg/L.

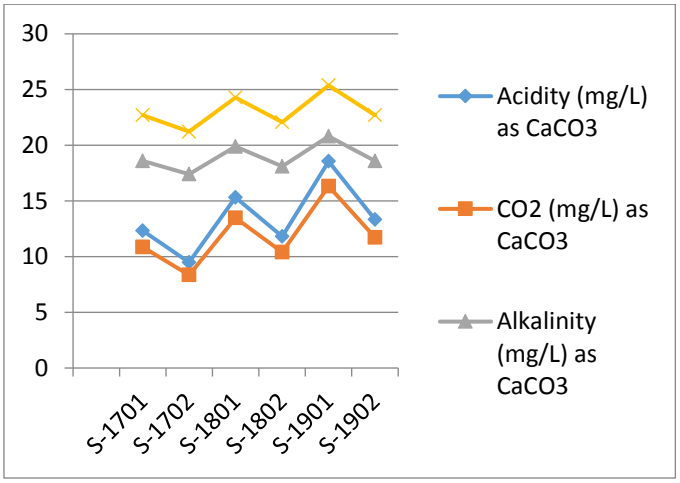

Figure 5. Variation in Acidity, CO_2, Alkalinity and Bi-carbonate of rainwater

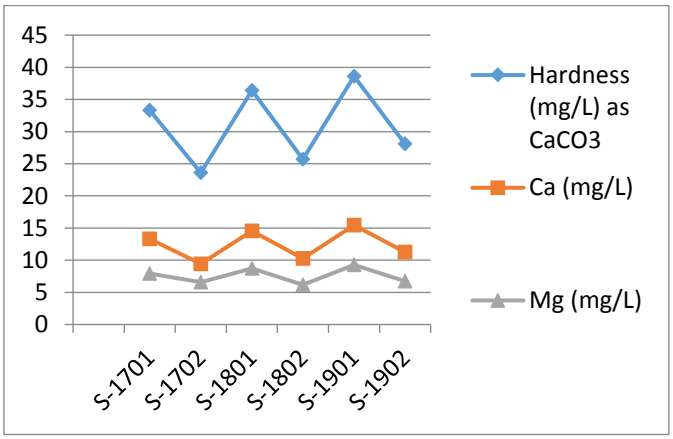

Figure 6. Variation in Hardness, Ca and Mg of rainwater

Total hardness concentration of the rainwater ranged from 23.6 to 38.6 mg/L, while calcium concentration ranged from 9.44 to 15.44 mg/L and magnesium concentration ranged from 6.17 to 7.94 mg/L. Calcium and Magnesium were found at a significant level in all samples.Ca & Mg are essential for the human body. Calcium is part of bones and teeth. In addition, it plays a role in neuromuscular excitability (decreases it), good function of the conducting myocardial system, heart and muscle contractility, intracellular information transmission and blood coagulability. Magnesium plays an important role as a cofactor and activator of more than 300 enzymatic reactions including glycolysis, ATP metabolism, transport of elements such as Na, K and Ca through membranes, synthesis of proteins and nucleic acids, neuromuscular excitability and muscle contraction etc

No heavy metals were present of rain water in Rajshahi city. As, Cd, Pb, Hg and Cr was found below the detection limit of AAS. It indicates rain water is safe potable water. Arsenic was found in water, soil, sediment,

fruits and vegetable in Rajshahi city [19]. Consumption of heavy metal of the foodstuffs could lead a potential health risk to human. That's why rain water harvesting is needed for drinking and agricultural purposes to ensure healthy life-style,

Table 4. Anions of rain water

Sample No.	Fluoride (mg/L)	Chloride (mg/L)	Nitrite (mg/L)	Bromide (mg/L)	Nitrate (mg/L)	Sulphate (mg/L)
S-1701	< 0.5	< 1.0	< 1.0	< 1.0	5.21	5.27
S-1702	< 0.5	< 1.0	< 1.0	< 1.0	3.22	5.18
S-1801	< 0.5	< 1.0	< 1.0	< 1.0	5.69	5.35
S-1802	< 0.5	< 1.0	< 1.0	< 1.0	3.59	5.21
S-1901	< 0.5	< 1.0	< 1.0	< 1.0	5.88	5.42
S-1902	< 0.5	< 1.0	< 1.0	< 1.0	3.92	5.26
ECR-1997 [15]	1.0	150-600	< 1.0	--	10	400
WHO (4th edition) [16]	--	250	--	--	50	250

Fluoride, chloride, nitrite and bromide value were below than detection limit. Nitrite value was observed more than 5.0 mg/L during pre-monsoon season but less than 3.0 mg/L during monsoon season. This can be attributed to the presence of higher particulate matter such as smoke, dust; suspended soot in the air is responsible for more nitrite value during pre-monsoon compared to monsoon. Power plants release the majority of sulfur dioxide and much of the nitrogen oxides when they burn fossil fuels, such as coal, to produce electricity. In addition, the exhaust from cars, trucks, and buses releases nitrogen oxides and sulfur dioxide into the air. Vehicle emissions control reduces emissions of nitrogen oxides from motor vehicles.

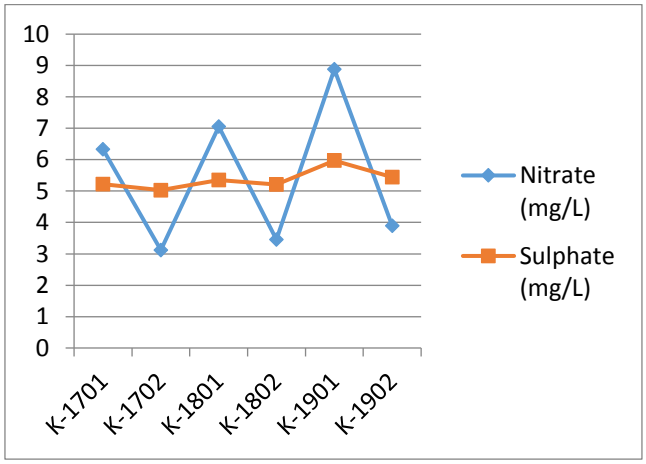

Figure 7. Variation in SO_4^{2-} and NO_3^- of rainwater

Sulphate value of rain water was about 5.0 mg/L. There was no significant change of sulphate value for season variation.

4. CONCLUSION

This study expressed that rain water is alternative potential source for drinking purposes . Rain water of monsoon season is better than that of pre-monsoon season in Rajshahi city due to the differences in the air masses reaching the sampling location from several sources like mills, industries, bus terminal, and local atmospheric circulation. The dust of the air mixes with the particles of the clouds and rains down on the earth's surface. Due to the lack of dust, smoke, suspended matter in the air, the pH, TDS, EC, hardness are lower during the monsoon season than during the pre-monsoon season. It is possible to eliminate the shortage of pure drinking water by collecting and storing rain water in arsenic prone and potable water deficient areas.

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Conflict of Interests

The authors declare that there is no conflict of interests regarding the publication of this paper.

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