Transport of Toxic Metals Through the Major River Systems of Bangladesh

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Summary: Bangladesh having an area of about 144000 sq. km with a population of more than 120 millions is situated in the northeastern part of the south Asia subcontinent and a vast area to the south in the Bay of Bengal. The largest delta in the world has a large catchments area of about 1554000 sq. km spread over five countries namely Bhutan, Nepal, China, India and Bangladesh. Environmental pollution usually refers to biological, chemical and physical materials introduced largely as a result of human activities. Water is one of the main sources of the environmental pollution and the contamination of water by the metal ions at the trace levels is generally occurred through natural processes or anthropogenic sources. Buriganga, Sitalaksma, Karnafully, Bramhaputra and Jamuna were selected for the present study. The toxic metal ions concentration in water samples of various region of different rivers were determined by AAS and GFAAS. The highest amount of As was found in the Karnafully river at KAFCOO (34.6±1.2 μg/L) in the dry season and lowest in the Buriganga river at Badamtoli (5.3±0.1μg/L). The highest amount of Pb was found in the dry season at Kalurghat (13.4±0.05 μg/L) in Karnafully river. The highest amount of Cd was found in the river of Karnafully at KAFCOO (27.2±0.4 μg/L) in dry season. These observations demand the need of regular monitoring of toxic metal ions concentration in different rivers especially Buriganga, Sitalaksma and Karnafully. The concentration of As, Pb and Cd determined in this study is below the recommended values of WHO (World Health Organization) and EQS (Environmental Quality Standards of Bangladesh). The methods that adopted to investigate these metals were in good agreement with standard solution (Marck, Germany, code no: J/4546/05), where ±2.0% deviation was found.

Introduction

All life on earth depends on water. The water existing in earth can be divided into ground water and surface water. The total water resource of the world is about 26.6 trillion tons. Approximately 94.7% of these occur in lithosphere [1]. The surface water that includes wastes of rivers, lakes, ponds, together with underground water found in lithosphere. The quality of water is of vital concern for mankind since it is directly linked with human welfare. The pollution of drinking water caused water borne diseases, which loom large on the horizons of developing countries including Bangladesh. The major sources of water pollution are domestic waste from urban and rural areas, industrial wastes which are discharged into natural water bodies and chemical pesticides and fertilizers, part of which is washed and goes to the water bodies. In our country the paper mills are situated on the bank of the river Karnafully, Surma, Padma. These mills were established long ago and do not have elaborate effluent processing systems. They discharges alkali, hypochlorite, chlorinated or sulphonated lignin compounds in these rivers [2]. Urea and TSP fertilizer factories are suited on the banks of the rivers Karnafully, Kushiara, Meghna and Shitalakaya. These industries have limited effluent processing arrangement. Urea and ammonia are the main pollutants from the fertilizer industry. Sugar mills are located around northwest part of the country. Effluent from tannery industries, mostly located near cities of Dhaka and Chittagong finds its way to the adjoining river Buriganga and Karnafully. Tannery industries use chromium salts, which are toxic even in low concentration.

The surface water is mainly used for drinking, domestic, industrial and irrigation purposes. The necessity of utilizing the water is increasing tremendously with the increase of both the population and the arsenic contamination in ground water. To keep the rivers of Bangladesh free from pollution; a base line data of pollutants are required. With this view in mind water samples have been collected from fourteen different locations of Buriganga, Sitalaksma, Karnafully, Bramhaputra and Jamuna. The toxic metal ions (As,Pb,Cd,Se,Cr) were determined by AAS, GFAAS, Electro-analyzer and anions (SO_4^{-2}, NO_3^-, NO_2^-, PO_4^{3-}, Cl^-) were determined by UV-Visible spectrophotometer and titrimetric method.

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Results and Discussion

From the analysis (Table-1, 1a, 2, 2a), it was found that the water of these rivers is generally alkaline in nature. The alkalinity varies with the season. It has been observed that the highest alkalinity is shown in the dry season. Highest alkalinity is shown by the water samples of Bramhaputra (Mymensingh, pH =8.2), Jamalpur (pH=8.0) and Jamuna (Jaghannatganj, pH=8.0) compared to the others. The suspended solid does not vary with the seasons. However, it varies from river to river. The maximum amount of suspended solid was found in the water of Karnafully (Kalurghat) in the dry season whereas in the water of Sitalakya in the rainy season. The highest amount of As was found in the Karnafully river at KAFCOO (34.6±1.2 μg/L) in the dry season and lowest in the Buriganga river at Badamtoli (5.3±0.1μg/L) and sampling sites may be correlated with the location of industries and their waste disposal. The highest amount of Pb found in the dry season at Kaurghat (13.4±0.05 μg/L) in Karnafully river. The highest amount of Cd found in the river of Karnafully at KAFCOO (27.2±0.4 μg/L) in dry season. The highest amount of Se was found in the river of Karnafully at Chandragona (32.3 ± 0.2 μg/L) whereas sitalakya at Adamjee contain 18.2± 0.04 μ/L of Se in the dry season. KAFCOO in the river of Karnafully contain highest amount of 89.0±4.0 μg/L of Cr in the dry season and Hazaribagh in the river of Buriganga contain highest amount of Cr (23.0±0.1 μg/L) in the rainy season. The highest amount of chloride and sulphate was found in the river of Buriganga at Hazaribagh (407.0 ± 5.1 mg/L) and (288.0±2.0mg/L) in the rainy season. Both the nitrate and nitrite found highest in amount at Badamtoli (22.5±0.2 mg/L) and (8.0±0.04 mg/L) in the river of Buriganga respectively.

Experimental

Collection of water samples and preservation: The samples were collected both in the rainy and dry seasons (July 2000-June 2001) in polythene containers. The containers were washed with dilute HNO_3 and distilled de-ionized water. The sample waters were collected at one feet depth from the surface of the river and were collected from the same locations in both rainy and dry seasons. In the laboratory the water passing through the suction pump to remove suspended material. One portion was kept for anion analysis and another portion was acidified for storing polythene containers.

Table-1:Concentration of As, Cd, Pb, Cr, Se in the Water of Different Rivers with the Seasonal Variations

Area and sites	pH	pH	Conductivity ms/cm	Conductivity ms/cm	As μg/L	As μg/L	Pb μg/L	Pb μg/L	Cd μg/L	Cd μg/L	Se μg/L	Se μg/L	Cr μg/L	Cr μg/L
	Rainy	Dry	Rainy	Dry	Rainy	Dry	Season Rainy	Dry	Rainy	Dry	Rainy	Dry	Rainy	Dry
Buriganga														
Hazaribagh														
Front	7.6	6.9	$8.4X10^{-1}$	$8.8X10^{-1}$	15.2±0.2	7.4±0.2	0.1±0.01	12.4±0.02	0.2±0.01	6.7±±0.05	9.5±0.02	10.3±0.02	11.0±0.1	5.0±0.05
Middle	8.1	6.8	$8.2X10^{-1}$	$8.2X10^{-1}$	14.1±0.1	5.3±0.1	0.3±0.01	14.4±0.01	1.0±0.02	7.4±0.04	9.7±0.02	12.0±0.02	23.0±0.1	8.0±0.05
Opposite	7.8	6.9	$8.4X10^{-1}$	$8.0X10^{-1}$	21.8±1.5	8.2±0.2	0.2±0.01	5.0±0.02	0.5±0.01	2.3±0.03	7.1±0.01	14.4±0.04	12.0±0.5	2.4±0.02
Badamtoli														
Front	7.5	7.2	$0.8X10^{-1}$	$9.4X10^{-1}$	9.3±0.2	17.2±0.3	0.3±0.02	8.2±0.02	0.5±0.01	7.6±0.06	5.0±0.01	32.2±0.02	17.0±0.1	3.2±0.02
Middle	7.5	7.2	$0.8X10^{-1}$	$9.4X10^{-1}$	11.6±1.2	13.4±0.2	0.5±0.01	6.2±0.01	0.5±0.02	10.6±0.04	5.7±0.02	21..0±0.05	12.0±0.02	1.2±0.02
Opposite	7.5	7.2	$0.8X10^{-1}$	$9.2X10^{-1}$	8.5±0.5	14.0±0.2	0.7±0.01	6.0±0.05	0.6±0.01	5.4±0.04	3.2±0.01	20.0±0.05	12.0±0.1	7.0±0.05
Postogola														
Front	7.5	7.2	$1.0\ X10^{-1}$	8.0 X10-1	8.4±0.3	16.2±0.2	1.0±0.02	6.2±0.02	0.3±0.01	1.7±0.05	4.3±0.02	14.5±0.05	6.0±0.02	2.4±0.02
Middle	7.5	7.2	$1.0\ X10^{-1}$	$8.0\ X10^{-2}$	11.4±0.5	17.3±0.3	0.4±0.01	8.5±0.05	BDL	4.1±0.04	3.2±0.01	24.3±0.03	6.0±0.02	2.0±0.02
Opposite	7.5	7.1	$1.0\ X10^{-1}$	$8.0\ X10^{-3}$	11.8±0.3	14.0±0.2	0.7±0.01	9.3±±0.03	0.2±0.01	6.4±0.04	5.0±0.02	21.3±0.02	3.0±0.01	7.0±0.05
SSMC														
Front	7.5	7.2	$1.2\ X10^{-1}$	$9.4X10^{-1}$	10.7±0.5	12.0±0.4	0.6±0.02	5.1±0.01	BDL	5.5±0.02	5.0±0.02	34.0±0.05	13.0±0.1	6.0±0.02
Middle	7.5	7.2	$1.2\ X10^{-1}$	$9.2\ X10^{-1}$	11.5±0.2	13.2±0.2	0.5±0.01	9.6±0.04	0.1±0.01	10.0±0.05	3.4±0.01	36.0±0.05	10.0±0.1	4.0±0.02
Opposite	7.5	7.2	$1.2\ X10^{-1}$	$9.4\ X10^{-1}$	10.1±0.2	10.0±0.2	0.6±0.02	8.0±0.05	BDL	5.3±0.03	4.0±0.02	35.6±0.04	14.0±0.1	7.4±0.04
Sitalakkya														
Demra														
Front	7.4	7.1	$1.2\ X10^{-1}$	$4.6\ X10^{-1}$	0.7±0.03	14.6±0.3	0.3±0.01	12.4±0.03	1.0±0.02	1.4±0.04	3.2±0.01	21.2±0.02	6.0±0.02	1.5±0.01
Middle	7.5	7.1	$1.2\ X10^{-1}$	$4.8\ X10^{-1}$	0.8±0.02	15.0±0.5	0.3±0.01	7.0±0.05	0.4±0.01	3.0±0.02	4.4±0.02	24.0±0.05	4.0±0.04	1.3±0.03
Opposite	7.5	7.1	$1.2\ X10^{-1}$	$4.7\ X10^{-1}$	1.0±0.01	15.0±0.5	0.4±0.02	9.5±0.05	0.2±0.01	1.2±0.01	4.4±0.01	18.6±0.04	3.0±0.02	1.4±0.01
Fatullah														
Front	7.5	7.5	$1.2\ X10^{-1}$	$5.5\ X10^{-1}$	1.0±0.1	16.0±0.4	0.3±0.01	6.0±0.02	0.3±0.01	5.5±0.02	3.4±0.02	23.0±0.05	6.0±0.1	3.3±0.02
Middle	7.5	7.4	$1.2\ X10^{-1}$	$5.2\ X10^{-1}$	0.2±0.01	15.2±0.2	0.4±0.01	5.2±0.02	0.3±0.01	5.4±0.02	3.4±0.01	20.0±0.05	7.0±0.1	2.3±0.01
Opposite	7.5	7.4	$1.2\ X10^{-1}$	$5.6\ X10^{-1}$	0.5±0.04	17.4±0.4	0.3±0.01	6.0±0.05	0.1±0.01	6.0±0.02	3.4±0.01	15.7±0.03	4.0±0.02	3.0±0.01
Adamjee														
Front	7.4	7.1	$1.2\ X10^{-1}$	$5.8\ X10^{-1}$	0.6±0.1	9.0±0.2	0.3±0.02	11.3±0.03	0.6±0.02	5.5±0.03	3.5±0.05	16.6±0.04	5.0±0.1	0.2±0.01
Middle	7.4	7.1	$1.2\ X10^{-1}$	$5.6\ X10^{-1}$	0.6±0.02	7.2±0.2	0.3±0.01	9.2±0.02	0.1±0.01	6.2±0.02	3.2±0.02	18.2±0.04	5.0±0.1	0.3±0.01
Opposite	7.4	7.2	$1.2\ X10^{-1}$	$5.9.\ X10^{-1}$	0.5±0.02	5.6±0.3	0.3±0.01	7.6±0.04	0.2±0.01	6.0±0.02	3.5±0.05	18.0±0.05	10.0±0.1	1.0±0.02

BDL= Below detection limit (0.2μg/L)
No of analysis (N)=4

Table-1(a): Concentration of SO_4^{-2}, NO_3^-,NO_2^-, PO_4^{-3},Cl^- in the Water of Different Rivers with the Seasonal Variations

Area and sites	SS g/L	SS g/L	SO_4^{-2} mg/L	SO_4^{-2} mg/L	NO_3^- mg/L	NO_3^- mg/L	NO_2^- mg/L	NO_2^- mg/L	PO_4^{-3} mg/L	PO_4^{-3} mg/L	Cl^- mg/L	Cl^- mg/L
	Rainy	Dry	Rainy	Dry	Rainy	Season Dry	Rainy	Dry	Rainy	Dry	Rainy	Dry
Buriganga												
Hazaribagh												
Front	0.1	0.03	288.0±2.0	42.3±1.2	12.2±0.4	12.0±0.5	7.0±0.04	0.1±0.01	114.4±2.5	116.6±2.4	196.4±4.3	107.6±2.4
Middle	0.1	0.01	249.0±2.0	40.2±2.0	11.0±0.2	11.5±0.5	5.0±0.05	0.1±0.01	115.0±6.0	117.2±2.2	407.0±5.1	98.5±2.5
Opposite	0.1	0.01	282.2±2.0	34.2±1.2	8.0±0.5	9.0±0.2	7.0±0.04	0.1±0.01	109.2±5.3	105.6±2.4	280.1±5.5	101.6±2.4
Badamtoli												
Front	0.5	0.04	190.0±3.0	26.3±1.3	8.5±0.05	22.5±0.2	5.1±0.05	0.2±0.01	109.2±2.4	126.0±2.0	46.0±3.1	64.2±2.2
Middle	0.3	0.02	190.3±5.3	25.4±2.2	10.6±0.05	9.0±0.5	8.0±0.04	0.1±0.01	108.7±2.3	125.0±2.0	22.0±2.5	70.4±2.4
Opposite	0.6	0.01	194.0±3.5	24.7±2.4	14.0±0.1	10.4±0.2	7.3±0.02	0.1±0.01	108.3±2.1	126.3±2.2	32.0±2.5	66.0±2.0
Postogola												
Front	0.04	0.03	231.2±2.3	20.3±1.5	10.0±0.05	6.4±0.4	7.0±0.2	0.1±0.01	109.2±2.2	124.0±2.5	24.5±0.5	130.4±3.2
Middle	0.06	0.01	243.2±4.2	21.7±1.5	9.1±0.04	7.5±0.5	7.1±0.05	0.1±0.01	109.6±2.5	125.2±2.2	21.0±0.4	125.3±2.3
Opposite	0.2	0.01	236.2±2.4	20.0±1.0	10.5±0.04	9.0±0.2	7.0±0.05	0.1±0.01	108.4±3.4	125.5±2.5	21.1±0.4	139.0±3.0
SSMC												
Front	0.8	0.03	236.2±4.2	30.4±2.2	10.5±0.5	11.0±0.5	9.1±0.05	0.1±0.01	109.5±4.1	124.6±1.4	17.5±0.05	79.0±3.0
Middle	0.8	0.01	206.3±2.5	24.3±2.3	10.6±0.4	8.3±0.2	9.5±0.05	0.1±0.01	109.5±3.2	120.0±2.0	21.0±0.04	70.4±3.2
Opposite	0.8	0.02	221.3±4.2	26.0±2.0	10.4±0.05	5.0±0.1	9.2±0.03	0.1±0.01	109.4±2.1	126.3±2.3	21.0±0.04	70.0±3.0
Sitalakkya												
Demra												
Front	0.2	0.04	130.2±5.2	14.5±0.5	3.3±0.04	11.3±0.2	0.2±0.01	0.3±0.01	109.0±2.5	102.3±1.2	59.0±0.04	27.0±2.0
Middle	0.3	0.03	148.2±5.0	15.3±0.4	1.2±0.2	13.5±0.5	0.2±0.01	0.3±0.01	108.3±2.5	103.5±1.5	39.2±0.05	25.0±1.0
Opposite	0.6	0.06	151.1±2.3	13.5±0.5	1.2±0.02	11.0±0.2	0.2±0.01	0.3±0.01	109.4±3.1	102.5±1.2	38.0±0.05	27.0±2.0
Fatullah												
Front	0.6	0.03	121.2±5.2	17.0±0.5	2.0±0.04	8.2±0.5	0.02±0.01	0.1±0.01	109.0±4.1	98.3±2.4	40.2±0.1	58.0±2.0
Middle	0.3	0.03	123.5±5.3	13.0±0.2	3.0±0.02	9.4±0.2	0.02±0.02	0.1±0.01	109.2±4.2	96.2±2.2	62.0±0.5	60.0±3.0
Opposite	0.2	0.01	150.2±5.2	16.3±0.5	1.3±0.2	11.2±0.2	0.02±0.01	0.1±0.01	109.1±4.2	99.5±2.5	52.0±0.4	66.0±2.0
Adamjee												
Front	0.2	0.01	132.3±5.2	15.6±0.4	1.6±0.03	12.4±0.4	0.2±0.01	0.1±0.01	105.3±2.5	106.0±3.0	53.0±0.5	58.0±2.0
Middle	0.2	0.05	110.2±3.2	14.3±0.5	2.7±0.02	10.6±0.2	0.2±0.01	0.1±0.01	106.2±2.5	105.0±2.0	51.0±0.5	60.0±2.0
Opposite	0.2	0.01	119.3±4.3	15.0±0.5	1.1±0.01	13.0±0.2	0.2±0.01	0.1±0.01	106.3±2.3	107.0±2.0	45.5±0.3	67.0±4.0

SS= Suspended Solid
No. of analysis(N)=4

Table-2: Concentration of As, Cd, Pb, Cr,Se in the water of Different Rivers with the Seasonal Variations

Area and sites	pH	pH	Conductivity ms/cm	Conductivity ms/cm	As µg/L	As µg/L	Pb µg/L	Pb µg/L	Cd µg/L	Cd µg/L	Se µg/L	Se µg/L	Cr µg/L	Cr µg/L
	Rainy	Dry	Rainy	Dry	Rainy	Dry	Season Rainy	Dry	Rainy	Dry	Rainy	Dry	Rainy	Dry
Karnafully														
Chandragona														
Front	7.3	7.2	$1.0X10^{-1}$	0.1X1	17.2±0.2	9.0±0.1	0.3±0.01	9.4±0.04	0.2±0.01	2.5±0.02	3.0±0.1	17.0±0.5	6.0±0.2	2.0±0.02
Middle	7.3	7.3	$1.0X10^{-1}$	0.1X1	9.3±0.2	6.6±0.2	0.6±0.01	12.3±0.02	BDL	1.0±0.02	3.2±0.1	32.3±0.2	5.0±0.2	3.0±0.3
Opposite	7.4	7.3	1.0X10-1	0.1X1	11.7±0.3	7.0±1.0	0.6±0.02	11.2±0.02	0.4±0.01	1.0±0.02	3.1±0.1	15.2±0.2	6.0±0.4	3.0±0.3
KAFCOO														
Front	7.3	7.8	$1.6X10^{-1}$	1.5X10	4.6±0.1	34.6±1.2	0.7±0.02	8.0±0.04	BDL	25.2±0.5	4.2±0.2	22.6±0.4	6.0±0.2	79.0±2.0
Middle	7.2	7.8	$1.0X10^{-1}$	1.5X10	5.6±0.2	30.4±1.2	0.8±0.01	8.4±0.04	BDL	27.2±0.4	5.0±0.2	24.2±0.4	5.0±0.3	89.0±4.0.
Opposite	7.2	7.8	$1.0X10^{-1}$	1.5X10	5.0±0.1	28.0±2.2	0.6±0.01	8.2±0.04	0.7±0.02	22.3±0.2	4.3±0.1	22.2±0.2	4.0±0.2	88.0±5.0
Estern Refinery														
Front	7.1	7.7	$1.0 X10^{-1}$	1.3 X10	6.4±0.3	31.2±2.2	0.5±0.01	11.2±0.04	BDL	41.0±1.0	4.2±0.2	20.2±0.5	4.0±0.2	55.0±2.0
Middle	7.2	7.8	$1.0 X10^{-1}$	1.3 X10	2.8±0.2	23.3±2.1	0.5±0.01	12.0±0.02	0.5±0.01	36.2±0.4	4.2±0.2	22.6±0.4	9.0±0.2	71.5±2.5
Opposite	7.1	7.8	$1.0 X10^{-1}$	1.3 X10	5.4±0.2	21.5±2.5	0.4±0.01	11.2±0.02	0.2±0.01	32.2±0.2	4.0±0.1	19.2±0.4	6.0±0.2	78.0±2.0
Kalurghat														
Front	7.1	7.5	$0.5 X10^{-1}$	1.3 X10	3.1±0.1	16.4±1.2	0.4±0.01	10.3±0.03	0.3±0.01	24.0±0.5	4.3±0.1	15.2±0.2	10.0±0.4	5.0±0.2
Middle	7.1	7.4	$0.5 X10^{-1}$	1.3 X10	4.2±0.2	18.2±2.2	0.4±0.02	13.4±0.05	0.3±0.02	35.5±0.5	4.5±0.2	21.2±0.2	8.0±0.2	4.5±0.3
Opposite	7.1	7.4	$0.5 X10^{-1}$	1.3 X10	3.2±0.2	15.5±1.5	0.4±0.03	12.2±0.02	0.3±0.03	21.2±0.4	4.4±0.2	17.0±0.5	8.0±0.3	5.6±0.4
Bramhaputra														
Mymensingh														
Front	7.5	8.1	$1.0X10^{-1}$	$3.4X10^{-1}$	1.6±0.1	18.0±1.2	0.2±0.01	10.0±1.0	0.7±0.02	5.2±0.04	3.4±0.1	8.6±0.4	4.0±0.2	0.5±0.01
Middle	7.5	8.2	$1.0X10^{-1}$	$3.3X10^{-1}$	2.4±0.1	10.5±1.2	0.3±0.01	9.2±0.5	0.3±0.01	1.6±0.02	3.0±0.1	12.6±0.4	11.0±0.4	0.5±0.02
Opposite	7.4	8.1	$1.0X10^{-1}$	$3.4X10^{-1}$	5.6±0.2	4.0±0.2	0.3±0.02	9.0±0.5	0.03±0.01	1.6±0.02	3.2±0.2	6.0±0.2	9.0±0.2	0.2±0.01
Jamalpur														
Front	7.5	8.2	$1.0 X10^{-1}$	$3.0 X10^{-1}$	5.0±0.1	12.0±0.4	0.4±0.01	10.0±0.5	BDL	1.4±0.02	4.6±0.1	18.0±0.5	2.0±0.02	2.6±0.02
Middle	7.5	8.2	$0.6 X10^{-1}$	$3.0 X10^{-1}$	5.0±0.1	10.2±0.2	0.7±0.02	10.0±0.2	0.2±0.01	1.4±0.02	4.2±0.2	8.6±0.4	2.0±0.02	1.0±0.01
Opposite	7.5	8.1	$0.8 X10^{-1}$	3.0 X10-1	4.2±0.2	12.0±0.5	0.4±0.01	9.2±0.2	1.0±0.01	2.3±0.03	4.5±0.3	8.6±0.4	3.0±0.01	1.0±0.01
Jamuna														
Jaghonnatganj														
Front	7.5	7.7	$0.8 X10^{-1}$	$2.2 X10^{-1}$	3.5±0.2	17.5±0.5	0.2±0.01	11.0±0.5	0.7±0.02	41.3±0.4	3.4±0.1	14.0±0.2	12.0±0.2	4.0±0.02
Middle	7.5	8	$0.8 X10^{-1}$	$2.2 X10^{-1}$	4.1±0.1	14.0±0.2	0.3±0.01	9.6±0.4	1.0±0.03	22.0±0.4	4.1±0.1	10.2±0.2	10.0±0.4	8.3±0.02
Opposite	7.5	8	$0.8 X10^{-1}$	$2.2 X10^{-1}$	5.1±0.1	15.0±0.5	0.5±0.01	13.0±0.5	0.8±0.02	32.0±0.5	3.1±0.2	15.0±0.5	8.0±0.2	2.0±0.02

BDL= Below detection limit (0.2µg/L)
No of analysis (N)=4

Table-2 (a): Concentration of SO_4^{-2}, NO_3^-,NO_2^-, PO_4^{-3},Cl^- in the Water of Different Rivers with the Seasonal Variations

Area and sites	SS g/L	SS g/L	SO_4^{-2} mg/L	SO_4^{-2} mg/L	NO_3^- mg/L	NO_3^- mg/L Season	NO_2^- mg/L	NO_2^- mg/L	PO_4^{-3} mg/L	PO_4^{-3} mg/L	Cl^- mg/L	Cl^- mg/L
	Rainy	Dry	Rainy	Dry	Rainy	Dry	Rainy	Dry	Rainy	Dry	Rainy	Dry
Karnafully												
Chandragona												
Front	0.1	0.02	44.7±1.0	10.3±0.2	0.7±0.01	9.3±0.2	1.3±0.02	0.1±0.01	107.4±2.3	93.0±2.0	40.2±3.2	18.6±0.4
Middle	0.1	0.01	28.0±2.0	10.2±0.2	0.7±0.02	9.0±0.5	1.4±0.02	0.1±0.01	97.4±2.5	92.5±2.5	27.0±2.0	26.0±2.0
Opposite	0.1	0.01	31.7±2.2	10.5±0.5	0.6±0.01	11.2±0.2	1.4±0.02	0.1±0.01	107.4±3.2	91.5±2.5	27.0±2.0	47.6±2.2
KAFCOO												
Front	0.03	0.2	29.4±2.3	324.3±3.0	1.0±0.02	13.2±0.2	1.4±0.01	0.5±0.01	98..5±2.2	69.3±2.2	27.2±2.2	27.0±3.0
Middle	0.02	0.2	33.4±2.2	320.0±5.0	2.3±00.3	10.3±0.4	1.5±0.02	0.5±0.01	104.6±2.5	67.4±2.4	20.2±2.2	24.0±4.0
Opposite	0.02	0.1	36.0±2.0	329.0±5.0	2.2±0.02	11.6±0.4	1.3±0.02	0.4±0.01	97.4±2.2	65.5±2.5	43.0±4.0	27.0±3.0
Estern Refinery												
Front	0.01	0.1	34.7±2.4	315.5±5.0	0.6±0.02	9.3±0.3	1.5±0.01	0.3±0.01	81.3±3.2	70.0±2.0	29.5±3.5	33.0±2.0
Middle	0.02	0.1	36.0±3.0	282.0±4.0	1.5±0.04	9.0±0.5	2.3±0.04	0.5±0.01	87.0±2.0	67.6±3.2	29.5±3.5	29.0±2.5
Opposite	0.05	0.1	36.7±1.5	292.0±4.0	1.2±0.02	11.2±0.4	1.4±0.02	0.2±0.01	87.5±2.5	68.3±2.2	29.4±3.2	29.0±2.5
Kalurghat												
Front	0.03	0.1	35.6±2.6	220.0±5.0	1.3±0.03	11.6±0.4	1.5±0.02	1.2±0.02	105.6±3.2	82.0±3.0	24.0±3.0	35.2±2.2
Middle	0.01	0.1	35.4±2.2	217.0±3.0	1.3±0.03	10.0±0.2	1.5±0.02	1.2±0.02	105.6±3.5	83.0±3.0	15.0±2.0	33.2±2.4
Opposite	0.06	0.1	36.7±2.5	216.4±2.4	1.2±0.01	10.0±0.2	1.5±0.04	1.2±0.02	105.6±3.2	81.0±2.0	18.2±2.2	32.2±2.2
Bramhaputra												
Mymensingh												
Front	0.2	0.04	35.6±2.5	11.0±0.5	2.7±0.04	5.2±0.2	1.4±0.02	0.3±0.01	107.3±4.2	113.0±4.0	40.2±4.5	50.0±2.0
Middle	0.2	0.01	40.0±3.0	13.0±0.2	1.5±0.05	7.4±0.4	1.4±0.01	0.3±0.01	107.0±4.0	111.0±5.0	51.3±2.3	46.0±1.0
Opposite	0.1	0.01	36.4±2.4	11.0±0.5	3.7±0.04	10.3±0.3	1.4±0.02	0.3±0.01	107.0±4.0	112.0±4.0	32.2±2.2	43.0±2.5
Jamalpur												
Front	0.04	0.01	36.3±3.3	15.0±0.5	2.2±0.2	9.2±0.4	1.5±0.01	0.3±0.01	107.2±3.2	104.5±5.5	70.0±4.0	18.4±2.4
Middle	0.01	0.02	40.4±2.4	13.0±0.2	2.7±0.3	7.3±0.2	1.5±0.01	0.3±0.01	107.0±2.0	104.0±5.0	35.0±3.0	16.5±1.2
Opposite	0.1	0.03	37.3±3.2	13.0±0.2	2.0±0.2	10.2±0.2	1.3±0.01	0.3±0.01	103.0±2.0	105.4±3.4	38.3±2.5	16.5±1.5
Jumuna												
Jaghonnatganj												
Front	0.5	0.03	44.7±4.2	18.6±0.4	2.2±0.2	8.0±0.05	1.5±0.02	0.3±0.01	106.0±3.0	91.3±2.3	35.5±2.5	12.4±0.4
Middle	0.3	0.06	44.6±3.4	16.5±0.5	2.7±0.1	11.0±0.4	1.5±0.03	0.3±0.01	106.0±3.0	87.3±2.2	32.3±3.4	14.4±0.4
Opposite	0.6	0.06	40.7±2.7	18.0±0.5	2.1±0.1	8.6±0.04	1.5±0.02	0.3±0.01	107.0±2.0	90.5±3.0	38.6±2.6	12.4±0.3

SS= Suspended solid
No. of analysis (N)=4

Methods of Analysis

1.pH meter (HM-16S, TOA, Japan) was used to measure the pH and conductivity meter (CM-5S TOA, Japan) was used to measure conductivity and total dissolved solid of the surface water.

2.UV-Visible spectrophotometer (160A, Shimadzu, Japan) was used to determine SO_4^{-2}, NO_3^-, NO_2^-, PO_4^{3-} and titration method was used to determine the Cl^- [3-4].

3.Atomic absorption spectrophotometer (AAS, Model AA-680 Shimadzu, Japan) was used to determine Pb, Cr, Cd. GFAAS (Model AA-680) was used to determine As, Se. Air-acetylene flame was used to determine Pb, Cr, Cd. Before analyzing metals from the water samples, the sample water was preconcentrated by gentle heating. The results of Pb were checked by Electroanalyzer (Model EC 786, USA). Nickel nitrate (Macrk, Germany) was used as matrix modifier in GFAAS [5-6]. The reproducibility of this method was checked by analyzing the standard solution of As, Se, Cr,Cd (Marck, Germany) as a sample after the preparation of calibration curve. Each water sample was analyzed four times and deviation was found ± 3-4%.

Calibration Curve

Calibration curve in AAS, GFAAS, UV-Visible spectrophotometer was prepared by using standard solution (E-Marck, Germany) contained known concentration of the element to be determined.

Validity of Analysis

The validity of these methods were checked by analyzing the standard solution as a sample and analyzed by the help of other methods (Electro-analyzer, GFAAS, AAS). The results were in good agreement with the certified values of the standard solutions. The reproducibility of AAS, GFAAS, UV-Visible Spectrophotometer were verified by measuring each sample four times. A precision of ± 2.5% was obtained. The concentrations of lead was checked by using Different methods of analysis and found approximately the same results (Table-3), where deviation was found ±3.5%.

Table-3: Concentration of Pb Found in Various River Water Samples of Dry Season by Different Methods.

Sample No.	Name of the rivers and the sampling locations	Concentration of Pb found by different methods		
		AAS	GFAAS	Electroanalyzer
1	Buriganga(Hazaribagh)	12.4±0.04	13.0±0.02	12.0±0.04
2	Sitalakya (Demra)	9.5±0.05	9.2±0.02	9.0±0.02
3	Karnafully (Chandragona)	11.2±0.02	11.0±0.04	11.5±0.04
4	Bramhaputra(Jamalpur)	10.0±0.05	10.5±0.05	9.5±0.02
5	Jamuna(Jagannathganj)	11.0±0.5	11.5±0.2	11.2±0.2

Table-4: Comparison of the Results with the Guide Level Values [7-8]

Parameter	Drinking water (EQS)	Drinking water (WHO)	Highest Result found
pH	6.5-8.5	6.5-8.5	8.2
As	50μg/L	50μg/L	34.6μg/L
Pb	50μg/L	50μg/L	13.4μg/L
Cd	50μg/L	50μg/L	27.2μg/L
Se	20μg/L	20μg/L	32.3μg/L
Cr	50μg/L	50μg/L	89.0μg/L
Cl^-	150-600 mg/L	250mg/L	407.0 mg/L
PO_4^{3-}	6mg/L	-	126.0 mg/L
SO_4^{2-}	400mg/L	400mg/L	288.0 mg/L

EQS= Environmental Quality Standards of Bangladesh
WHO= World Health Organization

Conclusions

The concentration of As, Pb, Cd (Table-4) determined in this study is below the recommended values of WHO (World Health Organization) and EQS (Environmental Quality Standards of Bangladesh). They recommended the tolerance level of As, Cd, Pb (50μg/L) in the drinking water. However, the concentration of Cr and Se metal ions found in this study are above the recommended values (50μg/L of Cr and 20μg/L Se) of WHO. The concen-tration of phosphate is also higher than the recommended value of EQS (6mg/L) but chloride, nitrate and nitrite are below the recommended values of EQS (Environmental Quality Standards of Bangladesh). From the above-mentioned results and Satellite pictures, it was concluded that the transport of heavy metal loaded from upper stream flows towards Bay of Bengal.

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