

ARSENIC POLLUTION IN SOIL AND GROUNDWATER OF BANGLADESH

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Abstract

The scientists of Rajshahi University together with Research Group for Applied Geology (RGAG) and Asian Arsenic Network (AAN) of Japan suspect that groundwater of about 56 districts out of 64 districts are seriously contaminated with arsenic. There are 11 Million tubewells in Bangladesh out of which about 5 Million tubewells are highly arsenic contaminated. About 75 Million people of the affected districts are at risk and the total number of patients suffering from Arsenicosis are about 7000 and out of which about 200 persons already died. To give safe water to the peoples more investigations in the whole country is essential. The source of arsenic in groundwater of Bangladesh is as yet unknown. But it is now widely believed that the high arsenic levels in the groundwater in Bangladesh have a natural geological source which may be due to abstraction water from Quaternary confined and semi-confined alluvial or deltaic aquifers. Groundwater in Bangladesh from sandy alluvial deposits are considered to be arsenic free. It is essential to consider the groundwater occurrences, its distribution and geological and hydrogeological settings of the country for the mitigation of arsenic problem. To know the basic understanding of the source and mobility of arsenic it is essential to investigate the sampling depth and aquifer provenance. Present study will give some clue about the future action plan for the mitigation of the arsenic problem in Bangladesh. The result of investigation have been discussed. To save these huge population of the area all sorts of international help are essential. If precautionary measures against arsenic contamination are not taken immediately consequences like death of many people will be inevitable and massive. A awareness raising about the issue among the people should be the first step for precaution.

Keywords

Aquifer Provenance, Arsenic, Contamination, Groundwater, Hydrogeological Settings, Geochemical occurrences.

1 INTRODUCTION

The continental fluvial sediments have known to be common in the present upper continental crust (UC) because sediments have large provenance and are well mixed during the transportation of the particles (Taylor and McLennan, 1985, McLennan et al, 1993. Condie, 1993. The Ganges river is one of the biggest rivers with its source in the Indian shield and the Himalayan Mountains. Thus fluvial sediments of the Ganges can be regarded as a representative of the Asian continental crust.

Besides the homogeneous compositions of these sediments, they are rich in organic matters derived from higher plants vegetated under humid and warm climate. This is due to favorable aquifer supplied by the Ganges. Tube wells have been much utilized for irrigation and drinking water since such systems were established (Yokota et al, 1997. However, arsenic contamination of groundwater is now confirmed in the wide regions of Bangladesh and eastern India, and became one of the serious impacts on health conditions (Rahman,1997,Yokota et al, 1997. Under these circumstances, core-boring was operated to obtain sediment samples at Samta

village in southwestern Bangladesh to examine arsenic concentration of the sediments (RGAG 1997,1999). Geochemical composition of the core samples were studied by examining the source materials of the Ganges fluvial system. Possible linkage of arsenic to other elements in the sediments have been described. Core samples mainly consist of alternating beds of fine sands and very fine sands, and muds occur at an interval of 3-4.9m (upper muddy layer). Sands are composed of well sorted quartz grains accompanying significant mica flakes. Tourmaline and zircon are abundant heavy minerals. Muds hue dark gray to black, rich in organic matters. Both sands and muds include carbonate materials which were tested by HCl acid treatment in the field.

1.1 History Of Arsenic Contamination In Groundwater Of Bangladesh

Field experience and available data shows that both soil and under groundwater of a vast area of Bangladesh has been threatened with arsenic contamination affecting health of millions of people. In Bangladesh high arsenic concentrations are suspected to exist so far in 41 districts out of total 64 districts. About 75 Million people of the affected districts are at risk and the total number of patients suffering from Arsenicosis are about 7000.

The physiographic regions (Fig-1) vulnerable to arsenic contamination are the (a) Ganges flood plain (b) The Atrai flood plain (c) The Tidal region (d) The Coastal plain and (e) The Meghna flood plains. The high probability zone, moderate probability zone and low probability zone of arsenic contaminated area are together cover almost about 60% of the total country area. Arsenic pollution in ground water of Bangladesh is possibly the largest mass poisoning case in the world now. The large scale unplanned withdrawal of ground water may be theoretically the main reason of Arsenic contamination in Bangladesh. There are several speculations about the potential source of arsenic. Now it is established that the real source of arsenic in groundwater seems to be lie in the geological formation.

The arsenic affected areas of west Bengal i. e. on a sediment of younger deltaic deposition which extends eastward towards Bangladesh covering the approximate area of the 41 district which lie mostly in the Gangetic, Atrai, Meghna flood plains and the tidal regions of the country (Fig-1). The datas and records of geological investigations of the areas adjoining to the western border in West Bengal show's that there are three types of aquifers presently in use for groundwater occurrences and distribution. (i) The shallow aquifer (about 30 m) (ii) The intermediate aquifer (40-80 m) with an aquitard (or an impervious layer) of about 10 to 15 meters. (iii) The deep aquifer (below 100m) under the second (Fig-2) aquitard (Dave 1996. Arsenic was observed to have been deposited in the first aquitard as absorbed primary metal on sand grains of biotite and quartz with a few scattered grains of arsenopyrite. Arsenic (leached out of the first aquitard) appears to be confined to the intermediate aquifer (30-45 m depth). 4.0 million Tubewells in Bangladesh Supplying Drinking water to the people and among them 1.12 million Tubewells are contaminated with arsenic.

2 ANALYTICAL RESULTS OF INVESTIGATION.

2.1 Sample Preparation

Core boring has been done in different locations in Samta village under Sharsa Police station of Jessore district, Bangladesh for the collection of soil samples for Analysis in the laboratory. About 50 g of each sample was dried at 110 °C, and was powdered to a particle size (<63µm) using an automatic agate pestle and mortar for 30 minutes. About 5 g of each sample was ignited at 1000°C for 1 hour to examine LOI (Loss on ignition).

2.2 Major Elements and Trace Elements

Major elements (SiO₂, TiO₂, Al₂O₃, Fe₂O₃, MnO, MgO, CaO, Na₂O, K₂O, and P₂O₅) and trace elements (Th, Sc, Pb, Cu, Zn, Zr and Sr) were analyzed using the RIX-2000 XRF system (Rigaku Denki Co. Ltd.) at Shimane University. Analyses of these elements were made on glass beads prepared with a flux (mixture of lithium tetraborate and lithium metaborate in ratios of 4:1) to sample ratio of 2: 1 followed by Kimura and Yamada (1996). Other trace elements (As, Ni, V and Cr) were analyzed by the power press method (Ogasawara, 1987). Average errors for traces comprise less than 10% and the results are acceptable compared with other values. Results are given in Table 1 and Table 2.

Table 1 Major Elements Of Core Sample Sediments In Samta.

Oxides (Wt. %)

No	Feet	SiO ₂	TiO ₂	Al ₂ O ₃	Fe ₂ O ₃	Mn O	MgO	CaO	Na ₂ O	K ₂ O	P ₂ O ₅	Total	LOI
0	10.5	57.67	0.94	19.07	7.79	0.12	3.47	5.14	0.83	3.81	0.14	98.98	8.78
1	12	61.57	0.83	16.49	6.54	0.10	3.05	6.33	0.99	3.32	0.13	99.35	8.31
3	13.8	59.28	0.89	17.63	8.05	0.12	3.08	5.90	0.87	3.44	0.14	99.40	8.72
5	15	59.49	0.96	20.99	8.48	0.05	2.79	1.39	0.57	3.68	0.12	98.52	8.13
7	17	58.55	0.85	18.39	7.66	0.16	3.15	6.50	0.76	3.44	0.15	99.60	9.13
9	19	61.15	0.83	16.68	8.64	0.15	2.95	3.64	1.01	3.44	0.27	98.76	7.16
11	21	60.15	0.91	20.02	7.92	0.9	3.12	2.40	0.83	3.68	0.15	99.26	8.89
20	31	76.58	0.51	10.09	3.31	0.05	1.87	3.76	1.36	2.25	0.12	99.90	3.99
23	35	75.14	0.53	10.85	4.15	0.06	2.00	3.20	1.32	2.59	0.10	99.94	3.62
28	45	79.35	0.39	9.37	2.70	0.05	1.35	3.13	1.39	2.19	0.10	100.00	2.93
37	63	78.97	0.39	9.39	2.79	0.04	1.49	3.20	1.35	20.20	0.09	99.91	3.18
45	79	77.88	0.42	9.93	3.43	0.05	1.72	2.90	1.29	2.28	0.09	99.98	0.55
51	91	87.40	0.14	6.82	0.83	0.01	0.59	1.30	1.22	1.56	0.04	99.93	2.05
53	95	84.46	0.21	7.87	1.52	0.02	0.93	1.83	1.22	1.88	0.05	100.00	2.56
55	99	78.42	0.42	9.53	3.14	0.06	1.55	3.27	1.35	2.13	0.10	99.98	3.22
64	117	81.87	0.32	7.70	1.89	0.04	1.28	3.95	1.26	1.56	0.12	99.98	3.28
70	129	81.13	0.30	9.06	2.15	0.04	1.06	2.40	1.45	2.24	0.07	99.90	2.35
76	141	81.78	0.29	8.70	2.18	0.03	1.20	2.23	1.35	2.14	0.06	99.96	2.99
81	151	82.07	0.32	8.22	2.23	0.05	1.10	2.27	1.29	1.74	0.10	99.40	2.78
86	161	84.77	0.21	7.77	1.41	0.03	0.78	1.30	1.27	1.70	0.06	99.30	2.43
94	177	82.64	0.26	7.30	1.69	0.04	1.19	3.86	1.23	1.49	0.09	99.80	3.79
100	187	81.17	0.46	8.59	2.45	0.05	1.44	4.10	1.33	1.84	0.13	101.55	1.95
105	197	72.23	0.56	12.44	4.93	0.05	2.38	2.86	1.28	3.17	0.06	99.96	3.54

Table 2 Trace Elements Of Core Sample Sediments In Samta.

Trace elements (ppm)											Wt. %		
As	Cr	Cu	Ni	Pb	Sc	Sr	Th	V	Zn	Zr	TOC	CC	TN
14	88	52	45	30	18	124	22	138	52	182			
8	76	24	38	20	17	137	20	126	44	255			
7	86	24	42	22	18	130	19	142	46	222			
12	113	30	60	34	17	91	21	201	65	182			
16	88	24	45	23	19	101	20	144	47	197			
9	80	24	36	21	16	104	22	148	42	244			
16	96	27	52	42	16	96	22	178	55	199	1.35	0.29	0.09
5	58	19	20	18	10	116	18	59	26	361	0.18	0.47	0.03
4	67	19	26	20	9	110	14	81	33	262	0.12	0.38	0.04
2	59	19	20	20	10	109	13	49	20	260	0.10	0.26	0.05
4	67	9	18	17	8	111	12	46	22	226	0.09	0.36	0.04
4	67	8	25	19	10	103	9	90	29	150	0.16	0.30	0.04
3	54	5	10	21	6	102	6	21	9	147	0.08	0.29	0.04
4	63	6	16	19	6	98	8	53	17	134	0.08	0.29	0.04
3	63	7	16	20	9	110	15	61	24	262	0.14	0.31	0.04
2	57	6	7	17	9	109	13	31	13	214	0.08	0.48	0.04
3	56	4	14	19	7	105	9	47	19	176	0.10	0.17	0.04
3	60	6	10	18	7	107	9	52	22	180	0.12	0.42	0.04
3	64	7	19	20	9	114	18	67	16	254	0.09	0.17	0.04
3	58	6	8	19	7	106	10	48	13	201	0.10	0.22	0.04
3	53	4	7	17	8	119	14	29	13	232	0.08	0.65	0.04
4	65	7	12	17	8	117	20	42	18	436			
4	68	11	24	19	10	105	8	103	41	151			

2.3 Analysis Of Organic Carbon, Nitrogen And Sulfur

Contents of total organic C (TOC) , total N (TN) and total S(TS) were measured after 1M-HCl treatment of 15 mg samples by combustion and gas chromatography using a Fisons (Carlo Erba) EA 1108 CHNS Elements Analyzer at Shimane University (Sampie et al, 1997. The errors inherent to this analysis comprised within 3% for TOC and TN and 4% for TS. The results are given in Table 2. Total sulfur was less than 0.01 wt % in all examined samples.

2.4 Broad variation with stratigraphy

Sands show high concentration of SiO₂ (mostly over 80 wt %) which is due to enrichment of quartz grains in sand samples. Among other major elements, TiO₂, Fe₂O₃, MgO, K₂O and P₂O₅ show gradual increasing in the upsection probably related to sorting effect (Taylor and McLennan, 1985; Nesbitt et al., 1997) or absorption on clays. Muds contain rich organic matters revealed by higher LOI (Loss on ignition) over 8 wt % They have TOC (total organic carbon) values over 1.0 wt% (Table 2). Sands and muds have CC (carbonate carbon) values of about 0.3 wt%. The total sulfur concentration, however, has not been detected for these samples. The core sediments generally homogeneous compositions in terms of geochemical indices representing source rocks, SiO₂/Al₂O₃, Al₂O₃/TiO₂, and Th/Sc ratios are examined with stratigraphy. These ratios show small variation in the column excluding middle portion of the horizon 27.7m and 28.9 m shown in SiO₂/Al₂O₃, Al₂O₃/TiO₂ ratios, which may be due to influx of coarse sands.

Table 3. Rare Earth Elements And Other Trace Elements Found In Core Sample In Samta.

INAA

No	o	3	7	20	37	53	70	86	105
ppm									
La	42.7	41.0	40.4	39.5	26.1	16.9	19.8	23.0	17.9
Ce	85.8	81.2	83.0	81.2	55.5	35.9	44.2	48.7	37.6
Sm	7.7	7.3	6.9	6.9	4.4	3.0	3.5	3.9	3.3
Eu	1.2	1.2	1.3	1.0	1.7	0.6	0.6	0.6	0.6
Gd	10.8	10.0	9.3	10.1	7.5	6.8	7.4	6.4	3.6
Tb	9.0	1.0	1.1	9.0	5.0	4.0	5.0	5.0	6.0
Yb	3.0	2.3	2.9	2.6	1.8	1.3	1.7	2.0	1.4
Lu	0.53	0.48	0.54	0.47	0.3	0.2	0.3	0.3	0.2
Hf	4.2	4.9	4.9	9.1	5.8	3.1	4.2	4.4	3.4
Ta	1.6	1.4	1.3	1.1	0.7	0.6	0.7	0.7	1.3
Cs	14.7	11.7	11.5	6.2	6.5	5.5	5.9	4.3	10.8
Ba	55.8	44.2	49.4	29.2	21.6	28.3	28.4	22.3	41.6
Sb	1.3	1.4	1.3	0.7	0.6	0.3	0.5	0.4	0.8

As, Pb, Zn and Sb

Arsenic occurs in mud samples of the upsection (4.6 to 6.4m, over 20 mg/ l excluding one sample) and As/Al₂O₃ and As/Pb show significant projection in this horizon. In the natural system, As behaves similar to Pb thus As/ Pb ratios may indicate As enrichment related to other reactions. As concentration, however, is still lower than that of average soil (As = 30 mg/l) thus higher concentration in groundwater should be considered as an active solution of As from the sediments. Zn shows no significant concentration in the section. Sb concentration ranges from 0.4 to 1.4 mg/l (Table 3) showing lower concentration compared with average soil (1.0 mg/l).

Cr, Ni, V and Cu

In general, concentrations of these compatible elements are affected by diagenesis especially related to sulfur reducing reaction (Calvert and Pedersen, 1993, Jones and Manning, 1994). The results show no anomalous enrichment in samples for Ni and Cr compared to Al_2O_3 (Table 1). Vanadium, however shows enrichment relative to Al_2O_3 in the samples, V was probably effectively fixed in association with rich organic compounds (e.g. porphyrin compounds), during progressive burial (Arthur and Sageman, 1994, Calvert and Pedersen, 1993). Sediments show positive correlation between As and V (correlation coefficient, $R^2=0.75$), but Cr, Ni and Cu do not show correlation with As. This geochemical feature suggests that As is not related to sulfide minerals but to organic compounds, because As may substitute for Fe.

A Possible Linkage Of As Concentration To Other Elements

Muds with rich organic matters generally concentrate metal elements and are utilized as mineral resources (e.g. Arthur and Sageman, 1994; Calvert and Pedersen, 1993). The reaction of such elements is complex and is proceeded through several stages. The present limited data could not reveal wholistic reaction of As concentration in the sediment samples, nor As contamination of groundwater. The present study, however, demonstrates the relationship of As concentration with other possible guide elements having similar behavior. Arsenic generally behaves very much like divalent Fe and they correlate well in concentration. The samples show positive correlation between Fe_2O_3 and As ($R^2=0.71$) suggesting that Fe may be a guide element for As concentration in ground water of Bangladesh.

3 CONCLUSION AND RECOMMENDATIONS

Priority should be given to the following points for the mitigation of arsenic problem in Bangladesh and give people access to arsenic free water.

- a) Arsenic affected areas on the Ganges Delta are so vast and there is a huge population. To save these huge population of the area all sorts of help from the experts, national, international organizations and NGO's all over the world are expected to come forward to carry out field investigations and to take proper measures for the mitigation of arsenic calamity in Bangladesh.
- b) If precautionary measures against arsenic contamination are not taken immediately, consequences like death of many people will be inevitable and massive. Awareness raising about the issue among the people should be the first step for precaution.
- c) Without quality assured data correct steps can not be taken for the mitigation of arsenic problem of Bangladesh. Establishment of Quality assurance in the analysis of soil and water samples related to Arsenic problem is very important.
- d) Essential to findout the exact and possible sources of arsenic in the groundwater in the arsenic affected areas of the whole country.
- e) It is also very important to know the mechanism of arsenic contamination in groundwater.
- f) Not to jump from one local explanation to a nation wide or basin wise explanation because there is no reason to think that these answer's will be applicable in all cases.
- g) To identify arsenic patients and initiate their treatment. Skin test is the most reliable to detect chronic arsenic poisoning .

- h) Surface water such as ponds, lake, river can be used as a source of drinking water after boiling it. Rain water can be another safe source.
- i) Immediately identify the high risk zone of arsenic. The people of the area should stop drinking tube well water.
- j) Sophisticated laboratory facilities should be developed to detect arsenic concentration in tube well water as well as that in human body.
- k) Efficient watershed management is necessary.
- l) Arrange to supply arsenic free drinking water because safe water is the best medicine for the people of the arsenic poisoning areas.

REFERENCES

Arthur, M.A, and Sageman, B. B.(1994) Marine black shales: Depositional mechanisms and environments of ancient deposits. *Annu Rev Earth Planet Sci*, 22:499-551.

Calvert, S.E. and Pedersen, T.F.(1993) Geochemistry of recent oxic and anoxic marine sediments: implication for the geological record. *Marine Geol*, 113,67-88. Calcutta. PP-3.

Condie, K.C.(1993)Chemical composition and evolution of the upper continental crust: Contrasting results from surface samples and shales. *Chem. Geol*, 104,1-37.

Dave J. M. Arsenic contamination of Drinking water in Bangladesh WHO assignment report December 6-20, 1996.

Jones, B. and Manning, D. A. C. (1994) Comparison of geochemical indices used for the interpretation of palaeoredox conditions in ancient mudstones. *Chem. Geol*, 111,111-129.

Kimura, J. and Yamada, Y. (1996) Evaluation of major and trace element XRF analyses using a flux to sample ratio of two to one glass beads. *Jour. Min. Petrol. Econ. Geol*, 91,62-72.

McLennan, S, Hemming, S, Mac Danie, D.K and Hanson, G.N. (1993) Geochemical approach to sedimentation, provenance and tectonics. *Geo.Soc. Am. Paper*, 284,21-40.

Nesbitt, H.W. Fedo, C. M. and Young, G.M.(1997) Quartz and feldspar stability, steady and non-steady state weathering, and petrogenesis of siliciclastic sands and muds. *Jour.Geol*, 105,173-191.

Ogasawara, M. (1987) Trace element analysis by X-ray fluorescence spectrometry, using Rh tube. *Bull. Geol. Surv. Japan*, 38,57-68.

Rahman M.H. (1997). Arsenic Hazards in Bangladesh. Think of Arsenic Contamination Problems in Asia. Special issue of the Association for the Geological Collaboration in Japan (Chigaku Dantai Kenkyukai) Nov. 1997, P. 74-83.

RGAG (1997) Preliminary Results of Groundwater investigation in Arsenic affected areas in Bangladesh. A Report Prepared by RGAG Japan.

RGAG(1999) Arsenic contamination of ground water in Bangladesh Interim Report of the Research at Samta village, Jessore, Bangladesh, April 1999.

Sampei, Y, Matsumoto, E, Kamei, T. and Tokuoka T. (1997) Sulfur and organic carbon relationship in sediments from coastal brackish lakes in the Shimane peninsula district, southwest Japan. *Geochem. Jour*, 31,245-262.

Taylor, S.R. and McLennan, S.M (1985) *The Continental Crust: its composition and evolution*. Blackwell, Oxford, PP.312.

Yokota, H. Tanabe, K, Akiyoshi, Y Kawahara, Hashiguchi, M, Tsushima, S, Khan, A.W, Ahmad, Sk. A and Hadi, Sk. A.(1997) The arsenic pollution of ground water in Samta, Jessore, Bangladesh. *Bilateral Consultation between Bangladesh and India on Arsenic in Drinking Water*, WHO/SEARO, New Delhi, April 1997.

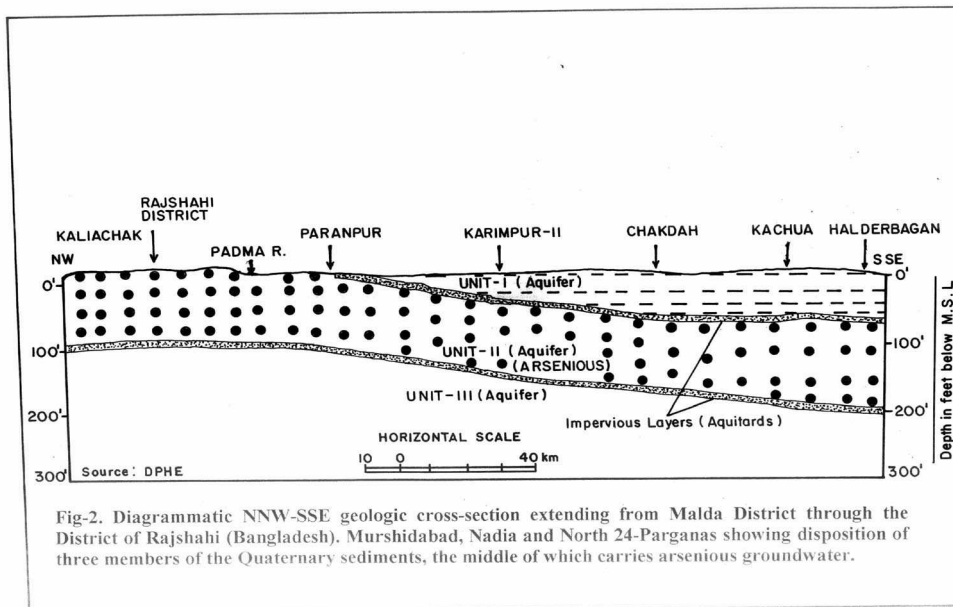


Fig-2. Diagrammatic NNW-SSE geologic cross-section extending from Malda District through the District of Rajshahi (Bangladesh), Murshidabad, Nadia and North 24-Parganas showing disposition of three members of the Quaternary sediments, the middle of which carries arsenious groundwater.

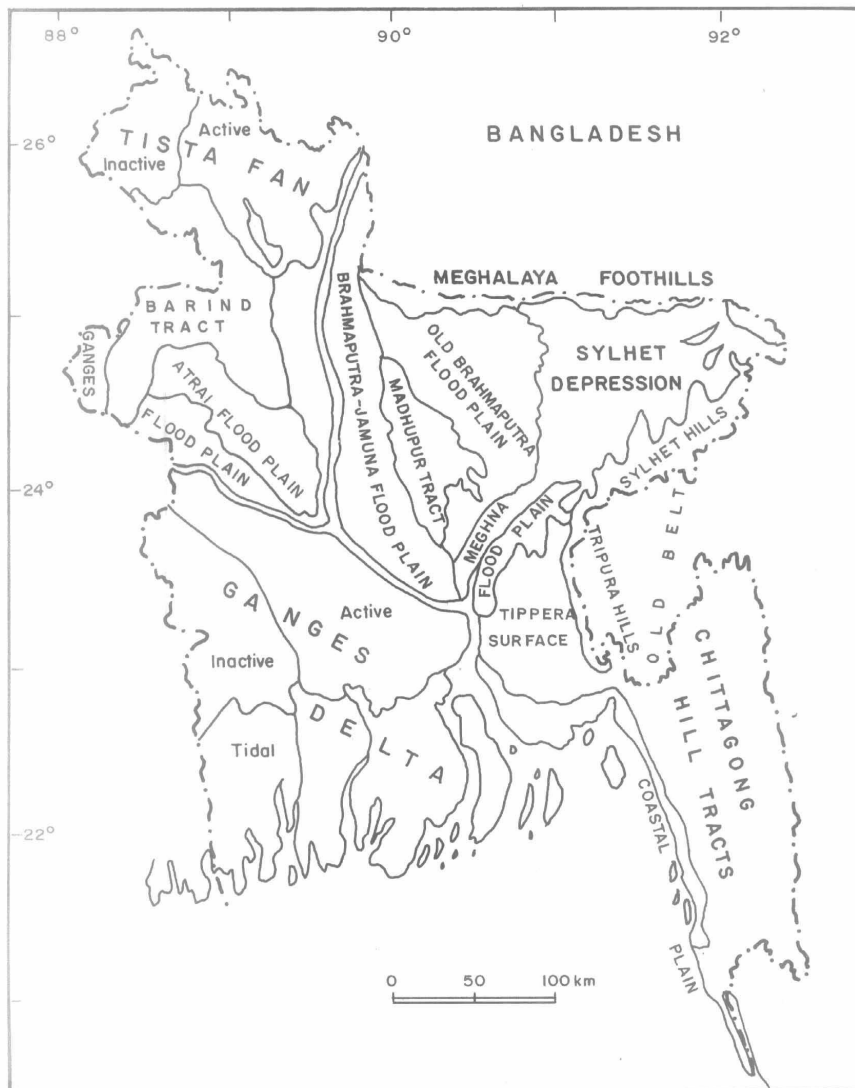


Fig-1. Generalized Physiographic Map of Bangladesh.