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HYDROCHEMISTRY OF LOWLANDS WATER OF SOUTHWEST BANGLADESH

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ABSTRACT: The paper presents the physical properties and chemical constituents of surface and groundwater of southwest lowland area. Annual seasonal and tidal flooding are the common phenomenon in lowland of Bangladesh. Monsoon climatic condition is the main responsible for the flooding both from onshore to offshore areas. These physical processes, the regional hydraulic head declination during the dry period (November-April) and some man-made activities have caused the present deterioration of water quality from the acceptable limit for conjunctive use of the area. Physico-chemical analyses of water from river and groundwater have revealed that EC, TDS, TH, Na^+, Cl^- are higher concentration levels then the standard limit. In this context, many studies on water quality have revealed that the surface water of southwestern lowland area is of primary salinity type, which can be found in the every dry period. Observation shows that the salinity level normally decreases when the high stream flow discharges from the upstream rivers during the very wet periods.

INTRODUCTION

Hydrology and Hydrogeology are important subjects for human development programs in lowlands or any other the regions of the world. Occurrence, origin and movement of water in the form of rainfall / snowfall, river water / surface water, soil water and groundwater in lowlands which effects the human activities of the particular reasons. Regional Water Management and Development Program (RWMDP) in lowlands can play a vital role in this regard. Hydrogeochemistry / Hydrochemistry in the RWMDP, is a prime important as well as in the environmental aspects too. For example, ion exchange, a physico-chemical process between water and soil/rock particles changes the chemical composition of groundwater during its passage through the sub-surface reservoir. Dissolution of salts in the surface or sub-surface for example $CaCO_3$ from carbonate formations which leads to increasing concentrations of such salts in water during its passage through the sub-surface (Dam, 1994).

Most of the lowlands on the earth surface can be found in the coastal belt and deltaic regions. The lithology of these areas consists mainly of sedimentary rocks that carried by the rivers, streams or marine transgression and regression phenomena. Generally, the lithology in lowlands is heterogeneous composition of gravels, sand, silt, clay, shell and shell fragments, peat, etc, both in lateral and in vertical distributions of the sedimentary sections. The hydrogeologic conditions of any area are generally observed by the sub-surface sedimentary, structural geological, geological set-up and the fluid flow (water) conditions. The flow movement depends on the sub-surface geological materials and the basinal boundary conditions. The boundary conditions can be considered with the local topography, natural recharge, water divides regional hydraulic head distribution and its annual fluctuation within the basin or catchment area. The chemical and isotopic composition of the groundwater is, in turn, an indication for the origin of the groundwater flow condition of the area. Oxidation and

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reduction are geochemically important processes, which together with the hydrogen ion activity (pH) determine the solubility of many substances, hence the occurrence of substances in groundwater. The oxidation processes run faster in warm climates than in cold, and faster in humid and alternating humid and dry climates than in arid climates. Many elements (e.g., S, Se, As, Cr, V, Mo, W and U) can be oxidized to easily soluble anion complexes and are therefore especially mobile in the oxidation zone. Other substances, for example iron and manganese are transported as divalent ions or as colloids, and are deposited as hydroxides under oxidizing conditions, even in relatively acid solution and concentrated in the boundary between reducing acid solutions and can be concentrated in the boundary region between reducing and oxidizing conditions. Iron then forms ferric hydroxides or hydrated oxide, which inverts to hematite Fe_2O_3 during aging processes; tri-or quadrivalent manganese precipitation as hydroxide or oxide. The reducing power of a system increases with decreasing radox potential. The radox potential in an aqueous solution generally falls with rising temperature and pH. Short-term fluctuation in redox potential in the zone of water table fluctuation can lead to sudden changes in groundwater quality.

Bangladesh is the second position in terms of lowland of Asia and Oceanic region of the world. About 8.5×10^6 ha lowland area in Bangladesh has been estimated by Stoutjesdijk (1982). Lowlands can be defined as lands affected by fluctuating sea water levels and where human activities are already existing or are being proposed have always been of concern to human societies. They encompass a wide range of terms such as Swamp, Wetland, Tidal plain, Mangrove Forest, etc. (Miura and Madhav, 1994). Topographically, lowland can be considered about 3 m high land from mean sea level and also in below sea level by using the polder system. In Asia-Pacific region these lowlands can be found in Bangladesh, China, India, Indonosia, Japan, Korea, Philippines, Thailand, Taiwan, Myanmer, Singapore, Vietnam, etc. An extensive research on the geoengineering characteristics of soil, ecological, land reclamation development, environmental conditions and their economical aspects of lowlands are essential in the present time for the human resources program for sustainable development of each country. The present paper deals with the preliminary observation on the hydro-chemical situation of the lowlands water of southwest Bangladesh (Fig. 1). The mean (1973-93) annual rainfall ranges from 1657 mm (Jessore) to 2334 mm (Patuakhali) of lowlands of southwest Bangladesh. About 88% of annual rainfalls occur during the wet period (May-October) and the rest 12% occurs during the dry period (November-April). The mean annual evaporation varies from 899.25 mm (Faridpur) to 1027.7 mm (Bhola). The mean monthly maximum temperature at Satkhira is 30.25°C and at Bhola is 28.60°C May. The minimum monthly temperature at Faridpur is 18.45°C and at Patuakhali is 19.75°C in January (Hassan, 1998b).

MATERIALS AND METHOD

The water quality data were collected from Bangladesh Water Development Board of different years from 1977 to 1988, 1993-94 (Rahman) and 1997 (Hassan) during the dry period from different places of lowlands of southwest Bangladesh. The water samples were taken from river, ponds, shallow to deep tubewells (range from 20 to 294 m depth) of the area.

The EC, pH and T°C of the water samples were recorded in respective meters after proper calibration with standard buffer solution (except temperature, T°C) in the field and laboratory conditions. Element concentrations (Ca, Mg, Fe, Mn, Cu and Zn) determination were made on Atomic Absorbtion Spectrophotometer (AAS - Pye Unicum SP9 model) following Page et al. (1982). Na^+, K^+, were determined using Flame Analyzer following Page et al. (1982). Cl^-, NO_3^-, NH_4, HCO_3^- were determined using expandable Ion Selective Analyzer (Orion EA 940

USA). PO_4 was determined colorimetrically developing blue colour by using visible spectrophotometer at the wave length of 660 nm (Murphy and Riky, 1962) and the SO_4^{2-} was turbidimetrically determined using visible spectrophotometer at the wave length 420 nm following the procedure described by McClung et al. (1959).

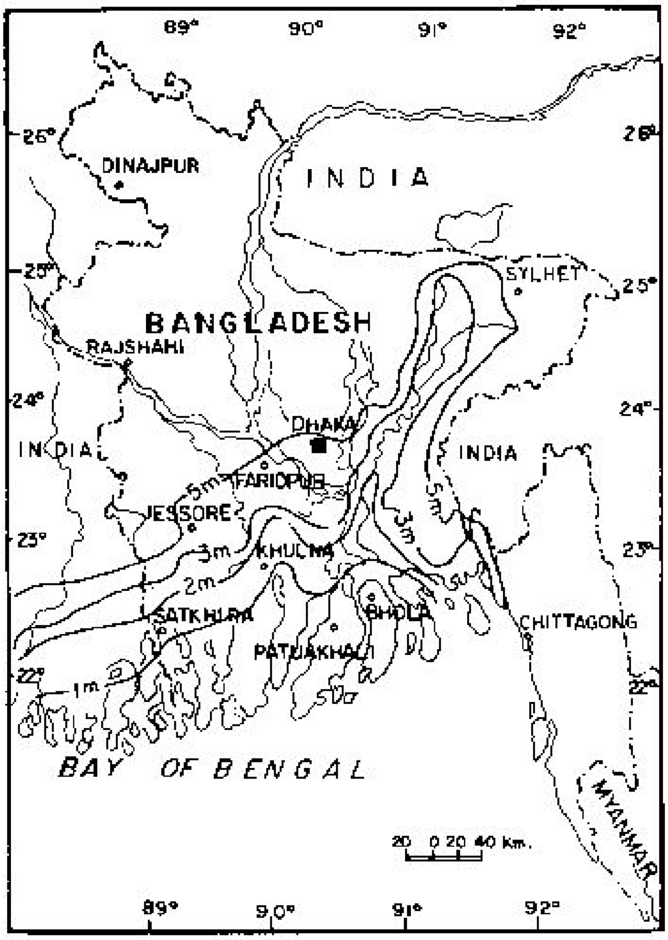

Fig. 1 The lowland of southwest Bangladesh affected by one, two and a five meter rise in sea level which would submerge half of the country's land area (modified from Wood Hole Oceanographic Institute, 1986)

RESULTS AND DISCUSSION

Surface Water Salinity

Salts dissolved in water are mainly, in terms of cations, Na^+, K^+, Ca^{++} and Mg^{++}, and anions Cl^-, HCO_3^- and SO_4^{2-}. Generally in fresh water as low as few tens of mg/l and on the other hand, salinity in water as high as roughly 19,000 mg Cl^-/l is seawater. The salinity distribution in surface water and groundwater in the coastal lowland area depends on the regional annual hydraulic head distribution and its fluctuation round a single hydrological year. Generally, high-level salinity can be found in the dry period of the coastal lowland rivers due to the declination of the seasonal hydraulic heads. The declination of the hydraulic head in every dry period of the coastal lowland areas has been observed from the records for the last 40 years. On an average, from the salinity data it can be found that, April is the month for the higher surface water salinity and the lower flow surface water condition in the rivers. Figure 2 shows the relationship between the surface water flow and the surface water salinity condition over the year of lowlands rivers. Observation from the field investigation and long-term recorded data that seasonal sea level and regional hydraulic head fluctuations in the coastal lowlands favour saline water intrusion into the groundwater reservoir from the sea, espceially in every dry period.

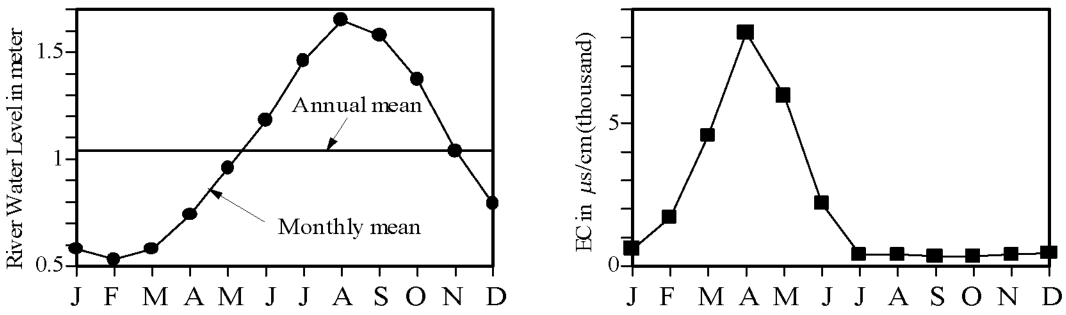

Fig. 2 Relationship between the river water head and the surface water salinity at Khulna (Khu 241) of the Rupsa river of southwest Bangladesh

In lowlands of southwest Bangladesh, several hydrogeological and hydrochemical investigations were performed (Khan 1978, UNDP 1982, MPO 1986, Khan, 1988, Hassan 1992, Hassan 1995a, Hassan and Ahmed 1996, Hassan 1997, 1998, Rahman 1994), which indicates that the groundwater has been contaminated by saline water during every lean period. Table 1 shows chloride in rivers and groundwater of Khulna and Mongla of lowlands. The increased average Cl^- in groundwater and river water in reference to time period can be noted.

Table 1 Chlorid concentration in water of Khulna and Mongla areas

Year 1993*	Khulna (River)	Groundwater	Mongla (River)	Groundwater
January	3566 mg/l	1992 mg/l	5566 mg/l	3402 mg/l
March	6566 mg/l	2195 mg/l	11355 mg/l	4242 mg/l
May	12557 mg/l	2308 mg/l	18703 mg/l	5568 mg/l
Year 1997**				
March			19900 mg/l	

* Observation by Rahman (1993), ** observation by Hassan (1997).

Hydrochemical studies of 20 water samples of St. Martin's Island in 1992 (December) and 1993 (January), indicate that groundwater of this island is also contaminated by saline water (Hassan and Ahmed, 1996).

Groundwater of Lowlands

The lowland of southwest Bangladesh is covered by Quaternary to Recent deltaic sediments. Observation on the vertical hydrogeological section up to 125 m depth from the landsurface of a lowland area of southwest Bangladesh has been made. This hydrogeological section can be divided into two aquifers, namely, the aquifer I, consists mainly of clay-silt and the aquifer II is of sand of different grain size. The groundwater system of this area is considered to be in hydrodynamic equilibrium condition that is, the annual discharge is equal to annual recharge approximately: where ΣR is total recharge and ΣD is total discharge, respectively.

$$\Sigma R = \Sigma D$$

The total recharge (ΣR) exceeds total discharge (ΣD) during the monsoon period and the groundwater level rise. On the other hand, during the dry period recharge is considerably less than discharge and then the groundwater levels decline (Hassan, 1992).

On average in Bangladesh about 26% of total annual groundwater recharge is being lost by discharges through evaporation in canals, streams and rivers before the start of the irrigation season in the month of November (Karim, 1987). The runoff has been estimated as 20 to 40% of the excess (Precipitation - Potential Evaporation) rainfall (UNDP, 1982), which is dependable on their local hydraulic gradients. Groundwater head in lowland can be seen within a few fraction centimeters to 1.0 m below the landsurface depending upon their locations and the seasons. They occur generally under unconfined to semi-confined conditions, sometimes in pocket lenses and perched aquifers. Most of the aquifers are hydraulically interconnected in the tidal flood plain and coastal plain in lowlands of southwest Bangladesh.

Physical Properties of Water

a) Hydrogen Ion Concentration (pH): The pH of water of lowland varies from 7.65 to 10 with a mean value of 8.9 which is indicating that the waters are alkaline in nature.

b) Electrical Conductivity (EC): The EC of the study area ranges from 304 to 6848 µS/cm with a mean value of 2178 µS/cm (Hassan el al., 1998). The EC is a function of ion concentration and can be used for quick checking of dissolved ionic species in waters. The importance of EC is its measure of salinity, which greatly affects the taste and thus has a significant impact on the users acceptance of water as potable.

c) Total Dissolved Solid (TDS): The TDS refers to the sum of all the dissolved components in water. The dissolved solids concentration in water ranges from 290 mg/l in Jessore (1973) to 8000 mg/l in Khulna (1986) with a mean value which is higher than the maximum permissible level prescribed by WHO (1983). The highest amount recorded in the Mongla area is considerably higher than the maximum limit of 1000 mg/l desired for drinking water. The high concentration level to be due to sea water intrusion from the south, the Bay of Bengal. The TDS content can amount to less 10 mg/l in rain and snow, less than 25 mg/l in water in humid regions with relatively insoluble rocks, and more than 300,000 mg/l in brines (Davis and DeWeist, 1967; Hem, 1980).

d) Total Hardness (TH) : The TH ranges from 131 to 632 mg/l with a mean of 267.5 mg/l (Hassan et al., 1998). The hardness is mainly due to the presence of bivalent metallic cations (Calcium and Magnesium) and expressed as an equivalent amount of calcium carbonate. The mean value of hardness in the study area (267.5 mg/l) is indicative of hard water. Generally, the ranges between 150 and 300 mg/l of hardness in drinking water which may cause heart disease and kindney problems.

e) Alkalinity : The alkalinity is the capacity of water to neutralize acid. All alkalinity of natural water is produced by carbonate and bi-carbonate ions (Bower, 1978). The alkalinity of groundwater of the study area ranges from 231 to 510 mg/l with a mean of 352.7 mg/l. Hardness and alkalinity indicate that the groundwater of the study area is of alkaline earth bi-carbonate type.

Chemical Constituent

a) Sodium (Na^+) and Potassium (K^+): Groundwater generally contains a higher amount of sodium than potassium because the potassium bearing minerals weather much slowly than those containing sodium. In addition it is strongly adsorbed by clay minerals (like illite) in soil and therefore, is relatively scar in groundwater and most natural water. Sodium (Na^+) ranges from 168 to 1498 mg/l with a mean of 387.9 mg/l which is not safe for drinking or for irrigation purposes when compared with WHO Standard. The potasium (K^+) value ranges from 4.2 to 24.7 mg/l with a mean of 11.83 mg/l for the study area. The mean value of potassium is much less than the values prescribed by WHO.

b) Calcium (Ca^{++}) Magnesium (Mg^{++}): Calcium (Ca^{++}) together with magnesium (Mg^{++}) causes hardness in water. In the analysed samples the concentration of calcium ranges from 16.6 to 53.5 mg/l with a mean of 25 mg/l and that of magnesium ranges from 21.3 to 123 mg/l with a mean of 49.92 mg/l (Hassan et al., 1998). The presence of these materials in water in excess of about 100 mg/l decreases the cleaning and lather properties of soap (Hem, 1980).

c) Carbonate (CO_3) and Bi-carbonate (HCO_3): Along with hydroxide are responsible for the alkalinity of water. Solubility of carbonate minerals in pore water is very low but they get dissolved and form bi-carbonate compounds in water containing carbondixide. The carbonate and bi-carbonate of the study area ranges from 7.0 to 29.0 mg/l and 268 to 575 mg/l with a mean value of 18.73 and 372.8 mg/l, respectively (Hassan et al., 1998).

d) Sulphate (SO_4): The sulphate concentration in groundwater at different location of the study area during the dry period 1993 ranges from 7.89 to 27.6 mg/l with a mean of 11.77 mg/l which is well within the permissible ranges for human consumption (Hassan et al., 1998). Sulphate concentration in drinking water should not exceed 250 mg/l because the water will have a bitter taste and can produce laxative affects at higher levels (Bower, 1978).

e) Nitrate (NO_3): is the most prevalent form of nitrogen in groundwater. The presence of nitrogenous compounds indicate the presence of organic matter. Nitrogen fixing plants (legumes) and bacteria, chemical fertilizers, sewage and decaying organic matter are the principal sources of nitrate in water. The nitrate content of unpolluted water rarely exceeds 10 mg/l (Rainwater and Thatcher, 1960). High concentration of nitrate (more than 20 mg/l) could be a concern specially when used for drinking or irrigation. The nitrate content in the groundwater ranges from 6.78 to 14.0 mg/l with a mean of 9.48 mg/l (Hassan et al., 1998). This fairly high concentrations may be due to percolations of surface water containing human and other agricultural by products in the groundwater reservoir.

f) Phosphate (PO_4) and Amonium (NH_4): concentration in the area is low and therefore, poses no problem to the groundwater quality.

g) Chloride (Cl^-): is an indication of salinity in water. It is one of the major important constituents of natural water. Most chloride in groundwater comes from evaporites, salty connate water and sea water. Groundwater containing significant amount of chloride also tend to have high amounts of sodium indicating the possibility of contacts with water of marine origin. This situation is observed in the study area. Chlorides in the area ranges from 87 to 2346 mg/l with a mean of 514.5 mg/l (Hassan et al., 1998). The ratio of Na^+ to Cl^- is as indication of sea water intrusion in groundwater at some places of the study area. The highest chloride concentration was found at Mongla Port which is considerably higher than the maximum limit of 250 mg/l as specified by WHO(1983) for drinking water.

h) Boron (B): Boron concentration is mostly in relation to irrigate agriculture. It is a toxic constituent. Small amount is essential to plant growth. However, greater concentration (less than 0.50 to 1.0 mg/l) of boron in irrigation water is harmful. The boron concentration of groundwater of the study area is almost uniform, ranging from 0.24 to 0.91 mg/l with a mean of 0.53 mg/l (Rahman, 1994), which indicates that the waters are free from any hazardous condition from boron.

Arsenic Contamination (As)

Recent studies on groundwater in several places of lowlands have been suggested that the groundwater is also contaminated by arsenic. Arsenic in groundwater can be found about more than 2 mg/l. The maximum permissible concentration of arsenic in drinking is 0.05 mg/l (WHO, 1983). Arsenic is a toxic metal that accumulates in the human body. Certain type of skin problems suffered by some lowland dwellers can be attributed to the factor.

CONCLUSION

The physico-chemical analyses results of groundwater sample of the study area of southwest Bangladesh show that the waters are primary salinity type and marked by a relatively higher proportion of Cl^-, Na^+, HCO_3 where as the other chemical concentrations are well within the permissible level prescribed by WHO standard. More than permissible concentration of arsenic in groundwater has been reported by several studies of lowland area of southwest Bangladesh.

REFERENCES

Bower, H. (1978). Groundwater Hydrology. McGraw-Hill Series in Water Resources and Environmental Engineering, New York, USA: 480.

Dam, J., C. Van (1994). Groundwater Hydrology in lowland. Lowland Development & Management. A.A. Balkema, Netherland: 219-246.

Davis, S.N. and DeWeist, R.J.M. (1967). Hydrogeology 2nd. ed. John Wiley & Sons, New York: 463.

Hassan, M.Q. (1992). Saline Water Intrusion and Hydrogeological Modeling in Southwest Bangladesh. Schelzky & Jeep Publ. Berlin: 157.

Hassan, M.Q. (1995). Surface Water Flow and Surface Water Salinity in the Rivers of Southwest Bangladesh. The Journal of National Oceanographic and Maritime Institute (NOAMI), 12 (1& 2) Dhaka: 58-65.

Hassan, M.Q. and Ahmed, K.M. (1996). Hydrochemistry of Groundwater in the St.Martin`s Island, Bangladesh. Jr. of Bangladesh Academy of Science. 20(2), Dhaka: 145-154.

Hassan, M.Q. (1997). A Note on the Sundarbans Mangrove Forest and Its Environment. A Short Field Report of German Cultural Centre, Dhaka: 4.

Hassan, M.Q. and Okubo, K. (1998). Surface Air Temperature Distribution : A Study from southwest Bangladesh. Jr. of the Faculty of Environ. Sci. & Tech. Okayama Univ. Japan. 3(1): 97-104.

Hassan, M.Q., Rahman, M.M., Islam, M.S. & Shamsad, S.Z.K.M. (1998). Effects of salinity on the Hydro-Evnironment of Khulna City and Mongla Port area of Bangladesh. Dhaka University J.Biol. Sci. 7(2): Dhaka : 113-127.

Hem, J.D. (1980). Study and Interpretation of the Chemical Characteristics of Natural Water. 2nd. ed. USGS. WSP. 1473, Washington, D.C.: 363.

Karim, M.A. (1987). Upazila-wise (subdistrict) Groundwater Recharge Conditions of Bangladesh. Report, BWDB, Dhaka: 74.

Khan, R.I. (1978). A discussion of the possible adverse effect of large scale groundwater development in Bangladesh. 4th Annual Bangladesh Geol. Conf. Dhaka.

Khan, Q. (1988). Groundwater Resources Development in Bangladesh, Report, Master Plan Organization, Dhaka: 51.

McClung, A.C., Deteritas, L.M.M. and Loot, W.L. (1959). Analysis of several Brazilian Soils in Relation to Plant Response to Sulphur, Soil Sci, Soc. Am. Proc. (23): 221-224.

Miura, N., Madhav, M.R. and Koga, K (1994). Lowlands, Development and Management. A.A. Balkema, Netherlands and USA.: 485.

MPO (Master Plan Organization) (1986). National Water Plan. Report Bangladesh, vol. 1(salinity) Dhaka: 33.

Murphy, J and Riky, J.P. (1962). A modified single solution method for determination of phosphates in natural waters, Anal. Chem. Acta. (27): 31-36.

Page, A.L. et al., (1982). Method of Soil analysis, Part 2, Chemical and Microbiological Properties, 2nd. ed. Am. Soc. Agron. Inc. SS SA, Madison, USA,: 341-528.

Rahman, M. (1994). Hydrochemistry and Hydraulic Head Distribution of Khulna City and Mongla Port, SW Bangladesh, Unpubl. M.Sc. thesis, Dhaka University, Dhaka: 164.

Rainwater, F.P and Thatcher, L.L. (1960). Method for collection and analysis of water samples : USGS. WSP 14, Washington, D.C.: 93-301.

UNDP (1982). The Hydrogeological Conditions of Bangladesh. Report No. DP / UN / BGD - 74-009, Washinton/Dhaka: 113.

WHO (1983). Guidelines for Drinking Water Quality, Geneva.

Woods Hole Oceanographic Institude (1986). Rising Sea Level and Damming of Rivers; possible effect in Egypt and Bangladesh of Brodns. J. Milliman, J. and Strevens, E. in Sea Level Rise and River Deltas. 18(2). Mass., USA.