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Environmental Pollution Around Dhaka EPZ and its Impact on Surface and Groundwater

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Abstract

Industrial sector is gradually playing a more important role in Bangladesh economy and EPZs have provided a good platform of industrial establishment. Dhaka EPZ since its establishment has altered the fragile environment of the surrounding area. Huge amount of effluents discharged from Dhaka EPZ has been polluting the surface and groundwater. Surface water contamination by industrial effluents released from Dhaka Export Processing Zone (DEPZ) and the ramification to groundwater have been estimated. The study involves analyzing physicochemical properties along with major Anionic contaminants in waste water samples. Conversely their potential transmission into groundwater has been evaluated by analyzing HTW water samples from the surrounding area. Some important physical parameters were measured while collecting the sample in field condition. The suite of 6 major anions (F^-, Cl^-, NO_2^-, NO_3^-, SO_4^{-2} and HCO_3^-) have been measured in ppm level of concentration by analyzing with chemically suppressed Ion Chromatograph while HCO_3^- content was determined by Titration method. Analysis reveals pH maximum 9.55, DO maximum 2.40 mg/L, TDS maximum 1280 mg/L, Bi-carbonate maximum 891 mg/L, Sulfate maximum 452 mg/L, Chloride maximum 179 mg/L, Nitrate maximum 44 mg/L and Fluoride not above detection limit. Higher concentration of Cl^-, SO_4^{-2}, NO_3^- in waste water samples compared to the standard by DOE (Department of Environment) as well as background concentration from uncontaminated water can be correlated with industrial effluent discharge. On the other hand low level of concentration found in groundwater samples indicates that groundwater is still safe. This phenomenon is explained by the presence of impervious clay layer.

Key words: Dhaka EPZ, Effluent, Madhupur Tract, Contaminants, DOE, Environment, Clay layer

Introduction

Discharge of industrial effluents into natural hydrological system is by far number one threat to our environment. With the advent of industrialization in mid 50's major industrial clusters have been preferably developed close to river system with a view to get the advantage of easy effluent discharge. Thus for the last few decades, water pollution has been pervasive enough to bring deleterious consequences over key environmental resource- Water; that encompasses both surface water and groundwater circulating by Hydrogeologic cycle.

Almost all tributaries of major river system are already saturated (and are declared Dead Rivers) with pollution. This is remarkably severe for the rivers around capital Dhaka. Effluent discharge in these rivers has increased to such a level that even wet period flow cannot flush them out. On the other hand, during dry priod entire river water is replaced with hazardous industrial effluent.

Major impacts are the destruction of aquatic habitats that includes extermination of our unique and diversified fish community from rivers and other water bodies, disqualifying the water to be served for irrigation. Groundwater quality destruction is far more alarming because it is difficult to control, predict, remedy and to delineate the extent of pollution whereas it is very intimate to human exposure and thus can cause health hazards. Some study (Isotopic Analysis) reveals that this contaminant river is contributing to the nearby groundwater recharge system which is accelerated by over-extraction from the aquifer.

DEPZ being the 2nd EPZ of the country has started its operation back in 1993 and till date has not set up a Central Effluent Treatment Plant (ETP) instead keep discharging untreated effluent into the low-lying natural water body.

Dhaka EPZ houses 92 industrial units which are categorically the leading pollution creators.

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Table I: Types and number of industrial units in DEPZ

No	Industry Type	Number of Units
1	Cap/Accessories/Garments	42
2	Textile/Knitting	22
3	Miscellaneous	11
4	Plastic Goods	6
5	Footwear/Leather Goods	4
6	Metal Products	2
7	Electronic Goods	2
8	Paper Products	1
9	Chemical and Fertilizer	1
Total		91

Every industrial unit is supposed to have effluent treatment plant to treat the respective waste they generate. However, so far only a few industries have installed such plants. Even then most of the plants operate occasionally only to be qualified to international buyers and to get clearance certificate from DOE.

Pollution from the Dhaka EPZ has already polluted the wetland and some of the streams which has ruined aquatic habitats and natural fisheries. Natural wetland of the study area used to serve the fresh water demand especially irrigation. The toxic waste water now being used for irrigation and thus contaminating the agricultural land as well.

Study Area

Study area for this research belongs to Dhamsona Union under Savar Upazila of Dhaka District. It is about 35 kms from Dhaka City and 25 kms from Hazrat Shahjalal International Airport in the NW direction and represents a limited extend of landscape yet having distinct morphological features. Topography of this area comprises irregular elevated land blocks on which people live and surrounding low-lying area which are mostly cultivation lands and water bodies. There is however, moderately elevated paddy land on the western fringe of the study area (Figure 3) that is cut by the canal connecting waste lagoon and Bansi River.

On the way through the connecting canal to reach Bansi River, the effluent pools in the depressed area next to the EPZ boundary forming an unexpected waste beel (Figure 1) whose perimeter grow larger by excess precipitation plus runoff during Rainy Season. At that time contaminated water spills and inundate the elevated lands too, thus pollute them as well.

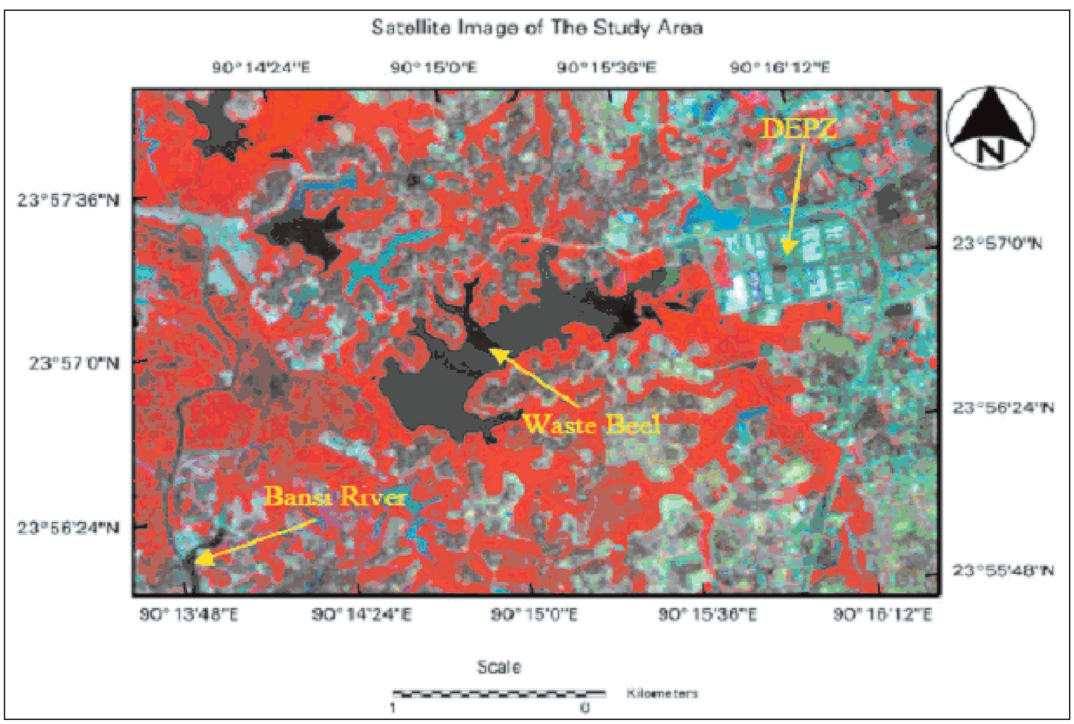

Fig. 1: Satellite Image showing DEPZ, Waste Beel and Bansi River

Geology and Hydrogeology

Physiogaphically the study area belongs to Madhupur Tracts, which is a Pleistocene elevated landscape distinct from the surrounding Fluvio-deltaic plains by Ganges, Brahmaputra and meghna River. Madhupur Tract extends in Dhaka Mymensing and Tangail Districts. The appearance of Madhupur Tract in its present form is attributed to neo-tectonic activities since Quaternary period (Pleistocene Epoch ~ 1.8 My).

The study area actually is located on the southwestern fringe of the Madhupur Tract. Geomorphology of the study area does not however, represent a continuous block of either uplifted or residuum Madhupur Tract .This area rather represents the junction between overlapping older Madhupur Tract and Recent Flood-plain deposits. Locally the elevated village mounds represents Tract deposits and the low-lying area is may be the infilling of depressed areas by the flood plain deposits of recent time (Figure 3).

This physiographic feature has many special characteristics although many of which are not apparent in the study area (exposed). This is because in the study area Madhupur Tract has been affected by Recent flood-plain deposits and soil formation at depositional break.

There is indication of relict paleosols within the stratigraphic sequence in the Madhupur Area which is characteristic to Madhupur Formation. The modern soil is also in fact, a relict soil of the pre-existing paleosol materials.

The reddish brown colour of Madhupur / Barind formation is clearly related to the iron compounds. A detail study of clay minerals of Madhupur Formation has been performed by Hassan (1986) and he found the iron rich clay minerals, such as Illite, Chlorite and Vermiculite. Among the iron oxides the authigenic hematite (Fe_2O_3), goethite (FeOOH), Lepidochrocite (FeOOH) and hydrated-ferric-oxides gel ($Fe(OH)_3.H_2O$) are important.

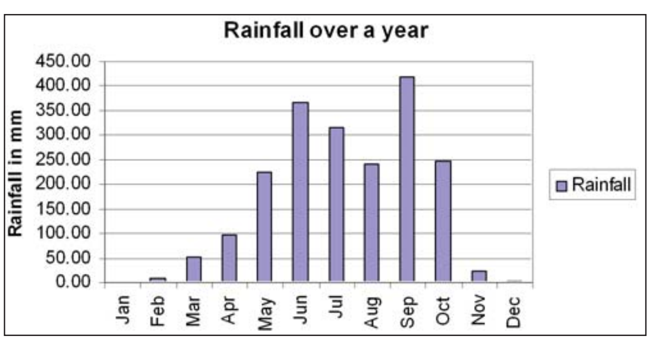

Fig 2: Rainfall data of the Study Area.

Hydrology of the study area is governed by rainfall intensity and distribution, permanent or ephemeral water bodies and rivers or canals.

Figure 2 shows the average rainfall distribution in various months for 7 years (2001-2007). The pattern shows distinct conformation with the climatic pattern prevailing, with strong Monsoon influence.

Special feature of this area is many isolated water bodies that occupy the low lying/ depressed areas- connected or not with the river system (Figure 3).

On regional scale, Bansi-Daleshwari and Turag comprises the drainage network of the study area - Bansi on the west and Turag is away on the east. Both are flowing parallel with a due NS trend having the flow direction towards south.

Regionally the top soil is underlain by Madhupur Clay Formation having limited and varying thickness that particularly represents Pleistocene to Holocene sediments. This Madhupur Clay Formation and underlying thick column of Miocene-Pliocene sediments comprise the Aquifer System of the study area.

Based on different hydrogeological characteristics, Mio-Pleistocene and Holocene sediments have been categorized into Upper and Lower Aquifer Sequences.

While Upper Aquifer Sequence represents variant admixture of Sand, Silt and Clay, Lower Aquifer Sequence comprises five Aquifer layers separated by impervious Aquitards.

Method of Study

Reconnaissance survey over the study area has been conducted before attempting detail field survey. It revealed that the general status of the physical environment. Sampling location has been selected from this initial survey with the help of GPS and satellite imagery.

Detailed field study includes samples collection from appropriate locations, field measurements (pH, DO, Temperature, SEC, Eh etc). Photographs were taken to document the status of the study area and sampling locations.

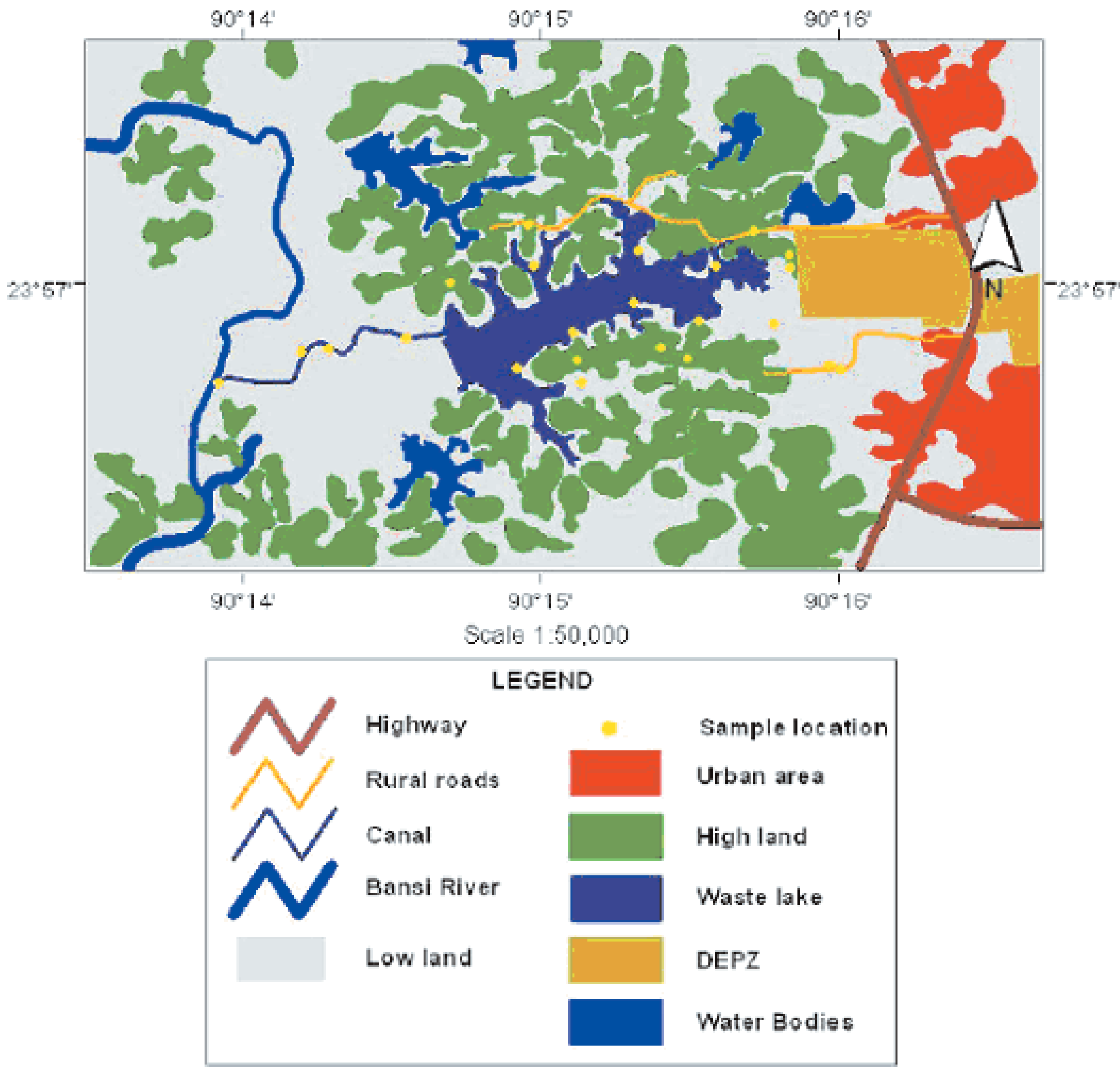

Fig. 3: Land-use map with Sampling Location of the Study Area

The field study for sample collection was carried out from December to May month- that belongs to the dry season of year. This research hence, is presenting the snap shot pollution scenario of the study area.

This study is designed assuming Dhaka EPZ the point source for industrial pollution of the area. Thereby all the samples were collected from the vicinity of the effluent discharge site and transportation pathway.

Waste-water samples, labeled as 'WW Samples' were collected from the waste beel, canal and Bansi River. Total 13 waste water samples were collected from the study area.

Groundwater samples, labeled as 'GW Samples' were collected from village houses around the waste beel (Figure -3). 8 groundwater samples were collected for the analysis.

Groundwater samples were all collected from hand tube-well i. e. depth not exceeding 30 to 40 m. All these represent GW from the shallow topmost aquifer layer. Tube-wells are located in the village mound areas that surround the waste lake. One uncontaminated surface water sample, SW 001 was collected from a pond isolated from waste beel.

Portable field instruments were used to record sensitive field parameters on site for GW, WW and SW samples. These parameters include-Temperature, PH, Eh, DO and SEC. Waste Water samples were collected from stagnant or flowing condition in the waste beel, canal and Bansi River. These were collected with a plastic Jar from the surface without disturbing the flow condition or stir. On the other hand groundwater samples were collected after few minutes of pumping the well.

When the field measurements are done, the samples were stored in plastic containers of 1 litre volume and leveled with sample id, type, date and location on the sticker tag.

A customized field data sheet was used to record relevant information regarding the sample e.g. Results of Field Measurements, location GPS, site status etc. The bottles were entirely filled with sample so that no air was trapped inside that can react with the sample to alter its characteristics.

Some quality control measures were followed carefully to avoid errors in the laboratory analysis. During sample preparation, the apparatus were washed and rinsed three times with distilled / de-ionized water. Rinsing the pipet and volumetric flux with the sample to be measured has been done to avoid interference and uncontrolled dilution.

SIMADZU (Chemically Suppressed IC) was used to analyze the anions except Bi-carbonate which was measured in Titration Method. The results were formulated by Class VP Software. A Buffer Solution was used in the analysis as the Mobile Phase containing Na_2CO_3 0.1908 gm and $NaHCO_3$ 0.1428 gm. The volume was made 500 ml and filtered with 0.2 um Membrane Filter.

Made Standard Solution containing the anion suite was prepared which was used during the analysis for quality control. 500 ml volume of Made Standard contains:

F^- = 5 ppm	NO_3^- = 10 ppm
Cl^- = 20 ppm	Br^- = 10 ppm
NO_2^- = 10 ppm	SO_4^- = 50 ppm

Un-acidified and filtered GW, WW and SW samples were used for the analysis.

About 20 ml of samples were taken into plastic vials (containers for the sample to be placed in the tray of the instrument). Before that, the samples were filtered in two stages- using Whatman Filter Paper #41, and then with Micropore Filter (0.45 um) with the help of Syringe. To get the result within the measurement limits of the instruments and also retain the curve peaks following dilution were applied-

GW Samples-1T
SW Samples- 5T and
WW Samples - 10 T
De-ionized water was used for all the washing, dilution and volume preparation during the analysis with IC.

Results and Discussion

Analysis results are described in two categories, the physico-chemical parameters and the anions.

Analysis of the Physical Parameters

Most important Physico-chemical parameters are pH, DO and conductivity that are very much related to water chemistry altered by pollution.

pH of an aqueous solution is a measure of the number of hydrogen ion (proton) present. It is defined as the negative logarithm of hydrogen ion activity. It ranges from 0 (most acidic) to 14 (most basic) and at 25 degree Celsius, pH 7 means that the solution is neutral. The pH is especially sensitive to the amount of dissolved CO_2.

River water in areas not influenced by pollution generally has a pH in the range 6.5 to 8.5.

GW Samples

With an average of 7. 32, GW sample pH ranges from slight acidic to slight alkaline zone (~6.5 to 7.25). Although the highest pH obtained is 8.03, most of the samples contain pH < 7.

WW Samples

pH values are higher in the waste water samples. Although the minimum value is 7.77 most of the samples have pH > 9. However, the maximum value obtained is 9.55.

DO is the measure of free oxygen in dissolved state, which is a factor of Atmospheric pressure, temperature and salinity. The equilibrium concentration of dissolved oxygen (DO) in water in contact with air is a function of temperature and pressure, and to a lesser degree, of the concentration of other solutes.

The higher forms of aquatic life require oxygen for survival. The DO concentration may be depleted by processes that consume dissolved, suspended, or precipitated organic matter, and values above equilibrium can be produced in systems containing actively photosynthesizing biota.

Oxygen is supplied to groundwater through recharge and by movement of air through unsaturated material above the water table. This oxygen reacts with oxidizable material encountered along the flow path of the water.

At a contact pressure of 1 atm, 100% saturated water at 4 degree celcius and 24 degree celcius contains 13.11 mg/L and 8.42 mg/L of DO respectively. DO decreases with the increase of temperature.

GW Samples

In the GW samples DO varies from 4.2 to 7.9 mg/l with the calculated average value of 5.95 mg/L (~6.0 mg/L). However, majority of the samples have DO > 5.0 mg/L.

WW Samples

In general waste water samples contain very low amount of DO. Yet the maximum amount recorded is 5.97 mg/L, for most of the samples it is not above 2.4 mg/L. The average value was calculated 2.65 mg/L.

TDS was calculated by measuring the conductance of water samples. Conductance increases with the salt content. Because natural water contains a variety of ionic and undissociated species, conductance cannot be singly related to TDS. However, conductance is easily measured and gives results that are conveniently used as a general indication of dissolved solids. For most natural water, 1mg/L is equivalent to 1.56 uS/cm.

GW Samples

From the analysis, the average TDS value calculated is 70.88 mg/L. While the maximum concentration is 97.7 mg/L, most of the GW samples have value between 60 to70 mg/L.

WW Samples

TDS content is many times higher in waste water samples. Although the minimum content is 685 mg/L, most of the samples contain around the calculated average of 1084 mg/L. However, the maximum value is 1280 mg/L.

Comparison with BD Standard

Among the physical parameters measured for the waste water samples mostly in the field conditions, conductivity and pH exceed the standard value while the DO content is much less than the minimum level should be present. As supported by the conductivity, TDS is high and very close to the maximum acceptable limit and so is the temperature (Figure 4).

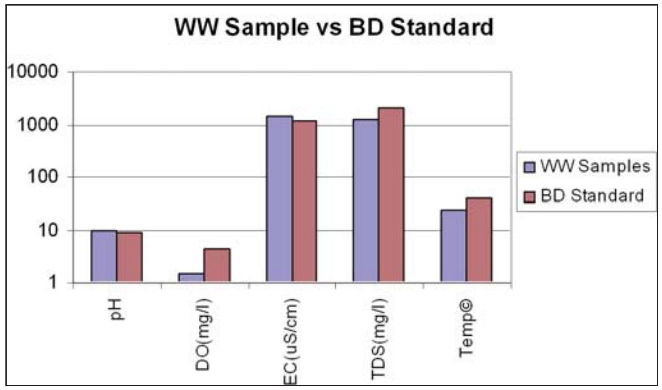

Fig. 4: Comparison of Physical Parameters

Analysis of the Anions

Seven major anions were determined for GW, WW and SW samples. Except Bicarbonate all other anions were determined as a suite with Ion Chromatograph. Non acidified samples were used for IC analysis.

Bi Carbonate

Bi-carbonate concentration of natural water generally is held within a moderate range by the effects of carbonate equilibria. The concentration in rainwater commonly is below 10 mg/L and sometimes is much less than 1 .O mg/L, depending on pH. Most surface streams contain less than 200 mg/L, but in groundwaters somewhat higher concentrations are not uncommon.

Bicarbonate is of little significance in public supplies except in large amounts, where taste is affected or where the alkalinity affects the corrosiveness of the water.

GW Samples

Most GW samples has <100 mg/L HCO_3^- with the calculated average concentration of 89.45 mg/L. However, the minimum value measured is 81.01 mg/L of HCO_3^-.

WW Samples

Much higher HCO_3^- is present in WW samples. Whereas the minimum value is 329.10 mg/L, most of the samples contain >500 mg/L HCO_3^- with the calculated average value of 623.92 mg/L. However the maximum concentration obtained is 891.11 mg/L.

Sulfate

When sulfide minerals undergo weathering in contact with aerated water, the sulfur is oxidized to yield sulfate ions that go into solution in the water. Hydrogen ions are produced in considerable quantity in this oxidation process.

Sulfates are commonly present in some mining and Industrial wastes. Sulfate has a secondary standard of 300 mg/l. High levels can give water a bitter taste and rotten-egg smell, cause diarrhea, and in combination with calcium, form scale in boilers.

Sulfates occur naturally in numerous minerals and are used commercially, principally in the chemical industry. They are discharged into water in industrial wastes and through atmospheric deposition; however, the highest levels usually occur in groundwater and are from natural sources.

GW Samples

Although the maximum value as obtained from the analysis is 10.427 mg/L, most of the samples contain <1 mg/L of SO_4^{-2}. The minimum concentration is however 0.171 mg/L.

WW Samples

Analysis reveals that SO_4^{-2} concentration is abnormally high in WW samples, the maximum concentration is 542.28 mg/L. Majority of the samples cluster around 400 to 500 mg/L and the minimum value is found 171.31 mg/L.

Chloride

Chloride is present in all natural waters, but mostly the concentrations are low. In most surface streams, chloride concentrations are lower than those of sulfate or bicarbonate. Exceptions occur where streams receive inflows of high-chloride ground water or industrial waste or are affected by oceanic tides.

Small quantities of chloride have little effect on the use of water. Sodium chloride imparts a salty taste, which may be detectable when the chloride exceeds 100 ppm, although in some water, 500 ppm may not be noticeable. Chlorides in high concentrations present a health hazard to children and other young mammals.

Chloride is dissolved from rocks and soils and is usually present at levels less than 50 mg/l. High levels are caused by sewage, oil-field brine, industrial effluent, or seawater intrusion. High levels, in combination with sodium, can give drinking water a salty taste and may increase the corrosiveness of water. It has a secondary standard of 300 mg/l.

GW Samples

Chloride values range between <1mg/L up to 36.44 mg/L. While most of the samples contain < 5 g/L of Cl^-, the average concentration calculated is 6.77 mg/L.

WW Samples

Unlike GW samples, Cl^- concentration is much higher in Waste water. Majority of the samples have Cl^- content > 150 mg/L, while the maximum value is 179.01 mg/L (The minimum concentration measured is 57.56 mg/L).

Nitrate and Nitrites

These are readily transported in water and are stable over a considerable range of conditions.

The nitrite and organic species are generally considered to be indicators of pollution through disposal of sewage or organic waste.

Excessive concentrations of nitrate in drinking water may cause methemoglobinemia in small children.

Concentrations of nitrate that approach or exceed 44 mg/L NO_3^- are present in many rural water-supply wells. Most investigators have attributed this nitrate to drainage from nearby barnyards or septic tanks and cesspools. Water from many small and medium-sized rivers in agricultural areas has nitrate concentrations exceeding 10 mg/L.

Sources of nitrate (NO_3^-) are decaying organic matter, sewage, nitrate fertilizers, and nitrates in soil. Nitrate encourages growth of algae and other organisms that cause undesirable tastes and odors, concentrations much greater than the local average may suggest pollution. Nitrate in water may indicate sewage or other organic matter. The primary health concern regarding nitrate and nitrite is the formation of methaemoglobinaemia, so-called "blue-baby syndrome."

GW Samples

Most of the GW samples contain detectable NO_3^- and the concentration does not exceed 3.0 mg/L. The calculated average value is however 0.95 mg/L.

WW Samples

Much higher NO_3^- level is present in WW samples. While the maximum value is 44.59 mg/L, most of the samples contain > 20 mg/L of Nitrate.

Fluoride

Fluorite (CaF_2) is the most common fluoride mineral. This mineral has a rather low solubility and occurs in both igneous and sedimentary rock.

Mineral particles that contain fluoride are widespread constituents of resistant sediments. Ground water containing fluoride concentrations exceeding 1 .O mg/L has been found in many places in a wide variety of geologic terrains.

The concentration of fluoride in most natural water, which has a dissolved-solids concentration of less than 1,000 mg/L, is less than 1 mg/L.

GW Samples

All the GW samples contain very low level of Fluoride. Most of the samples cluster around the calculated average value of 0.22 mg/L forming a uniform pattern. All the samples however, contain <1 mg/L of F^-.

WW Samples

None of the WW samples contain Fluoride within above the detection level.

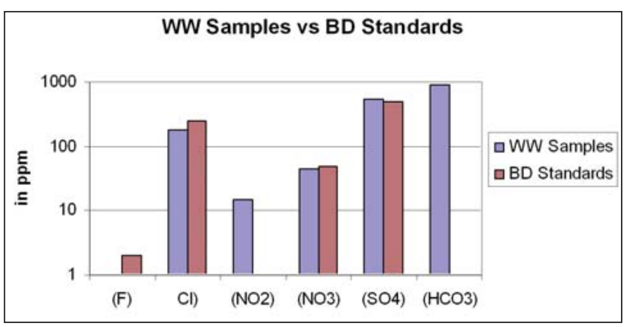

Fig. 5: WW samples has higher concentration than BD Standards

Comparison with BD Standard

The maximum Anionic concentration in waste water samples shows Sulfate (SO_4^{-2}) has concentration exceeding the acceptable limit. On the other hand, for both Chlorine (Cl^-) and Nitrate (NO_3^-), the concentrations are just below the maximum acceptable limit (Figure 5). These anions are potential pollution indices and in the same time key ingredients of industrial effluent. Thus accumulation of these pollutants in beel water is perceptibly attributed to industrial effluent disposal.

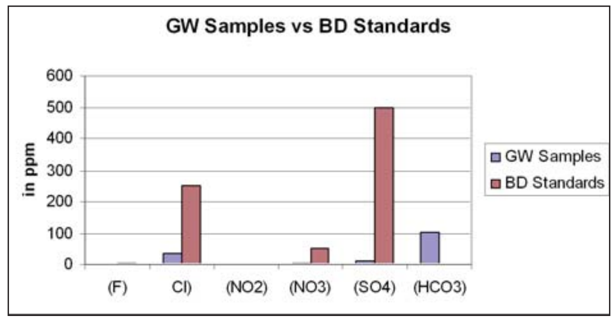

Fig. 6: GW samples have lower concentration than BD Standards.

Another very important observation is drawn from Figure 6. It shows that in Groundwater the selected anionic pollutants have much lower concentration than the standard by DOE which is not the case for beel water. This situation can happen only if the shallow aquifer underlying the study area is hydrologically isolated from surface water. Geology of this area reveals the surficial horizon is a Madhupur Clay which is impermeable. This clay layer is prohibiting the contaminants to transmit into the groundwater. The result is quite safe groundwater yet we have surface water above being polluted for more than a decade.

Concentration in the non-polluted water

One surface water sample (SW001) has been collected from an isolated pond which is not connected with the effluent flow pathway from DEPZ. This sample thereby is used to analyze the background concentration of various pollutants in the study area.

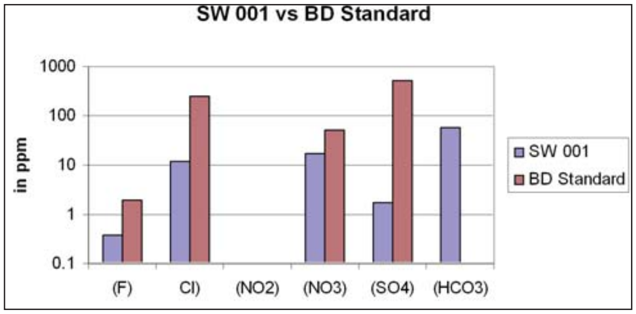

Fig. 7: SW001 has lower concentration than Bangladesh Standards.

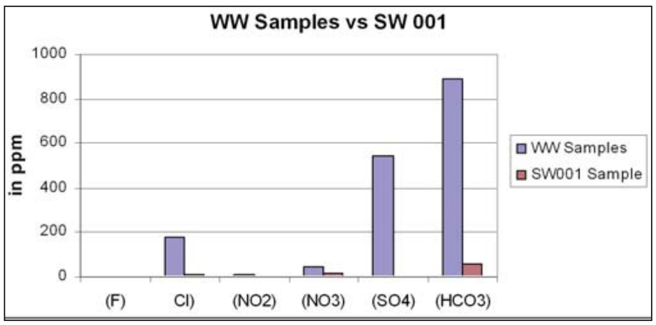

Fig. 8: Maximum Concentration in WW is much higher than SW001.

As analysis reveals, Anionic pollutants in the uncontaminated sample has concentration well within the standard limits for Bangladesh (Figure 7). On the contrary, maximum concentration analyzed from waste water samples is distinctly higher than this background concentration of the study area (Figure 8). This scenario implies that at virgin condition surface water of the study area was not contaminated but incessant disposal of industrial effluent for years has caused higher concentration of pollutants in natural water bodies.

Conclusion

DEPZ is using the adjoining low lying agricultural lands to discharge effluent. Thus a waste beel has formed nearby which is connected with Bansi River. Water of this waste beel has remarkably higher concentration of pollutants compared with sample from non-polluted water body. This implies the effluent contains hazardous pollutants that are destroying the geo-environment and ecosystem of the surrounding area. It is alarming to observe that waste beel water has higher concentration of Cl^-, SO_4^{-2}, NO_3^- beyond standard limits for Bangladesh. This contamination is uniquely attributed to effluents from DEPZ by the fact that isolated water body has much less concentration of these pollutants than that of waste beel. Sample from isolated water body also represents background concentration for the study area and has much lower values than Bangladesh Standard. This fact leads to the conclusion that prior to the initiation of DEPZ, the natural surface water of this area was unpolluted

These contaminants while have become more concentrated in the surface water beyond national acceptable standards, the groundwater samples from shallow depth reveals safe concentration. The surficial impermeable Madhupur Clay Formation is serving as infiltration barrier that perhaps inhibits the percolation of polluted water.

The surface water, however, has already suffered from loss of aquatic flora and fauna including fish resources. The quality of being used for irrigation and other domestic purposes has completely ruined and thus is a threat to land fertility. The color of the water has altered and disseminate stench to cause vexation among the vicinity. This effluent discharge if continuous will impose long-lasting damage to the surrounding vulnerable geo-environment.

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