Different Land Use and other Physical and Socio-economic Parameters in Ground Water Arsenic Concentration

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Abstract—An attempt has been made to evaluate how different physical and socio-economic parameter like land use / land cover class, geomorphology, geohydrology and population density impact ground water arsenic concentration of the study area, the district North 24 Parganas, West Bengal, India. In order to accomplish this, overlay and buffering analyses have been extensively performed in a GIS platform. Using supervised classification technique land use/land cover map has been prepared from IRS-1D LISS III satellite image of the study area. In this research a total 80 hydraulic stations (tube well) with their corresponding arsenic concentration value, have been encoded by spatial entity of ‘Point’ on GIS based map of the said district. Half of the encoded hydraulic stations were selected randomly and were categorised into four classes according to their arsenic concentration value. A ring buffer was created around each selected hydraulic station (40 out of 80) with the radial distance of 1km from centre of the ring. The buffered zone was then overlaid on land use/land cover map to extract the extent of each land use/land cover class within the buffered zone. A comparative study was made statistically to predict the importance of land cover class to ground water arsenic value of the area. This research confirmed an obvious correlation between ground water arsenic concentration and dominant land use/land cover pattern of the area. Further those buffered layers were overlaid on digitized geomorphological, geohydrological and population density map of the study area to know whether these parameter have some impact to ground water arsenic concentration or not.

Key Words: Arsenic (As), Ground Water, GIS, Overlay, Buffering, Satellite Image, Shallow Tube Well (STW).

1. Introduction:

Pollution of subterranean water by arsenic (As) and the risk for using that water both for drinking and irrigation purpose has the potential of turning into the greatest environmental chemical disaster in human history affecting millions of people in the Bengal Basin. [Das et al., 1995, 1996; Mandal et al., 1996; Dhar et al. 1997; Biswas et al., 1998; Karim, 2000; Smith et al., 2000]. In the Bengal Basin, the health of domestic consumers of groundwater has been adversely affected by arsenic pollution (Dhar et al. 1997; Smith et al. 2000; Saha and Chakrabarti 2001; Chakrabarti et al. 2003). Immense population lives in this fertile alluvial tract of the Bengal Basin mostly spanning between India and Bangladesh (Ravenscroft et al. 2008). Unbridled growth of population slaps constant demand of food grain on this superbly fertile landmass rendering it as one of highest cropping intensity terrain of the world. Because of this ever burgeoning populace with concomitant infrastructural sprawl over the years affect the sustainability of the land use/land cover pattern of the area.

In the last three decades, the number of shallow tube wells (STW) has increased dramatically in this region. These STWs are providing a reliable and inexpensive source of irrigation water, which allows farmers to grow additional crops during the dry season, and ensures them of water security during periods of drought. Scientific studies in the last couple of years have reported potential risks from As in irrigation water because of land degradation affecting agro-ecosystem services (Alex Heikens, 2006).

Our present study area, the district North 24 Parganas of West Bengal is situated in the southern part of this Bengal Basin (SOES, JU; McArthur et al. 2004). The district is bordered by Hugli River on the west and the international border of Bangladesh on
the east. This district is one of the worst arsenic affected districts of West Bengal. According to census-1991 the average population density of this district was 1779 per sq. km. and it increased to 2182 per sq.km according to census 2001. (Statistical Handbook-2006). The primary land use is homestead tree cover / orchard, settlement, water bodies and agriculture. The agricultural land grows rice, vegetables, jute and pulses with and without irrigation (McArthur et al, 2004). Multiple cropping is carried out in this densely populated district over the years. Crop intensity is very high in many blocks of the district. The climate is tropical monsoonal, with a dry season between November and May. Rainfall is typically 1300 mm/yr. Most of rainfall occurs in the monsoon season between June and October (Sengupta and Sarkar 2006). This ever increasing growth of population affects sustainability of land use/land cover and ultimately it degrades eco-system of the region.

The major objective of this paper is to probe if there is a correlation between land use/land cover class and other physical parameter with ground water arsenic concentration of the study area- by appropriate use of data, garnered from authentic sources.

2. Data Used:

The water samples collected from different tube wells has been tested in the chemical laboratory of SWID (State Water Investigation Directorate, Govt. of West Bengal, India). From that laboratory we got arsenic concentration value (μg/L) from year 2006 to 2008 of two seasons (pre/post monsoon) for each water samples. These arsenic values have been used extensively for this research study. Other different surrogate data used in this research are: NATMO (National Atlas and Thematic Mapping Organisation) district planning map, Survey of India topographical sheets, Districts Statistical Handbook, Census Data, District Resource Map from Geological Survey of India and Satellite Image (IRS-1D LISS-III) of the district North 24 Parganas, from National Remote Sensing Centre, Hyderabad.
The GIS application software used was – ArcGIS 9.3. The image processing application software used was- ERDAS IMAGINE 9.0. The graphical software used was – Origine 7.0.

3. Methods

Available software resources like ERDAS IMAGINE’s image processing techniques and ArcGIS’s Geographical Information System had been used to derive a method of compiling all available data to achieve our goal.

The processing steps involved and followed in this investigation are as follows:

1 Data Georeferencing:

The NATMO district planning map of North 24 Parganas was georegistered with reference from Survey of India (SOI) toposheets. The georeferencing information was collected from 8 topographical sheets of 1:50,000 scale covering the entire district. The process of geocoding and then reprojection was done using Universal Transverse Mercator projection and referenced ellipsoid with Everest datum.

The satellite image (IRS 1D LISS III) was also georeferenced through above mentioned co-ordinate system. The process of geocoding required ground control points which was collected uniformly over the whole district.

3.2 Data Digitization:

i. Preparation of district boundary and block boundary map of North 24 Parganas:

From the geocoded scanned NATMO map, the district boundary was digitized. The block boundaries were also digitized. Process of digitization was done in the ArcGIS environment. Different blocks and their names were taken into database of Arc GIS in .mxd format.

ii. Preparation of Geomorphological and Geohydrological Map of North 24 Parganas:

The geomorphic and geohydrological map of the district collected from Geological Survey of India was also georeferenced through the above mentioned process and then digitization had been done using ArcGIS.

The different geomorphic units were (fig.1.2):

- a) Upper matured deltaic plain
- b) Lower matured deltaic plain
- c) Flood plain of river basin
- d) Lower active tide dominated deltaic plain.
3.3 Data Input:

i. Preparation of point map (location of tube well) block wise of the district [Spatial Data Input]

This is the process to identify and locate the block wise well location on the map. We selected three or more tube wells in each block randomly in order to accomplish the task. We pronounced this tube well as ‘Hydraulic Station’ (HS). The x, y lat/long value of those hydraulic stations was evaluated by GPS survey. Using that value we encoded the location of tube well in the digitized block map (Fig. 1.4) of the said district by spatial entity of points. The process was accomplished through the Arc GIS’s data editing technology. In this research study an aggregate of 80 Hydraulic Stations have been surveyed and located throughout the district.

ii) Attribute Data Entry:

Water samples collected from selected Hydraulic Station (HS) were tested in chemical laboratory of SWID. Arsenic concentration values in microgram/liter (μg/L) of each sample from year 2006 to 2008 for two seasons (pre/post monsoon) were recorded. The depth of each hydraulic station was collected from field survey. These data served as attribute data for this research study. Various fields in attribute database of arsenic point maps are: block name, location of HS (village name) under that block, year of sample collection, season of sample collection, arsenic concentration value for a particular season of year, and depth of HS. Attribute data reside as tables in a relational database. An attribute table was organized by row and column. Each row represents a spatial feature, and each column or field describe characteristics. Now if we click on any hydraulic station in Arc GIS environment by identifying the tool bar then it will show the Name of the block in which HS is situated, location (name of the village) of that HS, year of sample collection, season of sample collection, arsenic concentration value for a particular season of year, and depth of the tube well etc. The process was carried out through the Arc GIS’s data editing technology.

iii) Joining between spatial and attribute data:

The feature ID serves as the key in the georelational data model to link spatial data and attribute data. This unique combination enhances the role of GIS in decision making process and to make query generation process easier.

4. Image Classification through Supervised Classification technique: Preparation of land Use/Land cover Map using Satellite Image:

Supervised classification was performed with 8 classes for the available satellite image (IRS 1D LISS III) of the study area. In this type of classification, we make use of priory knowledge available from different field surveys while training the computer by way of assigning “training areas” about various features that are to be classified by the computer (Lillesand & Kiefer, 2000; Jensen, 1996). The various features trained to computer are- Surface Water (Water Body), forest (Here Tree) cover, fallow land, water logged area, marshy fallow land, vegetation, arable land and settlement (Fig.1.4). Using their feature signatures given, each pixel with similar characteristic signature is grouped and assigned to respective classes. The supervised classification was performed using ‘Maximum Likelihood Classifier’ algorithm.

Figure 1.5 Land use/land cover Map of Dist. North 24 Parganas

5. Preparation of block wise socio-economic data layer of the district: Population density layer:

Population density of any area is one parameter which has an overwhelming impact on the socio-economic status of that area. We may recall the hypothesis that “socio-economic attributes have a
profound impact toward worsening of arsenic contamination”, so to evaluate arsenic contamination status and its health effect, we must have to be concerned with the most important socio-economic parameter i.e. ‘Population Density’. So one data layer has been made about population density of the district in block wise form. Previously we prepared digitized block map of the district. This was following by joining of the attribute table related to population distribution. Attribute table was prepared from data of Census – 2001. Various fields in attribute database were- block name, total population, Area in sq. km, population density in sq. km.

6. Finding correlation between different land use/land cover and other physical parameters with arsenic concentration value of the study area using Buffering Technique:

Buffering creates buffer zones by covering a fixed radial distance from the selected point features. Buffering creates two areas: one area that is within a specified distance of selected features and the other area that is beyond (Chang, 2002; Elangovan, 2006; Burrough, 1986). Thus buffering around points create circular buffer zones.

Figure 1.6 Ring Buffer around selected Tube Wells in Block Gaighata.

Figure 1.7 Land use/land cover within subsetted buffered zone around a selected hydraulic station (Krishnapara) in Hasnabad Block.
In this research study buffering has been done several times for doing GIS based analysis using tools of ESRI’s Arc GIS software package. For buffering we selected 40 Hydraulic Station randomly out of total 80 throughout the study area. Then we classified those HS in four categories according to their arsenic concentration value.

Worst Affected - (0.20-0.70)μg/L, Highly Affected - (0.05-0.2)μg/L, Low Affected - (0.02-0.05) μg/L and Very Low or Arsenic Free- (below 0.02) μg/L.

Next we selected 10 tube wells from each category and a ring buffer had been prepared around each tube well with radial distance of 1km from the centre of the ring (Fig. 1.5). We assumed that this 1km radius buffered area is the influence area of that tube well or hydraulic station.

Now we evaluated the dominating land use class (with their areal extent), geomorphologic and geohydrologic units and population density around the buffered zone of four types (Worst, high, low affected and Very low or Arsenic free) hydraulic station. To do this, we overlaid these buffered layers on previously prepared land use/land cover layer, geomorphologic layer, geohydrological layer and population density layer for making a comparative study between different four arsenic concentration classes.

After doing buffer of 1km around at least 10 selected Hydraulic Station of each category (worstly affected to arsenic free), we overlaid that buffered zone on land use/ land cover map of that study area and subsetted the buffered area using ERDAS Imagines subsetting tool.

Then again from ERDAS IMAGINES “Raster Attribute Editor” icon the area of each land use/land cover class within buffer zone has been extracted (Fig.1.6).

The areal extent of each land use/land cover category within buffered zone of each hydraulic station of different arsenic concentration class has been depicted from Table-1.1 to Table- 1.4).

**Table-1.1:** showing areal extent of Different Land use/Land cover class and population density around buffered zone of Worstly Arsenic affected (0.20-0.70) μg/L hydraulic stations

<table>
<thead>
<tr>
<th>Name of Block</th>
<th>Name of H.S.</th>
<th>Land Use/ Land Cover Class (Areal Extent in Acres)</th>
<th>Population Density</th>
</tr>
</thead>
<tbody>
<tr>
<td>Bongon</td>
<td>i) i) i) i)</td>
<td>Surface Water Arable Land Settlement Fallow Land Forest Cover Vegetation Marshy Fallow Water Logged Area</td>
<td>1022/sq.k m</td>
</tr>
<tr>
<td></td>
<td>ii) ii) ii) ii)</td>
<td>0 312.549 301.307 38.823 38.300 53.856 24.444 23.790</td>
<td></td>
</tr>
<tr>
<td></td>
<td>iii) iii) iii)</td>
<td>0 265.36 275.425 32.810 61.830 128.62 25.882 1.830</td>
<td></td>
</tr>
<tr>
<td></td>
<td>iv) iv) iv)</td>
<td>0 163.922 358.693 0 29.673 239.739 0.784 0</td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td>0 238.824 335.164 6.013 45.751 153.333 9.803 4.183</td>
<td></td>
</tr>
<tr>
<td>Gaigata</td>
<td>v) vi) vii) viii) ix)</td>
<td>0 248.889 227.059 28.627 9.2810 279.216 0 0.1307 1235/sq.k m</td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td>0 119.346 420.654 11.241 87.712 86.274 56.209 10.849</td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td>0 155.948 309.673 5.620 103.791 209.02 4.444 4.836</td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td>0 73.5948 318.562 1.437 106.797 209.28 57.124 24.575</td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td>0 181.177 346.405 1.699 11.634 248.758 0.1307 3.267</td>
<td></td>
</tr>
<tr>
<td>Baduria</td>
<td>x)</td>
<td>0 441.046 315.425 15.032 1.830 14.902 3.790 1.307 1378/sq.k m</td>
<td></td>
</tr>
<tr>
<td>Mean Value</td>
<td>0</td>
<td>220.365 320.836 14.130 49.659 18.261 1164/sq.k m</td>
<td></td>
</tr>
</tbody>
</table>

Next we selected 10 tube wells from each category and a ring buffer had been prepared around each tube well with radial distance of 1km from the centre of the ring (Fig. 1.5). We assumed that this 1km radius buffered area is the influence area of that tube well or hydraulic station.

**Table-1.2:** showing areal extent of Different Land use/Land cover class and population density around buffered zone of highly Arsenic affected (0.05-0.20) μg/L hydraulics stations

<table>
<thead>
<tr>
<th>Name Of Block</th>
<th>Name of H.S</th>
<th>Surface Water (Acre)</th>
<th>Arable Land (Acre)</th>
<th>Settlement (Acre)</th>
<th>Fallow Land (Acre)</th>
<th>Forest Cover (Acre)</th>
<th>Waterlogged Area (Acre)</th>
<th>Waterlogged Area Populaion Density (sq.km)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Deganga</td>
<td>i)</td>
<td>0</td>
<td>312.941</td>
<td>303.399</td>
<td>15.686</td>
<td>10.588</td>
<td>6.274</td>
<td>139.216</td>
</tr>
<tr>
<td></td>
<td>ii)</td>
<td>0</td>
<td>292.06</td>
<td>338.17</td>
<td>19.869</td>
<td>9.150</td>
<td>21.960</td>
<td>87.320</td>
</tr>
<tr>
<td></td>
<td>iii)</td>
<td>0</td>
<td>61.699</td>
<td>521.7</td>
<td>1.960</td>
<td>25.359</td>
<td>162.092</td>
<td>13.464</td>
</tr>
<tr>
<td>Habra-I</td>
<td>iv)</td>
<td>0</td>
<td>265.621</td>
<td>259.216</td>
<td>32.0262</td>
<td>56.9935</td>
<td>44.9673</td>
<td>109.15</td>
</tr>
<tr>
<td></td>
<td>v)</td>
<td>0</td>
<td>299.477</td>
<td>367.32</td>
<td>55.817</td>
<td>7.712</td>
<td>55.4249</td>
<td>2.875</td>
</tr>
<tr>
<td>Baduria</td>
<td>vi)</td>
<td>0</td>
<td>1.9607</td>
<td>52.4183</td>
<td>22.091</td>
<td>0.6535</td>
<td>13.5948</td>
<td>516.079</td>
</tr>
<tr>
<td>Haroa</td>
<td>vii)</td>
<td>0</td>
<td>3.1372</td>
<td>276.732</td>
<td>136.34</td>
<td>35.817</td>
<td>0.5228</td>
<td>7.8431</td>
</tr>
<tr>
<td>Hasnabad</td>
<td>viii)</td>
<td>0</td>
<td>48.2353</td>
<td>92.9412</td>
<td>0</td>
<td>0.2614</td>
<td>36.4706</td>
<td>243.137</td>
</tr>
<tr>
<td>Minakhan</td>
<td>ix)</td>
<td>0</td>
<td>277.647</td>
<td>326.536</td>
<td>32.1563</td>
<td>12.4183</td>
<td>137.255</td>
<td>3.529</td>
</tr>
<tr>
<td>Mean Value</td>
<td></td>
<td>.566</td>
<td>209.644</td>
<td>263.07</td>
<td>21.481</td>
<td>13.73</td>
<td>157.95</td>
<td>1305/sq.km</td>
</tr>
</tbody>
</table>


**Table-1.3:** showing areal extent of Different Land use/Land cover class and population density around buffered zone of low Arsenic affected (0.02-0.05) μg/L hydraulics stations

<table>
<thead>
<tr>
<th>Name Of Block</th>
<th>Name of H.S</th>
<th>Surface Water (Acre)</th>
<th>Arable Land (Acre)</th>
<th>Settlement (Acre)</th>
<th>Fallow Land (Acre)</th>
<th>Forest Cover (Acre)</th>
<th>Waterlogged Area (Acre)</th>
<th>Waterlogged Area Populaion Density (sq.km)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Bagda</td>
<td>i)</td>
<td>0</td>
<td>419.216</td>
<td>304.445</td>
<td>10.0654</td>
<td>3.5294</td>
<td>37.3856</td>
<td>0.5228</td>
</tr>
<tr>
<td>Rajarhat</td>
<td>ii)</td>
<td>0</td>
<td>412.81</td>
<td>354.641</td>
<td>8.888</td>
<td>0.5228</td>
<td>13.594</td>
<td>1.307</td>
</tr>
<tr>
<td>BarasatI</td>
<td>iii)</td>
<td>0</td>
<td>304.967</td>
<td>424.052</td>
<td>3.006</td>
<td>0</td>
<td>60.784</td>
<td>0</td>
</tr>
<tr>
<td>Haroa</td>
<td>iv)</td>
<td>0</td>
<td>338.17</td>
<td>406.144</td>
<td>33.856</td>
<td>0.2614</td>
<td>3.660</td>
<td>8.6274</td>
</tr>
<tr>
<td>Hasnabad</td>
<td>v)</td>
<td>0</td>
<td>274.118</td>
<td>466.405</td>
<td>7.843</td>
<td>0.1307</td>
<td>44.444</td>
<td>0</td>
</tr>
<tr>
<td>Minakhan</td>
<td>vi)</td>
<td>0</td>
<td>41.307</td>
<td>21.8301</td>
<td>1.045</td>
<td>0</td>
<td>10.849</td>
<td>475.686</td>
</tr>
<tr>
<td>Swarupnagar</td>
<td>vii)</td>
<td>0</td>
<td>136.209</td>
<td>595.033</td>
<td>0.1307</td>
<td>0</td>
<td>63.137</td>
<td>0</td>
</tr>
<tr>
<td>Sandesh-I</td>
<td>viii)</td>
<td>0</td>
<td>24.183</td>
<td>538.17</td>
<td>121.307</td>
<td>0</td>
<td>261.4</td>
<td>4.705</td>
</tr>
<tr>
<td>Sandesh-II</td>
<td>ix)</td>
<td>0</td>
<td>65.620</td>
<td>373.726</td>
<td>99.4772</td>
<td>63.529</td>
<td>1.0457</td>
<td>12.1569</td>
</tr>
<tr>
<td>Mean Value</td>
<td></td>
<td>9.978</td>
<td>315.41</td>
<td>310.37</td>
<td>25.635</td>
<td>0.609</td>
<td>69.556</td>
<td>1237/sq.km</td>
</tr>
</tbody>
</table>


Table-1.4 showing areal extent of Different Land use/Land cover class and population density around buffered zone of very low Arsenic affected or arsenic free (below 0.02) μg/L hydraulic stations

<table>
<thead>
<tr>
<th>Name Of Block</th>
<th>Name of H.S.</th>
<th>Land Use/ Land Cover Class (Areal Extent in Acres)</th>
<th>Popu lation Density</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td>Surface Water</td>
<td>Arable Land</td>
</tr>
<tr>
<td>HabraII</td>
<td>i)</td>
<td>0</td>
<td>262.353</td>
</tr>
<tr>
<td>BasirhatI</td>
<td>ii)</td>
<td>0.5228</td>
<td>144.967</td>
</tr>
<tr>
<td>BasirhatII</td>
<td>iii)</td>
<td>0.39215</td>
<td>18.1699</td>
</tr>
<tr>
<td>BarrackI</td>
<td>iv)</td>
<td>0.26143</td>
<td>229.412</td>
</tr>
<tr>
<td>BarrackII</td>
<td>v)</td>
<td>0</td>
<td>257.647</td>
</tr>
<tr>
<td>SandeshI</td>
<td>vi)</td>
<td>69.542</td>
<td>10.719</td>
</tr>
<tr>
<td>SandeshII</td>
<td>vii)</td>
<td>6.7973</td>
<td>539.739</td>
</tr>
<tr>
<td>Hingalganj</td>
<td>x)</td>
<td>19.477</td>
<td>524.314</td>
</tr>
<tr>
<td>Mean</td>
<td></td>
<td>35.346</td>
<td>241.764</td>
</tr>
</tbody>
</table>

After that we calculated mean areal extent of each land use/land cover class of each arsenic concentration category around 10 Hydraulic Station (worstly affected to arsenic free). Table-1.5 illustrated that statistical figure and also other dominant physical parameter for each arsenic concentration category:

The following table also indicates the correlation between ground water arsenic and other environmental parameters (Like: predominant land use/land cover class, regional geomorphological and geohydrological unit and population density) within a particular buffered zone around hydraulic stations of different arsenic concentration class.

The below table (table - 1.5) was statistically analyzed in graphical format using graphical software (Origine 7.0), which statistically shows the relation of different land use/land cover with their arsenic concentration counterpart, which resulted in the following diagram (Figure- 1.8):

7. Discussion

Upon investigation of land use/land cover study for this research area it has been seen that ground water arsenic contamination of any area depends directly or indirectly on dominant Land Use / Land Cover feature of that area. In this research the study area has been classified in six LU/LC class: Surface Water (i.e., Water Body), Arable Land, Settlement, Fallow Land, Forest (here Tree vegetation) Cover and Marshy Fallow Land. For a definite areal extent (for this study ‘circle of one km radius’), the composition of average areal extent of each LU/LC class is quite varied in all arsenic concentration class (Table 1.5).

From above table (Table 1.5) and also above mentioned graph it has been seen that presence of average areal extent of ‘Surface Water’ is very very low or nil compared to ‘Arable Land’ (220.365 acres/sq.km) and ‘Settlement’ (320.836 acres/sq.km) around buffered zone of ‘ Severely (Worstly) Affected Hydraulic Stations’ (fig.1.9). The blocks falls under this category are: Bongaon, Gaighata, and Baduria. Because of lack of surface water people have to depend mostly on ground water both for their irrigation and other utility purposes. So the pressure on ground water is very high here. Besides, owing to the presence of abundant ground water in shallow depth (average depth of tube well is 50-60 mts), shallow pumps are extensively used for extracting ground water. Water from shallow tube well is mostly affected by arsenic. Furthermore, high population Density (1235/ sq.km) of this area causes unsustainable land utilization and also this high population is responsible for over extraction of ground water which is another cause for increasing population is responsible for over extraction of ground water both for their irrigation and other utility purposes. So the pressure on ground water is very high here. Besides, owing to the presence of abundant ground water in shallow depth (average depth of tube well is 50-60 mts), shallow pumps are extensively used for extracting ground water. Water from shallow tube well is mostly affected by arsenic. Furthermore, high population Density (1235/ sq.km) of this area causes unsustainable land utilization and also this high population is responsible for over extraction of ground water which is another cause for increasing
The figure below (Fig. 1.9) depicted the abrupt areal dissimilarity between different land use/land cover pattern around a hydraulic station of severely affected block. On the other hand in case of ‘Arsenic Free Hydraulic Station’, presence of average areal extent of surface water is 35.346 acres/sq.km compared to ‘Arable Land’ (241.764 acres/sq.km.) and ‘Settlement’ (219.673 acres/sq.km.) within the buffered zone (Table 1.5). The sources of “Surface Water” in this area are mostly smaller river channels like Raimangal, Kalindi, Haribhanga, vidyadhari etc. People use this river water through canal system for their irrigation and other utilization purposes. This water is mostly arsenic free. Blocks fall under this arsenic class are: Sandeshkhali-I, SandeshKhali-II, Hingalganj etc. From geohydrological map it has been seen that, in this area fresh water is overlain by saline ground water. So shallow tube wells yield brackish water.

People do not construct shallow tube well in these areas. Average depth of tube well is 110 mts. (bgl) here. Ground water from this depth is normally arsenic free. Population density in these zone is also lower (655 per sq km), compared to highly affected zone, which maintain sustainability of land utilization. The figure below (Fig. 2.0) depicted the areal extent of different land use/land cover pattern around an arsenic free hydraulic station.

Noticeably areal extent of ‘fallow land’ and ‘marshy fallow’ also increases with the transition of ‘very highly affected’ arsenic class to ‘arsenic free’ class.

#### Table 1.5: showing average areal extent of Different Land use/Land cover class, dominant geomorphic and geohydrologic units and population density around buffered zone of hydraulic stations in four types of arsenic concentration class

<table>
<thead>
<tr>
<th>Arsenic Concentration Class</th>
<th>Land Use / Land Cover Class (average areal extent in acres)</th>
<th>Dominant Geomorphic Unit</th>
<th>Dominant Geo-hydrologic Unit</th>
<th>Population Density per sq km</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Surface Water</td>
<td>Arable Land</td>
<td>Settlement</td>
<td>Fallow Land</td>
</tr>
<tr>
<td>i) Worstly or severely Affected Hydraulic Station (0.20-0.70)μg/L</td>
<td>0.566</td>
<td>209.644</td>
<td>263.0</td>
<td>21.48</td>
</tr>
<tr>
<td>ii) Highly Affected Hydraulic Station (0.05-0.2)μg/L</td>
<td>9.978</td>
<td>315.410</td>
<td>310.3</td>
<td>25.63</td>
</tr>
<tr>
<td>iii) Low Affected Hydraulic Station (0.02-0.05)μg/L</td>
<td>35.346</td>
<td>241.764</td>
<td>219.6</td>
<td>58.18</td>
</tr>
<tr>
<td>iii) Very Low or arsenic free Hydraulic Station (below 0.02 μg/L)</td>
<td>35.346</td>
<td>241.764</td>
<td>219.6</td>
<td>58.18</td>
</tr>
</tbody>
</table>
Above information also indicate that, geomorphology in the severely as well as highly arsenic affected zone falls under mostly 'Upper matured deltaic plain', which formed under varying hydrodynamic condition in a typical fluvial regime (Strahler and Strahler, 1989). The ground water in the upper delta plain, primarily in the area of abandoned meander belts, is mostly affected by arsenic enrichment (SOES, JU, 1996). But in order to establish a relationship between ground water arsenic concentration and corresponding geomorphology or geohydrology further extensive research is needed.

Figure 1.8 Relation of different land use/land cover with their arsenic concentration.
Figure 1.9 shows land use/land cover scenario within one sq.km buffered area around a worstly or severely affected (ground water arsenic concentration 0.20μg/L) hydraulic station (Gaighata Block), where presence of Water body i.e. Surface Water is zero.

Figure 2.0 shows the land use/land cover scenario within one sq.km buffered area around an arsenic free (arsenic concentration 0.00μg/L) hydraulic station (Sandeshkhali-I Block), where presence of Water body i.e. Surface Water is 69.5425 acres per sq.km.
Conclusion:

To study the impact of other physical parameter (like Land use/land cover, geomorphology, geohydrology), with ground water arsenic concentration of the study area, overlay and Buffering techniques have been used several times. This constitutes the GIS based analysis aimed at deciphering the underlying causes of arsenic (As) incidence in ground waters. It has been seen that average ground water arsenic concentration depends on the dominating land use/ land cover pattern of any area. Besides other geogenic factors, unsustainable use of ‘Land Use/ Land Cover’ pattern emanating from ever-increasing population density is an important factor of escalating arsenic concentration in ground water. This research study concludes that, over extraction of ground water perhaps remains the main cause of this increasing trend of ground water arsenic. Use of ‘surface water’ is important to combat against such menace. So we should protect our surface waters. The decision makers of several govt. or non-govt organizations should keep this factor in mind. There is a court verdict in West Bengal that the ponds and tanks cannot be filled for development purpose. So the research findings too point to the importance of surface water in precluding arsenicosis. This research paper also suggests importance of ‘Fallow Land’, as areal extent of this particular land cover type is very small in highly affected zone compared to other less affected or arsenic free zone, indicating the possible over-utilisation of lands for agricultural activities to cater to high population density. Ultimately, people’s awareness about arsenic calamity, its health effects and cause of its increasing trend in ground water is very necessary to combat against such ‘Environmental Chemical Disaster’.

References:


19. SOES & DCH, “*Summary of 239 Days Field Survey from August 1995 to February 2000*”, Groundwater Arsenic Contamination in Bangladesh, A survey report conducted by the School of Environmental Studies, Jadavpur University, Calcutta, India and Dhaka Community Hospital, Dhaka, Bangladesh, 2000.