Arsenic mapping for North 24- Pargana District of West Bengal – using GIS and Remote Sensing technology

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INTRODUCTION:

Groundwater is one of the most important sources of drinking water and is not presence in abundance in nature. The contamination of groundwater with Arsenic is one of the serious problems encountered in developing countries. Thus there is a rising need to map the level of arsenic concentration, trend of arsenic flow and the temporal changes that occur in concentration level. The present study was an effort to map arsenic concentration in a district level that might lead to a broader understanding of it's regional presence and significance.

India and Bangladesh has been reported to suffer a lot from Arsenci contamination problems. West Bengal is one of the affected states in India. According to a UNICEF study, access to safe drinking water in Bangladesh has declined by 17% in the last three years due to arsenic contamination. The most commonly observed symptoms of chronic arsenic poisoning are conjunctivitis, melanosis and hyperkeratosis. In severe cases, gangrene in the limbs and malignant neoplasm have also been observed.

The geochemistry of arsenic had been recently been reviewed by Thornton (1996). The main constituent of around 200 mineral species is arsenic. Out of these 60% are arsenates, 20% sulphides and sulphosalts and the remaining 20% includes arsenides, oxides, silicates. From the observations in the Cordoba it was concluded (Astolfi *et al.*, 1981) that the regular intake of drinking water containing more than 0.1 mg l^{1} of arsenic leads to clearly recognizable signs of arsenic toxicity and ultimately in some cases to skin cancer.

The solution to such a problem lies in understanding the intricate relation between the various socio-economic factors associated with it. It has been found that Arsenic consumed may be quickly excreted from the body through methylation (often termed as detoxification) in the body through mostly urine. But this methylation reaction needs methyl donors coming from a balanced nutritional methionine-rich food sources like green vegetation and meat. Thus economic conditon, the demographic status is also a key to such solution. The geology of the area, the land use and the irrigation and drainage pattern attributes to finding a plausible solution for such problem.

Geographical Information System acts as an excellent tool to unify data from various source and integrate them into a single environment to analyse the relationship amongst them. The satellite images helps in identifying the various land use pattern and may provide a clue to identification of patterns and source with respect to it's geological setup. Thus Geomatics can act as a decision support tool to analyse the various data source for mapping the risk zone map of the area.

The present project was mooted by PHED and a pilot project was undertaken using PCI Technology (through industry participation of Lord's Infotech) using the various groundwater data available in the department for mapping the arsenic concentration in the district. The other available data on Chlorine, Iron contents and depth of occurrence were also used for preparing a hazard zone map of the area and site suitability map for safe drinking water zones of the area. The latest satellite images were used to detect the various land use and land cover of the district to verify the changing pattern of surface water presence of the area. An attempt has been made to model the affected zone map using various GIS technology.

• REGIONAL SETTING :

The district of North 24 Parganas of West Bengal is in the southern part of the Bengal Basin. The geographical extent of the district lies between 88d19m E, 23d20m N to 89d10m E,22d01m N. The basin is actually a peri-cratonic basin and comprises of Ganga-Brahmaputra delta in the southern part. It had broken from the Gondowanaland along the margin of the Indian plate and then moved towards northerly in the early Cretaceous (125Myr ago). The collision of the Indian and European plate began in the early Eocene (40 –41 Myr ago) and resulted in the Himalayas. Due to this the two sediments from Ganga and Brahmaputra got subsequently merged. Relatively recent folding and uplift (Quaternary epoch) of the Brahmaputra sediments close to the intraplate boundary redirected the course of the Brahmaputra to its present configuration (Morgan *et al.*, 1959; Lindsay *et al.*, 1991).

There is a thickening of the Ganga-Brahmaputra delta towards the south and has three stratigraphic sequence – the proto-Ganges delta, the transitional delta and the modern delta (11 Myr ago) with a successive sequence of sands, sandy mud, silt and mud which were deposited under a major eustatic sea level low at about 11 Myr ago. The modern delta has been formed primarily of alluvial sediments transported by the rivers, *e.g.* the Mayurakshi, the Ajoy, the Damodar *etc.* originating from the Chotanagpur Uplands in the west and subsequently by the rivers flowing from the Himalayan foredeep basin *e.g.* the Ganges, the Padma, the Bhagirathi, the Brahmaputra *etc.* flowing from the north when a gap, the Garo-Rajmahal gap, was created due to

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tectonic movements (Auden, 1949). Arsenic contaminated groundwater occurs in the modern deltaic sediments.

From the IRS LISS satellite images certain geomorphological features are distinctively present. The delta can be divided into two regions: (1) the upper delta plain of meander belts of the Padma- Bhagirathi rivers in the north; and (2) the lower delta plain with several tidal creeks in the south. The upper delta plain is characterised by a series of meander scars of various wavelengths and amplitudes, abandoned channels, oxbow lakes, formed under varying hydrodynamic conditions in a fluvial regime. Abandoned meander scrolls are the most common form and could be related to flood-plain formation in the upper delta plain with a very gentle southerly slope.

Earlier report on the hydrogeology of the area suggests that there are shallow aquifer (12 - 15 m below ground level, bgl) in the upper delta plain and is mostly under unconfined conditions except near its southern fringe where it occurs under semi-confined to confined conditions. There are two more aquifers with depths ranging from 35 to 46 m and 70 to 150 m in the districts North 24-Parganas. There is generally a southeasterly gradient of the water surface sub-parallel to the general slope of the area. All the aquifers are interconnected due to spatial variations in grain size.

The intermediate aquifer, constituted of sub-angular to sub-rounded medium sand, sandy clay and clay with fine sands, and its heavy mineral assemblage (biotite, garnet, kyanite, opaques) indicates a dominantly metamorphic origin.

While the lower aquifer is constituted of sub-rounded to rounded fine to coarse sand with occasional clay bodies, and its heavy mineral assemblage (opaques, altered biotite tourmaline, rutile *etc.*) indicates an igneous provenance (Steering Committee Arsenic Investigation Project, PHE Dept, Government of West Bengal, 1991). The intermediate aquifer usually shows arsenic contamination.

• DATA USED :

For the current project the following data sets and maps were used.

- The District Statistical Hand Book , 24 Parganas North published by the Bureau of Applied Economics and Statistics, Government of West Bengal.
- The Survey of India Topographical Sheets
- The Natmo Map

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- The database in Foxpro
- The LISS image
- The Pan image.

The application software on Geographical Information System used was SPANS. The Image Processing application software used was Geomatica Prime. Both these products are from PCI Geomatics, Canada.

♦ METHODOLOGY :

The processing steps involved and followed in this project are given below.

- a) The NATMO District planning Map Series (1:2,50,000) of North 24 Parganas was scanned at a resolution of 400 dpi in the Tagged information File format and was then geo-registered with the Survey of India Toposheets (1: 50,000). The georeferencing information was collected from the 8 SOI Topographical sheets as mentioned earlier. The process of geocoding required ground control points which was collected uniformly over the whole district and them mathematically warped to fit into the real world co-ordinates using Longitude/Latitude projection and Referenced Ellipsoid with Indian Datum.
- b) The IRS LISS 1C and Panchromatic data was used for the project. The following images with Path/Row 108/55, 108/56, 108/57 and 109 / 55 covers the whole district. The individual scenes were geocoded with control points thereby enabling each scene to return the co-ordinates at each position. The LISS and Pan image is having a spatial resolution of 23.5 meters and 5.8 meters respectively.
- c) All the scenes were mosaic using PCI Solutions. Thus a whole area covering the whole district was obtained. The NATMO map and the image was overlaid and the district boundary was digitized. The boundary of the district was used to mask the satellite image and the image falling within the boundary was restored. The block boundaries were also digitized and overlaid on the image as shown in figure 1.



Figure 1 North 24 Parganas with block boundaries.

- d) The LISS Image and Panchromatic image was fused using HIS Transformation and the resultant image has the spectral resolution of the LISS Image and the spatial resolution of the PAN Image. Hence we get a colored image with the resolution as that of the pan image.
- e) Thus scanned maps have different scale with respect to SOI maps. A project was created in the SPANS GIS environment. From the geocoded scanned NATMO map, the block boundaries and other layers of information were digitized in the SPANS environment. The different blocks and their names were taken into the database of SPANS. The various fields in the database are Block names, Mouzas as point values, the Arsenic recorded in the wells in the block, the PH values, the iron contents and the Chlorine contents at few observed wells are recorde in the database. All the layers of information are recorded as either point or line or polygons in the graphical mode.
- f) From the arsenic values as provided from the field data, contour was generated over the whole district using point-to-surface generation programs in SPANS as shown in figure 2.

Map India Conference 2003 © GISdevelopment.net, All rights reserved. The thematic map indicates the area of high arsenic concentration and low arsenic concentration as observed from the water tested in the laboratory and plotted on the map as points corresponding to each block. The arsenic concentration map is shown below





- g) The depth of Arsenic occurrence as obtained from the field data posted as point information on the map is mapped sing the depth values at which arsenic is reported to have a value above the danger level of .5 mg/lt. This depth of occurrence map is saved as a quad tree for further analysis.
- h) A site suitability map for safe drinking water was prepared using the modeling tool in SPANS. The modeling used for the purpose is Matrix Overlay. The two parameters used for the purpose of matrix overlay are Arsenic concentration thematic map and the depth contour thematic map of water presence or indirectly the water table map. The low safe zone of arsenic concentration and low water level depth was chosen to be the ideal site for safe drinking water zone. Raster GIS of modeling was used in this regard. The result of matrix modeling is shown in figure 3.



Figure 3 Suitability Zone using Matrix Modeling

- i) Multi-criterion modeling was performed to prepare a zonation index map showing "Danger" to "Safe" zones. This modeling was used in this area having the type of regional settings as of North 24 Parganas. These modeling can be applied to any area of such settings. The three parameters used for this analysis are Arsenic concentration map, Depth map and Population distribution map of the area. Different weightages and scores were applied on these parameters to find an area of highest danger and safe areas. These results confirm with the earlier studies on the same area.
- j) Image was classified using Supervised Classification scheme and the land cover and land use was classified using Maximum Likelihood Classifier and obtained 6 different classes of the district. The result of multi-criterion is overlaid on the classified image, which is shown in figure 4.



Figure 4 Multi-criterion analysis on classified image

♦ ANALYSIS :

From the various process as described above, the following analysis have been derived.

- a) The contour map of arsenic concentration of each block was derived using weighted average of the arsenic concentration value. A thematic map was generated to form a classified output with five ranges. The classified output was converted into layer to get an idea of the total area affected.
- b) The matrix modeling was performed using arsenic concentration values and the depth of occurrence of arsenic values. In the present scenario high arsenic value at a shallow depth was considered to be unsuitable for drinking water and low value at shallow depth was considered to be safe for drinking water. With the help of matrix overlay, the two thematic maps were algebraically mapped to bring out five classified areas in an index scale of five, higher index means unsuitable and lower means safe.

Arsenic b	oreak value	es	0.01	0.05	1.5	2.00	2.85
		0	1	2	3	4	5
Depth	0	0	0	0	0	0	0
112.31	1	0	0	5	5	5	5
261.29	2	0	4	4	4	4	5
410.27	3	0	3	3	3	4	4
559.25	4	1	2	3	3	4	4
708.23	5	0	1	1	1	1	2

c) Multi-criterion modeling was performed using three impacts to find out an area which can be consider to a highly sensitive zone or danger zone. The presence of arsenic alone over the district is not important; the other related issues like population density and the depth at which it is occurring are also very important considerations to bring out the most danger prone zone. Here also the raster GIS concept of map algebra was used to corelate the individual weight ages of arsenic concentration, population density and depth. Arsenic was given the highest weightage and it's further subdivisions were again scaled and given scores. The second important factor considered was population of that area and the third parameter was the depth at which it was present. In a scale of 100, arsenic concentration was given a weightage of 50, the population density of that district was given a weightage of 30 and depth at which it occurs was given 20. In this way the further subdivisions was given due scores, so effectively the quantitative values was given a qualitative preference to bring out from the whole areas those blocks which can be considered as danger zones or safe zones. An index map was generated and a legend developed to show those regions of danger and arsenic free zones. The multi-criteria map was generated using the following table

Arsenic Concentration Weightage

50

Values Scores

0.01	1
0.05	2
1.5	3
2.0	4
2.86	5

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Population Density		Wightage	30
Values Scores			
30	1		
40	2		
50	3		
60	4		
70	5		
Depth of water	level	Weightage	20
Depth of water	level	Weightage	20
Depth of water Values Scores	level	Weightage	20
Depth of water Values Scores 112.31	level 5	Weightage	20
Depth of water Values Scores 112.31 261.29	level 5 4	Weightage	20
Depth of water Values Scores 112.31 261.29 410.27	level 5 4 3	Weightage	20
Depth of water Values Scores 112.31 261.29 410.27 559.25	level 5 4 3 2	Weightage	20

An output was generated with an index of 5 being the safe zone and index 1 as the danger zone.

- d) The wells where Iron and Ph values were measured are also saved into layer. It is generally observed that wells with high Iron values are having low Arsenic values. Though this predictive conclusion does not bear any correlation in terms of regression formula, it will require more data sets to reach at any conclusion whatsoever.
- e) From the multi-criterion map that has been generated by using Multi-criterion modeling using three parameters, the different zones were obtained as raster classes. Using GIS technology, these layers were converted into vector layers and we obtain the area that is affected by each class. Hence we get the percentage of area that falls into danger zone of safe zone or intermediate zones.

• RESULTS and DISCUSSION:

From the work that has been concluded for the particular district, the following results and discussions can be concluded.

1. The geocoded satellite images of the area is perfectly overlaid on the base map, and it is observed that each natural feature exactly coincides with the

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image even at a scale of 1: 10000, this indicates that when the block boundaries are overlaid, we get the exact amount of actual earth surface within that block. Any observation on the land use and land cover within a block is very clearly observed, hence the changes that might occur in the coming few years in terms of surface water or urbanization can or natural features can clearly be measured for changes in actual earth coordinates over a period of time.

- 2. The image has been classified using supervised classification technique with Maximum Likelihood classifier algorithm. The whole area has been classed into Water bodies, Forest areas, Urban areas, Wetland, Rural Areas, Arable Land and Fallow Land. The total area covered under surface water is 0.86% of the total land and covers around 129 sq kms. The Urban area constitutes around 6.3% whereas rural area is around 1.5% of the district, thus around 950 sq.kms is Urban area and 224sq kms of rural areas. The detail classification report was given earlier. Hence we see that this district has a sizable amount of urban and rural population.
- 3. From the zonation map that has been created from the multi-criterion modeling has 6 classes namely Safe Zone, Below Affected level, Moderately affected, highly affected and Danger Zone. The area covered under "Danger Zone" is around 7 square kilometers and Highly affected zone is around 27 square kilometers. On overlaying the block map over the zones it has been found that the eastern region of Barasat I block falls under danger zone and western region of Deganga block, North Western region of Barrakpur II, middle region of Barasat I, southern region of Habra –II and North Eastern region of Amdanga falls under highly affected zone.
- 4. From the classified satellite images it is being observed on overlaying the zonation map that the "danger Zone" falls mainly on the arable land and certain regions of urban land in the east Barasat I block and portions of fallow land and wetlands.on ... and the moderately affected zone falls on the arable land and certain regions on the urban and fallow land.
- 5. The map obtained from Matrix over lay shows the various zones safe for drinking water. The result of Matrix Modeling shows that the area safe for drinking water. This area falls in the blocks Sandeshkhali-I, some region of Hingalganj, major area in the block Minakhan. It is also found that the safe zones fall mainly on the rural areas and fallow lands.
- **6.** Thus it can be concluded from the above that the danger prone zone is urban areas and arable land where shallow pumps are extensively used for

Map India Conference 2003 © GISdevelopment.net, All rights reserved. extracting groundwater thereby raising the water table. The reason for such an increased effect of arsenic is now open to diverse research for finding out a plausible cause for such an effect in such areas.

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