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SUSTAINABLE ENVIRONMENTAL SANITATION AND WATER SERVICES

Presentation of arsenic data using GIS techniques

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THE OCCURRENCE OF arsenic in ground water and its associated health implications is one of the greatest current challenges in supply of safe drinking water. Lack of information and knowledge about arsenic poisoning is often mentioned as one of the main challenges in arsenic mitigation (Hoque, et. al., 2000).

DPHE-Danida Arsenic Mitigation Pilot Project (AMPP), a bilateral project between the Department of Public Health Engineering (DPHE) and Danish International Development Assistance (Danida) had been working on arsenic mitigation in two pourashava (municipality) areas in the coastal region of Bangladesh from March 1999 to March 2001.

The main objectives of the project were to conduct action oriented research and implementation, from which useful experiences and knowledge were gained about arsenic concentration level of hand Tube Wells (TW) installed in shallow depth (<200 meter) and TW users' knowledge and awareness about arsenic contamination in TW water over the project area. One of the major activities of the project was to create an integrated database system using Geographical Information Systems (GIS) tool to develop a strong information base for decision-making.

A GIS should include software for the display of maps, graphs and tabular information, which depict the spatial or aerial distribution of various objects and/or phenomena (Smith, et. al., 1987). This was the reason to choose Arc/Info and ArcView GIS software including spatial analyst module to manage the storage, analysis, interpolation and visualization of spatial and nonspatial data.

This paper presents the use of GIS for integrated analysis of spatial and nonspatial data to present the magnitude and distribution of arsenic concentration and TW users' socioeconomic information in most attractive way, which is very helpful to identify and visualize the arsenic affected areas and proper planning to implement area based arsenic mitigation options.

Materials and methods

Study area and target group

The study areas were Chaumuhani pourashava (26.3 sq. km.) of Noakhali and Lakshmipur pourashava (20.7 sq. km.) of Lakshmipur district in the coastal region of Bangladesh. Majority of the shallow hand tube wells of these areas are contaminated with arsenic above Bangladesh standard (BGD Std. Asd"0.05 mg/l) acceptable limit of 0.05 mg/l (DPHE & BGS, 1999).

The primary target group was approximately 4,500 families who depend on 834 shallow tube wells for drinking water provided to the poorer sections of the population during a previous Danida financed water supply and sanitation project from 1991 to 1997.

Data collection

A diagnostic survey was carried out to gather benchmark data about tube well users' knowledge and awareness about arsenic poisoning and socioeconomic conditions. The principal aim of this survey was to find the enormity of the arsenic disaster and people's perception to combat the issues.

Data used for this study were collected by the project employed field staff. During the data collection period each hand tube well was identified and coded (numbered) with a unique number. Relevant attribute data (i.e. TW depth, age of installation, operational status, users information) of 808 TWs (Chaumuhani 423 and Lakshmipur 385) were collected using structured questionnaires.

Water samples were collected from 715 TW of which 366 from Chaumuhani and 349 from Lakshmipur pourashava. Rest of the tube wells was found nonfunctioning during the surveying period. The collected samples were analyzed at the DPHE-Danida laboratory, Noakhali for arsenic, iron, chloride, pH, conductivity, salinity and Total Dissolved Solids (TDS). Silver Diethyldithiocarbamate (SDDC) method was used for laboratory analysis of arsenic. TW attributes, water quality data and users' socioeconomic baseline data were stored in MS Access 97 database software following Relational Database Management System (RDMS) technique.

Hard copy maps (scale 1:10,000) prepared by the previous Danida financed project of both of the pourashava containing ward boundaries, roads, water bodies and public structures were available during the study period. Field survey was carried out using DGPS (Differential Global Positioning Systems) satellite receiver for error correction and georeferencing to map the features. Then both of the pourashava maps were digitized using Arc/Info GIS to prepare digital data.

Later, project staff and pourashava surveyors collected TW point data using mouza maps (scale: 1 cm. = 40 m.). Each TW point data was located on the mouza map asking the plot number of installed TW to the respective tube well's caretaker. At the same time the code number of the respective TW was also recorded. The collected information was verified with the provided information including

Table 1. Arsenic concentration range in study area

Study Area (Pourashava)	Arsenic concentration range (mg/l)					No. of TW Tested
	0 – 0.01	>0.01 – 0.05	>0.05 – 0.20	> 0.20 – 0.50	> 0.50 – 1.1	
	TW (%)	TW (%)	TW (%)	TW (%)	TW (%)	
Chaumuhani	0	4.9	55.2	30.3	9.6	366
Lakshmipur	0.30	5.2	41.8	43.8	8.9	349
No. of TW	1	36	348	264	66	715

plot number in the users' group application forms for TW installation. The collected point data were then digitized using Arc/Info software and combined with the digitized pourashava administrative map.

The limitation of this method of point data collection was that the identification of the exact location of a TW within the area of a mouza map plot was quite impossible. 25% of the digitized TW data were cross checked in the field to verify the deviation of the TW location. The verification results showed that the highest shifting was ±30 m., which was within the acceptable limit for the present study purpose. This could be concluded that the applied method of point data collection is applicable for the study in a small area with densely installed tube wells.

Results and discussions

Distribution of arsenic

Distribution of arsenic concentration in Chaumuhani and Lakshmipur pourashava is shown in Table1. In Chaumuhani 40% TWs were found with arsenic concentration >0.20 mg/l and 50% in Lakshmipur pourashava. On the basis of the laboratory test data no tube well was found within WHO (World Health Organization) standard (Asd"0.01mg/l) in Chaumuhani and only 5% of the tube wells were found within Bangladesh standard acceptable limit (Asd"0.05 mg/l) in both of the pourashava.

In this study, geographical and vertical distribution of arsenic concentration and their relationships were also investigated. The depths of the installed shallow hand tube wells were almost the same (depth ranges 10–20 m.), which is very much difficult to find the variation of arsenic concentration in such a small deviation of depth as because all of them are installed in shallow aquifer. There are however, limitations like small study area–the aerial coverage of Chaumuhani and Lakshmipur pourashava are 20.7 sq. km. and 26.3 sq. km. respectively. The distributions of the tube wells within the pourashava areas are also not uniform. Within such small area and such uneven distribution of the tube wells no distinct conclusion can be drawn about aerial distribution of arsenic. However in Chaumuhani there is a tendency of high arsenic concentration (^{3}0.20 mg/l) in central and western part of the pourashava (Figure 1.a). In Lakshmipur the northwest part of the pourashava has a trend of high arsenic concentration (Figure 1.b).

Point data were interpolated to find the aerial distribution pattern of arsenic concentration using IDW (Inverse Distance Weight) interpolation assumptions (ESRI, 1996) technique. The IDW interpolator assumes that each arsenic point data has a local influence that diminishes with distance. It weights the points closer to the processing cell greater than those farther away. The form of the resulting map based on this interpolation technique is strongly dependent on the value of grid cell and number of neighbouring points within the grid cell. The neighbouring points may be regularly or irregularly spaced (Aronof, 1989).

Figure 1 shows the arsenic point data interpolated with IDW method using 10x10 m grid cell and calculating twelve neighbouring points for distance weighted average values. The interpolated map (Fig. 1.a) illustrates that higher arsenic concentration tendency was detected in the western part of Chaumuhani pourashava and in Lakshmipur the interpolated maps (Fig. 1.b) shows higher concentration in northern part of the pourashava.

This could be mentioned that no matter which interpolator is selected, the accuracy of the resulted maps through interpolation was exclusively dependent upon a number of factors including the nature of the spatial variation of arsenic concentration data and the sample density and distribution within the study area. The interpolation method has no inbuilt technique of testing for the quality of predictions, so taking extra observations can only assess the map quality. It is important to realize that in calculating missing values from neighbouring points, data are assumed to behave in a spatially predictable manner over the map area. Limitation of the interpolation results was that tube wells installed by the previous Danida project were only in the fringe areas of the pourashava, where piped water supply was not easily accessible. So, no data was available in the central area of the pourashava for the spatial analysis to get more accuracy in interpolated results.

Awareness about arsenic contamination

The analysed results about use of tube well water data showed that the majority (94%) of users prefers tube wells as their drinking water source, the rest (6%) prefers other sources like piped water supply, deep tube well water and rain water for drinking. For cooking, washing and bathing the majority of the users prefers pond water, second popular is TW water while few prefers piped water supply

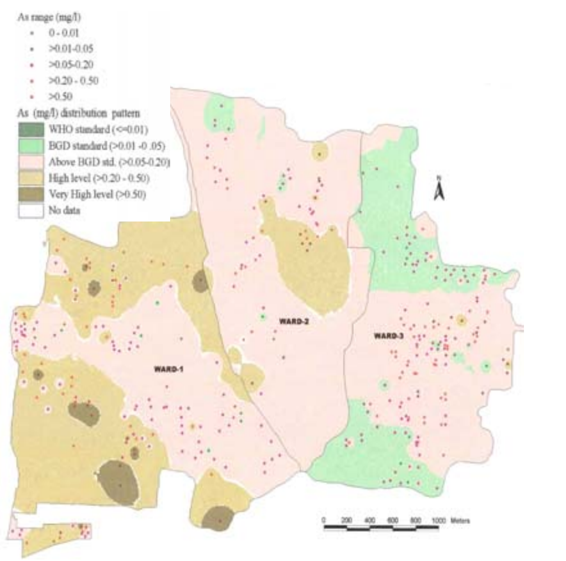

Figure 1a. Chaumuhani Pourashava

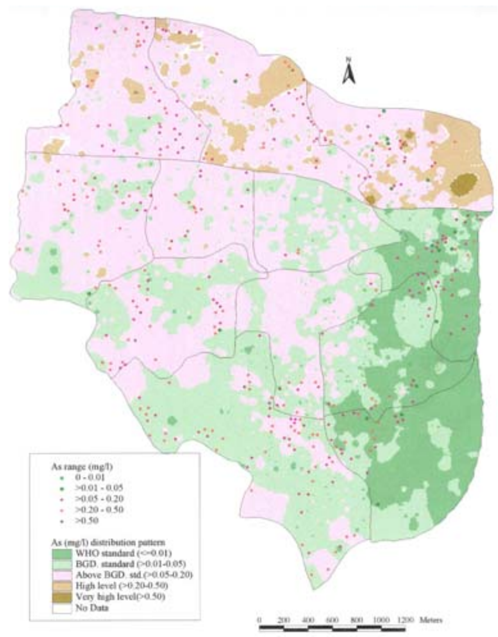

Figure 1b. Lakshmipur Pourashava

Figure 1. Interpolated maps showing arsenic concentration level and distribution pattern in the study area

and rainwater harvesting. The majority of the users (97%) use TW water directly for drinking, while the remaining 3% use the TW water after boiling/ alum treatment or filtration.

The survey reveals that 45% household at Chaumuhani (figure 2.a) and 59% household at Lakshmipur (figure 2.b) were not aware about arsenic. On the other hand 58% respondents of Chaumuhani and 71% respondents of Lakshmipur did not know the source of contamination of arsenic in water. This study result reflects that majority of the people are in dark about the basic information and source of arsenic contamination. Awareness about arsenic diseases was minimal. Since this is a new issue, it is obvious that people are less informed. Data shows that more than 85% people still have no knowledge about the diseases caused by ingestion of arsenic contaminated water. The study shows that 99% of the households are not aware of arsenic mitigation techniques.

The tube well users arsenic awareness data (point) are interpolated on the basis of Inverse Distance Weight (IDW) assumptions (ESRI, 1996) to find the aerial distribution pattern of awareness within the study area in figure 2.a and 2.b. In this IDW interpolation method all points within 150 meters distances (i.e. highest distance of users house from the tube well location) are used to determine the output values for each location.

This aerial distribution reflects that no such distinct area was found where most of the people were well informed about the severity of arsenic poisoning. However, this analysis will give the benchmark information about area based arsenic awareness, which can be compared after any kind of social intervention in the study area about arsenic awareness campaigning.

Conclusion

As foregoing discussion has illustrated, GIS is a powerful technology for the collection and integration of spatial and nonspatial data, which provides a subsequent statistical and spatial analysis tool followed by a mean for visualizing and displaying the analysed results in map, chart and tabular form.

Considering the present situation of arsenic problem in Bangladesh, it is evident that the rate of generation of arsenic related spatial and nonspatial data from different sources will continue to increase for a long future, leading to huge volume of data for storage, retrieval and analysis. The demand for GIS to handle such volume of data in a large variety of decision-making situations will also increase dramatically. In this context, it is very important that the design, implementation and use of GIS be placed on a more systematic and scientific basis than has generally been the case until recently.

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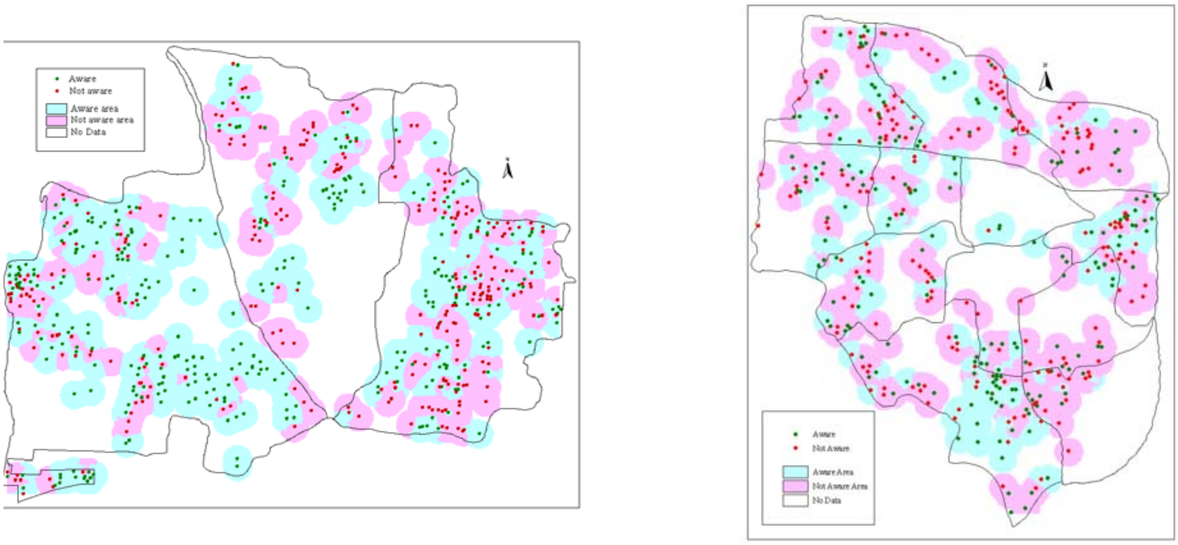

Figure 2a. Chaumuhani Pourashava

Figure 2b. Lakshmipur Pourshava

Figure 2. Interpolated maps showing arsenic awareness pattern in the study area

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