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GIS based Risk Analysis for Arsenic Contamination: A Case Study of Chapai Nawabganj District in Bangladesh

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Abstract—Arsenic contamination of groundwater has emerged as a severe environmental disaster in Bangladesh over two decades. The number of patient seriously affected by arsenic from drinking water has now risen to thousands. The paper focuses on GIS based risk analysis for assessing the breadth of the arsenic contamination in the district of Chapai Nawabganj. GIS ArcView has been used to make a risk assessment about the extent and magnitude of the problem based on estimated exposed population and degree of contamination. The study shows 78% of the tested tubewells were found having arsenic contamination greater than Bangladesh standard with estimated population of 71,413 are exposed to high risk zone, 140,298 are exposed to medium risk zone and 199,957 are exposed to low risk zone in the study area. It is expected that based on the risk analysis the decision makers will be able to take potential mitigation options.

INTRODUCTION

Groundwater has been the major source of safe drinking water in Bangladesh. After Bangladesh achieved success in providing safe drinking water to nearly 95 % of its population through tubewells [1], the detection of arsenic in the groundwater from different parts of the country has raised a major public health concern. The first case of arsenic contamination in groundwater was reported in 1978 in West Bengal [2]. However, arsenic was first detected in groundwaters of Bangladesh by the Department of Public Health Engineering (DPHE) in the district of Chapai Nawabganj in late 1993 following reports of extensive contamination in the adjoining area of West Bengal. Arsenic is released from the unstable iron oxides to the flowing river system as deposition of sediments by river organic matters rapidly consume the available oxygen giving rise to strongly reducing condition [3], [4], [5].

The number of patient seriously affected by arsenic from drinking water has now risen to thousands and possesses a great risk to human health. Risk analysis is the process of quantifying the probability of a harmful effect to individuals or populations from certain geological, physical or anthropogenic activities. Risk assessment examines the potential human health challenge due to exposure to toxic contaminants in various environmental media. Its purpose is to estimate the severity or magnitude of risk to human health posed by exposure to an environmental hazard [6], [7], [8]. The present paper focuses on the application of GIS based risk analysis for presenting and assessing the breadth of the arsenic problem in Bangladesh.

STUDY AREA

Chapai Nawabganj district is situated on the north-west part of Bangladesh, bordering the state of West Bengal, India in the west, Rajshahi district on south-east and Noagaon district towards north east. The two major rivers Ganges and Mahananda along with tributaries like Pagla, Purnabha and Tangan flows through the district of Chapai Nawabganj. It has an area of 1,702 sq. km with a population of 1,396,000. The district has 5 thana: Nawabganj Sadar, Shibganj, Nachole, Bholarhat and Gomastapur. Arsenic patients were first detected inChapai Nawabganj district, and the survey carried out by BGS showed some of the areas of the district are extensively contaminated by arsenic known as hot spots [9]. The present study was carried out in Chatrajitpur Union of Shibganj thana in the village named Chatrajitpur. The Chatrajitpur village is 5 km north west of Shibganj thana. The survey was done on a random basis in 67 households out of an estimated 163 households.

Groundwater is the most important source of water supply in the study area. The depth of aquifer varies from zero to 54 m below ground surface. The hydrographs for the district Chapai Nawabganj piezometers show a large seasonal fluctuation with water levels ranging from around 1 m below the ground level at the end of the monsoon period to around 7 m below ground level during dry season [9] (BGS and DPHE 2001). The seasonal fluctuation is therefore around 6 m. Groundwater levels for dug wells showed very similar responses to the piezometers during the monitoring period with fluctuation of around 6 m.

In the shallow aquifer, groundwater flows from north to south with localized outflow into the major rivers. Ground water gradient varies from 1:1,000. Transmissivity of the shallow aquifer has an average value of 3,172 m2/day with storage coefficient of 6.7 x 10-3 [10]. Although the aquifer has high transmissibility the horizontal flow of ground water is very slow because of the low groundwater gradient.

METHODOLOGY

The methodology consists of a survey, carried out to identify the user's responses on arsenic problem and identification of tubewells in the study area on household basis. The tubewells were tested for arsenic contamination. The relevant information such as location of tubewell, year of construction, ownership, depth of well, type of well was recorded. The locations of tubewells were identified using GPS (Global Positioning System) equipment conducted by BGS. The samples for arsenic contamination were measured by Field test kit and lab analysis through spectrophotometer. The gathered information was put into a database to generate a map based on buffer distance. The maps (shape files, *.shp) regarding the location of tubewell were analyzed with the screening criteria. The screening criterion includes selection of tubewells exceeding arsenic concentration (0.05 mg/l) and creating a buffer distance of

500, 1000 and 1500 m. radius around each contaminated tubewell. In the study area, people usually have access to tubewells within 5 m distance. It is estimated that there are about 12000 tubewells which is almost 100 times greater than the number of tubewells recorded with GPS. Since the ratio is 1: 100 for the number of tubewells and therefore, buffer distance has been applied with 100 times greater than the buffer distance that could be originally applied. The exposed population to be affected by each contaminated tubewell is calculated by multiplying the created buffer zone with the population density of the buffered area. Thus GIS ArcView produces final product in the form of maps (showing extent of arsenic contamination) or statistical reports (such as a table listing the number of population exposed to arsenic contamination).

RESULTS AND DISCUSSIONS

The survey carried out in the area of Chatrajitpur found that 97 % of the respondents heard about arsenic. It was found that 99% of the households have their own tubewell. About 88% tubewells were tested by UNICEF for arsenic contamination and 78% of the tested tubewells were found having arsenic contamination greater than Bangladesh Standard. 1 % of the respondents were detected with arsenic disease diagnosed by Thana Health Officer of which 64% is male 36 % female. In the survey area 33% households had own pond of which 95% never completely dries up. Only 5% ponds were extensively used for fish cultivation.

The alternative option for safe drinking water mainly consists of use of arsenic free tubewell and dugwell. It was observed that due to lack of availability of options 32% households are still drinking the water from Arsenic contaminated tubewell. There are very few dugwells of which only 3% are still in use. The survey shows almost 100% households stored rainwater during rainfall but they stored only for cooking purpose. Not a single family surveyed was found to store rainwater for drinking purpose. When asked how much they are willing to pay to obtain safe drinking water, the study showed that 42% of the total respondents are willing to pay below 300 Tk. (1 US $ = 69 Tk., July 2010), 33% of them 300-899 Tk., 17% of them 900-1999 Tk. and the rest 8% between 2000-4999 Tk. respectively as shown in the Fig. 1.

The cost includes both initial cost and running costs. However, criteria like technical effectiveness, susceptibility to bacteriological contamination was not considered as people in the study area were lacking in knowledge upon which those two criteria could be assessed. Based on the assessed score it was found that Three pitcher filter is most widely acceptable options based on the cost, continuity of supply, ease of maintenance and social acceptability. The options like dugwell, pond sand filter, rainwater harvesting seemed quite promising.

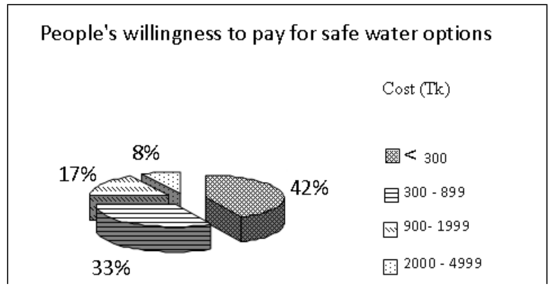

Figure 1 Peoples willingness to pay for safe water options in the study area of Chatrajitpur of Shibganj Thana

The map generated by the analysis of GIS ArcView (based on buffer distance) shows that area of 70.263 sq. km (17.36 % of the total generated map) with estimated population of 71,413 are exposed to high risk zone, area of 137.92 sq. km (34.08 % of the total generated map) with estimated population of 140,298 are exposed to Medium risk zone, area of 196.57 sq. km (48.56 % of the total generated map) with estimated population of 199,957 are exposed to low risk zone as shown in the Fig. 2 below.

Arsenic concentrations in the 15 tubewells were below the contaminated level of 0.05 mg/L. 53 tubewells had arsenic concentrations of 0.05 to 9.99 mg/l, 10 tubewells had concentration between 10 to 99.99 mg/L and the rest 29 tubewells had greater than 100 mg/L.

The result of the field survey shows that the majority of the households are willing to spend maximum of 300 Tk. to at best 900 Tk. for alternative safe water options. This price range indicates that options like Three pitcher filter and BTU (Bucket Treatment Unit) are more feasible in the study area as compared to other alternative safe water options. The option like piped water supply though efficient is yet to gain good responses from the people when it comes to cost and user friendliness. However, options like Pond Sand Filter and sanitary dugwell are quite promising if community could be mobilised to share the installation cost.

CONCLUSIONS

The spatial analysis was done based on the wells which were recorded with GPS and therefore it could added that significant number of tubewells were out of this data base though they were screened for arsenic contamination. The generated map would be more effective when all the tubewells with spatial distribution were entered into the database and thereby exact number of population exposed to arsenic contamination could be forecasted. It is expected that based on the risk analysis the decision makers will be able to take potential mitigation options. By risk analysis, less time and money need to be spent in identification of severely contaminated area. A variety of tools such as data-bases (DB) for knowledge management, Geographic Information Systems (GIS) for geospatial data management, Decision Support Systems (DSS) and methods can be employed for disseminating information related to Arsenic contamination.

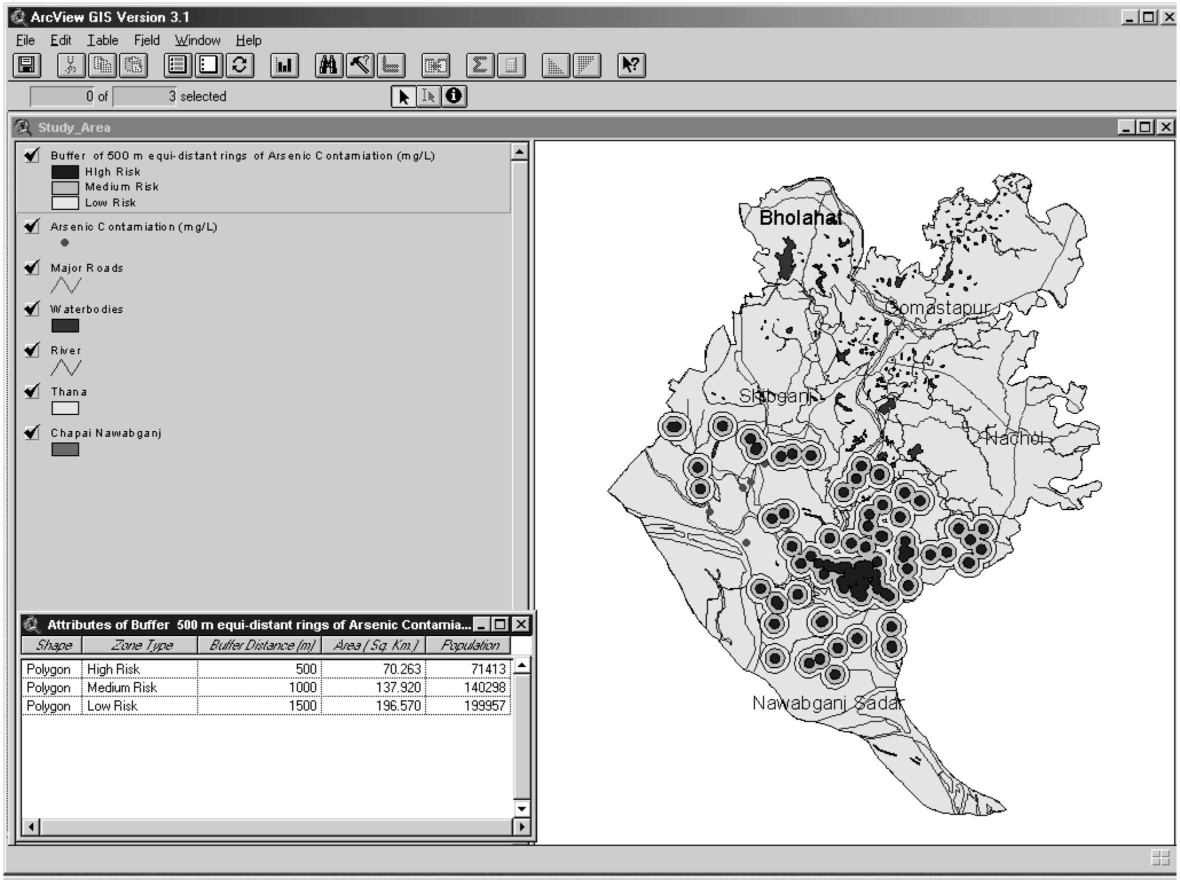

Figure 2 The map indicating high, medium and low risk zone based on buffer distance.

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