ESTIMATING ARSENIC-AFFECTED POPULATION IN BANGLADESH USING HIGH-RESOLUTION LANDSCAN GLOBAL POPULATION MODEL

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ABSTRACT

The present study has analyzed the spatial dependency of dissolved As distributions in alluvial aquifers and estimated the population exposed to an elevated As concentration (> 50 µg/L) using a fine resolution (< 1 km) LandScan global population model 2005 (United States Department of Energy's Oak Ridge National Laboratory) and the National Hydrochemical Survey (NHS) of Bangladesh arsenic dataset.

Spatial variability of groundwater As concentrations in aquifers is extremely high and Spatial dependency of arsenic ranges from 30 km to some 100 km on regional scales. Arsenic concentrations vary from ~0.5 µg/L to approximately 1,600 µg/L and high values are mostly concentrated in the south-central Bangladesh. Ordinary and disjunctive kriging methods were applied with a probability of exceeding 50 µg/L of As concentration (Bangladesh standard) to estimate the affected population using the LandScan population model. The total As-affected population was estimated by summing up the population in each probability zone of the kriged map exceeding As concentration of 50 µg/L. In each probability zone, the total number of people (from LandScan model) was multiplied by the probability value to represent the actual As-affected population.

Results from geostatistical analyses suggest that a minimum of 22 million people are exposed to As concentrations exceeding 50 µg/L as estimated by ordinary kriging method, whereas, the disjunctive kriging method estimated a minimum of 27 million people in the country. The estimated average population exceeding the threshold arsenic level of 50 µg/L varies from 27 to 32 million which differs from the previously estimated population of approximately 35 million exceeding the same threshold limit using spatial geostatistics and statistical methods on Bangladesh 1991 population census data.

This study offers new opportunities to estimate arsenic-affected population at a national-scale to a village-scale for better health and environmental hazard management. The method applied here can also be used in areas affected by other natural hazards.

INTRODUCTION

Groundwater arsenic in alluvial aquifers in South Asia, particularly in Bangladesh (Fig. 1, 2) and neighboring West Bengal, India is the worst case of groundwater poisoning in the world. Many studies have been completed on the biogeocomplex of arsenic contamination in groundwater of Bangladesh (e.g., BGS and DPHE, 2001; van Geen et al., 2003; Yu et al., 2003; Saunders et al., 2005).

Gaus et al. (2003) estimated As-affected population in Bangladesh based on the National Hydrochemical Survey (NHS) of Bangladesh As dataset using both geostatistical and conventional statistical methods. Their disjunctive kriging estimate for As-effected (> 50 µg/L) population was approximately 35 million, whereas, conventional statistical result showed nearly 28 million. They estimated the total number of population of approximately 125.5 million for Bangladesh in 1999.

Our study has used the LandScan Global Population Model 2005 (United States Department of Energy's Oak Ridge National Laboratory) and the National Hydrochemical Survey (NHS) of Bangladesh arsenic dataset. According to LandScan 2005 model the total population of Bangladesh was approximately 144 million. We applied both ordinary and disjunctive kriging on the same NHS dataset used by Gaus et al. (2003).

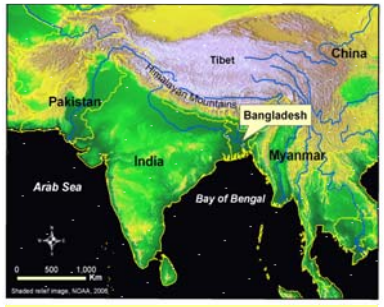

Fig. 1 Map showing the regional setup of Bangladesh, which is located in the South Asia and bordered by India and Myanmar in three sides, but opens to south into the Bay of Bengal.

DATASETS AND METHODS

Arsenic Dataset: The present study has used Bangladesh National Hydrochemical Survey dataset (BGS and DPHE, 2001), which was conducted by British Geological Survey, Department of Public Health Engineering of Bangladesh and Mott McDonald Ltd. between 1998 and 1999 (Fig. 2).

LandScan Population Model 2005: Since the late 1990s, the United States Department of Energy's (USDOE) Oak Ridge National Laboratory (ORNL) has been working on a global-scale population model (Fig. 3). Four primary geospatial input datasets: land cover, roads, slope, and night time lights that are key indicators of population distribution were used (Bhaduri et al., 2002). Using an innovative approach with Geographic Information System and Remote Sensing, researchers at ORNL have been the pioneer in developing, refining, and updating a global population database known as LandScan, which is the finest global population data (< 1 km resolution) ever produced and is several orders of magnitude more spatially refined than some of the previously available global population datasets.

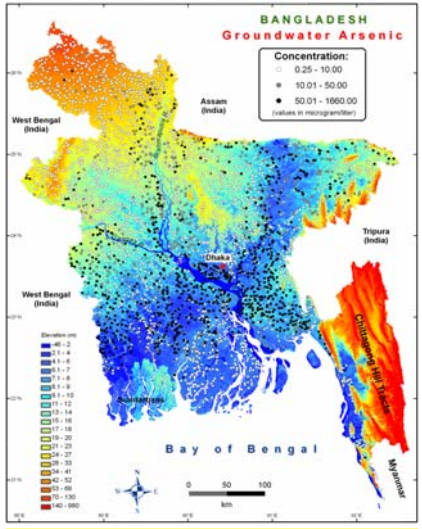

Fig. 2 Groundwater arsenic concentrations are superimposed on the Digital Elevation Model (DEM) of Bangladesh. High arsenic wells are located in low-lying areas.

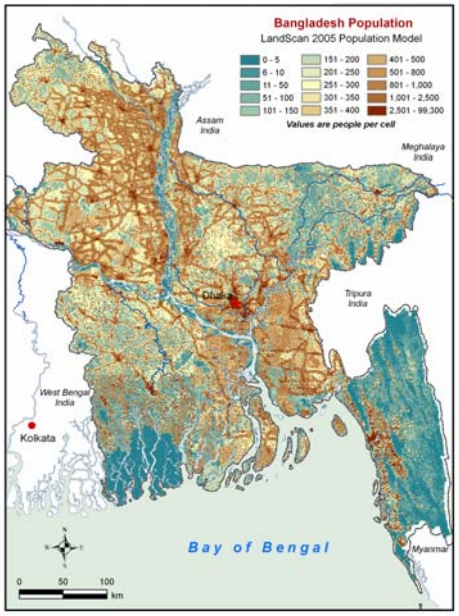

Fig. 3 Population density map of Bangladesh based on the LandScan 2005 Global Population Model by the United States Department of Energy's (USDOE) Oak Ridge National Laboratory (ORNL). The spatial resolution of population estimate is less than 1 km.

RESULTS

As-affected population models in Bangladesh (Fig. 4, 5) based on geostatistical methods are summarized in Table 1. The total population was estimated 144 million in the LandScan 2005 model, whereas, recently the Central Intelligence Agency estimated the total population of 150 million (CIA World Factbook, 2007). Ordinary kriging estimates for As-affected population in Bangladesh range from 22-32 million, whereas, disjunctive kriging estimates range from 27-37 million. The mean As-affected population is approximately 27-32 million, which is close to the estimate of 28-35 million of the study by Gaus et al. (2003).

Table 1 Summary of estimated population living with As concentration of 50 µg/L or more based on different geostatistical and conventional statistical methods. Values in million.

Methods applied to estimate As-affected population	This Study		Gaus et al. 2003	
	Range	Mean	Range	Mean
Ordinary Kriging	22 - 32	27	Not applied	Not applied
Disjunctive Kriging	27 - 37	32	Not available	35
Statistical estimation	Not applied	Not applied	Not applied	28

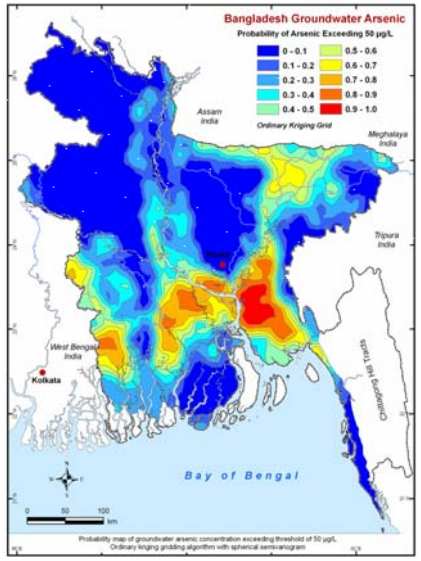

Fig. 4 Ordinary kriging grid for As concentrations in Bangladesh. The map shows the probabilities of As concentrations exceeding 50 µg/L.

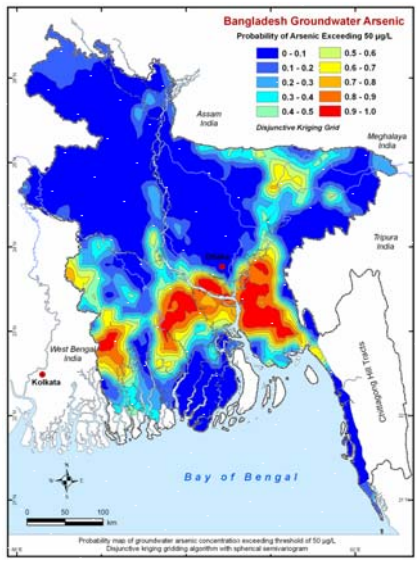

Fig. 5 Disjunctive kriging grid for As concentrations in Bangladesh. The map shows the probabilities of As concentrations exceeding 50 µg/L.