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Stable groundwater quality in deep aquifers of Southern Bangladesh: The case against sustainable abstraction

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HIGHLIGHTS

- Tens of millions of people in Bangladesh are affected by arsenic pollution of groundwater.
- Deep wells in potentially non-renewable aquifers are the dominant form of mitigation.
- Water quality in these aquifers has remained stable for 13years and probably >50years.
- The deep aquifers are predicted to provide long-term sources of safe water.
- An ethical case is made for temporary unsustainable abstraction to alleviate current human suffering.

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ABSTRACT

In forty six wells >150 m deep, from across the arsenic-polluted area of south-central Bangladesh, groundwater composition remained unchanged between 1998 and 2011. No evidence of deteriorating water quality was found in terms of arsenic, iron, manganese, boron, barium or salinity over this period of 13 years. These deep tubewells have achieved operating lives of more than 20 years with minimal institutional support. These findings confirm that tubewells tapping the deep aquifers in the Bengal Basin provide a safe, popular, and economic, means of arsenic mitigation and are likely to do so for decades to come. Nevertheless, concerns remain about the sustainability of a resource that could serve as a source of As-safe water to mitigate As-pollution in shallower aquifers in an area where tens of millions of people are exposed to dangerous levels of arsenic in well water. The conjunction of the stable composition in deep groundwater and the severe adverse health effects of arsenic in shallow groundwater lead us to challenge the notion that strong sustainability principles should be applied to the management of deep aquifer abstraction in Bangladesh is, the notion that the deep groundwater resource should be preserved for future generations by protecting it from adverse impacts, probably of a minor nature, that could occur after a long time and might not happen at all. Instead, we advocate an ethical approach to development of the deep aquifer, based on adaptive abstraction management, which allows possibly unsustainable exploitation now in order to alleviate crippling disease and death from arsenic today while also benefiting future generations by improving the health, education and economy of living children.

1. Introduction

In the Bangladesh part of the Bengal Basin, some 22 million people drink groundwater containing more than 50 μg/L of As, the Bangladesh and Indian standards for drinking water (BBS/UNICEF, 2011). Applying the WHO Guideline Value (GV) for Drinking Water of 10 μg/L raises the exposed population estimate for 2009 to 52 million, or 32% of the population (BBS/UNICEF, 2011). The crippling and fatal impacts on human health are severe (Dhar et al., 1997; Smith et al., 2000; Chakraborti et al., 2010; Argos et al., 2010).

The principal options for arsenic mitigation include substitution of As-polluted wells by switching to nearby As-safe (defined as conforming to relevant standard) shallow wells, installing dug wells or deep As-safe wells, rainwater harvesting, and pond sand filters (e.g., Ravenscroft et al., 2009). Surface water sources may be intermittent and, along with dug wells, are prone to microbiological pollution (APSU, 2005). Switching supply to nearby As-safe (e.g., community) wells work for some (van Geen et al., 2003) but is often accompanied by later denial of access to some social groups, and in the most affected areas is inapplicable.

Deep wells were originally drilled to avoid salinity in shallow groundwater, and are a popular and cost-effective means of arsenic mitigation (Ravenscroft et al., 2009; Mosler et al., 2010; BBS/UNICEF, 2011).

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By ‘deep wells’ we mean those screened at depths in excess of 150 metres below ground level (mbgl), and down to a practical maximum of about 350 m, and by ‘deep aquifers’ we mean simply those that deep wells abstract from, although it is noted that these sediments predate the Last Glacial Maximum (LGM). These definitions have practical value across the Bengal Basin, but do not preclude local refinement. To date, several hundred thousand deep wells have been installed in areas where shallow groundwater is polluted by arsenic or salinity (SI 1). Although the geographical extents of saline and arsenic-polluted groundwater overlap, these influences occur at different depths, and their origins are entirely unconnected. Continued development of deep aquifers raises questions of sustainability: for how long will deep wells continue to provide safe water? Should development continue, possible future problems, are: 1) the drawing down of As-pollution from shallower aquifers; 2) the drawing down of salinity from overlying brackish groundwater at depths of around 100 mbgl; 3) lateral intrusion of brackish groundwater from the seaward sections of the deep aquifers; and 4) lowering of water levels in the deep aquifers, which will both reduce accessibility by suction-mode hand tubewells, and induce land subsidence in overlying, poorly compacted, and sometimes peaty Holocene sediments.

Bangladesh's approach to arsenic mitigation has been marked by divergence between policy and practice; the use of deep hand-pumped tubewells was, for fear of unsustainability, officially the least preferred option, and yet has been the de facto strategy for mitigation (GoB, 2004; Ravenscroft et al., 2009). Despite fears of unsustainability, there has been no quantitative assessment of the magnitude of deep aquifer resources of the Bengal Basin nor of their sustainability, although a few preliminary efforts at modelling have appeared, based on limited or generalised information (Michael and Voss, 2008, 2009; Burgess et al., 2010). Shallow wells have been demonstrated to change composition with time in response to migration of As (McArthur et al., 2010), but we know of no convincing evidence (as opposed to claims) of As-pollution being drawn down into the deep aquifer (SI 2). We reiterate that we refer to the migration of arsenic, or arsenic-mobilising fluids, as distinct from the natural presence of arsenic at unusually great depths (SI 1 and 2). A few deep wells exhibit high concentrations of arsenic (Aggarwal et al., 2000; Mukherjee et al., 2011) or salinity, both of which may be natural, or in some instances result from fracture of casings at intermediate depth, an effect characterised for salinity by the ‘salt in the morning’ phenomenon (Minhazur Rahman, pers. comm.).

Here, we address the issue of sustainability of deep aquifers by evaluating (i) the rate at which deep groundwater changes its composition over time and (ii) the operational performance of the deep tubewells as mitigation devices. We use this information to explore the sustainability of deep-well abstraction for potable water supply, within the context of extant definitions and methodologies for assessing the sustainable development of water resources (e.g., Flint, 2004; Kalf and Woolley, 2005) and the documented mass poisoning of a population by arsenic (Smith et al., 2000).

2. Hydrogeological setting

The study area (Fig. 1) comprises the south-central part of the Bengal Basin, where deep aquifers are most intensively exploited (SI 1). Neither the aquifers nor the degree of exploitation are

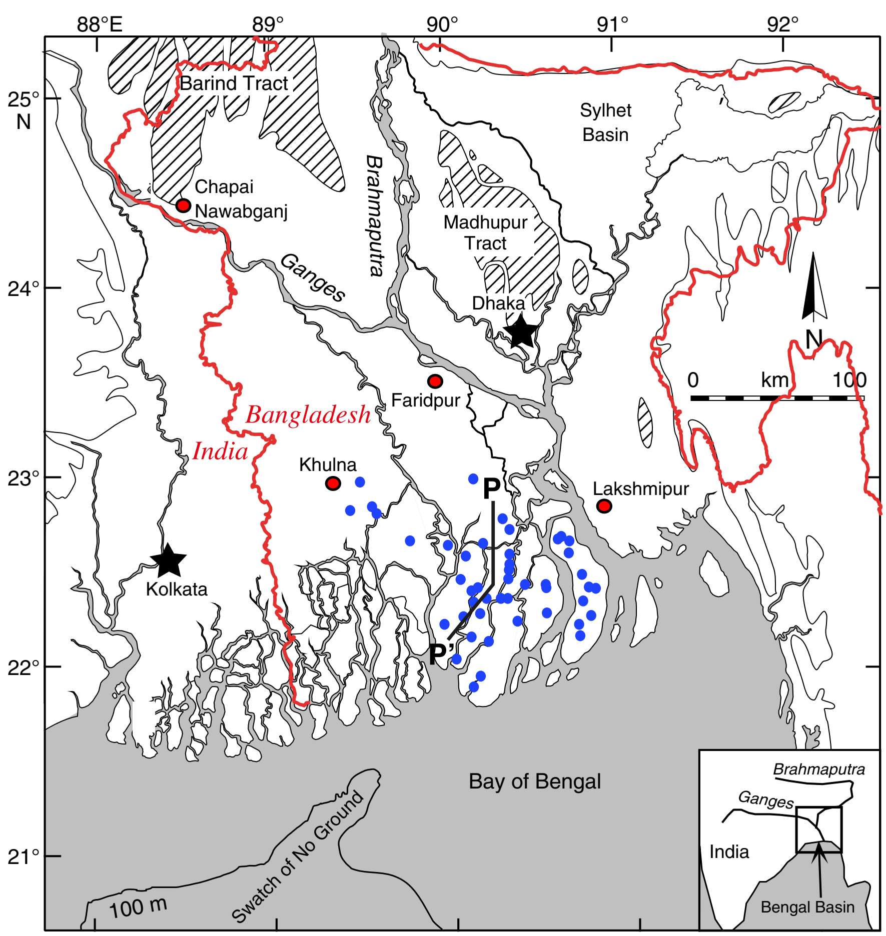

Fig. 1. Locations at which deep wells were resampled in 2006 and/or 2011. The line of section (P–P′) is that shown in Fig. 2. The hatched areas are Pleistocene terraces.