Habitat International 51 (2016) 79–89

Contents lists available at ScienceDirect

Habitat International

journal homepage: www.elsevier.com/locate/habitatint

Strategic assessment of groundwater resource exploitation using DPSIR framework in Guwahati city, India

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ARTICLE INFO

Article history:
Received 7 April 2015
Received in revised form
30 September 2015
Accepted 15 October 2015
Available online 29 October 2015

Keywords:
DPSIR
Groundwater
Urban households
Urbanization
Water accessibility

ABSTRACT

Millions of people on the urban settlements in Asia rely on groundwater for fulfilling daily water needs. And while groundwater storage is vast, its replenishment is limited, and many aquifers are exhibiting signs of inadequately controlled pumping. However, efforts to understand the impacts of a society on the availability, equity, and sustainability of groundwater and its repercussions has received little attention till date. Therefore, using Guwahati city, India, as a case, the aim of this paper is to understand the socio-political factors and their intra and inter-relationships with groundwater which in turn influences the urban households' accessibility to water. Overall methodology used the DPSIR framework for which inputs were generated from questionnaire survey of 150 households and other official, literature records. It is revealed that high population density of 4445 persons/km^2, rapid urbanization with haphazard construction, pertaining groundwater rights with land rights, and coverage of only 27% of the population by water supply services have acted as thrusts to exceed groundwater extraction over safe yield. This situation however has a feedback in the form of increasing number of households with reduced accessibility to water as many have stated about declined water levels, increasing issue of water affordability and subsequent emergence of water poor. The paper recommends use of water use fee rate and indirect groundwater pricing through energy tariffs for enhanced conservation of groundwater as opposed to present day method of its regulation.

1. Introduction

The Guwahati municipality has an area of 216 km^2 with the increase in urban population from 809, 895 in 2001 to 963,429 in 2011 respectively. The Guwahati Municipal Corporation (GMC), the Assam Urban Water Supply and Sewerage Board (AUWSSB) and the Public Health Engineering (PHE) departments together supply drinking water to merely 27% of the city's population, which has more than a million populations, and the demand for water is constantly increasing in the city considering its rapid population growth and urbanization (Goswami, Kalita, & Kalita, 2005). The urban households who do not have access to this network, have to depend on their own sources as tube wells, ring wells, bore wells, etc. derived from the groundwater which goes hugely unaccounted for, and this comprises of around 69% of the city population (Goswami et al., 2005); with extraction estimated to be 79 million liters a day (MLD), which is beyond the safe yield level for the city aquifers. Falkenmark et al., 2007 stated that population levels higher than 1000 people per flow unit of the resource (1 million cubic meter/year) indicate water shortage, termed as 'water crowding'. Owing to this over-pumping of the groundwater, it is observed that the water table in many parts of the city has been showing a declining trend (Das and Goswami, 2013a,b), due to which the urban households are increasingly facing the challenge of water accessibility.

In Guwahati city, groundwater is considered as a 'common pool' resource; and hence, the individual users have negligible or no incentives to consider the consequences of their over-extraction at present or in future (Soltani & Saboohi, 2008). As a result of which the aquifers in the city are continuously under stress since the beginning of mechanized extraction in early 1970s. This is further augmented by the conditions like weak groundwater governance (Brookshire & Whittington, 1993) in the national as well as in the state level which pertains groundwater rights with the land rights (Narain, 1998), unmonitored haphazard well construction, and unregulated groundwater extraction. Also, change in the land use pattern and subsequent failure in the enforcement of regulation for

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http://dx.doi.org/10.1016/j.habitatint.2015.10.003
0197-3975/

land use has led to arbitrary housing construction in the city (Borthakur & Nath, 2012), which eventually has increased the surface run-off and decreased groundwater recharge. Another issue of degradation of groundwater quality due to anthropogenic activities, which has been observed, is leachate from badly disposed solid waste which causes higher contamination of shallow aquifers (Viz. 2012) and therefore, extraction pressure is increasing in deeper aquifers for relatively better quality of water (Pandey, Chapagain, & Kazama, 2010), which again depicts the exploitative perspective towards the most extensively used water resource. Inaccessibility of the urban households to water, issues of water affordability and emergence of water poor has been found to be the repercussions of groundwater over-exploitation. Therefore, in order to restore groundwater utilization in a sustainable manner, water pricing is considered to be the most effective measure conceptually (Rogers, Silva, & Bhatia, 2002).

However, in the study area, there has not been any research if there could be enhanced household accessibility to water by means of economic instruments as compared to present policies governing groundwater usability. A number of studies were carried out to map the groundwater potential of the city's aquifers (Phukon, Chetia, & Laskar, 2012; Talukdar, Thakuriah, & Saikia, 2013), but those have particularly not shed light on the relationship of groundwater quantity and quality with the society, and the form of factors that influence its availability, equity, and sustainability.

In such a context, the main aim of this research is to understand the socio-political factors and their intra and inter-relationships with groundwater which in turn influences the urban households' accessibility to water. The scope of the research is that it has primarily based on field work consisting of household surveys and secondary data for groundwater investigation, which were analyzed using the Driver- Pressure- State- Impact- Response (DPSIR) framework.

2. Study area

Located as the gateway to the north-eastern region of India, is the state of Assam, comprising of Brahmaputra valley and Barak River valley with an area of 78, 438 Km^2, with a total population of approximately 31,169,272 as per the 2011 census. Guwahati Municipal Corporation Area (GMC), also known as Guwahati city forms the largest city of the state with an area of 216 Km^2 and is a part of the Guwahati Metropolitan Area (GMA), measuring about 262 Km^2. The total population covered under the GMA as per 2011 census is 968,549 and that only under GMC is 963,429. GMC is precisely situated at the southern bank of River Brahmaputra with its cardinal points as 26°10′ North and 92°49′ E; the city is situated on an undulating plain with varying altitudes of 49.5 m–55.5 m above Mean Sea Level. The southern and eastern sides of the city are surrounded by hillocks. Apart from the hilly tracts, swamps, marshes, water bodies also cover the city. Das and Goswami (2013a,b) explained that as per hydro-geological studies conducted by the Central Ground Water Board (CGWB) during 2004–2006, the net annual dynamic groundwater availability in Guwahati has been estimated to be in the tune of 11045.31 Ha-m or 11 mcm with a static ground water resource of 625,152 Ha-m or 625 mcm, up to the depth of 200 m.

Although the secondary data is collected in context of the whole city, the primary data is collected only from three wards, i.e., ward no. 02, 35 and 57 as these are located in three respective directions spanning the city, i.e., west, central and south (Fig. 1) with varying hydrogeomorphogical units (Fig. 2), and medium to high groundwater recharge zones (Fig. 3). In general, the level of groundwater in the city differs as per the local topographic conditions, such as, water level is deeper in regions having close proximity to undulating inselbergs or residual hills, and shallower in regions having flat alluvial plains or valley-fills (Das and Goswami, 2013a,b). Ward no. 02 situated in the western part is composed of alluvial plain (older and younger alluvial plains). These structures, lithologically, are made of intercalated beds of clay, silt and sand in different proportions (Goswami & Goswami, 1996, Goswami, Goswami, Duarah, & Deka, 1994); and in case of ward no. 02, upper layer of clay is thick only by a few meters and thickness of the sandy layer ranges from 40 to 50 m. Therefore, the infiltration of surface water is more and it falls under the high recharge zone. Ward nos. 35 and 57, situated in the central and southern parts are mainly composed of valley fills and older alluvial plains. They have sandy layers ranging between 40 and 60 m but because the upper layer of clay has a thickness of 10–20 m the percolation of surface water becomes restricted to a certain extent and hence, these falls under the medium recharge zones (Das and Goswami, 2013a,b).

3. Methodology

The overall methodology follows the DPSIR framework, developed by the European Environmental Agency in 1999, which is structured for analyzing the relationships between complex components of social, political and environmental systems, which are interrelated in nature and in managing the flow of information among them (Kristensen, 2004).

Driving forces represent major social, and economic developments in societies, and the resultant changes in the ways of peoples' lives, with enhanced production and consumption, which is encouraged by weak governing systems. The factors considered as driving forces in this paper, are population growth, urbanization, unavailability of supplied water and weak groundwater governance.

Pressures are referred to as the direct or indirect form of stresses caused by driving forces, which are anthropogenic in nature. The pressures are such interventions that disturb the normal functioning of the environment, posing higher risks if not checked. The factors as pressures in this paper are change in the land cover area, and unauthorized and unregulated use of groundwater and well construction in the city.

The state may be described by situations or propensities of a resource and its subsequent effect on a related entity which is not considered to be normal or healthy, induced by aforementioned driving forces and/or pressures. The factors of state considered in this paper are groundwater pollution, decline in water level and the issue of water affordability.

Impacts are defined as the forms of vulnerabilities faced by humans as well as the natural environment due to change in its state. However, these impacts vary depending on the socio-economic situation, geographic location and the capacities for mitigation, adaptation. Impacts considered in this paper are disturbance in the groundwater flow, poor water quality and emergence of water-poor.

Response is defined by the actions taken in order to bring modifications into the driving forces, to lessen down the pressure, to restore the state, and to alleviate the impacts. Responses can be made onto influencing the aspects of the DPSIR framework in individual levels or there can be wholesome approaches. Water supply projects, water use fee rate and indirect groundwater pricing through energy tariffs have been considered as responses in this paper.

Secondary data were collected from published/unpublished reports, papers and official data and primary data were collected by means of expert consultation and household survey in which 150 households were interviewed from three chosen locations. 50 households from each location in the city which do not have access