

Subramanian, Saravanan V.; Mavalankar, Dileep; Kulkarni, Suhas P.; Nussbaum, Sven; Weigelt, Martin

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Metabolized-water breeding diseases in urban India: Socio-spatiality of water problems and health burden in Ahmedabad

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Working Paper 130

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Cover photos:

Top-left: Water storage in unhygienic containers

Top-right: Sewerage lines encroached over by households

Bottom-left: Drinking water, sewerage, storm water and electric pipe lines exposed making it hazardous

Bottom-right: High rise apartments with their own water infrastructure

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Authors' addresses

V. S. Saravanan,
Senior Researcher,
Center for Development Research (ZEF), University of Bonn,
Walter-Flex-Str. 3
53113 Bonn, Germany
Tel. 0049 (0)228-73 4918: Fax 0228-731972
E-mail: s.saravanan@uni-bonn.de
www.zef.de

Dileep Mavalankar,
Dean (Academic),
Indian Institute of Public Health-Gandhinagar,
Ahmedabad 580054, India.
Tel. 0091(0)79-40240444: Fax: 0091 - 79 - 40240445
E-mail: dmavalankar@iiphg.org

Suhas P. Kulkarni,
Medical Officer,
Ahmedabad Municipal Corporation,
Ahmedabad, India.
E-mail: suhaspkulkarni@gmail.com

Sven Nussbaum,
Coordinator,
Center for Remote Sensing of Land Surfaces,
University of Bonn, Bonn,
Germany.
E-mail: svennu@uni-bonn.de

Martin Weigelt,
Department of Geography/Center for Remote Sensing of Land Surfaces,
University of Bonn, Bonn,
Germany.
E-mail: emeswe@gmail.com

Metabolized-water breeding diseases in urban India*:

Socio-spatiality of water problems and health burden in Ahmedabad

Saravanan, V. S., Mavalankar, D., Kulkarni, S., Nussbaum, S. and Weigelt, M.

*A modified version of this paper is forthcoming in the *Journal of Industrial Ecology*

Abstract

Studies on urban metabolism have provided important insights in the material and socio political issues associated with the flow. However, there is dearth of studies that reveal how infrastructure as a hybrid of social and material construct facilitates disease emergence. The paper brings together urban metabolism, political ecology and anthropological studies to examine how the material flow of water is socially constructed and reconstructed through everyday water problems and its health burden in Ahmedabad city, India. The article geo-references the water problems and occurrence of diseases and through interviews documents the socio-spatial characteristics of water problems and health burden in two case study wards. The paper provides a situated understanding of the everyday practices that exposes the water infrastructure through leakages, reveals the citizens desire for better water quality and struggle to gain access to water using diverse ,pressure' tactics. It is this social-material construct of infrastructure that gives structure and coherence to urban space, which spatially coincides with the occurrence of diseases. The analysis reveals the socio-political drivers of the water problems, spatial inequity in water access, and identify potential hypothesis of the hot-spots of disease emergences. Attempts to bring about a desired change have to be collective and incremental that takes into consideration the diffuse interplay of power by diverse actors in managing the flow of water. The methodology offers a way forward for researchers and development agencies to improve the surveillance and monitoring of water infrastructure and public health. By bringing ,place-based' and ,people-based' approach, the analysis charts out avenues for incorporating the socio-spatiality of the everyday problems within the field of urban metabolism for improving resource use efficiencies in cities of rapidly growing economies.

Keywords: Urban metabolism, techno-politics, institutional analysis, spatial analysis, public health, India

1 Urban Water Infrastructure: Flows, Politics and Semiotics

Urban water infrastructure plays a crucial role in securing public health (Alirol et al., 2011). The impact of poor water supply and sanitation on human health are well-documented in cities of rapidly growing economies (McGranahan et al., 2001; Agtini et al., 2005; Kolahi et al., 2010; Makwana, 2012; Saravanan & Gondhalekar, 2013; Schmidt, 2014). Although water infrastructure is known to influence human health, there is a dearth of studies that reveal how flow of water is transformed or metabolized by diverse actors to facilitate disease emergence. The article examines the everyday construction and reconstruction of water infrastructure by diverse actors engaging with water problems and its health burden in Ahmedabad city, India.

Infrastructures are built networks that facilitate flows of goods, people or ideas and allow for exchange over space (Larkin, 2013). Arising out of the industrial ecology, urban metabolism has contributed to analyzing the material flow of water to allocate the resources efficiently (Kennedy et al., 2012) and offered new ways of thinking about the sustainability of cities and opportunities for innovative urban infrastructures (Broto et al., 2012). Urban metabolism through its interdisciplinary perspective had offered a fruitful avenue to investigate urban transformation through diverse tools for development of social and environmental policy and, investigate the role of actors and power relations that shapes urban space. Despite its insights, they inform little about the 'everyday practices' of infrastructure (Graham and Thrift, 2007; Lawhon et al., 2013), the diffuse forms of power and more so less on policy planning and designing of urban infrastructure.

Infrastructure is an amalgam of technical, administrative and financial techniques that places systems at the centre of the analysis and focuses on system building (Larkin, 2013). This echoes, Latour's (2004) hybridization concept that shows how infrastructure is embedded in spatial, temporal and social practices and discourses are negotiated in everyday practices (cited in Zimmer, 2010:347). A situated understanding of the flow, power and knowledge in everyday practice forms the core towards alternative possibilities for progressive change (Lawhon et al., 2013). More so exploring the flow through the everyday practices of claim-making by actors will help to build a theoretical understanding of the southern urbanism (Lawhon et al., 2013). Coming from a technopolitics perspective, Larkin (2013) identifies concrete semiotic and aesthetic elements of everyday problems to analyze infrastructure. These elements are not separate from the purely technical functions, but are forms of expression through which politics is constituted. These include historical evolution, the aesthetics of the infrastructure and the "pressure" to access water (Larkin, 2013). Examining the historical setting places the infrastructure as a product in the contemporary context and captures the evolutionary thinking of how to bring about changes for enacting progress (see Bakker et al., 2008; Chaplin, 2011). Aesthetics generates much of the citizenry's sense of modernity and progressiveness, and cultivates technical skills and knowledge as a way of fulfilling the desire for efficient systems. This can be analyzed in two ways (Larkin, 2013): (i) how the systems and practices operate in comparison to their purported objectives (herein it refers to water leakage, compared to efficient water supply through pipelines), and; (ii) how the infrastructure embodies the experience of everyday life, through taste, touch, hearing, seeing, and smell (herein it refers to the perceived water quality). The pressure reveals how diverse social groups struggle through social network and technologies to gain access to unequal and scarce water (Anand, 2011). These elements of everyday water problems represents a product that includes decay, but is also rightly regarded as central to the creation of new forms of urban life (Graham & Thrift, 2007) that has significant influence on the human health.

The article contributes by understanding how the historical legacy and contemporary policies facilitate the socio-spatial inequality of urban water in Ahmedabad; how these inequalities are challenged through every day practices of reporting water problems; and what implication does

these have on the human health in two case study administrative wards – dubbed Ward A and Ward B (The names of these wards are kept anonymous to maintain confidentiality of the region) – in Ahmedabad, India. The following section provides an overview of the historic and contemporary settings that influences the way urban water is managed making residents vulnerable to health consequences. The third section provides the methodological details of the study and the steps taken in the spatial analysis. The fourth section elaborates on the socio-spatiality of: (1) the water leakage from pipelines; (2) the poor quality of drinking water; and (3) low pressure in the drinking water pipelines, as reported from the consumer end. These perspectives help us to understand the flow of water as interdependency between social actors, institutions and biophysical system. The final section highlights the role of emerging hydraulic diseases that plagues urban societies calling for significant innovation in the infrastructural governance. Drawing spatial coincidences between the water problems and health does not exclude other factors (e.g., socio-cultural and economic factors, hygiene and access to basic services) that are equally important (WHO/UN Habitat, 2010) in influencing health, but attempts to demonstrate the increasing role of infrastructure in influencing public health in rapidly-urbanizing economies such as India.

2 Ahmedabad: Water Infrastructure in a Segregated City

Ahmedabad represents one of the rapidly urbanizing economies in India. The overall population increased from a mere 837,000 in 1951 to 5.6 million in 2011 (UMC, 2012). To meet the growing drinking water needs, the city supplies a daily average of around 1030 MLD, or about 148 lpcd (UMC, 2012) of which surface water accounts for 90% of the supply and 10% with ground water. There are very few areas where tankers supply water. The city has been able to supply around 148 lpcd (liters per capita per day) to about 88% of its population, with a daily supply at the consumer end being 2.25 hours (UMC, 2012). In spite of this coverage there is recurrence of water- and vector-borne diseases in the city (Saravanan, 2013).

The city is plagued with spatial inequality which is deeply embedded in the pre-colonial textile-based economy and in the colonial legacy of segregated planning, which are actively exploited by diverse actors using public goods to benefit private interest (Chaplin, 2011; Saravanan, 2013). Currently, the city's settlement can be divided into informal settlements, chawls, housing societies, largely of low-income to middle-income groups, and independent housing complexes, a configuration that reflects the hierarchy from informal settlements to independent housing complexes in the levels of living, quality of housing and availability of basic services (Mahadevia, 2002:4851). To improve the water systems, the Corporation has prepared a Sanitation Plan (UMC, 2012) as per the requirement of the Jawaharlal Nehru National Urban Renewal Mission (JnNURM) a national level program to modernize the cities in India. These plans provide status quo of the water supply and sanitation situation rather than the social, institutional and physical complexities in everyday practice of water management. By taking a closer look at two administrative Wards in the city, the article reveals the social, institutional and physical complexities in the everyday practice of water management, and its health burden among urban residents.

Ward A had a population of 91,000 in 2011, situated in what are officially classified as "slum or slum-like" settlements (as they do not have legal land tenure). It was a thriving textile centre during the pre-colonial and colonial periods; it is now occupied by chawls, informal settlements, few housing societies, abandoned industries, solid waste disposal site, wastewater treatment plant and vast stretches of agricultural land. The land use of the ward is distinct in the north and in the south (as in Appendix 1). The northwestern and western parts of the ward consist of linear housing (chawls) bordering the industrial land, abandoned due to the neo-liberal policies of the 1980s and 1990s. Given their unclear land tenure status in chawls, households illegally connect to water pipes (constructed for public standpipes) and discharge their household waste outside their homes or into open drains. In the northeastern portion of the ward, there are housing societies with highly dense water networks, connected through public standpipes and private connections. Many of these housing societies have private water and sewerage connections through piped network. By contrast, the southern part is considered as a "no man's land" where no information on habitation is available; the area has agricultural land, a waste-water treatment plant (southeast of the ward) one of the city's solid waste disposal, and a vast plot of land occupied by squatter settlers. Given a lack of information, analysis could not be carried out for this part of the ward and hence the following maps depict only the northern part of the ward.

The Ward B has a population of 86,000 in 2011, 70% of whom lived in informal settlements occupied in public or private lands. Ward B was included in the city in the 1960s as a planned settlement to provide low-cost housing to the textile mill workers and employees when Ahmedabad was still a flourishing textile centre. With the closure of the mills in the 1980s and 1990s, many people remained unemployed, sought self-employment or were absorbed into the diamond-cutting industry that grew from the 1990s onwards. The diamond industry and the growing economy of Ahmedabad further increased the population. A large part of the housing within this ward was planned and built

by the Gujarat Housing Board (though a government program for providing housing to diverse income groups targeting low and middle-class households) for the workers of former textile mills (as in Appendix. 2). In recent years, private real estate companies have developed properties (sometimes illegally occupying common lands, as in this case in northwest), and a number of squatter settlements now surround the lake in the ward. While these informal settlements have certainly encroached on public lands, a number of households within the planned settlement also impinge on public roads; as in Ward A. Some even extended above the drainage and drinking water pipelines. The department of engineer (DoE), AMC has often had to seal off drinking water lines and re-lay the pipe in different areas, as they are politically unable to evict the trespassers. Most of them have access to drinking water and sanitation provided by the DoE through piped network. Aging infrastructure, poor alignment of pipelines, water logging and illegal drinking water connections are major hurdles to ensuring safe drinking water, adequate sanitation and effective disposal of sewerage waste.

3 Methods and Analysis

Information on water infrastructural networks is elusive in the Wards, like any other global south, where data on water infrastructure is scarce. The maps of the pipelines in the ward dates back to 1970's, and there is no clear understanding of how much water is supplied in the Wards, the quality and the diameter of these pipelines. In contrast, there is wealth of information on the complaints reported by households, and experiences from the lineman and contract laborers working with DoE over a decade. The information on the water leakages, water quality and water pressure was collected from Complaints Register Book maintained by the DoE, where households register their everyday complaints about road, water, sewerage and other public works issues. The report is an important documentation that makes the infrastructure visible through everyday water problems. The register runs several hundred pages, and there are four or five books per year. The register contains information about the complainant (name and address), the nature of the complaint, the location of the complaint (address or landmark) and the remarks of the junior engineer on whether the reported case has been addressed. These complaints are based on the people's everyday experiences and observations in their settlements. The information in these registers is not compiled in any way (for politically convenient reasons) for precautionary decision-making, excepting as a 'fire-fighting' approach by junior engineers to address day-to-day complaints, so it had to be documented and geo-referenced manually. The water network map was prepared by updating the 1970s engineering drawing available from the DoE through transit walks with the junior engineer, lineman and contract laborers employed by the DoE. Preparation of the network reveals a lack of technical expertise among the engineers, in identifying and describing the piped network. Junior engineer positions have a high rate of transfer, so they have a limited knowledge of the networks and their conditions; they are often patched up by a lineman who has decades of experience and contacts with the urban residents in the ward. Using Google Maps and the administrative ward maps as a basis, the 1970s network map was updated through transit walks with the lineman. This process allowed us to chart the direction of flow, dimension of the pipes and specific problems occurring in these networks. The exercise was limited to mapping the legal water lines, but there are a vast number of illegal water networks, and different types of (piped, open-pit drain and overflowing) sewerage lines, which the research team found it very sensitive and difficult to map given the resources at hand. The sewerage and storm water pipelines were sparse in the two wards, revealing how disconnected drinking water, sewerage and storm water lines exists in urban India, and also the reason for urban population drowning in their own sewage. Given the availability and its importance to health the analysis used the drinking water network for analysis. The settlement map was prepared based on the administrative map provided by the local authority, and field-tested through observation and interviews with local officials and urban residents.

The occurrence of diseases was georeferenced from the information gathered at the urban health centre in the ward and the health statistics unit, under the Department of Health (DoH), AMC. The department uses both active and passive surveillance, among other methods, to collect health information. Active surveillance involves a legion of health workers (known as "link workers" who cover around 1,000 population in a settlement) making door-to-door visits to every household in their jurisdiction to determine the health status of the households. If any symptoms or diseases are noted, the workers give a preliminary dosage of medicine or refer residents to nearby hospitals. Information on the confirmed cases of any disease is entered in the hospital records of the Urban Health Centre. Passive surveillance, on the other hand, involves reporting the number of patients (as well as their ages and addresses) visiting the public and private hospitals and clinics within the ward. The passive number thus includes only the confirmed cases. The data from active and passive surveillance are combined to form the city health statistics. Although surveillance is effective, underreporting is still widespread. Geo-referencing of the health information was available only for gastroenteritis, jaundice and malaria data in Ward A and for jaundice and malaria data in Ward B for

the period between July 2011 and December 2012. The georeferenceable information for Ward A represented 22%, 34%, and 24% of the total reported cases of malaria, jaundice, and gastroenteritis respectively, in the ward. The same for Ward B represented 81% and 74% of the total reported cases of malaria and jaundice respectively. The research team documented and geo-referenced the complaints on water infrastructure for 2011 and 2012 and superimposed them on the settlement map to visually describe the relationship. The spatial analysis was applied from July 2011 to December 2012 due to concurrent availability of geo-referenced information for water problems and occurrence of diseases.

The article applied the kernel density method to visualize the point data of water problems and the occurrence of diseases in this article. This method provides an overview of the distribution of water problems and the distribution of diseases through density and hotspot mapping. The kernel density method calculates the density of water problems and the density of the occurrence of diseases using a kernel function by taking into account the surrounding neighborhood in the analysis (Silverman, 1986). The density is represented by the amount of cases per hectare; the more cases per hectare, the higher the density. While the kernel density method can be used to provide an overview of the spatial distribution of a phenomenon, it does not explain the significance of the clustering in comparison to the entire research area.

Hotspot analysis was applied to determine significant clusters in the occurrences of water problems and the diseases over the spatial settlement pattern. A hotspot needs to fulfil three conditions: it has to be an area with a high number of cases; this area should be surrounded by areas that also have a high number of cases; and this clustering should be statistically significant in comparison to cases in the entire research area. The significance level is usually expressed as a confidence level reaching 90% to 99%. A confidence level of 99% means there is only a 1% chance that this spatial clustering has occurred randomly (For more information regarding applied hotspot methodology, known as the Getis-Ord G_i^* , (see Getis and Ord, 1992; Ord and Getis, 1995). After mapping the hotspots, we hypothesized that there is a spatial coincidence between the hotspots of diseases and the hotspots of water problems. To identify a possible spatial relation, we applied Pearson correlation analysis to the spatial distribution of the clustering properties (*Getis-Ord G_i^* z scores*) of each disease and WI incident type. The correlation coefficient r quantifies the spatial relationship using a range from -1 to 1. If the r of the spatial clustering properties/distribution of diseases and WI-related problems is closer to 1, then the spatial relationship is stronger. The correlation coefficient r and its level of significance (p -value) were calculated using the statistical software SPSS (Version 21).

4 Socio-spatiality of water problems and health burden

The flow of water in the ward coincides with the hierarchy of settlements in both the wards. The head-reach of the network has higher density of networks, where households lived in bungalows and in housing societies, suggesting that these settlements have better access to drinking water. As the network reaches its tail-end, the density decreases and leads to mushrooming informal settlements, which presumably have less access to drinking water. In Ward A, the head-reach area of the water distribution network has a moderate network density that is concentrated around the bungalows (as in Figure. 1, also Appendix. 1). In the middle-reach the network density increases as it becomes dominated by the housing societies in the north and northeast of the Ward. The network density decreases in the east central part of the ward, as it passes the main road surrounded by the chawls that border the vacant industrial areas. In the tail-end, the network tapers and reduces in density, in areas dominated with informal settlements (the western, southwestern and central parts of the ward). The network density around the chawls is moderate, likely due to their location along the boundaries of the industries, which often coincide with main roads. In Ward B, the main distribution pipeline is laid along the main north-south road of the ward (as in Figure 2, also Appendix. 2). The network branches out from the main road to the housing societies, where the density increases. As the network reaches its tail end with low density, there is a concentration of the informal settlements surrounding the central, the northeast and south central parts of the ward. Informal settlements tend to concentrate around the lake, as the availability of open space is convenient for squatting, the lake serves as a nearby water source and there is exposed land for open defecation. Being a planned settlement, Ward B in general showed a higher density of networks compared with Ward A. The distribution of the legal water network and its density is an indicator of the level of access to water for households in both the wards.

Figure 1: Land Use and Water Network Density - Ward A

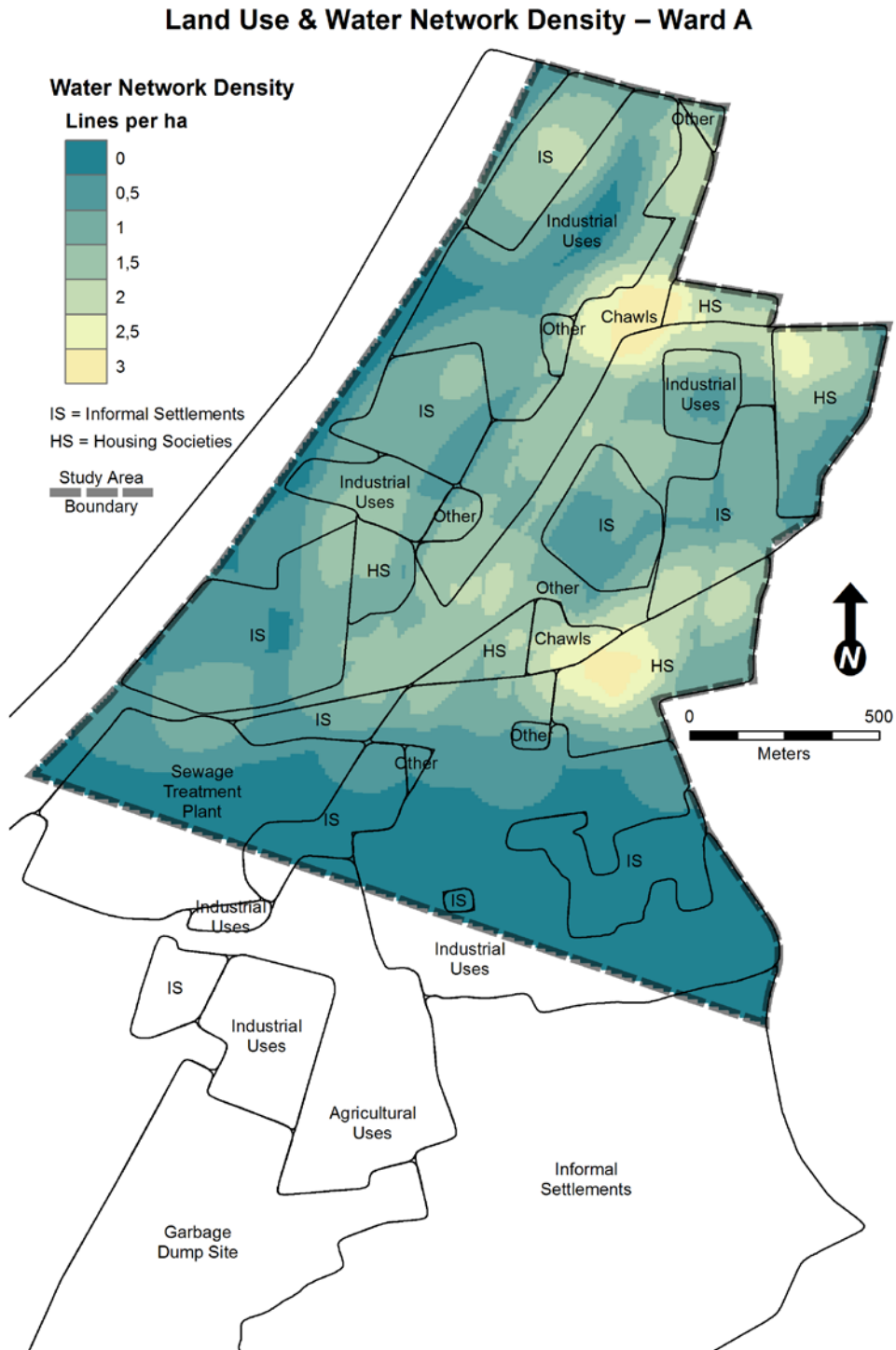
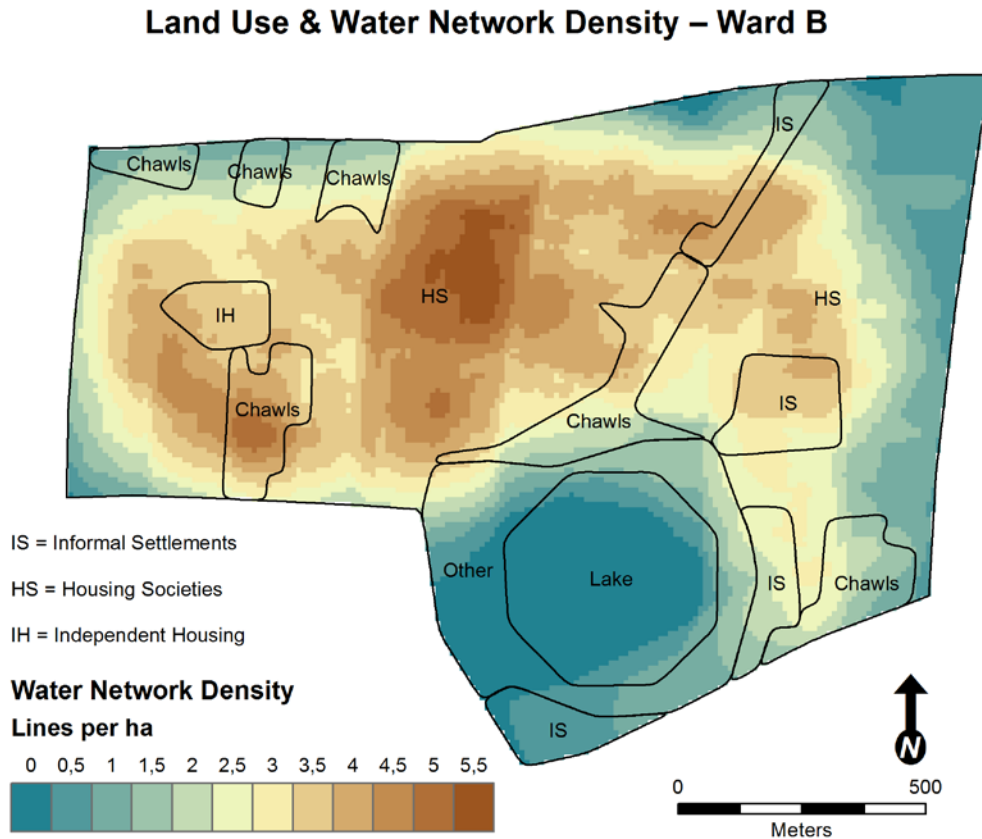


Figure 2: Land Use and Water Network Density - Ward B



4.1 Leaking networks – Filthy environment

The spatial grids reporting high density of water networks reported higher incidences (hotspots) of water leakage (as in Appendix 3). It is interesting to note that in areas reporting lesser dense water networks also revealed higher incidences of water leakage, indicating many illegal water connections in areas around informal settlements where households tamper with pipelines resulting in water leakage. In Ward A, the water leakages are concentrated around the chawls in the north, in the informal settlements of the central and western portions, and in housing societies adjoining the informal settlements in the north. In Ward B, water leakages are concentrated in the chawls in the southeast, at road junctions and around informal settlements in the central eastern and southeastern areas of the ward.

Leakages are a menace for both the people and the city engineers; when the pipelines are encroached upon by the residents. Encroachment is so rampant, that many of the residents are living on top of the sewerage and drinking water lines, a highly dangerous situation. Frequent deaths due to the release of poisonous gas from the sewerage lines are widely reported (The Times of India, 2013). The situation is not different in chawls and informal settlements where water leakage added by with water logging during rainy days are conducive for breeding vectors, expose people to contaminated water. Grabbing of public space and water resources prevents engineers from carrying out any maintenance activities.

Elected boards in the housing societies take care of the water problems in the lower-and middle-class households, by mediating between households and state authorities. In contrast, it is the political workers (in very few settlements, the households in informal settlements have formed societies) who are “caretakers” in chawls and informal settlements that have many illegal water connections in the ward, who mediate between households and state authorities through their (political) leader. At the same time they also legitimize and protect the illegal water connections. The elected boards in housing societies and political actors make claims over this infrastructure to reveal their political role and legitimize their residents’ tactics to access water. The leakage increases the chances of sewage contamination in drinking water pipelines that makes the households vulnerable to gastroenteritis and jaundice. Overflowing sewage water contaminates the drinking water pipes, leading to puddles, where children and even adults in informal settlements and chawls get exposed to the spreading bacteria and other pathogens. This phenomenon, combined with rain waters and open defecation in these settlements, allows flies and pests to breed in the water pools. The DoE and the Medical Department at the AMC are often blamed for poor urban health. One of the junior engineers pointed out, “given the strong nexus between politicians, our bureaucrats and the urban poor, it is impossible for us to evict these people and rehabilitate the existing networks.”

4.2 The ‘Pepsi’ waters: Injecting polluted water

The drinking water quality complaints reveal the people’s desire to access good-quality water. As a former municipal councilor of a ward put it, the households receive “Pepsi-like water,” with a black color, similar to soft drinks, visible for the first few minutes of the two hours of water supply. It is not just the color but also the accompanying smell that makes the water undrinkable. Poor water quality hotspots are found to be around the chawls and in informal settlements (as in Appendix 4). Few hotspots are also found around housing societies that are adjoining the chawls and informal settlements, indicating probable contamination across settlements. In Ward A, the hotspots of poor water quality are around the chawls in the north and in the informal settlements in the west and the central area. In Ward B, the hotspots are around the informal settlements built by private developers in the eastern central area (that is considered to be illegal settlement by the AMC), and to a lesser extent in the planned areas. Interestingly, poor quality of water was not an issue for the informal settlements around the lake in Ward B.

Early-morning (just after 6.00 AM when the water is released) visitors to chawls and informal settlements witness many households using cloth, stained brownish from continual exposure to the water, to filter the sediments and foul-smelling water. The absence of this ritual does not mean that housing societies receive a higher grade of water; rather, they have enough resources to treat the water in-house (e.g., with aqua guards and reverse osmosis plants). A former councilor for Ward A states that foul water is one of the reasons for their ward reporting one of higher incidence of gastroenteritis than the city average. The incidence rate of gastroenteritis in this Ward was 379 compared to city average of 100 in 2012. The former councilor insists that, after regular petitioning, in the last few years the corporation has been replacing the old pipes in Ward B. The task was not easy; the DoE’s junior engineer reports that evicting the encroachers, who are often supported by this councilor’s political workers, is a highly challenging duty without which “we cannot guarantee the quality of water in these wards”.

A junior engineer revealed that the problem of poor water quality occurs due to contamination between the distribution point of the treated water and the receiving end in the household. Chaotic alignment of water and sewerage pipelines caused by encroachment, aging pipelines and illegal water connections remains the main cause. The junior engineer explained that the distance between the drinking water and sewerage pipelines should be at least 1 foot. Contradictory to engineering specifications, many current networks (especially the tertiary pipelines) were less than 1 foot apart, sometimes adjoining to each other, with one pipe above or below the other (the research team were

informed that in some areas, the drinking water pipelines actually goes through the sewerage pipelines that has a larger diameter, but we did not come across them in the survey). The close spacing of these pipelines has severe consequences on public health. As the drinking water flows through gravity, it has low or no pressure throughout the day, excepting during the two hours water supply in a day. By contrast, the sewerage lines are always full and have high pressure throughout the day, as these pipes are at least 50 years old catering to the then population and are not able to accommodate the current demand. Therefore the sewerage lines are always full. All these pipelines have rubber joints, which expands and contracts due to high diurnal variation in the temperature (average diurnal temperature range to about 10 degrees in winter and summer), creating the space for leakage. Because of the close proximity of the pipelines, the high-pressure water from the sewerage pipelines easily enters the drinking water pipes when there is no water flowing during for much of the day. This unhealthy mixing increases when the pipes are old, when rains cause waterlogged ground, when pipelines are tampered during illegal connections, during summer's higher intake and when domestic or industrial wastewater is disposed off in an open area. Water logging is common in the chawls, in the informal settlements and in the housing societies adjoining them, often in low-lying areas that encourage the breeding of pathogens. Water logging in the chawls and informal settlements could contribute to higher incidence rates of gastroenteritis and jaundice.

4.3 Low water pressure - less pressure on diseases

Pressure is important for the urban authorities who construct high rise water tanks to ensure water flows to every household with the use of gravity. Households tend to gain more access to the water using various strategies. Households living in bungalows and housing societies use pumps to draw more water and use storage tanks to store excess water for their daily need. These settlements have concrete structures and enough money to install pumps and construct storage tanks inside their houses. The hotspots of the low pressure are distributed around them (as in Appendix. 5). Given that they have legal water connections, they tend to report low water pressure and they also report fewer diseases. Interestingly, pressure is not an issue around the Chawls and informal settlements in either ward.

The chawls and informal settlements often regard low water pressure as a fact of life and do not report much about it, as many of them have illegal connections. One chawls resident complained that they store water in buckets and drums (in unhygienic conditions), and cannot install pumps in their house, as they depend on public standpipes. Some of them who have (illegal) connections cannot install pumps inside their house, as neighbors would question and report them to engineers or political workers. This situation differs from the housing societies with concrete buildings that muffle sound so that pumps operate without the knowledge of neighbors. Pressure tactics play well with the lower- and middle class households in the housing societies, but not in the chawls and informal settlements. The lineman for the DoE claims that, to improve flowing water pressure for the chawls and informal settlement households, residents sometimes lower their pipe connections beneath the main pipeline, and lower their sump (or the water collection point) underground (a few households are even reported to have underground storage tanks beneath their houses). Though these strategies may enable them to obtain a little more water it runs the risk of getting contaminated with rainwater, overflowing sewage water and run-off from roadside waters. Low water pressure was less significantly related to the occurrence of gastroenteritis, jaundice and malaria in both wards.

Water leakage, poor water quality, and low water pressure makes the city water problems visible and vulnerable to urban households to health burden. The occurrence of water problems spatially coincides with the distribution of diseases (Table 1; as in Figure. 3 and 4). Of the three water

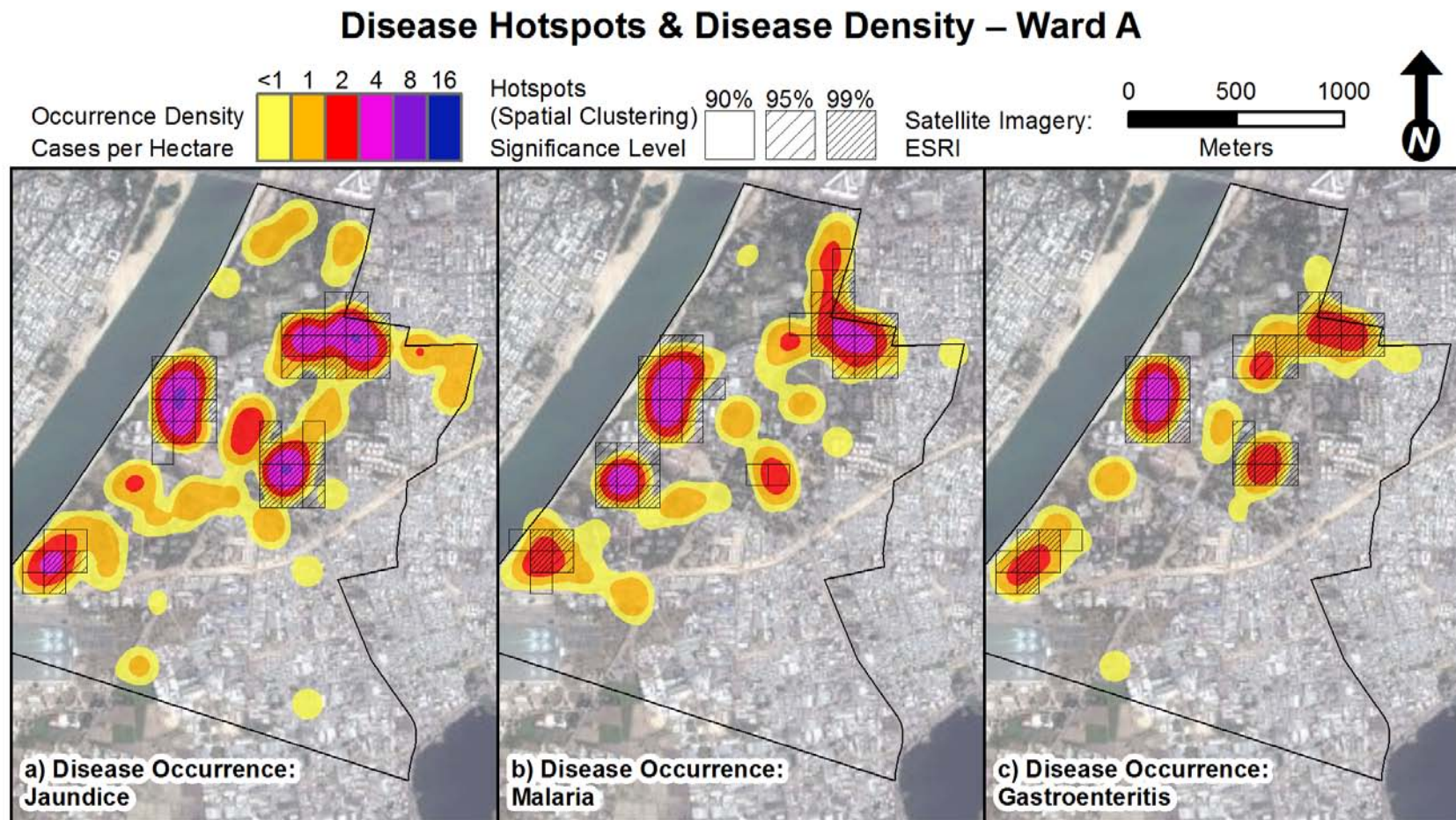
problems examined in Ward A, poor water quality and water leakage had a significant correlation (with r value of more than 0.60) to all the three diseases examined, compared to low water pressure (with r value less than 0.60). Of the three diseases, gastroenteritis showed a stronger correlation (with r value 0.76) to poor water quality, and jaundice showing a stronger correlation (with r value 0.76) to water leakage. The stronger correlation could only be explained due to infectious nature in a particular context. In Ward B, due to absence of gastroenteritis data, jaundice showed significant correlation (with r value 0.65 and 0.51) to poor water quality and water leakage, respectively, compared to low water pressure. Malaria was significantly correlated to water leakage, probably water logging allowing breeding sites for mosquitoes. Comparatively Ward A displayed stronger spatial coincidence of diseases to water problems, compared to Ward B. This could probably be due to higher informal and chawls types of settlement and proximity of solid waste disposable site, wastewater treatment plant and vast agriculture land.

Tab 1: Spatial correlation of water problems and health burden in Ward A and Ward B

	Ward A		Ward B	
	<i>r</i>	Level of Significance	<i>r</i>	Level of Significance
<i>Water Leakage</i>				
Gastroenteritis	0.68	0.01	NA	NA
Jaundice	0.76	0.01	0.51	0.01
Malaria	0.69	0.01	0.37	0.01
<i>Poor Water Quality</i>				
Gastroenteritis	0.76	0.01	NA	NA
Jaundice	0.69	0.01	0.65	0.01
Malaria	0.68	0.01	0.14	0.05
<i>Low Water Pressure</i>				
Gastroenteritis	0.58	0.01	NA	NA
Jaundice	0.59	0.01	0.25	0.01
Malaria	0.56	0.01	0.03	0.69

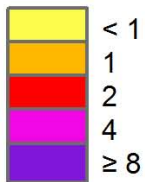
^a Gastroenteritis information was not available for Ward B

Figure 3: Disease Hotspots and Disease Density - Ward A

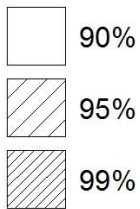


Disease Hotspots & Disease Density – Ward B

Occurrence Density
Cases per Hectare



Hotspots
(Spatial Clustering)
Significance Level



Satellite Imagery:
ESRI

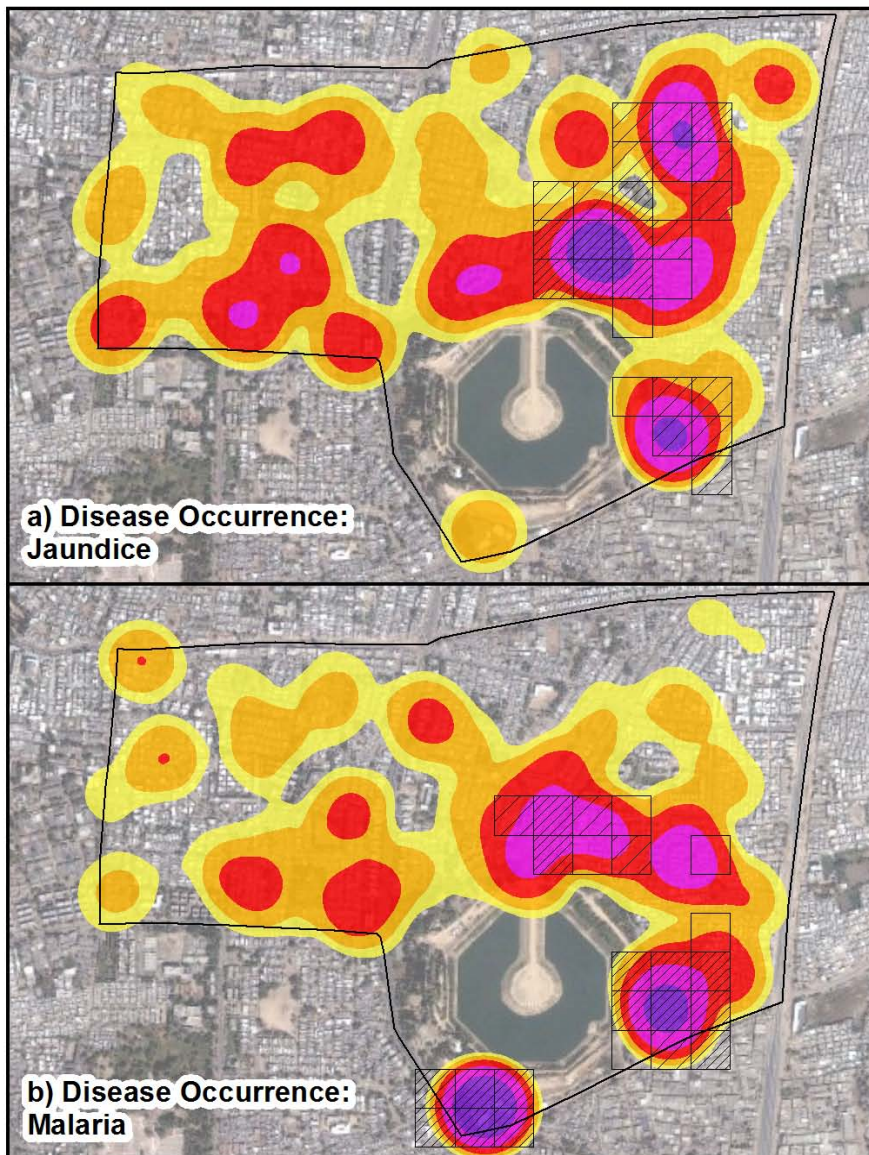


Figure 4: Disease Hotspots and Disease Density - Ward B

5 Emerging hydraulic disease: Situated understanding of the urbanism in India

The article provides a situated understanding of the semiotic and aesthetic elements of urban water and its health burden in Ahmedabad city. Studies on urban metabolism have provided important insights in the material and socio-political issues associated with the flow. Building on these conceptions, the article focuses on the hybridization concept of infrastructure, where the social element are not separate from purely technical functions, but are forms of expression through which households struggle to establish their urban space. Wide disparities in the settlement pattern and inefficient management of urban infrastructure that characterize urban space are deeply rooted in the colonial legacy of segmented planning and administration that are exploited by diverse actors (international and national agencies, private companies, politicians, and people of all classes) to reproduce the same creating conducive environment for breeding of water- and vector-borne diseases. This represents a vicious cycle of poor management, and breaking this cycle for a desired change requires innovative alternatives that fit with the context of urbanization in the south. Drawing on the urban metabolism, urban political ecology and technopolitics approaches the article provides critical insights on the hybridization of everyday water problems that give structure and coherence to urban space. A socio-spatial understanding not only reveals how the urban poor are pushed towards the margins, but also identifies the socio-political drivers of the water problems, drivers of disease emergence and identify potential hypothesis of the hot-spots of disease emergences. This could be effectively used by government agencies to improve planning and monitoring of water problems and its health burden.

The article contributes to the growing studies (Bakker et al., 2003) on the spatial coincidence of water network with socio-economic and hierarchy of the settlement pattern, but argues that the spatially segregated households are actively involved in reshaping their access to water and sanitation using their powers of social connections at the cost of their health. The households living in bungalows, given their economic dominance and better housing, could apportion a greater quantity and quality of water by installing pumps, storing and treating water, and maintaining environmental hygiene in and around their house. The diverse technology applied by these residents leads to the proliferation of low water pressure around these settlements. Given their better access to water and higher economic status, they could also afford improved health care. Greater usage by the head-reach residents obviously deprives the middle-reach and tail-end users. The housing societies located in the middle-reach struggle to meet their growing needs by using pumps, increasing water storage within their homes, encroaching the public space and by commissioning illegal water connections to consume a greater quantity of water. This increases water leakage and contaminates the drinking water, significantly affecting the tail-end users (chawls and informal settlements). These residents are often provided water through public standpipes and limited private connections. Though it is true that water infrastructure networks benefits the rich, the residents in the chawls and informal settlements, who are segregated and deprived, gain access to water through illegal connections, using substandard water-treatment methods and storing water at home in unhygienic containers. Complicated by poor environmental hygiene and inadequate sanitation, the situation is conducive for the spread of jaundice, gastroenteritis and malaria among the tail-end users and their adjoining middle-reach housing societies. The powers of social connections, claims over the right to water are all negotiated to gain access to water at the cost of ill health.

In this struggle to shape and reshape urban water, households make the infrastructure visible through everyday reporting of the water problems. It is through this reporting that urban residents display their diffuse power to reveal their desire for improved management and to gain access to water. Unfortunately all of this takes place at the cost of human health. The reporting of water leakage and poor water quality are closely related to poor housing quality, inferior water

infrastructure and deficient environmental and social hygiene in the chawls and informal settlements in both wards, which has significant effect in the occurrence of water-borne diseases (jaundice and gastroenteritis). Being located at the tail end (with the lone exception of the chawls in Ward A that border the main pipeline) of the distribution network, they bear the brunt of poor governance and diverse strategies adopted by households in the housing societies, a situation which is aggravated with their own illegal water connections, low economic status and encroachment on public lands. The high number of reporting of water leakage and poor environmental conditions in the informal settlements is conducive to the breeding of pathogens in the settlements, which could cause high occurrence of malaria and jaundice in wards. Low water pressure is a growing issue in housing societies and bungalows who have legal water connections, but does not reveal a stronger effect on water- and vector-borne diseases. Although the diseases are significantly clustered around the chawls and informal settlements in both the Wards, the housing societies (largely of middle class households) surrounding them are not spared, because of the interconnected nature of the infrastructure and social mobility. This is in contrast to wide held view that the middle class are insulated from the availability of antibiotics and therefore could avoid the effects of poverty (Chaplin, 1999). Contributing to the growing literatures on the hybrid conception of infrastructure (Latour, 2004; Anand, 2011; Larkin, 2013; Lawhon, 2013), the article reiterates the importance of examining the socio-spatiality of the everyday problems to build on the urban metabolism discourses for improving resource efficiencies in cities of rapidly growing economies.

Improving water infrastructure in urban areas is absolutely essential to the growth and health of cities in the developing countries. There are many technical, medical and socially-engineered advances to address water supply and sanitation in urban regions, but turning the tide against these killer diseases threatens to be an ever-growing problem. In the West, water infrastructure and system improvements made it possible to sustain and further the industrial revolution and the development of wealth. In the developing countries highly-contested urban spaces with a complex socio-political environment require an alternative for creating change. This is complicated with poor information on water infrastructure and public health. The methodology adopted in the article offers insights for documenting micro-scale information, from the complaint Registry Books and Department of Health's dual tacking methods that could prove vital for research and for the local government to improve their surveillance and monitoring of water and health outcomes. Though we expect many unreported cases of water problems and occurrence of diseases, the existing information, if made available in a meaningful form could be shared with various stakeholders to communicate the health risks thereby ensuring transparency and accountability. It also intends to help the urban utilities and planning agencies to efficiently integrate water system planning and demand forecasting, design centralized and/or decentralized water infrastructure, and develop recycling facilities to manage water losses. Such improvement can be targeted to the sites that are suffering the maximum health impact. This will lead to the most efficient improvement of water infrastructure with the most desirable health impacts. This indicative relationship could be explored further with contextual information on household density, household socio-economic status, household hygiene practices, health care practices and environmental hygiene to understand better the various significant factors influencing human health. Superimposing these data with spatial information of infrastructure and the occurrence of diseases will offer more insight into the potential forces behind the socio-spatiality of infrastructure and its implications for urban health.

Acknowledgments

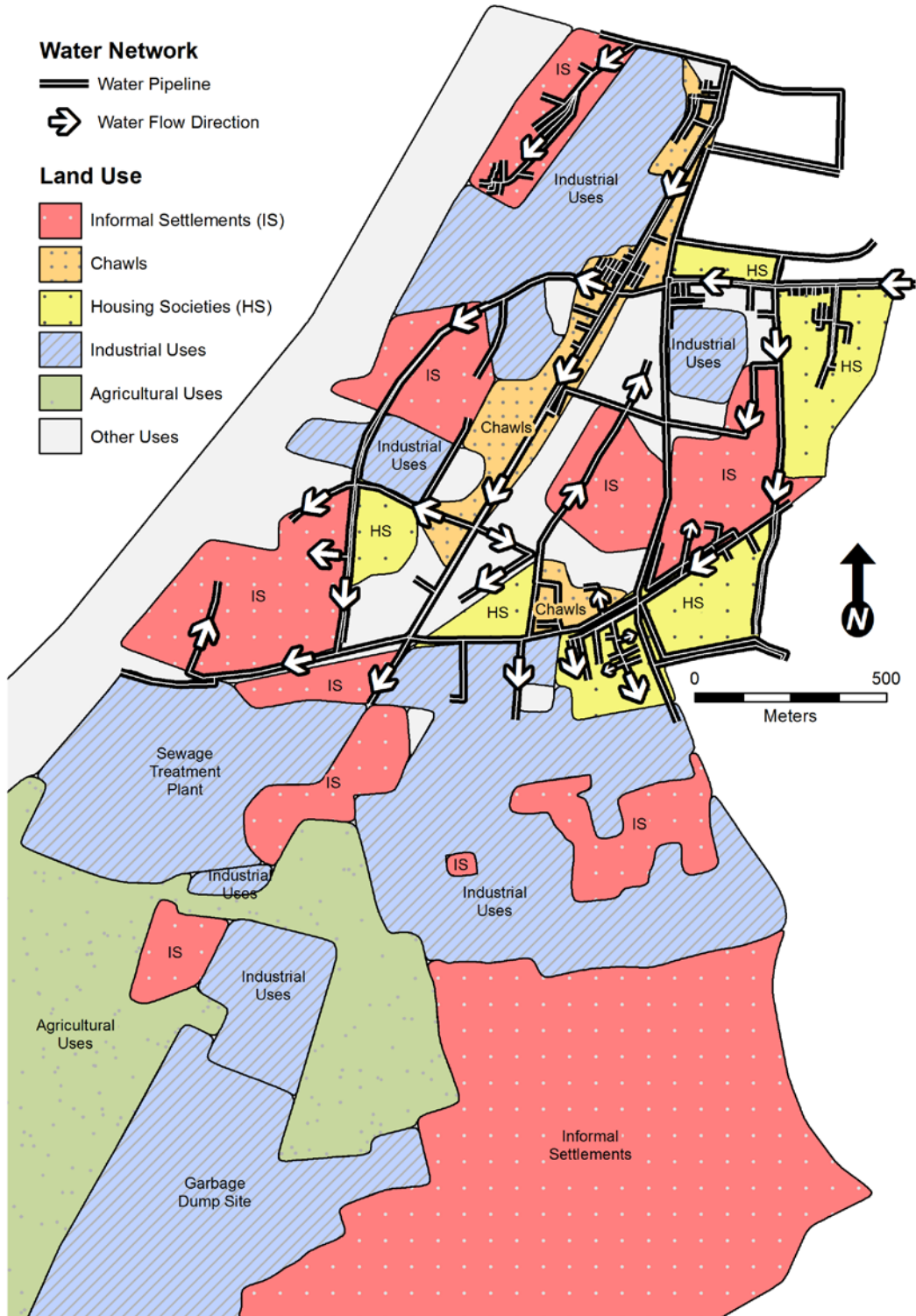
The authors are grateful to the German Research Foundation (Deutsche Forschungsgemeinschaft [DFG]) for supporting this research under the project "Water Resources Institutions and Human Health in Ahmedabad, India." The paper was enriched with the comments from Prof. Darshini Mahadevia and Dr. Anna Zimmer on the earlier draft, and four anonymous reviewers. The usual disclaimers apply.

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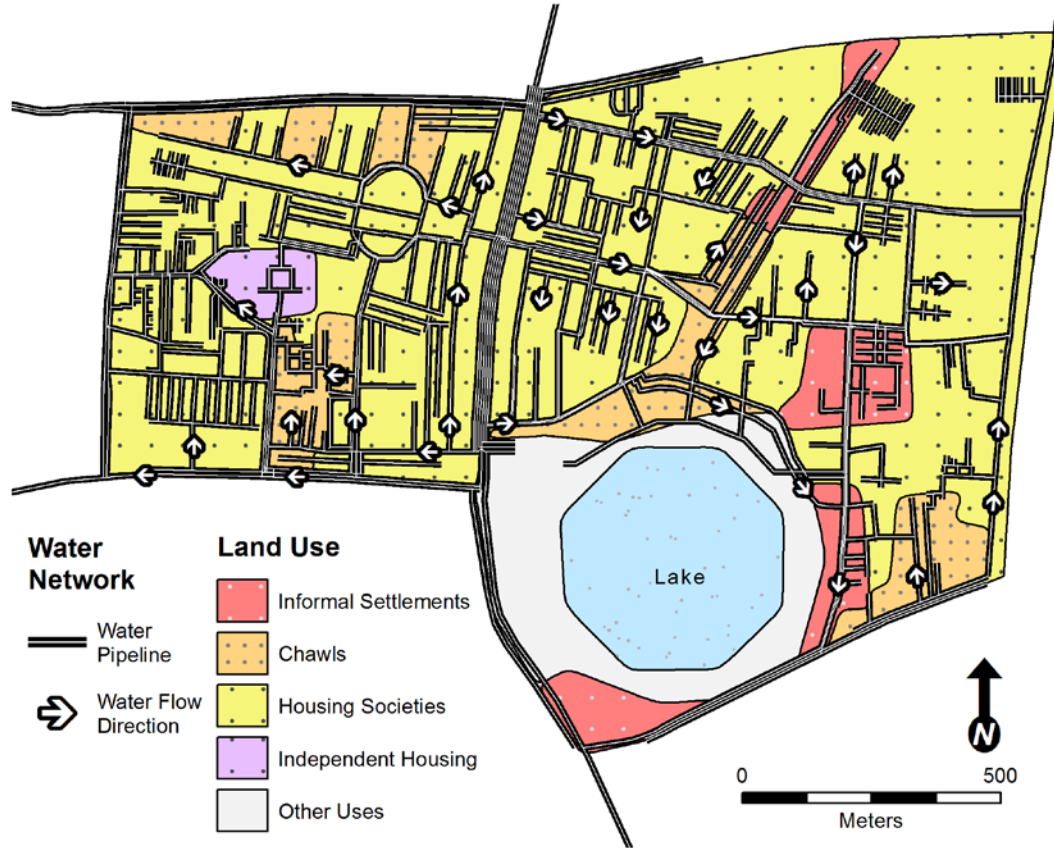
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Land Use & Water Network – Ward A

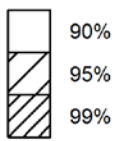


Land Use & Water Network – Ward B

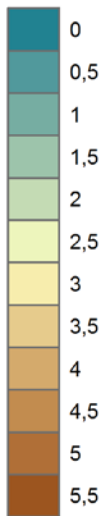


Hotspots of Water Leakage & Water Network Density

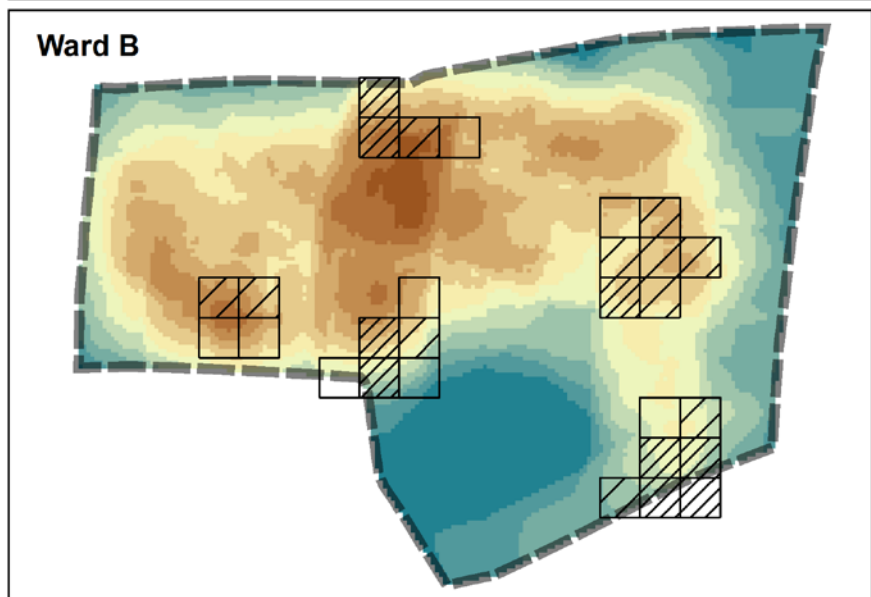
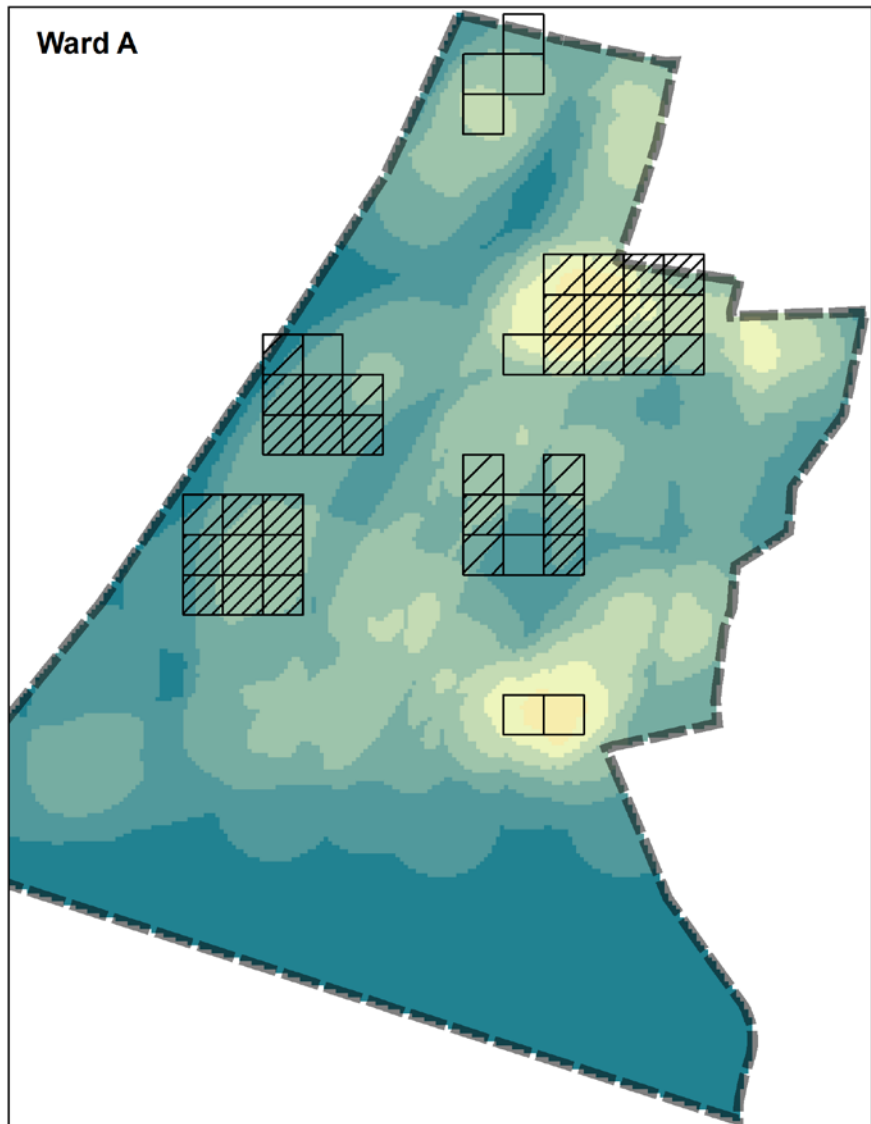
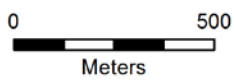
Water Leakage Hotspots Significance Level



Water Network Density Lines per ha

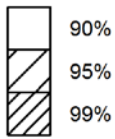


Study Area
Boundary

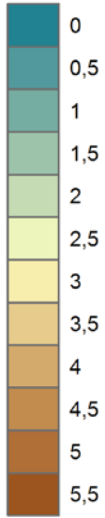


Hotspots of Poor Water Quality & Water Network Density

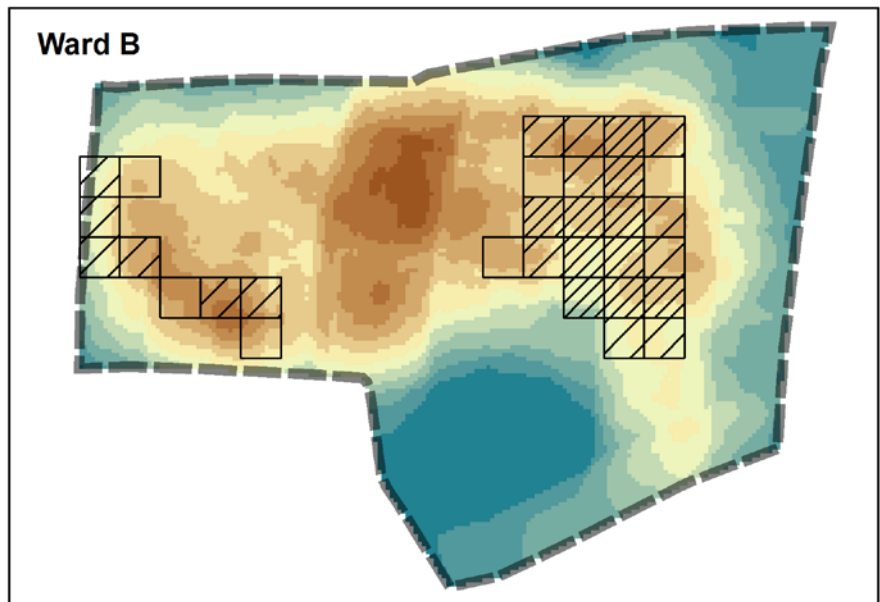
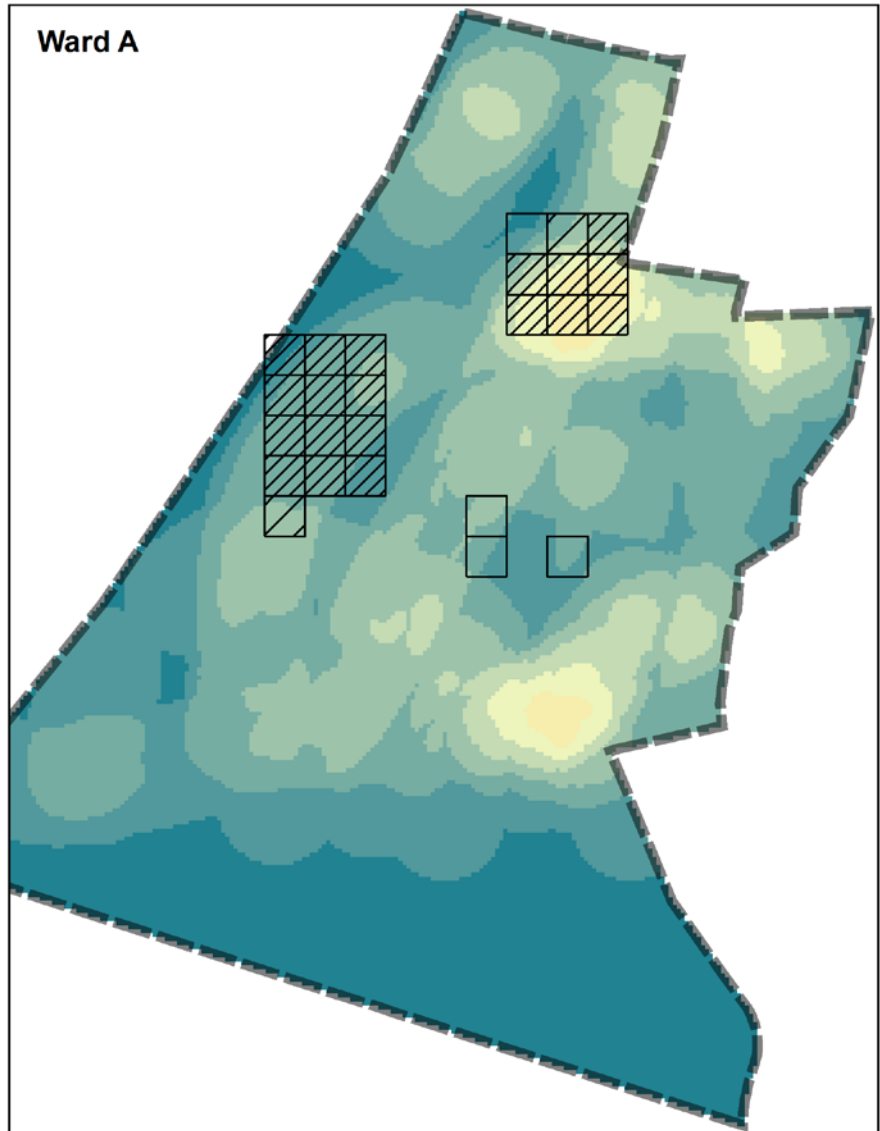
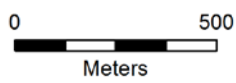
Poor Water Quality Hotspots Significance Level



Water Network Density Lines per ha

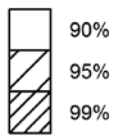


Study Area
Boundary

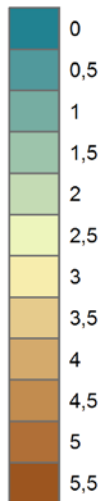


Hotspots of Low Water Pressure & Water Network Density

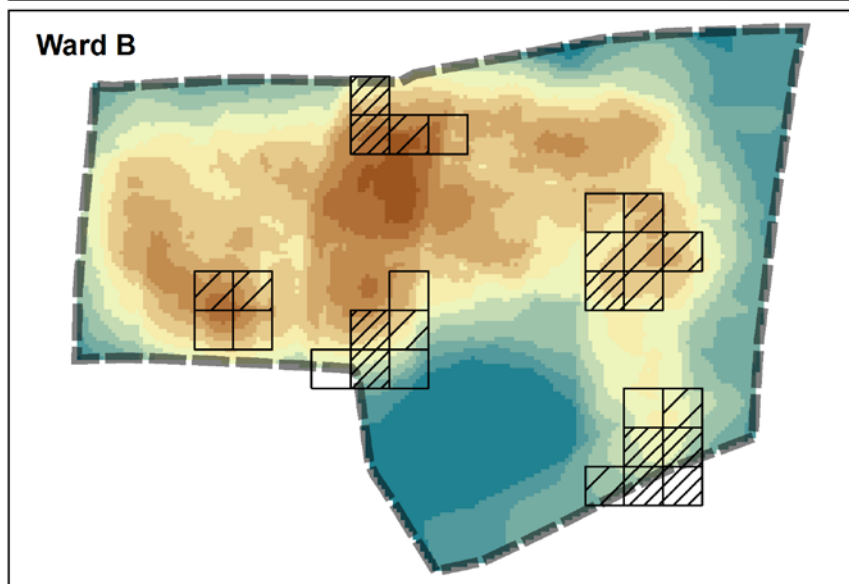
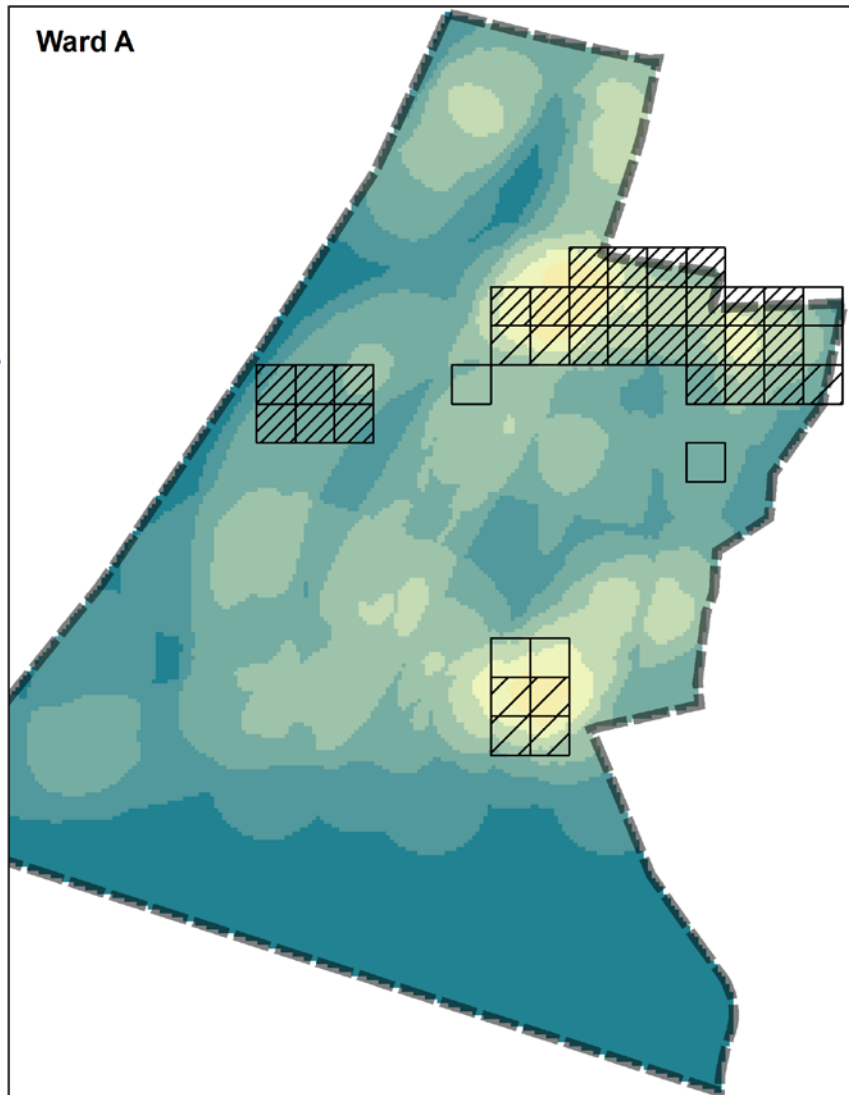
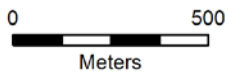
Low Water Pressure Hotspots Significance Level



Water Network Density Lines per ha



Study Area
Boundary



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Authors: Saravanan, V.S., Mavalankar, D., Kulkarni, S., Nussbaum, S. and Weigelt, M.

Contacts: s.saravanan@uni-bonn.de; dmavalankar@iiphg.org; suhaspkulkarni@gmail.com; svennu@uni-bonn.de and emeswe@gmail.com

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