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Towards sustainable urban sanitation: A capacity-building approach to wastewater mapping for small towns in India

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Abstract

Decentralized technologies and city-based governance are being actively promoted for urban sanitation in low-income countries. At the same time, municipal agencies in developing countries have little technical or financial capacity for sanitation planning. This paper develops an approach to sanitation planning that leverages citizen engagement and fosters local capacities. It presents an empirical study from two small towns in India, where collaborations among the research team, local academics and students, and the municipal government, produced planning-oriented sanitary maps of each town. The maps were built upon a social and spatial understanding of the diverse sanitation practices that already exist, coupled with Google Earth and free GIS software. The “waste watersheds” and “sanitation zones” identified through the mapping process provide a basis on which sanitation interventions can be assessed and weighed, so that sustainable solutions can be prioritized. The paper identifies three features for system interventions: first, making local municipal government the locus of sanitation interventions; second, engaging community-based organizations and academic institutions to develop local capacity; and finally, recognizing the fragmented nature of cities by developing a socio-spatial approach to sanitation zoning.

Key Words: sanitation planning, sanitation zones, waste watersheds, participatory mapping, capacity-building

Introduction

Sanitation and wastewater management in urban India have suffered historical neglect, first under colonial rule and later within a post-colonial state (Chaplin 2011). Though “WATSAN” infrastructure has received sizeable investments since 2005, the pace of change of sanitation on the ground has been slow (Planning Commission of India 2011; UNICEF and WHO 2015). Most of these investments have prioritized new construction over maintaining or managing existing facilities. For example, in 2014, the Government of India launched a national campaign (*Swachh Bharat* Mission), to dramatically expand access to toilets. The bulk of the urban allocation has gone into latrine construction and municipal waste management, with little left for safe fecal sludge disposal, education and communication, or capacity-building and administration[1].

The focus on expanding urban sanitation through infrastructure has deflected attention away from broad public health concerns towards a narrow technocratic endeavor, characterized by large investments in centralized systems, with flush toilets and water-borne sewer systems geared towards the better-off neighborhoods (Schertenleib 2005; McGranahan 2015). These consultant-intensive, capital-intensive and water- and energy-intensive pathways have exposed the water and sanitation sector to cost overruns, delays and inefficiencies, with highly skewed consequences for equitable and sustainable wastewater management (McConville *et al.* 2011; Larsen *et al.* 2016). The Census of India shows that 12.2 per cent of urban households still defecate in the open (meaning, without a toilet) and only 32.7 per cent are connected to a piped sewer system (Central Public Health and Environmental Engineering Organisation 2012). The capital intensity of conventional waste management systems has severely handicapped the ability of Indian cities to extend service provision; thus informal practices of sanitation and waste removal persist in most urban areas.

What sewage treatment capacity exists in India is concentrated in the largest ("metropolitan") cities with populations of over 1 million; these cities generate approximately 40% of the country's wastewater (Planning Commission of India 2011). Smaller cities and towns have found it extremely difficult to extend sewerage services, in part because they rarely have enough water, uninterrupted power supply, skilled staff, capital, or planning capacity. The passage of the 74th Amendment to the Indian Constitution in 1992, which encourages self-government in matters of

[1] See: http://www.cprindia.org/research/reports/budget-brief-2017-18-swachh-bharat-mission-urban [Accessed July 24 2017]

urban planning, has placed pressure on small town governments to manage – and finance -- their own water supplies, wastewater and solid waste. Yet twenty years of published research have consistently argued that urban local bodies (ULBs) in smaller cities do not have the technical, managerial, or financial capacity to take on the necessary water and wastewater management tasks (Indian Council for Research on International Economic Relations 2011; Rosenqvist *et al.* 2016). The staff members of small-town water agencies often lack even basic information on waterways and drains, or on the most prevalent sanitation practices, in different parts of their town.

This insight and its implications are not specific to India. Rosenqvist *et al.* (2016) note that the lack of sanitation service is now understood to be in part a crisis of urban governance, in need of community-based participation and "appropriate" technologies. Scholarship on sanitation planning has embraced sustainable sanitation through a mix of heterodox technological and governance options (Kalbermatten *et al.* 1999; Kvarnström & af Petersens 2004) and has evolved in the last thirty years from an engineering focus to a more participatory and user-focused future (Lüthi *et al.* 2011; Parkinson *et al.* 2013; Kennedy-Walker *et al.* 2014). Despite this shift, a top-down, non-systematic approach remains pervasive in urban sanitation exercises.

This study proposes a systematic and collaborative approach towards a situational analysis (i.e. understanding baseline conditions) of the wastewater system at the town level. We propose a bottom-up sanitary mapping method that reflects the social and spatial arrangements of small-town India, with local participation to make it contextual. Our primary goal is to develop a replicable and inclusive method for data collection, sanitation mapping, and sanitary problem diagnosis for small towns that are governed by under-staffed and under-resourced urban local bodies. Our secondary goal is to break down the often-cited binary of collaborative versus practical – we argue that, to map the sanitary city in light of our current low levels of knowledge, the collaborative *is* the practical (see also (Lüthi *et al.* 2011; Abeysuriya *et al.* 2016). Systematic sanitation planning needs data and maps and capacity, all of which are unreliable in small-town India. Our study is a practical (rather than ideal) capacity-building approach towards mapping wastewater flows and sanitation practices as a step towards sustainable treatment solutions.

Persistent problems despite paradigm shifts in sanitation planning

In recent decades, there has been a steady development in alternative technologies for wastewater management that prioritize wastewater treatment close to where it is created (Nelson & Murray 2008; Larsen *et al.* 2016). Sanitation has been conceptualized as a closed-loop service linking together diverse technologies and actors from waste generation to reuse(Tilley *et al.* 2008). These systems are meant to ensure that solutions are based on local skills and materials, place a lighter burden on communities for maintenance and asset replacement (Carrard *et al.* 2010) are needs-based (Kvarnström & McConville 2007), and are driven by locally-recognized priorities (Parkinson *et al.* 2013). The frameworks within which these systems are proposed usually incorporate normative concerns such as participation, affordability, and accountability. The attendant policy recommendations are often founded on the unspoken assumption that unserved individuals, given the correct set of incentives and policy environment, will choose low-footprint 'alternative' approaches to sanitation over conventional centralized approaches. Despite efforts by the Indian government to promote these technologies in its National Urban Sanitation Policy (NUSP) (Central Public Health and Environmental Engineering Organisation & Japan International Cooperation Agency 2013; Ministry of Urban Development 2013), their realization remains limited to philanthropic, non-governmental or private sector projects.[2]

In reality, there is no blank slate of the urban unserved; those without formal services find semi-formal or informal means of arranging for their sanitary and waste disposal needs. In their thorough review of sanitation planning frameworks, Kennedy-Walker *et al.* (2014) call for an iterative planning process based on understanding what is on the ground already and of the capacity of existing systems – technological and managerial -- to address specific problems. In

[2] See, for instance, DEWATS technology promoted by the Consortium for DEWATS Development, (http://www.cddindia.org/) and Auroville (http://www.auroville.org/contents/1127). The Ministry of Urban Development (MoUD) also launched a Center of Excellence (CoE) in Decentralized Wastewater Management at the Indian Institute of Technology Madras in 2012, for conducting pilot projects (http://www.civil.iitm.ac.in/dwwm/); retrieved April 8 2017.

line with this argument, India's NUSP proposes to address urban sanitation gaps through city sanitation plans instead of the centralized (and unaffordable) prescriptions that are currently followed (McConville *et al.* 2014).

These needs- and practices-based efforts encounter multiple barriers. Citizens are not always equipped to organize or participate in collaborative planning (McGranahan 2015); the very planners that are supposed to encourage them to organize are not willing to cede power to lay citizens (D. Satterthwaite 2001). In practice, therefore, collaborative town planning efforts have had mixed results. There are examples of successful community-driven enumeration and mapping efforts (Patel *et al.* 2012; Banana *et al.* 2015), but other efforts have led to intended and unintended exclusion because of the need for cost-recovery (Das 2015) or the use of inaccessible mapping technologies (Chambers 2006). Larsen *et al.* (2016) conclude that a major barrier to adopting technological and organizational alternatives, even if they are more sustainable, is the inability of "water professionals" to disrupt their traditional practices. On the other hand, the constraints of capacity and resources that small-town governments have to work with make participatory efforts genuinely challenging (Indian Council for Research on International Economic Relations 2011).

We propose a replicable and potentially sustainable approach to a situational analysis of prevailing sanitation and wastewater practices by integrating three aspects. First, we treat the local municipal government (i.e. the ULB) as the locus of sanitation interventions, as no matter what technologies or governance mechanisms are deployed, town-wide scale-up needs the ULBs. Second, we engage community-based organizations and academic institutions to conduct household surveys and hold group discussions with lay citizens, as this helps to develop analytical, and possibly implementation, capacity in local colleges. This informed citizen oriented approach to participation has its limits, but may be more realistic in more small towns than broad-based citizen-led engagements. Third, we develop a simple socio-spatial "zoning" of the city by wastewater flows and sanitation practices, as integrating these into citywide planning is the first step towards sustainable urban sanitation. We present our maps from two small cities as illustrations, and the usefulness, of our approach.

Research Strategy and Methods

We chose two towns from Western Ghats region of India (see Supplementary Information Figure S1) —Alibag in Maharashtra and Nedumangad in Kerala. Alibag is a coastal tourist city with a population of about 20,743. Nedumangad lies ~20 km from the coastline of Kerala, and its population of 60,161 is growing by 7.17% annually (Government of India 2011a, 2011b). We mapped drains, developed “waste watersheds” and created “sanitation zones” for both towns. Waste watersheds are physical units and sanitation zones are socio-spatial in nature; we treat these as mutually constitutive. In this paper we present the waste watershed results from Nedumangad because of its contrasts due to topography, whereas Alibag, which is flat but has high variation in socio-economic conditions, provides the more interesting sanitation zone mapping.

Figure 1 presents the sequence of steps our research team took to enter the communities, gain acceptance, learn about the perspectives of key stakeholders, conduct data collection, map waste watersheds and sanitation zones, and eventually produce a situational analysis report; this paper focuses only on the steps towards, and results of, the mapping exercise. We leaned on multiple participatory methods – such as transect walks, key stakeholder interviews, and focus group discussions -- throughout this process (Chambers 1997). We created sanitary maps based on the Survey of India topo sheets and Google Earth. Household surveys using a pre-tested questionnaire were also carried out.

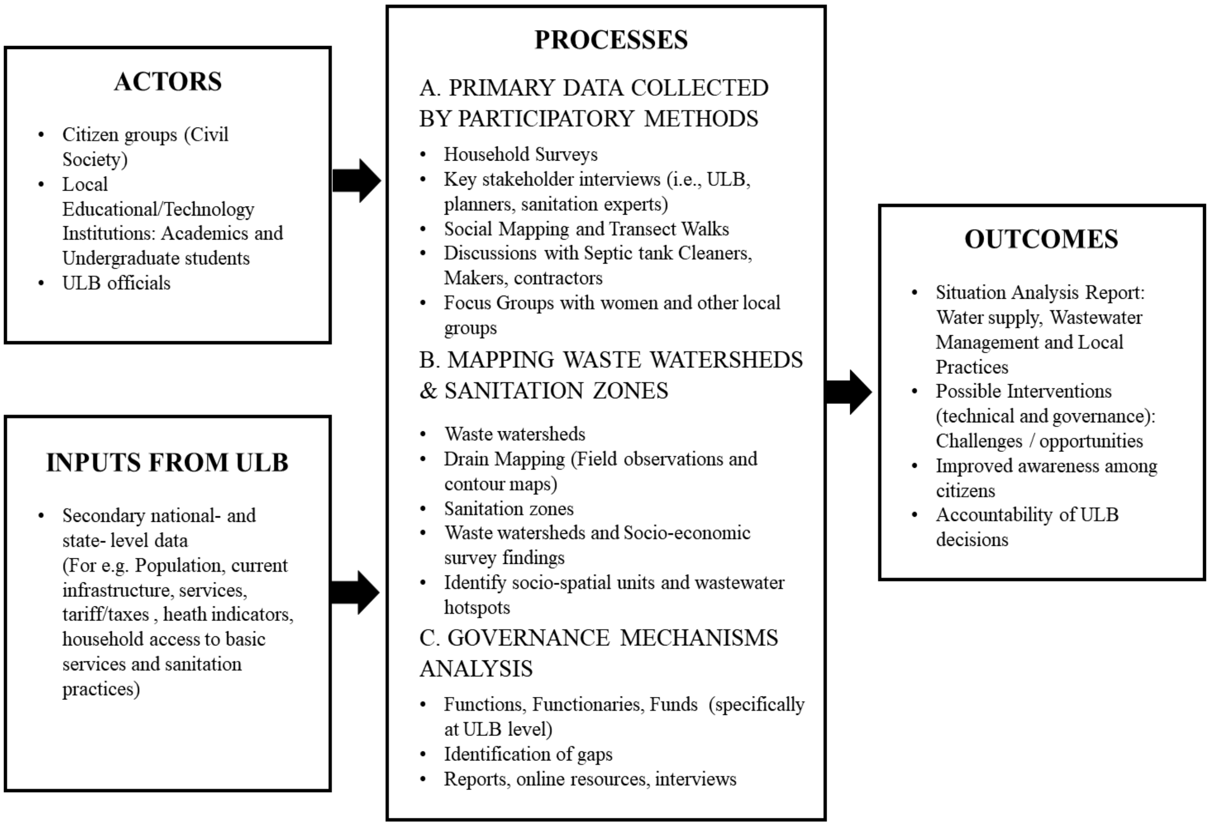

Figure 1: Elements of Participatory Situational Analysis: Sequence of steps in a collaborative situational analysis of urban sanitation and wastewater practices.

Citizen-based data collection

Our core method was to train students from local colleges and members of citizens’ groups to conduct surveys and focus groups, who then became the primary data collectors. Students and women’s groups communicated with the study respondents in the regional languages, and helped in understanding people’s experiences with water and wastewater. Our rationale was two-fold: (a) to make students and colleges, over time, repositories of knowledge with analytical capabilities for water and sanitation planning; and (b) to develop a cadre of public officers to make urban local bodies knowledgeable about, and accountable for, infrastructure provision and maintenance. The survey was conducted in Alibag in December 2015 and in Nedumangad in May 2016.

Household surveys were conducted mainly by local college students. The sample households were stratified (but not randomized) by slope of the surveyed area (i.e. upper, middle or lower), economic category (i.e. above or below poverty line) and social backgrounds (whether from marginalized sections, such as low-caste or religious minorities). The sample size was 350 households in Alibag and 700 households in Nedumangad; we sampled only households with access to piped water. Google maps helped to locate the households and ensure that the sampling covered all parts of the town for Alibag and the densely populated parts of Nedumangad. The survey questionnaire, launched after several pilot iterations, included details of water supply, water usage for different household purposes, disposal of wastewater from different household activities, water treatment and toilet use information, and feedback on municipal services in the wastewater and sanitation sector (see Supplemental Material S2).

It was challenging in these unmetered and intermittent households to assess the actual water consumption for household activities (see Kumpel *et al.* (2017)). We used two distinct but complementary approaches, both of which would be feasible to replicate in low-resource settings. First, we noted the diameter of the inlet water supply pipe into the households where municipal supply was available. Using city water supply information from the ULB, we estimated the quantity of water supplied through the town's Elevated Storage Reservoirs (ESRs) and, using the maps available with the ULB, estimated the population served by each of these ESRs. This generated a rough estimate of the per day water consumption in a locality, and thus of the wastewater, generally assumed to be 80% of water used. We also estimated per household per day water usage in our sample households; we either read the water meter in metered households, or used surveys to document the reported usage of water for the main household activities. The reported water use was, at best, a rough approximation of actual use, but it functioned as an order-of-magnitude check on our first set of estimates.

We observed where and how grey water is disposed of, documented this in household surveys and captured it using pictures/videos. We also documented sanitation practices, i.e., the types of toilet, methods of disposal, and paths of disposal (to the drain or to the ground). In Nedumangad, we measured the distance between the household well and the septic tanks/soak pits, given concerns regarding the pollution of water wells by septic tanks or pits. The most challenging component was to understand the disposal methods of the black water from the septic pit or tank. Very few surveyed households could tell us about this. In order to understand it better, we conducted group discussions and interviews with the local construction contractors who make septic tanks or pits, as the designs and specifications are context-specific.

Finally, we conducted interviews with officials in the public health and town planning departments, and with septic tank cleaning service providers. We observed flows, outfalls, and disposal sites of black septic water, thereby locating pollution hotspots (i.e. the points where the town's wastewater flows come together). Additional focus group discussions, especially with women's groups, helped us to understand the perceptions of sanitation and pollution from a cross-section of people, ranging from relatively affluent residents' associations in apartment complexes to fisher folk in the coastal stretches, where much of the pollution accumulates.

Drain Mapping and Delineating "Waste watersheds" (Nedumangad)

Guided by our survey data and observations, we mapped the town's drains through which wastewater flows traveled from households (and other sources). Typically, in small Indian cities, the storm water drains constructed along the roads also carry the grey water from households and wastewater from commercial units. Most of these reach natural streams or surface water bodies or groundwater aquifers. It is essential to understand these wastewater flows for wastewater management, yet few municipal governments in India have even rudimentary drain maps. We mapped the drains in six steps:

(1) Using Google Earth, we developed a base map of the study area.
(2) We marked the natural streams.

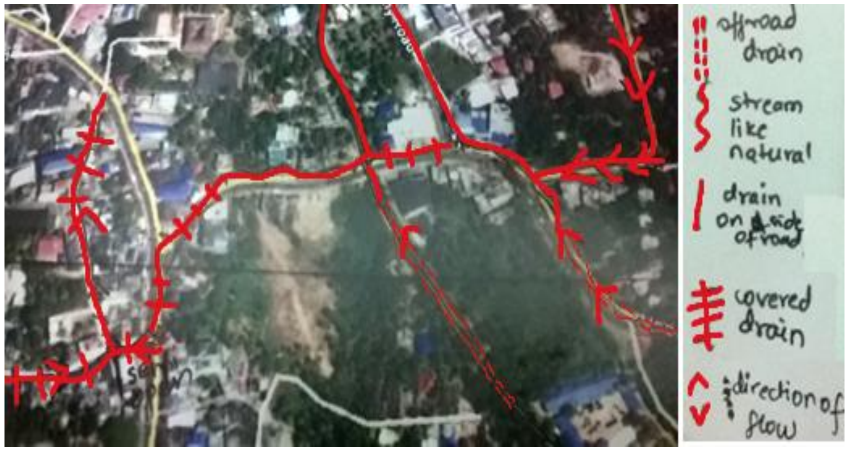

Figure 2: Sample field data collection map for drainage mapping

(3) Using the base map, we manually marked the flow direction of constructed drains using the mobile App GPS Tracker. Through extensive discussions with local people we identified major off-road drains. A sample of data collection from Nedumangad is shown in Figure 2, where field teams marked constructed as well as natural drains with different legends.

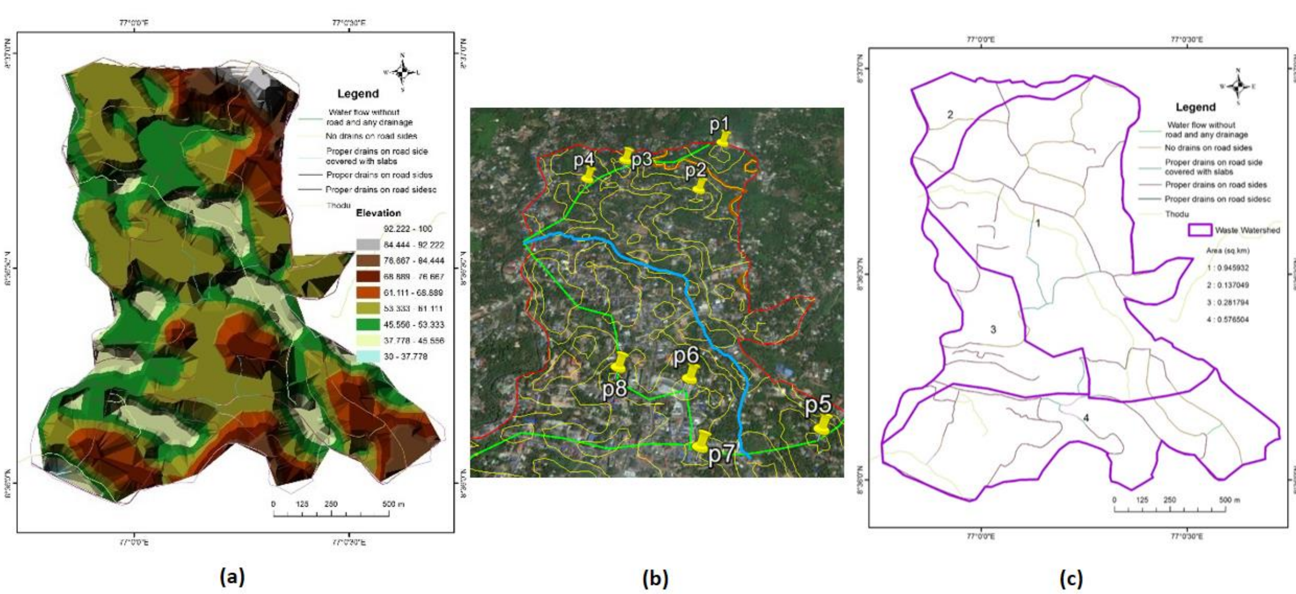

Figure 3: Steps in waste watershed delineation. (a) is Representation of physical terrain, elevations and streams over survey area. (b) shows in-progress watershed delineation using elevation information on Google Earth. (c) is the GIS representation of mapped data and delineated waste watersheds

(4) The digitized Google Earth maps were saved as KML shape files with their specific attributes (using ArcMap 10.2). The representation of the physical terrain, elevations and streams are shown in Fig 3(a).

(5) We used Google Earth to understand the terrain characteristics and contours, which helped in the delineation of watersheds.

(6) We delineated waste watersheds. Drawing from the methods for watershed delineation, the first step was to mark physical peaks in an area. Border lines were drawn connecting adjacent peaks by moving roughly perpendicular to the contour lines.[3] The slope directions were estimated using this method, as well as marking natural drainage. The polygons formed by these lines constitute the broad watersheds (Fig 3(b)). Waste watersheds were created in Google Earth and then converted within ArcGIS 10.2 software (Fig 3 (c)) by overlaying the earlier delineated constructed drains. Finally, wastewater hotspots (outfall locations combining major flows) were identified and geocoded.

Development of Socio-Spatial Sanitation zones (Alibag)

Waste watersheds determine and are determined by the spatial characteristics of settlements, water use, and wastewater generation and flows. Wastewater flows are also determined by the socio-economic situation of the users within this unit. The household survey data helped us to estimate the income status, type of houses, water use, wastewater generation and sanitation practices. These data were compiled to develop sanitation zones.

Sanitation zones simultaneously consider wastewater flows and the socio-economic situation and sanitation practices of the populace within the zone. This is achieved by using a composite assessment and delineation strategy based on the following factors: (1) habitation patterns (independent houses, apartment blocks, commercial/publicly owned buildings and government residential areas, and densely packed hutments), (2) waste watersheds; (3) caste and community characteristics; (4) sanitation practices (open defecation, type of toilets like pour or flush) and

[3] For a simple stepwise explanation of watershed delineation, see http://www.wvca.us/envirothon/pdf/Watershed_Delineation_2.pdf , retrieved on January 6 2016

type of waste disposal (soak pits, septic tanks, sewers). The habitation patterns were mapped from Google Earth and waste watersheds prepared as described above. The caste/community characteristics and sanitation practices were taken from the household survey. No sanitation zones were entirely homogenous, but they were useful approximations for correlating the dominant water disposal methods and socio- economic trends within a city. Such approximations are more informative than the current practice of considering the town as a single unit in conventional centralized sanitation planning.

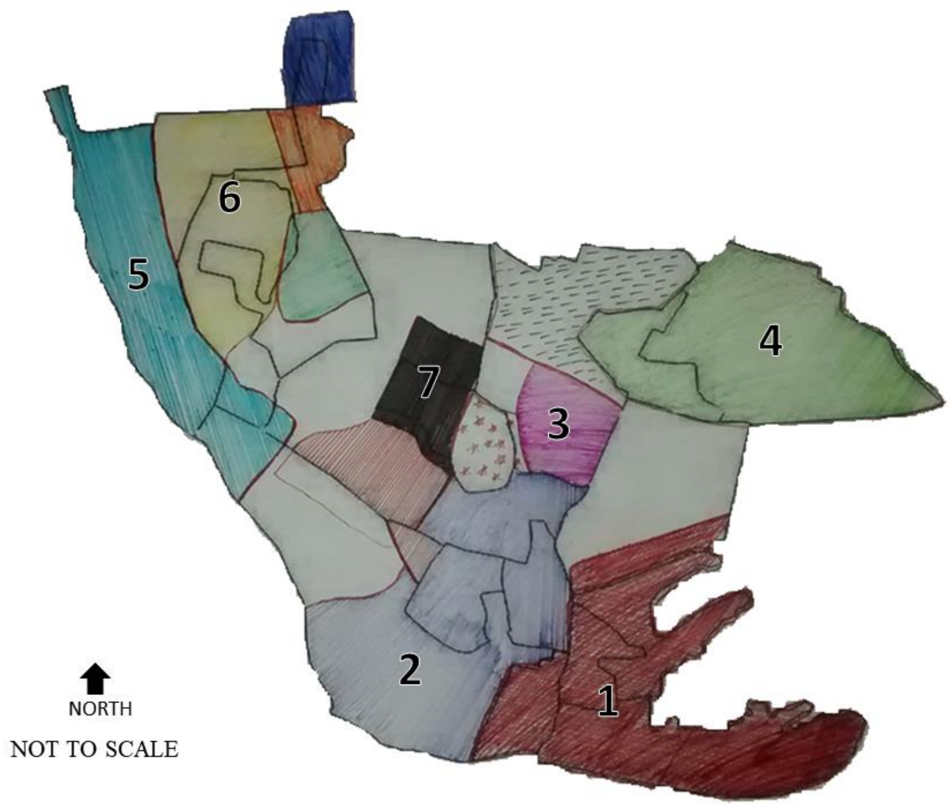

Figure 4: Sanitation Zones based on socio-economic and wastewater management (manually drawn) in Alibag

The sanitation zones for Alibag based on socio-spatial characteristics and wastewater flows are given in Figure 4 and Table 1. The brown zone in the coastal tract, for example, is at the receiving end of all polluted water and hosts the dumpsite of municipal solid waste. It is inhabited by the indigenous Koli community, who are fisher folk living in hutments near the sea. The wastewater is highly polluted here and occasionally floods during the rainy season. The zone has shared toilets but open defecation is common along the waterline. The sanitation problems in this area are severe, and will require a different management and treatment approach compared with other zones that are more sparsely populated, contain a considerable proportion of public land, and use soak pits extensively for grey water disposal.

Table 1: Sanitation Zones (Alibag)

Zone no.	Zone	Socio-economic Characteristics	Grey water management	Sanitation Practices	Intervention Needed
1		Lower income residents. Predominantly Koli fishermen and hutments.	Poor management	Open defecation very prevalent	Construction of Public toilets
2		Mix of apartments and bungalows. Middle and high income families	Gutters are stagnant.	Open defecation only in the eastern and northern boundaries of the zone	Needs better drainage by giving slopes to gutters
3		Very sparsely distributed houses	No usage of gutters with open discharge of grey water	Soak pits or open discharge of black water	Need construction of septic tanks
4		Spaced-out settlements with middle/high income groups	Use of septic tank or soak pit for grey water management. Gutters are completely dry in these areas	Adequately made septic tanks	No immediate priorities
5		Government buildings and very sparsely populated	Complete soak pit or open discharge or direct into sea	Very sparse use of toilets since mostly public buildings	
6		Police quarters and middle to low income residents	Complete soak pit or open discharge. Manholes constructed as part of the plan of construction centralized sewage treatment plan	Use of soak pits and septic tanks	Soak pits to be converted to septic tanks
7		Apartment dominated area with middle and upper income households. Also commercial establishments	All the gutters are narrow, shallow, closed.	Complete and adequate septic tank usage for black water	

The black and magenta areas are inhabited by more affluent groups and hence can be considered of lower priority for urgent sanitation interventions. Zones are not always homogenous; even the black zone is laced with pockets of slums and footpath houses with poor sanitation conditions and lack of access to water. The black water and septage collected by tankers from houses are also directly dumped into the water bodies of this zone. Thus the step-wise physical mapping and superimposition of socio-economic details allowed us to broadly understand which areas of the city produced most of the pollution, which were impacted most by the pollution, and where waste control interventions were most needed.

Going forward, ULBs and other city planners can use waste watershed and sanitation zone mapping as a tool to compare different methods of wastewater treatment, and to decide what wastewater infrastructure to prioritize and where to prioritize them. As an illustration of how our multi-method mapping approach could be used, a study by Jung (2016) on the feasibility of six potential sites for wastewater treatment, including possibly decentralized treatment with smaller and shallower gravity-drained sewers, was conducted and shared with local experts, lay citizens and the ULB.

Discussion

In this paper, we discuss the integration of data from surveys, citizen participation and Google Earth to develop a diagnostic tool for a situational analysis of sanitation – a first step towards sanitation planning that is grounded in prevalent practices. We focus on small towns in low- and middle-income countries such as India, as their municipal governments tend to be severely under-resourced in terms of finances and capacity. Our approach meshes well with existing international guidelines on urban sanitation that recognize the challenges, but also the practical and political importance, of building on existing institutions and existing knowledge (e.g. Parkinson *et al.* (2013); also Peal *et al.* (2014). We suggest that collaborations between place-based knowledge providers and practitioners are potentially a more affordable and sustainable means of building local capacity for infrastructure planning than no planning at all (because of the lack of capacity) or costly, consultant-driven planning exercises (that are currently the norm).

A socio-spatial approach to data collection and mapping could even foster new "environmental imaginaries" (Peet & Watts 1996) with respect to sanitation and wastewater.

With sanitation zones, urban planners can develop a typology of sanitation practices and consider different interventions for wastewater / blackwater management for different zones. This is especially useful for planning the location and scale of decentralized, or semi-centralized, wastewater treatment units, if these are being considered. The fragmentation of the city into sanitation zones also allows for other tools, such as Shit Flow Diagrams (http://sfd.susana.org/), to be produced for each separate zone rather than for the city conceived as one planning unit. With waste watershed maps and / or sanitation zones prepared, the ULBs have a rational basis for working with communities and academics to decide which of a range of sanitary practices to retain, strengthen or jettison. We thus propose sanitation zones as diagnostic tools that can develop (or enhance) the efforts of municipal governments to design and implement sanitary interventions. In the Indian context, in particular, waste watershed and sanitation zone maps can be a realistic first step towards NUSP's call for all cities, whatever their size, to prepare City Sanitation Plans (Ministry of Urban Development 2013).

Diagnostic tools for sanitation are not new in planning practice.[4] Our approach specifically highlights the strategic advantages of collaborating with local academics and students, and the strategic importance of keeping the priorities and constraints of the ULBs front and center. The participatory steps we propose are arguably less community-driven than others that have been proposed for Asia and Africa (e.g.David Satterthwaite *et al.* (2015); ch *et al.* (2015); Patel *et al.* (2012)). They fall well below the participation levels that would lead to planning as "co-production" (see Albrechts (2012)). Co-produced planning, however, needs distributed capacity to assess and map the sanitation situation, and widely-distributed capacity is both rare and difficult to foster, especially in smaller towns (Hartvelt & Okun 1991; Narayan-Parker 1993).

[4] Some examples: Local accessibility planning (Centre for Urban Equity 2014); DBNS methodology (Kraemer *et al*. 2010); DEWATS SanMap (Bremen Overseas Research & Development Association) are some recent examples from India. International consortia-led guidelines also begin with situational assessment tools, for example, CLUES (Lüthi *et al*. 2011).

Finally, participation for specific activities like mapping and surveys is one thing, but building and maintaining enduring systems requires skilled personnel. Our proposed approach builds knowledge and capacity of – and for -- the ULBs by training, and then collaborating with, educated college students from within each city. Such a strategy offers enormous downstream benefits if the ULB continues to work with local academics. With conventional sewage technologies failing or not being extended, capacity once generated for a situational analysis could potentially be leveraged towards a range of actions -- awareness generation, or design, operation and maintenance of systems – that can both institutionalize and democratize the governance of wastewater. Local colleges, social networks, and free software are three resources that even low-income cities have access to.

The major limitation of our approach to drain mapping is that the quantity of wastewater is a largely unknown input, and multi-seasonal flow and quality data has to be collected for designing a treatment system. Many of the needed parameters are strongly dependent on the amount of water supplied, water use patterns, and income levels. An additional challenge in India is the use of multiple sources of water, especially the heavy reliance on ground water, which then becomes problematic when a proxy of 80% of (piped) water supply is used for estimating household-level wastewater generation. Data gaps are also challenging for other sanitation mapping frameworks; for example, Shit Flow Diagrams must resort to innovative proxies to estimate the mass of waste produced in cities. These limitations mean that our drain maps are coarse at best, but, we posit, usable for broad planning purposes in low-resource urban settings.

There is a huge research gap in the black water management component, with respect to the effectiveness of septic tanks and soak pits and the practices of faecal sludge management. Given the extensive dependence on septic tanks and soak pits in low-income countries, research based on current practices of septic tank/pit construction and sludge management at the household level is a major need. As a twelve-city study by Peal *et al.* (2014) shows, much more work is needed to understand septic tank emptying cycles, current disposal methods, safety aspects of septage disposal for the users and cleaners, and the institutional capacities needed to make effective management possible. The ULBs should have enforceable regulations on emptying cycles and disposal mechanisms since these are public health concerns; this, too, is a form of capacity that many local governments are short on.

Conclusions

The major solution space in urban sanitation thus far has been to follow the tested but capital- and resource-intensive pathway of conventional waterborne systems adopted by industrialized countries. The specialized technical and managerial skills for operating, maintaining and extending these systems are often not available even in metropolitan India, let alone in smaller towns. Recent work has called for an iterative process of sanitation planning, including technologies and their governance, that starts with a situational analysis of current sanitation and wastewater practices. Motivated by this call, we proposed a local resource-based approach to sanitation mapping, and illustrated this approach in two small towns in south-western India.

Our proposed mapping method was socio-spatial in nature and emphasized place-based capacity-building. The exercise included multiple stakeholders and households across the socio-economic spectrum to help us understand wastewater management and current problems of sanitation. In particular, it included extended dialogue with town-level officials and training of students in educational institutions to build the capacity of these institutions for understanding their town's sanitation and waste management baseline. The process facilitated interactions among knowledge and governance institutions, who can then weigh the options in the solution space of technology and governance, and act in concert to mobilize local (and possibly national) resources and skills. Our approach also plays a role in democratizing sanitation, by working within the constraints and capabilities of urban local bodies and citizen stakeholders. It is more sustainable for small towns than bringing in outside expertise, which often brings global 'best practices' – whether centralized or decentralized -- to local problems, and de-skills local actors. All these concerns were central to the earlier mentioned frameworks in sanitation, but have rarely been addressed within a pragmatic *process* of sanitation planning. Our approach represents a practical yet participatory step in this direction.

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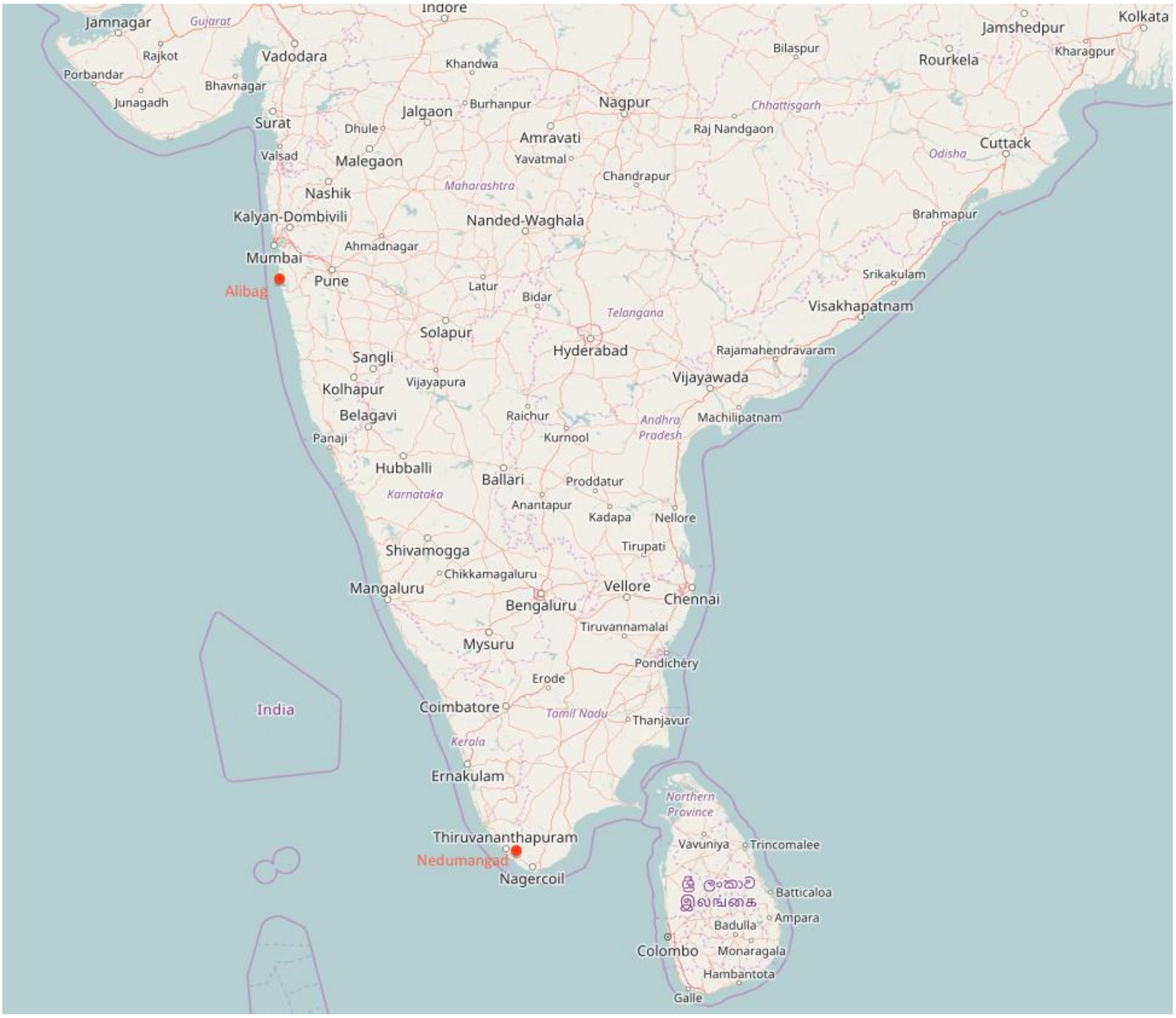
Supplementary Material

Figure S1: Map of peninsular India showing locations of field sites (Source: Open Street Maps)



S2. **Water & Wastewater Survey Questionnaire**

Household Details		
1	Location	(01)Upper slope (02) Middle slope (03) lower slope
2	Name of respondent	
3	Category	(01) APL (02)BPL
4	Religion	(01)Hindu / (02)Muslim/ (03)Christian / (99)Others
5	Caste	
6	Caste Category	(01)Scheduled caste / (02)Scheduled tribe / (03)OBC / (04)OEC / (05)General
7	Number of people live in this household	
8	House Type	(01)Concrete / (02)Tiled house / (03)Thatched house / (04)sheet / (99)Others(specify)
9	House ownership	(01)Rented / (02)own house / (99)others(specify)
10	No. of rooms in the house	
11	Approximate area of the house in sq.feet	(01)Less than 500sq.ft/ (02) 501-750sq.ft/ (03) 751-1000sq.ft/ (04) 1001-1500sq.ft/ (05) 1501sq.ft-2000 / (06) more than 2000
12	Type of floor	(01)Mud / (02)Cement / (03)Mosaic/ (04)Marble/ (05)Vitrified tile/ (06)Granite/ (07)others(specify)
13	Major source of family income	
14	Occupation	(01) Govt job/ (02) Private job/ (03)Business/ (04)Gulf/ (05) Daily labour/ (06)Agriculture/ (99)others(specify)
15	Does your household have	(01)Two wheeler/ (02)Car / (03) Auto rickshaw/ (99)others(specify)
16	Does your household have air conditioner	(01)Yes/ (02)No
Water Access and Usage		
17	Kerala Water Authority consumer number	

Table 23: S no.	Activities	Source (well, municipal pipe, etc.)	Unit of measurement of water (bucket, etc.)	Water consumption in units (A nos.)	1 unit= B litres (B)	Total quantity of water used (A x B = E lits)
23.1	Drinking	(01)KWA Pipe connection/ (02) KWA Public posts/ (03) well/ (04)Water bodies/ (05)Tanker/ (06)Bisleri/ (99)Others(specify)				
23.2	Cooking	(01)KWA Pipe connection/ (02) KWA Public posts/ (03) well/ (04)Water bodies/ (05)Tanker/ (06)Bisleri/ (99)Others(specify)				
23.3	Washing utensils	(01)KWA Pipe connection/ (02) KWA Public posts/ (03) well/ (04)Water bodies/ (05)Tanker/ (06)Bisleri/ (99)Others(specify)				
23.4	Bathing	(01)KWA Pipe connection/ (02) KWA Public posts/ (03) well/ (04)Water bodies/ (05)Tanker/ (06)Bisleri/ (99)Others(specify)				
23.5	Washing clothes	(01)KWA Pipe connection/ (02) KWA Public posts/ (03) well/ (04)Water bodies/ (05)Tanker/ (06)Bisleri/ (99)Others(specify)				
23.6	Toilet	(01)KWA Pipe connection/ (02) KWA Public posts/ (03) well/ (04)Water bodies/ (05)Tanker/ (06)Bisleri/ (99)Others(specify)				
23.7	Any other (garden, livestock, vehicle cleaning, etc.)	(01)KWA Pipe connection/ (02) KWA Public posts/ (03) well/ (04)Water bodies/ (05)Tanker/ (06)Bisleri/ (99)Others(specify)				
24	Total water usage by household (all activities)	________________ litres per day				
25	LPCD (T/no. of household members)	…………….				

26	Well information- ownership	(01)Own well/ (02)Shared well/ (03)Public well
27	Well type	(01)Dug well/ (02)Tube well/ (03)others, specify___________
28	Water drawing mechanism	(01)Pulley drawn (02)Hand pump (03)Electric pump (99)Others, specify____________

528 **Water Quality & Toilet information**

29	Do you treat the water before use?	(01)Yes / (02) No (01)Boiling (02)Filter (03) water purifier (99) others(specify)__________

	If yes , then method of treatment is			
30	How many toilets/Bathrooms do you have in the house?	Toilet- Bathroom- Common Bath cum toilet-		
31	If toilets are not available, what is the practice	(01)Using Public toilets (02)shared toilets (03)Open defecation		
32	Type of toilets used?	(01) Indian	02) Western	(03) Both
	Numbers			
33	Location of toilet	(01) Inside house	(02) Outside house	
	Numbers			
34	Flush mechanism	(01) Pour	(02) Flush	
	Numbers			
35	Mode of toilet wastewater disposal	(01)Septic Tank (02) Pit Latrine (99)Others(specify) ……………………….		
36	Age of the pit/septic tank	(01) Less than 1Yr (02)1- 3 Yr (03)4-6 Yr(04) 7-9yr(04)10-12yr (05)13-15yr(06)16-18yr (07)19-21Yr (08)More than 21Yr		
37	Distance between well and Pit/septic tank (in meters)			
38	Agency/Person called for cleaning/closing pit or septic tank	(01)Public (02) Private (03) Not yet saturated		
39	Charges for closing/cleaning pit or septic tank			
40	Frequency of closing/cleaning pit or septic tank or going for a new pit/septic tank	(01) less than 3 months (02)3 - 5 months (03)1/2- 2 yr (04) 2.1-5 yrs (05)5.1- 10 yrs (06) > 10.1 years (07) not yet		

529 **Disposal of wastewater**

41	Kitchen Wastewater	(01)Soak Pit (02) Public drain (03) premises of the house (04) Water streams (99) others specify.........................
42	Bathroom Wastewater	(01)Soak Pit (02) Public drain (03) premises of the house (04) Water streams (99) others specify.........................
43	Wastewater from cleaning Utensils	(01)Soak Pit (02) Public drain (03) premises of the house (04) Water streams (99) others specify.........................

44	Wastewater from washing clothes	(01)Soak Pit (02) Public drain (03) premises of the house (04) Water streams (99) others specify.........................
45	Toilet Waste Water (black water)	(01)Soak Pit (02) Public drain (03) premises of the house (04) Water streams (99) others specify.........................
46	Other wastewater (like cleaning verandah, livestock etc.)	(01)Soak Pit (02) Public drain (03) premises of the house (04) Water streams (99) others specify.........................

Name of the surveyor: ___________________________

Ward number: _________

Date: __________

Place: _____________