The Flaky Accretions of Infrastructure: Sociotechnical Systems, Citizenship, and the Water Supply

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The convergence of networked digital infrastructures and built environments have given rise to the "urban user", a conflation of "the user" and "the resident" or "the citizen". The urban user and the city infrastructures are mutually constituted phenomena formed through the interactions between them. In this research, we contribute an ethnographic study that focuses on the everyday interactions between the urban user and water infrastructures in Pune, India. Using Nikhil Anand's concept of "hydraulic citizenship" to analyze our ethnographic data, we showcase the mutually constitutive process of infrastructuring and subjectivization of the "citizen", bringing attention to the ad hoc, heterogeneously constituted water infrastructures in Pune that aspire to be "smart" even before becoming functional infrastructures. In doing so, we hope to expand possible research trajectories within smart city research agendas by decoupling it from Western assumptions and also by linking them to an interactional account of the everyday relationships among residents, infrastructures, and municipalities.

CCS Concepts: • Human-centered computing ~Human computer interaction (HCI) • Human-centered computing ~Human computer interaction (HCI) ~Empirical studies in HCI

KEYWORDS: Infrastructure; citizenship; water; smart cities; HCI4D; India; urban informatics

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1 INTRODUCTION

The development of networked computing systems and the growth of built environments have been on converging trajectories for decades, culminating in visions of smart cities, smart homes,

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and smart and connected communities. Such visions connect major public services and infrastructures—the power grid, public transportation, and the water supply—to emerging technological capabilities in ubiquitous sensing, cloud computing, artificial intelligence, data visualization, and dashboards. The convergence of networked computing systems and built environments is also contributing to a convergence of subjectivities: that between "the user" and "the resident" or "citizen," into a fused subjectivity sometimes referred as "the urban user" [24,20]. On its own, the "user" is a subjectivity that engages with technologies, while the "resident" or "citizen" is a subjectivity defined in relation to rights and responsibilities within a city or state.

As a synthesis of these two subjectivities, the citizen of urban cities ("The urban user"), according to [20] can be defined through various intersectional roles. For example, the city resident is also the user of technology and consumer of the city services through participation in automatic electricity and water meters.

Urban users, like other kinds of users, interact with technologies in situated contexts. Thus, it is not surprising that recent research has also warned against overly technological visions of smart cities, highlighting instead the need to attend to the cultural and situated contexts of residents and their socio-technical interactions [10,16,22,25,26]. CSCW research has sought to support "urban users" in their role as participants in community initiatives, e.g., in areas of civics and citizen participation [8,14,28,37,49]. Other research focuses on empowering citizens through technology [4,18]; for example, [22] illustrates the positions civic activism, social media, and media architecture can take at the intersections of people, place, and technology. [28] examine the importance of democratizing design so that researchers can "make a broader and diverse group of urban inhabitants."

Building on the pioneering work of Star and colleagues (e.g.,[62,63]), researchers increasingly focus on infrastructures and infrastructuring as key to the subjectivization of urban users. That is, urban users and infrastructures are mutually constitutive phenomena, in a process that unfolds through people's interactions with physical, social, and digital infrastructures [41]. Similarly, [35,40,53] have used the notion of *infrastructuring* to highlight the process through which infrastructures are made by interactions between people, technology, and networks. Accordingly, much CSCW research has sought to empower citizens through the application of technologies in support of civic bodies, cities, citizen groups, and communities [4,8,14,18,20,28,49].

The present research contributes to this line of research by focusing on a narrower scope – the city residents' everyday interactions with only the water infrastructure, and in a single city: Pune, India. We do so in hopes of providing qualitative richness and granularity to the aforementioned research on citizen empowerment and participation. The mutually constitutive process of infrastructuring and subjectivization unfolds through everyday interactions that residents have with urban infrastructures. Further, such interactions are culturally, geographically, and socially situated; that is, the ways that residents of New York City engage with water infrastructure is different from that of Pune, India, where the present study is based. In both cities, residents pursue their daily activities within the urban environment, and water services become a part of such activities. As we demonstrate, Pune's water infrastructure and the daily practices and attitudes of residents, entrepreneurs, government leaders, activists, and the media manifest in ways specific to Pune's history, geography, economy, and culture. Population growth—much of it driven by the arrival of I.T. professionals—has driven the city outwards far faster than the municipal water infrastructure could keep up. At its best, the

municipal water supply is intermittent. As a result, residents patch together a combination of municipal water, for-profit water tanker services, and mostly unregulated borewells in pursuit of "adequate water" (itself, as we show, a heterogeneously defined concept).

To support our analysis, we analyze our ethnography and autoethnography of water use in Pune, India, using Nikhil Anand's concept of "hydraulic citizenship." To Anand, hydraulic citizenship "is the ability of residents to be recognized by city agencies through legitimate water services, [which] is an intermittent, partial, and multiply constituted social and material process" ([2], p.8). As such, hydraulic citizenship "is not a singular, historical event... Instead, it is an incremental, intermittent, and reversible process that is composed of multiple temporalities" ([2], p7). By analyzing citizenship as such a process, we hope to expand the ways that CSCW researchers might understand and pursue smart cities, broadening the repertoire of possible interventions to support citizens to acquire essential services as well as to support municipalities in providing for residential needs.

In de-centering Western urban infrastructural norms, we hope to decouple smart city agendas from tacit Western biases and assumptions, expanding what "smart cities" and similar agendas might come to mean. Experiences with municipal water in Pune suggests that the concept of infrastructuring, and related concepts such as infrastructural breakdown, can be further expanded and refined, because our research in Pune suggests that these concepts play out across different processes and with different meanings than they do in Western contexts. Further, in focusing with high granularity on the micro-interactions between individuals and urban infrastructures, we reveal the interplay of ad hoc and overlapping water infrastructures; heterogeneous attitudes, standards, and expectations across stakeholders; the differing infrastructures for potable vs. non-potable water; micro-disenfranchisements of stakeholders viewed as unequal; the difficulties establishing trust or even ground truth across stakeholders; water supply hacks (or *jugaads* as they are known in Hindi); and other phenomena. Through it all, we highlight what to some might come across as a startling likelihood: Pune's public water supply will almost certainly be "smart" long before it is minimally functional—at least by Western standards. That is, efforts to implement networked technologies such as sensors and dashboards to Pune's municipal water services are already being implemented, even as there is no timeline for, indeed little likelihood of, the municipal water supply ever reliably providing potable water to all of its residents. In short, smart infrastructures might become smart before they become infrastructures, which has design implications not only for developing areas of the world but also, arguably, for collapse informatics and computing within limits research agendas, which focus on the roles of informatics in contexts of infrastructural crisis and/or breakdown.

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2 WATER, SOCIAL COMPUTING AND URBAN INFORMATICS

Civilization has transformed the ways in which we understand water. What was once a natural resource is now the content of a network of reservoirs, tanks and pipes; water now is infrastructure. Anthropologists and urban studies researchers have emphasized the social ways in which water comes to be experienced in today's cities, with a focus on the socio-materiality and politics of such experiences [2,6,7,27,38,46,56]. For example, cultural anthropologist Jessica Barns, in her study of the waters of the Nile, illustrates the politics of the quotidian yet important acts of blocking, releasing, diverting waters by citizens, farmers, and government engineers in Egypt. Such situated, mundane acts of water practices are constantly created and reconfigured on a daily basis with implications for citizens and international stakeholders alike

[6]. Matthan examines the increasingly volatile and political nature of waterworks and infrastructures in Mumbai, India, challenging the aspiration of the city to be a stable, reliable urban water space [46] . Ranganathan reveals how the presence of "Mafias" and informal services redefine water distribution processes in Bangalore[56]. Collectively, this body of work shows the techno- and bio- politics surrounding water distribution and access, especially when the water situation is precarious and unreliable. Any attempt to transform water infrastructures into smart and efficient water systems will need to first attend to the complexities of the existing infrastructures within which water is distributed, managed, and accessed.

In Pune, despite best efforts, the city cannot reliably provide water services to every resident, a challenge exacerbated by the region's heavy rains, monsoon-driven floods, and fast-expanding urban sprawl. And yet, the city planners and government officials aspire Pune to be the next "smart city", where the water works are to be equipped with interactive metering systems and digitized water management systems [71]. What is clear is that the water infrastructure will be smart long before it is fully functional--if the latter ever happens. The role of networked computing is not to bring further efficiencies to an already functional infrastructure; it seems that its role is rather to help diverse stakeholders continue manage, possibly even to incrementally improve, a complex, heterogeneous, and intermittently available infrastructure.

In the following sections, we synthesize prior work on infrastructures, urban informatics, and citizenship in CSCW/social computing research to situate our research. We then introduce Anand's theory of *Hydraulic Citizenship* [2] to support our analysis of the ethnographic data.

2.1 Infrastructures in Urban Informatics and Social Computing

As with other areas, Pune's physical water infrastructures include pipes, knobs, dams, reservoirs, gutters, storage tanks, and so forth. Yet, according to Anand [2], infrastructures include not only hardware, but also the actions and intentions of human bodies, politics, geographies, and water itself. Pune's physical water infrastructures are used and maintained by skilled practices, many of which are ad-hoc, unnoticed, and even concealed by stakeholders as part of their everyday lives. In short, infrastructures become assemblages of hardware and practices that are neither politically neutral nor always visible. Researchers who have studied the socio-material and political nature of infrastructures highlight the mutual constitution of people and infrastructures [12,34,52] a finding carried forward in social computing and urban informatics research [16,19,21]. [41] argue that infrastructures are not just limited to the relations and interactions between people, social groups, and material infrastructures, but also that social groups themselves are also infrastructures. In foregrounding infrastructural properties, [62] argues that users of systems and infrastructures become members of that system, when they acquire a "naturalized familiarity with [its constitutive] objects". They become members when the infrastructures fade into the background as an outcome of their familiarity. Similarly, [16] posit that, urban infrastructures are living, socio-political, and socio-material entities, continuously defining and being defined by those who live in/with/through them. Such situated narratives of interactions with infrastructures complicate Star and Ruhleder's [62] notion of "infrastructural breakdown". For example, in Pune, the phenomenon of visibility and invisibility of infrastructures is not only dependent on the smooth functioning of the physical water infrastructures, but also on the people. It is crafted through their choices and actions, and their everyday practices. Such in-use making, and unmaking can be viewed through the concept of "infrastructuring".

The concept of "infrastructuring" highlights design as an ongoing process in which infrastructures are built, re-configured, and appropriated in-use. This conception of infrastructuring offers a relatively collective view of innovation, bringing a potentially participatory character to the design process [35,40,53]. For example, [35] shows how residents of Cambodia collectively innovate online shopping by building a network of customers, business owners, delivery drivers through infrastructures made up of paper receipts, the internet, motorcycles, and feature phones. In Pune, residents similarly engage in infrastructuring activities in their daily encounters with water services, thereby functioning as *citizens*[1] in Anand's sense of the term.

Previous CSCW research has shown how infrastructuring can serve as participatory action that results in the formation of appropriated infrastructures. But Anand's "hydraulic citizenship" locates the co-emergence of citizenship and infrastructure in the micro-interactions that constitute everyday life; accordingly, such interactions are the focus of the present research.

2.2 "Citizenship" and Lived Human Experiences of Urban Residents

Citizenship, according [51], is a form of political subjectification, which manifests itself through continuous interactions between the state and the public. Such interactions happen not only through daily encounters with municipal infrastructures, but also through direct political participation, an area that CSCW research has emphasized. For example, urban informatics researchers have called for leveraging technologies and data as a means to bridge bottom-up citizen initiatives and "traditional top-down governance" [18,20,21,22,24,28]. These works focus on empowering citizens with technology. Yet, [25,43] show us how those in positions of power can leverage systems and infrastructures for economization of citizenship, undercutting the benefits of technology for the citizens. Similarly, [25] shows ways the city's smart city vision risks complicating civic engagement and the process of public, collective futuring. Much of these discussions are focused on the idea of political belonging; but research has also called for a more granular perspective that prioritizes citizens' situated and meaningful interactions in the city to drive any urban technological development [10,26]. Similarly, Lindtner et al [44] encourage us to find innovative actions and citizen agency "within the gaps, cracks and fissures" of larger socio-technical systems such as governments; as we document, the gaps, cracks, and fissures of Pune's water supply are many, wide, and deep, creating many—sometimes surprising—openings for innovative citizen actions. These prior works highlight an interest in viewing residents as co-creators of the city [19,21,22,26], both through participation and activism and also through their everyday mundane activities. Such a view calls for special attention to local practices, cultures, and situated accounts of living in the city [10,16,25,26].

Socioculturally oriented HCI research has often framed such situated accounts through user felt experiences, as in McCarthy, J., & Wright, P [5,47] and Hassenzahl, M., & Tractinsky [5,30]. Urging designers to prioritize experience McCarthy and Wright stress the "personal and particular character" of living with technology. The field has also derived from philosophical

1. Throughout this paper, we follow Anand in using the term "citizenship" to highlight the mutual rights and responsibilities between urban dwellers and government entities, regardless of dwellers' legal/political citizenship status. For example, our use of "citizen" would include a legal resident of Pune, who happens not to have Indian citizenship. That said, such differences do matter, as we demonstrate in this paper.

approaches to experience from Deweyan pragmatism [5,47] and Richard Shusterman's somaesthetics [32,33,42]. These approaches foreground "experiential qualities, such as involvement, delight, coming alive, pleasure, and embodiment [...] all of the objective and subjective qualities come together coherently as a whole" [47]. In researching placemaking as a lens for urban informatics research, Freeman and colleagues underscore the value of experience in social computing [26] by commenting on the importance of lived human experiences in forming attachment with the city. Experiences with water may not necessarily represent qualities of delight and pleasure or even mechanisms to form a desirable attachment to the city. However, water use is a life-sustaining activity and tacitly becomes a part of everyday experiences of living in the city. Understanding these negotiations between the city residents and the city's water infrastructures can play an important role in designing urban landscapes. As we shall see, linking civic participation and UX alike, lived experiences are also an integral part of what Anand [2] calls hydraulic citizenship, a concept central to the present work

2.3 Hydraulic Citizenship

Cultural anthropologist Aihwa Ong [51] posits that citizenship is an emergent form of political subjectification, made possible through the ongoing interaction and negotiation among the state and its subjects. Many anthropologists have argued that public infrastructures, natural resources and social infrastructures together mediate the interaction among a state and its subjects. [12,38,52]. However, of particular interest to us is the everyday negotiations that facilitate the use of water [2].

Channeling Ong and drawing from extensive ethnographic work in Mumbai's settlements about residents' water usage, Nikhil Anand argues that hydraulic citizenship is "the ability of residents to be recognized by city agencies through legitimate water services—is an intermittent, partial, and multiply constituted social and material process." ([2], p8). Not all residents and settlers are entitled to water services in the city, and the provision of water, even for voting citizens, is not always consistent or reliable. In one of the most striking examples Anand described, we learned that a resident and her family were once able to use self-made infrastructure in the home in the form of overhead storage tanks and internal plumbing to connect to the city's water services because they don't arrive at her home reliably, is now compelled to get water into her home "using her own bodily labor, by sucking water out of the pipes" ([2], p8).

The example illustrates Anand's belief that hydraulic citizenship is nonlinear, iterative, incremental, reversible, and highly dependent on the social histories, the material conditions of the water infrastructure, and the politics of water distribution in the city. As Anand argues:

> *Hydraulic citizenship emerges through diverse articulations between the technologies of the politics (enabled by laws, plans, politicians, patrons, and social workers) and the politics of technology (enabled by the peculiar and situated forms of plumbing, pipes, and pumps). It depends on the fickle and changing flows of water, the social relations through which everyday political claims are recognized, and the materials that enable residents to connect to and receive reliable water from the urban government. It takes a significant amount of work to become and remain a hydraulic citizen* ([2], p8, emphasis in the original).

Indeed, much of this paper reports on the "significant amount of work" we observed Pune's citizens doing to access water. The present paper reports on an empirical study of hydraulic citizenship in Pune, and while our findings tend to offer evidence in confirmation of Anand's

argument, our specific goal is to inform CSCW research on smart cities with detailed empirically driven insights about the ways that technological infrastructures emerge out of and perpetuate culturally contextualized enactments of citizenship. In doing so, we put several themes into focus: hydraulic infrastructure, which refers to the physical and technological system that actually provides water; lived experiences, which refer to the phenomenology of hydraulic citizenship in Pune; and legitimacy, which refers to the ways that different stakeholders are afforded and/or assert their stakeholder status.

3 RESEARCH SITE AND APPROACH

To account for how we sought to contribute to smart cities and similar CSCW research agendas through an ethnographic study of hydraulic citizenship in Pune, India, we introduce our research site and our methods.

3.1 Research Site

Pune is the second largest city in the western state of Maharashtra, India, and the 8th largest Urban agglomeration in India. It is also one of the first cities in India to be selected for the smart city and 24x7 water initiatives [71]. In India, urban areas are subdivided into municipal regions known as "corporations," each serving at least one million citizens and having its own mayor, and also "cantonments," which are smaller. The Pune Metropolitan Region, which originally formed on the banks of the river Mula and Mutha, features two corporations and three cantonments: the Pune Municipal corporation (PMC) and Pimpri Chinchwad Municipal Corporation (PCMC) and three cantonments--Pune, Khadki and Dehu Road. Pune has seen exponential growth in geographical area and population in the last decade due to the I.T. Industry boom [11]. The city blends urban modernization and a rich cultural history. It also experiences erratic monsoons that sometimes cause flash floods. The city's growth history and topography, its infrastructure, and the precarious water situation makes it a vulnerable urban space with a fragile water management system. The lead author is a native and is familiar with the city, its local languages and history.

The observations were carried out in Baner and Balewadi in the Pune Municipal Corporation (PMC) and the Pimpri Chinchwad Corporation (PCMC). We chose these two areas for the following reasons: as part of the Pune Municipal Corporation (PMC), Baner and Balewadi is one of the areas impacted by floods the most in Pune in recent years. The first author has first-hand experience living through and with these floods. Pimpri Chinchwad (PCMC) is the second largest corporation in Pune and was chosen for comparison reasons. The Tanajinagar area within PCMC is more established than the Baner and Balewadi area in PMC. The first author used to live and work in Tanajinagar and is thus familiar with the surroundings. In our ethnographic work, we focused on the study of residents' interaction with "corporation water." In common dialect, "corporation water" refers to water provided by the municipality.

Fig. 1. Old and new juxtapositioned. Image shows temporary tanks, pipes and old construction and buildings next to sophisticated water infrastructures in Balewadi. Fig. 2 river near which old and new settlement is visible in Balewadi.

Situated in the western side of the city, the Baner and Balewadi area was once considered the outskirts of Pune but has now grown to be part of the city due to the fast urbanization. A vast amount of agricultural land has been converted to residential dwellings. There are many high-rise buildings and affluent apartment complexes juxtapose the old, haphazardly constructed settlements along a river.

The vicinity of the old settlements to the river means that residents from the settlements used to use water directly from the river. Nowadays, residents tend to rely on self-made overhead tanks and pipe systems for both personal and communal use purposes and seldom get water from the river directly anymore. More affluent families rely on the combination of tankers, borewells, and corporation water for everyday use, and the corporation water flow has been reliable only for the last few years. In the 2019 monsoon, the entire area in the immediate vicinity of the river was under water (about one meter or three feet of flood water), and the residents had to be evacuated to a school nearby, which was used as a temporary shelter. Many of the houses were infected with pests once the floor water subsided, leaving residents to abandon their homes and seek shelter elsewhere. Pimpri Chinchwad/PCMC form the second biggest municipal corporation of the Pune Metropolitan Region, and being newer, the public infrastructure is on the whole in better shape than PMC. Our ethnographic work focused on a well-established area within PCMC.

3.2 Methodology

Data collection. The present work is drawn from the fieldwork we carried out in Pune, India from June to Dec 2019, document analysis of online newspaper articles and blogs, and the lead author's autoethnographic experiences. Below, we summarize our process of collecting this data.

Ethnographic Data. The primary data source was ethnographic, comprising non-participant observations as well as semi-structured interviews (both in person and remote) in the Pune Metropolitan Region to gain an in-depth understanding of residents' engagement with the city's water services as well as the municipal officials and civic engineers' work in the city. We worked with a total of eight interlocutors during our fieldwork. Four were residents of the city,

living in the suburbs within recently developed areas of Pune: an elderly couple who had lived in Pune all their lives to understand the city water infrastructures' transformation; a middle-aged woman who was a homemaker, to understand her day-to-day experiences with water; a migrant bachelor living on rent in an extension area of the city, to understand how a new resident who rents apartments experiences the city's water services. We also worked with three social and environmental activists in the city and a municipal official, a senior engineer in the water engineering department of one of the municipal corporations.

Study participants were snowball sampled, belong to urban middle-class families, and at the very least have piped water infrastructures. It is important to acknowledge that not everyone has access to piped water and some residents of the city have to completely live off stored water collected from community filling stations or tankers. Such residents have a much more challenging relationship with water infrastructure, but such experiences are different enough that they are out of the scope of the present study. Therefore, the urban-middle class participants do not represent the full breadth of water infrastructures and people living in Pune India. Rather, our study aims to focus on in-depth understanding of the nuances of everyday practices of the urban middle-class families and to investigate the experiences of seemingly "complete" water infrastructures.

Reflexive autoethnography. The second data source was autoethnographic engagement [17] of living in Pune by the first author from the Month of June 2019 - August 2019 and again in December 2019 and January 2020. The first author, being a native of the city, has a tacit understanding of the cultural histories, practices, and socio-technical tensions in the city around the use of water

Media collection and analysis. Finally, to understand the public perception of water use and crisis in the city, we also collected and analyzed media coverage. The goal of this collection was to contextualize the qualitative accounts of lived experiences using broader narratives surrounding water infrastructures. Media coverage and news articles both represent and shape public perception of civic bodies and cities. Coverage of water facilities and infrastructures thus can provide a broad picture of general sentiment of the public since it also informs individual lived experiences. We retrieved relevant articles by conducting a Google Search using keywords such as "Pune water", "meter connections", "24x7 water supply", "Pune floods." After removing redundant articles and webpages, our data set includes 250 online articles, spanning both local and national newspaper, magazine articles, online forum posts (and their comments), blogs, and TV news over the past 5 years. We also conducted archival analysis of policy documents related to water networks, the smart city initiative guidelines, and the smart city proposal for Pune. Recognizing that media reports sometimes introduce bias and represent different power dynamics, we deliberately collected a wide range of reports from different outlets (e.g., news sites, personal blogs, non-profit organizers, etc.), attending to who authored these reports, to take into account diverse points of view.

Interpretivist Methodology

The interpretative procedures were as follows: 1) Informed by humanistic interpretation [5,9], we began by identifying themes in the ethnographic data, media data, and policy documents, where themes are understood both to be what a text or discourse is about [36], and also what provides the text its organizational unity and connection to more general human concerns beyond the immediate subject itself [39] 2) The lead author supplemented these data sources by sharing with the other authors her direct experiences conducting the research and also living in

Pune. 3) All authors collaborated in an iterative interpretive process to discuss, combine, and refine themes in the preceding two steps in a mutually informing dialogue with Anand's concept of hydraulic citizenship, in which Anand's theory shaped how we read our data, and our data deepened our engagement with Anand's theory, particularly around the micro-interactions that constitute hydraulic citizenship in Pune. The results of this dialogue are presented below.

4 INFRASTRUCTURES, EXPERIENCES AND LEGITIMACY

We now turn to our account of how Pune residents become hydraulic citizens through their everyday interactions with water infrastructures.

4.1 Hydraulic Infrastructures

As CSCW research has shown, infrastructures are embedded in the cultural and socio-political practices of everyday life. Along similar lines, Anand [2] describes hydraulic infrastructures as socio-material assemblages made up of "flaky accretions of socio-material processes that are brought into being through relations with human bodies, discourses, and other things (sewage, soil, water, filtration plants). They are processes always in formation and always coming apart" ([2], p13). This implies that hydraulic infrastructures are formed as human infrastructures interact and connect with the physical infrastructures, giving it a layered, built over the time quality. As such, infrastructures are processes that are formed through a combination of human and non-human relations, politics, and values.

In this section, we unpack hydraulic infrastructures of Pune, demonstrating the "flaky socio-material processes" and foregrounding the public infrastructures, comprising people, material things and human bodies.

4.1.1 From the City to Citizen's home: The structures that form Hydraulic Infrastructures

As any city expands its population and geography, demands on its public services increase, thereby straining infrastructures and calling attention to them. Pune city has been undergoing haphazard development for more than a decade, driven by the establishment of the I.T. Industry and consequent population growth [11,71]. Geographically, this development is accommodated by the city's outward growth and inclusion of nearby villages to increase the physical capacities for the migrating urban population. This outward spread in a saucer-shaped city challenges the capacities of the hydraulic infrastructures. Water not only has to be supplied to more people, but it also must travel greater heights and distances. The outward development has become a crucial part of project plans and city planners plan for the fast growth. The PMC (Pune Municipal Corporation)'s 2014 water supply system's detailed project report also discusses the problems posed due to the "fast and chaotic development" of the city. Participant 8, a senior engineer in the municipal water department, was quick to allude to it in our interview with him, illustrating the growth in numbers he knew by rote:

> *In the decade of 80s, the Pune Municipal Corporation had an area of approximately 100 sq km, and sometime in 1997 twenty three villages merged and the physical boundaries have been extended 243 sq km..very recently, 2017, 11 more villages were added and as of now the administrative boundary of Pune Municipal corporation is three hundred and thirty three sq km and it is envisaged that another 23 villages are to be added, Pune city will go to be around 470 sq kms.*

The water distribution infrastructures that develop on a need-basis are stretched beyond their capacity to keep up with urbanization demands of the city. Keeping up is not limited to the physical pipes and materials, but also extended to the management and provisioning of water. These over-extensions are addressed by employing tactical measures that help managing the services, such as time sliced distribution. When the incoming water pressure to the city is not sufficient, water supply times are carefully calculated and divided amongst different areas and localities. While the time sliced distribution is often criticized by the opposition, social activists, and newspapers, civic authorities justify these measures by calling attention to how they lead to a fairer distribution of water across the city. In response to a newspaper article's concern about alternate day water supply, the chief of the water supply department justified the decision on the ground of fair and adequate distribution:

> *The areas on the higher ground and at the tail end of the distribution network do not get adequate water currently. Under the alternate day water supply management, we shall supply water of two days in a day.* ***As a result, all areas will get adequate water*** (Newspaper Article[68], emphasis added).

However, this notion of adequacy does not get sufficient support from the infrastructures at individual apartment and household levels. Most apartment complexes have two modes of accessing water. A common overhead tank, where water is collected and stored to be distributed across the apartments throughout the day for non-potable use. Second is a separate, single tap connection in each apartment, typically used for drinking water since direct "running" water is cleaner and much fresher than that stored in overhead tanks. When water is released by the civic body supply department, it is collected in the overhead tanks and is also individually distributed to the single tap in each of the apartments to access drinking water. The use of non-potable water and participation in the overhead storage tank water system is dependent on how much an individual household can practically claim of their 150 lpd per person (or more) by simply using it. Accessing the running, drinking water from the corporation tap, however, is a game of gravity.

> *Oftentimes, the water flow will suddenly stop and then start again with even more force; Sometimes it will trickle, taking eternity to fill my water filter. Someone from the lower level floors might be filling the drinking water (I think) and the minute they close the tap, the pressure is redirected towards my house, on the top-most floor of the apartment complex. (Lead author's first-hand experience)*

This push pull and tug against gravity, and each household's individual capacity to store the fresh running water defines how much each individual household will quantifiably get. But residents also employ tactics and technologies to overcome gravity and the tactical time infrastructures imposed upon them by the civic body authorities. A common habit in households used to timed water distributions is to leave the drinking water taps on. The taps act as an alarm clock, the daily "Water has come" indicators making taps not just a means to access water, but also an indication of whether residents will be able to participate in the water services. For the overhead tanks, apartment complexes use WhatsApp and other such messaging forums as an important part of their water infrastructures, the primary communication channel to discuss the water timings, cuts, and resident complaints. But like the adequacy representation of the civic bodies, the measures employed by apartment complexes are not always truly adequate since not all residents are equal. "Renters and outsiders" are viewed differently. Narrating her personal experiences, the lead author, staying on rent in an

apartment complex in PCMC, was not allowed to be a part of digital communication channels amongst the residents, because she was staying on rent and not an apartment owner. "*The WhatsApp group is meant only for flat owners*" was the neighbor's response when she asked to join.

Similarly, one interview participant discussed his lack of agency and outsideness in his society water matters, despite his interest and volunteering activities in the city's water sustainability drives. He lives in a rented apartment in Pune outskirts and is not from Maharashtra. With the tech industry growth in the city over the last decade and a large influx of migratory population, several apartments in the Pune outskirts are rented by those the locals view as "outsiders". Being able to speak in Marathi, is thus a privilege. The "outsider's" inability to speak in the local language not only contributes towards a communication gap, but also acts as a flag indicating the "outsiderness" of people. Further complicating his situation is that he lives in a shared apartment with others like him and not with his family. Frequently labelled as "bachelors" (which locally has bad connotations, suggesting nuisance to nearby family-occupied homes), many apartment complexes restrict owners from renting out the apartments to bachelors.

> *My society does not listen to bachelor's voice and the society manager is against non-maharashtrians. So, I can't implement any of these techniques in my apartment. (Participant 4, Male, Lives in a rented apartment in Pune Outskirts)*

The fact that he is an experienced volunteer who could help the apartment society manage their water better is secondary to his status as an outsider. His participation is undermined as the social infrastructures label him as a second-grade participant. His experience suggests that even as material infrastructures break and fall apart, the social and tactical infrastructures that attempt to compensate for the lagging materials also fall short. Ranging from the city to the household, the infrastructures that constitute water provisionings thus are more than just pipes and pumps. The pipes and pumps are made social and political through networks of people, the city's growth history and future planned trajectories, the socio-political management systems in place and even individual capacities to store and use water. Whether it is the generalizations and numeric illusions of "adequate" water or a mismatch in personal water storage capacities or the creation of second grade residents, water infrastructures are made up of flaky accretions: accumulated layers of less-than-ideal tactical techniques and materials. Given that water is such a basic necessity, residents are on a constant lookout for ways in which they can experience some relief from these struggling interactions with water infrastructures. Arising from this lookout, are hacked infrastructures: measures the residents take to overcome the failing infrastructures, lucrative (and potentially money fleecing) business opportunities emerge.

4.1.2 From the City to Citizen's home: The "informal" structures that form Hydraulic Infrastructures

In the previous section, we saw the water infrastructures of Pune, strained due to the chaotic and outward growth of the city creates infrastructures (material and social and consequently political) that are an equally chaotic assemblage of people, pipes, pumps, and water. In this section, we further explore the measures which the residents take to overcome the failings of the chaotic assemblages of the city's water infrastructures. While we might call these measures "informal" to distinguish them from the state governed, documented and top-down provisions, the boundaries between informality and formality are often blurry in practice, as we will also see in this section. Informal means of accessing water, according to the world urbanization report, are an outcome especially of outward growth of the city. This is hardly unusual:

"Between 25 and 70 percent of urban populations in the global South rely on informal arrangements to procure core services" [45]. As a result, informal services also form an ingrained part of the water infrastructures.

Two informal services have dominated the water market in Pune: water tankers, which are technically legal but unmonitored; and borewells, which are undocumented and unregulated. Tanker water services are well known and regulated mechanisms to access water, and are sometimes even government owned or subsidized, especially to provide services in those areas where piped connection is not yet extended. However, residents and social activists claim that the tanker system takes indiscriminate advantage of resident water situations in a bid to earn more profits. Many residents suspect collusion between government and water lobbyists, and the tanker infrastructures are popularly referred to as the "Tanker Mafia," aptly capturing public sentiment. Newspaper articles covering resident water problems often highlight the issues with water tankers and government involvement:

> *Vivek Velankar, a citizen activist, alleged that there is no regulation in place on the tanker lobby in the city. He said that residents living in housing societies were at the mercy of the tanker mafia as they were working hand-in-glove with politicians and the civic administration. (Newspaper Article[70])*

Residents are both dependent on and resentful of the tanker services, since societies pay large amounts of money - included in the maintenance funds - to facilitate the use of tankers. Residents also employ borewells, which are a highly unregulated source of water access, since the city water services, and the civic body hardly recognize their existence and usage. A blog post from a group "South Asia Network on Dams, Rivers and People" shows that the groundwater in Pune is unregulated and undocumented:

> *According to PMC there are about 1-2% of households dependent solely on groundwater. However, in reality, domestic dependence on groundwater seems much more. As told by Pravin Patil of 'Sai borewells' , demand for borewells is much higher in all the outer areas of Pune city. "Water supply in these areas is a major problem. Many areas like Bavdhan, Baner, Wakad, Ghorpadi, Wagholi etc. receive water alternate days only for a few hours with low pressure. These areas are heavily dependent on groundwater for their non-potable use. (Blog Article[72]).*

As indicated in the blogpost quote above, borewells (and for similar reasons, water tankers) are highly prevalent in the outskirts of Pune. One of our interview participants lives in a large apartment colony, comprising four apartment buildings and twenty-three row houses, each equipped with overhead water tanks. The entire colony has two common underground tanks. These tanks receive water from two six-inch corporation pipelines and two borewells and tankers. The common underground tanks are filled with water from all of these sources and then pumped to the tanks in the apartment buildings and rowhouses.

> *Living in the outskirts, initially, our society was completely reliant on tanker water as our main water line was not connected to the corporation line. Now we have two borewells, and in the summers, we hardly need 2-3 tankers. So, we have a mixture of corporation water, borewell, and tanker water. (Participant 3, female, a homeowner in Balewadi)*

This form of provisioning that many apartment societies in affluent areas employ generally provide a seamless interface to accessing water to individual resident homes. However, that convenience comes with its own issues. The differently sourced water has a harder water composition that clogs washing machines, creating caustic soda residues around the drums. It

also causes coatings of salt on utensils, bathroom fittings and buckets - a clear indicator that the water in the house may taste off as well. The residents have to accommodate these issues or invest in their personal water infrastructures. Some do that by adding water softening units that need regular salt inputs, others buy 10 liter units of bottled water, and yet some others invest in washing machine cleaning acids and powder. All available in the market if the resident is willing and able to purchase them.

Such investments are not limited however only to solve issues of water quality, but also of quantity. In apartment complexes, overhead storage tanks are a visible and formal means of storing water. However, residents with financial means can also install tanks, complete with intricate hacked plumbing in their kitchens and bathrooms, drawing more than their fair share of 150 lpd, thereby ensuring water security on the days when water is not released. Others purchase simple drums, numerous buckets and even use their kitchen utensils to store water. Infrastructure hacking, whether through the controversial socio-political and financially expensive tankers and borderline illegal borewells, or through individual extensions of infrastructures, point towards the necessity of hacked infrastructures to enable residents to access the public service of water. Taking this hacking further, deeply intertwined with hydraulic infrastructures and infrastructural hacking are the daily experiences the residents have with the water services and (the lack of) water, further expands the meaning of extended infrastructures beyond pipes and buckets, to human experiences and bodies.

4.2 Lived Experiences through Water

A hydraulic citizen is formed every time a resident successfully interacts with municipal water services. Interactions with water systems are inherently personal and the experiences that surround these interactions represent the ways in which humans navigate the city's water infrastructures. Anand illustrates this interaction through a vivid example:

> *Alka tai explained to me that her water problems did not have to do with a lack of water in her pipes. "There is water!" she insisted. To demonstrate this, she began sucking water out of the pipe in the washing room—a human pump. (*[2]*, p3)*

This anecdote shows the human labor behind hydraulic interactions that form a crucial part of participation in water services. Anand's referring to her as "a human pump" obviously blurs the boundaries between mechanical infrastructure and human experience. At the same time, what she means by the clause, "There is water!," is different from what citizens in other areas of the world might understand by it.

4.2.1 Cultures of Adjustment and Resilience with Public Water

In Pune, as demand outpaces supply, residents must make adjustments and workarounds to access water. We have already seen tanker lobby systems, uncontrolled borewells, and extended household infrastructures. The informal household changes people employ to make their daily lives manageable reflects an underlying deep-rooted cultural attitude of adjustment towards uncomfortable situations. The experience of lack of water is often buried under actions residents take to overcome it, for example via "jugaads," or hacks

Residents come to accept the need for workarounds and jugaads as part of everyday life. Some are able to purchase more capabilities to secure their water access, while those who cannot manage what is available, often to the point of becoming desensitized to water issues. One might think, many residents seem to perceive the lack of water as perfectly acceptable.

When we asked them about their water related issues, one of our interviewees, participant 1, elderly female, who lives in a row house in Pune outskirts with her husband, immediately responded "Oh, we do not face any issues!" The couple has lived in the city all their lives. The initial years of their lives were spent in the city's central areas, now known as old Pune or Pune gaon. In the year of 1998, they shifted to Kothrud, then an outskirt and now the city "center". Finally, they now live in a row house in Balewadi. Balewadi is infamous for its dependency on water tankers, and indeed their colony does order water tankers regularly. Their house has two overhead tanks, in which water is pumped from the society's mains. Their "corporation" water tap is installed in the backyard of the rowhouse, while the entire house is supplied with water from the overhead tanks. Curious about their satisfaction, we followed up to understand it better, and they explained:

> *After the flood of 1960, the condition was really horrible. There was only one tap in our area which had water - we used to carry buckets and buckets of water at that time right up till the third floor. But now, I don't see any issues. (Participant 1 Elderly Female and a long-time resident of Pune. Translated from Marathi to English by the author who is a native speaker of the language)*

She further explained that while water for non-potable use was never an issue, her husband had only ten minutes of window in which they could fill drinking water, a daily ritual of dropping whatever he was doing, and rushing to the backyard corporation water tap to fill the storage containers when the clock hit 7 pm. They fill the water in two large steel containers, one of 20 litres and the other of 30 litres. They use this water for drinking and cooking. When in a follow up conversation with the couple, we pointed this "issue" with their water services and the need to rush to store and save their potable water, her husband was quick to dismiss it.

> *But we do that because all our lives we have been taught that the corporation water is pure and tastes great. Pune was famous for its water taste, but if we were not so finicky, we could just install a filter and use the non-potable water for drinking as well. (Participant 2, Elderly Male and a long-time resident of Pune. Translated from Marathi to English by the author who is a native speaker of the language)*

Having lived in Pune all their lives, the willingness to adjust to the taste of a mixture of groundwater, tanker water, and some corporation water was viewed as an in-the-background reality of living in the city, a part of life. Oddly, although they often in fact lacked water, they did not *experience* it as a lack, if we understand "experience" in a Deweyan sense of a retrospectively organized memory of earlier experience flows. For if the absence of water was so taken for granted that it never entered their consciousness, then they did not experience a lack of water (i.e., a breakdown of what should be an always available water supply); they instead experienced intermittent water, a condition that they have long accommodated.

A similar phenomenon occurred with regard to clean water. One of our interviewees faced washing machine troubles because the hard water left cement-like deposits on the machinery. While they had had to call the maintenance often (whose business had flourished in that area) they also had their own ways to deal with it: *"It's very simple, we just pour in Harpic in the machine - it's acidic, so it melts the cemented salts and the machine works!"* (Participant 3, Female, resident of Pune. Translated from Marathi). Harpic is a cleaning product that contains hydrochloric acid, which can dissolve limescale. To apply it, her husband pours the cleaning agent on the washer's disk, and then he has to bend over on his top loaded machine and use his

hands to tug and twist on the disk till it starts moving freely. Once it starts moving, he can wash their clothes - until next time.

Such experiences are the result of daily encounters with Pune's problematic water services. Narrating her personal experiences of living in Pune City, the lead author had a similar shift of perspective within a month of living in less-than-ideal water services, despite actively documenting the experiences of living with lack of water. When she first faced a day without water, she felt frustration, panic and annoyance. The second time it happened, there was resignation and after the first two weeks, she was prepared with the schedule of the days of week without water and storage plans, almost casually waiting for the whole day to have a bath after an intense workout. While delaying bath times, ignoring the taste of the water, or accommodating fixed availability schedules are some of the habits and ways of being these adjustments create, such habits also change how the right to participation in these services is viewed. One commentator on a newspaper article, belonging to a drier city of Vardha angrily ridiculed the 24/7 water initiative:

> *Why want 24 hours of water? No one will hold the hand of the people of Pune for the waste of water. I lived in Wardha city. Water is provided every other 2 days and enough water is provided. This is the way it has been for the past 20 years. There is no one complaining about this, even though there is abundant water in the water supply scheme - (Comment on a Newspaper Article [73], translated from Marathi to English by lead author)*

These cases collectively demonstrate that the view that clean water should be available 24/7 as a public right is not universal, but rather an assumption borne of privilege. From not even noticing that lack of running water is a "problem," to resorting to "*jugaads*," (i.e., hacks) to using "this is the way it has been for the past 20 years" as an argument not to change—Pune's residents do not experience water shortages the ways that people from wealthy countries might expect that they would. Indeed, managing life under such circumstances can become a matter of pride. This culture of making-do can also be viewed as a vulnerability to exploitation (i.e., the public's willingness to put up with problematic infrastructures provides little pressure) or even public authority to improve the infrastructure. From a design standpoint, we are left with a situation where the experiences of hydraulic citizenship in Pune are not what researchers and designers from more affluent regions might assume them to be. "Water is provided every other 2 days, and enough water is provided": is that enough, and if not, what would be? Similarly, the links between user experiences and design implications might not be what user centered design tells us they are (if so, our research seems to suggest that CSCW might develop systems to support hacks and workarounds, while helping to lower public expectations, while leaving the broader infrastructural problems in place). Perhaps the more appropriate take-home is to seek to understand the public's experiences with water infrastructure in such a way that information systems can be designed to augment the power and agency of the public to own and to use its own (public) water infrastructure—but all of that turns on questions of legitimacy.

4.3 Legitimacy: Making Hydraulic Infrastructures Possible and Visible

Legitimacy is the ability of the resident to be recognized as the rightful participant in the city's water distribution services. However, becoming a legitimate hydraulic citizen goes beyond merely acquiring the legal documents that identify a resident as a rightful participant. City residents must put in effort and sometimes money to become and remain legitimate hydraulic citizens. Legitimacy is a process that makes hydraulic participation of the residents possible and

also visible. One way that legitimacy manifests as a process can be seen in Anand's concept of "leakage" ([2], Ch 5) which refers to accessing water infrastructure illicitly:

> *Facing demands for water from residents that they are either legally or structurally unable to serve because of exclusive city water rules, engineers and other city authorities also participate in the production of leakage (euphemistically called social leakage) when they permit otherwise ineligible residents to connect to the water system (*[2], *p128)*

Anand shows that legitimacy is not just about the strict de jure legalities of the matter, but also includes judgments about what is earned or deserved given an infrastructure that sometimes is too rigid to work properly. When designing for services and technology, uncovering and making visible these legitimizing processes thus becomes crucial in understanding participation in hydraulic services. Often such leaking processes become so naturalized that hydraulic citizenship itself is hidden and invisible. Anand explains this through hydraulic connections - citing that while some connections are metered, others are documented but not metered, but there are also some that "do not even exist on paper and others that "are unknown even to the engineers" ([2], p128).

In this section, we investigate the legitimacies of water provisioning and access in the city of Pune, by looking at the process of water supply from both ends: Those that provide and those that receive

4.3.1 Water Management and Distribution: "Sitting on a Live Bomb"

In the previous sections we saw that Pune's infrastructure, overly stretched by the outward growth and increasing population, is pushed beyond its capabilities. Those who manage the water distribution services also experience strains: on their capacities to provide water to everyone. Furthermore, Pune, situated downstream to two major dams, has access to abundant water but is also prone to flash floods in the months of monsoon and water cuts in the hot summer months. The downstream rivers, Indrayani, Mula and Mutha are used as flushing channels for the dams. Thus, they often overflow in the monsoons, and appear to be arid and abandoned canals during the rest of the year. In discussing Pune's water situation, the river activist we interviewed highlighted the difficulty of managing Pune's water, aptly summing up the predicament of those who manage the services.

> *It's a blessing that so much water is available for the city. But if you say to manage it, then it is like sitting on a live bomb (Participant 5, male, a river activist and a civil hydraulic engineer)*

But managing this "live bomb" is not just about managing the water. Those that facilitate the distribution of water in the city have to manage the residents' issues and complaints, which according to the senior engineer in the municipal water department, are plenty. While the continuous growth of physical boundaries of the city and the population strain the water management and infrastructures, there is a growing distrust amongst the municipal representatives and customers.

To overcome the people management issues and the constant strain on the city's water systems, one recent initiative under the smart city drive is an automatic metering system. The head of the department of water engineering, whom we interviewed, was looking forward to this change, not only because it would improve the materialities of managing water infrastructures, but also because it would help him legitimize (or possibly delegitimize) consumer complaints and, by extension, his own position:

> *With this introduction of AMR (Automatic Meter Reading) technology, at my desk itself I can say, "gentleman, this is your consumption pattern for the last 6 months 6 years you are supposed to consume 700-750 litres of water per day, and you are consuming 1300 litres, which is much more and based on that, because I am very much sure your consumption is on higher side that what you are supposed to. I can very point blankly tell them show them what their consumption was and what it is now. (Participant 8, a senior engineer in the municipal water department)*

Municipal representatives and customers alike do not trust each other, because there is no "ground truth" measure of how much water people are actually using. From the municipal perspective, "there are a lot many numbers of complaints from the public at large that they do not have water, and I myself I am not sure if these complaints are genuine or not". Automatic metering systems will grant legitimacy to some complaints and remove it from others. But this cuts both ways. Fighting on the behalf of the residents, numerous newspapers and online articles call into question not only the civic body's management capabilities, but also their claim that the issue is due to lack of water supply:

> *Social activist Maruti Bhapkar said, "The water-cut decision was taken because of the inefficiency of the ruling BJP and the Pimpri Chinchwad civic administration. It will cause trouble to citizens. This decision must be revoked, else we shall conduct an agitation. (Newspaper Article[68])*

"Conducting agitation", online newspapers and articles thus become a platform for the residents to express and find a place to vent their frustration. The articles such as above often have comments and statements from the general public, such as the one below, which accuses the government of failing to provide the bare minimum: "For god's sake, at least provide the basic water supply requirements to the citizens who trust you for this bare minimum. Smart city infrastructure is just a dream" (Comment on a Newspaper Article [82])

Citizens have not only called into question the municipality's legitimacy, but also their own status as citizens. One resident in a newspaper article tried to make his lack of legitimacy visible, by making visible the lack of the civic body's ability to provide the service.

> *After moving here, I realized that there was no water supply from PMC in our area. We were forced to be totally dependent on private water tankers for daily supply. While I was getting over the shock of the civic body not providing this essential resource, in October 2010 I got a property tax bill from PMC. Divided under various headers of services we had to pay for. One of the categories was water supply charges. I took objection to this and soon wrote a complaint letter to PMC, stating that it should ideally remove water supply charges from the overall tax." (Newspaper Article[67]).*

His complaints, however, went unheard, so he subsequently took the dispute a step further by refusing to pay that portion of his taxes designated for water. In effect, this resident delegitimated the whole relationship of paying taxes in exchange for services by choosing to opt out of taxes. However sympathetic one might be to his case, the municipality nonetheless was unwilling to relinquish its claims over this resident as its subject:

> *On Friday last week, however, he finally received his response. A notice for property attachment was directly pasted outside his bungalow in Paradise Villa complex dated December 27, 2019, asking Khan to pay Rs 10,36,104 within 15 days of notice's issuance date. (Newspaper Article[67])*

Both this case and the preceding one about the automated metering system are possible because it is impossible for the city to establish that residents are getting the use of the water system that they are paying for in taxes. City officials are aware that this is a problem and creates inequalities. In our interview with the head of the engineering department, he responded:

> *The water that is being supplied is charged as a component of the property tax irrespective of what you are going to consume, you are going to pay a fixed amount, so there are areas that consume 500 ltr water per capita per day, but pay 200-300 Rs annually whereas there are people to whom we supply water for 1.5 hours to 2 hours on alternate day basis but they pay the same amount. There is a mismatch over there. (Participant 8, a senior engineer in the municipal water department)*

Fig. 3. Existing, older metered water connection in some areas. These meters are either dysfunctional or connected to a very limited number of households. The meters were introduced around the year 2000 but were retracted due to technical issues and were a failure (Image source: Lead author. Information Source: participant 8).

However appealing automated water readings would be to help legitimize all stakeholders' positions, the complexity of Pune's actual water infrastructure—with its borewells, Tanker Mafia, rainwater collection, and so on—suggests that any meter reading would likely be contested—and thereby lack its own legitimacy. In this way, one might imagine that even with the metering systems, the legitimacy of all stakeholders will continue to be contested. Indeed, there is evidence that supports this conjecture: the Pune Municipal Corporation (PMC) installed around 5,000 meters in the Nagar Road areas, and soon 350 of them had been removed by the respective property owners, because the property owners were afraid that they would have to pay the water bills in accordance with the meter readings [76]. In summary, not only does Pune lack a ground truth about how much water is being provided and consumed, there is—at best—disagreement about whether such a ground truth is desirable in the first place.

The question that arises out of this disagreement and the preceding examples then is how do smart city designers even make space and create trust for ICT and digital technologies? In Pune, many residents believe that such interventions are an unnecessary overhead and even an infringement upon their privacy. Their acceptance of the water situation and opposition of any

"fixes" does not so much reflect a resistance to an improved water situation, as it reflects a resistance to the possibility of an authoritative ground truth that cannot be hacked or negotiated with. That is, the jugaads and other workarounds are a cultural resource over which residents have mastery and agency; technological "fixes" come at the cost of stripping residents of their hard-won (and culturally situated) agency.

5 INFRASTRUCTURE (RE-)GAINED

The preceding sections collectively suggest that Pune's municipal water infrastructure itself appears to lack legitimacy. That is, if we define legitimate infrastructures as those that facilitate a seamless in-the-background interaction to its residents as they go about living their lives in the city, then Pune's municipal water infrastructure lacks legitimacy. As a physical infrastructure, comprising pipes, water cleansing systems, sewage collection, and so on, Pune's water system cannot reliably provide clean water to its residents. Where it does provide clean water, it does so in uneven ways, with some neighborhoods getting far better service than others. As a political and economic infrastructure, it is also inadequate, because disputes between the municipality and the public are by and large intractable, and the taxation that underwrites it is—by all accounts—unfair. As a technical infrastructure, it is unable to provide basic information about who uses the water and in what amounts, which might facilitate dispute resolution. Star and Ruhleder [63] introduce the notion of "infrastructural breakdown," which is that moment people notice a hitherto virtually invisible infrastructure because it has a breakdown—the way we remember there is an electric grid every time there is a blackout. But "infrastructural breakdown" almost doesn't apply to the municipal water service in Pune, because the municipal water infrastructure is always in a state of breakdown.

One might imagine then that such an infrastructure is, in Star and Ruleder's terms, always visible. Yet, the resistance to adopt new technology suggests that this is not the case. Such resistance comes from new technology's destructive potential to one thing these residents have learned to rely on: the accretions of cultural practices, jugaads, and appropriations so delicately interwoven through everyday mundane actions. These accretions become one with the water infrastructures, and in doing so help almost achieve the invisibility Star and Ruleder discuss. This points towards a situation which we might refer to as *infrastructure (re-)gained*, to mark the moment when an infrastructure achieves a sufficient level of functional competence that it is able to recede from awareness. In achieving this invisibility, city residents in a way acquire a "naturalized familiarity with the [infrastructure's] objects" [62], making them legitimate members of the city's water infrastructures.

Thus, when we view Pune's water infrastructure as a heterogeneous assemblage of services, accommodating practices, and creative appropriations arising out of the resident's daily practices then it is possible not only to view it as a sufficient infrastructure (especially by the residents), but also one that can disappear from at least some users' awareness. That may be why it is difficult to imagine, given the "chaotic" growth of Pune and the deep culture of water inventiveness shown by its residents, that the municipal water system will ever become the infrastructural hegemon it is in other regions of the world. Lindtner et al [44] encourage researchers to seek "interventions within the gaps, cracks and fissures […]". In our study of water infrastructure in Pune, we found that the gaps, cracks, and fissures were more commonplace, understood, and even useful than the ostensibly primary service itself: the municipal water supply. Acting within these cracks and fissures were not public figures, activists, or some sort of Deweyan "public" but rather everyday citizens accessing water in their

everyday, mundane lives. Arising out of these activities are *flaky accretions of infrastructure*, embedded with cultural and socio-political aspects of a city.

5.1 Molding the flaky Accretions of Infrastructure

Anand's characterization of infrastructures as "flaky accretions of socio-material processes" might have sounded provocative, but it is all too easy to see its applicability to water infrastructure in Pune, and many infrastructures in the age of climate change and coronavirus.[26] remind us that hidden in these flaky accretions are the embedded cultural and socio-political aspects of a city, which research can help to make visible. We have shown that these aspects of the city emerge through the residents' subjective lived experiences with the city's water infrastructures and thus are deeply intertwined with residents' individual situations. For example, along with common overhead tanks, many residents build their own private tanks and store extra water, but not all residents can do this. Thus, even though from the perspective of the city service providers, all residents are seen (and taxed!) as equals, residents create for themselves highly bespoke water solutions. And where one complements the municipal supply, e.g., by installing a borewell, they might introduce new problems (e.g., mineral rich, unsanitary water) that calls for still new solutions, and with them both physical resources and skilled practices. The iterative cycle of new problems and solutions is possible because the residents also update their attitudes towards the city infrastructures.

And so, citizens and infrastructures co-evolve. [35,40,50,53,62,63] have used the notion of "infrastructuring" to explain the ongoing process through which citizens make infrastructures. Indeed, Pune's residents made infrastructures and even infrastructured water itself through makeshift storages, pumps, and even acids. However, this act of infrastructuring and the infrastructure [re-]gained is not rooted in a deliberate attempt to build a new system; it is about getting sufficient use out of the current system. Thus, one might imagine that new I.T. systems are met with scrutiny, not so much because residents do not trust the government, or because of some generalized technophobia, but because residents fear that technology will diminish their agency, by disrupting and preempting their jugaads. None of this should suggest that the water system is acceptable or sufficient. Even less so is it fair: the differences in socio-economic class, caste, and religion, as [2] has shown negatively influence infrastructuring capabilities. Our goal is not to celebrate the ingenuity of jugaads, but rather to fully recognize them as an integral reality of the city's water infrastructures when designing smart systems. One way this can be done is by not treating the public services as invisible, black-boxed hegemons, but as visible and fallible public entities with the potential to be shaped and improved upon (which, in fact, they always were). It also suggests that information might be heterogeneous as well, not as capturing a single truth about the system and its use, but rather informing stakeholders in diverse ways pursuing diverse—even cross—purposes.

Making visible such appropriated infrastructures can have important implications for future smart designs. Such infrastructures imply that the residents, much like water flow, will find a workaround in the gaps and caveats of material infrastructures. However, prevailing visions of "smart cities" [71] appear to promote monolithic infrastructures. While these visions aspire for a robust system with sophisticated management and control mechanisms, they fail to consider the ground level realities of accessing water. As shown with the resistance to smart meters, designers must consider the situated reasons for resistance to any one size fits all metering solutions[69,71]. As technologies and digital communication tools become an ingrained part of city services, a crucial aspect of citizen participation would then be to make visible such

workarounds and appropriations through citizen self-reporting mechanisms, but not as a report of issues and complaints. Issues and complaints indicate the citizen to be a subject of the state – creating a power differential between the state and the resident. Instead, such a space would have the intention to co-create the infrastructures and this would require that we redefine what it means to be a citizen.

5.2 Infrastructuring Citizenship

We conclude this paper by reflecting on the nature and implications of "hydraulic citizenship" for CSCW/Social Computing research and ways it contributes to infrastructural projects such as smart cities. We noted that cultural anthropologist Aihwa Ong's [51] characterization of citizenship is that it is an emergent form of political subjectification, made possible through the ongoing interaction and negotiation among the state and its subjects. Anand's notion of hydraulic citizenship locates those interactions and the political subjectification that arises from it with the public's use of service infrastructures, in this case, water supply. Our results have shown that the subjectification of the public's (and even municipal stakeholders') ongoing interactions and negotiations with water in Pune are only partly linked to the municipality. Hydraulic citizenship also entails navigating borewells (and the water quality issues they bring), private for-profit networks like the "Tanker Mafia," distribution schedules, bespoke accommodations (e.g., storing water in buckets and tanks), and so forth. It is hard to argue with Anand that "*It takes a significant amount of work to become and remain a hydraulic citizen* [2], p.10], but our research has led us to question the assumption underlying understanding of hydraulic citizenship as unfolding the ways "*that enable residents to connect to and receive reliable water from the urban government*" [2], p.10]

Rather, our research showed us that citizenship is at least partly constituted by a daily repeating set of interactions among residents, municipalities, and physical infrastructures—in the present case, pipes, tanks, borewells, meters, descaling chemicals, and so forth. In shifting our focus from governance to mundane interactions with infrastructure, we gain insights not only into how infrastructure actually works (or fails to), but also how specific communities believe it ought to work, which, as we have demonstrated, is often at odds with assumptions from other communities. The residents, through their everyday bids to make the water infrastructures work also help them almost fade into background. This invisibility is achieved not only by ad-hoc solutions and accommodating attitudes, but also through the residents' familiarity with them. Through this familiarity, they achieve a sense of belonging, a membership to the water infrastructures (and the city). When we look at it this way, The hydraulic citizen thus not only emerges from the "*significant amount of work"* but also from the resident's *"naturalized familiarity"* [62] with the water works. This formation of the hydraulic citizen happens at the level of everyday mundane attempts of the residents to go about living their lives.

Thus, to support equitable and fair participation and give more power to the city dwellers, we argue that citizenship should be perceived through the lens of everyday mundane practices. It can be thus defined as an evolving, work-in-progress membership the residents achieve through the activities that they undertake to make their everyday lives possible and livable. In a way, the resident's infrastructure their citizenship by engaging in an ongoing activity of making, remaking and redefining water services. That is, through *Jugaads*, they not only make the infrastructures functional, but also establish their ownership and membership in the city. Jugaads, as our research shows, do not need to be grandiose reformation of infrastructures, but

rather can be something as simple as extra buckets. Such adjustments (and thus also residents' resilience and vulnerability) can gain visibility only if we take a broader approach in defining public service infrastructures and the subsequent processes through which residents gain rights and agency over them. That is, by reconceptualizing citizenship as an infrastructuring activity, or as residents of Pune would say, doing Jugaad, we can make visible the efforts residents take to exercise their rights over the city's facilities. CSCW/Social Computing research urges us to design technologies that facilitate citizen empowerment [18,20,21,22,24,28], and yet, the notion of citizenship is often a static construct. By positioning citizenship as an interactional practice with, on, and through public infrastructures, researchers can open up new ways to support such practices.

In short, we are arguing to decouple empirical analyses of citizenship from governments and instead to couple them more tightly with a broader and more heterogeneous conception of public service infrastructures—especially important in an era where visions of and plans for "smart cities" are major economic and technological initiatives. In economics, there is the concept of the "natural monopoly," which is the idea that certain sectors have such high start-up costs and economies of scale that it is "natural" that there can only be one of them, which is either managed by a government or a highly regulated private entity. Infrastructures such as the electric grid and water services are often used as paradigmatic examples of natural monopolies. If our data shows anything, it is that there is nothing "natural" about a natural monopoly whatsoever; indeed, it appears to be a specific kind of achievement within certain social systems. In Pune, there is water infrastructure, but there is no monopoly (government controlled or otherwise), and indeed little prospect that there will ever be one

If CSCW is to support citizens and municipalities in doing the "significant amount of work" to become and remain a citizen, it must dismantle arguably dated assumptions about natural monopolies and the role of the state in the provision of services. Such assumptions include beliefs about the desirability of a single, authoritative information system that represents the state of the service, the goal of creating a unified central water system from the top-down, and that the elimination of "leakages" is desirable. In Pune at least, a more appropriate goal would be to support the public's access to clean water (whatever its provenance), and redundancies, hacks, leakages, public-private (mis-)partnerships, evolving and conflicting notions of "legitimacy" and so forth can contribute to that goal. Any of these components can potentially be improved: it's possible to imagine a more socially equitable and biologically safe distribution of groundwater; the Tanker Mafia could evolve to include more transparency, efficiency, and efficacy; pumps can be upgraded so that higher floors enjoy the same access as lower floors; policies can ensure that renters are afforded the same rights as homeowners; and so forth.

In an era where CSCW/Social Computing and HCI increasingly operates under conditions in which "collapse informatics" [64] provide design constraints, and in regions, like Pune, which for cultural and historical reasons never offered public services as natural monopolies, the central power of the state or municipality cannot be taken for granted as a norm. Accordingly, the rights, responsibilities, and practices that collectively constitute citizenship shift. There is still a public good, and a need to manage, grow, and sustain public resources such as water supply—the concept of citizenship as defined through political belonging still applies; it's just that citizenship cannot be defined solely in terms of a resident's interactions with or subjectivization to a state or municipality—even if they are taxed. Rather, citizens diversely engage in the collective work of accessing and managing the resources needed to sustain life—during infrastructural breakdowns and infrastructural (re-)gains alike.

6 CONCLUSION

The redefinition of citizenship itself as an infrastructuring activity has several implications for CSCW/Social Computing research that seeks to empower citizens. However, these implications are not what one might imagine to be design implications in terms of solutions and actionable analyses that might instruct smart city planners to design better tools. Echoing [15], by using embedded ethnographic methods, we intend to "provide [...] new ways of imagining the relationship between people and technology." In this paper, in a bid to support social computing's efforts to democratize city provisionings [4,14,25], make urban spaces inclusive and participatory [20,21,22], view city dwellers as co-creators [26], we seek to offer a new way of thinking what it means to be participant in the city through the city infrastructures and the resident's everyday actions. [61] encourages us to see the user as an everyday designer, and we build on that to suggest that the "urban user" is an everyday designer of public infrastructures, what we refer to as "infrastructured citizenship". We focused on water, a resource deeply embedded in the everyday mundane, where the phenomenon that citizenship is infrastructured through mundane activities is highly evident. While this study focuses on India, the concept of infrastructured citizenship can help us reimagine more generally, people's relationship with the state, city and space they live in, through everyday interactions with the public infrastructures and thus allow for a more embedded understanding of civic participation.

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