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RESEARCH PAPER

Socio-spatial Infrastructures: Drinking Water Supply and Formation of Unequal Socio-technological Relations in Rural Southern Bihar

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Abstract: This paper explores the social and spatial implications of drinking water infrastructures in rural southern Bihar. Hardiya, a multi-caste and multi-religion village, has a complex social arrangement. This village consists of original households, households resettled due to dam construction, and households resettled due to excessive fluoride contamination in groundwater. Excessive fluoride produces incidences of fluorosis among households, and historically, households have low access to clean drinking water. In response to the drinking water and public health crisis, multiple state, non-state, and transnational institutions intervened in Hardiya to provide safe technologies and infrastructures for clean drinking water. These twenty years of interventions have brought different technologies, institutions, and actors together to supply drinking water. However, these schemes are functioning inadequately on the ground, and access to clean water remains a big question amidst the development of drinking water infrastructures in Hardiya. This paper explores the dialectical relationship between drinking water infrastructures and social spaces, how both shape each other, through which assemblages, and what it renders. It explores the uneven outcomes of this technological intervention across different socio-spatial groups in Hardiya. Firstly, it examines how drinking water infrastructures arrange social spaces at the village, settlement, cluster, and household level. It further examines the changing nature of drinking water services and infrastructures in Hardiya and how various drinking water programmes incorporating multiple institutions, organizations, actors, and social groups arrange and settlement patterns in the village. Moreover, it

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examines how different social groups, with variable access to power, access water for their daily needs in the face of diversity in technologies, infrastructures, and responsiveness of local state actors. Using Political Ecology and Critical Geography frameworks, this paper argues that drinking water infrastructures and services, mediated by institutional and social actors, produce uneven access, power arrangements, and socio-technological relationships.

Keywords: Drinking Water Supply, Infrastructure Assemblage; Geography and Technology, Political Ecology, Southern Bihar.

1. INTRODUCTION

On 28 July 2022, while returning from a day of fieldwork in the village of Hardiya, I was looking for a water source to fill my empty bottle. The scorching heat had dehydrated me and propelled me to obtain water from nearby households. At the household I went to ask for water, I encountered Kavita Devi. On my request for drinking water, she asked me to sit down and told her younger daughter to bring water for me in a *lotah* (a brass or steel water jug) from their hand pump. Kavita Devi, who looks after her five children, shared with me that her husband was a migrant labourer and visited home only once or twice a year; in his absence, she was the head of the household. Soon after, her daughter fetched me some water. I was amazed and speechless when I saw the water: it was filthy, and micro-red residual particles were visible in it in enormous quantities. I asked hesitantly whether the tap water connection had yet to reach their household. Kavita Devi replied that her household has a tap water connection but does not receive water regularly. She said that at the time of setting up the tap water connection, the plumber had left the pipe open in the middle of the road, saying that the government had only provided that much length of pipe per household. Further, her household was located on higher ground, making access to piped water difficult. She quoted these reasons to justify their dependence on a hand pump.

I could not decide whether I should drink the water. I drank it, hesitantly, and asked Kavita Devi whether this water affected their health. She said that most of her family members merely faced colds and fever at times but that her elder son suffered from fluorosis and could not walk. When she told me this, she was calm and composed. She did not know much about fluorosis and that it was a water-borne disease. Consuming fluoride through contaminated drinking water had disabled her son's body, and she had to care for him. It seemed customary to accept the occurrence of fluorosis due to its prevalence in households.

I was frightened to consider how drinking such contaminated water would affect people's health in Hardiya. Over the decades, contaminated drinking water has worsened households' health and livelihood conditions and constrained "social reproduction[1]" in Hardiya (Norton and Katz 2017). Further, partial access to safe drinking water ultimately directs people to consume contaminated water through degraded technologies and infrastructures.

Like Kavita Devi's household, many other households in different parts of Hardiya suffer from incidences of fluorosis. Hardiya is a multi-caste and multi-religion village with a complex social arrangement, comprising multiple social groups, including the original settlement and villages displaced from the nearby forests and relocated here in the 1980s. Hardiya is not only deprived of clean drinking water; low groundwater availability (CGWB 2013), barren lands, poor soil quality, and inefficient cultivation (O'Malley 1906; Roy Chaudhury 1957) also produce absolute scarcity (Scoones *et al* 2019). In Hardiya, which is situated in the southernmost part of Bihar, diversity in topology, socio-economic differences, and technological and infrastructural interventions shape access to safe drinking water. Over the decades, multiple types of water infrastructures have emerged. Today, access to water is shaped by diverse technological interventions such as large dams, water treatment plants, irrigation canals, hand pumps, borewells, open wells,[2] pipes, and taps.

The presence of fluoride in the groundwater in the village has drawn the attention of state, non-state, and transnational organizations. Over the last two decades, many state and non-state institutions have intervened to provide water for agrarian and domestic purposes. However, focus group discussions conducted for this research reveal that these interventions performed poorly and failed to produce the desired outcomes. In a different *tola*,[3] one can see the remains of technological artefacts once introduced to

[1] Social reproduction is defined as daily and long-term reproduction of the means of production, which is enabled by labour power and social relations. Social reproduction also takes place outside the waged labour–capital relationship, where uneven access to state-based provision (e.g., public health facilities) in daily life restricts or enables the production and reproduction of material social relations and practices.

[2] Borewell and open well both extract groundwater but at different levels. A borewell is installed by drilling a pipe into the ground and is equipped with a pump to draw water. They extract groundwater stored at a deeper level. On the other hand, an open well is a big hollow place that allows manual access to groundwater.

[3] A *tola* refers to a neighbourhood usually consisting of a single social group.

improve water quality. During the fieldwork for this study, many people narrated their interaction with drinking-water infrastructures that had initially generated hope of safe and secure water access. However, over time, they resulted in disappointments due to poor operation and management, unattended grievances, and lack of technical expertise.

Figure 1: Abandoned Fluoride Removal Cylinder in a Resettled Area

Source: Amit Kumar Srivastwa

This study attempts to understand the changing nature of drinking-water services and infrastructures in Hardiya. It examines how various drinking water programmes incorporating multiple institutions, organizations, actors, and social groups shaped and continue to shape the village society and settlement patterns. It further examines how different social groups, with variable access to power, access water for their daily needs given the diverse nature of technologies, infrastructures, and responsiveness of local state actors. Through the existing literature in political ecology (for instance, Bakker, 2007; Budds, 2009; Sultana 2013; Krause and Strang 2016; Anand 2017; Goodwin 2018; Scoones *et al* 2019) and critical geography studies (for instance, Ferguson 1994, 2012; Gupta, 2001; Ferguson and Gupta 2002; Meehan 2014; Boelens *et al* 2016; Schouten and Bachmann 2022), this paper tries to link site-specific realities of water access with the stated purpose of diverse drinking-water infrastructures in policies.

The rest of the study is structured as follows. Section 2 discusses the methodology and describes the study area in terms of social arrangement, settlement, and structure of social and religious groups and livelihood activities. Section 3 explores the historically produced geography of Hardiya and describes how infrastructural and geographical processes have configured territories and spaces at the intra-village level in the past. Section 4 traces how groundwater contamination and the development of clean and safe drinking-water infrastructures have affected household water access across different socio-spatial groups in the study area. Section 5 further explains how the location of drinking-water infrastructures and accessibility to local state actors influence households' access to safe and clean drinking water at the inter- and intra-settlement, cluster/ward, and caste group levels. Section 6 elaborates on how different households meet their water requirements from multiple drinking-water infrastructures and the role played by social and economic power differences in this context. This study adds to the current discourse in urban political ecology and critical geography in a rural location, which views drinking-water infrastructures as a tool for arranging uneven power dynamics. Further, it highlights the role of infrastructures and local state actors in the making of caste-based hydrosocial networks and territories.

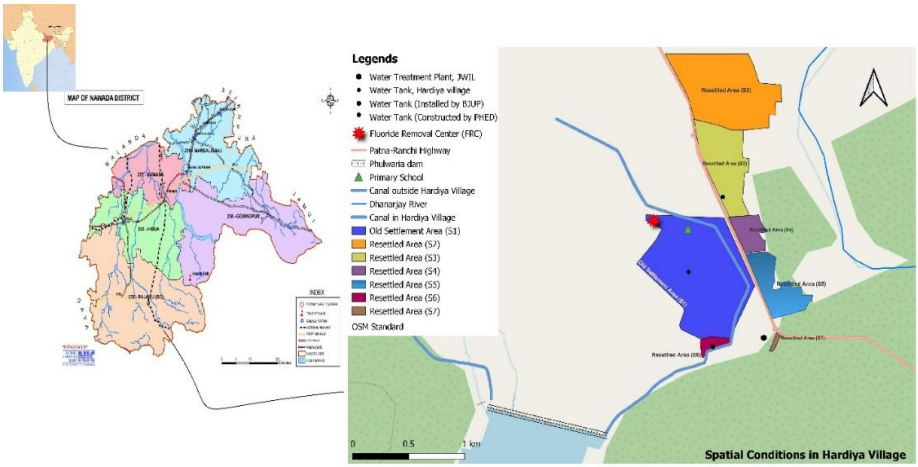
2. STUDY AREA AND METHODOLOGY

Hardiya is located in the Rajauli sub-division of Nawada district, in the southernmost part of Bihar, adjoining the border with the state of Jharkhand (Figure 2); the hilly tracts of the Chotanagpur Plateau run along its southwestern side. River Tilaiya flows along its western boundary, and river Dhanarjay runs along the eastern boundary. Since both are seasonal rivers, the water supply ends a few months after the monsoon. The southern boundary of the village is adjacent to a wide belt of brushwood forest (Roy Chaudhury 1957), which also has some mica reserves that are mined at a small scale. The Nawada District Gazetteers (O'Malley 1906; Roy Chaudhury 1957) describe this region as water scarce and attribute this scarcity to geographical factors such as altitude and rainfall. Census data reveals that the actual rainfall in this district decreased by 34% between 2006 and 2009 (Census of India 2011), creating ongoing risk and vulnerability in the daily lives and livelihoods of the people.

Central, state, non-state, and transnational institutions and agencies have implemented multiple schemes and programmes over the decades to provide water to the region for agricultural and domestic purposes. These

interventions include building water infrastructures—such as the Phulwariya dam and associated canals and piped-drinking-water infrastructures, such as *Neer Nirmal Pariyojana* (NNP, "pure water scheme"), a fluoride removal centre and cylinders, and other drinking water programmes. A significant attempt to ensure the availability of clean drinking water in the area was made in 2015–2016, when the Public Health Engineering Department (PHED), Nawada district, in collaboration with the World Bank and Jindal Water Infrastructure Limited (JWIL), sanctioned a large-scale project in Hardiya to supply water through piped water supply.

Figure 2: Spatial Configuration of Hardiya



Source: India Map – Wikimedia Commons, District Map – Census of India, and Hardiya Map – QGIS, Authors

Hardiya becomes an important site for understanding the complexity and entanglements of communities, institutions, and infrastructural arrangements. It helps examine how the materiality of drinking water, infrastructure, and local bureaucratic arrangements shape access to safe drinking water. In the following sections, we will discuss how this and other interventions have impacted the social groups living in settlements and influenced spatial conditions and technological availability in Hardiya.

As per the 2011 Census, the total number of households in Hardiya was 1,170. However, this number has increased to around 1,600 in the last decade, as indicated by our participatory rural appraisal (PRA) estimates and

Table 1: Social and Occupational Structure of Hardiya

Settlement	Social Composition	No. of Households (approx.)	Key Livelihood Activities
Old settlement area (S1)	This settlement has different caste groups, living in different clusters, which are originally from this village. Dominant castes: Sahu and Rajput Extremely vulnerable castes: Rajbanshi and Harijan Religious minority group: Muslim	375 (Sample size: 75 households; 20% from each cluster)	Dominant castes:[1] Agriculture, private jobs, and formal businesses SCs, OBCs,[2] and religious minorities: Agricultural wage labour, non-agricultural wage labour, migrated labour, informal businesses, and sustenance farming
Resettled areas (S2, S3, S4, and S5)	These settlements are constituted by different caste and religious groups, earlier residing in forest villages and rehabilitated due to the construction of the Phulwariya dam.	1,100 (Sample size: 220 households; 20% from each ward of each settlement)	Dominant castes: Agriculture, formal and informal businesses, and private and government jobs SC, OBC, and religious minorities: Agricultural wage labour, non-agricultural wage labour, migrated labour, sustenance farming, and private jobs
Resettled area (S6)	SC households earlier residing in a forest village and rehabilitated on the outskirts of the old settlement area S1.	50 (Sample size: 20% of total households, i.e., 10 households)	SCs: Non-agricultural wage labour
Resettled area (S7)	SC groups relocated from a cluster of the old settlement due to the presence of excessive fluoride in the groundwater.	50 (Sample size: 20% of total households, i.e., 10 households)	SCs: Non-agricultural wage labour, migrated labour

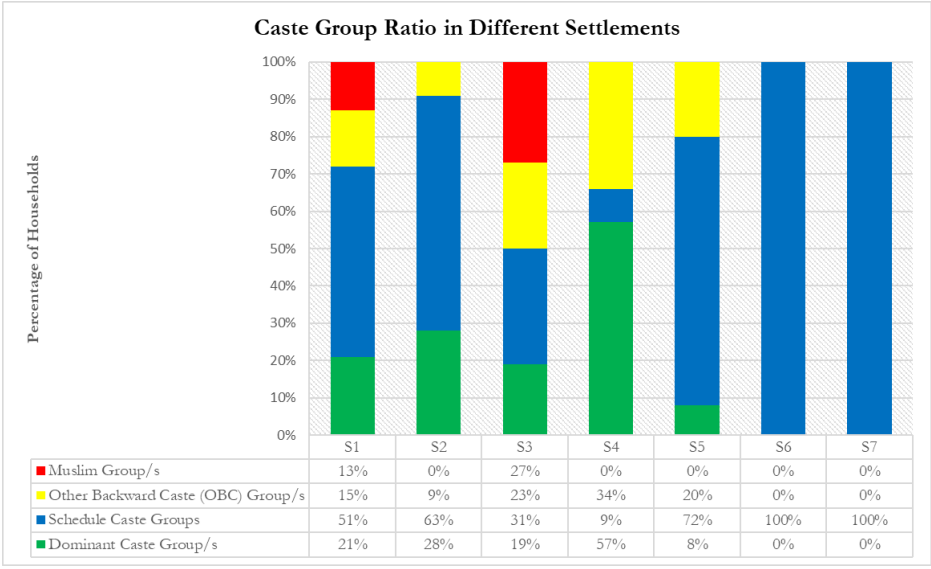
Source*:* Social mapping activity across settlements and clusters

Note:[1]Dominant caste consists of those social groups which may or may not belong to upper caste groups but hold or wield social, economic, and political power in a given context or space. [2] Scheduled Castes (SC) are those social groups which are historically disadvantaged socio-economic groups. Other Backward

Castes (OBC) are those social groups which are educationally and socially backward.

interactions with ward members. The major caste and religious groups include Sahus, Rajbanshis, Yadavs, and Muslims. Table 1 shows that dominant caste groups have better employment and income opportunities than the Scheduled Castes (SC), Other Backward Castes (OBC), and Muslim households.

Figure 3: Household Percentage of Social and Religious Groups in Different Settlements



	S1	S2	S3	S4	S5	S6	S7
Muslim Group/s	13%	0%	27%	0%	0%	0%	0%
Other Backward Caste (OBC) Group/s	15%	9%	23%	34%	20%	0%	0%
Schedule Caste Groups	51%	63%	31%	9%	72%	100%	100%
Dominant Caste Group/s	21%	28%	19%	57%	8%	0%	0%

Source: Demographic profile through primary data collection

The village has three categories of settlements. The first (S1 or old settlement) consists of those who originally lived in the village, while the second (settlements S2 to S6) consists of those who were displaced due to the Phulwariya dam construction and resettled in Hardiya (Figure 2). The last category (settlement S7) consists of a few households that were moved from the SC cluster of S1 in 2004 due to the occurrence of excessive fluoride in the groundwater. Thus, Hardiya has residents who originally lived here, residents who resettled due to dam construction, and residents who resettled due to groundwater contamination.

This study uses a mixed-methods approach to examine the nature of drinking-water infrastructures in the study village. We selected a

representative sample of 20% of total households through stratified random sampling, covering the village's different settlements, clusters, and wards. The survey questionnaire had five sections: a) demographic profile, b) source of drinking water, c) quality and expenses of drinking-water infrastructure, d) quality of water supply, and e) exposure to fluorosis.

Information on the qualitative aspects of people's local lived realities of drinking water access, services, and infrastructures was collected through conversations with key respondents and in-depth interviews. Key respondents were selected through snowball sampling. Some of the key respondents were pump operators, agents from JWIL, and persons from households with no access to piped water. Questions in these interviews varied according to the respondent. Questions to local state actors aimed to understand the trajectory of drinking water programmes, their shortcomings, and how they respond to household grievances. Questions to households aimed to understand whether they depend on one or several sources and what problems they face in accessing drinking water.

Quantitative data analysis was conducted using Microsoft Excel and Stata. Qualitative analysis was conducted through the frameworks of political ecology (Anand 2011; Sultana 2013) and critical geography (Dixon and Whitehead 2008). The spatial distribution of households and drinking-water infrastructures was mapped using QGIS and Google Earth. Oral narratives and ethnographic accounts (Ernstson and Nilsson 2022) were deployed to establish the role of infrastructural interventions in shaping different settlements. Focus group discussions (FGDs) and non-participant observations (LADDER Research Team 2001) were used to identify the changing nature of households' interactions with the various drinking-water infrastructures and institutions. FGDs were conducted to understand problems in accessing safe drinking water specific to each settlement/cluster.

3. GEOGRAPHIES OF INFRASTRUCTURE: SPATIAL CONFIGURATION AND RECONFIGURATION OF HARDIYA

Geography and infrastructure go hand in hand in shaping marginal identities and the sense of othering in social spaces. Flowing through landscapes and infrastructures, water either transforms or destroys places, lived spaces, social linkages, and boundaries, rendering new social, geographical, and water configurations (Mosse 2008). Water infrastructure

creates unequal spatial conditions (Meehan 2014), where households within or across spaces have restricted access to water due to the locations they live in. Water infrastructures can be seen as "material geographies of power" (Gandy 2004; Meehan 2014; Schouten and Bachmann 2022), where geophysical, biophysical, ecological, temporal, and spatial conditions shape the contested relation between communities, water infrastructures, and powerful state and non-state actors (Boelens *et al* 2016). These infrastructural, geographical, and social processes produce "hydrosocial territories", defined as spatially bound multi-scalar networks where human and non-human entities are aligned and defined through hierarchies (Boelens *et al* 2016). These territories and networks reorient the landscape and produce new values and meanings (Ferguson 1994), inclusion and exclusion (Boelens *et al* 2016), development and marginalization (Björkman 2015), and benefits and burdens (Appel, Anand, and Gupta 2018), which often generate precarious conditions for households.

In the mid-1980s, the irrigation department of Bihar constructed the Phulwariya dam near Hardiya to impound water from the Tilaiya river to improve water supply, agricultural conditions, and associated livelihoods.

Figure 4: Landscape Change in the Resettlement Area Between 2006 and 2011
Source*:* Google Earth

However, the Phulwariya dam displaced many households from the forest villages and destroyed the associated ecologies. The irrigation department resettled all of these villages in the remaining parts of Hardiya on the side of the Dhanarjay river. Between 1981 to 2011, the number of households in Hardiya increased from 100 to 1,170 (Census of India 1981, 1991, 2001, 2011). The rapid growth of the population created resource scarcity, as every household required forest and water resources to support their sustenance farming and domestic requirements. Dam construction eventually created contestation among resettled households who depended

upon Dhanarjay and the nearby forest to build and sustain their new habitat. The question of water remains the same, as Dhanarjay does not provide water in all seasons, and only those living on the river's banks can access water from it. Moreover, canals flow through the old settlement area, restricting resettled communities' access to Phulwariya dam's water. Figure 4 shows that the landscape of Hardiya changed drastically after the resettlement. The forest resources in the resettlement area have been reduced, and the river dried out in a short period. Over the years, deforestation—due to household demand for fuelwood and commercial tree-felling—and riverbed mining for stone and sand have caused siltation in the riverbed.

Most households in the resettlement area belong to SC and OBC groups (Figure 3) who relocated from an upland forest area to the plains of Hardiya. Earlier, these households depended on forests for resources such as fruits, wild meat, firewood, and fodder for their livestock. Displacement and resettlement impacted resource accessibility adversely. The SC households in resettled areas live in *kaccha* houses.[4] Most generate their livelihood by working as labour (non-agricultural and migrant). Women in these households spend a large part of their day collecting firewood from the forest area and caring for livestock. Resettled communities were promised to receive a fair amount of land in compensation but they actually received very little land for house construction. People in the resettled areas also narrated that the irrigation department provided different land amounts to different households, which was opposite to the proposed compensation. The resettled parts of the village are barren and undulating, with little scope for agricultural activities. During the social mapping activity across the resettled clusters, people reported that the land they received from the government was not enough for their living requirements. As families grew, the land was distributed among kin, and living spaces became congested. Those with fewer household members retained some land for sustenance farming. A resident of resettlement area S3 said that his household had a very good amount of land earlier, but after displacement, the state government had provided them with minimal land. He further narrated,

> We did not get a good amount of land during our displacement. Our forefathers had ample land, but when we came here after resettlement, the

[4] Mud house or under-constructed house.

> state government gave us very little land for subsistence farming and household construction. At the time of displacement, Karpuri Thakur was our CM, and he promised us government jobs, but we have not got any employment security from the state. Now, most of the households in our cluster do wage labour or some of the members from every household migrate for better employment opportunities. Those with social and political capital captured more land through their strong relationships with state officials, and people like us can't do anything about it but struggle.

Thus, dam construction reshaped the socio-spatial settlement pattern of Hardiya. First, at the village level, two spaces and identities emerged: the households living in the old settlement and households resettled due to the dam's construction. These spaces are formed based on identity, culture, knowledge systems, agrarian and livelihood practices, caste-based distinctions, and their access to water. Those initially residing in the village had the upper hand in terms of accessing resources, upholding social relations, and negotiating with the irrigation department and other government institutions. Dam construction, leading to displacement by default, created a hierarchy between old and new settlements, where the households of old settlements had access to canals from the Phulwariya dam and new settlements had to depend upon the river or rainfall for their farming needs.

Secondly, a large water infrastructure such as the Phulwariya dam reconfigured multiple social structures and spaces within the displaced community, where the location of a house shapes its access to water resources and, further, its material conditions. For instance, households living near the river can easily access water compared to people living near roads. Therefore, households' social spaces configure access to water; simultaneously, water constitutes and reconstitutes social groups as spatial entities. Reconfigured spaces further drive people to look for multiple water sources to fulfil their domestic needs. Dependence on multiple sources creates heterogeneity, wherein households struggle to access water in their everyday lives. Hardiya thus appears as a product of infrastructural and geographical processes, where socio-spatial conditions configure access to drinking water. The material conditions of drinking-water infrastructures have shaped the social spaces from above (dam, river, canal) and below (hand pump, taps, well) in this village.

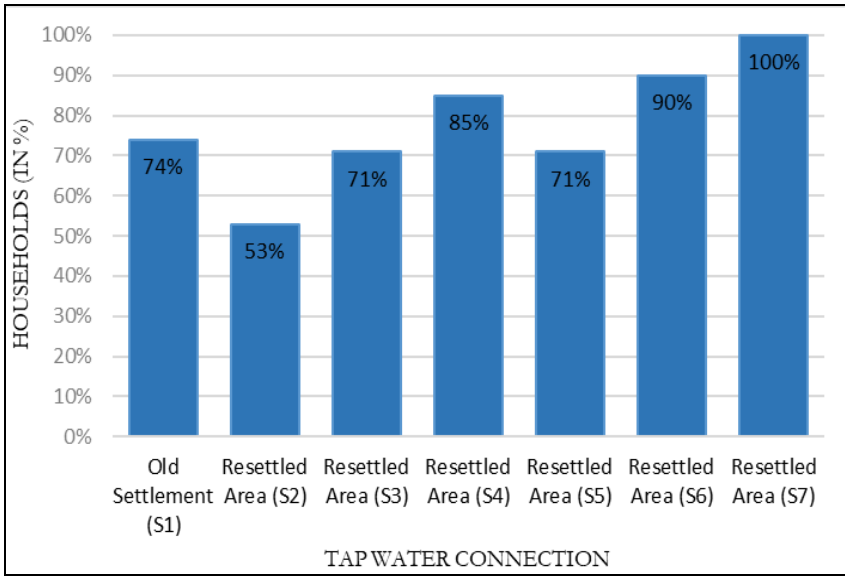
4. INFRASTRUCTURAL INTERVENTIONS IN THE PRODUCTION OF UNEQUAL SOCIO-TECHNOLOGICAL RELATIONS

The previous section demonstrated how past water-based infrastructural interventions created socio-spatial inequality in Hardiya. This section shows how recent interventions for access to clean water have aggravated these inequalities. In 2004, the PHED built a water tank and a network of pipes in one of the resettlement areas (S4) to supply clean drinking water to the fluorosis-affected households in the SC-majority tola of the old settlement (S1). This water tank extracts and purifies groundwater using chemicals (e.g., chlorine). In the initial years, households in resettled areas (S3 and S4) also accessed water from this tank. However, the water tank reportedly stopped functioning within a year or two due to poor operation and maintenance. In 2016, PHED, World Bank, and JWIL established NNP to provide safe access to clean drinking water to the entire village. This programme aimed to provide all households with a paid pipe-based tap water connection using water drawn from the reservoir of the Phulwariya dam.

However, in reality, the infrastructure created under this universal drinking water scheme produced diverse realities of water access across different socio-spatial settlements in Hardiya. The pump operator reported that the Bihar government had waived the installation and maintenance cost, making the tap water supply free and allowing everyone to use it. However, access to clean drinking water from taps depends on whether a household has a piped water connection and whether the taps connected to these pipes receive water supply. Even though programmes like NNP promised water for everyone, the actual spread of pipe connections varies widely across settlements in Hardiya. In Figure 5, it can be seen that while settlement S7 has universal access to pipe connections, in settlement S2, only 53% of households have a piped water connection. The reasons include (i) instability in tap water supply; (ii) the quality of water in traditional sources of water (hand pumps and borewells); (iii) divergence of views within settlements (especially those of mixed-caste groups); and (iv) irresponsiveness of state actors to demands for water connections.

The views of local state functionaries and community members diverge widely. For instance, the pump operator of the Hardiya water tank said,

Figure 5: Households with Tap Water Connections in Different Settlements



Source: Questionnaire-based, close-ended survey

> When we made the pipe connection five or six years ago, many households denied tap water. Many officials from the Nawada district came to Hardiya to inform households of contaminated drinking water, but households outrightly denied the clean water. What else can we do? These people are like that, illiterate and stubborn.

However, a resident of one of the SC tolas in the old settlement (S1) gave the following counter-argument,

> In 2015–2016, at the time of pipe water installation, some people, including our ward member, resisted the tap connection and said that the installation of pipes would damage their street. People were separated into groups and argued over the pipe connection; due to that, no one got the connection in our tola (cluster). Now, we have no other option but to share other households' hand pumps. We went to the pump operator asking for connections, but he refused our request by stating that he had no autonomy in providing a new piped water connection.

Households in the resettled areas (S2, S3, S4, and S5) echoed this narrative of unresponsive local state actors. For instance, some households at the far end of S3 have no tap connections and depend on hand pumps for their water supply. A resident of an OBC household said,

> When they (JWIL officials) were installing pipe connections, they said it was impossible to bring pipes to our homes. So, they left the pipe connection on the main road of the ward and told us to invest our money to extend that pipe to our households. You tell us. Who has this much money and time to look out for pipes and taps in the market?

Muslim and SC households in S3 face similar problems and deploy similar coping strategies.

However, access to a piped water connection does not mean access to sufficient water. This is because of factors such as inadequate water pressure, leakages in pipes, disruption of supply, and breakdown of taps. When pipes fail to supply clean drinking water, residents turn to other strategies to access water—traditional water sources such as rivers, open wells, and canals; private water sources such as common borewells; or evolving sources such as private or shared borewells/hand pumps. As a result, households in all settlements apart from S7 depend on multiple water sources (Figure 7), indicating the insufficiency of the piped water supply to serve domestic needs.

Resettled area S2 has three wards, each consisting of different social groups. Households in Ward 3, near the Dhanarjay (Figure 2), are more prone to have a lack of access to safe drinking water. This ward consists mostly of SC households with tap water connections, but these taps produce no or low water pressure. Consequently, they rely upon other open water sources such as the river, wells, and hand pumps. Residents of this ward registered their complaints with JWIL officials several times. However, a JWIL official responded,

> We have acknowledged their complaints and know that taps are not producing enough pressure in Turiya and Musahar tola (ward 3, S2). We have analysed the situation several times and found that the pipe connection from the water treatment plant to their tola is properly functional. I think we should make a direct pipe connection from the plant to their tola to provide better drinking water flow.

Due to low pressure in taps, many households have dismantled or disowned their tap water connections. The last ward of S2 has become a site of abandoned technological artefacts.

Figure 6: Abandoned Tap Connection in Ward 3, S2

Source: Amit Kumar Srivastwa

Resettled area S2 provides a mixed picture of tap water accessibility, with assured tap water supply decreasing along the axis of caste-based social stature. Households in wards 1 and 2 receive disrupted supply due to leakages or breakage. Households in Ward 1 mainly belong to dominant caste groups, which have the option of using hand pumps and borewells apart from tap connections. Households in Ward 2 are mostly from the OBC and SC categories, and they meet domestic water needs partly through tap water and water shared with other hand pump owners. The local representative of Ward 2, who also experienced a disrupted water supply through his household's tap, said,

> The pump operator or Jindal officials never visit this part of the village. You tell me how we should register our complaints?

Testimonies and data show that the idea of universal access to piped water supply has failed in Hardiya. Two important reasons underlie this failure. Firstly, local state actors often quote norms provided by the PHED and other state institutions as a basis for refusing tap connection requests from underprivileged social groups. Secondly, even where tap connections have been made available, the repair and maintenance facilities flow along social

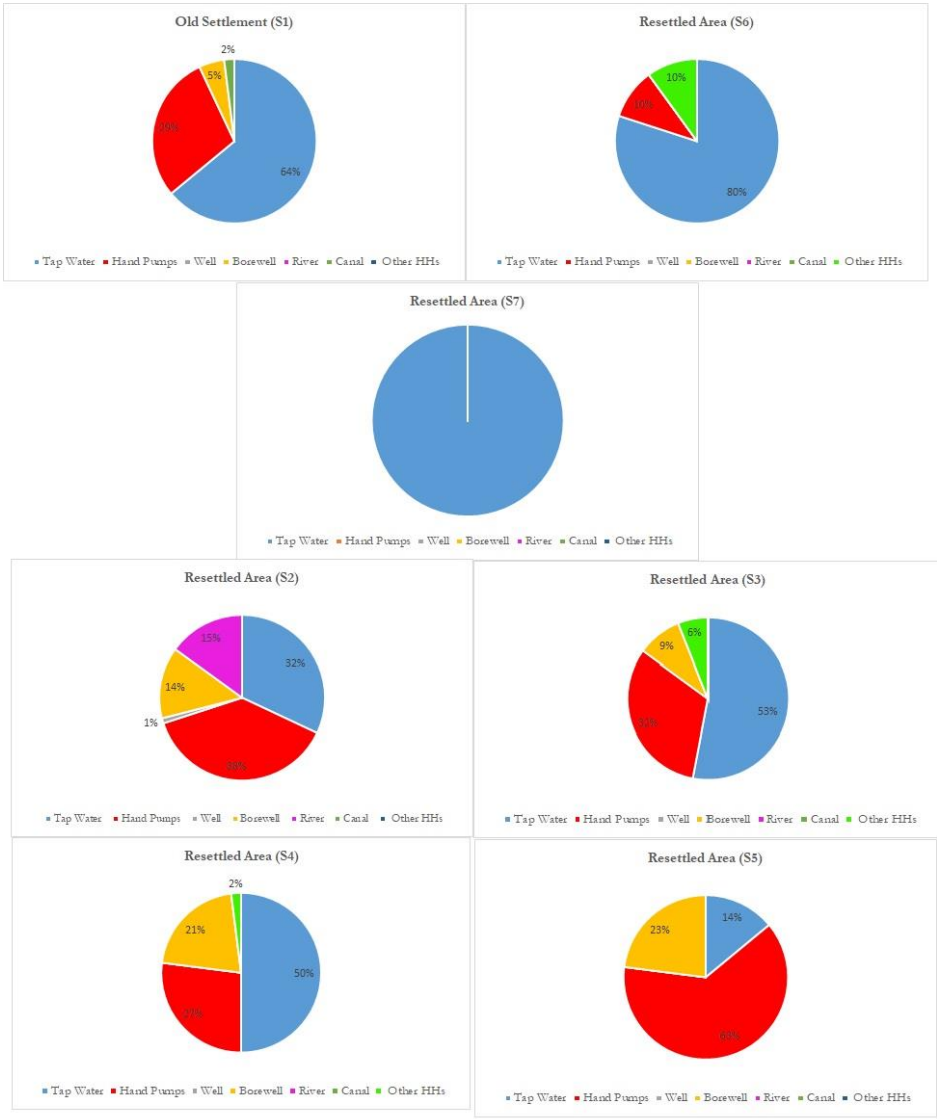
hierarchy lines. Local state actors are more efficient in repairing leaking pipes and correcting disruptions in upper caste wards than in SC and OBC wards. The "modern infrastructural ideal" (Graham and Marvin 2002, Breshinan and Hesse, 2020) of universal access to piped water supply did not materialize in Hardiya. Instead, uneven provision of tap connections and water availability has created unequal relations between households/social groups and local state actors.

However, heterogeneous water infrastructures are shaped not just by spatial and social relations but also by water quality. In Hardiya, the presence of fluoride has resulted in changes in the settlement pattern and, subsequently, shaped household water availability, as described in the later sections. Groundwater in Hardiya is contaminated by fluoride, which has made its residents vulnerable to fluorosis (see Section 5). Negotiations for safe infrastructure and technology underlies the technological relations among households and between households and other (state and non-state) actors. Infrastructural processes have thus created hybrid (Furlong 2014) and contingent realities (Dixon and Whitehead 2008) in Hardiya.

5. LOCATION OF INFRASTRUCTURES AND ACCESSIBILITY TO The LOCAL STATE ACTORS

The settlements on both side of the national highway have varied access to clean sources of drinking water (Figure 2). Households in S1, S6, and S7 have more sources of clean drinking water than households in the other resettled areas. Various state and non-state drinking water programmes cover S1, S6, and S7, except one, which cover S4. Only one water tank has been constructed in S4 (Figure 2), which was initially constructed for an SC tola in the old settlement. The location of a water infrastructure influences a household's access to water, and access differs for households not just across settlements but also across different clusters within the same settlement. Uneven infrastructural interventions made over time have created socio-spatial inequalities in accessing drinking water. All the local representatives and dominant social and political actors come from the old settlement. More often than not, these dominant actors act as service bearers for different developmental programmes at the local level and benefit from them.

Figure 7: Households' Primary Source of Drinking Water



Source*:* Questionnaire-based, close-ended survey

For instance, the pump operator of the Hardiya water tank volunteered in different drinking water and fluoride removal programmes, which allowed him to work for state and non-state institutions in Hardiya. Working for different institutions simultaneously gives him access to knowledge systems,

rules, regulations, norms, networks, and authority, which he exercises at his convenience and in line with his interests (Gupta 2018). These systems provide expertise and allow him to mechanize the provision of drinking water supply.

As agents of these state and non-state institutions, local state actors use their authority to manage, control, and negotiate drinking water provisions. The settlements near the water tank and treatment plant have more households using tap water as a primary source (S1: 64%; S6: 80%; S7: 100%). On the other hand, in the resettled areas, households have fewer or no clean drinking water sources (S2: 32%; S3: 53%; S4: 50%; S5: 14%) (Figures 3 and 8). As discussed in Section 4, households in resettled areas receive no or low pressure, and leakages and disruptions further impact the water supply. Gaining no or limited access to local state actors further pushes households to shift to conventional water sources. However, this does not imply settlements with better access to clean drinking water and infrastructure have access to local state actors. Uneven water supply provision flows on both sides of the national highway, and accessibility to local state actors also seems uneven at the settlement, cluster, and household levels.

Only all households in resettled area S7 use tap water as their primary source. Our interviews reveal that this settlement was created during 2003–2004, following a visit by the then–district magistrate, who observed a high incidence of fluorosis among the extremely vulnerable Rajbanshi (ST) community due to the excessive fluoride contamination of the groundwater. The officer offered the affected families a new site for relocation, combined with land for housing and secure access to clean water. Several families accepted this offer and moved to S7, while others subdivided their households to maximize access to new housing. The location of S7, right opposite the water treatment plant (Figure 2), ensures timely and adequate water supply as well as easy redressal of supply-related grievances, despite the socio-economic marginality of the residents. State and private water supply agencies showcase S7 as one of the project's success stories, which further assists the community in maintaining their access to clean water.

A resident of this settlement recalled an incident,

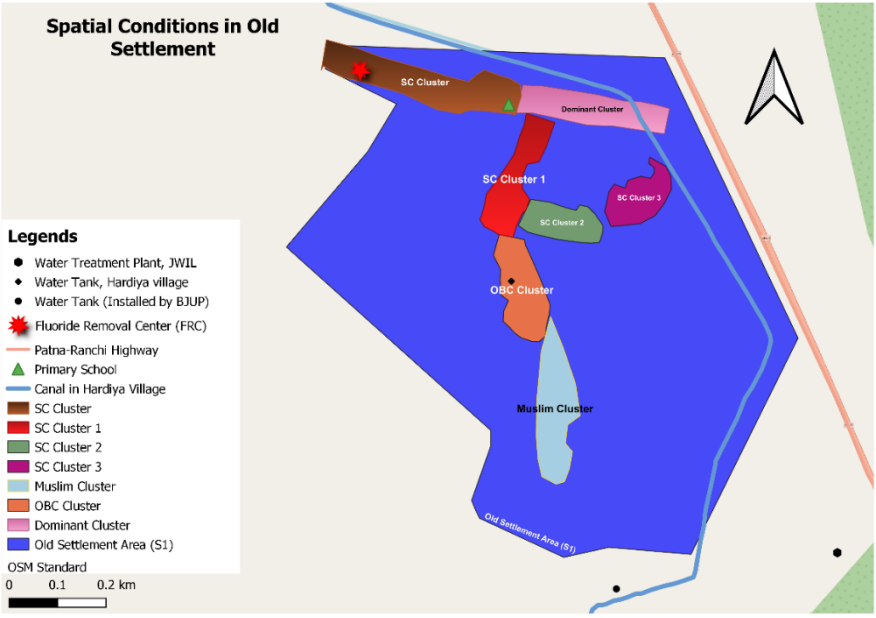
> Two–three months ago, someone stole taps from most of the houses. These taps are made from brass and are costly to purchase. So we went to

the Jindal office (in the water treatment plant), and people there fixed it within three–four days.

The location of the water treatment plant enables better water flow and pressure and, simultaneously, the spatial arrangement of S7 helps the households to approach JWIL officials to register their grievances.

Resettled area S6 is just behind the water treatment plant (Figure 2). Here, 90% of households have tap connections (Figures 5 and 7). However, this settlement has a common hand pump, a water tank installed by a non-profit organization, and a canal covering one side of the settlement. Around 80% of the households use tap water as their primary source; if these connections experience leakages or disruptions, they move to other accessible sources. The other 10% have tap connections but it produces leakages often, so they also access water from other households' taps. A plumber in the water treatment plant lives in this tola, and residents pass their grievances to higher officials through him. Sometimes, if a household is willing to pay for the repair of tap connections, the plumber helps to fix taps and pipes without any charge.

Figure 8: Social and Spatial Arrangement of the Old Settlement (S1)



Source: QGIS

In the old settlement (S1), every tola has a piped water connection except one. S1 consists of seven tolas, each presenting a different arrangement of socio-spatial hierarchies and access to tap water (Figure 8). For instance, if SC households face leakages or disruptions, they can register a complaint with the pump operator, as he resides in this tola, and get their concerns resolved easily. Next to the SC cluster is SC cluster 1 (SC1), and, as described in Section 4, none of the households in this cluster have tap water connections. SC1 has a common hand pump, and households access it to store water for daily domestic requirements. A few households are dependent on their neighbours to access hand pumps. The socio-technological relations of these clusters differ because of their relations with local state actors despite their identity as vulnerable SC groups.

On the other end of SC1 is located the OBC cluster. The water tank of Hardiya is situated in this tola, and the pump operator visits the tank daily to record water meter readings and regulate the water supply. Households in this cluster can access the pump operator on most days and register their grievances. However, people in this tola said that though the pump operator resolves their problems, sometimes grievances go unattended. A resident, in her interaction with the pump operator, aggressively said,

> How often do we have to tell you to fix the tap and pipes? You never listen to our complaints. See (pointing to her household's tap) how much water leaks when we open the tap!

In response, the pump operator said,

> I cannot provide new pipes or taps to you because it is not in my hand. You should go to the Jindal office (in the water treatment plant) and register your concern there. I am not allowed to give these materials to existing connections. You can buy pipes and taps from the Rajauli market. I only can arrange for a plumber to repair it.

The last tola in the old settlement consists of Muslim households. Households here have tap water connections but most are dysfunctional. Women in this cluster said,

> We have tap connections but mostly use hand pumps for our domestic requirements. We receive powder (chlorine) in our tap water, which tastes bitter, so we do not use it much.

The location of infrastructure and local state actors, therefore, socio-spatially determines the uneven provision of tap water supply and grievance redressal. The location of infrastructure configures the varieties of service

provisions available for different clusters and settlements. Moreover, the spatial arrangement of social groups determines the varieties of tap water supply available and grievance redressal. Therefore, location and accessibility create hydrosocial processes (Banister 2014; Björkman 2015) in Hardiya, wherein people, institutional actors, and technologies are arranged around the control of water in daily life (Boelens *et al* 2016). Furthermore, drinking water infrastructures embody dualistic political assemblages (i.e., formal–informal, legal–illegal) (Loftus 2006; Truelove 2020), where power is produced through informal practices and negotiations (Truelove 2019). These negotiations produce uneven social and political relations, further shaping access to drinking water infrastructures (Mcfarlane and Rutherford 2008; Appel, Anand, and Gupta 2018).

Households across different settlements interact with dysfunctional tap water daily. This dysfunctionality emerges through the irregular maintenance of pipe connections at the household and administrative levels. Therefore, it becomes crucial to understand how the problems of leakages, disruptions, and repair enable or restrict interactions between households and local state actors in everyday life (Appel, Anand, and Gupta 2018). Even though most of the clusters and settlements have tap water, damage, disruptions, leakages, and pressure lead to grievances redressal, and negligence of the same pushes communities to shift to other drinking water sources. For instance, in resettled area S5, where 72% of households are SC, only 14% of households use taps as their primary source of water. Most of the tap connections in S5 are broken, uprooted, and leaking, and the residents use shared or individual hand pumps (63%) and borewells (32%) (Figure 7). A resident of S5, who uses a shared hand pump, said,

> At the time of connection, the plumber fitted pipes adjacent to small sewages outside our homes. This pipe has no use because it is leaking now, and the sewage system brings filth and contamination into the pipes.

Households in resettled area S4 face a similar problem. However, 57% of households belong to dominant social groups and have strong social networks within the village. In many incidents of leakages and disruptions, these households called the pump operator and asked him to send a plumber to fix their taps. Some households only use borewells for their domestic water requirements. For instance, a resident said,

> We do not like the taste of this water (tap water). Sometimes it does not taste good. Many times we saw these pipes producing white-coloured

> powder in the water. I think they (the pump operator and other actors) put excessive chlorine in the water.

However, SC households do not have a similar network. For example, a resident, who is located at the end of S4, said,

> Our taps have received dirty water for the last six months. I do not know where to register my complaint. If you have that information, please explain our situation to them (JWIL officials).

Figure 9: Broken Taps and Uprooted Pipes in Different Settlements

Source: Amit Kumar Srivastwa

Leakages and disruptions seem common across settlements, but grievance redressal impacts a household's access to functional taps. Interactions and negotiations with local state actors vary between households and settlements. These interactions produce uneven provision of tap water supply at the inter-settlement, intra-settlement or cluster, and inter-household levels. Accessibility to local state actors depends on whether the household has cluster- or settlement-level representation in the water treatment plant and the household's relationship with them. Moreover, a strong socio-political network at the village, settlement, or household levels influences access to local state actors. Social groups spatially arranged near the water tank or treatment plant at the settlement or cluster level can easily access local state actors to register complaints. Households in resettled areas S2, S3, S4, and S5 have few interactions with local state actors. Their narrative explains that many households either do not know the grievance redressal process or do not have access to local state actors. In both cases, these households shift to an immediately available water source, which can provide them with a stable water supply for their daily requirements. Finally, uneven access to safe drinking water infrastructures and local state actors constructs multiple hydrosocial territories (Björkman 2015; Boelens

et al 2016) at the village, settlement, cluster, and household levels. These territories consist of heterogeneous infrastructures, both functional and abandoned, which provide or restrict safe water access to social groups based on their spatial conditions and relationship with local state actors.

6. UNEVEN HYDROSOCIAL TERRITORIES AND INTER-HOUSEHOLD SOCIO-TECHNOLOGICAL RELATIONS

Social groups are not just defined, constituted, and bounded by space, culture, identity, or class- and caste-based distinctions, water technologies existing historically in a society shape them into diverse socio-technical groups (Bijker 2012). Drinking water infrastructures are a physical signifier of how powerful actors territorialize a specific landscape, where social identity is formed and performed through socio-technological relations (Dixon and Whitehead 2008). Heterogeneous infrastructural configurations are spatially spread through the constitution of different socio-technological relations (Lawhon *et al* 2018). In this section, we discuss how households from different social groups negotiate water access when state provision of piped water supply fails or is inadequate.

Household dependence on many water sources in Hardiya is a stark indicator of precarity among households belonging to vulnerable sections of society (Meehan and Strauss 2015). Water unavailability at the household level and disruption in the tap water supply force people to cover long distances for their drinking water needs. Dysfunctional and inadequate water sources create heterogeneity in water access among households. How vulnerable households negotiate with more powerful households and other sources for water access is critical to our analysis of hydrosocial territories. The uneven ability of different households to obtain the attention of local state actors pushes underserviced households to return to conventional sources of water or find new alternatives through inter-household negotiations, which have wider ramifications.

A cluster of SC households in S2 from the Turiya community was resettled on the banks of Dhanarjay and traditionally fetched water from the river. However, water availability in the river has declined over time, pushing these households towards other water sources. A Turiya woman, who made wooden baskets (a traditional caste-based livelihood), pointed to a dysfunctional hand pump and said,

> It is a government (public) hand pump that has stopped functioning for a long time. Our household also has a tap water connection, but it gets no

> water. Not once have we gotten water from the tap. We have no other option but to fetch water from the river. We fetch water early in the morning and late in the afternoon. However, the river seldom provides enough water; sometimes, we have to go to a nearby well to collect water. We have registered several complaints about our disrupted tap water connection to the person who works in the water tank. He said that the government will fix our connections soon, but it has been a year, and no one has come to help us.

Drinking water infrastructures have temporal lives (Anand 2011), where minor disruption or damage leads to infrastructural dysfunctionality and further pushes households to adopt other strategies. Unlike the Turiya, in other social groups, households without adequate drinking water access depend on other households or community-level sources to access water. The ownership of these technological artefacts is diverse—they can be the private property of households, community-level structures, and infrastructures belonging to the state and large external non-state actors (including NGOs and corporate entities).

Heterogeneous infrastructure regulates the behaviours of households and social groups. Because of their dependence upon other households to access domestic water, many residents of Hardiya are constrained in their social actions vis-à-vis other community members. According to a resident of resettlement area S5,

> We cannot access water from the taps, as last year, the state government started constructing a flyover, which damaged the main pipeline outside the cluster. Our pipe got damaged six months after the installation, so we never utilized it. Now, we share a common hand pump. Sometimes it produces a bad quality of water or low pressure; then, we seek water from households with borewells. We do not have enough money to install a new hand pump.

Apart from large-scale water infrastructures like the Phulwariya dam, these small-scale technological artefacts also shape inter-household material and social relations in Hardiya. Some households in Hardiya depend on multiple drinking water sources by managing social relations, while others depend on one or two water sources by managing their spatial location. Access to water infrastructures depends upon the household's location and how many well-managed relationships households have within the village. Access to drinking water, therefore, becomes a contested space where households' social relationships form their access to water infrastructure—technology becomes a tool to generate power and a hierarchy among the households in

their everyday lives. These social relationships are performed through human bodies, spaces, gendered subjectivities, and emotions (Sultana 2011). These relationships produce specific moral economies (Trawick 2001, 2002) as well as emotional and imaginative geographies (Dixon and Whitehead 2008; Sultana 2011) within and across socio-spatial groups.

7. CONCLUSION

This article brings historical, geographical, developmental, bureaucratic, and everyday forms of infrastructure together to understand everchanging socio-spatial arrangements and relationships. It uses historical and geographical features as a methodological tool to understand infrastructures as a socio-spatial process that generates uneven access and power arrangements among households and with local state actors at the cluster, settlement, and village levels. Infrastructural development in Hardiya came as a promise to eliminate absolute scarcity (Scoones *et al* 2019), but inadequate technological regulation worsened the situation, and inadequate tap water supply produced a dependence on heterogeneous infrastructures. These inadequacies are shaped by dysfunctionality in drinking water infrastructures and irregularities in services. By addressing the question of resource access and conflict, this article examines the conditions of leakages, disruptions, no or low pressure, breakage, repair, maintenance, and ruination. These conditions manifest partial or complete suspension of tap water supply daily.

Moreover, suspension or disruption affects the everyday schedule of people and opens the scope for negotiations among households and between households and the local state. Over time, these negotiations produce various relationships and contestations, further rendering socio-political networks, hydrosocial territories, and uneven drinking water access and power arrangements. The location of infrastructures and local state actors further shape the material geographies of power, enabling access to some households while restricting it for others. In a complex social arrangement, the entanglement of communities, institutions, and infrastructures produces unequal socio-technological relationships between actors.

Scholarship in critical geography (Ferguson and Gupta 2002; Mosse 2008; Dixon and Whitehead 2008; Meehan 2014; Gupta 2018) views technology and space as inseparable characteristics that configure spaces and linkages at different scales. This article contributes to this methodology by examining infrastructural processes. Oral narratives further help trace household

dependence on, and struggle over, spatially bounded heterogeneous infrastructures. The existing literature on the political ecologies of drinking water infrastructure (Bakker 2012; Anand 2017; Truelove 2019, 2020; Björkman 2015; Appel, Anand, and Gupta 2018) mainly discusses the uneven power constellation of infrastructures in the urban realm. This article examines the assemblage of infrastructures, institutions, and local communities in manufacturing uneven access to safe drinking water in the rural sphere. It unpacks the divergent outcomes of a state scheme aimed at providing universal access to safe and clean drinking water. It finds that socio-political networks, infrastructure location, and local state actors enable or restrict tap water supply for different social and religious groups. This unevenness is multi-scalar and operates at the level of settlements, clusters/wards, and households within the same village, such that social groups like SC, OBC, and Muslims are impacted by these infrastructural processes. These groups often cope by returning to former or conventional drinking water sources. It further shows that apart from a household's economic capability to purchase drinking water technologies and infrastructures, access to safe drinking water in rural locations can also be made possible by shifting back to conventional water sources. However, the socio-economic cost of this in terms of drudgery, water quality, and ability to resist oppression by more powerful counterparts tends to be high in the process.

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