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Parameters of Successful Wastewater Reuse in Urban India

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Abstract

Studies of surface and groundwater in India show that dry season water availability will continue to decline over the next half-century, a challenge that will face many areas and countries around the globe. The need to develop wastewater recycling schemes is critical to improving conditions of water supply and ensuring the survival of agriculture and human consumption, as well as industrial production. The need for wastewater recycling is pushing communities, governments, and businesses to discuss, experiment with, and pilot projects using decentralized methods. This paper introduces four cases of wastewater recycling that are considered "success" stories and identifies the key parameters that enable these systems to function. The parameters pertain to human dimensions involving historical, institutional, regulatory, policy, and economic conditions and innovations. We then use these labels as heuristics for models of success in Indian conditions.

Keywords: wastewater, water reuse, recycling, closed loop, hydro-social cycle, National Green Tribunal, flexibat, India

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Resumen

Los estudios de aguas superficiales y subterráneas en India muestran que la disponibilidad de agua en la estación seca continuará disminuyendo durante el próximo medio siglo, un desafío que enfrentarán muchas áreas y países en todo el mundo. La necesidad de desarrollar esquemas de reciclaje de agua residual es crítica para mejorar las condiciones de suministro de agua y asegurar la supervivencia de la agricultura, el consumo humano y la producción industrial. La necesidad de reciclar aguas residuales está impulsando a las comunidades, gobiernos y negocios a discutir y experimentar con proyectos que utilizan métodos descentralizados. Este documento presenta cuatro casos de reciclaje de aguas residuales que son considerados "éxitosos" e identifica los parámetros clave que le permiten funcionar a estos sistemas. Los parámetros tienen que ver con las dimensiones que involucran condiciones históricas, institucionales, regulatorias, políticas y económicas y también innovaciones. Luego usamos estas etiquetas como heurísticas para modelos de éxito en condiciones indias.

Palabras clave: aguas residuales, reutilización del agua, reciclaje, ciclo cerrado, ciclo hidrosocial, National Green Tribunal, flexibat, India

摘要

有关印度地表水和地下水的研究表明，干旱季节水资源的可获取性将在下半个世纪内持续下降，全球许多地区和国家都将面临这一挑战。发展废水回用计划之需对于提高水供应、保障农业和人类消费而言至关重要，对工业生产而言也是如此。废水回用之需正在推动各社区、政府和公司就分散方法的使用对试点项目进行探讨和实验。本文介绍了四个被认为是成功案例的废水回用实例，同时识别了让这些废水回用系统得以运作的关键参数。参数所涉及的维度包括历史、制度、监管、政策和经济形势、以及创新。笔者之后将这些标签 作为启发式方法，探索印度形势的成功模式。

关键词：废水，废水回用，再循环，闭合环路，社会水循环，印度国家绿色法庭，flexibat，印度

Introduction

Concerned citizens and authorities in India are now raising the potential for grey water or wastewater reuse in urban areas to deal with fresh water scarcity, especially in the dry months before the onset of the monsoon (Narain 2018; Niti Aayog 2018; Shah 2016). This interest in finding new water supplies is pushing communities, governments, and businesses to discuss, experiment with, and pilot projects to treat wastewater and recycle it. In India, many of the projects are decentralized units or small-scale treatment systems operating in a neighborhood or an institutional setting. The treated water is used on site to avoid transport of the wastewater through underground and aboveground pipes to drains or treatment plants. The planning, installation, and effective operation and maintenance of these facilities create or require changes in housing and plumbing design, institutional setup, citizen engagement, governance, and technology.

The stress on water resources in India's urban and peri-urban areas is felt by all and threatens the viability of city living on a daily basis (Sengupta 2018). Neighborhoods supplied by water tankers rather than piped water are especially stressed in terms of availability and pricing. Residents in these peri-urban or "unauthorized" locales pay more for water per kiloliter from tankers than do other citizens who pay for piped water (Anand 2017; Bjorkman 2015; Narain 2018; Niti Aayog 2018). Residents in these and other stressed zones are sometimes able to combine small amounts of water from different sources, from low-quality piped water, from RO water (reverse osmosis) supplied by private vendors and in homes, from groundwater, and water supplied by city and private tankers (Maurya et al. 2017). These pressures and recent regulatory limits and bans on groundwater use push households and businesses to find other sources and to consider treated wastewater for nonpotable purposes. This connects to trends in experimenting with decentralized or modular approaches to water and energy currently underway (Cross 2016; Gupta 2015; Sovacooll and Ramana 2015; Ulsrude et al. 2011).[2]

This paper introduces four cases of wastewater recycling that we consider functional "success" stories; these are drawn from a larger pool of 40 recycling projects that we visited and gathered data on. The argument of the paper is that a variety of successful cases are emerging and understanding the key determinants will help plot out how success can be modeled for the Indian context. We identify the key parameters that make these systems work in a flexible way. We describe the historical, institutional, regulatory, and economic pressures leading to the creation of projects and explain the key policies and regulations that impinge on this sector. The analysis will show how the parameters of leadership, water availability, water pricing, regulations, and business savings are motivating functional wastewater reuse projects. We then use these labels as heuristics for models of success in Indian conditions.

Informality, the Hydrosocial Cycle, and the Flexibat Approach

Our approach extends from previous investigations of the acceptability of water reuse schemes in India and other countries (Hurlimann and McKay 2007; Kuttuva, Lele, and Mendez 2018; Molinos-Senante, Hernández-Sancho, and Sala-Garrido 2011; Lienhoop et al. 2014 Roomratanapun 2001; Suneethi et al. 2015).[3] We also contribute to discussions on the extent to which decentralized systems can replace or complement centralized wastewater treatment systems (Arora et al. 2015). Centralized systems work best in locales where there is a fully piped sewerage network with an accoutrement of pumping stations, bioreactors and ancillary equipment such as backup generators, and materials for repairs. There is nothing close to full sewerage for cities in India and more than 70% of wastewater runs untreated to contaminate surface and ground water supplies.[4] So, the majority of studies in India cover the functioning and acceptability of small-scale decentralized units (Kuttuva, Lele, and Mendez 2018; Lienhoop et al. 2012; Ravishankar, Nautiyal, and Seshaiah 2018; Suneethi et al. 2015).[5]

Here, we approach a similar question, which is, to what extent do small-scale systems work and why? How can we find the best examples? In our research, several key concepts and approaches have been useful in orienting our perspective. First, we draw upon the understanding of informality developed by others and that we have expanded in other work (Alley 2015, 2016; Follmann 2014; Ranganathan 2016; Roy and Ong 2012; Schwartz et al. 2015). Water informality happens when the state uses laws and principles that are appropriate for the moment, but then changes those uses and even works contrary to them at a later date. Ranganathan (2016, 3) defines urban water informality as the uneven application or suspension of laws, rules, and official procedures in the governance of space and water infrastructure. The inverted notion of informality developed by Ananya Roy (2009) and reformulated by Ranganathan (2016) describes the intentional vagueness or opacity of project maps, plans, protocols, and compliance to rules and regulations. The intentional vagueness in articulating and implementing official rules and procedures helps to keep the circle of real knowledge small, so that it can be controlled by fewer people (Bear 2015, 105–122). Roy (2009, 83) has noted that the absence of land titles, the existence of fuzzy boundaries and incomplete maps, and the vagueness of policies are "the basis of state authority and serve as modes of sovereignty and discipline." We find evidence of informality in the decisions taken in infrastructure design and contracting, and in the governance and control over groundwater.

Others have toyed with ways of describing infrastructure failures in sanitation by digging deeper into the actual running of facilities and services such as in operation and maintenance. For instance, Starkl et al. (2017) have noted that hidden failures may exist behind the appearance of functioning systems and that these layers of known and hidden failures are part of the complexity of creating decentralized facilities. In terms of identifying key parameters that determine the best examples of functioning projects, we follow from Starkl et al. and their critical view of "success" and "failure" in their analysis of the functioning of decentralized wastewater facilities across India. In a recent paper focusing on 58 projects across India, they (2017, 133) qualified how they were determining success and failure as follows:

> For this paper, "apparent success" is success in the view of local experts (step 1 of data collection) and "actual success" is success in the view of a closer inspection by international expert teams (step 2). "Hidden failure" is apparent success that is not actual success. This paper emphasizes hidden failures, as the subsample of hidden failures appears to be random, justifying statistical methodology. (In step 1, data could not be collected at random, as insight by the local experts about the systems was needed. However, as hidden failures result from a lack of information, one could not intentionally search for them.) "Hidden success" was not observed.

Apart from the use in research designs and conclusions, definitions of success and failure are part of the algorithm for funding agencies at local, national, and international levels. If identified as failed systems, these projects have little hope of continued support, even in a weak administrative regime. Alternately, the aim of failure stories may be to motivate concern, attention, and investment in infrastructure. Success stories bring more funds for investment or may provide justification that no more investment is needed. In this study, we draw from our notion of infrastructure disarray (Alley et al. 2018) to assume that success and failure are not mutually exclusive categories but are determined flexibly by the operation of parameters. We see that problems in infrastructure (1) are layers of failed systems that may or may not be physically connected; and (2) can be thought of not in terms of success versus failure or presence versus nonpresence, but as a multitude of interconnected, overlapping, or disconnected segments of the sewage services chain (Alley et al. 2018).

We also draw loosely from the framework of the hydrosocial cycle as we trace out the intertwined water and society patterns that coproduce the meanings, uses, and technologies of wastewater and water consumption and production (Budds 2008; Linton 2010; Linton and Budds 2013; Swyngedouw 2009). The hydrosocial cycle accounts for the ways the society—key actors and institutions—shape water uses through and with infrastructures and technologies. The hydrosocial cycle also means the ways water flows and turns into wastewater, the ways it is transformed to another state and becomes recycled water and how all these states of water reflect, refract, and empower or disempower social relations. Included in these social meanings and uses of water are the perceptions of the microbiology of water and of the impact different kinds of water have on the body and health.

These cases indicate that the hydrosocial cycle is shifting and calibrating to new flows of water and governance over time. Water flows are being altered in three ways. One way is in water provisioning for public sector or public–private partnerships; the second way is in the governance of wastewater treatment and the operation and maintenance of facilities. The third way is in water availability wherein polluted water is converted into usable water and added to rather than thrown off from the water supply chain.

Recently, Starkl et al. (2018) have argued for a perspective called "flexibat" which denotes the best possible and workable technology for a given wastewater situation. They showed the need to understand variability in the success and failure of these sewage treatment plants (STPs). Their analysis compared costs and benefits of a number of small-scale systems, such as membrane systems, soil biotechnology, phytorid, vortex, and sequential batch reactor. It found that some technologies such as vortex are more costly than the others. Their data show that the membrane or MBR technology is best for removal of pathogens.

This paper expands the approach to flexibat by identifying the key institutional, cultural, and economic parameters that are producing the best examples of decentralized systems. This includes attention to behavior, economy, regulation, policy, and leadership as different but co-existing systems and structures. We will show that the key parameters of leadership, water pricing, water scarcity, regulations, and closed-loop business savings are weighted differently in each case but that all are present to some degree in each case. They are therefore significant for India and stand to become best scenarios over time.

Wastewater providers and recyclers are not like water mafias (Ranganathan 2014) and valve or key men (Anand 2017; Dasgupta 2015) who hold power as water brokers, tanker owners, and operators. Rather they operate as "experiments" and "pilots" and often struggle with financing and repairs. There has been a general disinterest among government and citizen groups to engage in improvements with wastewater treatment; therefore, the projects we highlight are a welcome advancement.

Methodology and Verification

For this paper, we chose four cases that best represent the range of activities taking place across 40 sites we visited over a three-year period. To choose these cases, we surveyed 40 projects that we located through the advice of key NGO members, industry actors and companies, and the information provided in the databases of the Centre for Science and Environment, the Central Pollution Control Board (CPCB), the National Mission Clean Ganga (NMCG), and other engaged agencies. Snowball sampling techniques were also used to identify the persons with knowledge of projects at each facility location. Several research groups led by Indian Institute of Technology (IIT) professors were especially helpful in sharing information on existing STPs and their creators and funders and introducing the projects with the most effective performances. These teams of researchers also helped us gain access to functioning projects, given that it is up to the project owners or facility owners to decide whether they will allow a researcher entry and grant permission to collect water samples and interview project members.

Among the 40 sites we visited, we found a range of recycling projects at industries, university campuses, hospital grounds, housing complexes, neighborhoods, airports, malls, and city parks. In these, we identified five key parameters that we found across all sites to varying degrees (Frijns et al. 2016). We identified these key parameters after analysis of data collected at each site using qualitative focus groups, structured interviews, and participant observation. Key informants, official and company records, NGO reports, and university research projects were used as sampling frames for the conduct of focus groups and interviews at many of the sites we visited. Interviews with officials in the Ministries of Environment, Forests and Climate Change, Water Resources; Power; Renewables, Central and State Pollution Control Boards, the Sanitation departments of municipalities and other councils such as the NDMC produced an understanding of government interest and acceptability as well as institutional regulations and procedures. In interviews with authorities, project monitors, NGOs, and university teams, we explored institutional constraints and possibilities and technological innovations and limitations. Generally, in each site, we conducted 3–5 focus groups and 20–30 structured interviews to find convergence regarding important themes. Research reports, maps, feasibility reports, detailed project reports, and ecology, wildlife, and landscape projects were also collected and analyzed.

Selection of Cases and Key Parameters

In this paper, we introduce four cases of water reuse to show four functioning systems representing government, public–private partnerships, and business arrangements, and we discuss the working of key parameters for each case. We are concerned with overall functionality and with significant parameters that we have identified through the survey of 40 projects. Our survey led us to identify (1) leadership, (2) water pricing, (3) water availability, (4) regulations, and (5) business savings as the key parameters in the functioning of these projects. Departing from other studies that we reference later, we did not include the broad label of "acceptability" as a parameter. Since some of the projects we have investigated do not have a user public associated with them, acceptability of public or private users was considered more specifically in terms of leadership and the decisions that are made in the face of scarcity, pricing, and regulations and court orders.

We focused on the human determinants of functionality and did not assess technological adequacy, efficiency, or success.[6] We draw upon other recent reports for those measures (see Starkl et al. 2018). We are concretizing the notion of success here to mean a project that can reduce contamination of the ecological or hydrological system to a degree deemed to be an improvement from an immediately previous condition. The understandings of previous conditions and improvements are taken from information provided in the focus groups and interviews with concerned authorities, scientists, and citizens.

The four cases involve large agencies and/or businesses: the NDMC, a government agency; IIT-M, an autonomous government institution; the Keshopur Bus Depot, a public–private partnership; and the Marriott hotel, a fully private enterprise. The similarity among these cases is that all the water-consuming entities have to buy water from the government institutions responsible for water supply. These government institutions are the Delhi Jal Board (or DJB) in the case of the garden STPs and the Keshopur Bus Depot; the Chennai Metro Water Supply Board in the case of IIT-M; and the Brihannmumbai Water Supply Board in the case of the Marriott Hotel. The two main push factors in these cases are: (1) National Green Tribunal (hereafter NGT) orders on mandatory treatment and reuse of wastewater and (2) the NGT and Central Groundwater Commission limits or bans on the use of groundwater.[7] Apart from explaining these external push determinants, we also describe how variously positioned agents (as managers, scientists, and company members) discuss these treatment infrastructures, the microbial reactions that produce this water and the trace metals, substances, and pathogens remaining in the treated water. In these discussions, water values are directly related to the mechanics of technologies. Producers and consumers see the waters produced at different stages of treatment and recycling as differentiated forms. As Barnes (2014) has argued for irrigation water reuse in Egypt and Bjorkman (2015) has for Mumbai supply, water is not simply water, but becomes different waters, in terms of quality and quantity over time and space.[8]

The Bus Depot: Situated Categories of Water

Water recycling is now a legal requirement for large institutional users of water such as industries, universities, housing complexes, and five-star hotels.[9] With these requirements come readjustments in the ways citizens define their water sources and the relative quality they impute to each source. In general, most of our interviews with project communities revealed that recycled wastewater is considered inappropriate for direct human uses, but companies and municipalities are realizing its potential to supply nonessential or nonhuman contact uses, such as water for horticulture, toilet flushing, and industrial processes. This means that users are categorizing water supplies in new ways and directing that specific uses be made for each supply category. This demonstrates trends in water classification that are based on location-specific supplies and their qualities, and these classifications may vary depending on context.[10]

In west Delhi, as 125 buses enter the depot, about 45 buses are washed every day. The employees of this depot are reliant on recycled wastewater to do this cleaning. In the bus depot, employees use four categories to define their sources. These are: (1) potable water treated from surface water sources and provided by the DJB, (2) groundwater that is not treated, (3) treated wastewater that is piped from a decentralized project across the street, and (4) tanker water carrying poorly treated wastewater from a conventional, centralized STP across the street. Potable water is the purest for human consumption with degrading qualities in the other categories. When talking in Hindi, these employees used the English word "pure" to describe water from the DJB. Groundwater is preferable to treated wastewater. In some cases, however, employees remarked that in emergency situations, they have had to drink this recycled water.

Before 2016, there was only one company that had produced a viable decentralized pilot plant in Delhi (STPs). This was Absolute Water, a company spin-off from a large industrial sugar company. The owner realized that industries could recycle their water for reuse and see significant savings and a more reliable water supply. After installing a plant in their own industry, they convinced the DJB to let them build a pilot project on the campus of the Keshopur Sewage treatment facility in west Delhi. The DJB had enough land there to house the project. The company used its own funds to construct the plant on the vermiculture model that uses biomass and earthworms to bring down the biological content of the wastewater. The water is then passed through a carbon filter and a membrane to produce near bacteria-free water that can be considered potable quality water according to WHO standards. The facility is powered by a solar panel and uses 8 kW of energy to produce 100 kiloliters of water each day. The Delhi Chief Minister Kejriwal inaugurated the pilot plant on July 9, 2015, with a media blitz in which he was photographed drinking the treated water. Absolute Water operated the plant for a year before the DJB agreed to assume the operation and maintenance. Then the DJB found a user for this product in the bus depot across the street and laid a pipeline to bring the treated water to them.

The definitions and categories of water were immediately apparent in our discussions with the employees of the bus depot. Those working in the bus depot have a working knowledge of each source and a strong awareness of the differences between the four kinds of water they use. They are, in terms of their own labels: DJB piped water which comes from the water treatment plant at Wazirabad and is used for drinking; treated wastewater from the Keshopur pilot plant, called "pipeline STP water" or "Kejriwal pani"; treated wastewater coming from the Keshopur STP called "tanker water" and groundwater. In order of quality, the DJB piped (drinking) water is the best, but there was a close second with Kejriwal water. The poorest quality was the water coming from the large conventional STP that they call tanker water.

In other words, there are two pipelines supplying water to the depot. One brings drinking water from the DJB's water treatment plant and the other brings treated wastewater from the pilot project that uses earthworms and filters. The pipeline water from the pilot project is the most important, as it is the water used to wash the buses in the depot. On the day of our interview, there was a discussion about quality, with some explaining that clearer is better and that it must be without smell and bad taste to be useful beyond horticulture. In the following discussion, NM and AK are the researchers and the others are employees at the bus depot.[11]

UK: This is the govt. order based on court order ... and of NGT too ... they forbid us so we stopped this bore well, as in our department we need to issue foreclosure, we did the same and sent the report. Then we had this STP pipeline and then this water supply started. You know, previously we were fully dependent upon tanker-waters. In two days, we had to use three tankers.

NM: 30,000 l water.

UK: Yes, as we have 125 buses ... so around 45 buses get washed daily ... we do deep cleaning means cleaning from inside and washing from outside too. So we cannot wash all the buses in one day ...

AK: So he said that he saved groundwater? Now no more use of groundwater?

NM: No ... So you don't use groundwater at all?

UK: I will show you ... we have stopped our submersible ... because there is the strict order about this.

NM: So, now you water your gardens with STP water only?

UK: Yes.

NM: And you wash your buses with this water only?

UK: We wash our vehicles 100% with this water only.

NM: So, if someday there is no piped water then what do you do for gardening?

UK: In that case, we use remaining tanker water. After washing the vehicles if water remains in the tanker we use it for gardening ... you know tanker water is not as clean as the STP pipeline water ... I will show you the waters.

NM: From where do you get this tanker water.

UK: That water also comes from DJB Keshopur but from a different plant. It is not filtered water. So, what have you seen in the plant, tanker water does not get filtered.

AK: So ... that water comes from the big plant, not through the membrane filter ...

Em: It has some smell too ...

UK: They collect water in a tank and filter it and give it to us in a tanker, whereas the piped water they again pass it through the filter and then pump it to us.

NM: So STP pipe water is coming through the Kejriwal Point, and water by tanker is not from the Kejriwal point?

UK: Yes ... both are different.

NM: They are saying there is smell in the tanker water.

AK: Of course, we have just seen the outflow from the STP in the big drain ... it's too smelly and water is very dirty ...

UK: They make fertilizers from that ...

NM: They call it sludge ...

UK: You have had seen that on the back side they have a tank where they collect treated water. In that tank, there are wood saw and earthworms, these earthworm feed on that dirty water and clean it, purify it, then what comes out is this water ... they replace it about in six months ... they pour new earthworms ... to clean the water ... earthworms survive on dirt ...

AK: So, he is talking about the same treatment plant of Kejriwal ... have seen that ... and that water comes here.

UK: Tanker water is not from this plant, it is from the STP only ...

NM: It means tanker is not taking water from Kejriwal point but taking water before this point.

AK: Because Kejriwal points water comes here for vehicles ... this is the best water from that treatment plant, by using earthworms etc.

....

Em: What difference we will have in groundwater and DJB water, the same difference is here too ... groundwater would look clean and clear in a glass and DJB water would also look the same but only a machine can tell you about the quality of water.

AK: So, the water which comes from Kejeriwal's plant that does not have smell ...

UK: No..

Em: They add some chemical in it ... separately.

UK: They filter it and then add ...

AK: Add chlorine ...

UK: No, not chlorine, they add something else ...

Em: They add some chemical.

AK: Okay, so a membrane is there and water goes through the membrane and becomes drinkable.

UK: Yes ... They have written there very clearly and I have seen that ... and perhaps they have shown Kejriwal drinking this water...

NM: Yes.

UK: So when their Engineer came, who

has laid this pipeline. He said that not drinkable but not less than drinking quality. Means, there is still some inadequacy in this.

NM: But this is a good phrase—not drinkable but not less than drinking quality.

AK: Not worth to drink but not less than the quality of drinking water ... not drinkable means, there is no acceptance in the heart ...

UK: There still some minor particles ...

NM: So you believe that there is some ...

UK: Means, my heart says there is some defect in this water ...

Em: Madam, if one will not get water then one may drink this also ...

This discussion clearly shows that the bus depot employees have a detailed knowledge of categories of water that are provided to them and that the researchers are co-producing this knowledge through their questions as well. The employees conduct a personal evaluation of each based on daily contact and some usage. Their knowledge is an interactive and cumulative knowledge generated from experience and some understanding of the biological and microbial processes by which the wastewater is treated. They are co-producing their knowledge in some measure of interaction with the wastewater engineers and water scientists active across the street in the government sewage treatment facility. This detailed conversation helps to show that apart from the critical need to find sources of water to clean the buses, experiential learning is most important in generating acceptability of using this treated water. In addition, users are able to distinguish the qualities of various water supplies provided to them based on experiential practices such as sniffing and tasting. This is the practical knowledge that produces the choice for sustained usage. While a survey of literature by Fielding, Dolnicar, and Schultz (2018) found that acceptance of recycled water drops with increasing human contact, this case shows that the consumers' experience of using the treated water for a specific purpose (cleaning buses) and seeing and smelling its quality are strong motivators for the functionality or the "success" of the project.[12]

This depot is a public–private partnership between Delhi Transport Corporation and TATA Motors. The public sector entity and the private company that together run the depot pay three different rates for these three categories of water. They pay Rs. 7 per kiloliter for the STP pipeline water and Rs. 140 per kiloliter for the STP tanker water, which are both used for washing. Before the STP pipeline water supply started, they were drawing up groundwater with an electric pump. The estimated cost of the electrical pumping roughly prices groundwater at around Rs. 10 per kiloliter. In theory, there is savings to the partnership by shifting from groundwater to the new pipeline water from the pilot STP.[13]

This case mentions the motivating roles of the Central Groundwater Authority (CGWA) and NGT in ordering large water users to discontinue use of groundwater. Generally, regulatory power resides with these ministries and departments: the CGWA, the Ministry of Environment, Forests and Climate Change, the CPCB, the state Pollution Control Boards, the High Courts and Supreme Court, and now the NGT. Regulation occurs as a series of actions that impose rules, limits, and punishments on individuals, companies, and government offices. Citizens can also lead these efforts or contest them through petitions and participation in the NGT. However, it is important to understand where real regulatory power or pressure resides and this depends upon the state or region of the country. In the northern Indian states of Uttarakhand, Himachal Pradesh, Uttar Pradesh, and Bihar, the CGWA and the NGT rather than the MoEFCC, or the PCBs in the sanitation field exert more power. In Tamil Nadu and Karnataka, the State Pollution Control Boards exert more influence.[14] Across India, the policy shells of Namami Gange and Swachha Bharat help to set criteria or benchmarks for projects and provide the vision and mission for sanitation but play no role in regulation.[15] The Namami Ganga and Swachha Bharat programs also provide leadership in terms of policy vision and rhetoric. In terms of infrastructure, the Smart Cities program is providing a set of criteria for urban improvement which includes physical infrastructure and social infrastructure. On the physical infrastructure side, the government is promoting smart grid, smart roads, parking, solar power, water ATMs, and STPs (Bahinipati 2017).

A short history of groundwater regulations helps to explain how it emerged in importance as a driver for water recycling. In 2013, the NGT began a series of debates on groundwater usage and contamination in the context of petitions filed by citizens on water and sewage problems. In eight different cases, the NGT ruled that industries or other large quantity users must curb their use of groundwater (Charts 1–3). They ordered that large quantity groundwater users must obtain an NOC, or no objection permit, from the CGWA.[16] In addition, households were forbidden from using bore well water for gardening and horticulture, but this rule has been hard to enforce and monitor. Over time, new permits have become harder to procure. In the new draft guidelines of the Groundwater Bill in Parliament, this renewal period varies: for individuals, it is set at every five years, for industries, at every three years, and for real estate projects, at every two years. The draft guidelines also take out the need to recharge groundwater.[17] The bill advocates strengthening the regulatory powers of gram sabhas, panchayats, and municipal bodies related to groundwater. However, some argue these new guidelines are "trying to make a system wherein state or district level authorities will be giving NOCs but whether those authorities have capacity to give NOCs after understanding the implications is the question" (Sandrp 2017). It is within this context of regulating groundwater extraction that a stronger direction to use recycled wastewater has emerged.

Chart 1. Proposed Bills

1.	Model Bill for the Conservation, Protection, Regulation and Management of Groundwater, 2016	Gives emphasis on rainwater harvesting and recycling and reuse of water "for non-potable urban, industrial, and agricultural use, as well as augmentation of potable water supplies through indirect reuse." Without a permit issued by the appropriate authority no groundwater abstraction is permitted for nonpotable use, and for industrial and infrastructure projects
2	Draft National Water Framework Bill, 2016	States that (1) The appropriate Government shall make all efforts for appropriate treatment of wastewater and its gainful utilization (2) The appropriate Government shall evolve and implement economic models that promote sustainability of recycle-reduce-and-reuse of water resources, while ensuring adherence to principles of equity
3	Draft Model Building Bye-laws, 2015	Mandates rain water harvesting structures in all buildings having a plot size of 100 sq. m or more. And "All building having a minimum discharge of 10,000 litre. and above per day shall incorporate waste water recycling system. The recycled water should be used for horticultural purposes."

1. http://mowr.gov.in/sites/default/files/Model_Bill_Groundwater_May_2016_0.pdf
2. http://mowr.gov.in/sites/default/files/Water_Framework_18July_2016%281%29.pdf
3. http://mohua.gov.in/upload/uploadfiles/files/Draft%20MBBL-2015.pdf

Chart 2. Key Legal Framework and Accountable Institutions

1.	The Water (Prevention and Control of Pollution) Act, 1974 — Implementation of the Water (Prevention and Control of Pollution) Act, 1974 which seeks to restore water quality —Monitoring of treated sewage and trade effluents and to use recycled water in agriculture	CPCB/SPCB and PCC

2.	The Water (Prevention and Control of Pollution) Cess Act, 1977 — All Industries and Local Authority have to pay water cess. Provision of rebate in the case of installation of STP or ETP, as the case may be	CPCB/SPCB/ ULB/ Local Authority
3.	Environment (Protection) Act, 1986 under section 3(3) —constitution of CGWA "to regulate and control, management and development of ground water in the country and to issue necessary regulatory direction for the purpose"	CGWA

Chart 3. Key Cases

Sl. no.	Cases	Order
1.	M.C. Mehta versus Union of India and Anr., 1997(11), SSC312 Order date: December 10, 1996	The Supreme Court advised to constitute a CGWB, "As an Authority" for regulating the "indiscriminate boring and withdrawal of underground water in the country"
2.	Vikrant Kumar Tongad V/s Union of India & Ors. Order date: January 11, 2013	NGT directed "All the places in the Noida and Greater Noida not to extract any quantity of ground water for the purpose of construction or otherwise"
3.	Krishan Kant Singh versus M/s Deoria Paper Ltd. Order date: April 15, 2015	NGT directed to Central Ground Water Authority that "it shall be obligatory upon it to ensure that any person operating tubewell or any means to extract groundwater should obtain its permission and should operate the same subject to law in force, even if such unit is existing unit or the unit is still to be established"

4.	Yogesh Nagar versus Union of India & Ors. Order Date: December 10, 2015	In an important case related to the industries in the state of Uttar Pradesh, The NGT ordered that "All industries falling in any category and which are extracting Ground water would be required to obtain permission from the CGWA positively by 31st December, 2015. If they fail to obtain such permission and comply with the directions of the Board, the CGWA and the UPPCB shall take action in accordance with law"
5.	Mukesh Yadav versus State of Uttar Pradesh and Others. Order date: February 29, 2016	NGT ordered that "Greater NOIDA Authority shall in consultation with the CGWA issue guideline for ensuring that the future constructions permitted in the area take into account the status of ground water table and impose appropriate restrictions on digging below the ground water level for the purposes of construction of basements in the multi-story buildings/apartments and other related activities." For construction activity water should be drawn from STPs
6.	Paryavaran Suraksha Samiti and another versus Union of India & Ors. (writ Petition (C) No. 375 of 2012) Order date: February 22, 2017	The Supreme Court made it mandatory for the industries to have a functional primary effluent treatment plants and need to install a functional common effluent treatment plants within the given time for continuation of industrial activity and also to have an online effluent/emission monitoring system
7.	Sushil Raghav & Anr. versus Central Ground Water Authority & Ors. Order date: April 13, 2017	NGT ordered CGWA to ensure that no private individual, person or builder is allowed to extract ground water without permission or a valid NOC
8.	Shailesh Singh versus Hotel Jaypee Vasant, New Delhi and Others (M.A. No. 1333 of 2015) Order date: August 14, 2018	NGT ordered concerned hotels to seek permission and inform CGWA the time period for their extraction of ground water and monthly quantity extracted. NGT ordered CGWA to take action if the extraction was "in excess of the permissible limit".

1. http://cgwb.gov.in/cgwa/NGT/NGT%20Order%20on%20Industries%20in%20BISRAKH.pdf
2. http://cgwb.gov.in/cgwa/NGT/NGT%20order%20dated%2015th%20April%202015.pdf
3. http://cgwb.gov.in/cgwa/Documents/NGT%20ORDER%20DT.%2013.4.17%20SUSHIL%20RAGHAV%20VS%20CGWA.pdf
4. http://cgwb.gov.in/cgwa/NGT/Judgement%20order%20in%20MA%20No%2021%20of%202015%20in%20Application%20No%2047%20of%202015.pdf
5. http://cgwb.gov.in/cgwa/NGT/NGT%20order%20dated%2030.11.2015.pdf
6. http://cgwb.gov.in/cgwa/NGT/OA%20133%20OF%2014%20JUDGMENT%20%20IN%20MUKESH%20YADAV.pdf
7. http://www.uppcb.com/pdf/writ-prtition_080317.pdf
8. http://www.greentribunal.gov.in/DisplayFile.aspx

Garden STPs under the NDMC

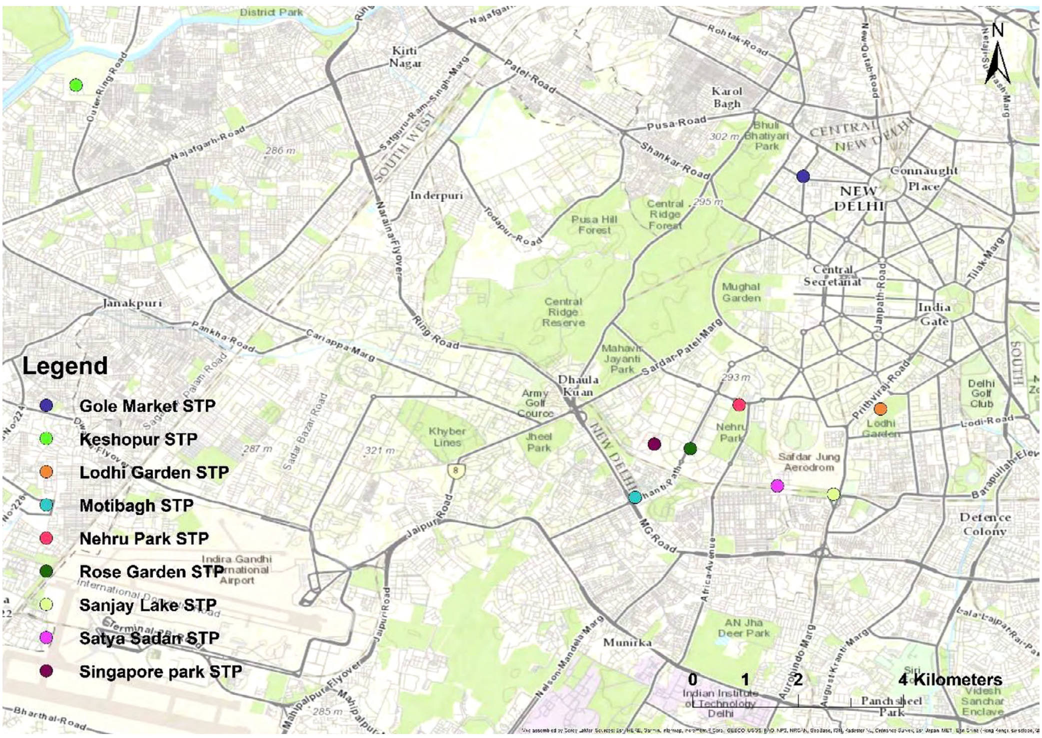
Now, we turn to the other projects in the Delhi region. There is a new push to set up decentralized STPs in the National Capital Region to provide this treated wastewater to the city gardens. A group of political and administrative leaders within the Delhi legislature and the New Delhi Municipal Council is driving this initiative. The Chief Minister of Delhi and the Chairman of the NDMC are the most visible leaders. Electricity, water, and sanitation were key issues in the party's campaign, and the party through the NDMC has initiated a number of sanitation, water, and electricity projects since 2015.

In September 2017, the Chief Minister Kejriwal took over the water portfolio in the Delhi government to assume a more hands on approach to reforms in the water sector. Earlier in his position as Chief Minister, Kejriwal had initiated water reforms by reducing the tariff for household water services (Pandey 2015). The tariff structure in 2015 included up to 20 kiloliters of free water with nominal charges for households. The CM called this lifeline water that should be provided to all residents. After a short time, however, the DJB and others protested that the city could not afford such a gracious provision and the volumetric rate was set at a low rate to recover at least some revenue for households using less than 20 kiloliter a month.

The New Delhi Municipal Council region consumes around 125 million liters per day (mld) of potable water, 120 mld of which it buys from the DJB for around Rs. 15 a kiloliter. Bore wells and rainwater harvesting make up the rest of the need. The estimated cost to procure groundwater is around Rs. 10 a kiloliter. The NDMC then distributes the 125 mld of water purchased from the DJB through its pipe grids and by water tankers to nonpiped areas. It is sold according to a revised rate scheme that gives the first 20 kiloliters of water at the rate of 3.45 per kiloliters with scaled rates above that.[18] These household uses are therefore heavily subsidized and the NDMC must earn higher rates from big users if it wants to recoup its costs. About 10% of the NDMC's water budget is used for maintenance of the city gardens and for other beautification structures such as fountains and lakes. This also has no user fees associated with it, so the cost is covered by the NDMC directly.

In the area controlled by the New Delhi Municipal Council, or Lutyen's Delhi, a number of beautiful gardens create an aesthetic ambiance for the capital. The New Delhi Municipal Council uses about 80 mld of water to maintain around 8,000 parks; until recently, this need has been supplied by a small amount of NDMC "pure" water and the rest from groundwater and treated wastewater from the Okhla STP. The DJB estimates that the total water treated at its STPs is about 455 million gallons a day (mgd) of which they claim to provide 142 mgd (or 645 mld) of treated water for horticulture and irrigation across the Delhi metropolitan region.[19] While it is difficult to verify whether this treated water is actually being used in the areas surrounding the city's STPs, it is more realistic to suppose that the treated wastewater from the closest STP in Okhla has been partially used for the NDMC parks. Several individuals in the CPWD described a "filtered water" pipeline from the Okhla STP to the NDMC garden areas. With groundwater levels depleting to over 300 feet in some sections of Delhi, there has been increasing focus on curtailing use of groundwater for horticulture and other nonessential services. In this context, in 2017, the NGT directed all urban municipalities to use treated wastewater for horticulture.

Figure 1. Map of decentralized STPs in the National Capital Region (created by Pratibha Prakash)



In March 2016, the New Delhi Municipal Council took the decision to promote decentralized STPs to help deal with the wastewater load in the city and promote recycling of treated water for functions such as horticulture and irrigation. The amount of usable water produced by these decentralized plants would then greatly supplement the minor supply they were receiving from the Okhla STP. The NDMC installed eight decentralized STPs and has plans to create over 10 more within its jurisdiction. These projects will help to reduce the dependency on groundwater and begin a separation of fresh and contaminated water. Fresh water sources from the upper catchments of the Ganga and

Yamuna rivers could be better protected from pollution if wastewater were diverted away from in stream flows and used in this manner after treatment.

At present, there are two private companies working with the NDMC to construct and maintain these new STPs. Ecosystem Resource Management Pvt Ltd has built five plants (four operating and one under construction) on the Soil Biotechnology model invented by Professor Shankar's team at IIT-Bombay. Over the last 20 years, M.Sc. and Ph.D. students have developed and tested the soil biotechnology approach and it is now a patented method for wastewater treatment. The plants are built quickly and operated with low skilled labor. They require very little power and take up much less land than conventional plants, for instance, 500 m^2 for a 500 kld plant. The other company working with the NDMC is SS Engineering Corporation. They have built two plants on the MBR or Membrane Bioreactor model and a third is under construction. This method requires very little land but consumes more electrical power in the activated sludge process. Sludge is generated every day, so it must be collected and distributed for horticulture and irrigation. The plants range in treatment capacity from 100 to 500 kiloliters per day. The NDMC plans to install other smaller units like these in schools and housing colonies. These smaller projects will be undertaken by NEERI—the National Environmental Engineering Research Institute—using their own patented phytorid technology. All of the STPs in this NDMC cluster draw their wastewater from a nearby drain or nala, and avoid the need to build long pipelines from point sources of wastewater. The longest pipeline is around 750 m. The specific arrangement in the public–private partnership between the NDMC and the company is that the company covers most of the costs involved in building and maintaining the sanitation supply chain. These costs include laying pipelines from the nearest wastewater source to the plant, treatment plant building costs, and operation and maintenance costs for 12 years. The installation costs include procuring, financing, plant construction, staff for operation and maintenance, water storage, and distribution. Over the whole system, a significant savings occurs by removing the need to transport the wastewater long distances to a treatment plant. It is simply a matter of tapping in to the subterranean tunnels of wastewater coursing underneath every part of the city. But land is a significant challenge and the NDMC case is unique in that available space in the parks can be utilized for these projects without causing any displacement. The tighter land situation in other cities may restrict the feasibility of decentralized STPs. STPs in the NDMC area are located in the parks maintained by the NDMC, so the scope for community participation is minimal.

In these garden projects, the contract between the government and the company defines the capital and maintenance responsibilities of both parties. In that contract, the NDMC agrees to buy all the water produced by the plant while allowing access to the city wastewater drain where the raw supply is drawn. The NDMC also provides the land for the STP at no cost to the private operator and then distributes the treated water, at its own cost, through water tankers to other gardens in the territory. The NDMC pays a rate between 30 and 37 Rs. per kiloliter to the company for the days that they collect the treated water and then adds a lower rated payment for those days that they cannot collect the water due to weather or other circumstances. The private company in theory should be able to pay off its investment and glean a profit from these regular payments made by the NDMC after about five or six years. The NDMC on the other hand does not have to come up with the initial capital for the project but pays over time by guaranteeing to purchase the water. This decentralizes water governance to the location of the facility but maintains institutional controls through government pricing and a guarantee to purchase the treated water. In this case, the government entity becomes the consumer rather than the producer, thus altering the hydrosocial cycle.

Figure 2. Rose garden with an SBT plant in the foreground, located along Shantipath near Embassies and Consulates. (Picture by Kelly D. Alley)

Closed-Loop or "Zero Discharge" Cases

In Karnataka and Tamil Nadu, the Pollution Control Boards are now requiring industries, housing societies, and five-star hotels to use recycled wastewater for gardening, toilet flushing, and industrial processes.[20] There are only a few water recycling projects in the country that can be considered closed-loop or zero discharge. They are interesting models and propose the most dramatic shifts in the hydrosocial cycle. They transform consumers into producer–consumers and this has interesting implications for governance over wastewater management.

The two projects we introduce as case studies are located in large institutional–business complexes. One is at the IIT in Chennai and the other is in the Renaissance Hotel and Convention Center in Mumbai. Both their systems were developed to help solve water-scarcity problems. The IIT needed water for its sprawling campus at a time when city provisions were running very short. Engineering professors were instrumental in getting the university administration to invest in a state-of-the-art system to recycle wastewater and re-engineer the entire campus for dual plumbing.[21] With a population of about 20,000, of which 9,000 are students, 9,000 are residents, and 2,000 constitute a floating population, the institute's one-day requirement is 2.8 mld and the Chennai Metro Water and Sewage Board supplies 1.2–1.8 mld of pure water. The gap is bridged by treated wastewater on site. Their STP provides recycled water for toilet flushing in the dormitories, for campus gardening, air conditioning, and other building and cleaning needs. The facility was built in a phased manner, at a cost of about 20 crores (Krishna Chaitanya and Krishna 2017). During the drought of 2015, the campus was able to function with very little city water, using their own internal resources through recycling. The lead professor in this effort recently explained to the Indian Express:

> The IIT-M STP treats close to 30 lakh [3 million litres per day], including 8 lakh litres [800,000 litres per day] of wastewater generated by the IIT-M research park. They send back 8 lakh litres of treated water to the research park for their utilization and 10 lakh litres is routed for flushing and upkeep of greenery. So the remaining 10–12 lakh litres is in excess, which is being diverted into ponds. Once those are full, two groundwater recharge wells are dug up, each having a capacity of 0.5 MLD. This will replenish the fresh water lake. Overall, nothing is wasted. (Krishna Chaitanya and Krishna 2017)

The second closed-loop system is in the Renaissance Hotel and Conference Center in Mumbai. The Manager of the Engineering department explains that they were first motivated to upgrade and fully utilize their own STP after water shortage affected their ability to run the AC cooling towers for three very large high-rise hotel buildings. At that time, they had a smaller

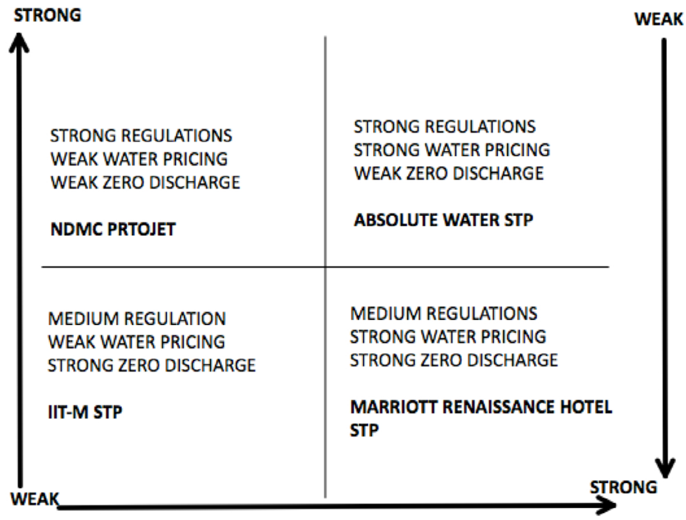
STP and were using the treated water for horticulture. They decided to upgrade the facility by creating two STPs with capacities to treat 750 and 650 kld underground at the back side of the complex. This provided more than enough water for their AC cooling towers, for flushing toilets, and for watering the gardens. The Management was able to install dual or double plumbing in the entire hotel to enable them to use recycled water for flushing toilets and city piped (pure) water for the kitchen, faucets, and showers in the rooms. The problem with older hotels, the Manager explained, is that they do not have the separate plumbing. It is hard to re-plumb and lay pipelines where they would have to shut down part of the hotel and lose revenue or disturb the guests. The manager explained:

> The challenge is that the old hotels do not have the separate piping system for flushing. Most have one pipe system for all uses in bathroom. The properties that have separate line for flushing can easily do it. A few old hotels have it but not all. Retro fit is expensive and its hard to do in a hotel where we cannot disturb guests and can't shut down because we will loose revenue. But now all new hotels and malls are designing for separate lines. Before water was readily available in India but now it is not available. It is not the case now that we have all the water we need. The water table is going down to 250 ft or more. It is too much. It used to be 20–30 ft. So that is why everyone is thinking about how to save the water. So they are thinking of recycling but we need to reduce our use also. So we are going for low flow aerators for wash basin. 4.5 liter/minute plus dual flushing system. We have completed one building for low flow in the wash basin. It is 10.8 liter per minute in the other buildings.[22]

They see direct savings in water bills (Chart 4). He continued:

> The regulation is one thing. It is our responsibility to give back to society. We can afford to have more fresh water but if we do that means someone is getting less. It is affecting our overall bottom line. In 2015, we were having problem from [our] STP and were not getting enough water. We went for upgradation. That time using for gardening and a little bit for cooling tower. We were using a little for flushing but mixing it with fresh water in the tank before going to the rooms. Then we did modification and we have reduced intake consumption by 45%. We get 110 Rs per kiloliter. That is our cost. So if I am getting 400 kiloliter from STP everyday I am saving. Plus you get a good feeling that you are doing your bit. It doesn't go under CSR because it is a requirement.

Chart 4. Matrix of Key Parameters for the Case Studies (Strong, Medium, and Weak)



Emerging Scenarios

The key parameters in these case studies can be profiled into scenario types or heuristics to provide guidance on what works, taking a flexible approach (see Chart 1). The scenario types are: "interested leader," "water availability squeeze," "water pricing," "rule bearing push," and "closed loop business savings." These labels help to identify current determinants of successes and should point attention to areas of importance to be strengthened in other projects around the country.

Interested Leader

Each of the four cases has the involvement of strong leadership, where the interest of the leader is in water conservation, increasing their water supply, reducing the use of groundwater, and saving money on the water bill. In the garden STPs in Delhi and at the bus depot, leadership provided by the Delhi Government and especially key figures such as Chief Minister Kejriwal strengthens the projects in terms of investment, joint public–private responsibility, and sustainability over time. In the IIT-M case, an engineering professor was instrumental in getting the campus STP established, funded, and equipped with monitoring tools for ongoing research purposes. In the Marriott case, the engineering manager led the efforts to upgrade and expand their onsite STP and this led to big savings in their water bill and a state-of-the-art dual plumbing system throughout the hotel. These cases show that leadership is diverse but critical to a project's success. Other kinds of leadership may emerge in other projects and this heuristic should direct inquiry toward those motivators in the hope that they will be supported.

Water Pricing

These decentralized STPs are systems that will have problems and we have seen many with one problem or another. However, it is a success in sewage management if local or on-site projects are able to deliver treated water for reuse within the same cost structure provided to citizens to purchase pure water. Water tariffs (for pure water) are either fixed or too low and it is difficult for service providers to recover costs from user charges and promote water conservation (Raghavendra 2006). Since surface water provided by a city or municipal department is subsidized and scaled, we expect that treated wastewater would need to be priced and scaled accordingly to attract the interest of consumers. Pricing may motivate industry and business users more convincingly than it motivates middle class, piped water users since the rates are so much higher for them and piped water is underpriced and subsidized for the low consuming general public. A rebate in prices after installation of recycling facilities may motivate users in housing complexes, but more research is needed on that. The unpiped consumers living in unpiped, peri-urban, or unauthorized zones may be more motivated to use treated wastewater since their water tanker prices are so high.[23]

Rule-Bearing Push

A significant amount of effort has been spent in motivating the government to do an effective job of wastewater management, and many of the discussions in the NGT reflect the fact that these tasks are not done well if at all (Alley 2002, 2014, 2015; Rohilla and Dwivedi 2013; Sanghi 2014; Tare and Roy 2015). Several state and central government agencies have imposed restrictions on using potable water for nonpotable purposes and have restricted groundwater use for horticulture and gardening and some industrial processes. The NGT stands out as the primary pusher of ground breaking rules that require new behaviors such as the limits and bans on groundwater use. The named implementing agencies, the Central Groundwater Commission and the Pollution Control Boards, must enforce these orders. We can expect more push from the NGT over time and conclude that a strong, legal apparatus is a critical motivator of improvements in sanitation and water supply and delivery.

Water Availability Crunch

All the projects we have surveyed including the four featured in this paper require new kinds of relationships between government, private, and public sector entities. Although private sector involvement is considered risky, these projects show specific kinds of public–private partnerships and their conditions. This helps to understand what works in terms of contracts and responsibilities over time. In terms of adding more expertise to this sector, projects may extend the reach of reforms since most government bodies cannot take up all the needed initiatives on their own. A broad-scale addition of public–private projects could make a significant change in the hydrosocial cycle by putting more usable water into the supply chain and reducing the amount of untreated wastewater that contaminates the good water of rivers and lakes. The garden projects put treated wastewater back into the soil where the soil biology and oxygen treat the wastewater even further. The projects also reduce the need to make large extractions of groundwater for horticulture. If done on a larger scale, these substitutions could have a noticeable effect on groundwater tables.

Closed-Loop Business Savings

Two of the cases show that entities requiring a large quantity of water on a daily basis are more motivated to create their own closed-loop systems and become producers as well as consumers over time. These wastewater reuse projects create closed-loop systems in the urban hydrosocial cycle. The IIT-M project and the Renaissance hotel project circulate water along a tighter path through treatment to business/institution use and then back into treatment.

In these two closed-loop projects, there is a devolution of responsibility for operating and maintaining the facility to the local level. There is also a devolution of control over water use through the reuse of existing supply. The local level means at the functioning of the STP or within the business, university, or housing society. In a business such as the Renaissance hotel, the hotel management is responsible for operation and maintenance of the STP, not the state-level engineering or water agency as is the case with centralized STPs (Alley 2002, 2014; Sanghi 2014). Likewise at IIT-M, engineering professors and their students are involved in monitoring the facilities as they are operated by university staff. This alters the roles of consumers and transforms them into operators and monitors. They are generating their own resource and then handling its reuse within their own community. It is a closed loop of responsibility, even though the requirement to recycle comes from the state and central pollution control boards, the municipalities, and the NGT.

This paper has argued that wastewater recycling is on the rise and can lead to significant contributions to water supply while reducing the pollution load on precious surface waters. These cases point attention to key parameters of success that can be identified and supported in other cases around India. A flexible approach to assessment, which takes success and failure in terms of the interplay of key parameters, can help to recognize specific areas of improvement and build upon them, to provide a greater sense of accomplishment and motivation over time.

References

Alley, Kelly D. 2002. *On the Banks of the Ganga: When Wastewater Meets a Sacred River*. Ann Arbor: University of Michigan Press.

Alley, K. D. 2014. "Ganga and Varanasi's Waste-water Management: Why Has It Remained Such an Intractable Problem?" *SANDRP South Asia Network* *on Dams, Rivers and People* (blog). Accessed July 14, 2018. https://sandrp.wordpress.com/2014/09/25/varanasis-ganga-wastewater-management-why-has-it-remained-such-an-intractable-problem/.

Alley, Kelly. 2015. "Rejuvenating the Ganga." *Global Water Forum*, July 13. Accessed July 14, 2018. http://www.globalwaterforum.org/2015/08/13/rejuvenating-the-ganga/.

Alley, Kelly D. 2016. Rejuvenating Ganga: Challenges and Opportunities in Institutions, Technologies and Governance. *Tekton: A Journal of Architecture, Urban Design and Planning* 3(1) March

Alley, Kelly D. , Jennifer Barr and Tarini Mehta. 2018. Infrastructure Disarray in the Clean Indian/Clean Ganga Campaigns." *Wiley Interdisciplinary Reviews: Water*. doi:10.1002/wat2.1310.

Amerasinghe, P., R. M. Bhardwaj, C. Scott, K. Jella, and F. Marshall. 2013. "Urban Wastewater and Agricultural Reuse Challenges in India." *IWMI Research Report* 147: 1–28.

Anand, Nikhil. 2017. *Hydraulic City: Water and the Infrastructures of Citizenship in Mumbai*. Durham: Duke University Press.

Arora, M., H. Malano, B. Davidson, R. Nelson, and B. George. 2015. "Interactions Between Centralized and Decentralized Water Systems in Urban Context: A Review." *Wiley Interdisciplinary Reviews: Water 2* (6): 623–634.

Bahinipati, Chandra Sekhar. 2017. "Coping Costs of Urban Water in Smart Cities in India: Status, Issues and Policy Lessons." Asian Cities Climate Change Resilience Network (ACCRN). The Rockefeller Foundation.

Barnes, J. 2014. "Mixing Waters: The Reuse of Agricultural Drainage Water in Egypt." *Geoforum* 57: 181–191.

Bear, Laura. 2015. *Navigating Austerity: Currents of Debt along a South Asian River*. Stanford: Stanford University press

Bjorkman, Lisa. 2015. *Pipe Politics. Contested Water: Embedded Infrastructures of Millenial Mumbai.* Durham: Duke University Press.

Budds, Jessica. 2008. "Whose Scarcity? The Hydrosocial Cycle and the Changing Waterscape of La Ligua River Basin, Chile." In *Contentious Geographies: Environment, Meaning, Scale*, edited by M. Goodman, M. Boykoff, and K. Evered, 59–68. Hampshire: Ashgate.

Cross, J. 2016. "Off the Grid: Infrastructure and Energy Beyond the Mains." In *Infrastructures and Social Complexity: A Companion*, edited by P. Harvey, C. Bruun Jensen, and A. Morita. New York: Routledge.198-209

Cullet, Philippe. 2017. "A Gathering Crisis: The Need for Groundwater Regulation." *The Hindu*, August 8, 2017, accessed July 14, 2018. http://

www.thehindu.com/opinion/op-ed/a-gathering-crisis-the-need-for-groundwater-regulation/article19446507.ece.

Dasgupta, Simanti. 2015. *Bits of Belonging: Information Technology, Water, and Neoliberal Governances in India*. Philadelphia: Temple University Press.

Fielding, Kelly D., Sara Dolnicar, and Tracy Schultz. 2018. "Public Acceptance of Recycled Water." *International Journal of Water Resources Development.* 34 (4) doi:10.1080/07900627.2017.1419125.

Follmann (2014)

Forest, Ecology and Environment Secretariat. Government of Karnataka? Bengaluru Notification January 19, 2016.

Frijns, Jos, Heather M. Smith, Stijn Brouwer, Kenisha Garnett, Richard Elelman, and Paul Jeffrey. 2016. "How Governance Regimes Shape the Implementation of Water Reuse Schemes." *Water* 8: 605.

Gupta, Akhil. 2015. "An Anthropology of Electricity from the Global South." *Cultural Anthropology* 30 (4): 555–568.

Hurlimann, A., and J. McKay. 2007. "Urban Australians Using Recycled Water for Domestic Non-Potable Use—An Evaluation of the Attributes Price, Saltiness, Colour and Odour Using Conjoint Analysis." *Journal of Environmental Management* 83 (1): 93–104.

Jamwal, Priyanka, Bejoy K. Thomas, Sharachchandra Lele, and Veena Srinivasan. 2014. "Addressing Water Stress Through Wastewater Reuse: Complexities and Challenges in Bangalore, India." Proceedings of the Resilient Cities 2014 Congress.

Kontogianni, Areti, Ian H. Langford, Andreas Papandreou, and Mihalis S. Skourtos. 2003. "Social Preferences for Improving Water Quality: An Economic Analysis of Benefits from Wastewater Treatment." *Water Resources Management* 17 (5): 317–336.

Krishna Chaitanya, S. V., and S. V. Krishna. 2017. "What Drought? Check out IIT Madras, It's an Oasis." *Indian Express* May 11, 2017, accessed July 14, 2018. http://www.newindianexpress.com/cities/chennai/2017/may/11/what-drought-check-out-iit-madras-its-an-oasis-1603523--1.html.

Kuttuva, P., S. Lele, and G. V. Mendez. 2018. "Decentralized Wastewater Systems in Bengaluru, India: Success or Failure?" *Water Economics and Policy* 4 (2): 1650043.Lienhoop Nele, Emad K. Al-Karablieh, Amer Z. Salman, Jaime A. Cardona. 2014. Environmental cost–benefit analysis of decentralised wastewater treatment and re-use: a case study of rural Jordan. *Water Policy* (16): 323–339

Linton, Jamie, and Jessica Budds. 2013. "The Hydrosocial Cycle: Defining and Mobilizing a Relational-Dialectical Approach to Water." *Geoforum*. (57): 170-180

Maurya, Nutan, Karthick Radhakrishnan, K. Alley, S. Das, and J. Barr. 2017. "A Review Report of the Decentralized Wastewater Treatment System (DEWATS) of Kachhpura Agra." Unpublished report. doi: 10.13140/RG.2.2.22748.28805.

Molinos-Senante, M., F. Hernández-Sancho, and R. Sala-Garrido. 2011. "Cost–Benefit Analysis of Water-Reuse Projects for Environmental Purposes: A Case Study for Spanish Wastewater Treatment Plants." *Journal of Environmental Management* 92 (12): 3091–3097.

Narain, Sunita. 2018. "Every Drop Matters. Opinion." *Down to Earth,* June 27.

Niti Aayog. *Composite Water Management Index: A Tool for Water Management.* June, 2018.

Pandey, Kundan. 2015. "AAP Government Announces Free Water, Cheap Electricity for Delhi Residents." *Down to Earth,* February 25, 2015.

Raghavendra, S. 2006. "Re-Examining the 'Low Water Tariff' Hypothesis: Lessons from Hyderabad, India." *Urban Water Journal* 3 (4): 235–247.

Ranganathan, M. 2014. "'Mafias' in the Waterscape: Urban Informality and Everyday Public Authority in Bangalore." *Water Alternatives* 7 (1): 89–105.

Ranganathan M. 2016. Rethinking Urban Water (In)formality. *Oxford Handbooks Online*. 2016-08-03. Oxford: Oxford University Press

Ravishankar, Chaya, Sunil Nautiyal, and Manasi Seshaiah. 2018. "Social Acceptance for Reclaimed Water Use: A Case Study in Bengaluru." *Recycling* 3: 4. doi:10.3390/recycling3010004.

Rohilla, Suresh Kumar, and Deblina Dwivedi. 2013. *Re-Invent, Recycle and Reuse-Toolkit on Decentralized Wastewater Management.* Delhi: Center for Science and Environment.

Roomratanapun, W. 2001. "Introducing Centralised Wastewater Treatment in Bangkok: A Study of Factors Determining Its Acceptability." *Habitat International* 25 (3): 359–371.

Roy, A., 2009. Why India Cannot Plan Its Cities: Informality, Insurgence and the Idiom of Urbanization. *Planning Theory* 8 (1), 76–87

Roy A. and A. Ong, eds. 2012. *Worlding Cities: Asian Experiments and the Art of Being Global.* Wiley-Blackwell

Sandrp. 2017. "DRP News Bulletin 16 October 2017: New Groundwater Guidelines threat to India's Water Lifeline." *SANDRP, South Asia Network on Dams, Rivers and People Blog.*

Sanghi, Rashmi, ed. 2014. *Our National River Ganga: Lifeline of Millions*. Switzerland: Springer.

Schwartz K, Luque MT, Rusca M, Ahlers R. 2015. (In)formality: the meshwork of water service provisioning. *Wiley Interdisciplinary Reviews: Water* (2): 31–36.

Sengupta, Sushmita. 2018. "At Least 200 Cities Are Fast Running out of Water." *Down to Earth*, March 31, 2018. http://www.downtoearth.org.in/news/bengaluru-beijing-mexico-city-and-istanbul-are-some-of-the-cities-that-are-headed-towards-day-zero-59984#.WrRr_-fLJAE.facebook.

Shah, Mihir. *A 21st Century Institutional Architecture for India's Water Reforms. Report Submitted by the Committee on Restructuring the CWC and CGWB.* July 2016.

Sovacooll, Benjamin K., and M. V. Ramana. 2015. "Back to the Future: Small Modular Reactors, Nuclear Fantasies, and Symbolic Convergence." *Science, Technology, & Human Values* 40 (1): 96–125.

Starkl, Marcus, Norbert Brunner, and Thor-Axel Stenström. 2017. Why Do Water and Sanitation Systems for the Poor Still Fail? Policy Analysis in Economically Advanced Developing Countries. *Environmental Science and Technology* 47, 6102–6110 Starkl, Markus, Josephine Anthony, Enrique Aymerich, Norbert Brunner, Caroline Chubilleau, Sukanya Das, Makarand M. Ghangrekar, Absar Ahmad Kazmi, Ligy Philip, and Anju Singh. 2018. "Interpreting Best Available Technologies More Flexibly: A Policy Perspective for Municipal Wastewater Management in India and Other Developing Countries." *Environmental Impact Assessment Review* 71: 132–141.

Suneethi, S., G. Keerthiga, R. Soundhar, M. Kanmani, T. Boobalan, D. Krithika, and L. Philip. 2015. "Qualitative Evaluation of Small Scale Municipal Wastewater Treatment Plants (WWTPs) in South India." *Water Practice and Technology* 10 (4): 711–719.

Swyngedouw, E. 2009. "The Political Economy and Political Ecology of the Hydrosocial Cycle." *Journal of Contemporary Water Research and Education* 142: 56–60.

Tare, V., and G. Roy. 2015. "The Ganga: A Trickle of Hope." In *Living Rivers, Dying Rivers: A Quest through India*, edited by R. Iyer. New Delhi, India: Oxford University Press.

Ulsrude, K., T. Winther, D. Palit, H. Rohracher, and J. Sandgren. 2011. "The Solar Transitions Research on Solar Mini-Grids in India: Learning from Local Cases of Innovative Socio-Technical Systems." *Energy for Sustainable Development* 15, no. 3 293-303 (September).

Vandewalle, Emily, and Wendy Jepson. 2015. "Mediating Water Governance: Point-of-Use Water Filtration Devices for Low-Income Communities along the US–Mexico Border." GEO: Geography and Environment 2(9): 107-121

Notes

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2 Additionally, this study finds that control of water begins to devolve toward the level of consumer control and these shifts can mean eventual changes in governance and in technological solutions (see Vandewalle and Jepson 2015).

3 In a study of Bangkok residents, Roomratanapun (2001) found that the level of acceptability for reuse projects declined when direct costs and changes in life style were involved. The study found that complex stimuli, such as cost-effectiveness and the convenience of the technology, tend to influence the degree of acceptability. Kontogianni et al. (2003) observed that those who were willing to pay for treated water believed in state investment for better water quality. They were also motivated by moral concerns linked to health and cultural issues, concern for future generations, and interest in environmental and educational issues.

4 There are many government reports and news items putting the estimate of untreated wastewater at around 70% of all wastewater generated in India. The most authoritative reports have been created by (1) the Centre for Science and Environment ("78% of sewage generated in India remains untreated" Down to Earth. DTE Staff, April 5, 2016); (2) the Central Pollution Control Board. Inventorization of Sewage Treatment Plants. March 2015; and (3) research reports such as Amerasinghe et al. (2013).

5 In Bangalore, Ravishankar, Nautiyal, and Seshaiah (2018) found that 67% of residents who were household owners were willing to buy reclaimed water, 20% were concerned about hygiene, and 33% of respondents lacked trust in the public agency with respect to water quality standards.

6 The potential for reuse also depends on the hydraulic and biochemical characteristics of the particular wastewater in question, making choice of technology an important determinant (Rohilla and Dwivedi 2013).

7 Directions of NGT order dated June 11, 2015, in the matter of OA No. 6/2012 & 300/2013, accessed July 14, 2018, http://delhi.gov.in/wps/wcm/connect/07be330048dbd704b6f9ff7a2b587979/Directions_Clarifications_NGT_11.6.2015.pdf?MOD=AJPERES&lmod=-287594179.

8 According to the Ministry of Water resource's Ganga basin report "the mean annual replenishable groundwater in India as a whole has been assessed at 433 BCM per annum, of which about 202.5 billion cumec per annum (46.8%) lies in the states of the Ganga basin" (Groundwater Observation wells, accessed July 14, 2018, http://nihroorkee.gov.in/Gangakosh/Water%20Resources/gwwells.htm).

9 Jamwal et al. (2014, 12) write, "Complexes of more than 50 apartments are required to install STPs and recycle and reuse all their effluents under a zero-liquid-discharge order by the KSPCB (CII 2014). Forest, Ecology and Environment Secretariat, Notification No FEE 316, EPC 2015, Bengaluru January 19, 2016"; in Delhi, the requirement is more provisional, with the Delhi Development Authority encouraging rather than requiring housing complexes to install recycling units (see Master Plan for Delhi—2021, Delhi Development Authority, draft compilation). In addition, Delhi Government offices, institutions, schools, and aided schools under the broad classification of Commercial/Industrial Category are eligible for 15% rebate on their total monthly bills, provided they adopt water harvesting and waste water recycling, http://www.delhi.gov.in/wps/wcm/connect/bef8998040c5c372b4b6be9bd169ec4a/New+Water+Tariff.pdf?MOD=AJPERES&lmod=-312894429&CACHEID=bef8998040c5c37

2b4b6be9bd169ec4a; see also para 7 of No. 19 of 2003, [17/3/2003]—The Water (Prevention and Control of Pollution) Cess (Amendment) Act, 2003, http://www.moef.nic.in/sites/default/files/No%2036%201977_0.pdf.

10 Hurlimann and McKay (2007) have argued that policies for wastewater reuse depend on the acceptance by the community on the basis of the price, color, odor, and salt content of the recycled water.

11 Conversation on September 27, 2017.

12 After surveying studies that addressed the acceptability of water recycling schemes and the use of recycled water around the world, Fielding, Dolnicar, and Schultz (2018) found that: "(1) public outreach is critically important to the success of a project; (2) public outreach must be targeted to specific stakeholder groups and include both proactive marketing and general education of the public in water-related matters, emphasizing the benefits of recycled water specifically; (3) planners need to earn the public's trust by being transparent and involving experts; and (4) the timing of proposing a recycling project plays a role, with times of more obvious lack of water being optimal" (2018, 24). They could not assert any cross-cultural patterns showing the dominance of one variable or another playing a significant role in promoting acceptability.

13 The Delhi Jal Board is the primary government entity selling water in the National Capital Region. It sells the same water to householders, charging Rs. 5.27 per kiloliter for a supply up to 20 kiloliter per month. After this, the charge jumps to Rs. 26.36 per kiloliter for 20–30 kiloliter of usage per month and they add a sewage maintenance charge of 60% of that water volumetric charge. A large hotel company would pay up to Rs. 175 per kiloliter for the same kind of fresh or "pure" water from the Delhi Jal Board. A sliding scale on pricing surface water favors conservation and makes buyers more motivated to find cheaper water sources including recycled or reclaimed wastewater. Groundwater is generally cheaper, as it is priced by the energy required to extract it. Water tanker prices for water supply in unpiped or "unauthorized" zones are much higher than the greatest consumer use category and can go to Rs. 100–120 per kiloliter in crisis periods.

14 STPs are mandatory for industries in Tamil Nadu and Chennai under enforcement by the State Pollution Control Board. There is also a zero liquid discharge rule in Tamil Nadu and a prohibition against groundwater use, both applying to industries. There are CETPs for small industries that operate as a cluster.

15 There are also abruptly administered national policies that create effects on approaches to sanitation. These include the policies imposed over night by the central administration that cause long-term ripples in society and economy, such as demonetization and the GST.

16 Draft guidelines for issuance of No Objection Certificate (NOC) for ground water withdrawal. Central Ground Water Authority, Ministry of Water Resources, RD & GR, Government of India. http://mowr.gov.in/draft-guidelines-issuance-no-objection-certificate-noc-ground-water-withdrawal. October 2017.

17 Cullet (2017) notes, "It [the new bill] is based on the recognition of the unitary nature of water, the need for decentralised control over groundwater and the necessity to protect it at the aquifer level. The Bill is also based on legal developments that have taken place in the past few decades. ... The Bill also builds on the decentralisation mandate that is already enshrined in general legislation but has not been implemented effectively as far as groundwater is concerned and seeks to give regulatory control over groundwater to local user."

18 Delhi Jal Board Water Tariff revised February 1, 2018.

19 Report of Effluent Usage at STPs, Delhi Jal Board, unpublished document. September 2017 (provided upon our request).

20 Forest, Ecology and Environment Secretariat Notification No. FEE 316 EPC 2015, Bengaluru, January 19, 2016; Tamil Nadu??

21 Interview with Dr. Ligy Philip, IIT-M, October 5, 2017.

22 Interview with Manager of Engineering Department, Marriott Renaissance Hotel and Conference Center, October 14, 2017.

23 Private water tankers hike prices by nearly 40pc as Bengaluru's water crisis deepens *Think Change India*, April 3, 2017, accessed July 14, 2018, https://yourstory.com/2017/04/water-crisis-hike-price/.