Comparing urban wastewater systems in India and Brazil: options for energy efficiency and wastewater reuse

Babette Never\textsuperscript{a} and Katharina Stepping\textsuperscript{b}

\textsuperscript{a}Corresponding author. German Development Institute/Deutsches Institut für Entwicklungspolitik (DIE), Tulpenfeld 6, 53113 Bonn, Germany. E-mail: babette.never@die-gdi.de

\textsuperscript{b}Federal Ministry for Economic Cooperation and Development (BMZ), Dahlmannstr. 4, 53113 Bonn, Germany

Abstract

This paper compares the drivers and barriers to urban wastewater treatment in India and Brazil. The analysis of various different cities focuses on energy efficiency and reuse of treated wastewater. Drawing on 60 semi-structured interviews in Brazil and 20 semi-structured interviews in India, the paper finds that the wastewater systems in both countries are still largely in a situation of lock-in, although innovative initiatives that focus on more resource-footprint, lifecycle-oriented approaches exist in some niche sectors. A combination of specific institutional changes and external triggers has the potential to break the lock-in. Pricing, mandatory regulations and standard setting present helpful instruments to advance institutional change, while a high number of stakeholders, vested interests and economic benefits of the status quo block it. Urbanization and land and water scarcity have been identified as external triggers for shifts in the dominant mindsets towards more sustainable solutions in both countries. For governance of the water–energy–food nexus, this paper finds that using less abstract concepts and language will increase the acceptance of the idea among local stakeholders. Additionally, cross-sectoral integration needs to be tailor-made and well-timed; immediate, full integration is not always the best option.

\textbf{Keywords:} Brazil; Developing countries; Energy efficiency; India; Wastewater reuse; Wastewater systems; Water–energy–food nexus

Introduction

Urban centres in Brazil and India face a range of similar challenges in the wastewater sector. This comparative paper is based on two discussion papers presenting detailed results for each country (see Never, 2016; Stepping, 2016). Sewage collection and wastewater treatment rates in both countries are low. On average, upper-middle and lower-middle income countries treat 38\% and 28\% of generated wastewater respectively, whereas low-income countries treat only 8\% (Sato \textit{et al.}, 2013). Brazil is in line with this average, with approximately 52.8\% of generated wastewater collected and 37.1\% of it being treated.
treated. In India, only 10% of all sewage generated is treated; 32% of urban households are connected to a piped sewer system (Sugam & Ghosh, 2013). In both urban Brazil and India, water and land are becoming scarce due to the increasing pressures of urbanization, economic growth and impacts of climate change. The energy consumption of wastewater treatment plants (WWTPs) is high and untreated wastewater produces substantial greenhouse gas emissions. A reduction in energy consumption would simultaneously reduce emissions, offering co-benefits for climate mitigation.

Resource-efficient solutions in the wastewater sector, such as approaches sensitive to the water–energy–food nexus, should thus be highly interesting to Brazil and India but it is empirically not clear yet whether and to what extent a shift is already happening. This paper asks what drives or hinders wastewater treatment in both countries in general and with respect to reuse and energy saving specifically. Answering these questions in an empirically-driven, inductive way will help to identify steps towards investments in more resource-efficient, life-cycle-oriented wastewater solutions in developing countries.

Generally, options for reuse of treated wastewater exist in horticulture, industry, agriculture and even as drinking water if treated up to the level required for human use. Energy saving in wastewater treatment plants is made possible by replacing some plant components (such as pumps and air blowers) or by completely re-engineering the entire treatment process. Sludge drying through solar radiation in a greenhouse instead of drying through thermal energy also saves energy. Biogas and combined heat and power (CHP) technologies offer opportunities for energy production in wastewater treatment, either to cover the plant’s own energy needs in terms of heat and electricity or even to feed electricity back into the grid.

Wastewater sectors across both developed and developing countries are generally considered to be very resistant to change: socio-technical systems are in a situation of lock-in (Maurer, Rothenberger & Larsen, 2006; Molle et al., 2009; Fuenfschilling & Truffer, 2014). Lock-in takes place when rules, organizational structures, actors’ mindsets and interests as well as investments, including costs sunk in infrastructures or particular types of training for engineers, together stabilize a certain vision and approach (Geels, 2004). Path-dependent decision-making, development and use of corresponding products and technologies further fortify dominant paradigms.

In water and wastewater systems, this reveals itself in the dominant sector logic of the past hundred years: the state-led provision of a secure, clean water supply and ideally piped sewage systems connected to a large centralized WWTP (which normally use activated sludge and aeration or membrane bioreactors). In developing countries, the role of the state can be particularly strong because water tariffs are often subsidized and not market-driven, i.e. cost-covering. Often, wastewater services and technology markets are dominated by a few large companies that exert a lot of economic and lobbying power. Physical assets in the wastewater sector have a long lifetime and are capital intensive, making socio-technical systems with a lot of infrastructure even more stable than others (Markard, 2011).

A shift to more sustainable solutions in wastewater systems that take innovative options for reuse and energy efficiency into account – including septage and decentralized systems – is therefore challenging. Efficiency and performance evaluation of existing systems are important in this regard (Pinto et al., 2017). Yet, it is safe to assume that opening up the path for sustainable solutions including energy, land and food considerations can contribute to breaking the lock-in. Incremental transitions, through small steps, are more likely to be possible than big transformational, disruptive shifts in infrastructure-intensive systems (Kemp et al., 2007; Fuenfschilling & Truffer, 2016; Rogge & Reichardt, 2016). The phasing in of sustainable, green technologies in developing countries depends on the
combination of instruments and incentives in a sequence suitable for the local context (Never & Kemp, 2017). With respect to the water–energy–food nexus, there is also a gap between understanding and developing the concept and actually connecting sectors on the ground (Allouche et al., 2015; Leck et al., 2015). In current policy debates, the idea of fostering a nexus implementation primarily via a national planning approach (that is, top down) seems popular. However, to what extent this is feasible in developing countries is unclear.

In sum, this paper has three goals: first, to close an empirical research gap; second, to generate new insights into sociotechnical systems literature; and, finally, to provide both empirically and theoretically relevant insights into nexus governance. The paper is structured as follows. The following section explains the methodological approach (research design and case selection rationale). The subsequent section presents the results, starting with an overview of existing energy saving and wastewater reuse practices in both countries. The instruments and incentives that foster or hinder energy saving and wastewater reuse as well as institutional, economic and behavioural factors that influence urban wastewater systems are discussed, each structured along similarities and differences between India and Brazil. The conclusions summarize the results’ implications for the theoretical debate and derive recommendations for policymakers.

Method

Research design

This paper is part of a larger project which analyzed incentives, instruments and mechanisms that impact on potential synergies and trade-offs between the water, energy and food (land) sectors in Brazil, Colombia, Germany, India and Zambia. Both case studies on Brazil and India analyzed the drivers and barriers to wastewater treatment, reuse and energy. While pursuing a comparative design with the same semi-structured interviews, the case study on Brazil focused more strongly on wastewater reuse while the Indian case study looked more closely at energy questions. The Indian case study was carried out with the support of the Deutsche Gesellschaft für Internationale Zusammenarbeit (GIZ) – National Urban Sanitation Policy Programme (NUSP).

The results of this report are based on 80 semi-structured interviews conducted with public utilities, private wastewater companies, federal, state and city administrations (called ‘urban local bodies’ in India), consultants, development banks, business associations and experts on the topics of wastewater, recycling and reuse of water. The same semi-structured questions were asked in both countries. The interviews in Brazil took place in Brasília (Federal District), São Paulo (São Paulo state), Rio de Janeiro (Rio de Janeiro state), Belo Horizonte (Minas Gerais state), Recife (Pernambuco state) and Salvador (Bahia state) between October and December 2015. These Brazilian cities face similar challenges, yet with varying degrees of importance and urgency. The interviews in India took place in Delhi, Nashik and Kochi in November and December 2015. These cities differ in various regards, representing a broader range of situations found in Indian cities (see case selection below). The differences in numbers of semi-structured interviews conducted (60 in Brazil, 20 in India) came about due to funding and time restrictions for the Indian case. Results are nevertheless comparable as the point of saturation was reached in both countries (Guest et al., 2006); the higher number of states visited in Brazil merely extended the database.

The interviews followed the logical chain of water and wastewater, including the following links: water supply, wastewater collection and treatment, wastewater reuse, sludge use, and energy efficiency
of WWTPs. Beyond topical questions, the interviews covered financial, economic, political and regulatory aspects of water and wastewater in Brazil and India (see Supplementary Material, available with the online version of this paper). The nexus as an approach and the possibilities for explicit nexus governance were discussed with experts familiar with the nexus idea. In Brazil, all interviews were conducted in Portuguese, recorded when possible and transcribed by six student assistants. The interviews in both countries were coded with the Atlas.ti software.

Case selection: Why make a comparison of Brazil and India?

A comparison of the emerging economies of Brazil and India is particularly interesting due to their differences in managing wastewater. The pressure of urbanization, increasing water consumption, water scarcity and energy security challenges, and insufficient wastewater treatment with effects on health and greenhouse gas emissions are common to both countries. Both are vast countries with shared responsibilities among federal, state and municipalities and with differing degrees of public–private cooperation in the wastewater sector. Differences exist with regard to types of sewage network: Brazilian municipalities prefer separate drainage and sewage systems, which is not the case in India. Brazil has very strict environmental regulations, while regulations in India tend to be more differentiated and staggered over time. Brazil has not yet pushed much for energy saving and biogas production in wastewater treatment; however, both topics are receiving increasing attention in India.

The city sample in both countries was chosen based on local expert opinions after the first few interviews. In India, GIZ-NUSP supports the building of a waste-to-energy plant in Nashik (wastewater and solid waste) and an innovative septage pilot project at the household-level in Kochi. This combination of a bird’s eye view on the one hand and concrete projects/programmes from various stakeholder perspectives on the other has allowed for an in-depth analysis of the sector, complemented by findings from a range of grey literature. This paper will not go into the detailed results for each city, as these can be found in previous publications (Never, 2016; Stepping, 2016). Rather, it draws together the broader trends and findings relevant for other developing countries. Table 1 summarizes the main wastewater service characteristics in Brazil and India.

Brazil is one of the world’s most water-rich countries (average discharge of almost 180,000 m³/s) but it is characterized by an asymmetric distribution of water resources in relation to population, with 45% of the urban population concentrated along the coast but with access to only 3% of the available water (ANA, 2010). The connectivity rates to the sewage network vary greatly across municipalities; the same applies to water lost in distribution (SNIS, 2014). Most of the providers with loss rates higher than 50% in 2014 were situated in the north and north-east regions. From 2004 to 2014, the sewerage network grew 8.3% annually and today attends to 31.4 million households. Most service providers charge a so-called minimum tariff, which is charged regardless of the water quantity consumed. The purpose of the minimum tariff is to guarantee the economic–financial viability of the service provider to sustain the operation and maintenance of the water and wastewater system (SNIS, 2014, p. 73; Leite, 2015).

The water and wastewater situations across Indian cities and towns are diverse, depending on water supply/scarcity, the existence and type of urban industries and peri-urban agriculture, and realistic options to lay or alter sewerage systems. For the vast majority of urban India, no secure data on the amount of sewage generated exists. Municipalities work with an assumption of 70–80% of the water supplied. The share of non-revenue water is high (lost in transmission or because no water meters exist) and freshwater and sewage often mix through broken pipes or unauthorized disposal, seeping...
back into the groundwater. There are generally no taxes for water or sewage services. Water tariffs are usually set by the urban local bodies and utilities.

Results and discussion: the state of energy saving and wastewater reuse in both countries

Energy saving in wastewater systems has only recently become a topic in Brazil and India. Hydro-power supplies more than three-quarters of Brazil’s electric power, but the worst drought in 40 years in the south-east impeded or lowered the electricity production via hydropower (United States Energy Information Administration, 2016). This has led to the increased use of thermal power plants, replacing lost hydroelectric generation with fossil fuel-fired generation at substantially higher costs. For political reasons, these higher energy production costs were only gradually passed on to consumers (Interview 5, Brazil). Once the significant price increase reached water and wastewater utilities, they had a strong economic incentive to reduce their energy consumption, and consequently to produce energy. This fueled the interest in resource-efficient, climate-friendly technologies, such as biogas (Interview 51, Brazil); hence, the price increase has led the utilities to start internalizing the environmental costs of CO2 emissions.

In India, energy comes into wastewater planning primarily as a cost factor. No systematic, integrated planning of water and energy is yet taking place. Energy saving in WWTPs is catching on especially for wastewater plants yet to be constructed. In Delhi, it is mandatory for the electricity provider to ensure

Table 1. Main wastewater service characteristics in Brazil and India.

<table>
<thead>
<tr>
<th></th>
<th>Brazil</th>
<th>India</th>
</tr>
</thead>
<tbody>
<tr>
<td>Population (2016)</td>
<td>207,652,861</td>
<td>1,324,171,325</td>
</tr>
<tr>
<td>Surface area (km²)</td>
<td>8,515,770</td>
<td>3,287,259</td>
</tr>
<tr>
<td>Percentage of population living in urban areas (%, 2016)</td>
<td>86</td>
<td>33</td>
</tr>
<tr>
<td>GDP (USD, 2016)</td>
<td>1,796,000,000,000</td>
<td>2,264,000,000,000</td>
</tr>
<tr>
<td>Urban population connected to sewage network (%)</td>
<td>58</td>
<td>32</td>
</tr>
<tr>
<td>Wastewater collection rate (%)</td>
<td>40.8</td>
<td>High variation: 50% in Delhi, less than 10% in Kochi</td>
</tr>
<tr>
<td>Average wastewater treatment rate (%)</td>
<td>37.1</td>
<td>10</td>
</tr>
<tr>
<td>Estimate of water lost in distribution (non-revenue water, %)</td>
<td>37 (average)</td>
<td>50 (Delhi)</td>
</tr>
<tr>
<td>Example of water tariff for domestic users (Brazil: Averages; India: Delhi)</td>
<td>Minimum tariff: R$3.6–53.2/m³; Social tariff: R$0.8–32.3/m³; Average tariff: R$2.75/m³</td>
<td>Up to 20 m³: free. 20–30 m³: 220 INR service charge, 22 INR volumetric charge [per m³]; Above 30 m³: 293 INR service charge, 37 INR volumetric charge [per m³]</td>
</tr>
<tr>
<td>Example of wastewater tariff</td>
<td>80–100% of the wastewater tariff</td>
<td>60% of volumetric charge in Delhi; no tariff in Kochi or Nashik</td>
</tr>
<tr>
<td>Wastewater reuse</td>
<td>Very little</td>
<td>Very little</td>
</tr>
</tbody>
</table>

R$ = Brazilian Real; 1 Real = 0.31 USD. INR = Indian Rupees; 1 INR = 0.01 USD.
Sources: ANA (2010); SNIS (2014); Leite (2015); own expert interviews.
stable supply to WWTPs, thus keeping power cuts to a minimum. Newly built WWTPs are required to cover up to 60% of their own electricity needs, usually via combined heat and power biogas production. While a national feed-in tariff for biogas has been implemented in Delhi, none of the WWTPs currently produce excess biogas to feed electricity back to the grid. The Nilothi WWTP in West Delhi, built by the company Veolia and with a capacity of 90,000 m³ per day, uses conventional biological treatment processes for sewage, covering 50% of its electricity needs through biogas production and more advanced technologies to reduce the amount of sludge. The remaining sludge is to be sold as manure to farmers at a low price.

In Nashik, the largest of the municipal WWTPs (130,000 m³ per day) works with upflow anaerobic sludge blanket (UASB) technology and produces biogas. Part of the electricity generated from methane is used for the plant’s own energy consumption and the generated surplus is sold to the grid under the Maharashtra feed-in tariff for renewable energy. The city is also building an innovative waste-to-energy plant which will consume both solid waste and black water, making it the first of its kind in India. Through combined heat and power production, the plant is expected to yield 21,000 m³ of biogas every day that will convert to up to 32,000 kWh of electricity. Any excess electricity not used by the plant itself will be fed into the power grid under the Maharashtra feed-in tariff. The compost that the plant generates will be sold to farmers at a low price. Concessions for the construction of the plant have already been awarded.

Middle-income countries such as Brazil and India tend to use both treated and untreated wastewater, ‘indicating a transition between unplanned and uncontrolled reuse to planned and controlled reuse’ (Jiménez et al., 2010, p. 7). Overall, the current levels of wastewater reuse in Brazil are very low. For instance, less than 1% of the current water supply provided by the state company SABESP in São Paulo comes from reused wastewater (Interviews 22 and 23, Brazil). The demand for treated wastewater outside the industry is questioned (Interview 13, Brazil), yet opinions differ, given the use of treated wastewater for street washing, car cleaning and municipal irrigation. In practical terms, the location of WWTPs – constructed in residential areas in the past when the agricultural or industrial sector did not have any use for treated wastewater – may limit the potential of wastewater reuse. This would require the treated wastewater to be carried to a wellspring or a water treatment plant, which would increase costs (Interview 21, Brazil).

Some few examples of reuse exist in the Brazilian cities surveyed. In an attempt to provide much needed solutions to the water crisis, the governor of São Paulo state, Geraldo Alckmin, proposed two plants for wastewater treatment for reuse in November 2014. The intended purpose was to increase the water availability in the Guarapiranga system by 14% and in the Baixo Cotia system by 100% (Veja prazos e custos, 2014). In July 2015, however, SABESP decided to prioritize the construction work to interlink basins, a decision that was heavily criticized. Scientists see the interlinkages as being a short-term solution for the ongoing water crisis, whilst wastewater reuse, directly or indirectly, would take care of the wastewater and water supply for the population. The most prominent and widely referred to example of selling treated water is the Aquapolo project in São Paulo. SABESP and the private company Foz do Brasil, a subsidiary of the Odebrecht Group, created Aquapolo Ambiental SA to treat municipal wastewater for industrial reuse in the so-called ABC region, with the aim of reducing water withdrawal. The wastewater treatment capacity amounts to 56,160 m³ per day, with the possibility of expansion to 86,400 m³ per day (Aqpapolo, 2016).

In India, the National Urban Sanitation Policy of 2008 recommended a minimum of 20% reuse of wastewater in every city. The National Water Policy of 2012 encouraged recycling and reuse of
water after treatment to specified standards as well as preferential tariffs to incentivize the reuse of treated wastewater in general. Despite these policies, recycling and reuse of wastewater is not yet a political priority at federal level nor at state or municipal level. It only takes place when water scarcity leaves no other option. Generally, water is reused in agriculture (treated and untreated), partly in horticulture, and in some industries for cooling, especially in water-scarce cities. In some peri-urban areas of India, sludge generated by WWTPs is also used by farmers.

Delhi has started recycling and reusing water and treated wastewater due to rapidly diminishing groundwater levels. Currently, about 630,000 m³ per day are being reused in power plants and horticulture. All government buildings must now use only recycled water for all non-drinking water purposes and the construction industry is required to use only treated wastewater as well, but the latter measure is only working to a very limited extent so far. The Pragati power plant runs exclusively on treated wastewater from the Delhi Gate sewage treatment plant because groundwater levels are now too low. The reuse of wastewater and sludge in agriculture is somewhat difficult to organize in Delhi as there are hardly any farmers left in the city’s peri-urban areas. Supply and demand are located very far from each other, leading to very high transportation costs. In Nashik, indirect reuse is happening as treatment plants are discharging treated wastewater into the river Godvari and a downstream power plant draws water from the river. Treated wastewater is not reused in Nashik directly and not at all in freshwater-abundant Kochi.

Instruments and incentives

**Similarities**

Political options to foster reuse and phase-in of green technologies such as energy-efficient wastewater treatment technologies can be classified into: command-and-control instruments; financial incentives; and information-based, often voluntary, tools. In the wastewater sector, the pricing of water and electricity as well as fees, service charges or taxes for sewage collection are important instruments of the first category. Mandatory standards for the discharge of wastewater into surface waters and mandatory requirements for WWTPs to cover their own electricity needs through biogas and combined heat and power add to this range of possibilities. By-laws for the construction industry and power plants to use only treated wastewater present another option. Financial incentives can take the form of preferential loan schemes and subsidies for private investments in the sector, tax redemptions for investors and guarantees of price in contracts and concessions (often combined with operation and supervision agreements) to support the business model and market development.

Command and control instruments function both as drivers and barriers in the wastewater sectors of both countries. The current subsidized pricing and the high amount of non-revenue water can be understood as a barrier to investments in the water and wastewater sectors, especially from a private sector perspective, in both Brazil and India. Non-revenue water is the water lost in freshwater pipes and in a sewage system due to leakages or the absence of water meters. In India, there is hardly any data on the amount of sewage generated, making exact pricing difficult, even if the political and public will to pay for wastewater treatment were there (see below). Usually, central and state governments share the costs of sewage equally (Interview 20, India). In Brazil, the costs of wastewater reuse and its economic viability are controversially discussed, and expert opinions diverge strongly, both on
pricing and the actual definition of reuse. The direct link between water and wastewater tariffs in Brazil limits the expansion of the wastewater infrastructure severely. Since both public utilities and private companies active in the wastewater sector need to at least partly cross-subsidize investments in wastewater treatment, even only slightly more expensive but more sustainable technologies are hardly competitive. Increases in water and wastewater tariffs are politically very sensitive in both countries. In Brazil, discussions have started about replacing the minimum tariff – charged regardless of the water consumed, usually with a limit of 10 m³/month – with separate fees for connection and consumption (e.g. in São Paulo; see Leite, 2015). Increases in electricity prices as well as regulations have helped to raise awareness for energy saving in WWTPs in both countries and led to first investments in Indian municipalities.

Environmental legislation, wastewater discharge standards and pollution levels for surface waters generally drive wastewater treatment but currently only help energy saving and reuse to a limited extent since implementation problems persist. There is no sludge regulation in either country, with most utilities seeing it as a mere nuisance (Interviews 3, 16, India). With regard to environmental legislation, Brazil is ‘a developing country with first-world legislation’ (Interview 37, Brazil) oriented towards international standards and not necessarily adapted to local circumstances: ‘We have rivers like in Bangladesh, but our norms are like in Scandinavia’ (Interview 16, Brazil). For instance, the regulatory agency CETESB (the Environmental Company of the State of São Paulo) sets the phosphor level at 0.01 milligrams per litre, which is very difficult to obtain (Interview 16, Brazil). Although ambitious legislation may have a signaling effect and pull compliance upwards, it is questionable whether these stringent norms and standards can accomplish this purpose. In India, discharge standards and first mandatory requirements to cover the electricity needs of WWTPs function as drivers for energy saving in the wastewater system, for example in Delhi, even if older WWTPs in particular do not always meet the required standards. The degree of compliance is likely to vary greatly across India and, to an extent, within municipalities as well. Many WWTPs do not work to full capacity, urgently need maintenance and retrofitting, or do not operate at all. A lack of operation and maintenance skills undermines the implementation of regulations in both Brazilian and Indian cities.

In terms of financial incentives, there was broad agreement among interviewees in both countries that technologies in the sector are generally available. Financial resources are not much of an issue due to the various national missions and various programmes offered by donor agencies (e.g. Interviews 6, 10, 15, 18, 19, India). Access to this finance is difficult for those cities that lack administrative capacity.

Information-based instruments could be an option to raise awareness for the water–energy–food nexus or as voluntary energy audits for WWTPs. Explicit nexus governance in this regard does not yet exist in either country. Many stakeholders struggle with the term ‘nexus’. Implicitly, first innovative solutions are being pursued at a local, municipal level when facing a concrete challenge, e.g. innovative septage solutions in Kochi. Delhi’s 2015 draft water policy recognized that a paradigm shift is required, namely one that sees sewage as a resource and reduces the energy and land footprints of wastewater systems, promotes recycling and reuse of water as well as decentralized treatment and alternative treatment systems. Decreasing the energy footprint of Delhi’s entire cycle of water operations (treatment, supply, sewage collection and treatment) is envisioned. This indicates some awareness of the nexus, but concrete implementation remains to be seen. In both countries, many municipalities still struggle with rudimentary problems in the sanitation sector. It is understandable that they focus on universalising basic wastewater services with their (often connected) limited technical and financial capacities before attempting reuse (Interview 32, Brazil).
Differences

Three main differences exist between Brazil and India in terms of instruments and incentives that influence the wastewater sector: reuse regulation, sequencing of discharge standards and the types of contracts and concessions for the building of WWTP and sewage networks.

In India, first regulation for reuse exists at federal level and also in some water-scarce cities not analyzed in this paper. The city government of Surat, for example, now only supplies the diamond and dyeing industries with recycled water, and is thus able to give more freshwater to the poor. The state government of Haryana had similar plans for the construction industry at the time of field research. As mentioned above, India’s National Water Policy of 2012 encouraged recycling and reuse of water after treatment to specified standards as well as preferential tariffs that incentivize reuse. In Delhi’s draft water policy, there are targets to increase wastewater reuse to 25% by 2017, 50% by 2022 and 80% by 2027. In Brazil, no national legislation for reuse, in particular municipal and industrial as opposed to agricultural reuse, exists as yet.

In India, standards for WWTP discharge into rivers and other surface waters are set sequentially, i.e. they are being tightened over time and this is communicated clearly to municipalities, utilities and companies running WWTPs. This early signalling and sequential tightening allows some time for retrofitting. If paired with operation and maintenance controls, this approach works quite well. This type of standard sequencing does not exist in Brazil. Such stringent norms do not allow for intermediate levels and, hence, result in norms that are too strict and in standards for the Brazilian reality that are frequently not complied with. Fixed and ambitious standards are ‘most useful where they can actually be met by treatment, and wastewater use is a planned and controlled activity’ (Jiménez et al., 2010, p. 18). This is often not the case. Although seen as being too strict in many regards, the insufficient enforcement of the existing legislation in Brazil is criticized when, for instance, an environmental crime is committed using sewage (Interview 17, Brazil), which is related to understaffing in the environmental agencies (Interview 45, Brazil).

The topics of privatization and challenges with contracts and concession processes are much more prominent in the interviews in India than in Brazil. In both countries – as in many other developing countries – the privatization of water and wastewater services has been debated for decades. The Delhi Jal Board (public utility) has increasingly awarded operation and maintenance contracts or design, build, operate and transfer (DBOT) contracts with a guaranteed runtime of 10 years for each WWTP. As a kind of guarantee mechanism, this lowers investment hurdles and eases monitoring for the Delhi Jal Board. The physical assets remain in its hands. Public–private partnerships including true private equity investment do not exist at this stage. The current Delhi state government has largely stopped efforts to privatize the sector, even though many experts agree that the service and delivery quality in Delhi’s wastewater sector has increased with higher private sector involvement. The Delhi Jal Board used to have 55–60% non-revenue water (of overall supply) before public–private partnerships reduced this to roughly 50% (Interview 11, India).

For new WWTPs in India, command-and-control instruments that require utility contractors to build energy efficiently are easier to implement. However, in the tender processes for these plants, specific technologies are already prescribed, instead of setting only the required quality standards and leaving it up to bidders to come up with the most efficient technologies. This reflects the tendency of engineering divisions and public utilities to choose what they already know (risk aversion). The possibilities for
inefficiency and political influence on the processes are high, making it hard for smaller players in the private sector to survive in the long term:

‘In these processes, there are a lot of possibilities for political influence, corruption. Between the DPR [detailed project report] and the tender opening, a minimum of two years pass in India, often three. It can be up to four or five years even’ (Interview 3, India).

Furthermore, contracts and tendering often do not take into account the environmental footprint of a WWTP’s whole lifecycle, including construction and operation. Similar issues concerning tendering and contracts were not mentioned in the interviews in Brazil. Table 2 summarizes the main similarities and differences concerning instruments and incentives between the two countries.

### Institutional, economic and behavioural factors

#### Similarities

The institutional landscape in the wastewater sector is fragmented in Brazil and India, both vertically and horizontally, leading to high transaction costs of cross-sectoral integration. In Brazil, the three administrative levels of federal, state and municipal government are involved: the federal government defines national policies and disburses budgetary means; the states are often involved via state utilities; and municipalities have the mandate to provide water and wastewater services (Interview 2). A municipality, as the rights-holder, also determines who is going to regulate and whether a regulatory agency is established (Interview 38). Coordination costs are also high horizontally because, at each level, several actors are involved in water resources and water services, including wastewater. The high number of bureaucratic steps and agencies in the process, the time it takes from initial expressions of interest to the contracting of WWTP building and the type of technology often prescribed in tenders remain obstacles, the latter especially in India.

At the federal level in India, six ministries are involved in different sections of water and wastewater planning. The number and functions of state and urban local bodies vary greatly. Some municipalities handle sewage issues directly, while others have outsourced different parts of the system, such as maintenance or design, building and operation. This often leads to complicated administrative procedures and creates a confusing picture for potential investors. Furthermore, many municipalities do not yet have a

<table>
<thead>
<tr>
<th>Similarities</th>
<th>Differences</th>
</tr>
</thead>
<tbody>
<tr>
<td>• Inadequate tariff structure</td>
<td>• First regulation of wastewater reuse exists in some Indian cities, but not in Brazil</td>
</tr>
<tr>
<td>• Regulation and standards only support energy saving and wastewater reuse to some extent</td>
<td>• Sequential setting and gradual tightening of discharge standards in India; fixed and ambitious standards in Brazil</td>
</tr>
<tr>
<td>• Lack of sludge regulation</td>
<td>• Stronger challenges with privatization, contracts and concessions in India than in Brazil</td>
</tr>
<tr>
<td>• Access to existing finance difficult for cities that lack administrative and technical capacities</td>
<td></td>
</tr>
<tr>
<td>• Low awareness of the ‘nexus’</td>
<td></td>
</tr>
</tbody>
</table>

Table 2. Instruments and incentives: Main similarities and differences between India and Brazil.
strategic plan for the wastewater sector at all. Unplanned, rapidly increasing urbanization is challenging for city administrations in both countries.

In both countries, many policymakers see freshwater supply and subsidized water tariffs as an election winner rather than prioritizing wastewater treatment and reuse which the public does not like to think about (Interview 6, India). In India, farmers have a strong election power, making any changes in the pricing of water and charges for treated wastewater and reuse extremely difficult. Many policymakers refrain from touching any issues that may contradict farmers’ interests in this field. In Brazil, the common perception among politicians is that improving wastewater infrastructure has little political return (Interview 42, Brazil) and is therefore unlikely to tilt the scales in elections.

Economically, the high amount of non-revenue water makes it difficult for wastewater companies to recover investment costs in both countries. Socio-political reasons for not increasing water and wastewater tariffs above the lifeline tariffs make any changes too difficult. As mentioned above, some municipalities lack the capacity to access national finance. The long amortization rate of big infrastructure and large sunk costs together with the general favouritism for large-scale WWTPs lead to a low willingness to experiment with innovative decentralized treatment plants or septage solutions in many city administrations.

The challenge of non-revenue water is related to actors’ strong interest in the status quo in various cities in Brazil and India. Brazilian municipalities tend to delegate their mandates for basic sanitation – including the planning – to the public utility, though it is ‘a non-delegable activity’ (Interview 18) due to its importance for the general public. In this context, it is important to remember that public utilities also have a stronger interest in the water supply than in wastewater collection and treatment (Interview 6). The economic rationale is that, on the one hand, wastewater investments are much more expensive and, hence, the payback period is much longer; on the other hand, the current tariff structure is not able to reflect these differences. In India, the influence of the so-called ‘water tanker mafia’ in cities such as Delhi and Bangalore which favours the sale of bottled water over fixing leaking pipes and a functioning water and wastewater system creates a vested interest in the status quo (see below).

In both countries, land and water scarcity function as an eye-opener to more sustainable solutions. Urbanization as an overarching issue constitutes both a driver and a barrier here. Land scarcity (Delhi, Kochi) and water scarcity (Delhi, Nashik) drive the diffusion of energy-efficient technologies and first changes in mindsets and investments in more sustainable solutions that integrate water, energy and land considerations. The recent water crisis in São Paulo in Brazil – now extended to a developed and affluent state in the south-east and no longer confined to the poor and underdeveloped northeast – has stimulated a discussion about alternative solutions such as reuse and rainwater harvesting, immensely fostering water savings and water reuse by households, and, in general, strongly increased awareness of water scarcity (Interviews 16 and 20, Brazil).

Land scarcity caused both by urbanization and territorial factors (as in Kochi) has started to become a factor in urban planning processes. The availability of land, the possibilities for government to acquire sufficient amounts of it for large-scale infrastructure in locations not too far from the production of the wastewater, as well as the distances between supply, treatment and discharge options restrict the practical feasibility of traditional centralized wastewater system options. The costs for transporting sewage from households to small decentralized treatment plants are much lower. The existence and increase of water scarcity forces many stakeholders to rethink their preferences and options. Freshwater is becoming a scarce good in several Indian states, making recycling and reuse of wastewater much more attractive:
‘Water stress and availability of water are the drivers of change here in India. Only where there is no water available, for industry for example, things change and then they [regulating agencies and consumers] are open for recycled water’ (Interview 22, India).

An increase in external pressures can therefore open a window of opportunity to change the dominant paradigms in both countries’ wastewater systems.

**Differences**

The influence of institutional, economic and behavioural factors differ in Brazilian and Indian wastewater systems in three ways: the willingness to connect to a sewage system and have a WWTP in the neighbourhood; the influence of the water tanker mafia in India; and the risk aversion and mindset among major actor groups.

In Brazil, there is a low willingness to connect to a sewerage network among both poor and more affluent households. Despite the legal obligation to establish a connection to the public sewage network and to pay for the service, the law is weakly enforced and it is often confronted with a lack of willingness to establish such a regular connection (e.g. Interview 37, Brazil). Irregular wastewater connections are not confined to *favelas* and can also be found in wealthier neighbourhoods (Lobel, 2016). Nevertheless, the low adherence rate can have a cultural aspect to it: for instance, in Manaus, with the water-rich *Rio Negro* (Black river), ‘the city looks to the river that seems to be an ocean and thinks to itself ‘why should my wastewater be treated?’’ (Interview 26, Brazil). Many households outside of *favelas* have a septic tank in their backyards. Although they are legally obliged to decommission the septic tank and connect their domestic sewage to the public sewerage network, once it is installed in the adjacent road, many owners refuse to do so, making the argument that they already have a septic tank and that the tariff is too expensive.

This phenomenon could not be witnessed in the Indian cities analyzed. In Kochi, the social acceptance of wastewater treatment systems is low despite the absence of any organized collection and treatment system at this stage. The government owns the land, but the surrounding neighbourhoods refuse to have a decentralized treatment plant close to them (the ‘Not in my backyard’ effect; Interview 10, India). While this particular problem has only been mentioned for Kochi and not for Nashik and Delhi, a common theme emerging in the Interviews in India and Brazil was people’s general mentality of ‘flush and forget’, indicating a disinterest and unwillingness to engage with the topic of sewerage (e.g. Interviews 37 and 48 in Brazil; Interviews 6 and 11 in India).

In Delhi, freshwater pipelines are damaged on purpose by the so-called ‘water tanker mafia’ to increase the sales of bottled water and water provided by tankers, leading to an even higher rate of mixed freshwater and sewage (Interviews 2 and 20, India). The linkages between the water tanker mafia and individuals within utilities and urban local bodies create a powerful shadow alliance preventing change. Both parties have an interest in a deficient water and wastewater system: the water tanker businesses keep selling their water while individuals within the urban local bodies receive payments and favours for not repairing and not changing the status quo. While the experts interviewed here outlined this challenge most clearly for Delhi, the problem is also known to exist in other cities and towns across India, for example, in Bangalore (e.g. Interviews 3, 5, 20, India). Thus, competing forces within urban local bodies and among the private sector make broad, radical changes towards innovative solutions difficult.
The actors working in different parts of the water-wastewater chain, policymakers as well as the consumers of water, have a certain mindset, management capacities, skills and personal preferences which either perpetuate or help to disrupt existing wastewater systems. While mindsets in both countries are generally geared towards conventional, centralized wastewater systems, largely disregarding energy efficiency and reuse options, a bit more openness towards innovative, sustainable solutions exists in India. Modern septage systems and combinations of centralized, piped systems with decentralized options are often not regarded as equally viable solutions.

‘Everywhere, even at local level in small towns, they have their mind set on providing networks and complete sewage system; they don’t look at decentralized systems much. At the state level, same thing’ (Interview 13, India).

Within utilities and urban local bodies in India, this view coincided with engineers’ risk aversion during the planning of wastewater systems. In many cases, such engineers stick to well-known and accepted solutions instead of pursuing innovative ideas (Interviews 1, 10, 18, India). Sometimes new ideas are blocked at higher levels of administration by bureaucrats who have no interest in risking new solutions. While experts and firms offering these decentralized systems have managed to change the mindset in some niche sector areas, coincidences with practical push factors such as land scarcity are necessary for actual implementation and deeper shifts towards lifecycle- and sustainability-oriented thinking.

Despite these various different barriers to both investments in energy-efficient solutions and integrated approaches towards water, energy and land, proactive stakeholders exist as well. Those bureaucrats, utility providers and company members who recognize opportunities, who have understood and are convinced of innovative solutions, lifecycle approaches or the necessity to control the implementation of regulations tend to become active. In Nashik, for example, several committed individuals in the municipal corporation have set up a tighter control system for regulations, following this up by phone, with internet-based monitoring and by site visits if necessary. The commitment and control of key actors is important to link and eventually change various different mindsets. Additionally, control and compliance mechanisms are important to counteract potential free riding.

Table 3 summarizes the main similarities and differences concerning influential economic, institutional and behavioural factors that influence the wastewater systems in both countries.

<table>
<thead>
<tr>
<th>Similarities</th>
<th>Differences</th>
</tr>
</thead>
<tbody>
<tr>
<td>Institutional fragmentation</td>
<td>Low willingness to connect to sewerage network in Brazil; low social acceptance of WWTP in some Indian neighbourhoods</td>
</tr>
<tr>
<td>Water supply and subsidized tariffs seen as election winner, rather than sewage</td>
<td>Existence of a water tanker mafia in India</td>
</tr>
<tr>
<td>High amount of non-revenue water</td>
<td>More open mindset towards innovative, energy saving wastewater solution in India</td>
</tr>
<tr>
<td>Vested interests in the status quo in many cities</td>
<td></td>
</tr>
<tr>
<td>Land and water scarcity drive sustainable solutions</td>
<td></td>
</tr>
</tbody>
</table>
Conclusions

This paper compared the urban wastewater systems of Brazil and India with respect to options for enhancing sustainable solutions such as energy efficient wastewater treatment and reuse of treated wastewater. While there is no specific nexus governance in place, pricing and subsidies in both countries as well as mandatory discharge standards and electricity-saving regulations in India are found to be important instruments for technology diffusion. Standards and regulations only work if they are introduced sequentially and gradually tightened, and if operation and maintenance controls are installed at the same time. Currently, the feed-in tariff for biogas in India hardly functions as an incentive for the wastewater sector. Regulatory gaps remain concerning fees or taxes for sewerage when new buildings are constructed, or for the systematic integration of sewerage into water tariffs and the systematic setting of discharge standards, reuse standards and regulations for nutrient recovery from sludge. In Brazil, however, regulatory standards are perceived to be too strict for the local reality, do not allow for intermediate levels and are frequently not complied with.

Due to (1) the high amount of non-revenue water, (2) vested interests, (3) the still dominant mindset towards centralized, conventional treatment solutions and (4) a range of procedural difficulties, investments in energy-efficient, lifecycle-oriented wastewater systems that are most suitable for concrete local conditions still lag behind. Concrete problem-driven thinking and cost-reduction arguments as well as land and water scarcity can work as triggers. In other words, the systematic consideration of water, energy and land/food in policy and investment planning is only taking place to a very limited extent. When it does take place, this is in concrete, problem-driven situations at local level and not top down.

Our results have both theoretical and policy implications. For the theoretical debate on socio-technical systems, our comparison implies that both the Brazilian and the Indian wastewater sectors are still largely in a situation of lock-in. The potential to break this lock-in and achieve a gradual shift of the socio-technical system lies in a combination of institutional change and external disruptions. Our comparison allows for the general conclusion that the combination of several conditions influences the chances for institutional change: the number of stakeholders, presence of vested interests and the economic benefits of the status quo. A great number of stakeholders with strong vested interests and clear economic benefits in keeping the status quo make the implementation of sustainable wastewater system solutions unlikely. In turn, fewer stakeholders with less interest in the status quo and clear economic benefits in alternatives can help to instigate change. External triggers have the capacity to break the lock-in of socio-technical systems, as transition management theory suggests (e.g. see Geels & Schot, 2007). Urbanization and land and water scarcities present such triggers in the case of the wastewater sectors in emerging economies. If one or more of these external pressures coincide with a low risk aversion and an open, entrepreneurial mindset among public utilities and municipalities, then the chances for investments in energy-efficient technologies and the use of recycling and reuse options increase. To what extent this applies to other emerging economies and developing countries requires further analysis.

For the policy debate, our results give rise to seven key recommendations that apply to both Brazil and India. They are likely to be applicable to countries with similar conditions and contexts:

1. **Introduce standards and regulations sequentially and tighten gradually; install operation and maintenance controls in parallel** (see above).
2. **Reduce regional disparities in capacity to broaden access to budgetary means, including the access to climate finance.** The attention of federal governments and donor agencies in increasing technical
capacities are often not equally distributed across cities in different regions. The high amount of greenhouse gases emitted through untreated wastewater and sludge could open up new investment and financing options for resource-efficient solutions, such as international investment from climate funds.

3. **Reform the wastewater tariff structure to allow full cost recovery.** This is a well-known argument, now more important than ever, given that the current tariff structure is a major obstacle to expanding and reforming the wastewater infrastructure. Socially acceptable, staggered tariffs, with separate tariffs for water and wastewater and related regulatory reforms would be helpful.

4. **Use the potential of green procurement.** Lifecycle-oriented thinking already in the planning stage should be supported to shape tenders and contracts accordingly. Green procurement offers many possibilities to change the wastewater sector; a lifecycle-oriented mindset needs to be further promoted and to be reflected in tenders and cost calculations.

5. **Use the momentum of the recent water crisis in Brazil and recurring water shortage in India to further raise awareness and exert more pressure.** The recent drought and subsequent water crisis in the state of São Paulo has increased awareness of the role of insufficient collection and treatment of wastewater for freshwater availability in the whole country. In India, water shortages drive the development and acceptance of innovative solutions. The urbanization process increases the pressure to universalize wastewater services in both countries.

6. **Support pragmatic mindset change and orientation towards cost arguments.** This can help enhance investments in energy- and water-efficient technologies. Concrete problem-oriented thinking and cost-reduction arguments at local level opens up possibilities for both energy-efficient technology investment and holistic approaches to the problems in the wastewater sector.

7. **Use a less abstract term than ‘nexus’**. Using the language of local actors increases interest and identification with the topic. The nexus concept in itself is regarded as too abstract by many stakeholders; it would be better to avoid it as a framework and replace it by the language spoken by stakeholders (e.g. ‘holistic’ or ‘cost-efficient, lifecycle-oriented approach’).

8. **Don’t introduce later steps before the first steps have been taken.** The institutional context is complex, given the number of governmental institutions. A top-down integration of governance is therefore unlikely to work, given the manifold difficulties in the water, wastewater and energy sectors and the high number of actors and agencies at federal, state and local level. Putting more effort into getting each sector to run properly before adding intersectoral integration requirements is more useful because additional complexity could lead to undesired inertia.

**Disclaimer**

This paper reflects the authors’ opinions. It does not represent the opinion of the German Federal Ministry for Economic Cooperation and Development.

**References**


Received 8 August 2017; accepted in revised form 29 July 2018. Available online 27 September 2018