Wastewater Reclamation in India: From Policy to Execution

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Abstract
In this study, we analysed wastewater reclamation policy in India and provided recommendations to reduce limitations in implementing effective wastewater reclamation. We overviewed the strategy in policy and implementation for wastewater management for three major water management issues in India: Scarcity of water resources, source water protection and wastewater treatment capacity exhaustion. We recommended possible solutions to problems such as inconsistency in funding and land disputes which can impede wastewater collection and treatment in developing regions such as India. As a more achievable approach, smaller decentralized plants can be suitable for rapidly developing, densely populated regions due to energy-efficient reclaimed water pumping, modular expansion and lower capital investment. We also provided a framework for policy amendments for augmenting wastewater reuse in India, which relied on a robust pricing structure for wastewater treatment, transparency in water quality reporting, incentivizing treated wastewater reuse for non-potable and irrigational uses; and drawing investment from private entities such as new building developments to decentralized wastewater facilities.

Keywords
Reclamation; Wastewater; Decentralization; Water Policy; Public Health; India

INTRODUCTION

The concept of wastewater collection, treatment and reuse at or near its point of generation is called decentralized wastewater treatment (Tchobanoglous and Crites, 1998). Though developed urbanized areas generally rely on centralized treatment due to a higher economy of scale; there is an increasing need to establish “satellite” treatment plants as urban areas diverge from their core.

The lack of access to wastewater collection and treatment renders many developing regions susceptible to disease outbreaks. In South and South-East Asian nations, less than 1% of the wastewater is treated by existing treatment facilities (Kamal et al., 2008). Decentralized systems can also be an excellent alternative to land-intensive and low performance technologies such as septic tanks. Decentralization can serve as an alternative to capital-intensive expanded trunk sewers to accommodate increased flow. Providing wastewater collection and treatment access to remote communities can be easier with smaller, low capital decentralized sewers and treatment plants.

Many Indian urban areas are developing rapidly, straining existing resources especially due to increased water demand. Also, land is especially scarce in these densely populated urban areas. About 31 % of the Indian population lives in urban areas which form only 2 % of the total political area. The population density of Indian megacities ranges from 3300 to 7200 persons per sq. km (2050-4500 per sq. mile) (Census of India, 2011). As of 2010, the wastewater treatment capacity was 19%, which operated at 72% capacity (Centre for Science and Environment, 2010). Low-end industrial reuse can be competitive with fresh water supply. Regional water authorities began scoping the possibility of revenue from the use of by-products from wastewater for agriculture and other uses (IWMI 2013).

Wastewater reclamation is potentially the most effective way of meeting rising water demands for rapidly growing densely populated urban areas. Effective wastewater reclamation can be achieved through systematic regulation and strategic investment. We overviewed issues with declining groundwater level, source water protection and wastewater facilities capacity exhaustion with two example cities in India and their approaches towards wastewater management and the resulting issues. We analysed these examples for scope of improvement in policy, enforcement and wastewater management strategies. We reviewed the existing regulatory policy for wastewater reclamation. We provided recommendations to concretize the regulatory policy for wastewater management and reclamation in India. We aimed to provide low cost and achievable approaches to improve access to wastewater treatment in developing countries.

WATER MANAGEMENT ISSUES AND CASE STUDIES

In a previous study, we had quantitatively demonstrated the public health improvement achieved by solely wastewater treatment, which emphasized the need for decentralized treatment (Naik and Stenstrom, 2012). We had also prescribed a standard preliminary feasibility assessment for the most general scenarios to compare decentralized and central configurations, with the example of Hollywood, Los Angeles and established the economic advantages of decentralized treatment for reclamation (Naik and Stenstrom, 2016).

We analysed the current guidelines for wastewater reclamation provided by the Government of India and the subsequent scope for localizing water resources through wastewater reclamation. We focused on the cities of Nagpur, Noida and Gurgaon in India to provide a glimpse of the current state of affairs and potential solutions. We studied their strategy in capacity design, location of plants and community and government participation. We recommended measures to resolve relevant issues in these cities and improve wastewater management in India.

Source Water Pollution (Nagpur, India - Nag River)

Nagpur is a metropolitan area in the state of Maharashtra in western India. It has urbanized rapidly in the past decade. It has three major source waters: Gorewada Tank, Kanhan River and Pench Canal (Nagpur Municipal Corporation, 2013). The Nag River is an indirect tributary of the Kanhan River. Nagpur directly disposes domestic wastewater into the Nag River. This is a public health threat since it affects the water quality of one of the major water sources.

A university campus disposes its domestic waste into the Nag River (Khadse et al, 2008). Fig. 2 is a map of Nagpur showing Nag River and the University. The Nagpur Municipal Corporation (NMC) plans to install 5 wastewater treatment plants of 1000 m^3/day each (1.3 MGD) to clean up Nag River. About 5000 ft^2 of land with a 5000 ft^2

buffer zone is required for each plant. The NMC suggested utilizing some university land for these plants but the university refused to yield bringing the project to a standstill (Times of India[a], 2013). The reason behind the refusal to cede the required area of land is unclear. Also, despite having the option of privatizing wastewater treatment, the financing depends on the Government. The funding from the Government has been observed to be inconsistent for other treatment plants for the same river system.

Figure 1 Map of Nagpur showing Nag River and the University.

Infrastructure Capacity Exhaustion - Gurgaon, and Noida, India - Yamuna River

Gurgaon is a city 30 km (18.75 miles) south of New Delhi, the capital of India. The existing wastewater treatment plants have a total capacity of 148,000 m3/day (39 MGD), whereas the current demand is 225,000 m3/day (59.5 MGD). The untreated wastewater bypasses the plants to the Yamuna River.

Figure 2 Map of Northern India showing Gurgaon, Noida, Yamuna and Hindon Rivers.

Noida is a relatively newer city 20 km southeast of New Delhi. Fig. 3 is a map showing both cities and Yamuna and Hindon Rivers. Noida has been rapidly industrialized. This city generates about 150,000 m3/day (40 MGD) of wastewater but has a total treatment capacity of only 70,000 m3/day (18.5 MGD). The remaining 80,000 m3/day (21.5 MGD) flows directly into the Hindon River, a tributary of the Yamuna River (Times of India[c], 2004). As of 2015, no additional treatment plants were constructed to treat wastewater flowing into the Hindon River from Noida (Times of India[a], 2013). The Haryana State Pollution Control Board allocated funds to its budget to install wastewater treatment plants in Gurgaon to prevent wastewater flowing into the Yamuna River (Times of India[a], 2013).

Water Scarcity - Rural Maharashtra

In January 2015, the State Government of Maharashtra declared a “drought-like condition” in 60% of the rural areas (Times of India, 2015) affecting the agricultural communities adversely. This compelled a part of the rural populace in severely affected regions to migrate to cities such as Mumbai in summer months for drinking water supply (DNA[a], 2016), further straining the urban water supply. In interior Maharashtra, where agriculture is the primary means of income, only 3% of the stock remained in all of the 814 dams used for irrigation (DNA[b], 2016). With local water resources dwindling, the drought-stricken regions were compelled to move towards imported water. For example, a 50 wagon train imported 2.5 million litres (660,000 gallons) of water into the city of Latur (DNA[c], 2016). This led to a stipulation of conservation targets of at least 10% on industries in interior Maharashtra. The government is now considering mandating the use of recycled water for industrial purposes.

RESULTS AND DISCUSSION

The State Govt. installed a 35,000 m3/day (22 MGD) 8 years after the capacity exhausted (The Hindu, 2013). The city had to depend on the Government funds for the treatment plant. The State Government also upgraded two existing plants for better treatment and will complete the installation of a large treatment plant with the capacity of 50,000 m3/day (31.25 MGD) (Times of India[b], 2013). Though the State Govt. claims to have a buffer capacity of 18,000 m3/day (11.25 MGD), the deficit from previous reports is not equal to the capacity increase from the recent reports. Fig.4 shows the demand and existing and additionally installed capacity over the past few years.

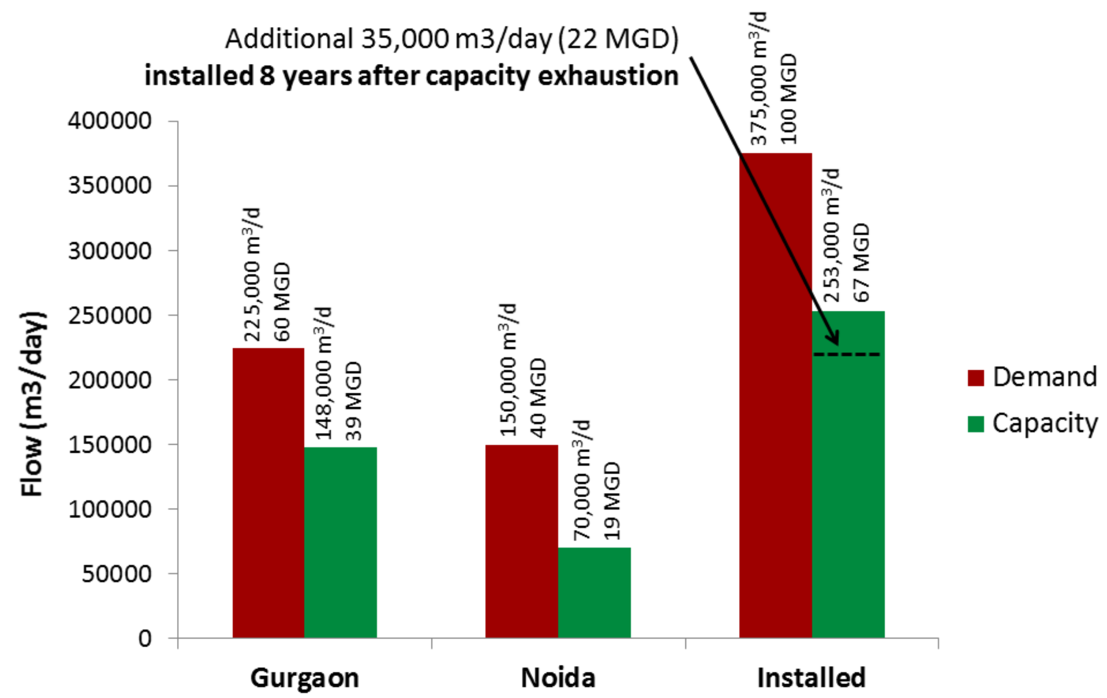

Figure 3 Wastewater treatment facilities capacity exhaustion in Gurgaon-Noida.

Protecting Source Water in Nagpur, Maharashtra, India - Nag River

The Nagpur case can use low footprint plants as the main obstacle in treating wastewater is space crisis. Processes such as the UASBR, trickling filter or RBC can reduce the plant footprint, resolving land scarcity (Naik and Stenstrom, 2011). The key is to install multiple small plants at economical and feasible locations. Acquiring several smaller areas of land is more feasible than a large piece of land. The University has about 4000 students and about 600-800 persons in staff. It requires a treatment plant capacity of about 1000m3/day (0.25 MGD). Using low physical footprint technologies can reduce the land cost for this plant, making it a more feasible option for the Government and University. The Government can provide subsidized water rates to or buy reclaimed water from the University, providing it a financial incentive along with environmental protection.

Nag River is a tributary of the source water for consumption. The compromised source water quality compels residents to use expensive household water filtration devices, an inadequate replacement of wastewater treatment (National Geographic article, 2012). These filtration devices might not effectively remove organic matter and pathogens and can require frequent replacements. A small fee for installing a reliable treatment plant instead of expensive water filtration devices can be an incentive to accumulate funds from sources other than the University for the treatment system.

Capacity planning and expansion for Gurgaon and Noida, India - Yamuna River

Though the State Government installed new treatment plants in Noida a decade after capacity exhaustion, we predict that the excess capacity will be exhausted in 3-4 years. A very conservative buffer capacity for future demand, the associated capital and dependence on inconsistent government funding are a problem for such cities. With decentralization, modularizing capacity expansion can reduce the required initial capital. With smaller plants, economy of scale becomes less significant, enabling selection of more modular treatment processes. Housing communities and commercial complexes can install ‘Design-Build-Operate’ treatment units with the occupants contributing to the capital through maintenance fees.

The cities need to procure more reliable financial resources than Government grants. It can decentralize wastewater management and entrust it to individual residential communities, commercial complexes, universities and industrial sectors. The occupants can accumulate the capital through maintenance fees. Another option is to privatize the wastewater treatment system designing and building and selling it to the local Government to recover its cost. Similar to the Nag River, the contamination of the Yamuna River can pose a threat to public health. Replacement of expensive household filtration devices by dependable treatment can encourage public participation and generate capital.

Regulatory policy for wastewater reuse

Currently agriculture is a major demand area for reuse of wastewater. Indirect wastewater reuse (post-treatment) has a higher irrigation yield (36 hectares per million litres per day) than direct wastewater reuse (6 hectares per million litres per day). The total area of irrigable land in India is 1.1 million hectares (IWMI, 2013). Due to high treatment costs, mostly untreated or partially treated water for agriculture as it is perennial and nutrient-rich. The wastewater irrigation market was 900 million USD in 2004 with an anticipated increase at 14% each year. The IWMI recommended exploration of recycling and alternative options as conventional options were expensive (IWMI, 2008). The current regulatory policy for reuse of wastewater is incorporated in the water quality regulations for various uses of water as shown in Table 1.

Table 1 Regulations for water quality for different uses by the Central Pollution Control Board, Ministry of the Environment and Forests (Central Pollution Control Board, 2016)

Designated best use	Class	Criteria
Potable water source without conventional drinking water treatment; but with disinfection	A	Total Coliforms Organism MPN/100ml shall be 50 or less pH between 6.5 and 8.5 Dissolved Oxygen 6mg/l or more Biochemical Oxygen Demand 5 days 20°C 2mg/l or less
Outdoor bathing	B	Total Coliforms Organism MPN/100ml shall be 500 or less pH between 6.5 and 8.5 Dissolved Oxygen 5mg/l or more Biochemical Oxygen Demand 5 days 20°C 3mg/l or less
Potable water source with conventional drinking water treatment and disinfection	C	Total Coliforms Organism MPN/100ml shall be 5000 or less pH between 6 to 9 Dissolved Oxygen 4mg/l or more Biochemical Oxygen Demand 5 days 20°C 3mg/l or less
Propagation of wildlife and fisheries	D	pH between 6.5 to 8.5 Dissolved Oxygen 4mg/l or more Free Ammonia (as N) 1.2 mg/l or less
Irrigation, Industrial cooling, Controlled disposal	E	pH betwwn 6.0 to 8.5 Electrical Conductivity at 25°C micro

		mhos/cm Max.2250 Sodium absorption Ratio Max. 26 Boron Max. 2mg/l
	Below E	Not meeting water quality criteria of A, B, C, D, E categories

The Government of India does not have enforceable regulatory policy on reusing wastewater for various uses. Due to the water scarcity and quality issues described in the previous section, the Government encourages reclamation of wastewater. It recommends guidelines to improve water reclamation via various aspects of water resource management. The guidelines for improving water use efficiency relevant to reclamation are as follows (Ministry of Water Resources, 2014):

1. Improving water use by 20% by measures such as incentivizing water reuse
2. Prioritizing water basin-wide integrated water resources management
3. Developing a database for estimating various usages, especially agriculture
4. Improving reuse of irrigation water
5. Leak detection and repair and eliminating unmetered accounts and unauthorized connections to collect accurate revenue for better investment in reclamation infrastructure
6. Currently, only cess for wastewater collection is charged and no revenue is collected to cover the wastewater treatment costs. Improving the price tariff structure for operation and maintenance, capital cost and depreciation
7. Providing fiscal concessions for commercial and local establishments that practice waste water reuse, recycling and resource recovery. Requiring dual plumbing systems for new building developments.
8. The Town and Country Planning Organisation of the Ministry of Urban Development recommends Model Bye laws for new development that incorporate water reclamation:
    a. Separating kitchen wastewater, greywater and sewage to reuse greywater and kitchen wastewater for gardening and washing purposes.
    b. Devising rain water harvesting provisions to augment groundwater recharge (Ministry of Urban Development, 2004)

The Government also suggests guidelines to remedy the issue of declining groundwater tables (Ministry of Water Resources, 2013).

1. The State Government should prepare a scheme with other agencies to plan for amount of groundwater recharge based on the inputs within a watershed.
2. The guidelines also provide the required chemical, biological and physical properties for recharge. For recharge by spreading, the water quality can be of secondary treated effluent, whereas for direct recharge, the secondary effluent is required to be subjected to chemical clarification, air tripping, granular activated carbon, reverse osmosis and disinfection.
3. They recommend a cost-benefit analysis for various scenarios:
    a. Saline water ingress/subsidence or augmentation of supply for projects of strategic importance - Benefit to cost ratio: 0.9-1
    b. Subsistence irrigation for drought-prone and semi-arid areas – Benefit to cost ratio: 1
    c. Augmentation for industrial and agricultural water use in humid areas – Benefit to cost ratios: 1.5-1.

Policy and Protocol Recommendations

1. Since the authorities only charged the consumers for wastewater collection and not treatment, the Government should revise the price structure to collect more revenue. An increase in rate structure will be acceptable only if the connected customers can avail the service effectively (IWMI, 2008). Decentralized collection and treatment will allow the Government to invest in smaller instalments and eventually obtain revenue for treatment services.
2. Develop database for groundwater use, and deficit. Global database available (IWMI, 2016).
3. Public awareness and transparency in sharing of treated effluent quality information to “explain” expenditure is essential. Reports on water quality and infrastructure monitoring should be made accessible to public.
4. Metering and infrastructure rehabilitation must be expanded based on its cost-effectiveness with respect to revenue losses in drinking water (Naik and Glickfeld, 2016). With recycling water being closely related to alternative drinking water sources, it is practical to adopt integrated water management practices on a watershed or regional basis.
5. The Government provides guidelines for source water quality direct and indirect recharge. But their lack of enforceability is a challenge to facilitating water reclamation. The Government should take steps on concretizing the framework for regulation for reusing treated wastewater.
6. The cost-to-benefit ratio analysis for groundwater recharge is important. Water balance analysis for the watershed should accompany this.
7. Incentivizing reuse of wastewater for certain uses such as landscaping, commercial and other outdoor uses.
8. As the irrigation yield is higher with treated wastewater, the government should emphasize on treating wastewater. Additionally source water needs to be protected for improved water resource management. Decentralized treatment systems can help achieve this (Naik and Stenstrom, 2016). A “polluter pays” concept is in place for industrial wastewater treatment in India, new developments must invest a certain part of building profits towards wastewater management.

CONCLUSIONS

Wastewater reclamation policy is in the nascent stages in India, with more emphasis on disposal standards. To rely on local water and augment groundwater supplies, decentralizing wastewater treatment can be a more achievable solution for developing countries, while being customizable to diverse scenarios. Decentralized plants are generally of small capacity reducing the required capital investment, which can be provided by the residents or occupants of the area. This can eliminate the dependence on funding from the Government which has been observed to be inconsistent in developing regions. In developing regions, this can ensure public health and source water protection thus fulfilling water demands by improving the management of water resources.

Concretizing the regulatory framework for reuse of wastewater is crucial to improving alternative local water resources. Wastewater treatment must be prioritized as treated wastewater has a 6 times higher yield in irrigation than raw wastewater which is currently more commonly used. A more cost-effective price structure for wastewater treatment with transparency in water quality reporting can aid in improving treatment. Scientific approaches such as water balance and cost-benefit analyses and reliance on groundwater databases can lead to effective integrated water resource management. Incentivizing reclaimed water for non-potable uses and following the “polluter pays” concept for new building developments can lead to more investment in wastewater facilities by private entities.

Community participation is the key to implementing decentralization; hence it is necessary to spread awareness about the benefits of proper wastewater management. It is important to tailor the wastewater management process train and network configuration to meet local requirements and choose an economical configuration. Efficient wastewater management requires a nexus of public participation, water demand assessment and resource allocation stemming from geographical or local constraints.

REFERENCES

Census of India 2011 Ministry of Home Affairs, Government of India http://censusindia.gov.in/2011-prov-results/indiaatglance.html (Accessed 01/21/2013).

Centre for Science and Environment 2010 Do-it-Yourself Recycle and Reuse Wastewater, New Delhi.

Crites, R., Tchobanoglous, G. 1998 Small and Decentralized Wastewater Management Systems, WCB McGraw Hill, 11-18.

Naik, K. S. and Stenstrom, M. K. 2012 Evidence of the influence of wastewater treatment on improved public health. *Water Science and Technology* **66**(3), 644-652.

Central Pollution Control Board, 2007 Annual Report 2006-2007, Ministry of Environment, Forests and Climate Change, Government of India.

Mekala, G. D., Davidson, B., Samad, M., Boland, A. M. 2008 Wastewater reuse and recycling systems: A perspective into India and Australia. International Water Management Institute. (IWMI Working Paper 128).

Town and Country Planning Organisation 2004 Model Building Bye-Laws, Ministry of Urban Development, Government of India.

Central Pollution Control Board, Water Quality Criteria, Ministry of the Environment and Forests, Government of India, http://cpcb.nic.in/Water_Quality_Criteria.php (Accessed, June 20, 2016).

Amerasinghe, P., Bhardwaj, R.M., Scott, C., Jella, K., Marshall, F. 2013 Urban wastewater and agricultural reuse challenges in India. International Water Management Institute. (IWMI Research Report 147).

Naik, K. S. and Stenstrom, M. K. 2016 A Feasibility Analysis Methodology for Decentralized Wastewater Systems – Energy-Efficiency and Cost. *Water Environment Research* **88**(3), 201-209.

Nagpur Municipal Corporation, http://www.nagpurwater.com/PageExsiSysDetails.aspx (Accessed 01/22/2013).

Khadse, G. K., Patni, P. M., Kelkar, P. S. and Devotta, S. 2008 Qualitative evaluation of Kanhan river and its tributaries flowing over central Indian plateau. *Environmental Monitoring and Assessment* **147**(1-3), 83–92.

The Hindu, April 2, 2013 http://www.thehindu.com/news/national/other-states/akhilesh-opens-purse-strings-for-noida-greater-noida/article4573145.ece (Accessed 01/21/2013).

Times of India[a], May 29, 2013 http://articles.timesofindia.indiatimes.com/2013-05-29/nagpur/39601248_1_nag-river-vnit-mld (Accessed 01/21/2013).

Times of India[b], May 31, 2013 http://articles.timesofindia.indiatimes.com/2013-05-31/noida/39655076_1_sequential-batch-reactor-sbr-functional-stps (Accessed 01/22/2013).

Times of India[c], Sept. 20, 2004 http://articles.timesofindia.indiatimes.com/2004-09-20/delhi/27152661_1_sewage-treatment-mld-untreated-sewage (Accessed 01/23/2013).

Times of India, Feb. 3, 2015 http://timesofindia.indiatimes.com/city/mumbai/Drought-hits-90-lakhs-farmers-in-Maharashtra/articleshow/46100600.cms (Accessed May 15, 2016).

DNA News[a], April 24, 2016 http://www.dnaindia.com/mumbai/report-displaced-by-drought-migrants-flock-to-city-s-outskirts-2205413 (Accessed May 15, 2016).

DNA News[b], April 22, 2016 http://www.dnaindia.com/india/report-maharashtra-7-out-of-11-major-irrigation-dams-have-no-water-left-2204921 (Accessed May 15, 2016).

DNA News[c], April 21, 2016 http://www.dnaindia.com/india/report-maharashtra-mulls-law-to-make-it-must-for-units-to-use-recycled-water-2204648. (Accessed May 15, 2016).

Kamal, A. S. M., Goyer, K., Koottatep, T. and Amin, A. T. M. N. 2008 Domestic wastewater management in South and Southeast Asia: the potential benefits of a decentralised approach. *Urban Water Journal* **5**(4), 345 — 354.

Naik, K. S. and Stenstrom, M. K., (2011), Economic and Feasibility Analysis of Process Selection and Resource Allocation in Decentralized Wastewater Treatment for Diverse Geographic Regions. *84th Annual WEF Technical Exhibition and Conference Proceedings*, Los Angeles, CA.

The Hindu April 2, 2013, http://www.thehindu.com/news/national/other-states/akhilesh-opens-purse-strings-for-noida-greater-noida/article4573145.ece (Accessed 01/21/2013).

Morrison, D. 2012 India: The Cost of Bad Water, National Geographic News Watch http://newswatch.nationalgeographic.com/2012/01/05/india-the-cost-of-bad-water/ (Accessed 01/22/2013).

Central Water Commission, 2014 Guidelines for Improving Water Use Efficiency in Irrigation, Domestic and Industrial sectors. Ministry of Water Resources, India.

Common Guidelines for Preparation of Scheme on Management of Declining Groundwater Table for Sustaining Food Production in States of Punjab, Haryana and Western Uttar Pradesh. 2013 Ministry of Water Resources, India.

Naik, K. S. and Glickfeld, M., Integrating Water Distribution System Efficiency into the Water Conservation Strategy for California: A Los Angeles Perspective. *Manuscript in preparation*.

Water Data Portal, 2014 International Water Management Institute, http://www.iwmi.cgiar.org/2014/06/global-wastewater-database/ (Accessed June 20, 2014).