



Wastewater Discharge Standards in the Evolving Context of Urban Sustainability—The Case of India

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OPEN ACCESS

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Specialty section:

This article was submitted to
Water and Wastewater Management,
a section of the journal
Frontiers in Environmental Science

Received: 08 July 2019

Accepted: 28 February 2020

Published: 17 April 2020

Citation:

Schellenberg T, Subramanian V,
Ganeshan G, Tompkins D and
Pradeep R (2020) Wastewater
Discharge Standards in the Evolving
Context of Urban Sustainability—The
Case of India.
Front. Environ. Sci. 8:30.
doi: 10.3389/fenvs.2020.00030

Across the world, recent decades have witnessed large scale and rapid urbanization. Centralized wastewater treatment is typically considered the most desirable solution to meet domestic wastewater treatment needs in growing urban centers. These rely on extensive—and often expensive—infrastructure and treatment solutions that require expert engineering management to ensure effective operation. It is argued that the urban sustainability challenge of inadequate sanitation, deteriorating water quality, and rising water stress are best met through poly-centric and integrated approaches that include nature-based solutions, community-scale and community-managed systems. Today's objectives are to create climate-resilient, enduring, self-governing systems—as well as systems that close the loop, encouraging resource re-use and recycling. This policy review informs on wastewater discharge (and related) standards for sewage treatment plants within the context of present-day India. With its booming urban population, highly visible and impactful pollution, water quality and insecurity challenges, India provides huge opportunities for creative approaches to urban sanitation—but to fully exploit these opportunities will require new policy and regulatory thinking. The current regulatory developments are undergoing frequent changes with observed inconsistencies over the last years leading to a growing confusion in the sector. Examined questions include: How clear are policy objectives and regulations? What are reasons for observed inconsistencies in current pollution control regulations and what are their implications? How well-aligned are standards and regulation with these objectives? How forward-looking? Are solutions sufficiently responsive to the urban sustainability challenge? In particular, this review considers whether regulatory approaches disadvantage decentralized and innovative approaches that could offer resilient, community-based systems—even within the megacities of the twenty-first century. This study further draws on examples from other emerging economies—and contextualizes these examples with the situation in Western Europe, where a single set of targets has led to diverse solutions. Standards and regulations need to be reimagined for this evolving urban context which might require it to become more

nuanced, more holistic, more dynamic, more transparent, more participative, and more contextual. Enforcement mechanisms will need to incorporate phased/graded approaches to compliance—to suit various contexts that could include water reuse for different application areas.

Keywords: wastewater standards, reuse, sustainable sanitation, regulation, policy, decentralized integrated management, nature-based, India

INTRODUCTION

Globally water management systems are facing enormous challenges of accelerating water insecurity, flooding, and contamination of water resources. According to the UN 80% of sewage is currently discharged without treatment [UN WWAP (United Nations World Water Assessment Programme), 2017].

The lack of adequate sanitation infrastructure contaminates the environment and permeates through all societal functions increasing the burden on human health, which in turn leads to loss of economic activity and thus the overall development potential. The UN indicates that for every USD spent on sanitation, the estimated returning benefit to society accounts in 5.5 USD [UN WWAP (United Nations World Water Assessment Programme), 2017].

Feasible and financially viable wastewater treatment still represents a significant challenge in the Global South, particularly within a rapidly changing urban environment. It is increasingly recognized that the ideal of the “networked city” fails to address current SDG goals of the wastewater sector and is inadequate for the difficulties and reality of the Global South (MoUD, 2008; Massoud et al., 2009; Libralato et al., 2011; Larsen and Gujer, 2013). Innovative approaches and technologies are required, which enable the overall concept of sustainability in terms of economic feasibility, social equity and acceptance, technical and institutional applicability, environmental protection, and resource recovery—in addition to the central objective of protecting human health and environment (Balkema et al., 2002; MoUD, 2008; Molinos-Senante et al., 2010, 2015; Ganoulis, 2012; Wichelns et al., 2015; Ricart et al., 2019).

With the shifting paradigm from “waste”water treatment to resource recovery systems, the sanitation sector, among a few others, holds the most prospering potential in change toward a sustainability transition (Binz et al., 2012; UN WWAP (United Nations World Water Assessment Programme), 2017; Van Welie and Romijn, 2018; Van Welie et al., 2018). However, the transition faces considerable hurdles and requires changes along all levels, including regimes, landscapes and niches (Markard et al., 2012; Swilling and Annecke, 2012; Lachmann, 2013). While industrialized nations are dealing with the challenge of lock-in mechanisms due to historic investments in established centralized infrastructure and routines formed a passive involvement of society and consumer roles, the main challenge in the Global South remains the establishment of overall access to sanitary systems. This situation provides significant opportunities for emerging economies to leapfrog and establish new alternatives and more

sustainable approaches to sanitation that address all dimensions of sustainability.

Decentralized and ecological systems can play a crucial role in delivering this new reality, since they represent comparatively more economically affordable and ecologically sustainable options, which are socially accepted and require low maintenance (Parkinson and Tayler, 2003; Massoud et al., 2009; Libralato et al., 2011; Larsen and Gujer, 2013). However, full and appropriate exploitation of these systems requires regulatory institutions to overcome historical barriers and create an enabling environment to open windows of opportunity.

In India wastewater treatment, especially in booming urban centers, continues to be a big challenge. While the Central Pollution Control Board (CPCB) reported in 2013 that 19,827 MLD out of 53,998 MLD generated were treated in metropolitan, class one and class two cities, it further indicates in 2017 that out of 18.6% of total treatment capacity, only 13.5% of sewage is effectively treated (CPCB, 2013 and CPCB, 2017c). Although the impact of diarrhea has decreased over last years, it still belongs to the five major health burden in India. The disease burden or Disability Adjusted Life Year (DALY) rate for diarrheal diseases, iron-deficiency anemia and tuberculosis was 2.5 to 3.5 times higher compared to global rates and countries with similar geographies (Indian Council for Medical Research, 2017). Alongside the given challenges, more than half the country faces high to extremely high water-stress, and future projections paint an even grimmer water availability scenario (MoWR, 2017; WBSCD, 2019). An integrated view of the wastewater and water supply sectors is not optional but an urgent imperative.

Recognizing these urgent pressures, several jurisdictions within India have established reuse policies and Zero Liquid Discharge regulations. However, implementing these initiatives is currently challenging due to national standards for treated wastewater—which undergo frequent change and have ceased to distinguish between wastewater re-use for irrigation and wastewater discharge to surface or ground waters. Furthermore, inconsistencies in approach and objectives between different governmental institutions, variations in policy at a state level and aggravated access to information are resulting in confusion and hesitation within the sector. The intention behind stringent standards in protecting the environment and public health represents a common shared aim between all stakeholders. However, without a long-range planning and reasonable budget allocation, stringent standards can result in pockets of excellence, leaving the majority of the Indian population and environment at high risk. In addition, one fixed set of standards for different

application areas can tend to neglect, both the dangers and also the benefits of this resource.

In this paper, the outputs of a broader evidence review based on Indian policies and regulations and complementary interviews with governmental institutions, sectoral experts, and technology providers in India are combined to analyze and understand pollution control measures and approaches that focus on municipal domestic sewage treatment and wastewater reuse. While the first section of the assessment summarizes wastewater risk management approaches, section two reports the findings on the current scenario of wastewater discharge standards for sewage treatment plants in India and discusses the feasibility and possible implications. Although focused on the current situation in India, a comparative analysis in section three presents examples of institutional approaches and structures on discharge and wastewater reuse in other countries. Based on the review, the possible way forward for India and lessons for other nations of the Global South are suggested.

ASSESSMENT OF WASTEWATER RISK MANAGEMENT

Within the following the results of the assessment of wastewater risk management in India is presented and discussed. This assessment is built upon three sections to analyze and inform on (a) wastewater risk management approaches with special focus on wastewater reuse, (b) wastewater risk management and related wastewater discharge standards for sewage treatment plants (STPs) in India over time, and (c) wastewater discharge and reuse standards from other countries.

Methodology

Wastewater risk management approaches, central governmental policies and acts in the scope of wastewater risk management, sanitation, and water management in India have been identified through literature review based on government databases and website research. The Karnataka State policy on urban wastewater reuse was identified through website research and considered as reference for a comparative to central regulations.

Central governmental regulations for pollution control measures in the wastewater sector in India were identified through literature review based on governmental databases and website research. All historically applicable wastewater discharge standards for STPs in India were considered for the assessment.

International regulations on wastewater discharge and reuse standards were informed by representatives of the multinational (EU-funded) INNOQUA-Project with a further extended literature review based on website research. The range of selected countries for assessment was based on the development status, climatic conditions and water insecurity status in order to allow a broad overview and comparative relative to local conditions or limiting factors.

Qualitative interviews with former and present governmental officials at central and state level in India were carried out in order to access printed materials and missing information on (a) the standards setting process, (b) the applicability of

wastewater discharge and reuse standards and related norms due to observed inconsistencies during the assessment process, (c) the reasons for observed changes of standards over the years and related inconsistencies in applied and recommended measures among governmental institutions at central level and central-state level, and (d) investment and development plans in the wastewater sector.

Literature review based on website research and complementary qualitative interviews with governmental officials, sectoral experts, and technology providers have been carried out in order to allow a broader perspective for the discussion on the feasibility of discharge and reuse standards and possible implications of recent observed developments in pollution control management in India.

Wastewater Risk Management Approaches

In the modern era, Britain was among the first nations to address environmental conditions of water bodies in its cities and plays a vital role due to historical regulations in India. The need for coordinated action in Britain was formed as response to growing industrialization, which led to untreated effluents being discharged into water bodies and breaching their intrinsic carrying capacity. This created human health and environmental crises that are still a common occurrence in rapidly-urbanizing centers of the Global South (Lens et al., 2001). Whilst the initial response to these crises was to assume that “the solution to pollution is dilution,” it was soon recognized that sewage treatment would be required. The Royal Commission on Sewage Disposal (which convened between 1898 and 1915) led to the formulation of the first standards for Biochemical Oxygen Demand (BOD) and suspended solids (TSS) in treated wastewater—at 20 and 30 mg/l, respectively. These standards remained in place for several decades, eventually being superseded by the Water Act of 1973 and the Urban Waste Water Treatment Directive at a European level (Johnstone and Horan, 1996). Britain has never set regulatory standards for water re-use, unlike a number of other nations of the Global North. However, regional demographic pressures coupled with changing patterns of precipitation mean that this is set to change. This section summarizes the conceptual underpinnings of wastewater risk management.

Wastewater Discharge Standards

Wastewater discharge standards are set (at least) at a national level for centralized treatment systems for salient receiving environments. The key feature of a water body from a discharge perspective is its assimilative capacity i.e., maximum amount of pollution that can be diluted or degraded without affecting preliminary defined designated best uses. Effluent discharge standards can be concentration-based or load-based. Concentration-based standards are the most common and specify a permissible mass of pollutant per liter. A limitation of concentration-based standards can be that it does not promote wastewater treatment, since dilution can be used to meet the discharge standard. The original standards developed in Britain were concentration-based—although those standards assumed a minimum 8-fold dilution in the receiving water body. Most

countries in the Global South have adopted discharge standards from the Global North and they have not been developed for their local context.

Load-based standards, as applied in the US, harmonize concepts of ambient water quality and effluent discharge through risk modeling of the water body. The Total Maximum Daily Load (TMDL) allocates the threshold value for a pollutant that will ensure compliance with a desired water quality standard based on stakeholder preference for the use of that water body. Criteria for the prevention of (eco)toxicity are based on both short term and long-term effects. States calculate TMDL for their water bodies based on monitoring evidence and water quality modeling. TMDL is used to issue permits to discharge in the catchment, and risk modeling encompasses variations in flow—from the lowest daily flow occurring once every 10 years (for acute effects) and once every 10 years averaged over a 7-consecutive-day period (for chronic effects) (National Research Council, 2001; US EPA, 2020).

Different countries base their standards on various characteristics of treated wastewater—although BOD is almost universally used. A snapshot of regulated parameters across countries is illustrated in **Figure 1**, which also shows that discharge limits are most commonly set on the basis of organic pollutants and nutrients.

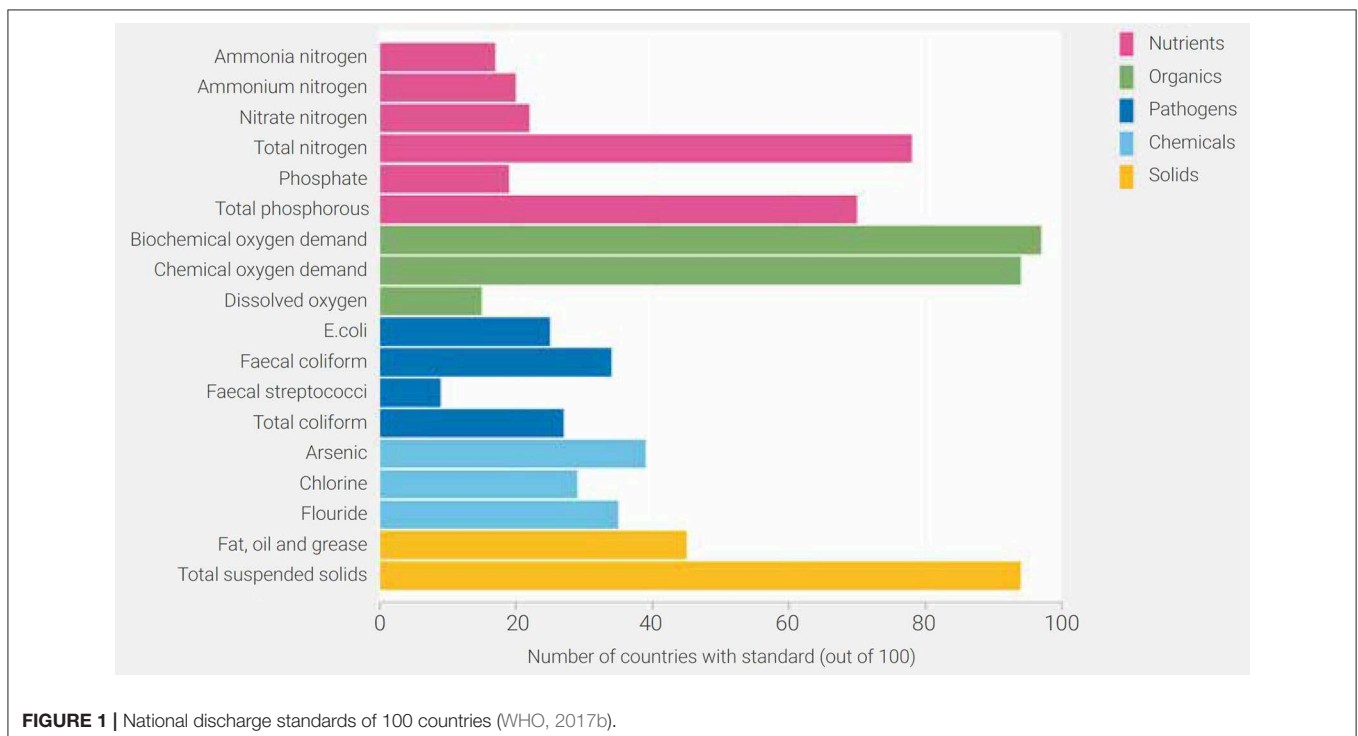
Once the desired discharge standard is fixed, the choice of technology is determined by the desired quality of treated wastewater, and two principle approaches to technology selection have been delineated in the literature: Best Available Technology (BAT) and Best Practicable Technology (BPT). Either approach works in tandem with a discharge standard. BAT is the dominant paradigm in the Global North where treatment technology costs

are more affordable. BPT is followed in the Global South where the contextual factors must be considered. The economic and behavioral aspects of risk are considered using the “As Low as Reasonably Achievable” (ALARA) principle, which delimits the risk management envelope (“BPT plus”) (CPCB, 2009).

Wastewater Reuse Approaches

Water is a finite resource with significant variations in spatial and temporal availability. This, and changing climate, are making a strong case for reuse of wastewater for specific applications. Wastewater contains valuable nutrients such as Nitrogen and Phosphorus, essential for plant growth, and further represents a resource for energy recovery. The increasing scarcity of phosphorus in conjunction with land degradation (which is a plant macronutrient and thus plays a major role in food security), paired with the fact that abstraction for agricultural use accounts for 70% of total water withdrawal, makes wastewater a lucrative resource for irrigation (Cordell et al., 2009; FAO - Aquastat, 2016).

However, depending on its source, wastewater carries a broad variety of impurities—which can be toxic, pathogenic, and inhibitory to public health and can harm the environment. In order to achieve maximum beneficial re-use, the extent of wastewater treatment depends on specific reuse applications and their associated characteristics/risks. There are two major categories for wastewater reuse: (a) potable uses and (b) non-potable uses such as: irrigation in agriculture; industrial reuse (e.g., water cooling); aquifer recharge and other urban reuses such as toilet flushing, subway washing, coach cleaning, ground cooling, or building construction. Two major approaches to address risks associated with wastewater re-use were developed



by the United States Environmental Protection Agency (US EPA) and the World Health Organization.

USEPA's single barrier approach to reuse risk management

USEPA follows the no risk approach for setting standards, and consequently adopts comparatively strict limits (US EPA, 2012) with recommendations on technology design to achieve these in the effluent or so-called "single barrier." WHO adherents critique the USEPA standards as impossible to achieve in developing countries, as technological solutions for the specified limits are highly cost intensive. Within the updated guidelines, the USEPA (2012) responded that these standards had evolved over a history of investment and capacity building and were not suitable for the Global South.

WHO's multiple barrier approach to reuse risk management

The WHO approach is characterized by: (a) the definition of a maximum tolerable additional burden of disease; and (b) a multi barrier perspective in impact and risk reduction along the whole chain (including treatment, crop restrictions, access to the public, vulnerable groups, irrigation techniques, and produce handling) (WHO, 2006 and WHO, 2016a). The WHO approach focuses on the need for alternative measures and targets locations where conventional and cost-intensive treatment technologies are economically not feasible. The Multi-Barrier Approach is illustrated in Figure 2.

Pathogen elimination along several different measures considered, can play in the range of 1–7 log reduction units, which are displayed according to barriers in the following Table 1.

Risk and Benefits of Wastewater Reuse

An integrated risk-benefit approach to wastewater risk management can address inadequate sanitation, waterbody

pollution, and water scarcity. The risks and benefits of wastewater are summarized in Figure 3 from following subsequently presented characteristics of specific parameters.

Organic matter

Total Organic Carbon (TOC), BOD, and Chemical Oxygen Demand (COD) represent indicators to identify the concentration of organic matter (OM) in water. The decomposition of OM can lead to a depletion of oxygen which is crucial for other aquatic organisms. In soil iron or manganese along with organic acids can disrupt the absorption of nutrients (Asano et al., 2007). As a nutritious ground for microbes, OM can cause difficulties in disinfection processes and further affects the color and odor of the water (US EPA, 2012). Excessive amounts of BOD can cause problems for irrigation infrastructure. Low to moderate concentration of OM, however, can be beneficial. The Central Public Health and Environmental Engineering Organization (CPHEEO) recommends in their report in 2013 that 11.0 to 28.0 kg/ha/day of organic loading (BOD₅) is required to maintain a static organic matter content in the soil to condition the soil with microorganisms and prevent clogging. However, higher rates are manageable depending upon the system type and resting period. The usage of primary effluent can result in loading rates exceeding 22.0 kg/ha and day but without causing problems.

Nutrients

Nutrients which are discharged to an aquatic environment can cause eutrophication, which in turn can lead to high accumulation of dead biomass and by this to depletion of oxygen in water bodies. While nutrients are beneficial for plant growth, they can cause water contamination if applied in excessive amounts and in areas with low groundwater table. Ammonia is harmful to freshwater aquatic life and can interfere with

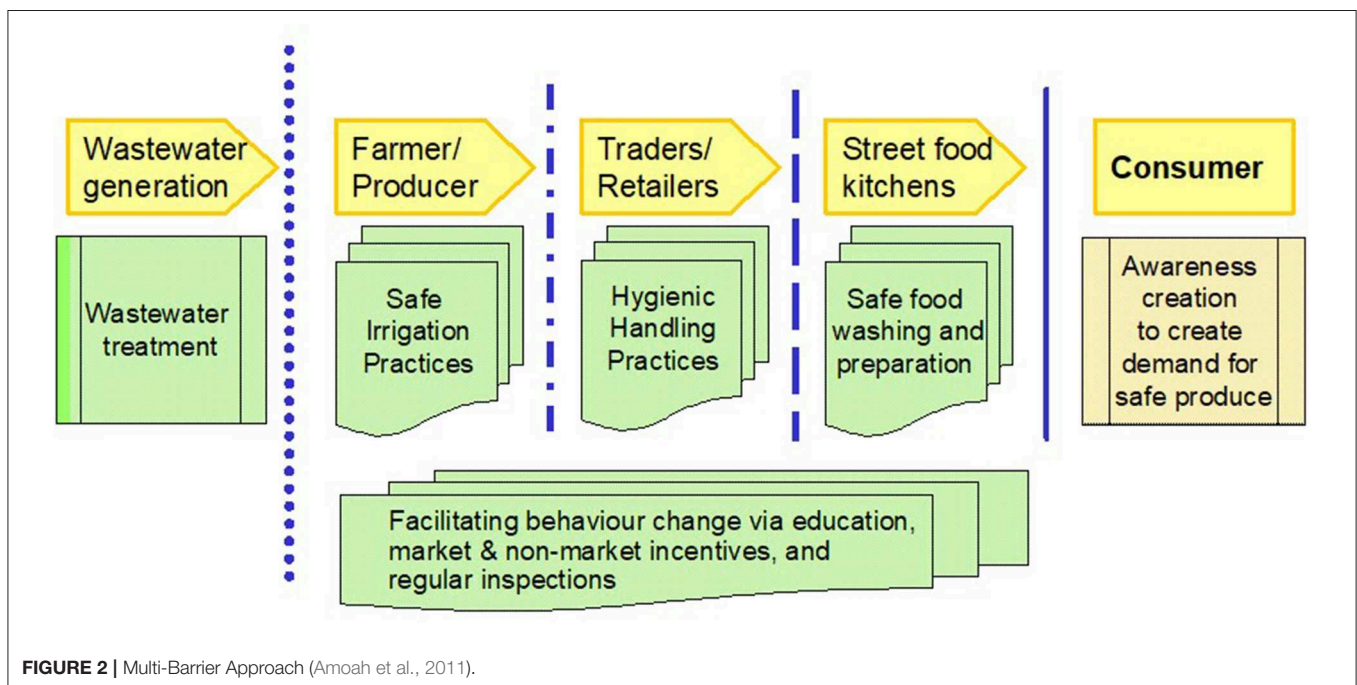
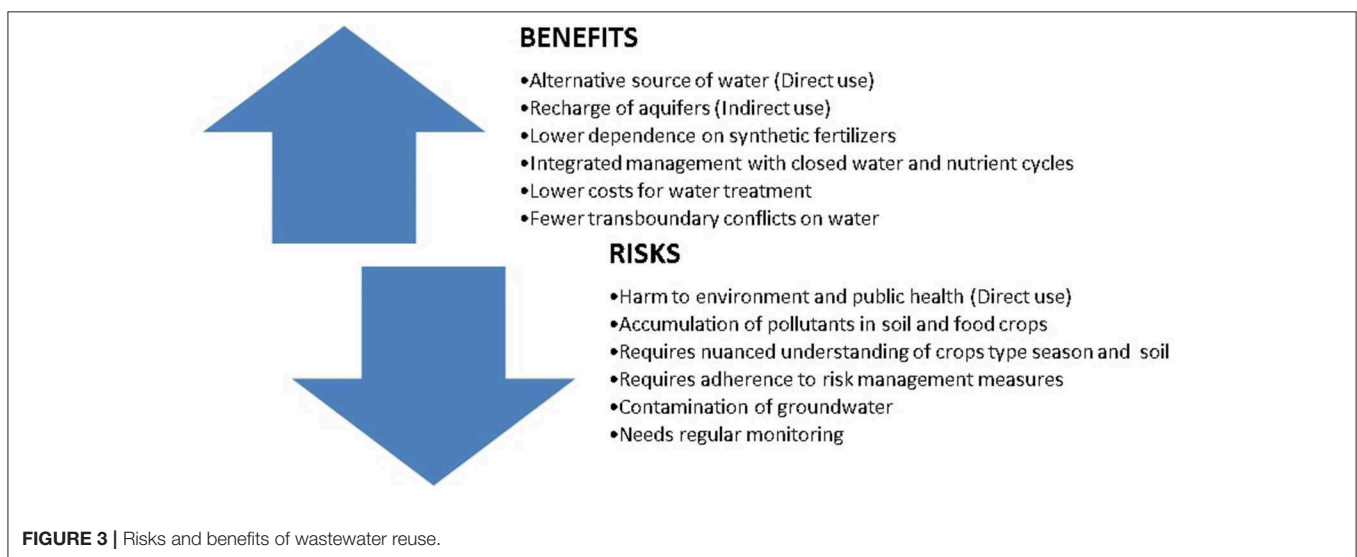


TABLE 1 | Pathogen reduction along Multi Barrier Approach, modified from Mara et al. (2010).

Control measures	Pathogen reduction (log units)	Dependence of reduction and options
A. Wastewater treatment	1–7	Type and degree of treatment technology
B. On-farm options		
Crop restriction (i.e., no food crops, raw eaten)	6–7	(a) Effectiveness of local enforcement of crop restrictions, and (b) comparative profit margins of the alternative crop(s).
On-farm treatment	0.5–3	Type and degree of treatment, options can be tree tank system, simple sedimentation, filtration
Method of wastewater application		
Irrigation method	1–4	Method and system, such as furrow - drip irrigation, reduction of splashing
Irrigation cessation before harvest	0.5–2/day	Climate, time, crop type etc.
C. Post-harvest options at local markets		
Storage and handling	0.5–3	Overnight storage in basket, washing crops, removing the outer layer
D. In-kitchen produce preparation options		
Produce disinfection	2–7	Disinfection, produce peeling, cooking



chlorination processes (US EPA, 2001). Wastewater contains 26–70 mg/l of nitrogen, 9–30 mg/l of phosphorus pentoxide, and 12–40 mg/l of potassium oxide (CPHEEO, 2013). The recommended Nitrogen-Phosphorus-Potassium dose ratio for crops is described as 5:3:2 (CPHEEO, 2013). High levels of total nitrogen concentrations can lead to a decrease in yield production due to lodging, reported especially for application on rice fields (Setter et al., 1997). With a resulting stimulation of algal and bacteria growth, it can further lead to clogging of irrigation infrastructure (Shatanawi and Fayyad, 1996). Application levels as for best practice in agriculture would depend on several factors, such as plant intake ratios, soil type, and groundwater level (WHO, 2006).

Solids

Total Suspended Solids (TSS) and turbidity are measures for particles in a medium, and in excess amounts can lead to clogging of infrastructure and soil, sludge deposition, and by this to anaerobic conditions. Providing a surface area for attachment

of microbes, high TSS can be associated with higher microbial contamination. High turbidity levels can further complicate the disinfection processes (US EPA, 2012).

pH

The range of pH affects the solubility and by this also the mobility of metals, which in turn can be absorbed by plants. High levels of alkalinity or acidity have an impact on plant growth and the structure of the soil (WHO, 2006). Wide deviations in the pH can further cause damage to infrastructure.

Trace elements and heavy metals

Heavy metals such as lead or cadmium are usually found in industrial wastewater, which can accumulate in soil and plants and pose high toxicity to livestock or humans (Gupta and Gupta, 1998). While trace elements in specific doses are highly relevant for plant growth, applied in excessive amounts, they can be harmful to crops and may impact the productivity or root growth (Asano et al., 2007).

Salinity/dissolved inorganics

Electric conductivity (EC) is used as a parameter to measure the salinity level of a medium. Wastewater contains high levels of salt content. For the application on land via irrigation, this parameter according to the Food and Agriculture Organization (FAO) is considered as one of the most relevant parameters. High salinity can substantially affect plant growth, cause ion toxicity and affect nutrient absorption by plants (Beltran, 1999).

Pathogens

Health hazards form one of the main constraints in wastewater reuse and thus, the microbial composition is one of the most important parameters. While pathogens caused vast waves of epidemics in the past, they still constitute a significant health burden in many different countries. Diarrhea as an exemplar, forms the second leading cause of death in children under 5 years and is estimated to cause 485,000 deaths annually (WHO, 2017a, 2019). With restrictions by costs and complexity in analysis, *Escherichia coli* and Fecal Coliforms nowadays still form the major reference indicator for fecal contamination levels in wastewater effluents. However, there are wide debates that the sole quantification of *E. coli* is not sufficient to determine the overall risks in wastewater as some pathogens show higher resistance in disinfection processes (Salgot et al., 2006; WHO, 2016b). The WHO suggests reference indicators covering bacteria, viruses, and protozoa for safe water reuse and drinking water (WHO, 2006, 2011). Further critiques address the difficulty in assessing pathogens in media apart of water and the precision of current risk modeling methods (Salgot et al., 2006; Alcalde-Sanz and Gawlik, 2017). With risk being a function of the microbial agent, the human host and the given environment or application areas, overall risks can differ in a wide range or may not apply according to given local conditions.

Current Situation of Wastewater Management in India

While wastewater management in India currently faces many challenges, the pollution of rivers and water bodies has come under scrutiny, and their rejuvenation has been subject to much attention. Municipal wastewater has been identified as the chief source of pollution of the Ganga and Yamuna rivers, and the revitalization of these rivers has seen substantial investment over the last several decades (IIT Consortium, 2015; Government of Haryana, 2018). The Central Pollution Control Board has been monitoring water quality in rivers over the last 30 years and uses BOD data to classify river stretches in five priority groups (e.g., stretches where BOD value greater than 30 mg/l is termed “priority 1,” while BOD values between 3.1 and 6 mg/l are “priority 5.”) (Koshy, 2018). The CPCB observed sharp deterioration in water quality with 71 polluted stretches in 2005 and 375 polluted stretches in 2018 (Koshy, 2018). In September 2018 the Honorable National Green Tribunal (NGT) directed states to constitute a four-member ‘River Rejuvenation Committee’ (RRC) in order to prepare and implement action plans for render polluted river stretches fit for bathing use (National Green Tribunal, 2018). While states have submitted action plans of varying detail, the Hindon River Action Plan,

which envisions multi-stakeholder governance management of the Hindon basin till 2030, has been highlighted by CPCB as an example of a comprehensive action plan (State of Uttar Pradesh, 2014; CPCB, 2018a,b; Water Resources Group (WRG), 2018).

With fast depleting fresh and ground water resources, government bodies have also shown interest in centralized reuse of water. In another recent order, the Honorable NGT directed states to submit action plans for utilization of treated wastewater by June 2019 (Press Trust of India (PTI), 2019). In addition to providing a quota for desired applications, reuse action plans are also supposed to include infrastructure augmentation and monitoring plans for reuse (Press Trust of India (PTI), 2019). States including Gujarat and Karnataka have already promulgated reuse policies for some years, but this recent NGT order aims to promote the focused implementation of reuse throughout the whole country.

It is stated that almost half of the wastewater generated in urban India is already being reused [CSE, Bharat Lal Seth, (nd)] and most of it is assumed to be reused indirectly and without treatment. Typical reuse applications in India include forestry, horticulture, toilet flushing, industrial use (e.g., non-human contact cooling towers), fish culture, and various indirect uses (CPHEEO, 2013).

Institutional Structure for Wastewater Management in India

In India pollution control activities are the joint responsibility of three different institutions: The Ministry of Environment Forest and Climate Change (MoEF&CC), the Ministry of Housing and Urban Affairs (MoHUA), and the recently formed Ministry of Jal Shakti. The MoEF&CC is the nodal agency and together with the Central Pollution Control Board these bodies are responsible for laying down policies, acts and related standards. **Table 2** below lists key institutions with related mandates, subunits, and functions.

With water as a precious resource and wastewater as a major pillar of societal infrastructure, wastewater management necessitates inclusion of various disciplines and perspectives. It is observed that other critical sectors such as public health and agriculture do not play an explicit role. While public health is represented indirectly through the MoHUA, the importance of public health and increasing reuse patterns is significant. The recent creation of the Ministry of Jal Shakti is indicative of India’s move toward integrated water and wastewater management.

Institutions implement their functions through regulatory statutes. In 1974 the *Water Prevention and Control of Pollution Act* was released as a first regulation for the prevention and control of water pollution and led to the establishment of responsible bodies at central and state level for implementation. While this act was primarily focused on water bodies, in 1986, the *Environment Protection Act* was released—targeting protection and improvement of the wider human environment. With growing urbanization, the National Urban Sanitation Policy was established in 2008 mandating the total coverage of sanitation in all Indian cities and towns. **Table 3** below states important regulations and their functions chronologically.

TABLE 2 | Institutional structure for setting wastewater discharge standards.

Institution	Mandate	Subunit	Subunit function
MoEF&CC	Formulation of policies and programs for the conservation of natural resources and pollution abatement and guidance for sustainable development and enhancement of human well-being (MoEFCC, 2017a)	CPCB	Provision of technical services to MoFE&CC regarding the Environment (Protection) Act, 1986. According to the Water Act, 1974, their function is to promote cleanliness of streams and wells in different areas of the States by prevention, control and abatement of water pollution (CPCB, 2019)
		SPCB	Inspect wastewater treatment facilities; enabled to tighten standards; evolve methods of treatment and utilization of sewage or related disposal (Singh, 2014)
MoHUA	a) Formulation of policies, sponsorship and support programs b) Coordination of activities of various Central Ministries, State Governments and other nodal authorities c) Monitoring programs concerning housing and urban affairs (MoHUA, 2017a)	CPHEEO	Technical wing of the ministry with specialists in public health engineering/environmental engineering. The organization does not only support the ministry in policy formulation but also handholds states by way of technical advice, guidelines, scrutiny and appraisal of schemes, and propagation of new technologies. It acts as advisory body at central level for concerned state agencies and Urban Local Bodies (ULBs) in implementation, O&M (operation and maintenance) of urban water supply and sanitation projects (CPHEEO, 2019)
Ministry of Jal Shakti	Formed in May 2019 by merging Ministry of Drinking Water and Sanitation, Ministry of Water Resources, River Development and Ganga Rejuvenation for optimal sustainable development, maintenance of quality and efficient use of water resources		<ol style="list-style-type: none"> 1. Overall planning, policy formulation, coordination and guidance for water resources 2. Technical guidance, scrutiny, clearance and monitoring of the irrigation, flood control and multi-purpose projects 3. General infrastructural, technical and research support for development 4. Providing special central financial assistance for specific projects 5. Overall policy formulation, planning and guidance in respect of irrigation management 6. Overall planning for the development of ground water resources 7. Formulation of national water development perspective 8. Coordination, mediation and facilitation of interstate interests 9. Operation of the central network for flood forecasting 10. Inter-state negotiations 11. Ensure effective abatement of pollution and rejuvenation of the river Ganga by river approach (Ministry of Jal Shakti, 2019)

Setting Wastewater Discharge Standards for STPs in India

The fundamental basis for standards-setting is the identification of “designated best uses” (DBU), or the use from any particular water body that demands the highest water quality (CPCB, 2002). A classification system of five common human uses has been adopted that associates each DBU with related water quality criteria that must be fulfilled. **Table 4** below illustrates defined designated-best-uses with the related class of water and relevant criteria.

The DBU concept forms the fundament for risk management in India but is not without limitations. Human use-based water quality criteria may not satisfy ecological health criteria, and this has been found to be the case in practice (CPCB, 2002). Unorganized uses of waterbodies have not been considered, and these may constitute the majority of risks, particularly in rural India. Further, DBU may vary across seasons and stretches of the river and this results in a further challenge in the practical utility of the concept. These problems have been evident in the monitoring of large rivers like Ganga and Yamuna (IIT Consortium, 2015; Government of Haryana, 2018).

Following a review of international standards (USEPA, Europe, and Japan), and consideration of economic feasibility in India, first general discharge standards were proposed in 1986. These are concentration-based, and the first iteration considered four different application areas (MoEFCC, 1986b). Standards are set as minimum requirements for all states, allowing states to

set more stringent standards based on the condition of their water bodies.

Current Scenario of Evolving Discharge and Reuse Standards

The established wastewater discharge standards for STPs have changed considerably over the past 4 years, with changes in terms of limits and overall parameters—as well as a move to just one fixed set of standards irrespective of end uses over land or discharge to inland water. After revision and the formulation of comparatively stringent draft norms in 2015 under one fixed set of standards, these underwent a second change in 2017 with a relaxation of limits and the inclusion of different criteria for metro cities. These norms, in turn, were followed by an order by the NGT (National Green Tribunal) (1995). The frequency of changes, coupled with observed difficulties in direct access to relevant information on central online platforms and the lack of transparency in standards-setting have led to confusion and hesitation within the sector on upcoming projects. An adaptation time of 7 years was proposed by a nominated expert committee for old STPs to comply with updated standards but rejected by the NGT. While water quality criteria form the baseline for setting standards, incoherence is observed. Detailed reports on standards setting procedures, relevant parameters for evaluation or detailed development plans are not accessible or existent and thus could not have been provided. **Table 5** below informs on Indian STP discharge standards over time.

TABLE 3 | Overview of policies and acts in India for wastewater management.

1974	Water (Prevention and Control of Pollution) Act	Prevention and control of water pollution in maintaining or restoring of the wholesomeness of water through the establishment of pollution control boards (central & state level) for implementation ^a .
1986	Environment Protection Act	Provision of protection and improvement of the environment in a broader sense, including the human environment ^b .
1995	National Environment Tribunal Act	Provision of strict liability for damages arising out of any accident by hazardous substances; establishment of a National Environment Tribunal for effective and expeditious disposal of cases arising from such accidents ^c .
2008	National Urban Sanitation Policy	All Indian cities and towns become totally sanitized, healthy and liveable and ensure and sustain good public health and environmental outcomes for all their citizens with a particular focus on hygienic and affordable sanitation facilities for the urban poor and women ^d .
2011	National Mission for Clean Ganga	Ensure effective abatement of pollution and rejuvenation of the river Ganga by adopting a river basin approach to a) promote intersectoral coordination for comprehensive planning and management and b) maintain minimum ecological flows in the river Ganga ^e .
2012	National Water Policy (NWP)	NWP proposes the recycling and reuse of water including return flows for demand management and efficient use of water, incentives through efficient water pricing ^f .

^aMoEFCC (1974), accessible via <https://cpcb.nic.in/displaypdf.php?id=aG9tZS93YXRlci1wb2xsdXRpb24vRG9jMy5wZGY=>.

^bMoEFCC (1986a), accessible via <https://cpcb.nic.in/displaypdf.php?id=aG9tZS9lcGEvZXB3RlY3RfYWNOzE5ODYucGRm>.

^cNGT (National Green Tribunal) (1995), accessible via http://www.greentribunal.gov.in/FileDisplay.aspx?file_id=hp6pqcrv0hY1hc2OYg8Sk8xCFwF7gv7AbtSt83%2FRxrgXurTbWxFcg%3D%3D.

^dMoUD (2008), accessible via <http://www.indiaenvironmentportal.org.in/files/nusb.pdf>.

^eNMCG (2019), accessible via https://nmcg.nic.in/about_nmcg.aspx.

^fMoWR (2012), accessible via http://mowr.gov.in/sites/default/files/NWP2012Eng6495132651_1.pdf.

TABLE 4 | Water quality criteria under designated best use classes (CPCB, 2017a).

Designated-best-use	Class of water	Criteria
Drinking water source without conventional treatment but after disinfection	A	- Total Coliforms < 50 MPN/100 ml - pH between 6.5 and 8.5 - Dissolved Oxygen > 6 mg/l - BOD ₅ days 20°C 2 mg/l or less
Outdoor bathing (organized)	B	- Total Coliforms < 500 MPN/100 ml - pH between 6.5 and 8.5 - Dissolved Oxygen > 5 mg/l - BOD ₅ <3 mg/l or less
Drinking water source after conventional treatment and disinfection	C	- Total Coliforms < 5000 MPN/100 ml - pH between 6 to 9 - Dissolved Oxygen > 4 mg/l - BOD ₅ < 3 mg/l
Propagation of wildlife and fisheries	D	- pH between 6.5 to 8.5 - Dissolved Oxygen > 4mg/l - Free Ammonia (as N) < 1.2 mg/l
Irrigation, industrial cooling, controlled waste disposal	E	- pH between 6.0 to 8.5 - Electrical conductivity at 25°C micro mhos/cm max. 2250 - Sodium absorption ratio max. 26 - Boron max. 2 mg/l
	Below-E	Not meeting A, B, C, D, & E criteria

While in 1986 standards, discharge to inland surface water and land irrigation was differentiated, the subsequent draft standards were applied for both categories where human contact with reused effluent was possible (though specific reuse applications were not defined). Apart from the standards set under the CPCB, several different recommended norms for wastewater reuse are provided in guidance documents such as the Manual on Sewerage released in 2013 under the CPHEEO and the

MoHUA or the Urban Water Reuse Policy developed under the Urban Development Department in Karnataka state published in 2017 (Government of Karnataka, 2017). While the board for the formulation of the Karnataka policy included a wide range of sectoral bodies under various Ministries (including state pollution control boards) and given parameters and limits refer to CPHEEO norms, the recommended norms are rather different to standards set elsewhere. The recommended norms for wastewater reuse under the CPHEEO are shown in **Table 6**.

In comparison to norms recommended by the CPHEEO, the stated application areas under the Urban Reuse Policy in Karnataka are agriculture, industry, urban non-potable use and environment. For agricultural use, the norms cover pathogens and pH, whilst norms for discharging effluent into water bodies to increase flow (for example) are more stringent and cover similar parameters as to standards proposed.

Furthermore, while under the Open Defecation Free Agenda of the Swachh Bharat Mission decentralized onsite sanitation systems were widely built in urban areas, a specific set of standards for onsite or decentralized systems does not exist, neither standards along the whole sanitation value chain, including fecal sludge management (MoHUA, 2017b).

Technology Considerations Under the Regulatory Framework

Reported wastewater treatment systems in India comprised a range of 13 different technologies in 2013, with Upflow Anaerobic Sludge Blanket (UASB) as the most commonly used technology. However, current trends and STPs under development include Activated Sludge Process (ASP), Moving Bed Biofilm Reactor (MBBR), and Sequencing Batch Reactor (SBR) plants (CPCB, 2013, 2015). An overview for decentralized technologies is not given. CPCB has previously evaluated several technologies according to performance and cost (CPCB, 2013).

TABLE 5 | Overview Indian STP discharge standards over time (MoEFCC, 1986b, 2015, 2017b; National Green Tribunal order, 2019).

Parameters	General norms ⁹ 1986				Draft norms Nov. 2015**	MoEF & CC notification, Oct. 2017**	NGT order 2019**
	Inland surface water	Public sewers	Land irrigation	Marine coastal areas			
1 BOD [mg/l]	30	350	100	100	10	30 20 (metro cities) ^h	10
2 COD [mg/l]	250	–	–	250	50	–	50
3 TSS ⁱ [mg/l]	100	600	200	100 (process water)	20	100 50 (metro cities)	20
4 pH	5.5–9	5.5–9	5.5–9	5.5–9	6.5–9	6.5–9	5.5–9
5 TN ^j [mg/l]	100	–	–	100	10	–	10
6 Ammonical Nitrogen as N [mg/l]	50	–	–	50	5 ^k	–	–
7 Free NH ₃ [mg/l]	5	–	–	5	–	–	–
8 Nitrate [mg/l]	10	–	–	20	–	–	–
9 Diss. PO ₄ as P [mg/l]	5	–	–	–	–	–	1 ^l
10 Fecal Coliform [MPN/100ml]	–	–	–	–	<100	<1,000	<230

⁹Standards set in 1986 cover in total 40 parameters, which are not depicted in this illustration. NOTE: industrial wastewater standards are regulated under CETP (Common Effluent Treatment Plant) set, which is not focus of this study.

^hMetro Cities, all state capitals except in the state of Arunachal Pradesh, Assam, Manipur, Meghalaya Mizoram, Nagaland, Tripura Sikkim, Himachal Pradesh, Uttarakhand, Jammu and Kashmir and Union Territory of Andaman and Nicobar Islands, Dadar and Nagar Haveli Daman and Diu and Lakshadweep Areas/Regions. **Standards applicable for discharge into water bodies and land disposal/applications, while reuse is encouraged.

ⁱAs SS in [mg/l] in General Norms, 1986.

^jAs Total Kjeldahl Nitrogen in General Norms, 1986.

^kAs NH₄-N.

^lValid for Phosphorus Total (for discharge into ponds and lakes).

The technologies included ASP, MBBR, SBR, Upflow UASB-EA, Membrane Bioreactor (MBR), and Waste Stabilization Pond (WSP). The following **Table 7** presents the CPCB evaluation alongside DEWATS (Decentralized Wastewater Treatment System), which follows a concept with low cost, O&M and energy intensive nature-based systems, mostly composed of anaerobic treatment and extended planted gravel filtration.

The Challenges of a Changing Wastewater Management Regime

In light of the changing landscape of pollution control measures and the lack of transparency in standards-setting, literature review, and interviews with several governmental officials, sectoral experts, and technology providers in India have been carried out, to assess applicability of standards and norms set, the reasons for the changes, associated challenges and discuss possible implications. The interviewees provided their comments on an anonymous basis. Their feedback with findings is synthesized and discussed in the following sections.

Background for revision of general standards in 2015

CPCB reported a severe deterioration of river quality, which formed the initial ground for a revision of general standards as indicated in interviews. While polluted river stretches in 2005 only numbered 71, the number rose to 300 in 2012 and further to 351 in 2017 (Bhardwaj, 2005; CPCB, 2018b), although it should be noted that the monitoring network developed over this period

from an initial 784 to 3,000 stations in 2018. Considering the increase in both monitoring stations and polluted river stretches, a qualitative analysis of pollution levels at the given stretches would deliver a more holistic picture on the dimension of contamination levels. Reasons for increased pollution in rivers are multiple, ranging from increased water withdrawals coupled with an increase in wastewater volumes and climatic and seasonal variations. Historically, some rivers had base flows only during the monsoon season (for around 3 months annually) while nowadays most streams are perennial as a result of wastewater discharge. Norms for effluent quality were tightened in 2015 since it was argued that dilution effects within water bodies could no longer be considered. Analyzing the compatibility of discharge standards and required water quality criteria for designated best uses, it is observed that set limits under a zero dilution factor cannot fulfill intended thresholds and thus can fail to eliminate risks as to given objectives (compare **Tables 4, 5**).

Background on frequency of constant changes

In contrast to 1986, standards in 2015 were formulated under the mandate of the MoEF&CC to combat high pollution levels. Since parameters such as economic feasibility were the responsibility of other Ministries, interviewees reported that they were not considered under the first draft. The disparity in the management environment of wastewater discharge and reuse standards is reflected in the contrasting landscape of varying interest and requirements. With water as the central resource and wastewater

TABLE 6 | Recommended norms of treated sewage quality for different uses (CPHEEO, 2013).

Parameter	Toilet flushing	Fire protection	Vehicle exterior washing	Non-contact impound-ments	Landscaping, horticulture & agriculture				
					horticulture, golf courses	Crops		Colorless	Colorless
						Non-edible crops	Edible crops		
						Raw	Cooked		
Turbidity (NTU)	<2	<2	<2	<2	<2	AA	<2	AA	
SS	nil	nil	nil	nil	nil	30	nil	30	
TDS				2100					
pH				6.5 to 8.3					
Temp. (°C)				Ambient					
Oil and Grease	10	nil	nil	nil	10	10	nil	nil	
Minimum Residual Chlorine	1	1	1	0.5	1	nil	nil	nil	
Total Kjeldal Nitrogen	10	10	10	10	10	10	10	10	
BOD	10	10	10	10	10	20	10	20	
COD	AA	AA	AA	AA	AA	30	AA	30	
Dissolved Phosphorus as P	1	1	1	1	2	5	2	5	
Nitrate	10	10	10	5	10	10	10	10	
Fecal Coliform/ 100 ml	nil	nil	nil	nil	nil	230	nil	230	
Helminthic eggs/liter	AA ^m	AA	AA	AA	AA	<1	<1	<1	
Color	Colorless	Colorless	Colorless	Colorless	Colorless	AA	Colorless	Colorless	
Odor	Aseptic (Not septic and no foul odor)								

^mas arising when other parameters are satisfied.

TABLE 7 | Technology performance (CPCB, 2013; adapted with data based on DEWATS by Singh et al., 2019).

Assessment parameter/technology	ASP	MBBR	SBR	UASB+EA	MBR	WSP	DEWATS ⁿ
Performance after Secondary Treatment							
BOD (mg/l)	<20	<30	<10	<20	<5	<40	
SS (mg/l)	<30	<30	<10	<30	<5	<100	
Fecal Coliform, Log unit	Upto 2<3	Upto 2<3	Upto 3<4	Upto 2<3	Upto 5<6	Upto 2<3	
T-N removal efficiency (%)	10–20	10–20	70–80	10–20	70–80	10–20	
Performance after Tertiary Treatment							
BOD (mg/l)	<10	<10	<10	<10	<10	<10	<20
SS (mg/l)	<5	<5	<5	<5	<5	<5	<40
TN							<10
NH ₃ N (mg/l)	<1	<1	<1	<1	<1	<1	
Total Coliforms, MPN/100 ml	10	10	10	10	10	10	

ⁿDEWATS technology serves as comparative for nature-based solutions due to lack in data availability for other systems.

treatment as significant pillar of societal infrastructure, a cross-sectional interest is formed. However, it is stated that the process of standards-setting and related decision making does not consider a regulated consensus phase including all stakeholders to devise feasible solutions to complex problems. The lack of consultation or consensus during the development of the 2015 MoEF&CC draft norms meant that they were published and went into application before being reviewed by other institutions and stakeholders. Given the lack of communication and inclusion, the draft norms subsequently underwent two rounds of reversal, while the applicability of current enforced standards is reported to remain under further revision.

Aside from individual stakeholder perspectives, interviewees stated that detailed assessment through health risk or river basin modeling has not been undertaken due to capacity constraints. While the aspiration of the regulatory authorities is toward BAT and zero risk, the absence of detailed human or environmental impact assessments, indicative budgets, and targets for infrastructure implementation mean that the eventual outcome cannot be predicted with any certainty. It was further reported that international limits may not reflect characteristic or the impact of parameters under given environmental conditions found in the Global South. While in the North coliforms may persist for longer timescales, increased UV radiation in

the South can have an effect on their elimination. In turn increased temperatures may enhance organic decomposition processes. The given uncertainty due to a lack in profound risk management for local conditions leaves behind room for fundamental recurring questions and discussions. To facilitate a more structured and holistic management process, big data for water bodies, environmental, and public health must be collected and analyzed, and this capacity is yet to be developed within the relevant Indian institutions.

Background for the change to fixed set of standards

Although in interviews it is widely agreed that standards set do not necessarily represent required limits for certain application areas, one fixed set of standards for discharge and reuse has been set because of high mistrust of illegal discharge. It was stated that many STPs cannot meet 1986 standards because of electricity break downs, O&M intensive technologies and the lack of interest in investing in training of operators by the private sector who is often responsible for the O&M of treatment plants. Further dysfunction in the wastewater analysis sector was reported as observation, while illegal disposal of sludge due to lack of appropriate disposal options is a common occurrence. With insufficient resources in monitoring, one fixed set of discharge standards was considered to facilitate pollution control. Illegal discharges are observed along the whole wastewater chain. The causality and net benefit resulting from the implementation of one fixed set of standards remains unclear and fails to address the root cause—which is formed by insufficient capacity in monitoring. Further, without proposing nuanced and feasible pollution control measures for reuse, regulations can fail to address the reality on ground and existing risks to a large proportion of the population, particularly farm laborer and the poor.

While one fixed set of standards can simplify implementation and monitoring, it can also neglect the benefits and risks of wastewater. For example, in an irrigation context, wastewater composition, soil characteristics, type of crop, and protection measures can influence risk. Certain trace elements can affect the integrity of soil structure and accumulate in crops, rendering them unfit for human consumption. Considering the quantities of wastewater used for irrigation in India, and the growth in agriculture in peri-urban areas as a response to perennial flows, the elimination of nutrients essential for crop growth at high cost remains indefensible (CPCB, 2013).

Changes in the standards setting approach

As a primary driving objective indicated in the protection of water bodies, the NGT order envisages stringent standards achieved through the implementation of the BAT approach. Under the focus of one application area and a limited set of technologies considered in the evaluation process, the resulting implementation would require energy and mechanically-intensive technologies that increase electricity consumption and rule out opportunities for direct nutrient recycling. Smith et al. (2019) perform a benefit-cost assessment of China's stringent wastewater standards in 2015, and find an additional annual electricity consumption of 3–6% and a 7-fold benefit

to agricultural reuse. There is an ever-increasing landscape of technology options, many of which were not considered during the 2013 CPCB review (CSE 2019; CPCB 2013). While it is claimed that the BAT approach is technology-neutral, it was commonly stated that decentralized and nature-based solutions are disadvantaged under the proposed discharge and reuse standards.

Economic and risk implications

The immense pollution arising from improper or inexistent sanitation requests for allocation of adequate funding schemes in order to achieve set targets. However, most interviewees stated that strict standards were not applicable at the current time in India due to the lack of economic and technical feasibility, with substantial constraints around operation and maintenance. Detailed development plans of the sector including financing schemes and related targets in treatment coverage over time could not have been shared. It is stated that the economic feasibility for implementation of the MoEF&CC norms at all levels has not been fully explored, and the efforts of the wastewater sector to provide sanitation has stalled due to a lack of clarity on goals and a lack of applicable technologies.

It was indicated that the sector would face a mammoth challenge in acquiring finances to retrofit current systems to meet the proposed limits—not just in terms of the infrastructure required, but also the additional land area required to accommodate that infrastructure, especially in highly dense urban areas. According to the Bangalore Water Supply and Sewerage Board, 50 out of 57 STPs would have to be adapted and a budget of 2,000 crore Rs (260 Mio. €) has been already drawn up (Deccan Herald, 2019). It is further reported that 134 STP projects are currently in the bidding stages and that tenders may have to be revised—both for these as well as for proposals that have already been issued (Global Water Intelligence, 2019). The detailed implications for institutional costs and technological retrofitting are not known but are presumably quite large.

When analyzing the capital costs of treatment systems considered in the CPCB report in 2013, prices are indicated in the range from 23 lakhs Rs/MLD (0.029 Mio. €/MLD)¹ for WSP to 300 lakhs Rs/MLD (0.382 Mio. €/MLD) for MBR. While this is a wide range, capital expenditures (CAPEX) for other treatment systems fell within the range of 68–75 lakhs Rs/MLD (around 0.087 to 0.096 Mio. €/MLD). Capital costs for tertiary treatment were indicated as 40 lakhs Rs/MLD (0.051 Mio. €/MLD) representing ~ 60% of total capital investment for ASP, MBBR, SBR or UASB+EA, 13% for MBR and 173% for WSP. Against the intensive investment in tertiary treatment, the overall additional gain in BOD removal rate as for ASP is indicated in 10 mg/l while a comparative for removal efficiencies for nutrients at the different stages is not directly given and cost calculation in relation to removal rates cannot be derived. Considering that half of the wastewater is reused informally for irrigation in India, decentralized plants near agricultural areas could allow to recover

¹Conversion rate based on 78.87 Rs/EURO annual average for 2019, dated 13th of December, 2019, sourced at <https://www.x-rates.com/average/?from=EUR&to=INR&amount=1&year=2019> (X-Rates, 2019).

resources instead of their cost intensive elimination, which in turn could be used for the development of broader coverage of treatment infrastructure.

Unless the total governmental budget for wastewater infrastructure development increases drastically, infrastructural development and coverage are likely to slow down even as the population continues to grow. This trend can result in higher pollution and health burden and enforce higher risk inequalities as only certain areas could be served while others would be exposed to an unsafe and dangerous environment. Overall, it can be stated that there is a wide gap in institutional capacity at all levels—highlighting a pressing need for more holistic management processes.

International Comparison

In the following chapter an international comparison has been carried out in collaboration with the INNOQUA consortium, informing on institutional approaches and pollution control measures in different countries.

International Comparison of Approaches and Discharge Standards

The international comparison of approaches and discharge standards provides insights from regulations on the European level, Ireland, France, Tanzania, and different set of standards in a wider perspective in relation to India.

The European Union

As with India, legislation in Europe has to cover a broad range of geographies with different environmental sensitivities. The initial priority was to ensure that wastewater was captured and treated—with an emphasis on wastewater from “agglomerations” of more than 2,000 Population Equivalent (PE). PE is used as a metric since it allows for the inclusion of combined sewerage systems that are common across Europe—in which mixtures of surface runoff, domestic, commercial, and industrial effluents are conveyed to treatment facilities. This regulatory structure was set out in the 1991 Urban Wastewater Treatment Directive (UWWTD), obligating European member states to:

- a. collect and treat wastewater, where PE is higher than 2,000
- b. preauthorize industrial discharges into urban treatment plants
- c. achieve effluent standards by secondary or equivalent treatment
- d. apply nutrient removal objectives, where receiving catchment are sensitive
- e. monitor treatment plants and receiving waters
- f. control sewage sludge disposal.

The nutrient removal objectives apply to agglomerations of 10,000 PE and above, where the treated wastewater, discharged into water bodies, can cause eutrophication. They cover nitrogen and phosphorus and set limits for these elements.

In principle, the UWWTD prevents the use of decentralized systems within population centers (of >2,000 PE). However, the Directive does include the following caveat: “Where the establishment of a collecting system is not justified either because

it would produce no environmental benefit or because it would involve excessive cost, individual systems or other appropriate systems which achieve the same level of environmental protection shall be used” (EEC, 1991). In the following **Figure 4**, the coverage in wastewater treatment and related stages is presented. As it can be seen, there are significant differences in EU countries. It can be assumed that wastewater from the percentage of the population not covered in these statistics is managed in decentralized systems and as illustrated apart of the UK, decentralized systems still represent a significant fraction. Further as illustrated, tertiary treatment is not yet universally applied throughout all EU countries and the implementation of this treatment stage is still a comparatively young development.

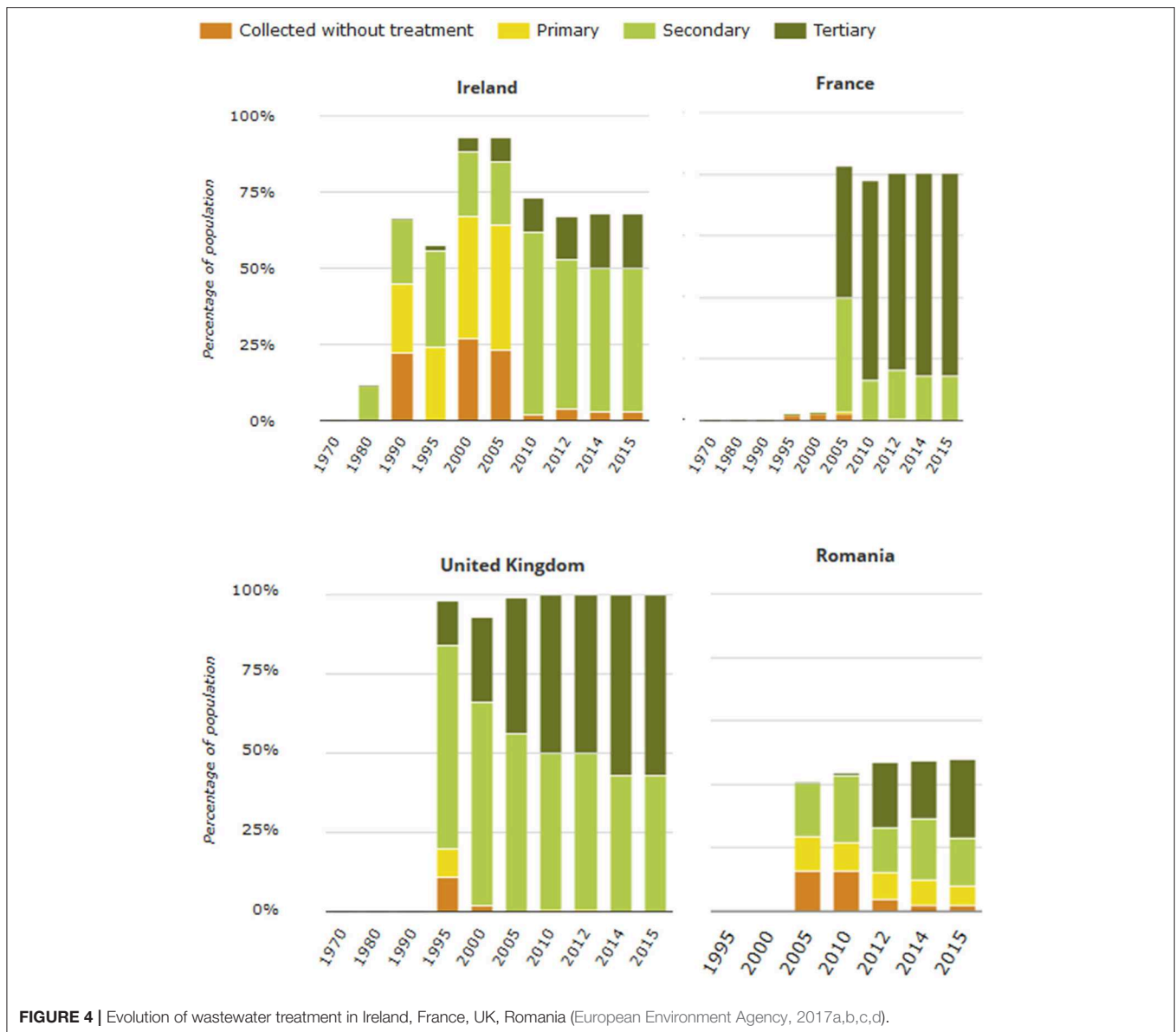
More recently, European legislation has moved away from setting specific discharge standards to consider water quality as a whole. Under the 2000 Water Framework Directive (WFD) (European Commission, 2019c), member states are required to understand the current ecological condition of their water bodies (both surface and ground water) and compare this with “good” ecological status. Good ecological status is defined through a number of metrics that are based on the quality of water bodies that might be expected where there was minimal human interference. Programs of measures must then be defined and implemented to improve poor quality water bodies until they achieve at least “good” ecological status. The WFD operates at river basin scale, requiring international cooperation where (for example) rivers pass through more than one country. Since the programs of measures can target point and diffuse sources of pollution, the WFD interacts with a large number of other regulatory instruments—including those relevant to agriculture. Since it is left to individual member states to determine how “good” ecological status should be interpreted for each water body, the WFD does not set prescribed limits for wastewater discharge.

Ireland

Over 80% of rural households (accounting for one third of Ireland’s population) treat and discharge wastewater onsite with a resulting estimated 500,000 domestic wastewater treatment systems (DWWTS) treating wastewater from single houses that are not connected to a public sewer system *An Taisce* (2015). The Irish Environmental Protection Agency (EPA) has published a *Code of Practice: Wastewater Treatment and Disposal Systems Serving Single Houses* (PE ≤ 10) which serves as the key guideline and design practice for DWWTS (EPA, 2010). Technologies considered under the EPA include

- a. Septic tanks for primary treatment
- b. Constructed wetlands, soil filters and sand filters for secondary treatment
- c. Package plants (primary and secondary treatment)
- d. Constructed wetlands, soil filters and sand filters for tertiary treatment.

Wastewater treatment plants, processing loads of between 500 and 10,000 PE, must meet the standards listed in the UWWTD, whilst larger plants must meet tighter, site-specific standards—that allow water bodies to comply with the requirements of



the Water Framework Directive. Ireland has no specific reuse standards in place.

France

As in the case of Ireland, France has set standards for smaller treatment plants. Unlike Ireland, France has standards for reuse, as set out below. Standards are classified amongst systems with a capacity below 1.2 kg of BOD₅ per day and above 1.2 kg of BOD₅ per day but below 120 kg per day and address BOD, COD and SS as presented in **Table 8** (Legifrance, 2007, 2009).

Tanzania

In 1991 the Government of Tanzania prepared the first National Water Policy to address the challenges on water supply and sanitation services (Tanzania Bureau of Standards (TBS), 2005). This policy identified the Government as the

sole implementer and provider of water and sanitation services. Under the framework of the National Water Policy, Water Supply and Sanitation Authorities (WSSAs) are mandated with sanitation and sewerage service provision. The policy's objective for urban areas is to implement more appropriate environmentally-friendly technologies for wastewater treatment and recycling. Although discharge standards are comparatively stringent, wastewater treatment only covers a fraction of wastewater production.

Unlike in India, in Tanzania the formulation of discharge standards follows a national standardized participatory process involving stakeholders from several sectors over a phase of up to 5 years. The standards are based on information from other countries (notably Brazil and India, which have similar characteristics in terms of economy and environment). Following the initial expert revision, the draft standards are opened for

TABLE 8 | Discharge standards in different countries^o (MoEFCC, 1986b, 2015, 2017b; EEC, 1991; Tanzania Bureau of Standards (TBS), 2005; Legifrance, 2007, 2009; EPA, 2010; MWI, 2012; Ministerio del Ambiente, 2015; National Green Tribunal order, 2019).

Country	PE treated	pH	t (°C)	SS (mg SS/l)	DO (mg O ₂ /l)	COD (mg COD/l)	BOD ₅ (mg BOD ₅ /l)	TN (mg N/L)	Total ammonium (mg NH ₄ -N/l)	Total ammonia (mg NH ₃ -N/l)	TP (mg P/l)	Microbial indicators
EU Urban Wastewater Treatment Directive (UWWTD) ^p	>2,000			35/90% reduction		125/75% reduction	25/70-90% reduction	–			–	
	10,000 – 100,000							15			2	
	>100,000							10			1	
Ireland	≤10			30			20	5	20		2	
France	>2,000	UWWTD apply as a minimum, but may be more stringent to comply with Water Framework Directive (WFD)										
	<20			30			35					
Romania	20 - 2000	6–8.5	<25	50% reduction		60% reduction	35, 60% reduction					
	>2000	UWWTD apply as a minimum, but may be more stringent to comply with Water Framework Directive (WFD)										
Ecuador	>2,000	6 - 9	±3 ^q	130		200	100	50 TKN	30		10	<2000 FC MPN/100 ml
Tanzania		6.5–8.5	20–35	100 TSS		60	30	15 TKN			6	<10,000 TC counts/ 100 ml
Jordan				60 TSS	>1	150	60	70			15 as T-PO ₄	<1,000 <i>E. coli</i> MPN/100 ml Nematodes < 1
India 2015		6.5–9		20 TSS		50	10	10	<5			<100 FC MPN/100 ml
India 2017/18	Metro	6.5–9		50 TSS			20					<1,000 FC MPN/100 ml
	Non-metro			100 TSS			30					
India NGT 2019		5.5–9		20 TSS		50	10	10			1	<230 FC MPN/100 ml
India 1986 ^r	Inland water	5.5–9	<5	100		250	30	100 TKN		5 as free NH ₃	5 diss. PO ₄ as P	
	Land irrigation			200			100					

Note to the table: Coliforms represented include *E. coli*, Fecal Coliforms (FC) and Total Coliforms (TC).

^oDetail for ranges of permitted consents omitted from this version for clarity.

^pTP and TN only considered in designated "sensitive" areas.

^qOf the receiving water body.

^rTotal set covers a range of 40 parameters and three further application areas for discharge into public sewer, marine coastal areas.

public comments. The review takes place every 5 years and is thus a constant process. Under the current revision, it is indicated that discharge standards for decentralized systems will be developed. However, a nuanced set of re-use standards is not included, despite reported high volumes of re-use.

When comparing wastewater discharge standards, it can be seen that limits vary considerably—although there is some commonality in determinants, such as TSS, COD, and BOD, TN. It is noticeable that the planned Indian standards have the strictest levels in terms of BOD₅, TSS, and TN removal, followed by Peru, Romania and Tanzania. In contrast, Ecuador and Jordan show the most relaxed limits. It can also be observed that—while EU countries must all comply with the same legislation—this still allows individual member states such as Ireland and France to apply discharge standards for small systems that suit their situations. A first iteration toward the principle of load-based standards categorized as metro and non-metro city could be observed in 2017 but contested in 2019.

International Comparison of Standards for Wastewater Reuse

Globally, a rising number of countries is incorporating regulations for wastewater reuse. In Alcalde-Sanz and Gawlik (2014) reported that criteria were applied in Australia, Canada, China, Israel, Japan, Jordan, Mexico, South Africa, Tunisia, the USA, and several states of the EU. Within the following insights and pollution measures of different countries are presented.

The European Union

Pressures from climate change, droughts and urban development have put a significant strain on freshwater supplies in Europe (European Environment Agency, 2012). Europe's ability to respond to the increasing risks to water resources could be enhanced by broader reuse of treated wastewater—but to date only six member states have established regulatory or voluntary standards for reuse.

In order to stimulate increased water reuse across Europe, the European Commission has recently proposed a set of standards for implementation across all member states (European Commission, 2019a,b)—but only for water reuse in agricultural irrigation. It classifies four minimum reclaimed water quality classes in relation to crop category, irrigation method, and indication for water treatment (secondary in combination with filtration/disinfection). The quality requirements include: *E. coli*, BOD, TSS, turbidity, and pathogens, as listed in **Table 9**.

France

Among European nations, France was one of the first countries to issue wastewater reuse standards in 1991. These follow the WHO guidelines, with additional restrictions on irrigation and distances from irrigated areas (Hanseok et al., 2016). They include limits for COD, TSS, Enterococci, phages, and spores (Paranychianakis et al., 2015).

Jordan

ACWUA reports that Jordan is considered one of the most advanced countries in its approach to the application and safety

of wastewater reuse. Due to severe water scarcity, 90% of treated wastewater is reused, mainly for irrigation in agriculture. A pragmatic approach to safety was developed that focusses on water quality at the point of use as outlined by the WHO. Farmers are aware of the nutrient content in wastewater, and this allows to reduce fertilizer application by up to 60%, which in turn provides economic benefits and can reduce the contamination of water (ACWUA, 2010, 2011). In an analysis of the public health indicators in terms of deaths, episodes and DALYs attributable to diarrheal diseases published under Lancet in 2017 (The Lancet, 2017), Jordan indicates one of the lowest ranges globally despite the very high urbanization rate of 83.91% and high reuse (The United Nations Population Division's World Urbanization, 2018).

The comparison of different wastewater reuse standards in different countries shows vast differences in limits, allowable applications and overall approaches. Most commonly, restrictions vary according to the intended use of crops. However, combinative measures are also considered, such as for France or the new standards proposed by Europe, which both vary according to different combinations of crop and irrigation methods. With the proposed regulation on reuse in the EU it can be observed that standards are indicating an evolved combination of safety measures.

The most stringent standards are observed in South Korea, USEPA, and Israel in terms of BOD, however here it can be seen that no limits for TN or TP are applied and there is some variation for TSS. Approaches to pathogen management also vary widely—both from country to country and between uses within a country. For example, *E. coli* limits range from 250 to less than 100,000 CFU per 100 ml in France depending on whether crops are consumed without cooking or whether fruits are harvested from drip-irrigated trees. By comparison, the implementation of just one set of standards for both discharge to inland water and use on land in India is regressive with international practice and discourages nutrient recycling.

CONCLUSION AND KEY RECOMMENDATIONS FOR THE WAY FORWARD

In the face of continuously growing population and the lack of proportionate sanitation infrastructure, authorities in India face a mammoth task to safeguard the environment and citizens' public health. This paper has explored recent developments in Indian wastewater discharge and reuse standards alongside the approaches adopted elsewhere. Observed constant changes and inconsistencies have led to a widespread confusion and further reported hesitation in sectoral development. Reasons for these developments are rooted in the shortages of adequate institutional capacity, related lack of detailed risk assessment and a missing consensus phase in the standards setting process including all stakeholders. While the contamination of Indian rivers is reported to be tremendously increasing and requires action, the implementation of a single set of stringent standards without a detailed development plan can risk to slow down the

TABLE 9 | Wastewater reuse standards in different countries (MoEFCC, 1986b, 2015, 2017b; MWI, 2012; CPHEEO, 2013; Ministerio del Ambiente, 2015; Hanseok et al., 2016; European Commission, 2019a; National Green Tribunal order, 2019).

Parameter		BOD	COD	TN	TP	Coliforms	TSS	pH	Helminth eggs (HE)/Intestinal Nematodes (IN)	Turbidity	Conductivity
	Unit	mg/l	mg/l	mg/l	mg/l	CFU/100ml	mg/l	-	egg/l or applicable	NTU	
WHO	Unrestricted					<1,000 <i>E. coli</i>			<1 (IN)		
	Restricted					<10,000 <i>E. coli</i>					
US EPA	Food crops	<10				ND FC (median)		6.0-9.0		<2	
	Processed food crops	<30				<200 FC (median)	<30			-	
EU directive ^s	A All irrigation methods	<10				<10 or ND <i>E. coli</i>	<10		<1 HE and <1,000 CFU/l <i>Legionella</i> spp.	<5	
	B All irrigation methods	25				<100 <i>E. coli</i>	35				
	C Drip irrigation	25				<1,000 <i>E. coli</i>	35				
	D All irrigation methods	25				<10,000 <i>E. coli</i>	35				
Jordan	Cut flowers	30	100	70	NA	<1.1 <i>E. coli</i>	15	6-9	<1 (HE)		
	Field crops, industrial crops and forest trees (C)	300	500	70	30	-	300				
	Fruit trees, side of road outside city and landscape (B)	200	500	45	30	1,000 <i>E. coli</i>	200				
	Cooked vegetables, parks, playground, side road in city (A)	30	100	45	30	100 <i>E. coli</i>	50				
Israel		<10	<100	<25	<5	FC <10	<10	6.5-8.5			<1,400
South Korea	Food crops	<8				ND TC		5.8-8.5		<2	<700
	Processed food crops					<200 TC (MPN)				<5	<2,000
Italy		<20	<100	<15	<2	<100 (max); <10 (80%) <i>E. coli</i>	<10	6.0-9.5			<3,000
Spain	Uncooked vegetables					<100 <i>E. coli</i>	<20		<1/10l (IN)		<10
	Crops for human consumption					<1000 <i>E. coli</i>	<35				
Portugal	Unit	mg/l	mg/l	mg/l	mg/l	CFU/100ml	mg/l	-	egg/l or applicable	NTU	
	Vegetables consumed raw					<100 F	<60	6.5-8.4	<1 (IN)		<1000
	Cooked vegetables					<1,000 FC					
France ^t	Unrestricted	<60				≤250	<15				
	All crops except those consumed raw	varies				<10,000	varies				
Ecuador ^u						1,000 FC (MPN)		6-9	absent		
India 2015		10	50	10; 5 for NH ₄ -N		<100 FC (MPN)	20	6.5-9			
India 2017	Other than metro cities	30				<1000 FC (MPN)	100	6.5-9			
	Metro cities	20					50				
NGT 2019		<10	50	10	1 ^v	<230 FC (MPN)	20	5.5-9			
India old norms 1986, Land for irrigation ^w		100					200	5.5-9			
CPHEEO ^x 2013	Horticulture, golf course	10	AA	10	2	NIL	NIL (SS)	6.5-8.3	<1 (HE)	<2	2100
	Non-edible crops	20	30	10	5	230 FC (MPN)	30			AA	
	Crops eaten raw	10	AA	10	2	NIL	NIL (SS)			<2	
	Crops eaten cooked	20	30	10	5	230 FC (MPN)	30 (SS)			AA	

Note to the table: Coliforms represented include *E. coli*, Fecal Coliforms (FC) and Total Coliforms (TC).

^sA-Food crops consumed raw, direct contact; B and C-Food crops consumed raw where edible part is produced above ground and is not in direct contact with reclaimed water, processed food crops and non-food crops including crops to feed milk- or meat-producing animals, D-Industrial, energy, and seeded crops; recommendation for all classes is secondary treatment+disinfection.

^tExcept during period from blossoming to picking, allowed if drop by drop irrigation; Enterococcus, F-specific bacteriophages, spores of sulfate reducing anaerobic bacteria (all log reduction).

^uAdditional regulations exist for Al, Fe, Pb, Cd, As, Cr, Zn, Cu, Mn, Ni, sulfate, nitrite, DO; fecal bacteriophages and spores of sulfate-reducing anaerobic bacteria > 4log reduction.

^vValid for discharge to ponds and lakes.

^wFurther include arsenic, oil and grease, cyanide, alpha and beta emitter, a bio-assay test.

^xValues both for TN and N; TP as dissolved P; further includes, oil and grease, color, odor and temperature.

overall sectoral development through heavy investment and by this result in higher pollution levels and public health concerns for unserved regions. One fixed set of standards for both discharge and reuse is unlikely to be effective in controlling the risks from domestic wastewater pollution and increasing water insecurity in the majority of Indian cities. India's challenges might be better addressed by aiming for treatment throughout the country first, while building-up an evidence base that will allow more nuanced future regulations. Toward this end, the 1986 discharge standards, specifying four receiving environments and location classification, offer a more realistic national level discharge framework with more feasible limits than currently proposed standards. In alignment with the objective to encourage reuse, CPCB could prescribe a range of appropriate norms and best practices for various wastewater reuse applications. Given the risks associated with raw wastewater reuse, "safe reuse" should be operationalized using the best available evidence on the treatment needed for specific environmental and human health exposure scenarios.

CPCB's surface water monitoring guidelines stipulate 25 parameters during the pre-monsoon period and 11 parameters at 2-monthly intervals for the rest of the year (CPCB, 2017b). However, capacity constraints have meant that this frequency has not been achieved in practice. To build a strong evidence base for future water quality modeling, monitoring of four key parameters should be mandated, namely pH, BOD, TSS, and Fecal Coliforms. BOD data is already collected as part of CPCB's National Water Quality Monitoring Program. In addition, information on seasonal flows, surface water and groundwater quantity, and information on existing treatment capacity (quantities collected in sewers and treated at STP, quantities collected on-site and transported and treated off-site, quantities collected and treated *in situ*) will facilitate the development of location-specific discharge standards.

The wholesomeness of rivers must be restored under the River Monitoring Committees, comprising central and state bodies. The State Pollution Control Boards have the authority to set location-specific stringent standards (CPCB, 2009), and this approach could be implemented for specific highly polluted stretches or dry season flows. However, the implementation of these stringent standards must be supported by a targeted investment plan providing comprehensive wastewater treatment coverage and water conservation measures at a catchment scale, following a long-term infrastructure plan. Such a plan (e.g., the 2041 sewerage investment plans for Delhi and Bengaluru) would provide recommendations for sewer networks and appropriate combinations of centralized and decentralized systems for each city based on: population projections, type of buildings, climate and financial aspects—under an urban planning approach (Delhi Jal Board, 2014).

Most exercises to compare technologies in India show a bias toward the state of art or best available technology approaches. This bias has led to a focus on a limited set of mostly conventional systems, thereby omitting innovative, decentralized, nature-based solutions that could provide cost-effective and appropriate treatment. India has a broad landscape in technology innovation.

However, many innovative technologies lack real-world and long-term demonstration mainly due to economic factors. Since most funding for research is located in the North, the feasibility of studied systems may not apply in the Global South. Given the lack of appropriate performance trials and data, mistrust of new alternative systems, the comfort provided by widely deployed conventional technologies or capacity constraints in gathering information on novel systems, innovative technologies face many challenges and opportunities are missed. This implies that discharge and reuse standards may be set without due reference to technologies that can be both economically and environmentally suited to the situation at hand. Wider commercial and research portfolios are under constant development and include a broad range of alternative technologies and system configurations that are resilient, sustainable, low O&M, low/zero energy and low/zero chemical consuming, making them economical and technically feasible options (CSE, 2019). Such technologies should be included in future standards-setting to ensure that thresholds for discharge or reuse are both adequate and affordable, while constant research would be required to progress on further technology innovation and prove feasibility through long-term demonstration projects.

While the comparative analysis shows that there is a variety of options for more nuanced setting of standards, the perspective of the paradigm shift in the wastewater sector is still nascent. The European Union directive and experiences of countries under the EU illustrate that legislation for a broad range of countries can be formulated, allowing more flexibility to address given variations of a local context. An integrated river basin approach provides a more holistic ground for assessment, regulation through the facilitation of an overall common target in water body protection; apart of territorial management difficulties and in focus of local requirements. The consideration of all water uses and related stakeholders of a water body is essential to incorporate a consensus on management and avoid incoherence. The EU case shows that both for sensitive areas, more stringent discharge standards can be set, while other areas can have more relaxation. It is observed that proposed wastewater reuse standards consider a set of several measures, including water quality criteria in tandem with irrigation methods and suggested technological options. Although nowadays still most institutional frameworks are lagging in setting regulated measures, despite the reality of reuse on the ground, there is a given trend in adapting regulations and by this also more contextualized solutions will evolve. However, comprehensive risk management and assessment are fundamental and along with long-term studies on water quality and public health to provide further detailed necessary insights for appropriate pollution control measures in the local context and an extended set of application areas.

To address sustainability on a broader level, the whole sanitation chain would have to be considered, starting from rising awareness with active "consumers" rather than a "flush and forget" society, involving the "reduce, reuse, recycle" principle. This would require less water consuming toilets, sewerage systems with smaller loops and separated collection systems.

TABLE 10 | Observations and related recommendations for the way forward.

Observation	Recommendation
Frequent changes and inconsistencies	Standards and recommendations throughout involved institutions and policies are not conform
	Standards are not aligned to water quality criteria
Confusion and hesitation amongst sectoral stakeholders due to frequent, not transparent changes	
Deficits in institutional capacity for regulation and implementation of standards	
Insufficient risk assessment	
"Copied" guidelines targeting at best available technology are adopted as national standards	
Mistrust on implementing more nuanced standards due to assumed illegal discharge	
Targeted standards cannot be achieved by treatment plants	
Conflicting interest and disfunction of water analysis sector	
The range of parameters in standards set and the limits of given parameters are not adequate	
High expenses for overall sectoral development	
Inadequate monitoring	
	<p>a. Implementation of technical and qualitative consensus finding phase amongst all stakeholders to achieve a better and overall alignment of all interests.</p> <p>b. India has wide variations in environmental conditions and necessities. Formulated standards should be guiding, and target based, providing the possibility for adequate local requirements/interests.</p> <p>c. With given high deviations in seasonal patterns, diminishing resources due to increased water use and associated water pollution, the river basin approach and integrated water resources management would offer a holistic solution. Detailed assessment and modeling could help to a) identify uses, pollution and risks, b) understand dimensions of river characteristics better and c) take appropriate practical and justifiable control measures.</p> <p>d. Water quality criteria and wastewater discharge standards have to consider all designated uses and standards have to be aligned.</p> <p>Accessible, more transparent and better-structured information systems.</p> <p>Adequate institutional capacity is fundamental for regulation and implementation of pollution control.</p> <p>a. Incremental approach to capacity development</p> <p>b. Partnering with NGOs and address the current trend in rising citizen groups as a window of opportunity to drive further societal awareness, responsibility and community involvement in direct actions and participatory bottom up approaches.</p> <p>a. Better monitoring and assessment of prevalent risks, e.g. detailed data on public health burden.</p> <p>b. Wider interaction and exchange with involved sectors.</p> <p>c. Setting a health-based target, rather than assuming a no risk scenario despite given high risk reality on ground</p> <p>d. Detailed risk modeling, assessment of possible safety measures along multi barriers, including a wider set of urban planning approaches and technological options with detailed plans for coverage targets and related budget allocation over time.</p> <p>a. Each country should follow a holistic risk assessment according to local conditions and by this develop applicable standards. The sectoral development in the Global North took centuries, long-term investment at many stages to arrive at given standards.</p> <p>b. Stringent standards can create pockets of excellence if not aligned with economic feasibility, and by this reinforce inequality and increased risks. A broad coverage and equal access for all should be set as first target.</p> <p>a. Increase necessary resources and capacity for monitoring.</p> <p>b. Provision of different discharge options to avoid illegal dumping and establishment of infrastructure along the whole chain.</p> <p>a. Set realistic pollution control measures.</p> <p>b. Treatment technologies have to be aligned to local conditions. Treatment technologies, which are electricity and O&M intensive are reported as not feasible.</p> <p>c. Intensive training campaigns for certified operators. Eliminate conflict of interest by private operators of STPs, through reinforcement of trained operators and increase in monitoring capacity of STPs.</p> <p>More stringent certification process with certified personnel and frequent monitoring</p> <p>a. Standards and related limits should address the targeted risk elimination in consideration of economic feasibility and coverage of all relevant parameters</p> <p>b. Water uses and related water quality criteria have to be reassessed and a more nuanced set of standards has to be formulated to address both the dangers and benefits of wastewater for all use and discharge categories.</p> <p>a. Sectoral development should consider economic feasible and suitable technologies for application targeted treatment.</p> <p>b. Comparative technology assessment has to cover a broader range of technologies to address best suitable solutions instead of favoring conventional systems, which are capital and O&M cost-intensive</p> <p>c. Identification of polluters and enforced suitable revenue collection</p> <p>d. Associated risk and economic loss due to lack of sanitation is immense. Overall expenses for the development of the sector have to be increased. Regarding reuse the Multi-Barrier-Approach offers a viable and more economic solution.</p> <p>a. A nationwide online monitoring was implemented as a first step to address monitoring with related challenges. However, training of operators for proper calibration and maintenance is required to achieve qualitative results.</p> <p>b. Include citizen-based monitoring to achieve a quantitatively wider monitoring.</p>

(Continued)

TABLE 10 | Continued

Observation	Recommendation
Low acceptance toward innovative and low-tech sanitation solutions	a. Increase in acceptance through information transfer at all levels, including decision-makers and population. b. Increase in capacity for demonstration projects and innovation research in the Global South to collect more data.
Lack in awareness on risks of wastewater	Nation-wide awareness and education campaigns on WASH-related topics.
Wastewater composition is not suitable for further reuse	a. Holistic urban planning with designated areas for different sectors. b. Separate collection of varying wastewater streams with appropriate treatment and according to aimed reuse application area. c. Creation of smaller loops through poly- and decentralized solutions.

Decentralized, onsite, nature and community-based sanitation systems can help to address the urban sustainability challenge, but they would require an enabling environment throughout all levels. Based on the findings and observations of this study, the following related recommendations for the way forward in India are summarized in **Table 10**.

AUTHOR'S NOTE

Interviewees have requested strict anonymity and that no data from qualitative interviews to be presented that can be traced to individuals and institutions. Hence only insights have been presented.

AUTHOR CONTRIBUTIONS

GG conceived of the original idea and helped to supervise this study. TS took the lead in assessment and writing of the publication. VS and DT contributed in assessment of data and information and in writing of the publication. RP assisted in assessment through interviews and review of the publication. All authors listed have made a substantial, direct and intellectual contribution to the work, and approved it for publication.

FUNDING

The INNOQUA Project received funding from the European Union's Horizon 2020 research and innovation programme under grant agreement No. 689817.

ACKNOWLEDGMENTS

We want to thank all numerous experts from the government ministries, academics, and the private sector for their valuable

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information on this topic. A special thank you is dedicated to Jean-Baptiste Dussaussois (NOBATEK/INEF4), Evelyn Herrera (Bremen Overseas Research and Development Association), Eoghan Clifford (National University of Ireland, Galway), Louise Hannon, J. Kihila (National University of Ireland, Galway), Maria Augusta Hermida Palacios (Universidad de Cuenca, Ecuador), Andrés Alvarado (Universidad de Cuenca, Ecuador), Nicolás Salmon (Yes Innovation) from the INNOQUA Project Consortium under the EU Horizon 2020 for providing information for the comparative analysis and overview on pollution control measures in the different countries; and Prerna Prasad and Karthik Seshan from CDD Society, India for their support in gathering information on Indian regulations and in the review process. We further want to express our gratitude to Christoph Sodemann for his coordination support and Dr. Abhijit Banerjee for networking assistance.

WITH CONTRIBUTION FROM

Evelyn Herrera (INNOQUA Project Consortium, EU Horizon 2020, Bremen Overseas Research and Development Association), Eoghan Clifford (INNOQUA Project Consortium, EU Horizon 2020, National University of Ireland, Galway), Jean-Baptiste Dussaussois (INNOQUA Project Consortium, EU Horizon 2020, NOBATEK/INEF4), Louise Hannon, J. Kihila (INNOQUA Project Consortium, EU Horizon 2020, National University of Ireland, Galway); Maria Augusta Hermida Palacios (INNOQUA Project Consortium, EU Horizon 2020, Universidad de Cuenca, Ecuador), Andrés Alvarado (INNOQUA Project Consortium, EU Horizon 2020, Universidad de Cuenca, Ecuador), Nicolás Salmon (INNOQUA Project Consortium, EU Horizon 2020, Yes Innovation), Prerna Prasad (CDD Society, India), Karthik Seshan (CDD Society, India).

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Conflict of Interest: The authors declare that the research was conducted in the absence of any commercial or financial relationships that could be construed as a potential conflict of interest.

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