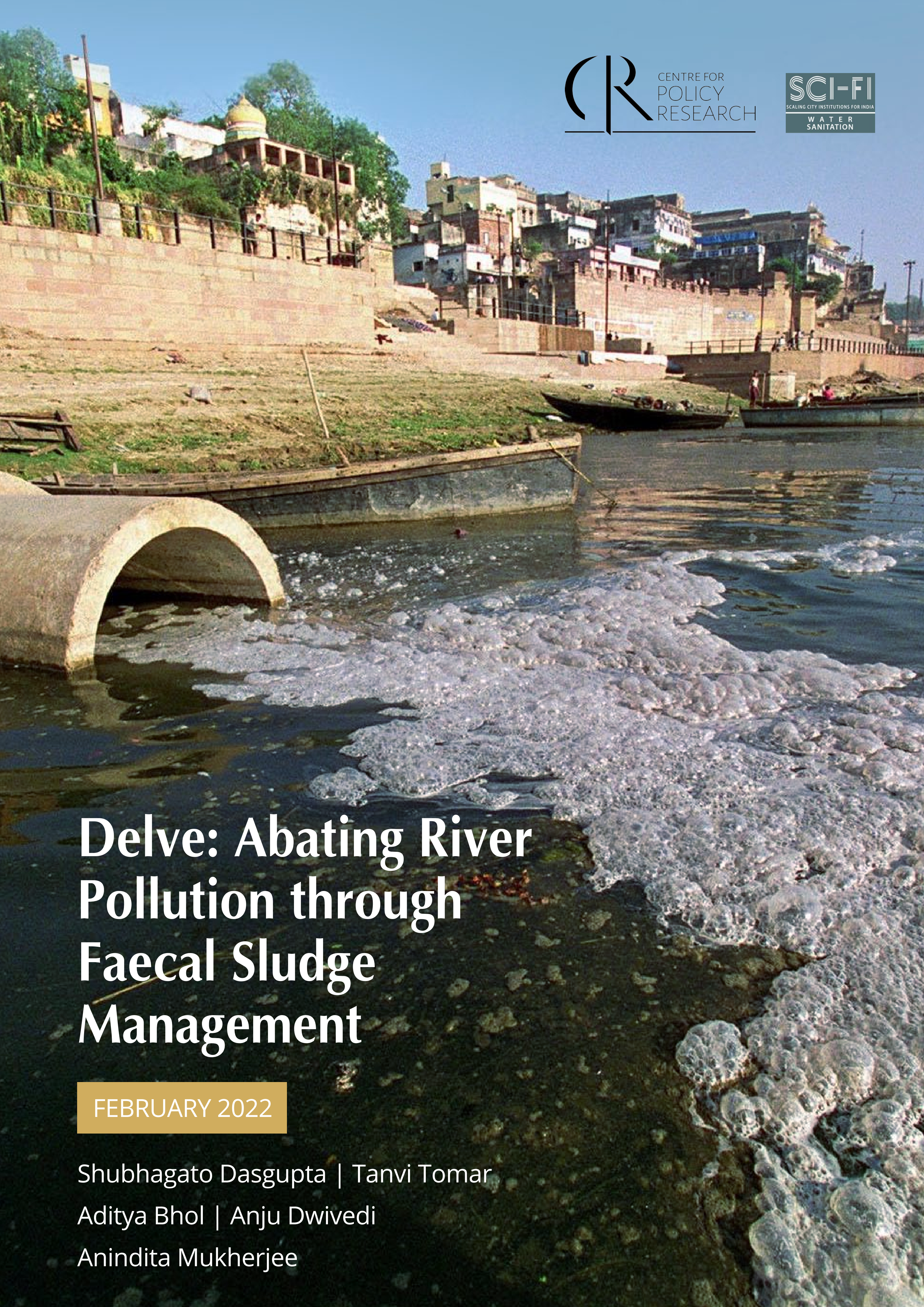

CENTRE FOR POLICY RESEARCH

SCI-FI
SCALING CITY INSTITUTIONS FOR INDIA
WATER SANITATION

Delve: Abating River Pollution through Faecal Sludge Management

FEBRUARY 2022

Shubhagato Dasgupta | Tanvi Tomar
Aditya Bhol | Anju Dwivedi
Anindita Mukherjee

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AUTHORS

Shubhagato Dasgupta, Tanvi Tomar, Aditya Bhol, Anju Dwivedi, Anindita Mukherjee

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List of Abbreviation

AMRUT: Atal Mission for Rejuvenation and Urban Transformation

AU: Assessment Unit

BCM: Billion Cubic Meter

BIS: Bureau of Indian Standards

BOD: Biological Oxygen Demand

CAA: Constitutional Amendment Act

CAG: Comptroller and Auditor General

CGWB: Central Ground Water Board

COD: Chemical Oxygen Demand

CPCB: Central Pollution Control Board

CT: Community Toilet

CWC: Central Water Commission

E. Coli: Escherichia Coli

ENVIS: Environmental Information System

EPA: Environment Protection Act

EPR: Environment Protection Rules

FC: Faecal Coliform

FS: Faecal Sludge

FSSM: Faecal Sludge and Septage Management

FSTP: Faecal Sludge Treatment Plant

GAP: Ganga Action Plan

GEC: Groundwater Estimation Committee

GIS: Geographic Information System

GOI: Government of India

GW: Ground Water

HO: Hydrological Observation

IHL: Individual Household Latrine

ISRO: Indian Space Research Organisation

IWRM: Integrated Water Resource Management

JNNURM: Jawaharlal Nehru National Urban Renewal Mission

KPI: Key Performing Indicators

MLD: Million liter per day

MoEFCC: Ministry of Environment, Forest and Climate Change

MoHUA: Ministry of Housing and Urban Affairs

NCT: National Capital Territory

NFSSM: National Faecal Sludge and Septage Management

NGT: National Green Tribunal

NLCP: National Lake Conservation Plan

NRCD: National River Conservation Directorate

NRCP: National River Conservation Plan

NWMP: National Water Monitoring Programme

OSS: On-site Sanitation

PCA: Public Census Abstract

RNA: Ribonucleic Acid

SBM: Swachh Bharat Mission

SDG: Sustainable Development Goal

SeTP: Sewage Treatment Plant

ST: Statutory Town

T. Coli: Total Coliform

TSS: Total Suspended Solids

UIDSSMT: Urban Infrastructure Development Scheme for Small and Medium Towns

UIG: Urban Infrastructure Governance

UN: United Nations

WQAA: Water Quality Assessment Authority

WQM: Water Quality Monitoring

WHO: World Health Organisation

WRIS: Water Resource Information System

Executive Summary

One of the primary ways to curb river water pollution in India is through effective faecal sludge management (FSM). The Government of India (GOI)'s flagship sanitation programme Swachh Bharat Mission (SBM) – which addresses the mammoth task of making India open defecation free (ODF) through widespread toilet construction, followed by planning for a sustainable ODF+ (toilet with water, maintenance and hygiene) and ODF++ (toilets with sludge and septage management) framework – is a big step in that direction. While there is no agreement on the extent of success of toilet construction under Swachh Bharat Mission (SBM) Grameen and Urban, the focus on the sanitation sector triggered by the programme has been monumental. It has underscored the need to understand and improve the entire sanitation value chain to ascertain safe disposal and possible reuse of faecal sludge and wastewater as vital goal that adheres to the Sustainable Development Goals.

In India, AMRUT (Atal Mission for Rejuvenation and Urban Transformation) cities and Class I cities collectively account for around 60 per cent of the total urban population. These bigger cities of India, also happen to be the only cities with sewage treatment plants (STP's). However, not all of these urban agglomerations have STPs. It is, thus, imperative to chalk out the cities which are potential beneficiaries of large infrastructure investments pertaining to water and sanitation under the flagship government scheme of AMRUT and the ones which are left out from its purview for devising future strategy.

This study attempts to arrive at a comprehensive understanding of water pollution caused by untreated urban and rural wastewater. In doing so, it explores the correlation between river and groundwater pollution. Further, the study aims to provide a clear understanding of various faecal sludge (FS) indicators associated with water pollution and the interlinkages between surface and groundwater pollution due to FS loading; such an understanding is critical for abating pollution through FSM, which is still at a nascent stage in the country.

The presence of multiple institutions to address and reduce surface and groundwater pollution poses difficulties in sourcing and collating data and positing hypotheses based on holistic analyses. The fact that data from different sources has been used in this study only highlights the need for standardisation of data and its public provision for academic and policy analyses on river and groundwater pollution abatement.

Finally, this study investigates the country's most polluted river stretches based on violation of the Central Pollution Control Board (CPCB) STP effluent standards and other environmental norms. For groundwater, the study adheres to Central Ground Water Board (CGWB) data on nitrates violation to establish the case of groundwater pollution through FS. The key objective of this study is to understand the correlations between urbanisation, sanitation infrastructure, and pollution in major rivers and ground water in India. In doing so, the study attempts to focus on the major pollutants from untreated urban wastewater such as Faecal Coliform and total coliform to make a case for adequate FSM in the cities of India.

Image Source: www. indianexpress.com

Introduction

Background

India's booming population and rapidly expanding urban areas, in the absence of proper treatment technology, have adversely impacted its water resources resulting in polluted surface water bodies and overexploited groundwater resources. It is estimated that around 70 percent of surface water in India is unfit for human consumption (Hirani & Dimble, 2019). This alarming statistic can be attributed to almost 80 percent of untreated wastewater that enters rivers and other water bodies (DTE Staff, 2016). Restoration of Polluted River Stretches Report by (Central Pollution Control Board,2018) has identified 317 polluted river stretches on 293 rivers and tributaries. India's water bodies are rife with pollution from untreated sewage and septage, thus, endangering the lives of millions of people depending directly or indirectly on these polluted river stretches. With the uncertainties triggered by the current pandemic, the situation becomes graver. While reports; thus far, have found only contact and respiratory transmission of the coronavirus, studies have also expounded on the survival of the virus in its entirety or as RNA fragments in water and human feces (Giacobbo et al., 2021). It appears that transmission of the virus through water and faecal-oral routes cannot be ruled out yet. The COVID-19 virus is a new pathogen, disease-causing pathogens like Escherichia Coli (E.coli), Faecal Coliform (FC) and worms are already found in high traces in the water in India (Rayasam et al., 2020). This has grave implications with the provision of drinking water in the form of treated tap water remaining low in urban and rural areas. And if the survival of the coronavirus in untreated and even chlorinated water for two days is corroborated by more scientific studies, it would have severe consequences for India (Satheesh, 2020)..

India is the seventh-largest country in the world with a geographical area 32,87,263 km² (2.45 percent of the world's land resources) and the second-most populous country with over 1.2 billion people (17.5 percent of the World's population). It holds 4 percent of the world's freshwater resources. Access to water is a significant factor in development. Every year India receives 4,000 BCM of water during monsoon season, of which the available water for use is 1,869 BCM. Out of this total available water, the utilizable water from surface water resources is 690 BCM and that from groundwater resources is 433 BCM, adding up to only 1,123 BCM (Central Water Commission, n.d.). As per the Central Water Commission (CWC), the per capita availability of water is 1,588 cubic meter per year (2010) which is sufficient against the benchmark value of 1,000 cubic meters per capita per year as a 'Water Stressed" condition. In the shadow of continued population growth, water availability projected for 2025 is 1,434 cubic meter per capita per year.

But these figures are highly debatable. As per a report released by NITI Aayog in June 2018, India is suffering 'the worst water crisis in history' ("India sufffering worst water crisis", 2018). Further, according to a 2018 report by Water Aid, India tops the list of waterless countries with 19.33 percent of the total population (an estimated 163 million people out of India's population of 1.3 billion or more than 1 in 10) without access to clean water. And the impact of pollution does not stop here. A 2019 World Bank Report (Damania et al., 2019) reveals considerable economic losses for the country arising from this situation. The cost of environmental degradation is estimated to be INR 3.75 trillion ($80 billion) a year. The health costs related to water pollution are estimated at INR 470-610 billion a year (Damania et al., 2019); release of pollution upstream lowers economic growth in downstream areas, reducing GDP growth in these regions by up to a third, it is estimated. Apart from the economic cost, lack of water, sanitation and hygiene costs 400,000 lives per year in India Water and Sanitation Program, 2011. Hence, the country is at the brink of turning into a land of future water wars.

The government and citizens of India have identified this chronic issue that needs immediate attention. The country has seen a string of judicial rulings involving urban rivers in recent years. In 2019, GOI established the Ministry of Jal Shakti in 2019 by merging the Ministry of Water Resources, River Development and Ganga Rejuvenation with the Ministry of Drinking Water and Sanitation and further nested its existing ministries for a complete overhaul of the system. The Ministry of Water Resources, River Development and Ganga Rejuvenation was the apex body for formulation and administration of rules and regulations relating to the development and regulation of the water resources in India. The ministry was formed in January 1985 following the bifurcation of the then Ministry of Irrigation and Power. The Ministry of Drinking Water and Sanitation has been formed in 2011.

CWC and CPCB have established over 1500+ monitoring stations on major rivers for continuous monitoring of water quality. CWC, Ministry of Water Resources and Indian Space Research Organisation (ISRO), Department of Space joined hands for the development of Web-enabled Water Resources Information System (WRIS) of India (India Water Resources Information System, n.d.). Considering river basins as the basic hydrological units for water resources planning and management, the country is divided into 25 basins and 101 sub-basins under the India-WRIS project based on the digital elevation model. Parallel functioning of government institutions often lead to overlapping information, and India is no exception. Each organisation working in this sector has adopted different methodologies and criteria for basin classification and hence arrived at different basins and their areas.

Introduction

Even though the country has made commendable progress in institutional arrangements and water quality monitoring, there has been a lack of sectoral progress. The sanitation sector still remains a significant contributor to pollution due to the dearth of proper conveyance and treatment infrastructure. According to the estimates of the National Green Tribunal vide order no.673/2018, more than 60 percent of sewerage generated by urban India is untreated and enters water bodies, thus contributing to 75-80 percent of water pollution by volume. Sewage generation and treatment capacity of the cities and towns along polluted river locations are inadequate with treated/untreated and partially treated municipal wastewater flowing into the rivers, causing pollution in the downstream reaches. Issues regarding the regular operation of these STPs and compliance with discharge standards have been identified. New standards for STPs (with BOD-10 mg/l, COD-50mg/l, Suspended Solids -10mg/l, T-Nitrogen – 10 mg/, Total Coliform < 230 MPN, pH 6.5 -9.0, NH4-N 5 mg/l, PO4-p 2 mg/l) have been proposed to encourage the use of treated water for non-potable domestic, commercial or industrial use, as well as to reduce water pollution.

Rationale

The pollution of water bodies has been constantly increasing. Since the 1980s and, more importantly, the 1990s, especially after the liberalisation of the economy, India has been on a staggering growth path, with substantial improvements in the manufacturing and services industry. Consequently, India has been rapidly urbanising. According to the 2011 Census, the urban population grew to 377.1 million compared to 286.1 million in the 2001 census showing a growth of 2.76 per cent per annum during 2001-2011. The level of urbanisation in the country rose from 25.7 per cent in 1991 to 27.82 per cent in 2001 and 31.14 per cent in 2011 – an increase of 3.3 percentage points during 2001-2011 compared to a rise of 2.1 percentage points during 1991-2001. However, sanitation infrastructure hasn't kept pace with this rapid urbanisation in India. Census 2011 reports only 36 per cent of urban households in Statutory Towns (ST) and 14 per cent in Census Towns (CT) with toilets are connected to sewers. Around 42 per cent of households in STs and 62 per cent in CTs still rely on on-site sanitation (OSS) systems, and 12 and 18 per cent of households in STs and CTs respectively practice open defecation.

The recent Clean India initiative under the flagship SBM focused on toilet construction and has led to substantial access to toilets for households in urban and rural areas. Unfortunately, wastewater treatment and safe disposal remain an elusive goal due to the inadequacy of wastewater treatment infrastructure and their treatment capacities. According to a 2015 report of CPCB the total 816 STPs across 35 states of India, only 522 are operational, as shown in Table 1. The operational treatment facilities are operating at 81 per cent treatment capacity. Some of these STPs were built by the National River Conservation Directorate (NRCD) under central assistance, some were built by the state water and sewerage boards, and small number are private constructions. Several sewerage projects were approved under the JNNURM's UIG and UIDSSMT schemes. CPCB also reported that a total of 145 STPs were proposed to be built (Board, 2015).

TABLE 1: Status of Treatment Plants in India, 2015

Sl. No.	State/Union Territory	Capacity of Municipal STPs	No. of Municipal STPs	Operational Capacity (MLD)	No. of STPs Operational	Non-operational Capacity (MLD)	No. of STPs Non-operational	Under Construction Capacity (MLD)	No. of STPs Under Constructions	Proposed Capacity (MLD)	No. of STPs Proposed
1	Andhra Pradesh	247.27	12	156.27	9	-	-	91	3	-	-
2	Arunachal Pradesh	-	-	-	-	-	-	-	-	-	-
3	Andaman & Nicobar Islands	-	-	-	-	-	-	-	-	-	-
4	Assam	0.21	1	0.21	1	-	-	-	-	-	-
5	Bihar	124.55	6	99.55	5	25	1	-	-	-	-
6	Chandigarh	314.5	5	314.5	5	-	-	-	-	-	-
7	Chhattisgarh	-	-	-	-	-	-	-	-	-	-
8	Delhi	2693.7	35	2671.2	34	22.5	1	-	-	-	-
9	Daman Diu & Dadra Nagar Haveli	-	-	-	-	-	-	-	-	-	-
10	Goa	74.58	7	34.5	4	-	-	40.08	3	-	-
11	Gujarat	3062.92	51	2111.64	32	498	4	359.5	8	93.78	7
12	Haryana	852.7	41	805	38	2.7	2	45	1	-	-
13	Himachal Pradesh	114.72	66	79.51	36	35.21	30	-	-	-	-
14	Jammu & Kashmir	264.74	19	145.74	15	2	1	117	3	-	-
15	Jharkhand	117.24	15	117.24	15	-	-	-	-	-	-
16	Karnataka	1304.16	57	1112.05	44	-	-	192.11	13	-	-
17	Kerala	152.97	10	112.87	6	3	1	37.1	3	-	-
18	Lakshadweep	-	-	-	-	-	-	-	-	-	-
19	Maharashtra	5160.36	76	4683.9	60	344.5	10	131.96	6	-	-
20	Madhya Pradesh	482.23	17	475.48	14	6.75	3	-	-	-	-
21	Manipur	-	-	-	-	-	-	-	-	-	-

Sl. No.	State/Union Territory	Capacity of Municipal STPs	No. of Municipal STPs	Op-erational Capacity (MLD)	No. of STPs Op-erational	Non-op-erational Capacity (MLD)	No. of STPs Non-op-erational	Under Construc-tion Capacity (MLD)	No. of STPs Under Construc-tions	Proposed Capacity (MLD)	No. of STPs Proposed
22	Meghalaya	1	1	-	-	1	1	-	-	-	-
23	Mizoram	10	1	-	-	-	-	10	1	-	-
24	Nagaland	-	-	-	-	-	-	-	-	-	-
25	Odisha	385.54	13	158.04	7	-	-	227.5	6	-	-
26	Puducherry	68.5	6	17.5	3	-	-	51	3	-	-
27	Punjab	1245.45	86	921.45	38	15.2	4	276.7	31	32.1	13
28	Rajasthan	865.92	63	384.5	16	-	-	149.3	11	332.12	36
29	Sikkim	31.88	11	8	1	5	1	18.88	9	-	-
30	Tamil Nadu	1799.72	73	1140.83	33	5.17	1	521.08	28	132.64	11
31	Telangana	685.8	18	634.8	17	-	-	51	1	-	-
32	Tripura	0.05	1	0.045	1	-	-	-	-	-	-
33	Uttar Pradesh	2646.84	73	2372.25	62	89.59	7	170	3	15	1
34	Uttrakhand	152.9	24	90.75	10	-	-	39.15	12	23	2
35	West Bengal	416.9	28	235.36	16	181.54	12	-	-	-	-
Total	**23277.4**	**816**	**18883.2**	**522**	**1237.16**	**79**	**2528.36**	**145**	**628.64**	**70**	

SOURCE: Central Pollution Control Board, 2015

Cognizant of the necessity of building the entire sanitation value chain, the GOI introduced the Atal Mission on Rejuvenation and Urban Transformation (AMRUT) and Smart Cities Schemes in 2015, through which there has been an emphasis on building STPs to ensure proper treatment and safe disposal of urban liquid waste. Further, in February 2017, the government introduced a seminal policy guideline – National Policy on Faecal Sludge and Septage Management. Acknowledging the limited scope of Smart Cities and AMRUT schemes- which benefit only large cities of India, the FSSM policy frames the roadmap for implementing faecal sludge treatment plants (FSTPs) in small towns where households rely mainly on OSS such as toilets with septic tanks and pits as their containment units. Subsequently, encouraged by the National Policy on FSSM, state sewerage boards have identified more than 7000 small towns where FSTPs need to be built to add to the sanitation value chain after the construction of toilets.

With 121 operational FSTP's, 215 under construction and 100 more (co-treatment facility) in tendering stage (MoHUA STP Data, 2020), the government is gearing up to restore the water quality of polluted river stretches. But the infrastructure development for sewage treatment, which is the terminal stage of the sewage journey, has been inadequate. The crucial intermediate steps such as proper storage, transportation and emptying are often overlooked, leaving a quantum of wastewater that is heavy to tackle. The resultant of this is 60 percent of sewerage generated by urban India remaining untreated and entering water bodies, thus contributing to 75-80 percent of water pollution by volume. Tackling this critical issue calls for a holistic approach by encapsulating the intermittent stages of the faecal matter journey (containment, transportation and disposal), determining pollution loading at each step and putting measures in place for curbing it- in other words, abating pollution through FSM (NFSSM Alliance & NITI Aayog, 2021).

Study Objectives

- Detailing acts, policies and environmental norms addressing river and groundwater pollution in India
- Understanding the criticality of ground and surface water resources in terms of levels of pollution due to FS
- Understanding ground and surface water resources of India and FS-related water quality indicators
- Identifying Key Performing Indicators (KPI's) related to FSM ground and surface water resources in India
- Assessing KPI's for identifying the study area
- Understanding the criticality of river water resources in terms of levels of pollution.
- Assessing current requirements and illustrating a policy gap analysis for river pollution

Limitations

Owing to the dearth of available data on the sources of FS loading in water bodies, the study is limited to assessing indicators directly monitored by various government institutions in India. Since it is a pan India study, field surveys are kept outside the purview of study and the entire study is drawn from the secondary data available. Thus, the study does not take in account FC loading due to animal excreta. Further, it limits itself to considering FC in terms of the sources resulting in elevated nitrates level in groundwater, keeping other contributors such as agriculture runoff and industrial discharge outside its purview.

For river water quality monitoring data, CPCB releases river water quality monitoring data yearly. The data is not available category-wise (eg: pre and post monsoon etc.) which makes it difficult to analyse it for certain points of time. For all parameters, minimum and maximum figures are available. That accounts for all ranges of variations across seasons. The average of these readings has been taken in the study which helps in sidestepping the biases in readings which might arise from first flush.

Image Source: www.cnbctv18.com

Literature Review

Review of Academic Papers

River pollution is a serious and rising concern in India. Due to the rapidly increasing population and the resulting spike in urbanisation, industrialisation and land development along the river basins, many Indian rivers are experiencing very high rates of pollution and degradation (Suthar et al., 2010). Many rivers may be the endpoints of effluents discharged from these industries (Phiri et al., 2005). Additionally, improvements in wastewater and sewage treatment infrastructure have not kept pace with the rapid population and industrial growth occurring over the past few decades, aggravating the stress on these rivers (Hamner et al., 2013).

Not only does the wastewater from urban runoff degrade the river bodies, it also poses a considerable risk to public health, for many settlement areas near the rivers are heavily dependent on them for the most rudimentary yet essential tasks (like bathing, drinking, irrigation etc.) (Suthar et al., 2010). When adequate sanitation is lacking, human faecal contamination of water transmits microorganisms that cause diarrhoeal diseases, including cholera, and equally dangerous non-diarrhoeal diseases such as hepatitis A (Hamner et al., 2007). It is universally accepted that higher sewage contamination leads to an increased number of coliform and FC in natural water bodies (Vincy et al., 2017). Rapid development of townships around the lower reaches may have aggravated the degradation of the river water quality. In addition, toilets in the urban agglomerations are located along the river banks. They have their outlets into the river systems, thus adding to the untreated sewage content of these rivers.

A number of factors closely related to river pollution and linked to the problem of sewage contamination were shown to be strong predictors for water-borne disease (Hamner et al., 2007). Faecal contamination is considered to be the main contributor of enteric pathogens to natural water resources. Infections originating from such sources, especially diarrhoea and typhoid fever, are highly endemic to India (Abhirosh et al.,2009). Visual observations and extremely high levels of FC and Biological Oxygen Demand (BOD) indicated the presence of faecal bacteria and organic waste (Hamner et al., 2007). Human faecal material is generally considered the greater menace to human health as it is more likely to contain human enteric pathogens (Scott et al., 2013). Therefore, the most important and desired aspect of water quality is freedom from contamination with faecal matter. It may thus be stated that the higher the level of indicator bacteria, the greater the level of faecal contamination and greater the risk of water-borne diseases (Pipes, 1982).

In a study titled 'Water Quality Assessment of River Hindon at Ghaziabad, India', conducted on a river passing through a rapidly urbanising city, two of the six testing sites were observed to have a higher level of BOD than others, possibly due to the mixing of wastewater from nalas (outfalls or drainage systems for the discharge of effluents) from the city and industries (Suthar et al., 2010) s. Further, the constant high load of the pollution indicator E. coli: considered the most accurate representation of FC, indicated the water body had severe sewage pollution, making FC an extremely relevant criterion while evaluating the level of river pollution due to sewage disposal into rivers (Vincy et al., 2017).

Another study on the river Ganga highlighted the Indian Council of Medical Research's National Cancer Registry Programme's announcement in 2012 that the Ganga was polluted with high levels of heavy metals and other toxic industrial waste responsible for various forms of cancer (Paul, 2017). Moreover, exposure to untreated sewage has led to simple practices of bathing and washing in this river being significantly linked to the contraction of water-borne diseases, including acute gastrointestinal infection, life-threatening cholera, dysentery, Hepatitis A and typhoid (Hamner et al., 2013).

Although the presence of FC does not explicitly prove contamination with pathogenic microorganisms, the presence and levels of faecal bacteria serve as an indicator of pathogenic organisms that may be present in faeces. Moreover, the high levels of BOD and FC count reveal an extremely high level of pollution. The impact of heavy sewage disposal by the heavily populated city of Varanasi on the downstream monitoring site of the river is not new. It is likely that the pollution load from raw sewage entering Ganga in Varanasi has increased over time due to the cumulative effects of continued discharges linked with population increase and deterioration of the sewerage network. The study titled 'Sewage Pollution of the River Ganga: An Ongoing Case Study in Varanasi, India', used logistic regression and found two testing sites with minimal access to sewerage to have the highest incidence of cholera and other water-borne diseases, 12 months before which the study was conducted (Hamner et al., 2007).

For groundwater, the path has not been this linear in India, mainly due to the absence of monitoring data explicitly pertaining to faecal contamination in groundwater. A study by IHE Delft (n.d.) on FSM tries to build upon OSS and groundwater pollution . It shows that the concentration and volume of FS are also greatly influenced by the inflow/infiltration of leachate into the environment from the system or groundwater into the system. The filling rate of systems will be slower if there is more leaching, resulting in a thicker FS. The permeability of containment systems is influenced by whether they are unlined, partially lined, completely lined, and connected to drain fields or soak pits, and the quality of construction. If systems are permeable, the amount of inflow and infiltration will be affected by the type of soil and the groundwater level. The exchange of groundwater with FS can result in groundwater contamination which is made worse during heavy and extensive rain due to flooding and the rise of the groundwater table. This is of particular concern in low-income countries where pit latrine and septic tank builders are frequently from the informal sector, they are often not aware of the consequences of FS leaching into groundwater or may not have the means to determine the groundwater level (Delft, n.d.).

Bakare et al. (2012) and Still and Foxon (2012) indicated that moisture content decreases with sludge depth because the unlined pits used in their studies were located above the groundwater table, implying that there was a net movement of water out of the pits. Thus, the exchange of sludge and water between the pits and the surrounding soils presents risks of groundwater pollution. The health of the residents that consume water in such contaminated aquifers is compromised (Kimuli et al., 2016).

Kulabako (2005) and Kulabako et al. (2007) conducted geo-hydrological studies in the slums of Bwaise, Uganda and found out that the groundwater table rises to less than 1.5 metres below the ground during the rainy season and this favors the ingress of water from the bottom layers of the surrounding soil into the pits (Kimuli et al., 2016).

A study titled 'Groundwater Pollution and Contamination in India: The Emerging Challenge' shows that non-point pollution caused by fertilisers and pesticides used in agriculture, often dispersed over large areas is a significant threat to fresh groundwater ecosystems. Intensive use of chemical fertilisers in farms and indiscriminate disposal of human and animal waste on land result in leaching of the residual nitrate causing high nitrate concentrations in groundwater (Kumar & Shah, 2006).

Pollution of groundwater due to industrial effluents and municipal waste in water bodies is another major concern in many cities and industrial clusters in India. A 1995 survey undertaken by CPCB identified 22 sites in 16 states of India as critical for groundwater pollution, the primary cause being industrial effluents. A recent survey undertaken by the Centre for Science and Environment in eight places in Gujarat, Andhra Pradesh and Haryana reported traces of heavy metals such as lead, cadmium, zinc and mercury. The shallow aquifer in Ludhiana city, the only source of its drinking water, is polluted by a stream that receives effluents from 1300 industries. Excessive groundwater withdrawal from coastal aquifers has led to induced pollution in the form of seawater intrusion in Kachchh and Saurashtra in Gujarat, Chennai in Tamil Nadu and Calicut in Kerala. All these factors make it difficult to pronounce FC is the primary reason for groundwater contamination.

Studies have been carried out to understand the interlinkage between surface water and groundwater as well. According to a study conducted by the US Geological Survey, point sources of contamination to surface water bodies are an expected side effect of urban development. Examples of point sources include direct discharges from STPs, industrial facilities, and stormwater drains. These facilities and structures commonly add sufficient loads of a variety of contaminants to strongly affect the quality of the stream for long distances downstream. Contaminants in streams can easily affect groundwater quality, especially where streams usually seep into groundwater, where groundwater withdrawals induce seepage from the stream, and where floods cause stream water to become bank storage. Point sources of contamination to groundwater can include septic tanks, fluid storage tanks, landfills, and industrial lagoons (Winter et al.,1998).

Literature Review of Government Reports on River water and Ground-water Pollution

In 2009, following rising concerns about water pollution in India, state stakeholders reached a consensus to flag it as an important subject. This was a critical moment in the history of India in the context of water pollution as for the first time, state stakeholder and not the relevant ministries – Ministries of Environment and Forests, Central Pollution Control Board and Ministry of Water Resources and their subsidiary departments, weighed in on the matter of water pollution in India. Moreover, for the first time, the Comptroller and Auditor General (CAG) of India underscored the alarming rate of water pollution in India and called for relevant stakeholders to converge their efforts to address the issue. Subsequently, in 2010 a detailed two-day International Conference on Environment Audit: - Concerns about Water Pollution was held in March 2010. This conference was attended by various civil society organisations, government agencies, international agencies and regulatory bodies. The heads of supreme audit institutions from Austria, Bhutan, Maldives and Bangladesh also shared their concerns about water pollution. The conference flagged many vital areas of concern about river, lake and groundwater pollution.

The audit report put together by the CAG (2012) had the following audit objectives – a) prepare an inventory of water sources to assess the overall status of quality of water in rivers, lakes and groundwater in India; (b) assess risks of polluted water to health of living organisms and the impact on environment; (c) review adequacy of policies, legislations and programmes and effectiveness of institutions for pollution prevention, treatment and restoration of polluted water in rivers, lakes and ground water; (d) carry out a holistic assessment of programmes for pollution prevention, treatment and restoration of polluted water in rivers, lakes and ground water to understand gaps in their planning, implementation and monitoring; (e) make an assessment of funds utilisation in an efficient and economic manner to further the aim of reduction of water pollution; (f) review the efficacy of mechanisms such as water quality testing put in place by the government to sustain measures to tackle water pollution; and (g) recommend course correction measures to relevant institutions to prevent further water pollution in India.

This was a landmark document that strengthened the conviction of state authorities to focus attention on river water and groundwater pollution. Further, it reinvigorated the Indian government's resolve to undertake a hydrological project and prepare an inventory of water resources (initiated by a World Bank project in 1996). A report was collectively drafted by the government of India and the government of the Netherlands. These instructions to policymakers of water pollution in India specified undertaking a nationwide hydrology study and revising the water quality monitoring. Subsequently, the National Water Policy of India was revised in 2002, for the first time since 1987, incorporating these suggestions to acknowledge the scarcity and, thus, preserve water resources with a focus on developing an information system to monitor surface water and groundwater quality and quantity. Water resource management was made an agenda under the national water policy for the first time.

With the National Water Policy of 2012, Integrated Water Resources Management (IWRM) was introduced taking river basin / sub-basin as a unit for planning, development, and management of water resources. This step was taken to conclusively devise a water management strategy for identified hydrological units suggested in the previous policy. Concurrently, it was directed in the new policy of 2012 that the departments / organisations at the centre/state government levels should be accordingly restructured and made multi-disciplinary. The new water policy also proposed establishing a National Water Informatics Centre to regularly collect, collate and process hydrologic data from all over the country, conduct the preliminary processing, and maintain it in an open and transparent manner on a GIS platform. This has been subsequently instituted into the database. The implementation of a web-enabled Water Resources Information System popularly known as India-WRIS was initiated through a Memorandum of Understanding signed on 3 December 2008. The

MoU was signed between the Central Water Commission (CWC), Ministry of Water Resources, River Development and Ganga Rejuvenation (now Ministry of Jal Shakti) and the Indian Space Research Organisation (ISRO), Department of Space. The CWC funded this project.

However, the hydrological study of India has occurred in a staggered manner. Due to the diversity of state stakeholders and institutions responsible for surface/river water and groundwater management and their water quality monitoring, reports on water quality have been engendered in a piecemeal manner. Moreover, many of these reports and documents do not necessarily address the effects of urbanisation on river water and groundwater pollution in India. CPCB is one of the institutions responsible for water quality monitoring in India. It released a document 'Restoration of Polluted River Stretches' in 2017, which discussed in detail and highlighted the major river basins in India that were adversely impacted by untreated sewage and septage from urban areas of India. It estimated a gap of 13,196 MLD of treatment capacity in 659 towns situated along rivers in India and a requirement of Rs 32,990 crore to bridge the gap of sewage treatment in these towns alone. Based on the prioritisation of polluted river stretches, the study identified 317 polluted stretches comprising these 659 towns. 110 of the 659 towns fall under priority level I based on BOD and FC in a total of 48 highly polluted stretches. Assam, Odisha, West Bengal (WB) and Uttar Pradesh (UP) account for most of these polluted stretches.

Besides this report, other independent studies and news articles talk about the alarming rates of contamination in the river bodies. Concurrently, standalone studies talk about groundwater contamination in various parts of India, which highlight mostly chemical contamination and depleting groundwater sources. However, comprehensive reports or documents discussing the impact of wastewater discharge on surface water and groundwater are scant.

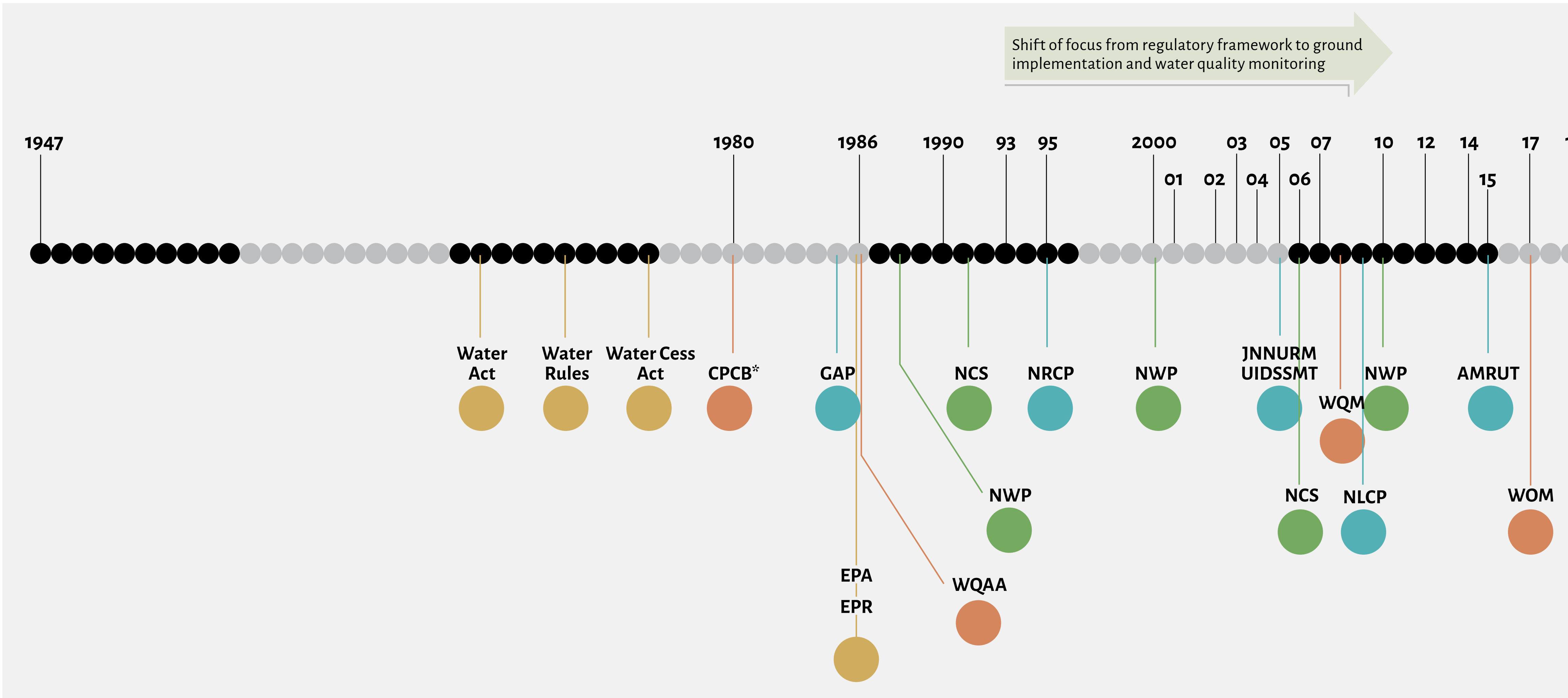
In terms of sanitation infrastructure, the report 'Inventorization of Sewage Treatment Plants' by (Central Pollution Control Board,2015) furnishes information on the inventory of STPs across all states, including their existing and operational treatment capacities. The document revealed that existing STPs were either non-functional or sub-optimally functional across different city class sizes, thus, leading to incessant disposal of untreated and inadequately treated wastewater into water bodies.

Over time, stakeholders have understood the importance of OSS systems – their higher prevalence in cities and further predominance due to the new toilet constructions under the ongoing SBM. Cognizant of the growing pressures to adhere to the stringent water pollution norms, the latest NITI Aayog report 'Faecal Sludge and Septage Management in Urban Areas', addresses this concern and discusses service and business models to implement better integrated wastewater infrastructure and management (NFSSM Alliance & NITI Aayog, 2021).

Institutional Setup for River Water and Groundwater Pollution in India

Water is a state subject in India. However, laws pertaining to water – its usage, quality and so on - have often been formulated at the national level. The Ministry of Jal Shakti is the apex institution for developing policies on river water and groundwater in India. It is the overarching institution under which the Central Water Commission (CWC) and the Central Ground Water Board (CGWB) are instituted. The CWC is responsible for water accounting, management and settling water disputes. It is also responsible for surface water quality monitoring with a focus on river basins and lake conservation. CWC operative network and monitoring parameters are discussed in the previous section.

FIGURE 1: Evolution of Water Quality Monitoring Framework



PROGRAM

- Ganga Action Plan (GAP), 1985
- National River Conservation Plan (NRCP), 1995
- National Lake Conservation Plan (NLCP)
- Jawaharlal Nehru National Urban Renewal Mission (JNNURM)
- Urban Infrastructure Development Scheme for Small and Medium Towns (UIDSSMT)
- Swachh Bharat Mission (SBM)
- Atal Mission for Rejuvenation and Urban Transformation (AMRUT)

POLICY

- National Water Policy (NWP), 1987
- National Conservation Strategy and Policy Statement on Environment, (NCS) 1992
- National Water Policy, 2002
- National Environment Policy (NEP), 2006
- National Water Policy, 2012

WATER QUALITY MONITORING

- Designated Best Use Classification of Surface Water (CPCB), 1978
- Water Quality Assessment Authority (WQAA), 1986 – Protocol for Water Quality Monitoring
- Guidelines for Water Quality Monitoring (WQM), 2008
- Guidelines for Water Quality Monitoring (WQM), 2017

LEGISLATION

- Water (Prevention and Control of Pollution) Act, 1974
- Water (Prevention and Control of Pollution) Rules, 1975
- The Water (Prevention and Control of Pollution) Cess Act, 1977
- Environment (Protection) Act, (EPA) 1986
- Environment (Protection) Rules, (EPR) 1986

FIGURE 2: **Institutional Setup for Groundwater Pollution in India**

Constitutional Provision	▸ Ground Water not mentioned in constitution. Water as whole falls in schedule VII, State list. ▸ The 73rd and 74th CAA, 1992 regarding Panchayats and Municipalities visualizes functional responsibilities in respect of several aspects of ground water use for local governments.
The Indian Easement Act 1882	▸ As much of ground water is a dynamic resource which flows through defined channels, owners of land can not claim absolute ownership over water under their land.
The Water (Prevention and Control of Pollution) Act 1974	▸ Act also incorporates provisions for creating Central and State Pollution Control Boards only
The Environment (Protection) Act (EPA), 1986	▸ Central ground water authority (CGWA, statutory body) has been constituted under section 3 (3) of the environment (protection) act, 1986 to regulate and control development and management of ground water resources in the country. Deals with GW Legislation
Central Ground Water Board	▸ Subordinate office of the Ministry of Water Resources and is the National Apex Agency entrusted with the responsibilities of providing scientific inputs for management, exploration, monitoring, assessment, augmentation and regulation of groundwater resources of the country.

River Water Monitoring

The Central Pollution Control Bureau (CPCB) and Central Water Commission (CWC) are the two primary public institutions at the forefront of ongoing efforts to address river pollution in India. While CPCB is instituted within the Ministry of Environment and Forests, CWC is instituted within the Ministry of Water Resources (now named Ministry of Jal Shakti).

CPCB monitors water quality and has established a wide network of stations to assess and monitor different water sources. CPCB strictly has the function of being a monitoring agency. The nine core parameters specified under the National Water Quality Monitoring Programme (NWMP) assessed by CPCB's monitoring stations are – Temperature, pH, BOD, Conductivity, Dissolved Oxygen, Nitrates, Nitrites, FC and T.Coli. Based solely on BOD as a qualifying criterion, CPCB identified a number of polluted river stretches across various priority levels.

CWC is responsible for water accounting, management and settling water disputes. It operate a network of 878 Hydrological Observation (HO) stations in different river basins of the country to collect data on (i) water level; (ii) discharge; (iii) water quality; (iv) silt, and (v) selected meteorological parameters including snow observations at key stations. CWC currently monitor water quality at 531 key locations covering all the major river basins of India. At present, the water quality network covers 67 main rivers, 138 tributaries and 64 sub-tributaries.

Ground Water Monitoring

CGWB, a subordinate office of the Ministry of Water Resources, is the national apex agency entrusted with providing scientific inputs for management, exploration, monitoring, assessment, augmentation and regulation of groundwater resources of the country.

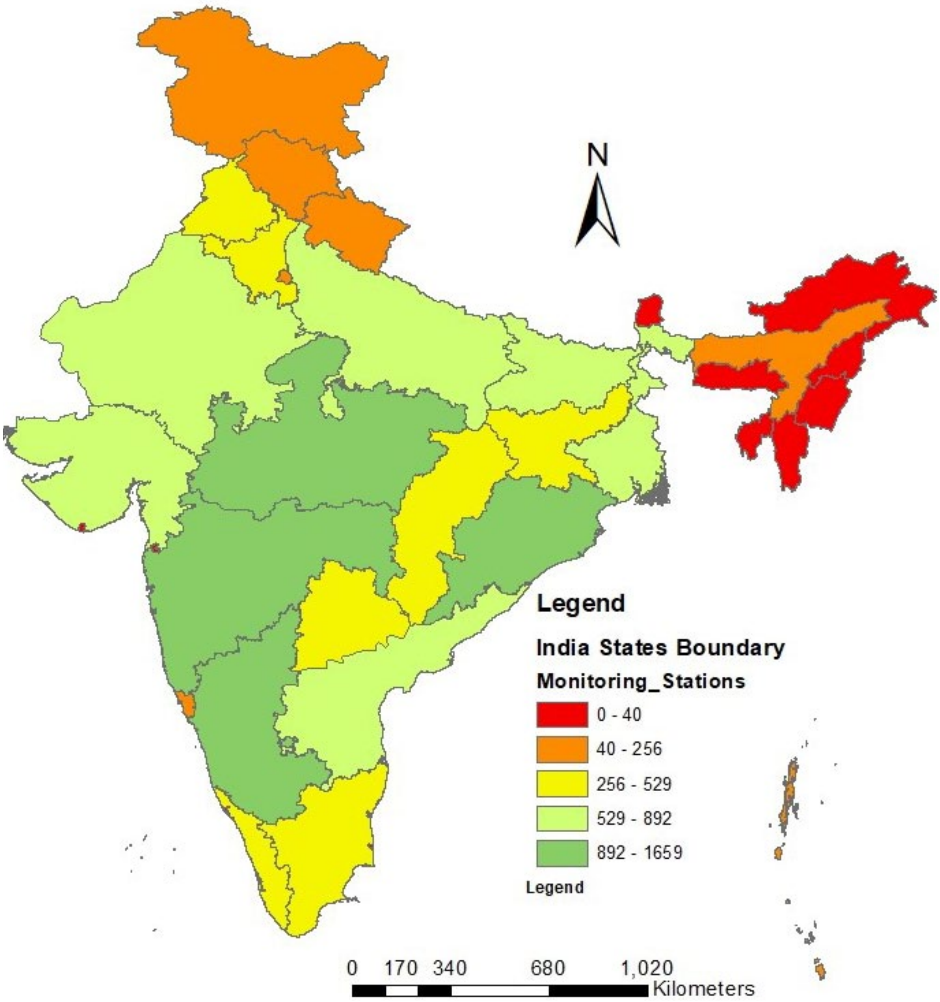
Established in 1970 by renaming the Exploratory Tube-wells Organisation under the Ministry of Agriculture, it was merged with the Groundwater Wing of the Geological Survey of India in 1972. The central office is situated at Faridabad. CGWB monitors a total of 15640 ground water observation wells.

CGWB has

- **18 Regional Offices each headed by a Regional Director,**
- **17 Divisional Offices each headed by an Executive Engineer and**
- **11 State Unit Offices for undertaking various activities in the country.**

The water levels are monitored four times a year in January, April/ May, August and November. Water samples are collected once in the year in April/May for groundwater quality monitoring. State governments also have a large number of stations and monitors as per their schedule. The map shows the state-wise monitoring stations of CGWB.

Figure 3: **State-wise Monitoring Stations of CGWB**



SOURCE: Central Ground Water Board, 2018

It can be inferred from Figure 3 that there is an inequitable distribution of monitoring stations across states. The highest concentration is seen in the states of Madhya Pradesh, Karnataka, Maharashtra and Odisha. Even though UP, Himachal Pradesh and Uttarakhand constitute the Ganga-Yamuna basin, very few stations are observed in this region. The north-east is the most sparsely covered region in this context in the country.

Addressing River Water Pollution

Data Sources

Central Pollution Control Bureau (CPCB) and Central Water Commission (CWC) are the two primary public institutions at the forefront of ongoing efforts to address river pollution in India. While CPCB is instituted within the Ministry of Environment, Forests and Climate Change, CWC is instituted within the Ministry of Water Resources (now named Jal Shakti Ministry).

CPCB monitors water quality and has established a wide network of stations to assess and monitor different water sources. CPCB strictly has the function of being a monitoring agency. The core parameters assessed by CPCB's monitoring stations are discussed in the previous section. The tables that follow show monitoring locations on multiple water bodies and priority listing of various river stretches as per CPCB norms.

Both CWC and CPCB adhere to the Guidelines on Water Quality Monitoring, 2017. However, in Level I laboratories of CWC, only four of the nine core parameters assessed by CPCB – temperature, conductivity, pH and dissolved oxygen and two other parameters – colour and odour, are analysed. Thus, Level I laboratories of CWC assess a total of six parameters. Level II laboratories assess 26 parameters, including BOD, Nitrates, Nitrites, FC and Total Coliform. Finally, Level III laboratories assess a total of 41 parameters.

While both CWC and CPCB are credible sources of information on water quality monitoring, CPCB data from 2016, as furnished by the Environmental Information System (ENVIS), is the latest and most extensive data on pollution parameters for major rivers and their tributaries. This data set presents data across all the major rivers and their tributaries, the states that they pass through, and the various upstream and downstream stations in all the states on the river basins. The data set provides the minimum and maximum figures for the following parameters:

1. **Temperature in degree Celsius**
2. **Dissolved Oxygen in mg/l**
3. **pH**
4. **Conductivity in µmhos/cm**
5. **B.O.D. in mg/l**
6. **Nitrate-N + Nitrite-N in mg/l**
7. **FC in MPN/100ml**
8. **Total Coliform in MPN/100ml**

There are a total of 275 major rivers that have been captured in the dataset. From these rivers, 875 data points in locations where water quality has been tested have been provided.

TABLE 2: Surface Water Monitoring Stations

Type of water body	No. of Monitoring Locations
River	2021
Lake	341
Pond	129
Tank	138
Creek/Marine/Sea/ Costal	63
Canal	65
Drain	60
Ground Water	1233
STP	56
Water Treatment Plant (Raw Water)	5
Grand Total	4111

SOURCE: CPCB, 2020

CPCB groups various river stretches in five priority classes based on the recorded BOD level. Priority 1 has river stretches showing the highest BOD violations, whereas priority 5 indicates the lowest range violations. While 13 percent of total river stretches fall under priority 1 class, priority 5 has 50 percent of the total river stretches (Central Pollution Control Board, 2018).

TABLE 3: Status of River Water Pollution

Priority	BOD Level in mg/lit	Number of Stretches
Priority 1	>30	45
Priority 2	20 to 30	16
Priority 3	10 to 20	43
Priority 4	6 to 10	72
Priority 5	3 to 6	175
Total		351

SOURCE: CENTRAL POLLUTION CONTROL BOARD, 2017

CWC is responsible for water accounting, management and settling water disputes. CWC operative network and monitoring parameters are discussed in previous section

TABLE 4: River Basin- wise Monitoring Site

S. No.	Name of Basin	No. of Sites
1	Brahmani-Baitarni Basin	15
2	Cauvery Basin	34
3	East Flowingrivers between Mahanadi and Pennar	13
4	East Flowingrive between Pennar and Kanyakumari	17
5	Ganga/Brahmaputra/Meghna/Barak Basin/TeestaBasin	445
6	Godavari Basin	77
7	Indus Basin	26
8	KrishnaBasin	53
9	Mahanadi Basin	39
10	Mahi Basin	12
11	Narmada Basin	26
12	Pennar Basin	8
13	Sabarmati Basin	13
14	Subernarekha Basin	12
15	Tapi Basin	18
16	Teesta Basin	5
17	West FlowingRivers from TadritoKanyakumari	29
18	West flowing rivers from Tapi to Tadri	22
19	West flowing rivers of Kutchh and Saurashtra including Luni	14

Parameters Considered for the Analysis

Eight primary parameters have been checked at these locations. From these eight parameters, three parameters– pH, BOD and FC have been considered adhering to NGTs new order on CPCB prescribed effluent standards for Class I cities. With data missing at some locations, data at 723 of these collection points could be calculated.

Based on the NGT order, the STP effluent standards for Class I cities considered for narrowing down polluted points from CPCB ENVIS data are:-

pH – 5.5 – 9.0

Biochemical Oxygen Demand (BOD) – 20

FC (FC) (Most Probable Number per 100 millilitre, MPN/100 ml) – 1000

TABLE 5: STP Effluent Standards as Prescribed by CPCB in 2019

Sl. No.	Industry	Parameters	Standards (Applicable to all mode of disposal)			
1	2	3	Mega and Metropolitan Cities	Class I Cities	Others	Deep Marine Outfall
1		pH	5.5-9.0	5.5-9.0	5.5-9.0	5.5-9.0
2		Bio- Chemical Oxygen Demand (BOD)	10	20	30	30
3	Sewage Treatment Plants (STPs)	Total Suspended Solids (TSS)	20	30	50	50
4		Chemical Oxygen Demand (COD)	50	100	150	150
5		Nitrogen- Total	10	15	-	-
6		Phosphorus Total (For Discharge into Ponds, Lakes)	1.0	1.0	1.0	
7		Faecal Coliform (FC) (MPN/100 ml)	Desirable- 100 Permissible- 230	Desirable-230 Permissible- 1000	Desirable- 1000 Permissible- 10,000	Desirable- 1000 Permissible- 10,000

Note:

(i) Mega-metropolitan cities have population more than 1 crore; metropolitan cities-population more than 10 lakh; Class-1-population more than 1 lakh.

(ii) All value are in mg/l except for pH and FC.

(iii) These standards are applicable for discharge into water bodies as well as for land disposal/applications.

(iv) These standards shall apply to all new STPs for which construction is yet to be initiated.

(v) The existing/under construction STPs shall achieve these standards within seven years from the date of notification.

(vi) In cases where the marine outfall provides a minimum initial dilution of 150 times at the point of discharge and a minimum dilution of 1,500 times at a point 100 m away from discharge point, norms for deep sea marine discharge shall be applied.

(vii) Reuse/recycling of treated effluent shall be encouraged.

(viii) State Pollution Control Boards/Pollution Control Committees may make these norms more stringent taking into account the local conditions.

SOURCE: National Green Tribunal Hearing 30.04.2019

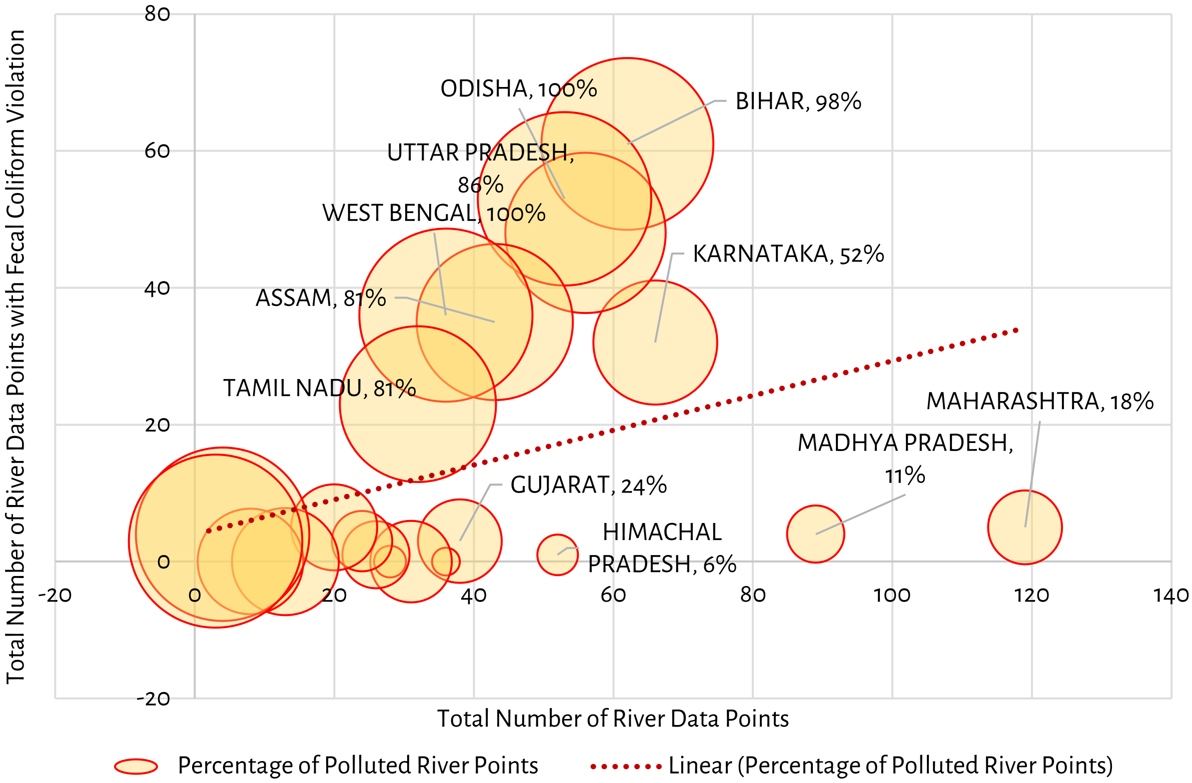
Why FC is an Important Parameter

Not only does the wastewater from urban runoff degrade the river bodies, it also poses a considerable risk to public health, for many settlement areas near the rivers are heavily dependent on them for the most rudimentary yet essential tasks (like bathing, drinking, irrigation etc.) (Suthar et al., 2010). Studies on water pollution in India have established that higher sewage contamination would lead to an increased number of coliform and FC in natural water bodies (Vincy et al., 2017). Rapid development of the townships in the surrounding vicinity of the lower reach may have added to the increased runoff and to an extent enhancing the degradation of the river water quality. Toilets in the urban agglomerations are located along the river banks and have their outlets into the river systems, thus adding to the untreated sewage content of these rivers. Faecal contamination of water in the absence of adequate sanitation infrastructure harbours disease-transmitting microorganisms that cause diarrheal diseases, including cholera and other hazardous non-diarrheal diseases such as hepatitis A and jaundice(Hamner et al., 2007).

The FC threshold taken for this analysis- adheres to CPCB's STP effluent permissible standard prescribing 1000 MPN/100 ml. Subsequent analysis has revealed a total of 105 river points that violate the desired standard for FC effluent. Most of such polluted river points were found in UP, WB, Bihar and Odisha. The most polluted rivers based on the presence of FC are Ganga, Yamuna, Mahanadi, Gomti, Hindon and Brahmani.

Figure 4 presents a bubble chart that plots the state-wise number of data points available in the CPCB dataset against the total number of monitoring locations with a FC violation. The size of the bubbles gives the percentage of FC violation points out of the state's corresponding total number of data points. It can be seen that the most critical states which have

FIGURE 4: **State-wise Analysis of Most Polluted River Stretches**



SOURCE: CPCB data on FC violations and CPR Analysis polluted points (river stretches) over 20 also exhibits a higher percentage of river pollution based on the available studies. These are the states of Assam, Bihar, Odisha, Karnataka, Tamil Nadu and UP.

Table 6 presents the state-wise list of the basic descriptive statistics of the CPCB-ENVIS data on pollution in major rivers and their tributaries. The table gives the number of violation points based on pH, BOD and FC. It is clear that most of the violations at these monitoring stations are due to FC exceeding the permissible limit of 1000 MPN/100ml. Of the total 373 violation points (based on all three parameters), 317 are due to FC violation. This clearly establishes FC as one of the most significant parameters of river pollution and hence corroborates the need to study the same with respect to urbanisation and sanitation infrastructure.

TABLE 6: State-wise Distribution of River Pollution Data Points Based on Selected Parameters

State	Total Number of Data Points	Only pH Violations	Only BOD Violations	Only FC Violations	Any of the 3 parameters violation	Percentage of Polluted River Points - %
BIHAR	62	0	2	61	61	98
ODISHA	53	0	0	53	53	100
UTTAR PRADESH	56	0	10	48	48	86
WEST BENGAL	36	0	3	36	36	100
ASSAM	43	1	1	35	35	81
KARNATAKA	66	0	3	32	34	52
TAMIL NADU	32	3	3	23	26	81
MAHARASHTRA	119	0	20	5	22	18
MADHYA PRADESH	89	1	6	4	10	11
GUJARAT	38	0	7	3	9	24
TELANGANA	31	1	6	0	7	23
ANDHRA PRADESH	20	0	0	5	5	25
RAJASTHAN	13	4	1	0	5	38
DELHI	4	0	3	4	4	100
UTTARAKHAND	26	0	4	1	4	15
HARYANA	3	0	0	3	3	100

SOURCE: CPCB ENVIS, 2016

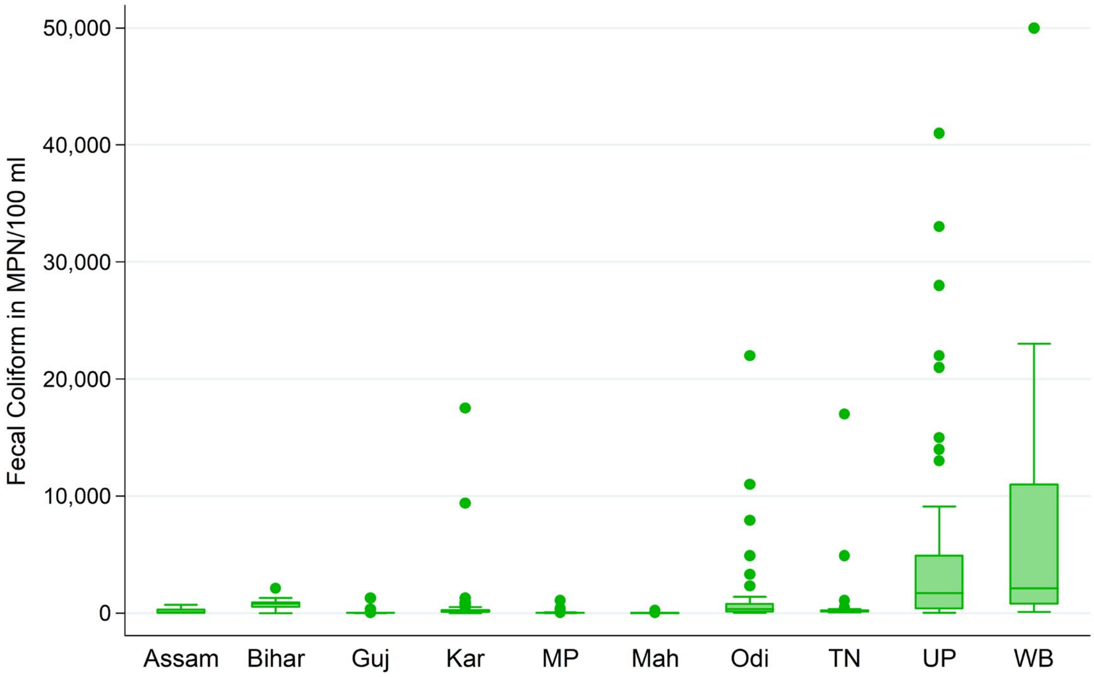
State	Total Number of Data Points	Only pH Violations	Only BOD Violations	Only FC Violations	Any of the 3 parameters violation	Percentage of Polluted River Points - %
HIMACHAL PRADESH	52	2	0	1	3	6
NAGALAND	8	1	2	0	3	38
PUNJAB	24	0	2	3	3	13
CHHATTISGARH	28	1	0	0	1	4
JAMMU & KASHMIR	36	0	1	0	1	3
JHARKHAND	31	0	0	0	0	0
KERALA	2	0	0	0	0	0
TRIPURA	3	0	0	0	0	0
Grand Total	875	14	74	317	373	43

FC Variations from the Prescribed Parameter across States

The previous section elaborates on the importance of FC as a pollution parameters. It is evident from the data that FC violation accounts for more than 80 per cent of violations in the major rivers and their tributaries and distributaries. This corroborates the finding that untreated effluents from municipalities lead to high levels of pollution with potentially hazardous health outcomes for river water users as has been established through the study 'Isolation of Potentially Pathogenic Escherichia coli O157:H7 from the Ganges River' by (Hamner et al., 2007). Thus, it is vital to understand how much variations are caused in FC in these rivers at the CPCB monitoring locations.

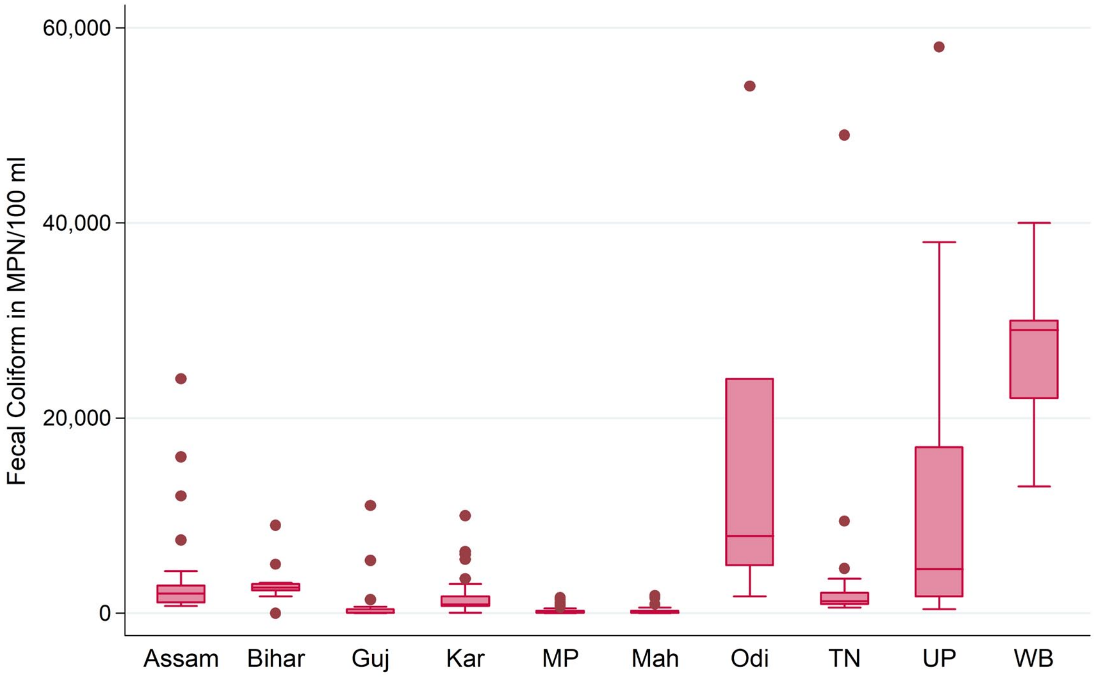
Figures 5 and 6 present the box plots of minimum and maximum levels of FC gauged at the monitoring locations. Only the FC violations in the top ten polluted states are shown. The minimum level of FC violations does not show much variation except in Odisha, Tamil Nadu, Uttar Pradesh and West Bengal, which have the highest levels of FC violation. The maximum levels of FC show much higher levels of variations for almost all the states. This may hint at the seasonal fluctuation of FC in river bodies with a higher maximum level of FC, possibly during monsoons.

FIGURE 5: Box Plot Showing Minimum Level of FC Violation



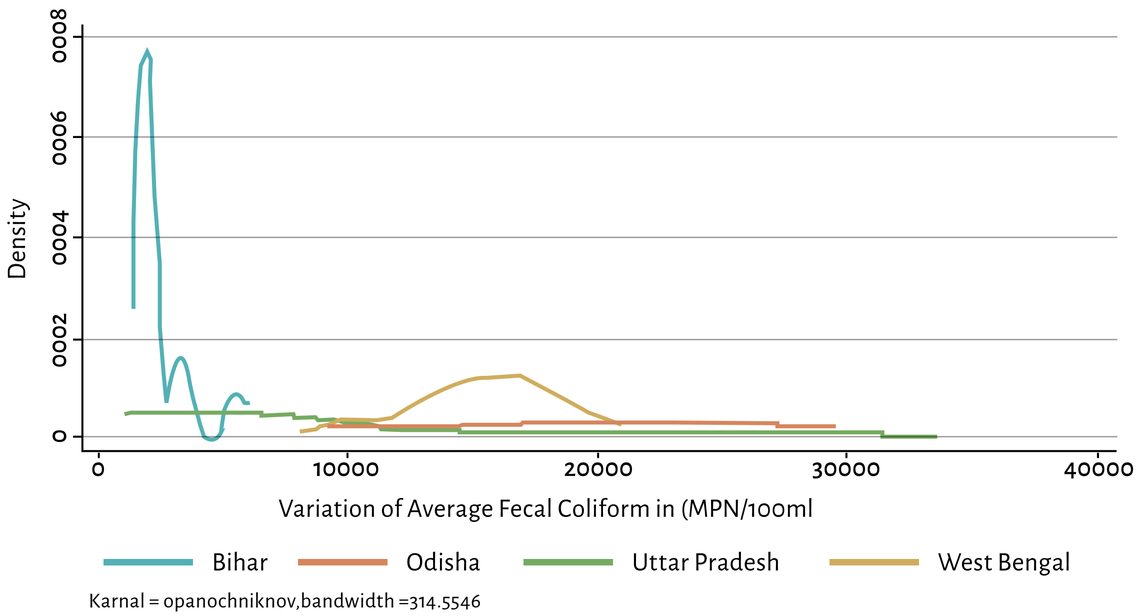
SOURCE: CPR Analysis

FIGURE 6: Box Plot Showing Maximum Level of FC Violation



SOURCE: CPR Analysis

FIGURE 7: **Kernel Density Estimate**



SOURCE: CPR Analysis

Figure 7 shows an example of the variation in different states to present a case for developing different strategies for river pollution in different states. Presenting the case of average FC violations in Bihar, Odisha, UP and WB, the kernel density plot shows that the nature of variations is different in these states. In Bihar, despite a high percentage of river pollution points of the total monitoring locations, it is seen that the average FC doesn't vary as much as it does in the states of WB and UP or for that matter, Odisha. But these violations still exceed the permissible limit of 1000 MPN/100ml and maybe a more significant problem in bigger urban agglomerations in the state along the banks of rivers. The problems can be inferred to be more severe in the states of WB and UP, which are highly urbanised and with bigger urban agglomerations housing larger population which are exposed to the ill effects of FS pollution. The study 'Water Quality Assessment of River Hindon at Ghaziabad, India', by (Suthar et al. ,2010) conducted on the water quality of a river passing through a rapidly urbanising city made similar observations but in terms of BOD. In Odisha, high variations are observed due to poor urban sanitation, but it is not highly urbanised. This does not necessarily undermine the levels of pollution in any of the states. Instead, it calls to our attention the need for a larger study to understand the precarity and gravity of river pollution in different states and requisite interventions to reduce pollution in these states, duly factoring in their respective urban and sanitation characteristics.

Addressing Groundwater Pollution

Data Sources

CGWB and CPCB are the two apex institutions conducting groundwater quality monitoring in India. Amongst the two, CGWB has a relatively higher number of monitoring stations. There are also variations in the parameters monitored by the two bodies.

At present, the methodology recommended by the 'Ground Water Estimation Committee' in 1984 is being adopted to compute the groundwater resources of the country in volumetric terms by CGWB. For groundwater quality monitoring, CGWB has set up water quality monitoring stations at the assessment unit (AU) level. AUs are basically administrative units. There is no delineation of AUs based on the natural hydrological unit, i.e. basin or watershed-: groundwater quality monitoring occurs at the following levels: blocks/ taluks/ mandals/ districts/firkas/valleys.

CGWB monitors groundwater on the following six parameters (Central Ground Water Board, 2020): Electrical Conductivity, Chloride, Fluoride, Iron, Arsenic and Nitrate. CPCB, on the other hand, does so based on seven parameters, Temperature, pH, Conductivity, BOD, Nitrate, FC and Total Coliform. Even though CPCB directly monitors FC and total coliform levels, the CGWB dataset on nitrates has been used for analysis due to CGWB's better-distributed monitoring stations across geographies. Table 7 shows the state-wise distribution of monitoring stations for CPCB and CGWB

TABLE 7: List of CPCB and CGWB Monitoring Stations

S.No.	State/Union Territory	CPCB Monitoring Stations	CGWB Monitoring Stations
1	Andhra Pradesh	20	772
2	Arunachal Pradesh	NA	21
3	Assam	43	233
4	Bihar	62	643
5	Chattisgarh	28	489
6	Delhi	4	99
7	Goa	NA	102
8	Gujarat	38	810
9	Haryana	3	529
10	Himachal Pradesh	52	112
11	Jammu & Kashmir	36	256
12	Jharkhand	31	407
13	Karnataka	66	1438
14	Kerala	2	364
15	Madhya Pradesh	89	1137
16	Maharashtra	119	1515
17	Manipur	NA	0
18	Meghalaya	NA	39
19	Nagaland	8	0

S.No.	State/Union Territory	CPCB Monitoring Stations	CGWB Monitoring Stations
20	Odisha	53	1659
21	Punjab	24	351
22	Rajasthan	13	613
23	Tamil Nadu	32	457
24	Telangana	31	360
25	Tripura	3	40
26	Uttar Pradesh	56	892
27	Uttarakhand	26	207
28	West Bengal	36	666
29	Andaman & Nicobar	NA	120
30	Chandigarh	NA	18
31	Dadra & Nagar Haveli	NA	12
32	Daman & Diu	NA	10
33	Pondicherry	NA	6
	Total	875	14377

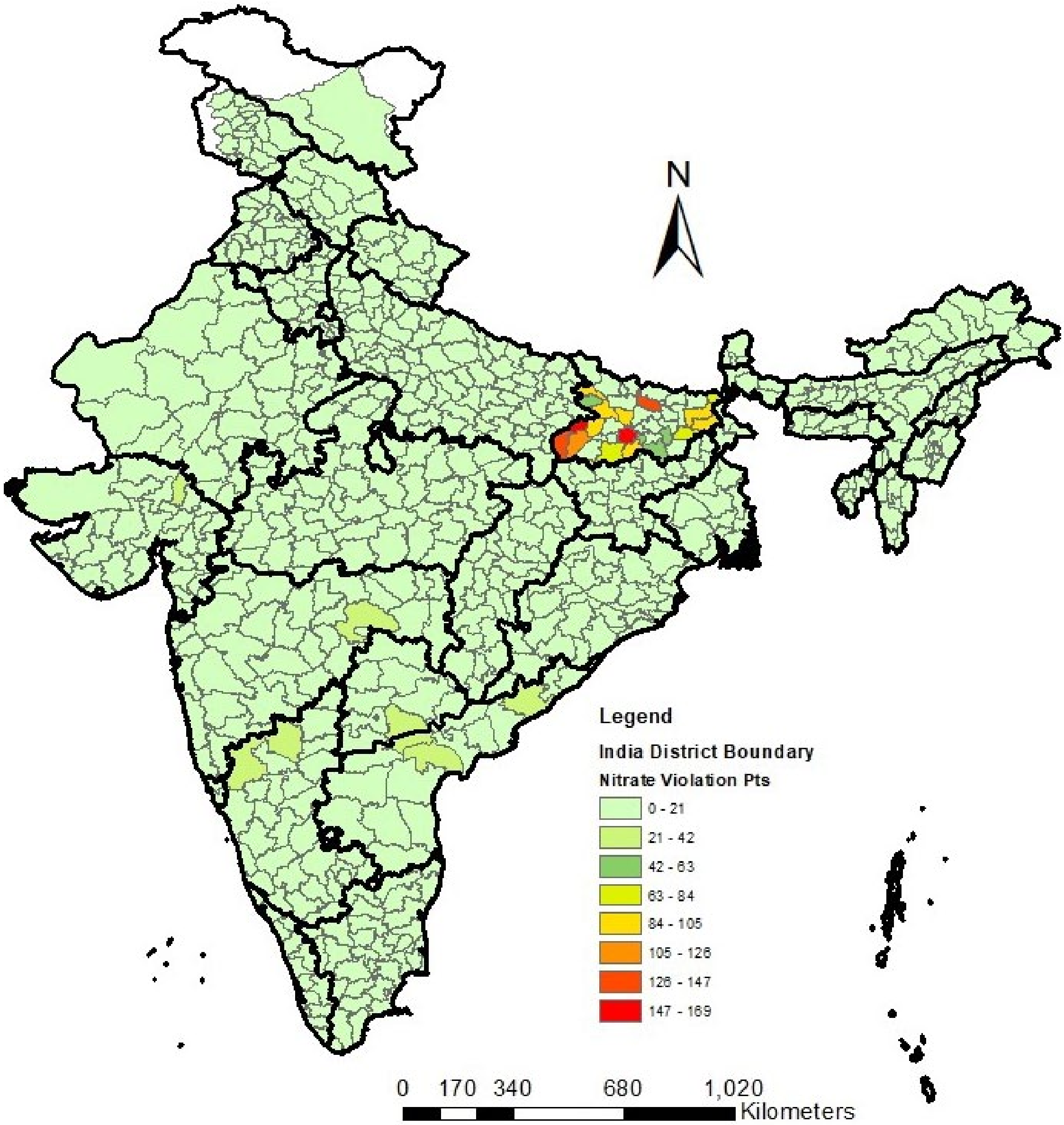
SOURCE: CENTRAL GROUND WATER BOARD, 2020 And Central Ground Water Board, 2018

As per the CGWB report 'Groundwater Quality in Shallow Aquifers in India' (Central Ground Water Board, 2018), dissolved nitrogen in the form of nitrates is the most common contaminant of groundwater. Nitrate in groundwater generally originates from non-point sources such as leaching of chemical fertilisers and animal manure, septage and sewage discharge etc. (Central Ground Water Board, 2018) . Various studies such as Groundwater Pollution and Contamination in India: The Emerging Challenge by (Kumar & Shah, 2006) also point to increased nitrate loading due to faecal contamination in groundwater. However, it still remains a challenge to identify the natural and man-made sources of nitrogen contamination in groundwater.

As per the Bureau of Indian Standards (BIS) standards for drinking water, the maximum desirable limit of nitrate concentration in groundwater is 45 mg/l with no relaxation. Although nitrate is considered relatively non-toxic, a high nitrate concentration in drinking water is an environmental health concern because of the increased risks of meatheomoglobinemia, particularly for infants (Bureau of Indian Standards, 2012).

Figure 8 shows the districts where the level of nitrate in groundwater has been found to be over 45 mg/l (Central Ground Water Board, 2018). The map is generated by plotting the total number of data points where violations were observed in the district. The data in the CGWB report exists at the block level, which is aggregated at the district level for mapping. It can be observed from the map that Rajasthan, Maharashtra, Gujarat, Karnataka, Andra Pradesh, Telengana and Odisha shows moderate violation points, whereas Bihar shows a high number of violation points. On the other hand, UP, Himachal Pradesh, Uttarakhand, Jammu and Kashmir, and Ladakh show fewer violations.

Figure 8: **Nitrate Violation in Districts across India**



SOURCE: Central Ground Water Board, 2018

Determining an approach to analyse Ground Water Pollution

Considering that studies validate nitrate contamination in groundwater due to agriculture runoff, sewage, and industrial discharge, it is imperative to study how each of these sources contributes to raised levels of such contamination in various districts. It was initially conceptualised to filter out the districts that show deviation from >45mg/l limit as prescribed by CGWB predominantly due to sewage pollution by running a regression analysis with each of the contributing parameters. However, while trying to consolidate the data, it was found that the available data was inadequate to carry out the analysis; there were

- Gaps in data available and
- Data was not available in the desired format

From this, it became evident that an indirect approach was to be established to address the challenge of analysing the interrelation between sewage contamination and high levels of nitrates in groundwater. Subsequently, it was determined that an effective way to do this was to run a regression analysis on the level of nitrates data, primary census abstract data and amenities data. The following data sources were used for this:-

1. **Primary Census Abstract (PCA) –** Settlement code, Population and Number of Households (Census 2011)
2. **Census Amenities Data** (Census 2011)

CGWB has a total of 14377 groundwater monitoring wells, of which 1284 showed nitrates violation. The data was collated at the district level through a matching exercise due to a higher number of aggregate points as against block level. Average block-level readings were taken to aggregate data at the district level for nitrates concentration in groundwater. Table 8 shows an example of this.

For the purpose of the study, the top five districts of the state (Karnataka in this case) showing maximum deviation were shortlisted to run a regression analysis and see if there was a correlation between the various PCA and Amenities parameters in a particular state.

TABLE 8: **Nitrate Violation in Districts Across India**

State	District	Average (NITRATE >45 (mg/l)	Total Points of Violation (At deistrict level)	Total Monitoring Point in State
		Karnataka		
Karnataka	Bagalkot	78	13	1438
Karnataka	Banglore Rural	89	6	1438
Karnataka	Banglore Urban	80	1	1438
Karnataka	Belgaum	120	26	1438
Karnataka	Bellary	111	7	1438
Karnataka	Bidar	56	4	1438
Karnataka	Bijapur	124	29	1438
Karnataka	Chamarajanagar	67	3	1438
Karnataka	Chikmagalur	81	8	1438
Karnataka	Chitradurga	75	11	1438

State	District	Average (NITRATE >45 (mg/l)	Total Points of Violation (At deistrict level)	Total Monitoring Point in State
Karnataka				
Karnataka	Dharwad	87	5	1438
Karnataka	Gulbarga	55	17	1438
Karnataka	Hassan	55	3	1438
Karnataka	Haveri	107	10	1438
Karnataka	Kodagu	55	7	1438
Karnataka	Kolar	69	9	1438
Karnataka	Koppal	65	11	1438
Karnataka	Mandya	64	11	1438
Karnataka	Mysore	65	10	1438

SOURCE: Central Ground Water Board, 2018

TABLE 9: **Top 5 Nitrate Violation Districts in Karnataka State**

GW Contamination in District					
State	Total Districts	No. of district showing violation	District with High Nitrate (N>45mg/l) Violations (Top 5)		
			Distt Name	Avg	Total Points
Karnataka	30	22	BIJAPUR	124	29
			BELGAUM	120	26
			RAICHUR	81	20
			GULBARGA	55	17
			BAGALKOT	78	13

SOURCE: Central Ground Water Board, 2018

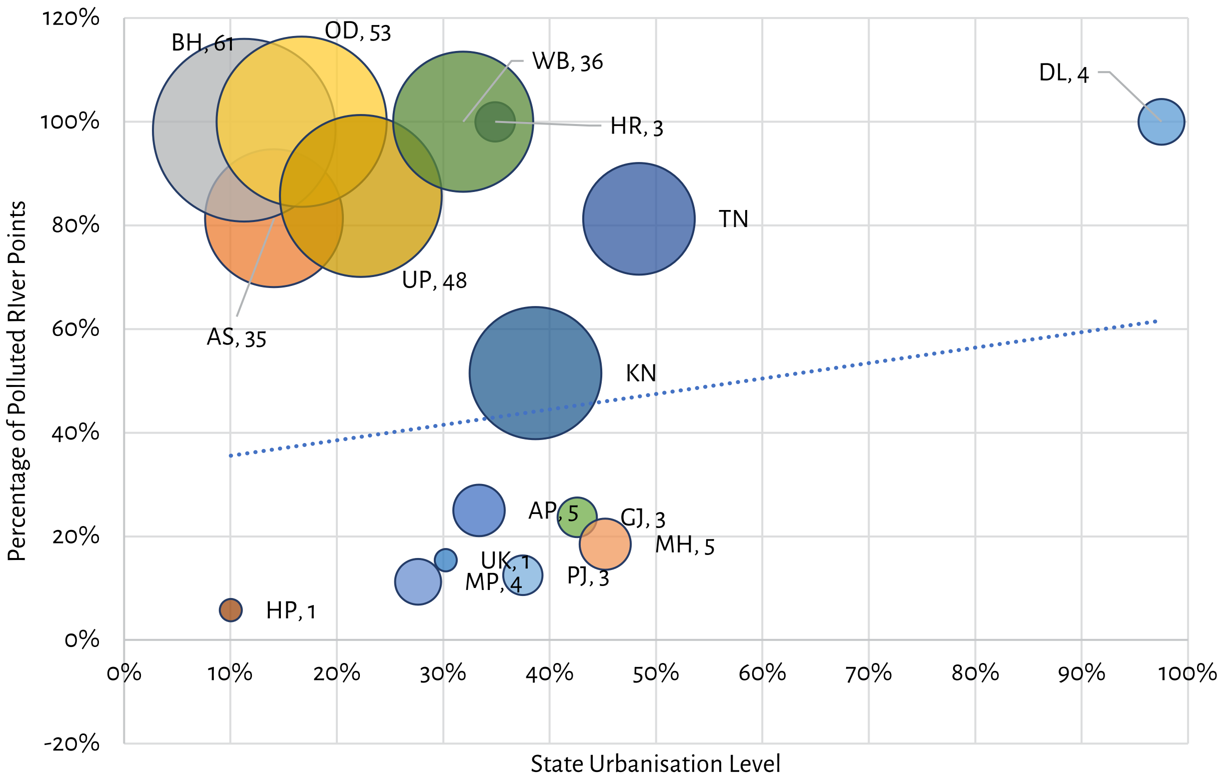
Image Source:www.medium.com

Determining Relationships

Linkages between FC Violations and Levels of Urbanisation

As observed in the previous sections, FC parameters constitute the most violated parameter as per the data released by CPCB for pollution at stations on major river basins of India. Fig 9 plots the total polluted river points against the urbanisation levels of the states, with the bubble sizes representing the actual number of stations where FC violations are recorded. It is evident that there is no strong positive correlation between urbanisation and river pollution. The five states which are highly urbanised (with greater than the national average of 31 per cent urbanisation rate) are seen to have a higher percentage of polluted river points; these are – National Capital Territory (NCT) Delhi, Tamil Nadu, Karnataka, Haryana and WB. However, the rest of the states with a very high percentage of polluted river points (in excess of 80 per cent) are Bihar, Odisha, UP and Assam, all of which have a lower urbanisation rate than the national average. The three other states with a percentage of polluted river points in excess of 80 per cent but with relatively higher urbanisation rates are Tamil Nadu, WB and Haryana. It is also to be noted that the states with a high number of FC violations are, in descending order of frequency – Bihar, Odisha, UP, WB, Assam, Tamil Nadu and Delhi. Bihar, Odisha, WB, Haryana and Delhi have 100 per cent of their river points polluted and all such stations record violation of the permissible limit of FC, which is 1000 MPN/100 ml.

Figure 9: **Relation between River Pollution and Urbanisation Levels**



Bubble Size: Station at which FC violations recorded

SOURCE: CPR Analysis

This inconclusive relation between urbanisation and river pollution should not, however, be read and understood in a generalised way. On the contrary, this makes the puzzle even more complicated. It is seen from the CPCB data that most of the monitoring locations are actually in the vicinity of cities, some of which are upstream and some downstream of the rivers. This underscores the need for a more detailed analysis of the urban sanitation infrastructure and its impact on river pollution. Several studies have already researched and reported the adverse impact of untreated municipal waste, primarily urban sewage, on river pollution (Misra, 2011). More importantly, studies have found that because of incessant discharge of municipal sewage, two primary parameters pertaining to organic pollution in rivers – BOD and FC, spike up the downstream of rivers (Seo et al., 2019). In particular, a report by CPCB found that around 35 Class I cities in the Ganga basin actively contribute to high BOD and FC in the river due to the discharge of municipal sewage. Such findings make an analysis of the correlation between sanitation infrastructure in cities and river pollution imperative for developing a detailed understanding of the subject to find trends and instruct policy.

A cleaned data set was prepared for ten states – Assam, Bihar, Gujarat, Karnataka, Madhya Pradesh (MP), Maharashtra, Odisha, Tamil Nadu, UP and WB from CPCB data of water quality testing in major river basins of India. These states were selected from the overall list of all states, and their selection was based on the two primary parameters – percentage of data points which exceeded the permissible limit of FC violation (the range is wide, as shown in the box plot) and STP treatment capacities in urban areas of these states. Table 10 distinguishes between the ten states according to their wastewater treatment capacities. Assam, Bihar, MP, Odisha and UP are states with low treatment capacity. Gujarat, Karnataka, Maharashtra, Tamil Nadu and UP are states with high treatment permissible limit with the exception of UP. However, the presence of a large number of data points across all the states, irrespective of their overall percentage of violations, has been found to be in big cities with high populations. Similar observations have been made in various other studies which show that with a rapidly increasing population and a resulting spike in urbanisation, industrialisation and land development along the river basins,

TABLE 10: State wise Wastewater Treatment Capacity and Average FC Violation Points

Treatment Capacity Level	State	Tptal CPCB Data Points	APC exceding Desirable Limit	APC Exceeding Permissible Limit	Percentage of APC Permissible Limit Violations
Low Treatment Capacity States	Assam	43	43	23	53%
	Bihar	62	61	61	98%
	MP	89	31	17	19%
	Odisha	53	53	52	98%
	WB	36	36	36	100%
High Treatment Capacity States	Gujarat	38	7	2	5%
	Karnataka	66	60	20	30%
	Maharashtra	119	33	20	17%
	TN	32	32	14	44%
	UP	56	56	48	86%
Total		594	412	293	49%

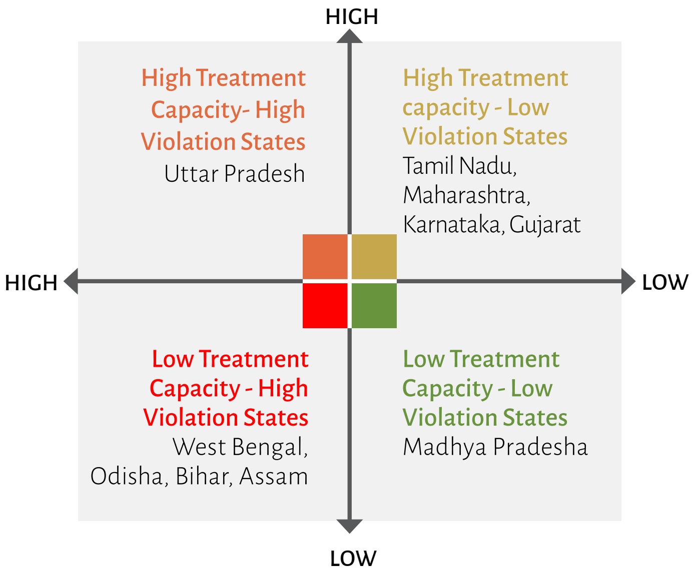
SOURCE: CPR Analysis

capacity. As it so happens, because of the high number of FC violations in these selected states, they collectively account for 594 out of the total 875 data points captured in the CPCB data.

It can be seen that states with low treatment capacity have high average FC violations in percentage terms and states with high treatment capacity have relatively lower average FC violations exceeding the permissible limit with the exception of UP.

many Indian rivers are experiencing higher rates of pollution and degradation (Suthar et al., 2010). Despite having high treatment capacity, states like UP, Karnataka, Maharashtra and Tamil Nadu, too, have a considerable number of monitoring locations near big and medium-sized cities where the average FC exceeds the permissible limit of 1000 MPN/100ml and far exceeds the desirable limit of 230 MPN/100ml. And this is considering the efflu-

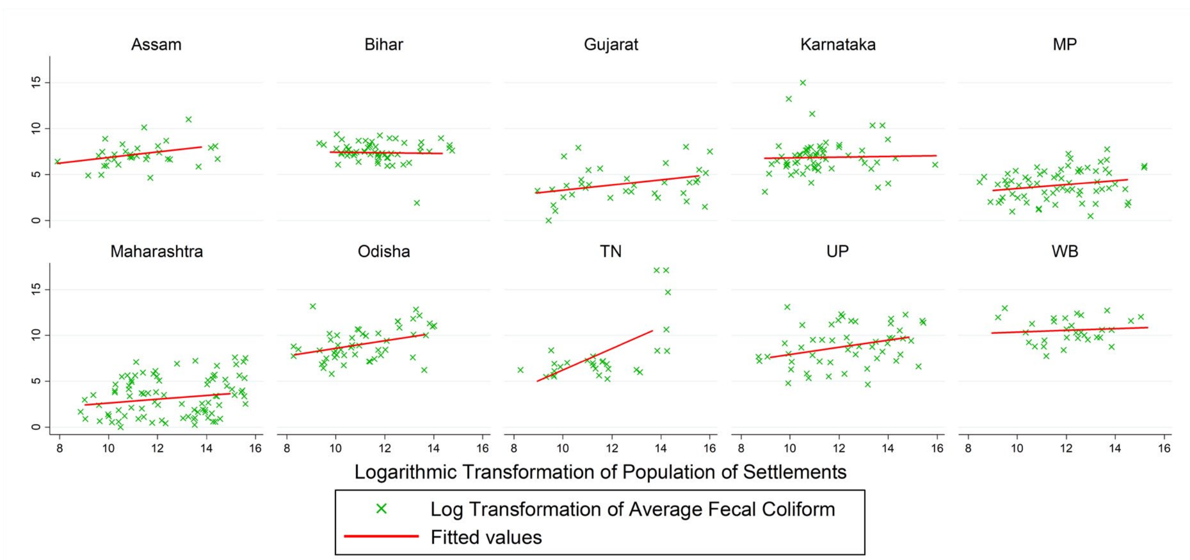
Figure 10: **Classification of States based on Treatment Capacity and Percentage Violation**



ent standard for Class I cities prescribed as the STP effluent treatment standard by CPCB and decreed by NGT. There would be far more violations and variations if the stricter standards for mega and metropolitan cities were to be considered.

Nevertheless, to better understand the impact of urbanisation on FC violation in rivers, a methodology has been devised after collating the CPCB data with PCA and Assets and Amenities data from Census 2011. This matching has been done at the town level to match Statutory Towns and Census Towns from the Census list with the CPCB data to canvass the data for a regression analysis to find the causal relationship between city size and FC violation. The subsequent regression analysis revealed that there was no direct/linear significant causal relation between FC and city size. However, when the variable was logarithmically transformed there was a clear non-linear relation between the dependent variable (FC) and the independent variable (city size/population) that was obtained from the Census data. It was also noted that the causal relationships established between the logarithmically transformed variables were not significant at the aggregate data for the ten selected states. But they were significant at the state level. Figure 11 shows the scatter plot for the logarithmic transformation of the population and the FC data at the CPCB water quality monitoring stations.

Figure 11: **Scatter Plot of Logarithmic Transformed population of City and FC**



SOURCE: CPR Analysis

It can be clearly seen from Figure 11 that there are specific state variations which were also seen in the box-plots and kernel density plots in Figures 5, 6 and 7. Subsequently, to validate the state variations explaining the causal relation between FC and city population, a log-log regression model was used to analyse the information by taking the ten states as dummy variables. Table 11 shows the results of log-log regression, which had FC as the dependent variable, city size (population) as the primary independent variable, and the state and the location of monitoring station (upstream/downstream/not known) as the two dummy variables to better understand the causal relationship between FC contamination and urbanisation and availability of sanitation infrastructure.

TABLE 11: Regression Analysis for Causal Relation between FC and Population of a City

Variable	Coefficients
Logartihmic Transformation of Population	27151188***
State: Reference	
Bihar	0.05350113
Gujarat	-3.5420612***
Karnataka	-0.5777196
MP	-3.5425486***
Maharashtra	-4.5072772***
Odisha	1.7496642***
TN	0.54986059
UP	1.1894956***
WB	2.9680748***
Upstream/Downstream: Reference Category- Not Available	
Upstream	
Downstream	.60751432*
_cons	4.1443264***
legend: * p<0.05; ** p<0.01; *** p<0.001	

SOURCE: CPR Analysis

The result of the log-log regression is significant and establishes a non-linear relationship between FC and the population of the city. It is seen that when the logarithmically transformed population of the city increases by one unit, FC increases by 0.27 units. In other words, when the average population of the city doubles (increases by 100 per cent), average FC concentration is found to increase by 27 per cent. This causal relationship is significant when state variations are accounted for through dummy variables. When Assam is taken as the base, it is seen that the FC and city population regression is significant for Assam, Gujarat, MP, Maharashtra, Odisha, UP and WB. The signs of the coefficients for the state dummy variables show the variations are more or less than the FC variations in the state of Assam. While Gujarat, MP and Maharashtra have fewer FC variations compared to Assam, the states of Odisha, UP, and WB have much higher variations of FC across different city sizes compared to what is observed in Assam.

Another significant component of the regression analysis shown here is the location of the monitoring station. The CPCB data provides information on whether the monitoring station is upstream or downstream of a major river for the particular city where they are located. The information is directly available for some data points; for other data points, they had to be figured out individually through a meticulous process or spatially located on Google Maps. There were some data points whose location (whether they were upstream or downstream) remained ambiguous. But when this variable was used as a dummy in the regression equation, it was seen that when an unknown location data points were taken as a reference, only the downstream data points and not the upstream data points had significant coefficients. This means that the variations of the FC explained by city size were clearly more in downstream river data points than upstream. Although this may seem like a very intuitive finding, it is significant to understand the adequacy of treatment capacity levels in different states.

Due to a dearth of data points it was not possible to conduct an interactive regression by interacting with the state and monitoring location variables to better understand the treatment efficacies in different states. However, this would be a vital takeaway for the relevant institutions to coordinate data on water quality monitoring, keeping in mind the stress of the urban population, especially in bigger agglomerations. This is on account of the fact that the locations downstream of one urban centre might be close to the upstream location of another urban centre for a given river, thus, increasing the cost of drinking water treatment for the subsequent urban centre if the FC is very high upstream of it.

Linkages between FC Violations and Poor Sanitation Infrastructure

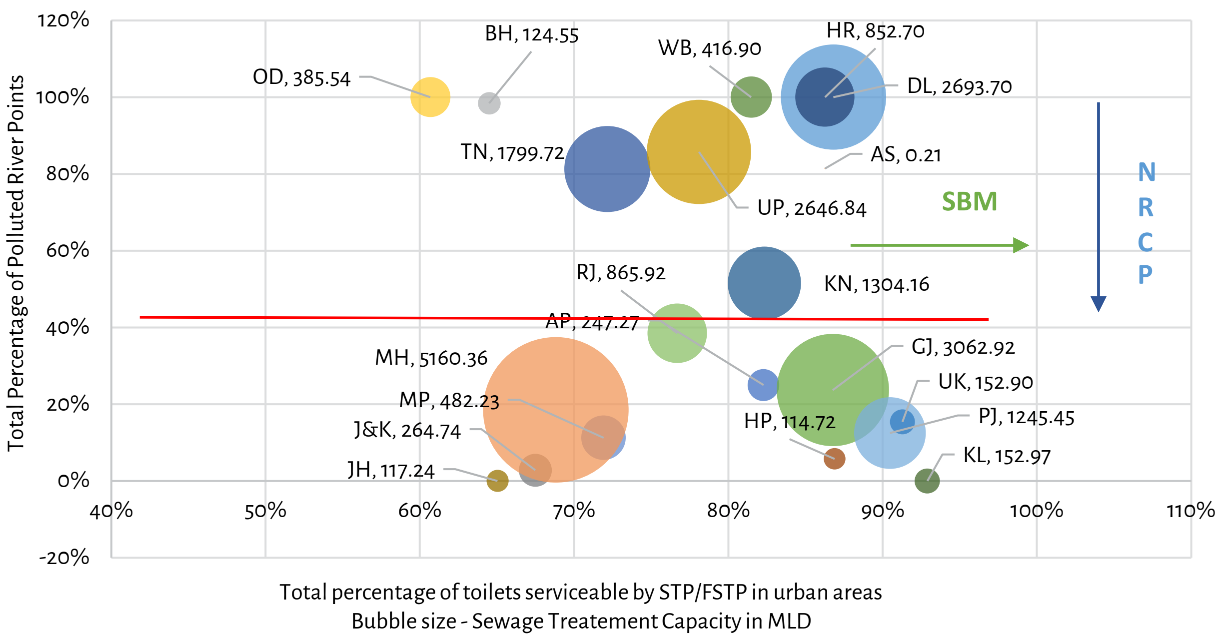
Alluding to studies that validate FC contamination in rivers due to the release of municipal sewage, an analysis of urban sanitation infrastructure has been carried out to develop a wider perspective of the topic of river pollution abatement. Based on Census 2011, 78 per cent of total urban households (including CTs as urban areas for the time being) had toilets that were serviceable by STPs and FSTPs. Toilets that are serviceable by STPs and FSTPs include those that are connected to piped sewers, septic tanks and pits with and without slabs. Further, since the inception of SBM, toilet construction has increased in India. With its primary objectives including the conversion of insanitary toilets to sanitary toilets which are serviceable by STPs and FSTPs and building of toilets for households with no toilets, SBM has sought to increase the number of toilet constructions in the country. The gaps in phase I of SBM are to be addressed by its phase II. Thus, it seems safe to say that the target of toilets for all adhering to the SDG set by the UN, will be met sooner or later. However, the treatment of the waste generated from the already existing toilets, including the ones built under SBM, has not been up to mark.

As discussed earlier, India has a total of 816 STPs with a 23277 MLD treatment capacity, of which only 522 are operational. And only 70 new STPs have been proposed. This is abysmal considering there are 7933 total urban settlements identified by the Census of India, especially when only 33 per cent (roughly) of the households in these towns have toilets connected to piped sewers. For many urban settings close to rivers, improvements in wastewater and sewage treatment infrastructure have not kept pace with the rapid population and industrial growth occurring over the past few decades, thus exacerbating the stress on these rivers (Hamner, et al., 2013). Around 45 per cent of the total households in India are connected to septic tanks and pits and end up relying on desludging by septic tank trucks and treatment at FSTPs. Hence, it is pertinent to understand the demand and supply of treatment requirements from the perspective of the sanitation infrastructure in urban areas in order to address the issue of river pollution.

Figure 12 plots the total percentage of toilets serviceable by STPs or FSTPs against the total percentage of polluted points in different rivers for all states of India (except Telangana, for which the Census data on toilets is not available). The bubble sizes represent the total existing treatment capacities of the STPs only. It can be seen that the states which have more than 40 per cent of their river bodies polluted because of the violation of pH, BOD and largely FC do not have 100 per cent serviceable toilet coverage. Some states like Delhi, WB, Haryana, UP, Karnataka and Assam have more than 75 per cent of serviceable toilets, but not all of them have adequate treatment capacities. There are also states with high river pollution points that have less than 75 per cent of toilet coverage; these are – Odisha, Bihar and Tamil Nadu. While the toilet coverage has burgeoned since 2011 due to the toilet construction activity undertaken under SBM and may well reach 100 per cent under SBM phase II, a major issue of concern is the incommensurate treatment capacity of the toilet waste. States like Odisha, Bihar, WB and Assam have an acute shortage of STPs and hence toilet waste treatment capacities. Even states with somewhat higher treatment capacities like Delhi, Haryana, UP, Tamil Nadu and Karnataka, have high river pollution. Studies have also revealed that the inadequacy of treatment capacity in these states actively contributes to the BOD and FC violations in rivers in these states (Board, 2015) (Central Pollution Control Board,2018).

The major worry is not just the inadequacy of STPs and their treatment capacities but also the fact that these treatment facilities are designed to treat waste only from toilets connected to sewer networks and in very rare cases carry out co-treatment of waste, including faecal waste coming from OSS. As mentioned earlier, only 33 per cent of total urban households were connected to piped sewers in 2011, and it is unlikely considering the high capital cost of laying down sewer networks that this figure may exceed, say, 40 per cent in the present date. Figure 13 plots the total number of FC violations in all states against their respective sewage treatment capacities, with the bubble sizes representing their total per cent of sewer connections. It can be inferred that the existing treatment capacities exist for only a certain percentage of the households that are connected to sewer lines: 53 per cent in Karnataka, 28 per cent in UP and 11 per cent in Odisha. Thus, it can be said that in order to curb river pollution due to FC violation which is evidently high in many states, there needs to be a focus on not only improving capacities for the treatment of toilet waste from sewers but also for the treatment of toilet waste from OSS systems. There is a strong and urgent need to provide infrastructure in the form of FSTPs and increase sewer connectivity over time.

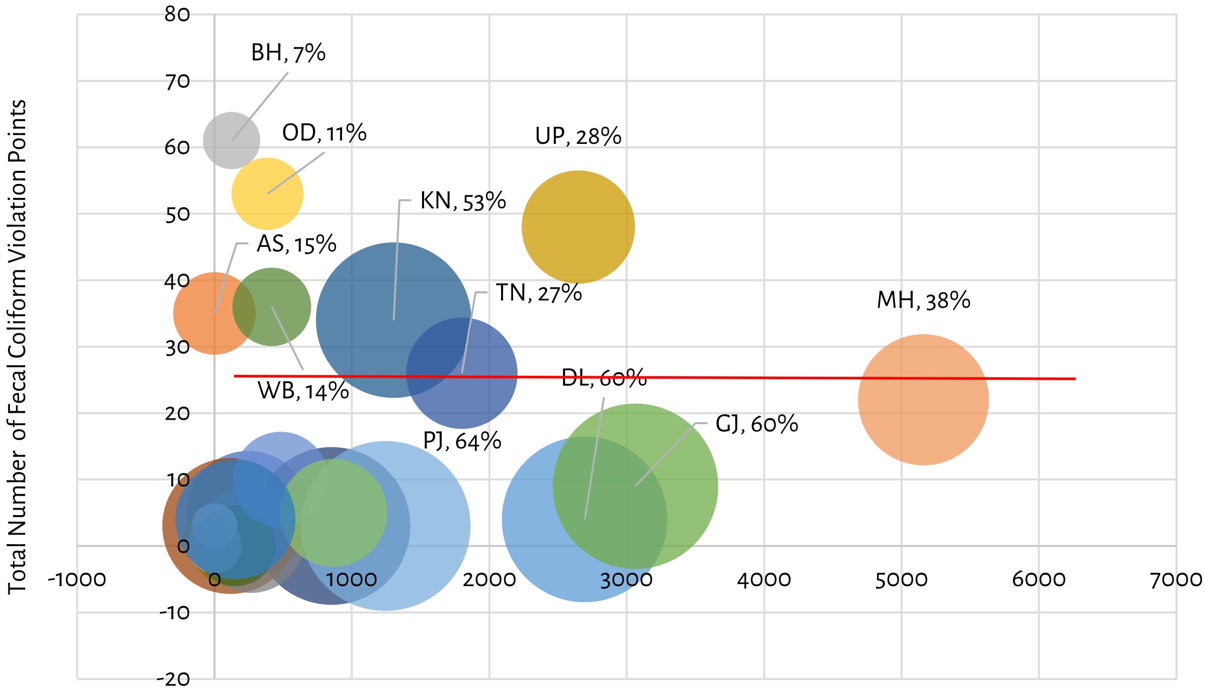
Figure 12: **Relation between River Pollutions and Serviceable Toilets**



Bubble Size: Total existing treatment capacity of STP's

SOURCE: CPR Analysis

Figure 13: **Relation between FC Violation and Treatment Capacity**



Bubble Size: Percentage of sewer connections

SOURCE: CPR Analysis

Figure 13, like figure 12, plots state-wise total river points polluted due to FC violations against the STP treatment capacities except that the bubble sizes here represent the states access to OSS systems – septic tanks and pits. When both the plots are compared, it is reasonable to interpret that the states highlighted below the red line with high FC violation points have high access to OSS systems. With the singular exception of Karnataka, it is seen that all the other states have OSS percentages greater than the piped sewer connections. There are, however, limited studies attributing direct discharge of faecal sludge from septic tanks (Ananth et al., 2018) and pits to river pollution or claiming linkages between groundwater contamination due to OSS and river pollution. But the numbers and data definitely adds up and suggest these linkages.

The regression analysis that was presented in the previous section validated the causal relationship between FC variation and city population. But having understood the predominance of OSS systems in all of India and particularly in medium-sized cities compared to bigger mega and metropolitan cities (which have a higher percentages of toilets connected to sewer systems), an analysis of the impact of OSS on river pollution is very relevant. This is also important due to the large scale construction of toilets in the last few years under the SBM. Thus, the regression model was replicated with a number of households with septic tanks and pits (OSS) as the primary independent variable, keeping the dependent variable and the dummies (states and location of monitoring stations) the same.

There was no significant direct relationship between FC and on-site sanitation systems. However, there was a clear significant relationship between the logarithmically transformed variables – FC and number of households with OSS- establishing a non-linear causal relationship made significant at the state level. Table 12 presents the results of the log-log regression between the dependent variable (FC) and independent variable – (number of households with OSS in the town) with state and location of monitoring station as dummy variables. It is seen that there is a significant causal relationship between FC variation and Individual Household Latrine (IHL) in a town. It is seen that when OSS connections in a city double (increase by 100 per cent), FC variation increases by 25 per cent. The states variations are similar to the previous regression using population size, and similarly, downstream stations show a significant relationship between FC and OSS connections in the town.

TABLE 12: **Regression Analysis for Causal Relation between FC and Access to Toilets**

Variable	Coefficients
Logarithmic Transformaiton of IHL HHs	.25800585***
State : Reference - Assam	
Bihar	0.2115534
Gujarat	-3.4344729***
Karnataka	-0.46490468
MP	-3.2708086***
Maharashtra	-4.3718972***
Odisha	1.9050197***
TN	0.63002311
UP	1.3471682***
WB	2.9760682***
Upstream/Downstream : Reference Category- Not Available	
Upstream	
Downstream	.676803**
_cons	4.6414049***
legend: * p<0.05; ** p<0.01; *** p<0.001	

SOURCE: CPR Analysis

It should be noted that population and IHL households could not be used in the same regression model due to multi-collinearity caused by the correlation between a town's population and its IHL households. Clearly, a bigger city would have a higher number of IHL households. Nevertheless, the significant non-linear causal relation between FC and IHL households highlights the need to augment treatment of untreated septage and waste from pits which are clearly spiking FC in river streams. This is all the more important with the substantial number of toilets constructed recently under SBM.

Linkages between Ground Water and Nitrates

For understanding the correlation between raised levels of nitrates and various PCA and Amenities parameters, a data matching exercise has been carried out. As per the CGWB report of 2018, a total of 1283 monitoring points out of 14377 showed nitrates violation (Central Ground Water Board,2018). The exercise resulted in 77 percent of nitrates violation data matching the PCA and Amenities data at the block level. Table 13 shows the state-wise results of the matching exercise:

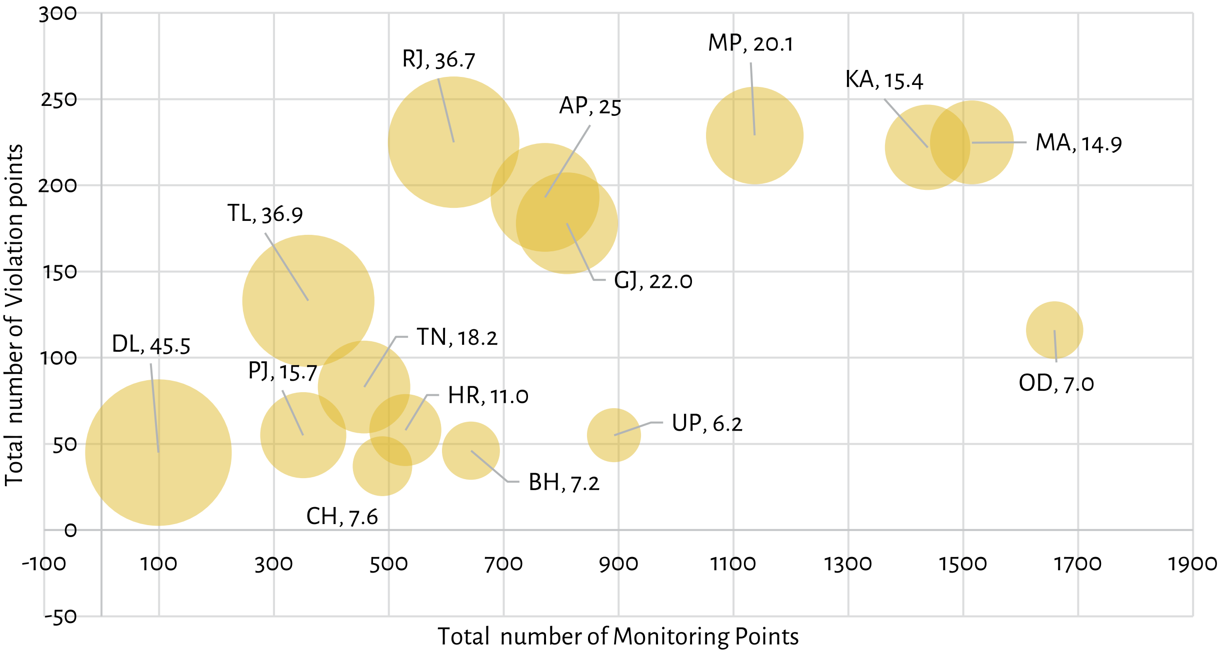
TABLE 13: State-wise Matched Data Points

State	Total Points	Matched Points	Matched %
Andhra Pradesh	157	153	97%
Maharashtra	133	127	95%
Madhya Pradesh	130	104	80%
Rajasthan	124	104	84%
Telangana	110	66	60%
Gujarat	104	98	94%
Karnataka	93	90	97%
Odisha	84	66	79%
Tamil Nadu	62	18	29%
Uttar Pradesh	54	25	46%
Bihar	44	35	80%
Punjab	36	19	53%
Jharkhand	34	23	68%
Haryana	33	16	48%
Kerela	32	7	22%
Chattisgarh	28	20	71%
Jammu & Kashmir	10	9	90%
Delhi	8	0	0%
Himachal Pradesh	5	5	100%
Uttaranchal	2	1	50%
Grand Total	1283	986	77%

SOURCE: Central Ground Water Board, 2018

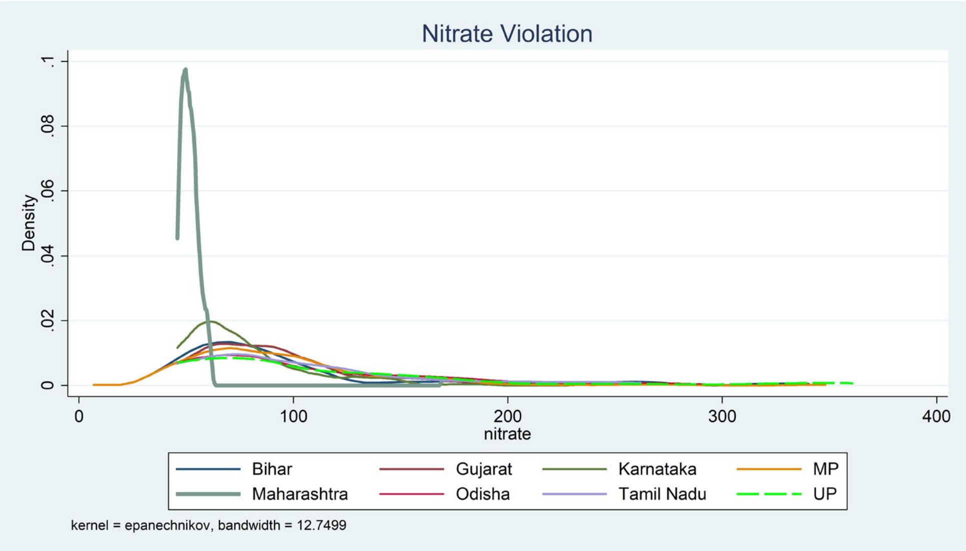
A lower percentage of matched data points in some states can be attributed to either a change in boundary delineation or spelling mismatches. These discrepancies were manually routed out, especially for states which showed a high percentage of violations, as presented in the bubble chart in Figure 14.

Figure 14: **Bubble Chart Showing State-wise Violation Points and Total Monitoring Stations**



Bubble Size: Percentage violation | SOURCE: Central Ground Water Board, 2018

Figure 15: **Distribution of Nitrate Violation in GW in 10 selected states for study**



SOURCE: CPR Analysis | Note: States of WB and Assam excluded because of lack of data

The bubble chart shows the distribution of monitoring points and total violation points based on nitrates level. The size of the bubble depicts the percentage of violation. A regression analysis was then carried out on the dataset to determine if there was a correlation between nitrates violation and groundwater contamination which showed the results depicted in Figure 15.

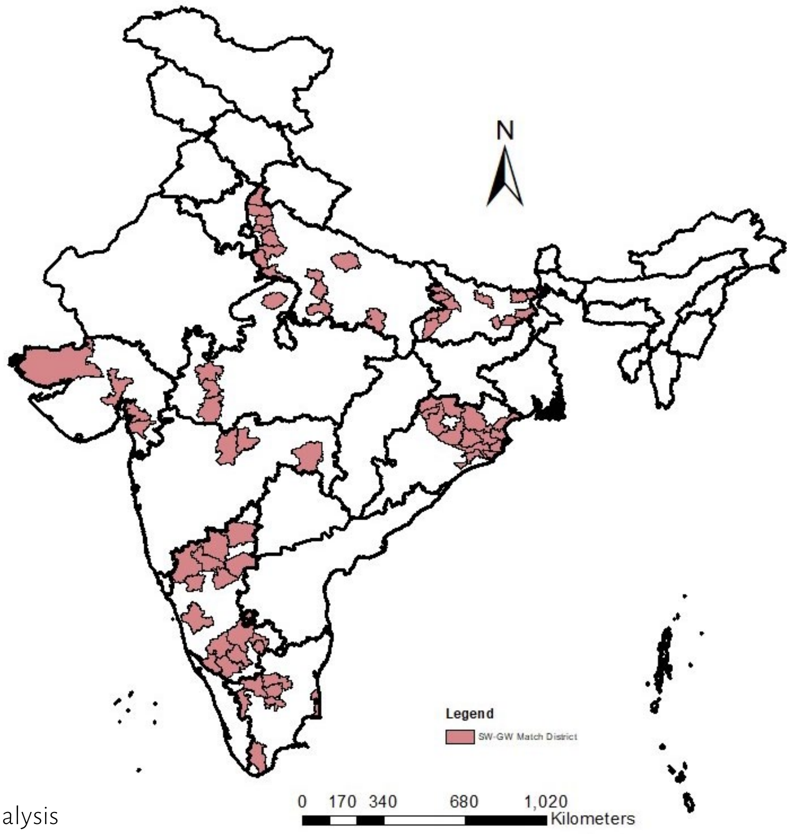
As observed in the figure, the results did not show any significant correlation between nitrates and population or IHL (even in logarithmic forms). A plausible reason for the obtained results is specification bias, which arises due to the availability of only violation points. During the study, we did identify confounding factors like agriculture runoff and industrial settlements, which contribute to nitrates loading but were kept out of the scope of study due to the inadequacy of data for analysis. However, it is important to consider them for arriving at a holistic conclusion.

This led us to devise an alternate method for district selection by creating a comparative list of districts with nitrate violation points for groundwater contamination and FC violation points for river pollution.

- 71/198 districts matched for river water and ground water pollution data from Bihar, Gujarat, Karnataka, Madhya Pradesh, Maharashtra, Odisha, Tamil Nadu and UP
- 11.93 percent correlation between nitrate violation and FC violation in 69 matched districts (two outliers dropped)
- 15.72 percent correlation between logarithmic transformed violations

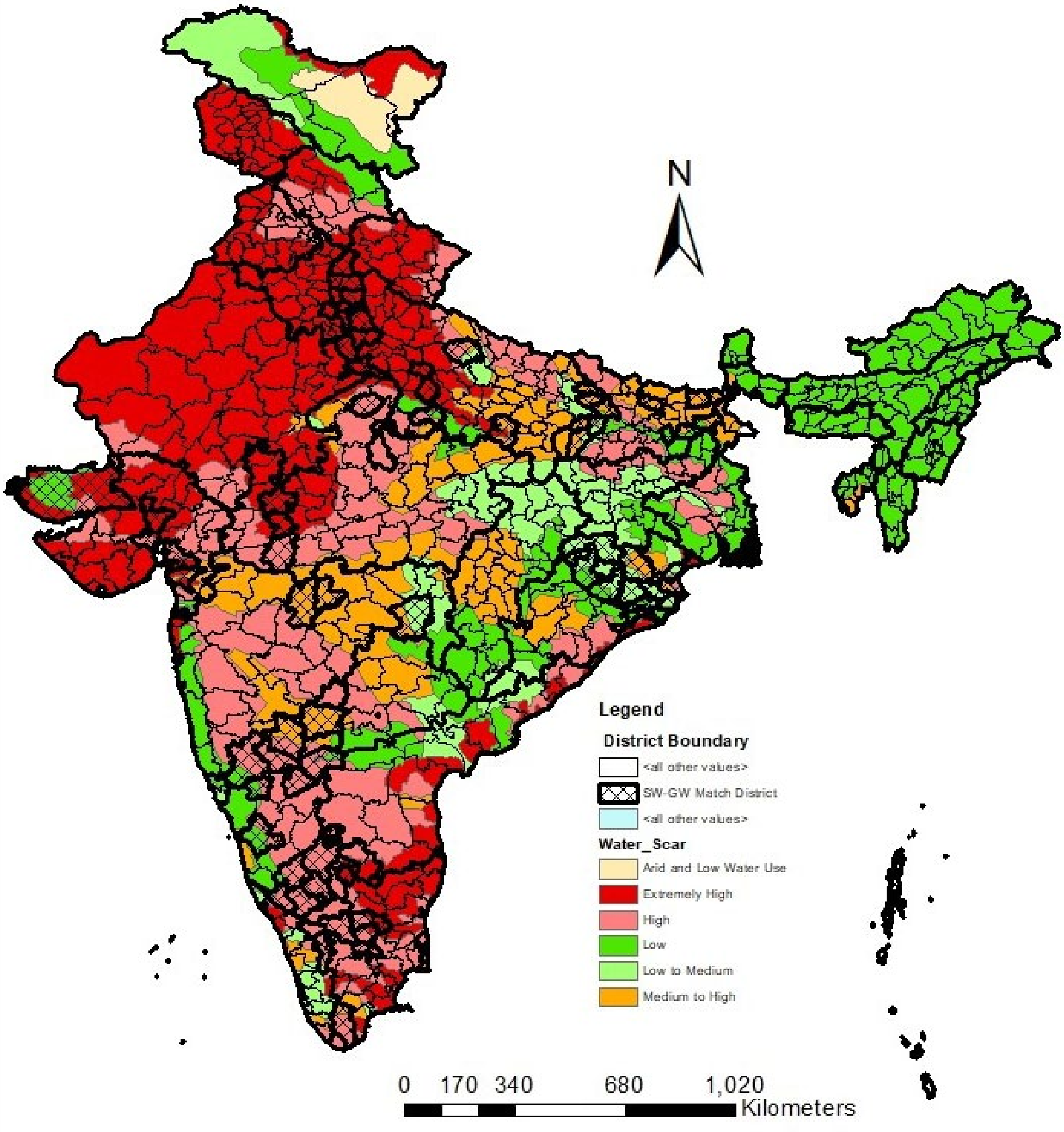
Based on the above results, districts have been identified, which shows linkages between groundwater and river water pollution, as shown in Figure 16. UP, Bihar, Odisha, Gujarat, Madhya Pradesh, Maharashtra, Karnataka and Tamil Nadu show both surface water and groundwater violations.

Figure 16: Linkages between River Water Pollution and Groundwater Pollution



SOURCE: CPR Analysis

Figure 17: **Water Scarcity and Identified District Overlay**



SOURCE: Water Scarcity Map: WRI, 2015; Identified Districts: CPR Analysis

When the identified districts showing both surface water and groundwater pollution were overlaid with the water scarcity map of India, variations were observed in terms of correlation between the two. The districts in Odisha and a few in Karnataka and Gujarat fall in the low water scarcity region, with some of them in medium and high water scarcity regions. Districts in Bihar, Madhya Pradesh and Maharashtra are predominantly of medium water scarcity and those in UP are high water scarcity regions. Preference shall be given to districts showing high violations and falling under high scarcity areas for future interventions through FSM

Image Source: www. thehindu.com

Detailed Discussion

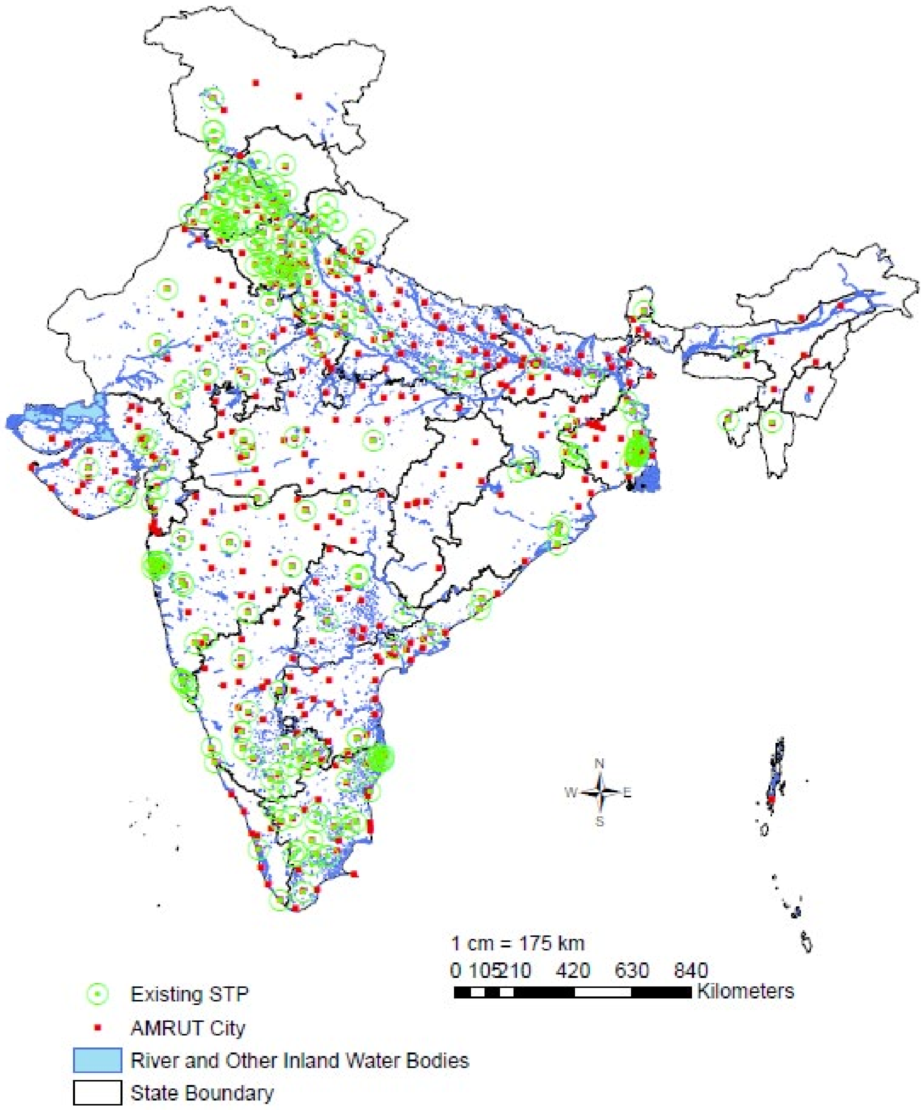
The analyses in the previous sections constitute a novel attempt to underscore the severity of river and groundwater pollution caused due to rapid urbanisation and unsafe discharge of untreated and partially treated wastewater in India. Not only has river pollution remained unabated, it has also burgeoned in the recent decades with increasing urbanisation and unplanned growth of urban areas where the sanitation needs of residents are seldom met. Concurrently, this has heightened the requirement for drinking water treatment provisioned by rural and urban public health engineering organisations. To this end, it is pertinent to understand the adequacy of sanitation infrastructure in terms of treatment facilities. This study has scrutinised collated information on river water and groundwater pollution data based on parameters for organic pollution caused due to discharge of untreated wastewater. From this, the following policy implications emerge as the most urgent ones pertaining to river water and groundwater pollution in India:

Urgency of Municipal Wastewater Treatment to Reduce FC Pollution in Water Bodies

Figure 18 presents a map that overlays the AMRUT cities, existing sewage treatment plants and water bodies in India. There are 500 AMRUT cities in India, including 46 mega/metropolitan cities (million-plus cities); the rest are medium-sized Class I cities (population of over 1 lakh). Collectively they account for around 60 per cent of the total urban population. These bigger cities of India, also happen to be the only cities with STPs. But not all of these cities have STPs. It is, thus, imperative to understand which of these prominent cities are potential beneficiaries of large infrastructure investments pertaining to water and sanitation under the flagship government scheme of AMRUT. It can be seen in the spatial representation of the AMRUT cities and the existing STPs that not all of them have STPs.

Further, it is clear from the map that there is a disparity in the distribution of STPs across states and across regions within states. For example, when the states of UP and Maharashtra are compared, it is seen that they have a similar number of STPs (73 in UP and 76 in Maharashtra). But despite Maharashtra's higher urbanisation compared to UP, it has only 44 AMRUT cities compared to 61 AMRUT cities in UP. At the same time, despite a higher number of CPCB monitoring points (119) in Maharashtra as opposed to 56 in UP, FC violation stands at only 17 per cent in Maharashtra as compared to 86 per cent in UP. Not to mention, spatially, it can be seen that UP has more riverine cities compared to Maharashtra, with a much larger number of cities (only some are shown on the map) directly contributing to pollution in Ganga and its tributaries. Many of these cities do not have any treatment facilities compared to a few big cities (mostly the AMRUT) with STPs, of which 11 are reportedly non-operational, operating collectively at less than 90 per cent capacity. And though the CPCB report (Board, 2015) mentions 170 new STPs, they add only a 15 MLD capacity. The cross-state disparities are validated in the regression analysis where the impact of the urban population is significant. In contrast, this impact is not significant for Maharashtra because of lower FC due to the high treatment capacity of existing STPs.

Figure 18: **AMRUT Cities, Water Bodies and STP's**



SOURCE: Water Body Shapefiles: ESRI India, AMRUT City: Census Coordinates and STP Data: MoHUA Database

It is also to be noted that there is a disparity in access to treatment infrastructure within the states. For example, not all cities in Maharashtra or UP have access to STPs. There are several cities which despite being identified under AMRUT, do not have access to STPs. Several projects have been identified and commissioned under the AMRUT scheme, but drinking water treatment takes precedence over wastewater treatment. Further, the city size-wise disparity underscores the emphasis on big cities like Pune or Kanpur, which lead to high FC pollution in Bhima and Ganga rivers, respectively. These cities do not have adequate treatment capacities to abate river pollution. This holds true also for medium and small-sized cities like Satara or Amravati in Maharashtra and Kannauj or Muzzafarnagar in UP where CPCB reports high FC contamination in the rivers.

However, while debating on the interrelation between the distribution of treatment capacities and various factors that should ideally govern them, care must be taken as the data under consideration has been obtained from only one source. A good example of the same is Namami Gange Programme: a flagship programme of the Union government to accomplish the twin objectives of effective abatement of river pollution and conservation and rejuvenation of the river Ganga. World Bank has been a key partner in its implementation, and currently, phase I of the programme is being executed. In the first phase, World Bank has helped in building critical sewage infrastructure in 20 pollution hotspots along the river to clean its tributaries (in progress until December 2021). Phase II of the project has been sanctioned in which river cleaning projects on Hybrid Annuity Model and DBOT Model shall be executed. So far, 313 projects worth Rs 25,000 crores have been sanctioned under the mission. The STP data projected on the map doesn't capture this information, and so detailed analysis of various targeted projects is advisable before arriving at any conclusion.

While there has been an endeavour to highlight such disparities and, at the same time, the need to plug the existing gaps in abating river pollution in this paper, the challenges faced in terms of collating information from government databases have been daunting. Although there is data on river pollution in different formats put together by the many institutions dealing with the subject, they are all disjointed, presumably due to a lack of coordination between the institutions. It is not surprising that there have not been many studies trying to collate all this information to present a holistic study on river pollution in India. There have been piecemeal studies that talk about specific river basins or region-specific groundwater analysis to expound on river and groundwater pollution problems separately. In addition, no studies have tried to quantify the extent of FC contamination caused due to urbanisation and inadequate sanitation even after completion of phase I of the SBM and the subsequent policy focus on faecal sludge management.

Early Demonstration of River pollution Abatement through Urban FSM

The state of Odisha is host to a number of river systems. The major river basins in Odisha are:

1. Subranekha
2. Buddha Balanga Basin
3. Baitrani Basin
4. Brahmani
5. Mahanadi
6. Tel Basin
7. Rushikulya Basin
8. Vanshadhara
9. Indrabati Basin
10. Nagavali Basin
11. Kolab Basin

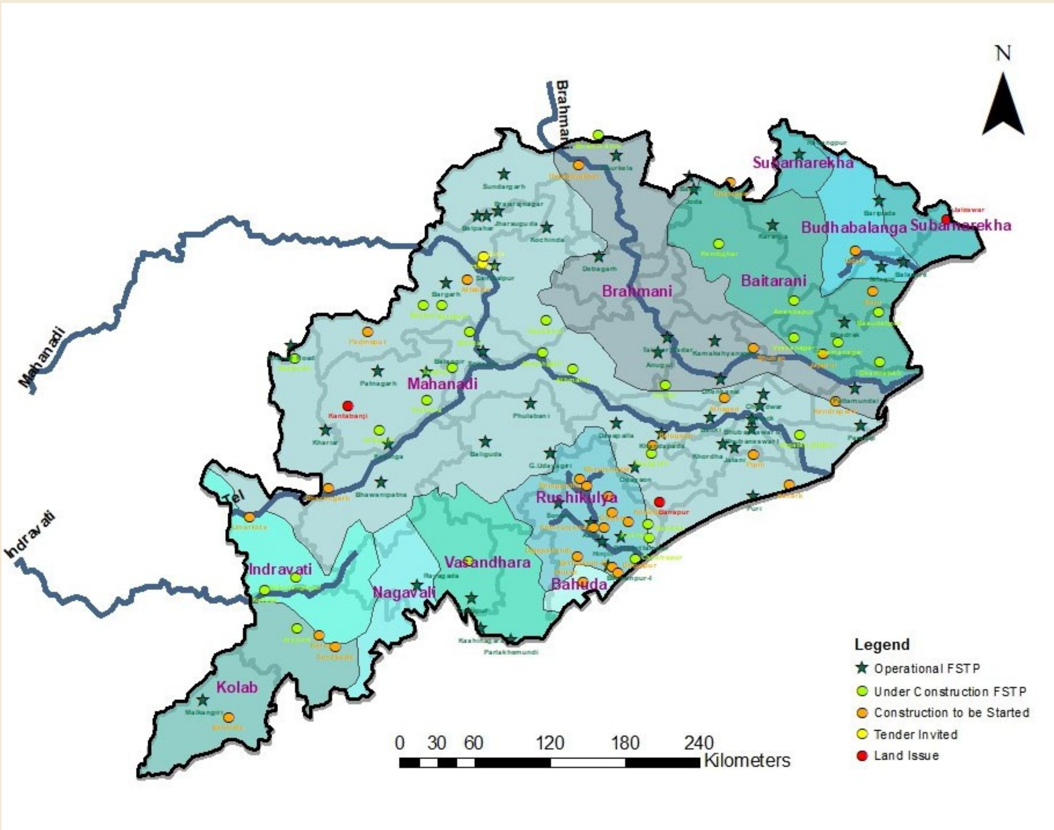
The map below shows these 11 river basins in Odisha with the statutory towns marked per river basin.

SOURCE: D/o Water Resources, G/o Odisha [List of Statutory Towns: HUDD, G/o Odisha]

Nearly 90 percent of urban areas in Odisha directly affect rivers in the state; the rest fall within existing river basins. With the open discharge of raw sewage into drains so dire, the sanitation policy considers action of cities within the wider ecosystem of river basin systems in the state.

Integrating broader environmental concerns in the provision of urban sanitation service delivery is one of the key principles of Odisha's Sanitation policy. For setting up pollution abatement systems, it mandates the prioritization of those cities that directly or indirectly affect rivers or river basins in the state due to discharge of untreated domestic wastewater.

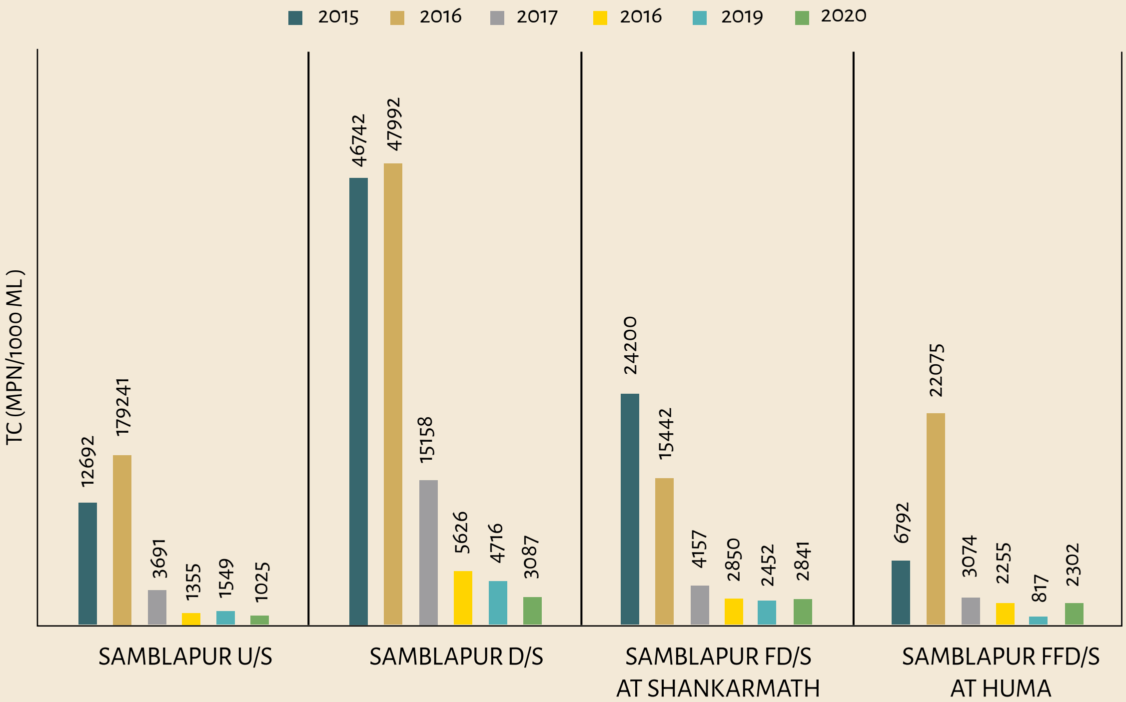
The government of Odisha operationalised its first Septage Treatment Plant (SeTP) in Puri in 2017. In 2018, six more SeTP's were operationalised from 2019 scaling up of plants across the state was undertaken along with strengthening institutions to sustain FSM. The following map depicts the current status of SeTP's across the state.



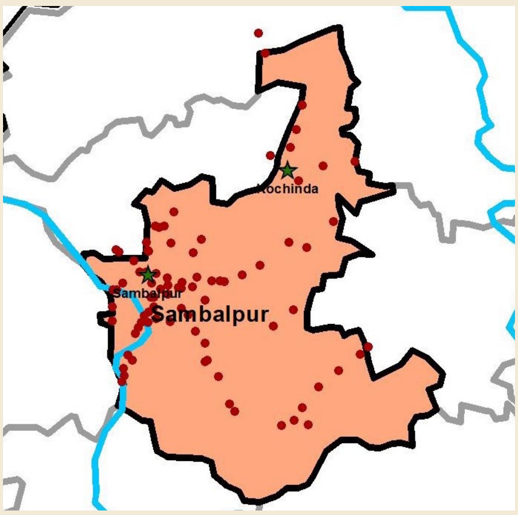
SOURCE: D/o Water Resources, G/o Odisha

The efforts of Odisha government have yielded positive results with reduction of total coliform levels in the Mahanadi river water at Sambalpur and Cuttack over the years. The following chart shows the observed readings from 2015 to 2020.

Mahanadi River System



SOURCE: D/o Housing and Urban Development, G/o Odisha



The following map shows the geolocation of groundwater monitoring wells and the operational FSTP's in Sambalpur district. It can be observed from the map that there is a higher concentration of monitoring wells in the blocks falling within catchment area of river Mahanadi. Furthermore, the location of FSTP within the catchment area of river ascertain government's finding of reduction in total coliform levels post FSTP commissioning.

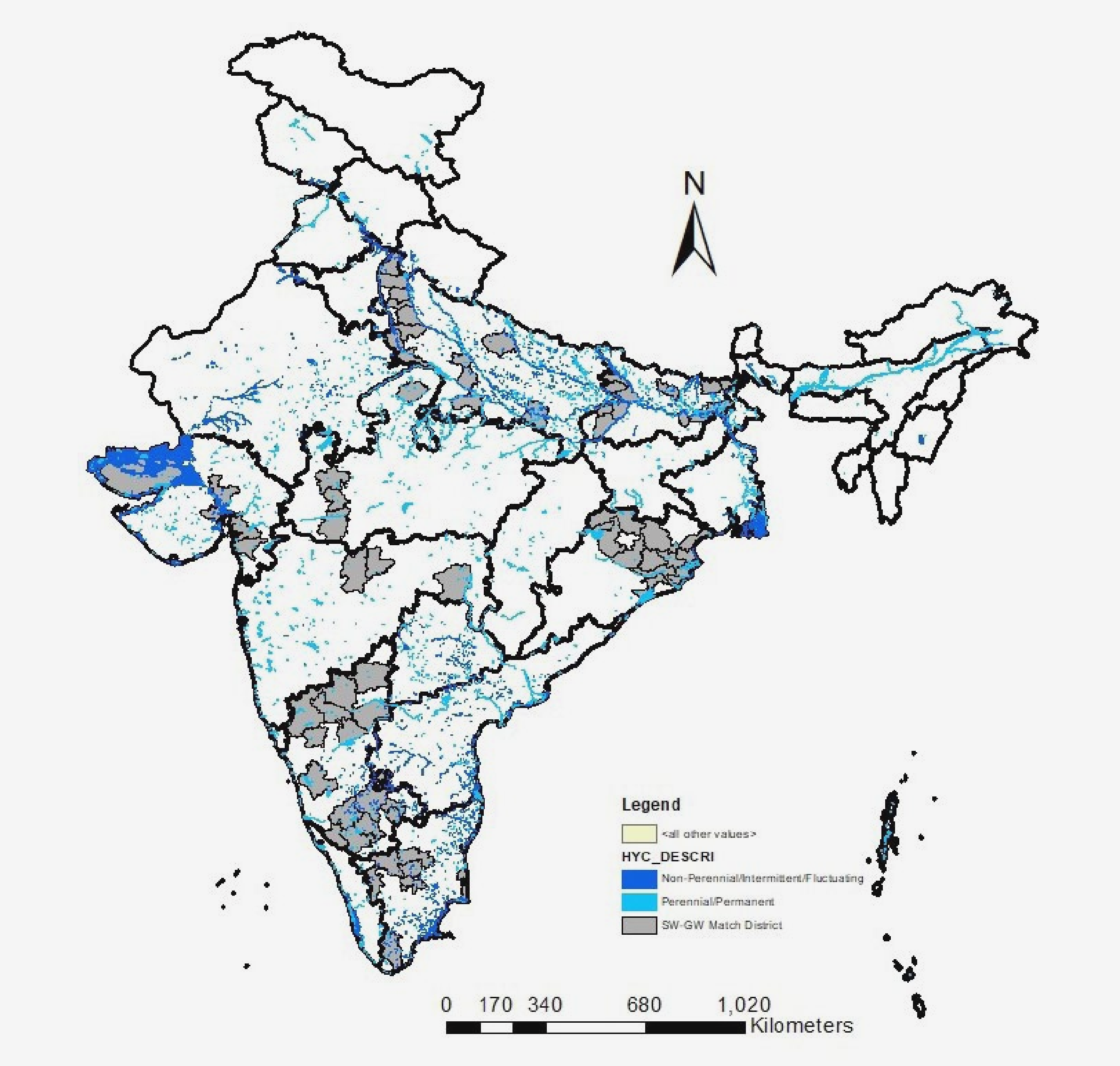
Identification of Districts with High River Water and Groundwater Contamination

In attempting to develop a comprehensive understanding of water pollution caused by untreated urban and rural wastewater this study also explores the correlation between river water and groundwater pollution. Due to the dearth of data for river water and groundwater pollution points, especially after matching these separate data sets, no statistically significant correlation could be established between river water and groundwater pollution regarding FC contamination. But it sure became pertinent to highlight the districts which report both high FC contamination in rivers and nitrate contamination in their groundwater.

The exercise of identifying districts with nitrate contamination in groundwater using CGWB data and subsequent matching of the information with the CPCB river pollution data points revealed those districts, undertaken in the statistical analyses for river pollution due to urbanisation and inadequate sanitation infrastructure. The matching of districts was possible for eight out of the ten states (excluding WB and Assam, for which nitrate contamination data was unavailable). For Bihar, Gujarat, Karnataka, Madhya Pradesh, Maharashtra, Odisha, Tamil Nadu and UP riverine districts with both high levels of FC contamination in rivers and high average nitrate contamination in groundwater were identified and have been shown in Figure 19. This spatial presentation of these districts highlights the criticality of water pollution in these districts that can be attributed directly to the discharge of untreated waste into river bodies or seepage of the same into groundwater. Some of the critical districts are Bengaluru (Urban and Rural) and Gulbarga in Karnataka; Bhojpur and Patna in Bihar; Sambalpur and Cuttack in Odisha; Nashik and Amravati in Maharashtra; Shivpuri and Ujjain in Madhya Pradesh; Erode and Dharmapuri districts in Tamil Nadu and Kanpur and Agra in UP.

A detailed ranking of these identified districts is beyond the scope of this study. However, spatial representation of the districts with nitrate contamination and superimposition of river and inland water bodies have been done to flag the districts with high river water and groundwater pollution. Although this is a simplistic presentation of the severely water polluted areas, it is a foray into a holistic representation of collated data without any publicly available hydrological information. Notwithstanding the other factors that may contribute to water pollution, such as fertilisers in agriculture, industrial effluents, etc., this exercise has only focused on the effects of urbanisation and urban sanitation on river water and groundwater pollution. To this end, the riverine districts identification exercise is invaluable to understand the criticality of the river water and groundwater contamination in highly urbanised districts where invariably either of the two sources also serves as the primary drinking water source.

Figure 19: **Linkages between River Pollution and Groundwater Pollution**



SOURCE: Water body Shapefiles: ESRI India, Identified Districts: CPR Analysis

The Importance of Institutional Mapping for a Comprehensive Hydrology Project

The difficulties in the collation of data from different analyses underscore one of the key obstacles to arriving at a somewhat comprehensive understanding of water pollution in India. The presence of multiple institutions to address and abate surface water and groundwater pollution poses huge difficulties in sourcing and collating data and formulating hypotheses based on holistic analyses. The fact that data from different sources has been used in this study only highlights the need for standardisation of data and its public provision for academic and policy analyses on the river and groundwater pollution abatement.

One can easily find a plethora of standalone studies on specific river stretches or groundwater contamination in specific districts or blocks. But the statistical analyses in the preceding section clearly underscore the homogeneity in the causal relationship between urbanisation, urban sanitation, and river water and groundwater pollution across different parts of the country based on the available data points. Although this may lead to a generalised understanding of this causal relationship, the analyses also manage to present a methodology to comprehend the relative criticality of water pollution in different states and districts. This would hopefully redress the biased attention that some states have been receiving by the prioritisation of some rivers over others in the country or prioritisation of certain districts on groundwater contamination over others where groundwater may be as contaminated but at the same time is scarce and the only source of drinking water available.

At the same time, to develop a hydrology project, the established institutions like CWC, CGWB and CPCB need to work in a more coordinated manner to address the problem of water contamination. The water quality monitoring guidelines have already been standardised in 2017. It is also evident that more or less similar parameters are being monitored across the different monitoring stations adhering to the Water Quality Monitoring Guidelines of 2017. In addition to this, the guidelines have also mandated the exchange of information pertaining to water quality monitoring between relevant institutions – CWC, CGWB and CPCB. However, this does not seem to be the case, and there is no publicly available information on the overlaps of water quality monitoring stations under these different institutions. It would certainly be beneficial for policymakers and researchers to assess the levels of pollutions in different rivers in the country and suggest adequate measures for their abatement if the data were more readily available, with better depth and richness regarding readings from different times of the year. There needs to be coordination between the different monitoring locations irrespective of which institution they are maintained by. Availability of the coordinates of the monitoring locations will help in undertaking of spatial analyses to understand the hydrology and pollution levels in different parts of the country.

Image Source: www. gilmoretee.com

Conclusion

This study on river pollution abatement was undertaken with the intent and objective of assessing the impact of urbanisation and urban sanitation on river pollution. This has been gauged through the violations in FC, which is obviously the parameter that can directly be linked to high urbanisation and poor sanitation; incidentally FC was found to be the biggest contaminant in all the river bodies. While the same analysis was done for groundwater, the dearth of FC data in this case prevented establishing of linkages that were statistically significant and could be as clearly established as for river water data. The analyses pursued to validate the detrimental linkages between the high urban population, poor urban sanitation, and lack of adequate treatment facilities shed light on the poor quality of data available in general, making such a study extremely challenging.

Need to develop a hierarchy of solutions: This would include source augmentation, demand management, wastewater management and recycling for water stressed regions based on their characteristics: Notwithstanding the challenges posed by the dearth of data, the study has endeavoured to come up with a methodology to establish a generalised relation between urbanisation, sanitation and FC pollution. At the same time, there has been a conscious attempt to highlight state-wise variations in pollution. This is particularly important given the absence of a national level hydrology report to highlight water scarcity and contamination in different parts of the country. Amongst the few important corollaries emanating from the analyses undertaken in the study, the most important is the need to ramp up wastewater treatment in urban areas, which clearly lead to high FC contamination in rivers and in groundwater (through indirect relation with nitrates) in some areas. While bigger urban agglomerations often have a better-sewered network, the treatment facilities have been inadequate, resulting in very high FC due to indiscriminate discharge of wastewater into river bodies and open land. At the same time, the high prevalence of on-site systems in small and medium-sized cities presents a huge challenge due to lack of access to sewered network and no treatment facility for the faecal sludge.

Developing a robust database at the national level: Urbanisation and urban sanitation are found to have an impact on river pollution. Although the same could not be established as convincingly for groundwater, there is no denying this is plainly due to a lack of adequate data. It is also to be noted that there are many other factors contributing to pollution; these other parameters are beyond this study's scope. For example, agriculture and the use of fertilisers are among the biggest contributors to water pollution in India, even more than industrialisation, the effects of which are more localised. Studies have shown the adverse effects on the groundwater table and quality due to paddy cultivation and fertiliser use in Punjab. Such factors and other associated pollution parameters that have been omitted from this study also underscore the need for a better repository of datasets at the national level. Further, there is a need to extensively map existing monitoring and physical infrastructure to holistically capture data and understand its ground-level implications. Data on monitoring stations, open drains, underground water/waste water channel, treatment infrastructure etc. needs to be integrated as well.

Need for carrying out detailed studies at state level on pollution and water scarcity: Another crucial corollary from the analyses is the variations in pollution levels across states and within states. While policy focus has been biased in favour of some river stretches such as the Ganga in UP, Yamuna in Delhi, Hooghly in Calcutta and Arkavathi in Bangalore, the study finds that other major river basins in India suffer high levels of pollution and command commensurate attention. Even though states like WB, Odisha, Karnataka and Tamil Nadu have fewer monitoring stations than Maharashtra and UP, the levels of pollution in the levels of FC are significantly high in these states. While Odisha with a lower urban density may seem to invoke less concern about urban pollution compared to more dense urban agglomerations in WB, the need for treatment infrastructure for wastewater and independent studies is critical in all of these states.

Decentralised shortlisting of monitoring parameters: Studies carried out by the World Health Organisation (WHO) indicate high level of arsenic contamination in UP and WB. However, arsenic has not been recorded as a major pollutant from any of the western or southern states. To capture these regional variations owing to differences in geographies certain parameters should be monitored locally by state pollution boards and local bodies even though they are not prescribed by CPCB or CGWB in the centralised list of monitoring parameters.

Formulation of a National River Water Data Policy: Currently CPCB is monitoring pollution levels in river water twice a year which is a bit limited in terms of capturing monthly variations. There is a need for CPCB to carry out real- time monitoring. At the same time, this should be linked with SPCB and CGWB databases along with that of institutions like CWC so as to create a centralised data portal.

India is staring at an imminent water crisis unless it takes adequate steps and fast. Studies have highlighted how some river stretches are extremely polluted and are on the verge of dying. At the same time, other studies have highlighted the grim situation of groundwater depletion and contamination in other places. The renewability of water as a resource has been drastically reduced to the extent of freshwater now being tagged as non-renewable due to the slew of anthropogenic actions in the form of urbanisation, agriculture and industrialisation and consequent pollution. The National Water Policy, cognizant of the criticality of water resource in India, has called for Integrated Water Resource Management, and the GOI is endeavouring to undertake a massive country-wide hydrological survey. However, the approach to curb water pollution and lack of coordination between different institutions undermine the objectives incorporated in the water policies. It renders ongoing efforts and interventions redundant or inadequate. It is imperative to develop a holistic understanding of different aspects of water pollution in India and adequately redress them through unbiased interventions.

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