MONITORING TOOLS FOR URBAN LAKES IN UTTAR PRADESH

Developing Checklists for Lakes under AMRUT

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EXECUTIVE SUMMARY

The Centre for Science and Environment (CSE), New Delhi, surveyed the state of the lakes in four towns of Uttar Pradesh, namely Banda, Jhansi, Rampur and Rae Bareli. These towns are located in the Indo-Gangetic Plains, and there is great demand for groundwater due to the increased rate of urbanization in these towns. Sustainability of the health of the lakes is thus vital for the town-level recharge of the groundwater reserve.

In its survey in August–November 2023, CSE found that except for very few, the lakes in these towns were threatened. Not only is rejuvenation of these lakes important, there should be adequate emphasis on their management plan.

This is possible only when there is a good monitoring tool developed for the waterbodies. For the sustainability of these lakes, CSE has developed checklists for monitoring the lakes. The checklists entail periodically collecting hydrological and water-quality data and deriving the biological index across years.

The checklists give guidance on what data to collect, when to collect and how to collect it. They can be used for lakes in cities and towns of the Indo-Gangetic Plains of Uttar Pradesh.

1. BACKGROUND

Lakes are essential surface-water sources for providing freshwater to households, industries, pisciculture and agriculture. They are also used for generating revenue through tourism and recreational activities. Urban lakes have the special characteristic of acting as sponges in cities to absorb extreme-storm events.

In the last two decades, rampant urbanization has destroyed urban lake systems. They have been encroached on by builders or have become dumping grounds for sewage, garbage and/or toxic waste. Increased rainfall intensity due to climate change has made preservation of lakes—the sponges in cities—very important. Cities such as Bengaluru, Delhi, Chennai, Ahmedabad, Mumbai, Guwahati, Kolkata, Srinagar and Lucknow—the list goes on—report frequent urban floods due to loss of waterbodies. This leads to scarcity of freshwater and increased pollution in urban areas, and increase in health costs.

Hence, moving towards Sustainable Development Goal (SDG) 6—which refers to safe water and sanitation, protection and preservation of the waterbodies/lakes—is very important. The Government of India has been proactively working on the protection, preservation and creation of waterbodies, which help urban areas specifically to avoid floods and to even recharge groundwater sources. So far, several acts, policies and programmes have been launched.

Some of the major initiatives by the Government of India are as follows:
1. In 2019, Jal Shakti Abhiyan was launched by the government. This was followed in 2021 by the Jal Shakti Abhiyan: Catch the Rain campaign.
2. In 2022, the Mission on Amrit Sarovar, aimed at developing and rejuvenating 75 waterbodies in each district of the country as part of the celebration of Azadi ka Amrit Mahotsav, was launched.
3. The Atal Mission for Rejuvenation and Urban Transformation (AMRUT) 2.0 was launched in 2021 under the Ministry of Housing and Urban Affairs. The overall aim of this programme is to attain water security in the towns of India.
4. The Mahatma Gandhi National Rural Employment Guarantee Scheme (MNREGS) launched in 2006 also includes restoration of the lakes apart from water conservation and groundwater recharge.

The Centre for Science and Environment, a New Delhi-based think tank, has been working with the Department of Urban Development (DoUD), Uttar

Pradesh, since 2018. The partnership entails safe management of faecal sludge in 56 towns of Uttar Pradesh. Taking this partnership further, DoUD collaborated with CSE to work on rejuvenating the lakes in four towns—Rampur, Banda, Rae Bareli and Jhansi—of Uttar Pradesh. The lakes in these towns help recharge groundwater, which in most of the towns is the major water source.

CSE monitored the lakes in these towns in August–November 2023. The lakes can be rejuvenated under AMRUT 2.0, but only rejuvenation cannot guarantee healthy lakes. Like any other mission, this mission also needs to be supported by a monitoring mechanism to foster sustainability of the lakes. In the absence of monitoring tools, the lakes suffer deterioration of water quality, siltation, encroachment and loss of biodiversity.

The lakes can be monitored for various aspects, including:

a. Is there regular deterioration in water quality?
b. Can the lake support fish, turtles, aquatic plants and birds?
c. Is the lake safe for outdoor bathing?
d. Is the groundwater in the lake area contaminating the waterbody?

Additionally, data generation at regular intervals helps to develop a comprehensive management plan for the lake.

Since the sample lakes studied are located in the Indo-Gangetic Plains, the monitoring tools have been developed for lakes located in this hydrogeological setup.

2. SETTING OUT THE OBJECTIVES

The first step in planning a monitoring tool for any lake is to decide on the objectives. The following are the three main objectives for developing the monitoring tools for the lakes located in the Indo-Gangetic Plains of Uttar Pradesh.

1. Monitoring of the fluctuation of the lake (hydrology);
2. Monitoring of the water quality; and
3. Monitoring of the biodiversity index.

This paper aims to develop checklists for all the above points. The checklists give guidance on collection of data, water samples and period of collection of data; water samples will be given. The data to be collected is for water quality, hydrology and biodiversity. A plan for rejuvenation can be developed after analysing the checklists.

3. DEVELOPING THE CHECKLISTS

The following—monitoring fluctuations of the lake (hydrology); monitoring water quality; and monitoring the biodiversity index—are the three main objectives for developing the monitoring tools for the lakes located in the Indo-Gangetic Plains of Uttar Pradesh.

Hydrological monitoring

Hydrological monitoring includes monitoring of rainfall, runoff and capacity (volume) of the lakes. The different parameters of hydrological monitoring have been discussed in the following sections.

Measuring rainfall

To monitor rainfall, a rain gauge should be installed near the lake. A minimum of one rain gauge is planned for one lake. The number of rain gauge stations increase with the increase in the area of the lake basin. A larger lake basin area, for instance 1,000 hectares, may have more than one rain gauge. The reading of rainfall from the rain gauge station for each lake shall be recorded regularly on a daily basis after which the cumulative amount for each month is incorporated in a table as shown below. S1 denotes the reading from one station for the lake.

Table 1: Table to collect rainfall data for a lake

Month	Apr.	May	Jun.	Jul.	Aug.	Sept.	Oct.	Nov.	Dec.	Jan.	Feb.	Mar.	Annual rainfall (sum of monthly rainfall)
Station	Pre-monsoon			During monsoon			Post-monsoon			Winter			
S1													
S2													
S3													
S4													
S5													
S_n													
S_{avg}													

Source: Compiled by CSE

'n' denotes the number of the rain gauge station; avg = average rainfall for each month

Calculating available runoff

To calculate the quantity of water influx inside the lake, the following calculation is considered.

RO = A x R x C cubic metres

Where R is the annual rainfall in metres, A is the catchment area in square metres and C is a coefficient of runoff (constant – depending on the type of rock and soil of the area).

This gives the volume of water that fills the pond in a year.

Measuring capacity of a lake

The storage capacity of any lake is the amount of water that a lake can hold at a specific point of time. When water reaches the lake from the catchment, it carries with it silt which deposits at the base of the lake. The deposited silt decreases the storage capacity/volume of the lake.

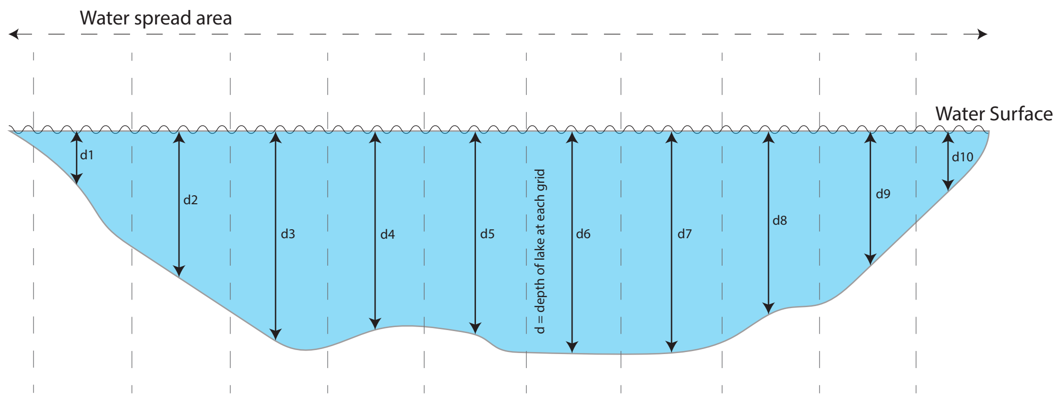
It is important to monitor the capacity of the lake periodically and plan for desiltation accordingly.

The storage capacity of the lake can be calculated as

Storage capacity = Surface area (Water spread area) x Average depth of the lake

The average depth is the mathematical mean of depths at different

Figure 1: Cross-sectional view of a lake or pond to measure depth at different grids



Source: Compiled by CSE

monitoring grids (see *Figure 1: Cross-sectional view of a lake or pond for measuring depth at different grids*). It can be calculated by measuring the depth of the lake at every grid and taking the mean of data.

$$\text{Average depth } D_m = \frac{d1+d2+d3+\cdots\ldots\ldots+dn}{n}$$

where d is the depth of lake at each grid and n is the number of grids where measurements have been taken.

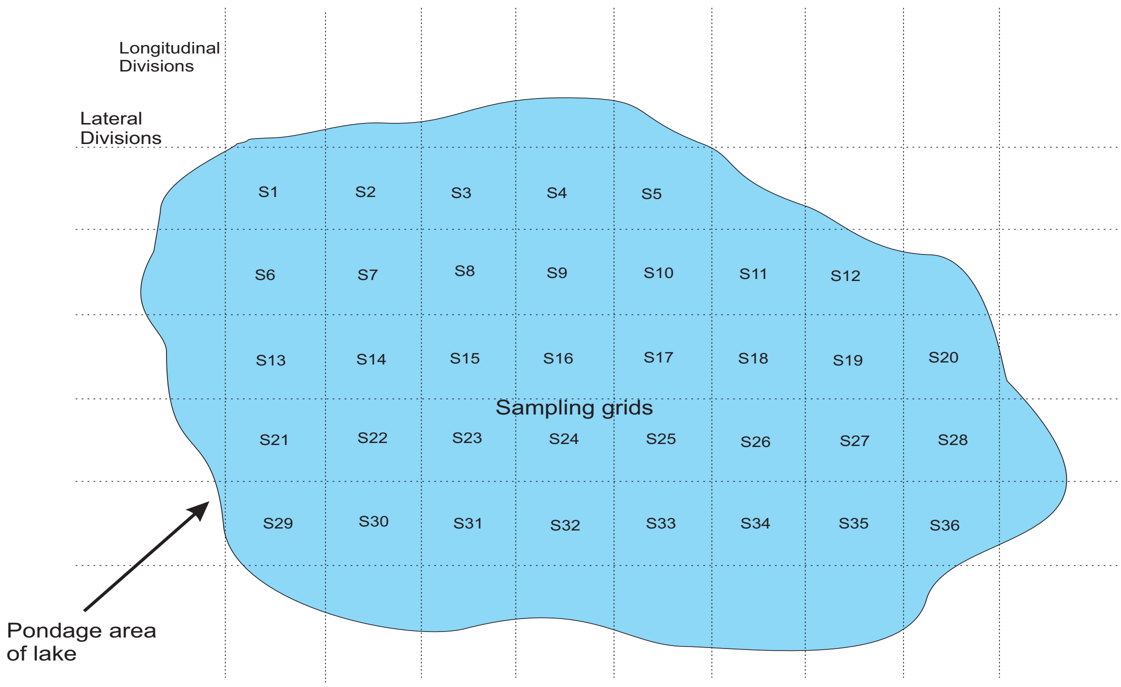
Monitoring water quality

Due to increased urbanization and industrialization, pollutants may enter from the surrounding areas into the lake (see *Figure 2: Grids for collecting water samples from lake*).This may create algal bloom and surfs and even make the water turbid. Water entering the lake may carry with it physical, chemical and biological pollutants.

Selecting the number and location of samples

Sampling water from a lake is the first step towards monitoring. Correct steps need to be followed to collect the samples. Since lakes can be of any size, from small to big, a uniform method of sampling would be best.

Figure 2: Grid for collecting water samples from a lake



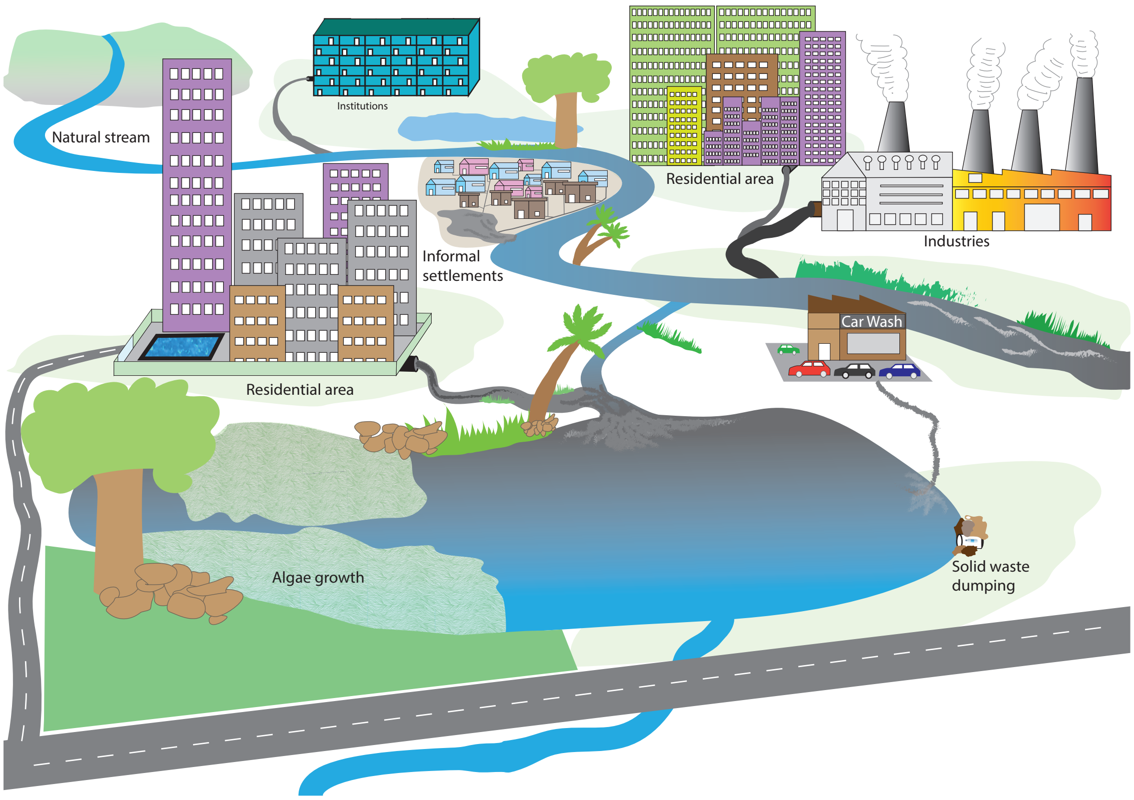
Source: Compiled by CSE

Table 2: Table for recording date of collecting water sample from a lake

Table for recording the date of collecting water sample from sampling grids of lake																	
			Sampling grid station														
Date of sampling	YEAR	PERIOD	S1	S2	S3	S4	S5	S6	S7	S8	S9	S10	S11	S12	S13	S14	S15
	YEAR 1	APRIL–MAY															
		OCT.–NOV.															
		DEC.–FEB.															
	YEAR 2	APRIL–MAY															
		OCT.–NOV.															
		DEC.–FEB.															
	YEAR 3	APRIL–MAY															
		OCT.–NOV.															
		DEC.–FEB.															
	YEAR 4	APRIL–MAY															
		OCT.–NOV.															
		JAN–FEB.															
	YEAR 5	APRIL–MAY															
		OCT.–NOV.															
		DEC.–FEB.															

Source: Compiled by CSE

Figure 3: Representation of influx in a lake



Source: Compiled by CSE

To take a sample from a lake, the pondage area (area of water spread) of the lake can be divided into grids (see *Figure 2: Grid for collecting water samples from a lake*) of any convenient dimensions, depending on the size of the lake. The samples can be taken from those grids. The concentrations of pollutants can be different at different locations, so for precise monitoring it is important to take samples from the grids. Apart from the lake reservoir, one monitoring station should be located before the inlet point of water.

Selecting the period of sampling

The sample should be taken a minimum of three times a year, i.e. in pre-monsoon (April–May), post-monsoon (October–November) and the lean period (December–February). In the pre-monsoon time, water levels in the lakes are comparatively low. In the monsoon, the lakes receive rainfall and surface runoff, and there is turbulence in the lake. In the lean period, lake water is comparatively stable.

Table 3: Table to monitor water quality parameters in a lake

Period of sampling: Pre-monsoon (Apr.–May)/post-monsoon (Oct.–Nov.)/lean period (Dec.–Feb.) Date:																								
Sampling station/ parameters	Temperature (degrees celsius)	Electrical conductivity (mho/cm)	Turbidity (NTU)	Colour	Odour	Total dissolved soids (TDS) (mg/L)	Calcium hardness (mg/L)	Magnesium hardness (mg/L (D)	Total hardness (mg/L)	pH	Dissolved oxygen (DO) (mg/L)	Biochemical oxygen demand (BOD) (mg/L)	Chemical oxygen demand (COD) (mg/L)	Free ammonia (mg/L)	Total nitrogen (TKN +NO_3) (mg/L)	Total phosphate (mg/L)	Sodium (Na) (mg/L)	Calcium (Ca) (mg/L)	Magnesium (Mg) (mg/L)	Sulphate (SO_4) (mg/L)	Chloride (Cl) (mg/L)	Potassium (K) (mg/L)	Faecal coliform (MPN/100 ml)	Total coliform (MPN/100 ml)
S1																								
S2																								
S3																								
S4																								
S5																								
S6																								
S7																								
S8																								
S9																								
S10																								

Source: Compiled by CSE

Selecting the parameters
The parameters to be studied should give an idea of the physical, chemical and biological pollution of the lake water. Sampling in the aforementioned periods will give the results on changes in seasonal and temporal trends of parameters under study.

Biodiversity index

Biodiversity indicates the presence of different species in any localized environment. It denotes diversity of living things, including plants, humans, animals, birds, insects etc. A healthy waterbody is an ecosystem where biodiversity is always rich. It becomes a home to different species.

The lakes should also be monitoed to include aquatic as well as terrestrial biodiversities. The lakes should offer shelter, nutrition and food to these species for their sustainability.

To study the ecology of the lake, the biodiversity index is calculated, which includes the record of all the species and their number in and around the lake.

It is important to note the species present in the lake ecosystem and record it annually. The following table can be used to keep a yearly record of all types of species present in the lake.

Table 4: Table for collecting biodiversity data

Name of the lake:								Town/district/state:					
Type of species	Name of the species	Year 1	Year 2	Year 3	Year 4	Year 5	Year 6	Year 7	Year 8	Year 9	Year 10	Year 11	Year 12
		Number of species in the lake ecosystem or Abundance (n)											
Type 1	Species 1												
	Species 2												
	Species 3												
	Species 4												
	Species 5												
Type 2	Species 6												
	Species 7												
	Species 8												
	Species 9												
	Species 10												
Total													

Source: Compiled by CSE

The biodiversity index can be calculated yearly using the following table.

Table 5: Table for calculation of biodiversity index

Simpson's Biodiversity Index for the year ________						
Species	n	n-1	n(n-1)	N	N-1	N(N-1)
Species 1						
Species 2						
Species 3						
Species 4						
Species 5						
Species 6						
Species 7						
Species 8						
Species 9						
Species 10						
Total number of all species (N)			Σn(n-1)			

Source: Compiled by CSE

To calculate the biodiversity index (BDI), Simpson's formula[1] can be used, as given below:

$$\text{BDI} = 1 - \left(\frac{\sum n(n-1)}{N(N-1)}\right)$$

where n is the abundance of every individual species and N is the total number of all species. The biodiversity index is in the range of 0–1. An index value closer to 1 denotes greater diversity in the lake ecosystem, while close to 0 represents poor diversity.

4. FINAL OUTPUT

The checklists developed can be used for monitoring the lake annually so that proper management mechanisms may be developed for rejuvenation of the lakes. CSE has developed these checklists keeping in mind that the lakes are located in the Indo-Gangetic Plains. The pollution parameters and rainfall variations are selected accordingly. The state of Uttar Pradesh may use these checklists for the lakes located in the alluvial plains. This will help in developing a strong management plan for the lakes in cities and towns in the alluvial plains of Uttar Pradesh.

[1] *R.M. Warwick, P.J. Somerfield, and K.R. Clarke, 2008, Simpson Index. In Sven Erik Jørgensen and Brian D. Fath (Editor-in-Chief), Ecological Indicators. Vol. [4] of Encyclopedia of Ecology, 5 vols. pp. [3252–55] Oxford: Elsevier)*

ANNEXURES

Annexure 1: Table for monitoring hydrological parameters

Hydrological parameters						
Lake	Year of monitoring	Average annual rainfall (metres)	Available runoff (cubic metres)	Capacity of lake in the year of monitoring (cubic metres)	Original capacity of lake at the time of construction (cubic metres)	Change in capacity of lake (cubic metres)
Lake 1						
Lake 2						
Lake 3						
Lake 4						
Lake 5						
Lake 6						
Lake 7						
Lake 8						
Lake 9						
Lake 10						

Annexure 2: Table for monitoring biodiversity index

Lake	Year of construction	Original no. of species at the time of construction	Monitoring year	No. of species in monitoring year	Biodiversity index	
					At the time of lake construction	In the monitoring year
Lake 1						
Lake 2						
Lake 3						
Lake 4						
Lake 5						
Lake 6						
Lake 7						
Lake 8						
Lake 9						
Lake 10						

Annexure 3: Consolidated table for water quality parameters

Sampling station/ parameters	Temperature (degrees Celsius)			Electrical conductivity mho/cm			Turbidity (NTU)			Colour			Odour			Total dissolved solids (TDS) mg/L			Calcium hardness mg/L			Magnesium hardness mg/L			Total hardness mg/L		
	Apr.–May	Oct.–Nov.	Dec.–Feb.	Apr.–May	Oct.–Nov.	Dec.–Feb.	Apr.–May	Oct.–Nov.	Dec.–Feb.	Apr.–May	Oct.–Nov.	Dec.–Feb.	Apr.–May	Oct.–Nov.	Dec.–Feb.	Apr.–May	Oct.–Nov.	Dec.–Feb.	Apr–May	Oct.–Nov.	Dec.–Feb.	Apr.–May	Oct.–Nov.	Dec.–Feb.	Apr.–May	Oct.–Nov.	Dec.–Feb.
Year	Pre-monsoon	Post-monsoon	Lean period	Pre-monsoon	Post-monsoon	Lean period	Pre-monsoon	Post-monsoon	Lean period	Pre-monsoon	Post-monsoon	Lean period	Pre-monsoon	Post-monsoon	Lean period	Pre-monsoon	Post-monsoon	Lean period	Pre-monsoon	Post-monsoon	Lean period	Pre-monsoon	Post-monsoon	Lean period	Pre-monsoon	Post-monsoon	Lean period
S1																											
S2																											
S3																											
S4																											
S5																											
S6																											
S7																											
S8																											
S9																											
S10																											

. . . continued Annexure 3

Sampling station/ parameters	pH			Dissolved oxygen (DO) mg/L			Biochemical oxygen demand (BOD) mg/L			Chemical oxygen demand (COD) mg/L			Free ammonia mg/L			Total nitrogen (TKN + NO_3) mg/L			Total phosphate mg/L			Sodium (Na) mg/L			Calcium (Ca) mg/L			Magnesium (Mg) mg/L			Sulphate (SO_4) mg/L			Chloride (Cl) mg/L			Potassium (K) mg/L		
Year ………………	Apr.–May	Oct.–Nov.	Dec.–Feb.	Apr–May	Oct.–Nov.	Dec.–Feb	Apr.–May	Oct.–Nov.	Dec.–Feb.	Apr.–May	Oct.–Nov.	Dec.–Feb.	Apr.–May	Oct.–Nov.	Dec.–Feb.	Apr.––May	Oct.–Nov.	Dec.–Feb.	Apr.–May	Oct.–Nov.	Dec.––Feb.	Apr.–May	Oct.–Nov.	Dec.–Feb.	Apr.–May	Oct.–Nov.	Dec.–Feb.	Apr.––May	Oct.–Nov.	Dec.–Feb.	Apr.–May	Oct.–Nov.	Dec.–Feb	Apr.––May	Oct.–Nov.	Dec.–Feb.	Apr.–May	Oct.–Nov.	Dec.–Feb.
	Pre-monsoon	Post monsoon	Lean period	Pre-monsoon	Post monsoon-	Lean period	Pre-monsoon	Post -monsoon	Lean period	Pre-monsoon	Post- monsoon	Lean period	Pre-monsoon	Post- monsoon	Lean period	Pre-monsoon	Post -monsoon	Lean period	Pre-Monsoon	Post -monsoon	Lean period	Pre-monsoon	Post monsoon	Lean period	Pre-monsoon	Post- monsoon	Lean period	Pre-monsoon	Post- monsoon	Lean period	Pre-monsoon	Post -monsoon	Lean period	Pre-monsoon	Post -monsoon	Lean period	Pre-monsoon	Post monsoon	Lean period
S1																																							
S2																																							
S3																																							
S4																																							
S5																																							
S6																																							
S7																																							
S8																																							
S9																																							
S10																																							

. . . continued Annexure 3

Sampling station/ parameters	Faecal coliform MPN/100 ml			Total coliform MPN/100 ml		
Year …………	Apr.–May	Oct–Nov.	Dec.–Feb.	Apr.–May	Oct.–Nov.	Dec.–Feb.
	Pre-monsoon	Post-monsoon	Lean period	Pre-monsoon	Post-monsoon	Lean period
S1						
S2						
S3						
S4						
S5						
S6						
S7						
S8						
S9						
S10						

Notes:

Notes:

Notes:

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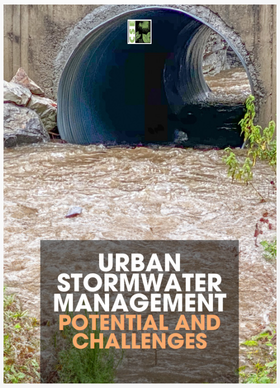

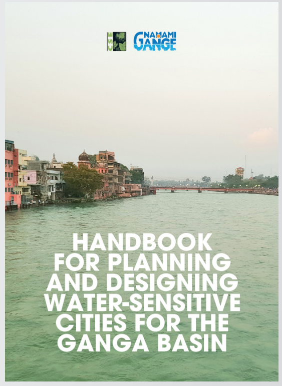

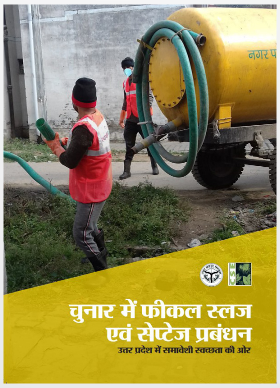

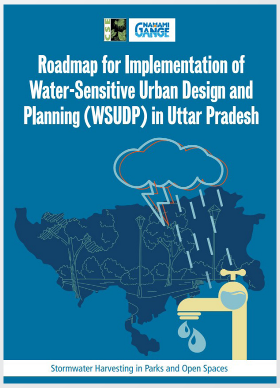

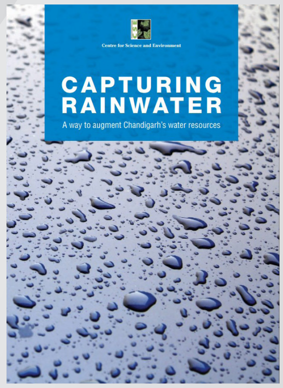

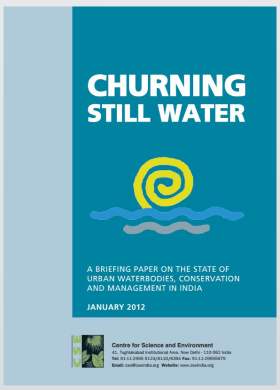

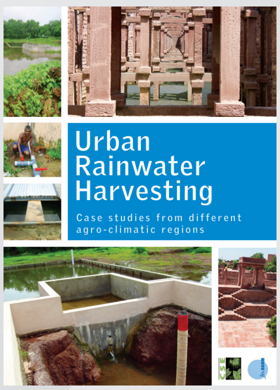

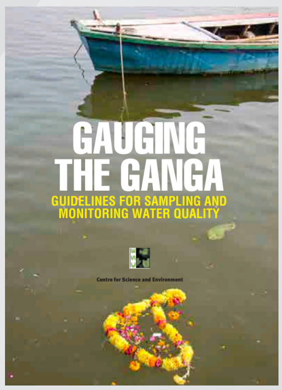

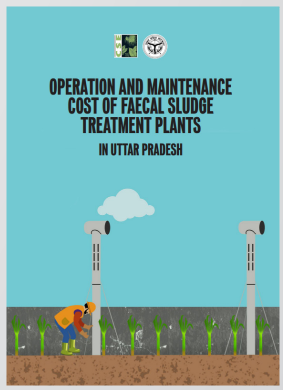

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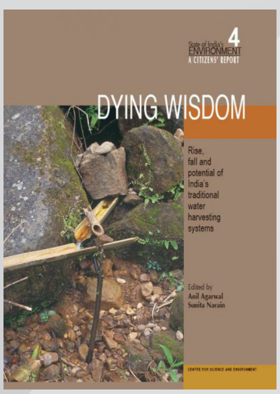

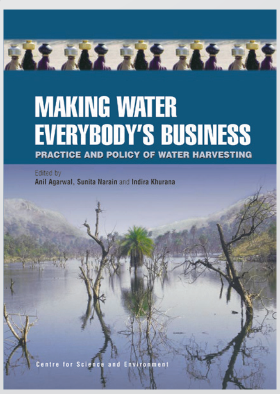

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In a climate-risked world, urban lakes play an important role in managing extreme-storm events. These water-bodies act as sponges, absorbing high-intensity rainfall. But they have become receptacles for sewage and/or solid waste, or have been built over. Urban lakes also act as significant groundwater recharge points for cities and towns, where dependence on groundwater is increasing due to unplanned urbanization. Restoring these lakes, however, is not the end of the task—they need to be monitored at regular intervals to have a management plan in place.

The Centre for Science and Environment (CSE), New Delhi, is supporting the Department of Urban Development (DoUD), Uttar Pradesh, to develop checklists for monitoring urban lakes. Selected towns in the Gangetic Plains in the state of Uttar Pradesh—the dependence of groundwater is fairly high in these towns—were surveyed to understand the condition of the lakes.

This paper draws out checklists that should be used for monitoring the lakes. It gives guidance on what data to collect, period of collection, and how the sampling should be done with regard to the parameters—hydrology, water quality and biological index—to be checked. The checklists can be used for different cities and towns of the Gangetic Plains.

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