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सत्यमेव जयते

निर्मलता / Nirmalta

EVOLVING River - Centric Criteria FOR SUSTAINABLE MANAGEMENT OF SURFACE WATERBODIES IN INDIA

cGanga

Centre for Ganga River Basin Management and Studies
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National Mission for Clean Ganga (NMCG)

NMCG is the implementation wing of National Ganga Council which was setup in October 2016 under the River Ganga Authority order 2016. Initially NMCG was registered as a society on 12th August 2011 under the Societies Registration Act 1860. It acted as implementation arm of National Ganga River Basin Authority (NGRBA) which was constituted under the provisions of the Environment (Protection) Act (EPA) 1986. NGRBA has since been dissolved with effect from the 7th October 2016, consequent to constitution of National Council for Rejuvenation, Protection and Management of River Ganga (referred to as National Ganga Council).

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cGanga is a think tank formed under the aegis of NMCG, and one of its stated objectives is to make India a world leader in river and water science. The Centre is headquartered at IIT Kanpur and has representation from most leading science and technological institutes of the country. cGanga's mandate is to serve as think-tank in implementation and dynamic evolution of Ganga River Basin Management Plan (GRBMP) prepared by the Consortium of 7 IITs. In addition to this it is also responsible for introducing new technologies, innovations and solutions into India.

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निर्मलता

Evolving

River-Centric Criteria

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Preface

India has historically followed the "designated best use" criteria for classifying its rivers into various classes (A to F), employing parameters such as pH, Dissolved Oxygen (DO), Biochemical Oxygen Demand (BOD), Total Coliform, free ammonia, Electrical Conductivity, and Boron. These criteria, largely developed in the 1980s and updated in 2019, may have been formulated by the best minds of that era. Applications of these norms have led to misleading information in many situations such as large gatherings of people (Kumbh Mela, spiritual and religious functions involving the faith of people taking a dip in the river and doing "आचमन" aachman with river waters) on the riverside. Many of the broadcasts intended for mass communication as well as remarks and orders by judiciary based on such criteria have led to the incorrect assessment of situation on ground. As such, with the current state of understanding and emphasis on river health, these criteria warrant review.

The relevance of parameters such as BOD and Total Coliform has been debated in many forums, including several editions of the India Water Impact Summits jointly organized by the Centre for Ganga River Basin Management and Studies (cGanga), IIT Kanpur and the National Mission for Clean Ganga (NMCG), Department of Water Resources, River Development and Ganga Rejuvenation (Do WR, RD & GR), Ministry of Jal Shakti (MoJS), GoI.

cGanga, a think tank created as a knowledge partner to NMCG in 2016 as a follow-up to the Ganga River Basin Management Plan (GRBMP) submitted by the Consortium of 7 IITs (IITC) in 2015, holds the mandate to support the implementation of the GRBMP and dynamically evolve future versions. It is with this background that cGanga, IIT Kanpur and twelve other Indian premier institutions involved in the Condition Assessment and Management Plan (CAMP) project of the National River Conservation Directorate (NRCD), Do WR, RD & GR, MoJs, GoI for six other rivers of India (other than the Ganga) have been brainstorming on this subject.

This report is an outcome of in-depth study and consultation with many groups of stakeholders including officials of local, state and central government, faith and spiritual groups, civil society organizations, industries and businesses, etc., by the Team cGanga and many hours of deliberation by experts nationally and internationally. The contributions of all involved are greatly acknowledged.

It is hoped that this report will serve as a basis for bringing about long overdue revision in criteria and policy to determine the status of surface water bodies in India, identifying the Polluted River Stretches, and setting the goals and milestones for evaluating the progress of river rejuvenation and conservation programmes.

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1. Prologue

The lifeblood of the nation, its rivers, face unprecedented challenges. For generations, these waterways have nourished lands, sustained communities, and woven themselves into the very fabric of their spiritual and cultural identity. Yet, as efforts are made to understand and restore their health, assessment criteria often fall short of capturing their true essence and ecological vitality.

The prevailing methodologies for evaluating the status of surface waterbodies, largely guided by Western paradigms, developed in the 1980s and updated in 2019 (CPCB, 2019), were primarily conceived through the lens of "designated best use" criteria. While valuable in their original context, these frameworks are inherently anthropocentric, prioritizing human consumption and recreational activities above all else. This approach, unfortunately, has often overlooked the intricate ecological status of rivers, failing to integrate the crucial aspects of sustainability that define a truly healthy and resilient ecosystem.

India's relationship with its rivers is profoundly different from that observed in most Western nations. Here, rivers are not merely geographical features or recreational spaces; they are living deities, integral to spiritual practices, cultural traditions, and daily rituals, from the sacred dip to the reverent "aachman" (**आचमन**). This unique human-river interaction, deeply rooted in ancient Indian history and rich literature, necessitates an assessment framework that acknowledges this profound connection.

Furthermore, India is a land of unparalleled diversity. Its topography ranges from towering mountains to vast plains, its climate from arid deserts to lush monsoons, and its culture, languages, and food habits span an incredible spectrum. This inherent heterogeneity extends to the country's river systems, making a one-size-fits-all approach to water quality assessment fundamentally inadequate. The biological profile of a Himalayan stream is vastly different from that of a peninsular river, and assessment norms must reflect this reality.

The stated objective of river basin management, particularly in terms of achieving "Nirmalta" (निर्मलता) – the purity and wholesomeness of water bodies – extends far beyond mere human usability. It fundamentally aims for the flourishing of indigenous flora and fauna, for rivers that are vibrant ecosystems teeming with life (Karr, 1991; Odum, 1985).

It is, therefore, time for a profound introspection. It is time to rethink, to learn, and, most importantly, to re-learn. A pivotal moment has arrived, demanding a paradigm shift in the approach and norms for assessing the status of surface water bodies and identifying truly polluted river stretches (PRS). This report embarks on that journey, seeking to lay the groundwork for a framework that is uniquely Indian, ecologically sound, and truly reflective of the living spirit of the nation's rivers.

2. Indian Framework for River Rejuvenation and Conservation

River rejuvenation and conservation is an interplay amongst several aspects represented in Figure 1 that include (a) setting the objective; (b) evolving river basin management plan with an appropriate framework; (c) developing, evolving and activating enablers for action on ground through science, technology, policies, laws, governance, economics, financing, and people participation; (d) ensuring that essentials 5 Ps such as political will, public spending, partnerships, participation and perseverance are in place; and most importantly (e) achieving convergence amongst another 5 Ps namely, policies, programmes, plans, projects and people's action that serve as means for activities in the field (IWIS-CITIS, 2022, 2023, 2024).

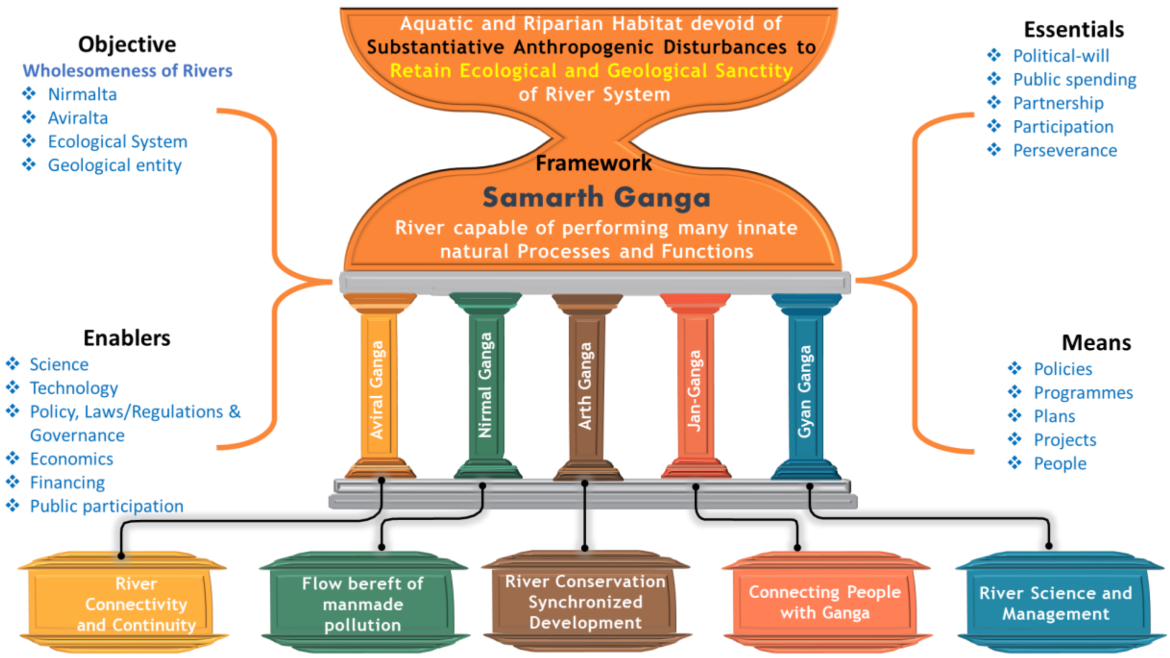

Figure 1: Representation of River Rejuvenation and Conservation Efficacy as an Interplay Amongst Several Aspects

The concept of "Samarth Ganga" encapsulates a holistic vision for river rejuvenation and conservation, aiming to restore rivers to a state of inherent capability and self-sustainability. Understanding the "Why," "What," and "How" of Samarth Ganga is crucial for effective river management.

Why Samarth Ganga?

The necessity of Samarth Ganga stems from the alarming decline in the health and functionality of rivers, not only in India but across the globe. Once formidable natural systems capable of performing myriad valuable tasks within their basins, rivers have significantly deteriorated due to a host of man-made reasons. This degradation is scientifically evident in several ways:

- **Diminished Flow Capacity:** Rivers have lost their natural ability to maintain optimal water flow and efficiently transport silt and sediments.
- **Impaired Ecological Conditions:** The availability of essential elements and other vital conditions needed by riverine organisms has been severely affected, disrupting the delicate balance of aquatic ecosystems.
- **Reduced Natural Resilience:** Rivers have lost their innate capacity to absorb surging volumes of water during heavy monsoon rains, leading to increased flooding and ecological imbalance.
- **Global Dependency:** Most rivers worldwide have become increasingly dependent on external interventions, public attitudes, and governmental financial allocations for their very existence and for carrying out conservation works.

The fundamental reason for pursuing Samarth Ganga is the imperative for sustainable use and conservation of river resources. Rivers must be restored close to their original or pristine conditions to the extent possible and feasible and where irreversible or irrecoverable changes have not occurred, as their natural processes and functions inherently occur within an "able" river. It is a cultural and scientific imperative to ensure that rivers can maintain their abilities, allowing them to thrive independently.

What is Samarth Ganga?

"Samarth Ganga" signifies a river that is **able, capable, and self-sustaining**. It represents a profound paradigm shift from perceiving rivers merely as utilitarian resources for human demands (such as recreation, irrigation, or industrial use) to recognizing them as dynamic, living entities with intrinsic ecological value.

The **objective** of Samarth Ganga is the **restoration of rivers as close as possible to their original or pristine conditions**, enabling them to largely manage their own health and functions. This restoration aims to reduce their dependency on constant external interventions and allow them to make necessary functional adjustments and improvements autonomously. Ultimately, a "Samarth" river embodies "Nirmalta" (**निर्मलता**) – the purity and wholesomeness of the water body – fundamentally aiming for the flourishing of indigenous flora and fauna, creating vibrant ecosystems teeming with life.

How to Achieve Samarth Ganga?

Achieving Samarth Ganga requires a multi-faceted and integrated approach, built upon five main interconnected pillars:

1. **Nirmal Ganga or Nirmal Dhara or Unpolluted Stream:** This pillar focuses on comprehensive pollution abatement. It involves implementing effective wastewater treatment, managing industrial effluents, controlling agricultural runoff, and preventing solid waste disposal into rivers, all to ensure the river's waters are pure and free from contaminants.
2. **Aviral Ganga or Aviral Dhara or Uninterrupted Continuously Flowing Stream:** This pillar emphasizes maintaining the uninterrupted and natural flow of the river. This includes ensuring environmental flows, managing water abstraction sustainably, and addressing physical obstructions to allow the river to maintain its ecological connectivity and self-purification capacity.
3. **Gyan Ganga or Gyan Dhara or Knowledge Stream:** This pillar promotes the acquisition and dissemination of knowledge related to rivers. It involves making people aware of both ancient wisdom and the latest scientific understanding of river ecosystems, their functions, and the impacts of human activities. This fosters informed decision-making and a deeper appreciation for river health.
4. **Jan Ganga or Jan Dhara or People-Connected Stream:** This pillar highlights the crucial role of public participation and fostering a strong connection between communities and their rivers. It involves engaging citizens in conservation efforts, promoting responsible behaviour, and building a sense of ownership and stewardship for river health.
5. **Arth Ganga or Value Stream:** This pillar focuses on the economic and financial sustainability of river conservation. It posits that once a river becomes "Samarth" through ecological restoration and community involvement, it will also be capable of contributing to economic (GDP) growth with its own river and basin goods and services. These goods and services, derived from sustainable economic activities within the basin, can then contribute to sustaining the river's identity and ongoing conservation needs, creating a virtuous cycle of ecological and economic well-being.

To truly make a river "Able," it is not only necessary to ensure it is unpolluted and continuously flowing, but it is equally vital to empower people with knowledge and foster their active participation. The collective efforts of government, administration, and common citizens are all essential to achieve and sustain the ability of rivers to reinvigorate themselves.

A New Vision for River Health: Simple, Scientific, and People-Centric Assessment

The journey towards "Nirmalta" – the purity and wholesomeness of rivers – necessitates a fundamental shift in how their health is assessed. Current methods, often anthropocentric and complex, fall short in capturing the true ecological vitality of diverse river systems. It is time to evolve **river-centric criteria and norms** for determining their status and identifying polluted stretches.

This new approach must be deeply rooted in **scientific understanding**, allowing for a true comprehension of the intricate ecological processes that define a healthy river. Yet, this scientific rigor must be translated into a framework that is **simple, reproducible, practical, and economically viable**. Assessments cannot be overly complicated, costly, or yield inconsistent results across the vast and varied landscapes rivers traverse.

Crucially, this paradigm shift demands the active **involvement of people**. River health is a collective responsibility, and local communities must be empowered to participate in monitoring and understanding their waterways. To facilitate this, the assessment should strive to use **as few parameters as possible**, focusing on those key indicators that provide the most comprehensive and actionable insights.

By embracing this streamlined, scientifically informed, and people-centric approach, a move can be made beyond merely managing pollution to truly nurturing the inherent ability of rivers to thrive, ensuring "Nirmalta" for generations to come.

3. Commonly Used Parameters and Current Practice in Some Typical Countries

There are two distinct approaches that could be adopted to assess the status of surface water bodies, one is anthropocentric and the other is nature centric.

Recreational Use: The primary goal is to protect human health and ensure a safe, enjoyable experience during activities like swimming, bathing, boating, and fishing. The focus is on direct human exposure to pathogens, toxins, and unpleasant conditions.

River Health / Ecological Integrity: The primary goal is to assess the river's ability to sustain its natural biodiversity, support healthy aquatic ecosystems, and perform essential ecosystem services. The focus is on the well-being of the entire living system, independent of direct human use.

A. Considering Recreational Use:

The following parameters are commonly employed by various countries when assessing water quality for recreational purposes:

- ***Escherichia coli or E. coli (EC)*:** This is a primary indicator of faecal contamination, particularly from warm-blooded animals, and is widely used, especially for freshwater (USEPA, 2012).
- **Enterococci:** Like *E. coli*, Enterococci are often preferred for marine and brackish waters due to their better survival in saline environments (WHO, 2021).

- **Total Coliforms:** Although Total Coliforms have been used in the past, this broader group of bacteria can include species not derived from faecal matter, which limits their specificity as health risk indicators. As a result, many developed countries are increasingly favouring *E. coli* and Enterococci (NHMRC, 2008).
- **Faecal Coliforms:** This group is a subset of Total Coliforms and indicates faecal contamination. Like Total Coliforms, their use is being superseded by more specific indicators in many regions.
- **pH:** This is a measure of hydrogen ion concentration which plays a major role that governs protonation or otherwise of many chemical species and solubility or otherwise of many constituents in water and is crucial for the survival of aquatic life and human comfort (CPCB, 2019).
- **Dissolved Oxygen (DO):** Essential for aquatic organisms, DO levels indicate the water's ability to support life. While critical for overall river health, specific limits for recreation might be less stringent than those for aquatic life protection but are still considered. (USEPA, 2024).
- **Cyanobacteria (Algae) and their toxins:** The presence of harmful algal blooms and their toxins (like Microcystins and Cylindrospermopsin) is a significant concern for recreational waters due to potential health risks. Guidelines often specify cell counts, biovolume, or toxin concentration limits (EPA, 2019).
- **Turbidity:** This measures water clarity. High turbidity can affect the aesthetic appeal of the water and reduce visibility, posing safety concerns (Government of Canada, 2012).
- **Aesthetic Parameters:** These include factors like colour, odour, the presence of oil, grease, and litter, which can affect the recreational experience and may indicate pollution.
- **Other Chemical Parameters:** Depending on local industrial and agricultural activities, specific chemical pollutants (e.g., heavy metals, pesticides) might be monitored if there's a risk to human health from recreational exposure.

Nitrogen and Phosphorus - Indirect Impact, but Critical Drivers of Recreational Water Quality Degradation

Nitrogen and phosphorus are not typically direct threats to human health during recreational contact in the way that pathogens (bacteria, viruses) are. One does not get sick from touching or inhaling small quantity of water having a high concentration of nitrogen (organic, ammoniacal, nitrate, etc.) or phosphate itself during a swim.

However, they are the primary drivers of eutrophication, a process that severely degrades recreational water quality (Smith & Schindler, 2009). Here's how:

- **Fuel Algal and Cyanobacterial Blooms:** Excess nitrogen and phosphorus act as fertilizers, leading to an overgrowth of aquatic weeds such as water hyacinth, and algae, particularly cyanobacteria (also known as blue-green algae). These "blooms" are the main concern for recreational users (EPA, 2021).
- **Aesthetic Degradation:** Algal blooms cause thick, green muck or scum and unpleasant odours, making the water unappealing for swimming, boating, and other activities. Reduced water clarity (turbidity) makes it difficult to see submerged hazards and diminishes visual appeal.
- **Oxygen Depletion (Hypoxia/Anoxia):** When large aquatic weeds or algal blooms eventually die, their decomposition by bacteria consumes vast amounts of dissolved oxygen (DO) in the water. This can lead to "dead zones" where fish and other aquatic life cannot survive, creating foul-smelling conditions and impacting the ecosystem's health, which in turn affects the overall recreational experience (USEPA, 2025).
- **Harmful Algal Blooms (HABs) and Toxins:** Many cyanobacteria produce toxins (cyanotoxins) that are harmful to humans and animals upon contact, ingestion, or inhalation of aerosols (WHO, 2021).
- **Impact on Drinking Water Sources:** If the recreational water body is also a source of drinking water, high nutrient levels and associated algal blooms can contaminate drinking water, leading to costly treatment challenges and potential health risks.

Why They Are Often Monitored Separately or Indirectly:

- **Indirect Health Risk:** As mentioned, their primary impact on recreation is indirect, through the promotion of algal blooms, rather than direct toxicity at typical environmental concentrations.
- **Variable Thresholds:** Unlike bacterial indicators, there isn't a single universal "safe" limit for nitrogen or phosphorus that applies across all water bodies. The nutrient levels that trigger a bloom depend heavily on factors like light, temperature, hydrology, and the specific ecosystem. Therefore, guidelines are often developed regionally or for specific water body types.
- **Focus on the Effect (Algal Blooms/Toxins):** Regulatory bodies often directly monitor the effects of nutrient pollution, such as cyanobacterial cell counts, biovolume, or toxin concentrations (e.g., Microcystin levels), which are the immediate public health concern for recreational use.

In summary while nitrogen and phosphorus are not always listed with direct recreational "permissible limits" like bacteria, they are fundamentally important. They are the upstream causes that lead to the effects (algal blooms, low DO, toxins) that directly impair recreational water quality and pose health risks. Therefore, they are extensively monitored as part of broader water quality management strategies aimed at preventing eutrophication and harmful algal blooms, which in turn protects recreational uses.

Examples of Country-Specific Parameters:

- **India:** Focuses on Total Coliforms as the primary bacterial indicator for bathing waters, along with pH and Dissolved Oxygen, and BOD as an indicator of organic pollution.
- **World Health Organization (WHO):** Emphasizes a risk-based approach and provides guidelines for faecal indicators (*E. coli* and Enterococci), cyanobacteria and their toxins, and aesthetic parameters.
- **Australia and New Zealand:** Utilize *E. coli* and Enterococci as key indicators, often with trigger levels based on statistical distributions of monitoring data. They also consider cyanobacteria and aesthetic qualities.
- **United States (EPA):** Recommends *E. coli* for freshwater and Enterococci for marine waters as primary bacterial indicators, with both geometric mean and statistical threshold values. They also have guidelines for cyanotoxins.
- **Canada:** Uses *E. coli* for freshwater and Enterococci for marine waters with specific guideline values. They also have detailed guidelines for cyanobacteria and aesthetic characteristics.

It's important to note that the specific parameters and their limits are continuously reviewed and updated based on the latest scientific understanding of health risks and environmental impacts. A shift towards *E. coli* and Enterococci as primary bacterial indicators, along with growing attention to cyanobacterial toxins, is evident in many international guidelines.

B. Considering River Health

The parameters used to assess river health (ecological integrity) are significantly different from those used for recreational use, which is an anthropocentric (human-cantered) criterion. While there might be some overlap (e.g., pH is important for both), the emphasis, target levels, and additional parameters are distinct (IWIS, 2022).

4. Detailing Water Quality Parameters: Recreational Use vs. River Health

A. Recreational Use (Anthropocentric Focus)

- **Goal:** To protect human health from waterborne diseases and ensure an aesthetically pleasing and safe environment for activities like swimming, bathing, boating, and fishing.
- **Key Parameter Categories and Specific Parameters:**
  - **Microbiological Indicators (Primary Focus):** These are the most critical parameters for recreational water quality as they indicate the potential presence of pathogens that can cause illness in humans through ingestion or skin contact.
  - **Escherichia coli or *E. coli (EC)*:** The most common and widely accepted indicator for freshwater recreational use. Its presence in water is strong evidence of recent

faecal contamination from warm-blooded animals (including humans), and it correlates well with the risk of gastrointestinal illness (Alm et al., 2011; NEERI, 2017).

- **Enterococci:** Often preferred as the primary indicator for marine and brackish waters, though also used for freshwater. They show better survival in saline environments and correlate well with swimming-associated gastrointestinal illness (Byappanahalli et al., 2012).
- **Faecal Coliforms (FC):** Historically widely used, but less specific than *E. coli* or Enterococci as they can include bacteria from non-faecal sources. Still used in some regions, particularly where resources for more specific testing are limited.
- **Total Coliforms (TC):** A very broad group, less indicative of faecal contamination or direct health risk, and largely phased out as a primary recreational indicator in favour of more specific ones (Noble et al., 2003).
- **Harmful Algal Bloom (HAB) Indicators & Toxins:** These are increasingly important due to their direct threat to human health (Dolah et al., 2001).
- **Cyanobacteria Cell Counts/Biovolume:** Measures the concentration of blue-green algae, which can form blooms. Thresholds are set to alert recreational users to potential risks (Ibelings et al., 2014).
- **Cyanotoxins (e.g., Microcystins, Cylindrospermopsin):** Direct measurement of the toxins produced by some cyanobacteria, which can cause skin irritation, gastrointestinal distress, liver damage, and neurological effects (Codd et al., 2020).
- **Physical/Aesthetic Parameters:** These affect the enjoyment and safety of recreational activities.
- **Turbidity:** Measures water clarity (cloudiness). High turbidity affects visibility (e.g., for seeing submerged hazards) and aesthetic appeal.
- **Colour:** Can indicate pollution or natural conditions, affecting aesthetic appeal.
- **Odour:** Unpleasant smells can indicate pollution (e.g., sewage, industrial waste, decomposing organic matter).
- **Floating Matter/Debris:** Presence of litter, oil, scum, or other visible pollutants.
- **Temperature:** While not a primary health risk, extreme temperatures can make water unpleasant for recreation.
- **pH:** While generally stable, extreme pH values can cause skin or eye irritation for swimmers. Relevant range for human comfort is typically between 6.5 and 8.5.
- **Specific Chemical Pollutants (Context-Dependent):** In areas near industrial discharges or heavy agriculture, monitoring for specific chemicals (e.g., heavy metals, pesticides, petroleum hydrocarbons) might be necessary if there's a

plausible pathway for recreational exposure and associated human health risk. This is less common as a universal recreational parameter.

B. River Health / Ecological Integrity (Biocentric/Ecosystem-Centric Focus)

- **Goal:** To assess the river's ability to support its natural biodiversity, maintain healthy aquatic ecosystems, perform essential ecosystem services (e.g., water purification, nutrient cycling), and be resilient to environmental changes. This involves looking beyond direct human use to the well-being of the entire living system.

- **Key Parameter Categories and Specific Parameters:**

  - **Biological Indicators (Primary Focus):** These provide an integrated assessment of the river's condition over time, as organisms respond to cumulative stressors.
  - **Benthic Macroinvertebrate Community Indices (e.g., Saprobic Index, BMWP Index, EPT Richness):** These are extremely valuable. Different species of macroinvertebrates have varying tolerances to pollution. The presence, absence, and relative abundance of sensitive vs. tolerant species provide a direct biological assessment of water quality and habitat integrity. They reflect conditions over weeks or months (Mir et al., 2021).
  - **Fish Community Structure & Health:** Diversity, abundance, age structure, presence of sensitive species, and signs of disease or abnormalities in fish populations indicate overall ecosystem health.
  - **Algal Community Structure (e.g., Diatom Indices):** The composition of algal communities can indicate nutrient enrichment, acidification, or other stressors.
  - **Riparian Vegetation Health & Diversity:** The health and extent of native plants along the riverbanks are crucial for bank stabilization, erosion control, providing shade, filtering runoff, and offering habitat.
  - **Chemical Indicators (Crucial for Supporting Biota):** These directly impact the physiological processes of aquatic organisms.
  - **Dissolved Oxygen (DO):** Critical. Levels and diurnal fluctuations (especially minimums) are monitored to ensure aerobic conditions for aquatic life. Low DO is a major stressor.
  - **Biochemical Oxygen Demand (BOD):** Measures the amount of oxygen consumed by microorganisms decomposing organic matter. High BOD indicates organic pollution, which depletes DO and impacts aquatic life.
  - **Nutrients (Nitrogen and Phosphorus compounds: e.g., Total Nitrogen, Total Phosphorus, Nitrates, Phosphates, Ammonia, Ammonium):** Excessive levels lead to eutrophication, algal blooms, and subsequent DO depletion, significantly altering

aquatic habitats and impacting biodiversity. This is a major difference from recreational parameters where their effect (algae/toxins) is measured, rather than the nutrients themselves.

- **pH:** Critical for aquatic life, as most species have narrow optimal pH ranges. Extreme values are directly toxic.
- **Conductivity / Total Dissolved Solids (TDS):** Indicates the total concentration of dissolved salts and minerals. High levels can indicate pollution (e.g., industrial discharge, agricultural runoff) and affect osmotic balance in aquatic organisms.
- **Specific Ions (e.g., Chloride, Sulphate):** Can indicate specific pollution sources or salinity intrusion.
- **Heavy Metals (e.g., Lead, Mercury, Cadmium, Zinc):** Toxic to aquatic organisms even at low concentrations, bioaccumulate in the food web.
- **Organic Pollutants (e.g., Pesticides, Pharmaceuticals, Industrial Chemicals, PCBs):** Many synthetic chemicals are toxic to aquatic life, can disrupt endocrine systems, and bioaccumulate.
- **Alkalinity / Hardness:** Reflects the water's buffering capacity against pH changes and the concentration of mineral salts, which are important for aquatic life.
- **Physical Habitat Indicators:** These describe the physical structure and form of the river, which are essential for habitat.
- **Flow Regimes:** The natural pattern of water flow (magnitude, frequency, duration, timing, rate of change) is critical for maintaining specific habitats and ecological processes. Alterations (e.g., from dams, abstractions) severely impact river health.
- **Sediment Characteristics (Substrate Composition):** The type of riverbed (sand, gravel, cobble, silt) is crucial for different aquatic organisms. Excessive fine sediment can smother habitats.
- **Riparian Zone Integrity:** The health, width, and native composition of vegetation along the banks.
- **Bank Stability & Erosion:** Reflects the physical integrity of the river channel.
- **Connectivity (Longitudinal & Lateral):** Unimpeded flow along the river and connection to floodplains and side channels, vital for fish migration and habitat.
- **Water Temperature:** Crucial for metabolic rates and oxygen solubility, deviations can stress or kill aquatic life.

In summary, while recreational assessments prioritize immediate human safety and aesthetics, ecological health assessments delve much deeper into the chemical, physical, and biological components that sustain the complex web of life within the river and its surrounding environment.

5. True Measure of True Value of Revered Rivers - Designated Best Use Versus Valuing Ecological Integrity of River Systems

It is important to have a true measure of the true value of the nation's revered rivers, including the holy Ganga. For too long, assessment criteria have been unduly influenced by anthropocentric perspectives, particularly human demands such as recreational uses (like rafting, boating, bathing), irrigation, industrial use, source of drinking water, etc., or even washing away past sins and spirituality. It is time for a paradigm shift, advocating for the flourishing of indigenous flora, robust riparian vegetation, and thriving fauna (the entire biota) as a far more profound and ecologically sound criterion for determining the true status of these rivers. This approach will not only allow the rivers to live but also pave the way for a sustainable future.

While the desire for clean water for human interaction is understandable, ancient spiritual and religious traditions offer a nuanced perspective. The act of taking a spiritual dip, and the practice of आचमन (aachman), as enshrined in these doctrines, are distinct from mere recreational bathing. These practices are often prescribed for specific locations and occasions, emphasizing a spiritual connection with the sacred waters rather than prolonged physical immersion across vast stretches. These traditions guide towards reverence and mindful interaction, not necessarily the transformation of entire rivers into swimming pools.

Therefore, the primary focus in assessing river health should transcend the narrow lens of recreational suitability and instead embrace a biocentric approach, recognizing the intrinsic value and ecological importance of the entire living community within and along the river. A river teeming with its native plants, supporting a diverse array of fish, amphibians, insects, birds, and mammals, and adorned with healthy riparian vegetation, signifies a truly healthy and resilient ecosystem.

Why prioritizing flourishing biota is a superior criterion:

- Reflects the fundamental ecological integrity: A thriving biota indicates a balanced and functional ecosystem, capable of supporting a multitude of life forms and sustaining natural processes. This encompasses water quality, habitat availability, flow regimes, and overall environmental health in a holistic manner (Palmer & Ruhi, 2019).
- Captures the long-term health and resilience: The presence of sensitive species and the complexity of food webs are indicators of a stable and resilient ecosystem, capable of withstanding environmental stresses and disturbances far better than simple chemical or bacteriological parameters.

- Aligns with the intrinsic value of nature: Rivers are not merely resources for human use; they are living entities with inherent ecological value. Prioritizing their biodiversity acknowledges this intrinsic worth and the responsibility to protect it.
- Provides a more comprehensive assessment than recreational standards: Recreational standards often focus on a limited set of parameters relevant to human health during water contact. A flourishing biota, however, integrates a much wider range of environmental factors and their complex interactions.
- Honors spiritual heritage: By focusing on the overall health and vitality of the river ecosystem, the sacredness of these natural entities in their entirety is respected, recognizing them as living manifestations of the divine, far beyond their utility for specific human activities.
- Addresses the interconnectedness of life: Healthy riparian vegetation stabilizes riverbanks, prevents erosion, filters pollutants, and provides crucial habitat for terrestrial and aquatic fauna, highlighting the interconnectedness of the entire ecosystem.

In conclusion, it is important to elevate the vision for the health of India's rivers, including the Ganga. Let the benchmark of a healthy river be the vibrancy of its indigenous flora, the robustness of its riparian vegetation, and the flourishing diversity of its fauna. This biocentric approach aligns more deeply with the ecological realities and the spiritual reverence traditions hold for these sacred waterways. By nurturing thriving ecosystems, it is ensured not only the long-term health of the rivers themselves but also a healthier environment for all living beings. Let the songs of the river be the chorus of a flourishing life, not just the echoes of human recreation.

6. Relevance of pH as an Essential Parameter

While the focus often falls on visible pollutants or microbial indicators, the hydrogen ion concentration, expressed as pH, plays a silent but critical role in shaping the very fabric of aquatic ecosystems and deserves to be recognized as an essential criterion.

Firstly, the native flora and fauna of Indian rivers are exquisitely adapted to specific pH ranges. Deviations from these natural conditions, whether towards excessive acidity or alkalinity, can inflict significant stress on these organisms. Fish, amphibians, insects, and aquatic plants all have physiological tolerances, and even subtle shifts in pH can disrupt vital processes like respiration, reproduction, and nutrient uptake. Extreme pH values can be directly toxic, leading to population declines and a loss of biodiversity, unravelling the intricate web of life that defines a healthy river ecosystem (Schindler, 1988). Therefore, monitoring pH is not just about a chemical property; it is about safeguarding the very survival of native aquatic communities.

Secondly, pH is remarkably easy to monitor. Affordable and reliable instruments, from simple litmus paper to sophisticated electronic meters and continuous monitoring probes, are readily available. This ease of measurement allows for widespread and frequent data collection across diverse river stretches, providing a consistent and readily accessible baseline understanding of water conditions. Unlike more complex parameters requiring extensive laboratory analysis, pH can be assessed in situ, offering immediate insights into potential problems and facilitating timely interventions.

Thirdly, pH acts as a master variable, reflecting the fundamental chemistry of the water and significantly influencing the speciation and bioavailability of numerous chemical entities that are crucial for the health of flora and fauna. Consider ammoniacal nitrogen (NH_3), a critical nutrient but also a potent toxicant to fish. The toxicity of ammonia is highly pH-dependent; at higher pH values, a greater proportion exists in the more toxic unionized form (NH_3). Therefore, knowing the pH is essential to accurately assess the potential harm posed by a given concentration of total ammoniacal nitrogen. Similarly, pH governs the solubility and availability of essential nutrients like phosphorus and metals, influencing their uptake by aquatic plants and their potential toxicity to animals.

Furthermore, pH is intrinsically linked to other vital water quality parameters like alkalinity and buffering capacity. Alkalinity, the water's ability to neutralize acids, directly influences pH stability. Rivers with low alkalinity are more susceptible to rapid and drastic pH shifts from acidic inputs, posing a greater risk to aquatic life. Monitoring pH alongside alkalinity provides a more complete picture of the water's chemical resilience and its capacity to maintain a stable environment for its inhabitants.

In conclusion, pH is not a passive characteristic of river water; it is an active and influential factor that underpins the health and functionality of the entire aquatic ecosystem. Its direct impact on native flora and fauna, its ease of monitoring, and its crucial role in determining the speciation and bioavailability of other significant chemical entities make it an indispensable parameter in the assessment of Indian rivers. By prioritizing and consistently monitoring pH, a fundamental understanding of the chemical environment that sustains life within these vital waterways is gained, enabling better protection of their ecological integrity for generations to come.

7. DO and NOT BOD

The health of India's rivers is paramount to its ecological integrity and the well-being of millions. A scientifically sound and practically implementable approach to assess this health is through a most critical primary focus on ensuring a minimum Dissolved Oxygen (DO) level of > 5 mg/L (ideally the value to be stated as 70-80 of the DO saturation value which is dependent on temperature and decreases from 13 mg/l at 5ºC to 7 mg/l at 35ºC), specifically measured at dawn, and a cautious shift away from relying heavily on Biochemical Oxygen Demand (BOD) as a routine assessment parameter across the country's diverse river systems.

The cornerstone of a thriving aquatic ecosystem is the availability of oxygen. A DO concentration above 5 mg/L (at its daily minimum, which occurs just before sunrise) directly addresses the most critical period for aquatic life. This ensures that even after a night of respiration and the cessation of photosynthesis, sufficient oxygen remains to support the metabolic needs of fish, invertebrates, and other vital components of the riverine ecosystem. Focusing on this critical low point provides a robust and ecologically relevant measure of the river's capacity to sustain life.

Conversely, while the concept of BOD as an indicator of organic pollution is valuable, its practical application in the vast and heterogeneous context of Indian rivers presents significant challenges. The nation's rivers are dynamic systems, experiencing wide variations in flow, temperature, and inputs from diverse sources, including agricultural runoff, industrial discharge, and human settlements. This inherent heterogeneity makes obtaining a truly representative sample for BOD analysis exceedingly difficult (Bagchi et al., 2018). A single sample may not accurately reflect the overall organic load and its oxygen demand potential across a meaningful stretch of the river. Consequently, BOD measurements can exhibit high variability.

Furthermore, the standard five-day incubation period for the BOD test introduces a critical delay. In the face of rapid pollution events or fluctuating environmental conditions common in Indian rivers, these delayed results limit the ability to implement timely and effective management interventions.

Prioritizing the dawn DO minimum offers a more precise, direct, immediate, and ecologically significant assessment. It reflects the actual oxygen available to aquatic organisms during their most vulnerable period. Moreover, advancements in DO monitoring technology allow for more frequent and even continuous data collection, providing a real-time understanding of the river's oxygen status and enabling swift responses to any concerning declines.

By focusing resources and monitoring efforts on achieving and maintaining a minimum DO of > 5 mg/L at dawn, a criterion is adopted that is:

- **Ecologically relevant:** Directly addresses the oxygen needs of aquatic life during a critical period.
- **Practically measurable:** DO can be measured reliably and even continuously in diverse riverine environments.
- **Actionable:** Real-time DO data can trigger immediate management responses.

While organic pollution remains a concern, the primary focus for routine river health assessment should be on ensuring the fundamental requirement for aquatic life – sufficient dissolved oxygen, particularly at its daily minimum. This pragmatic approach will provide a more effective and ecologically meaningful framework for safeguarding the health of India's precious rivers. If minimum DO > 5 mg/L is ensured, BOD levels up to 10 mg/L are ecologically and otherwise are inconsequential (IWIS, 2021, IWIS 2022). Ensuring BOD values less than 10 mg/L pose a serious legal challenge due to limitation of state-of-the-art sampling and measurement techniques.

8. Saprobic Index than Bacterial Indicators such as Total Coliform (TC), Faecal Coliform (FC), Escherichia coli (EC), Faecal Streptococci (FS) and/or Enterococci

The assessment of pollution in India's sacred rivers and monitoring of river restoration and conservation programmes such as Namami Gange as well as relevant feedback to strategize for future warrants a critical re-evaluation of the reliance on bacterial indicators such as Total Coliform (TC), Faecal Coliform (FC), Escherichia coli (EC), Faecal Streptococci (FS), and Enterococci. While these indicators historically may have played a role, particularly in certain cultural and climatic settings, their limitations within the unique ecological, climatic and cultural context of India raise serious concerns about their efficacy and relevance in accurately reflecting the health risks associated with the nation's rivers.

Firstly, a significant load of these bacterial indicators in Indian rivers undeniably originates from non-human sources. The nation's rivers are intertwined with the lives of a vast array of animals – domestic livestock bathing and drinking, thriving populations of wild animals and birds, and even the native fish themselves contribute to the presence of these bacteria. Agricultural practices involving manure application further exacerbate this non-human load. Consequently, elevated levels of these indicators do not automatically signify human faecal contamination and, more importantly, fail to directly reflect the presence and concentration of human-specific pathogens that pose the greatest risk to human health (USEPA, 2024; NEERI, 2023).

Secondly, there is a lack of robust information on the ratio of actual pathogens to these bacterial indicators specifically within Indian river waters. This ratio can vary dramatically depending on the source of contamination, environmental conditions, and the specific bacterial indicator being measured. Without a clear understanding of this relationship in unique riverine environments, it is not possible to reliably extrapolate the levels of these indicators to the actual risk of waterborne diseases among people using rivers for recreational purposes, including the revered practice of taking a spiritual dip and the ritual of आचमन (aachman).

Thirdly, there is a lack of compelling evidence demonstrating a direct and consistent correlation between the occurrence of waterborne diseases among the large number of people taking dips and/or performing आचमन (aachman) in the nation's rivers and the number of any of the bacterial indicators. While anecdotal accounts or localized outbreaks may exist, large-scale epidemiological studies establishing a clear dose-response relationship between these indicators and illness rates in the context of these specific cultural practices are often missing or inconclusive. This absence of strong correlation casts doubts on the predictive power of these indicators for assessing the actual health risks associated with these traditional river uses.

Thus, specifying any norms for these to reflect on human health risk and/or to identify Polluted River Stretches (PRS) cannot be evidence based, scientific, and is bound to communicate incorrectly. Enforcing such norms may compel authorities to introduce practices which otherwise may be ecologically insensitive, create harmful side effects (e.g. introduction of potentially carcinogenic substances), and may exert unnecessary pressure on limited available resources.

Fourthly, the reliability of sampling and enumeration techniques for these bacterial indicators in the complex matrix of river waters is often questionable. Factors such as turbidity, sediment load, the presence of interfering substances, and the spatial and temporal variability of bacterial distribution can significantly impact the accuracy and reproducibility of the results. Obtaining truly representative samples across vast and heterogeneous river stretches poses a considerable logistical and scientific challenge.

Finally, it is crucial to recognize that these bacterial indicators may be more appropriate for assessing the potential of point sources of faecal contamination, such as sewage treatment plant effluents and domestic water supplies, where the origin of contamination is more clearly human faecal matter. However, their applicability to the complex and dynamic nature of natural surface water bodies like Indian rivers, with their diverse inputs and ecological interactions, is far less certain. The presence of these bacteria in rivers is a natural occurrence to some extent, and attributing all detections to human pollution and subsequent health risk is an oversimplification.

In contrast to the use of bacterial indicators for assessing human health risk due to interaction with rivers for recreational/spiritual activities and/or to identify Polluted River Stretches (PRS), the Saprobic Index offers a more integrated and ecologically meaningful assessment. This index utilizes the composition and abundance of benthic macroinvertebrates – small, bottom-dwelling organisms like insect larvae, worms, and crustaceans – as direct indicators of water quality. These organisms exhibit varying degrees of sensitivity to different types and levels of pollution. Their presence, absence, and relative abundance provide a biological assessment that reflects the long-term ecological health of the river, integrating the cumulative effects of various stressors (Cairns *et al*., 1993).

The Saprobic Index presents several compelling advantages in the Indian context:

- **Holistic assessment of pollution impact:** It integrates the effects of organic pollution, nutrient enrichment, and even certain toxic substances on the living biological community, going beyond simply indicating faecal presence (Cairns *et al*., 1993).
- **Reflects long-term ecological conditions:** Benthic macroinvertebrates have life cycles ranging from weeks to years, providing an integrated assessment of water quality conditions over time, offering a more stable and representative picture than transient bacterial counts (Rosenberg & Resh, 2012).
- **Less susceptible to transient fluctuations and non-human sources:** Unlike bacterial levels that can fluctuate rapidly due to episodic events or the natural presence of wildlife, changes in macroinvertebrate communities are typically more gradual and directly indicative of sustained pollution pressures.
- **Directly reflects ecological health:** The presence of pollution-sensitive species signifies good water quality, while the dominance of pollution-tolerant species indicates environmental stress, providing a direct link to the river's biological integrity.
- **More accurately reflects human-induced stress:** While natural factors influence macroinvertebrate communities, sustained and significant shifts towards pollution-tolerant species are strong indicators of anthropogenic impacts.

By embracing the Saprobic Index as a primary criterion for identifying polluted river stretches, a move can be made towards a more ecologically relevant, scientifically robust, and practically insightful assessment framework that acknowledges the unique complexities of Indian rivers. It allows for more effective differentiation between natural biological components and the detrimental impacts of human-induced pollution, leading to more targeted and ultimately more successful river management and restoration strategies. It is time to listen to the river's living inhabitants – they offer a more accurate and comprehensive story of its health.

9. Proposed Criteria for Determining "निर्मलता/Nirmalta" and Identifying Polluted River Stretches

To truly achieve "Nirmalta" (**निर्मलता**) – the purity and wholesomeness of Indian rivers, fundamentally aiming for the flourishing of indigenous flora and fauna – a river-centric assessment framework is essential. This framework must be scientifically sound, simple, reproducible, practical, economically viable, and involve people, utilizing a focused set of parameters.

Based on the principles outlined in the previous sections and general scientific understanding, the following criteria are proposed for monitoring "Nirmalta" of rivers, specifying desirable ranges for key parameters:

Objective of Monitoring for Nirmalta: The primary objective is to assess the river's ecological health, reflecting its ability to sustain its natural biodiversity, support healthy aquatic ecosystems, and perform essential ecosystem services. This goes beyond anthropocentric uses to ensure a vibrant ecosystem teeming with life.

Proposed Parameters and Ranges for Nirmalta:

A. pH (Hydrogen Ion Concentration)

- **Significance:** pH is a master variable reflecting the fundamental chemistry of the water, significantly influencing the speciation and bioavailability of numerous chemical entities crucial for flora and fauna. Native flora and fauna are exquisitely adapted to specific pH ranges; deviations can inflict significant stress or be directly toxic (Moore, 1989). For example, the toxicity of ammoniacal nitrogen (NH_3) to fish is highly pH-dependent, with higher pH values increasing the proportion of the more toxic unionized form. pH is also intrinsically linked to alkalinity and buffering capacity, reflecting the water's chemical resilience.
- **Proposed Range for Nirmalta: 6.5 to 8.5**. This range is generally considered optimal for most of the aquatic life and reflects a balanced chemical environment.

B. Dissolved Oxygen (DO)

- **Significance:** DO is absolutely critical for aerobic aquatic life. Its levels indicate the water's ability to support life, and low DO is a major stressor. Monitoring DO, especially at its minimum daily point, provides a direct and immediate indicator of the river's capacity to sustain its biota. The diurnal minimum of DO typically occurs just before dawn, as respiration by aquatic organisms continues overnight without photosynthetic oxygen production.
- **Proposed Range for Nirmalta (Minimum at Dawn): > 5.0 mg/L**.
- **Context of Saturation:** It is also beneficial to consider DO in terms of percentage saturation, which accounts for temperature and pressure. For instance, at 5°C, 100% DO saturation is approximately 12.77 mg/L. At 35°C, it is approximately 6.95 mg/L. Therefore, maintaining DO above 5.0 mg/L, especially at dawn when levels are lowest, ensures a substantial percentage of saturation even in warmer waters, supporting diverse aquatic life.
- **Rationale for Focus:** This criterion directly addresses the fundamental requirement for aquatic life. It is practically measurable with readily available technology, allowing for continuous monitoring and timely intervention.

C. Saprobic Index (Benthic Macroinvertebrate Community Index)

- **Significance:** The Saprobic Index utilizes the composition and abundance of benthic macroinvertebrates (small, bottom-dwelling organisms) as direct indicators of water quality. These organisms have varying sensitivities to different types and levels of pollution. This index provides a holistic and ecologically meaningful assessment that integrates the effects of various stressors over time, offering a more stable and representative picture than transient chemical or bacterial counts (Cairns et al., 1993; Rosenberg & Resh, 2012; IWIS-CITIS, 2024). It is less susceptible to fluctuations from non-human fecal sources (e.g., from animals, birds, fish, manure) that can confound bacterial indicators, thus more accurately reflecting human-induced stress.
- **Proposed Classification for Nirmalta:** To achieve "Nirmalta," the Saprobic Index should indicate **Oligosaprobic** or **β-Mesosaprobic** conditions.
  - **Oligosaprobic:** Characterized by very low organic pollution, high DO, and a diverse community dominated by pollution-sensitive species (e.g., stonefly nymphs, mayfly nymphs). This represents excellent water quality.
  - **β-Mesosaprobic:** Indicates moderate organic pollution, good DO levels, and a diverse community with a balance of sensitive and moderately tolerant species. This represents good water quality.
- **Rationale for Focus:** This biological indicator reflects long-term ecological conditions and is less confounded by the heterogeneity and non-human sources that limit the reliability of bacterial indicators for overall river health assessment. It directly reflects the flourishing of indigenous flora and fauna, aligning with the core objective of "Nirmalta."

Implementation Principles:

- **Scientific Understanding:** The interpretation of these parameters will be based on established ecological principles and local baseline studies.
- **Simplicity & Reproducibility:** pH and DO are easily measured in situ. While Saprobic Index requires specialized expertise, standardized protocols can ensure reproducibility.
- **Practicality & Economic Viability:** Focusing on these core parameters allows for efficient resource allocation compared to extensive, less indicative testing.
- **People Involvement:** Local communities can be trained for basic pH and DO monitoring, fostering participation and stewardship. Expert involvement will be crucial for Saprobic Index assessment.
- **Few Parameters:** This focused set provides robust insights into river health without unnecessary complexity.

By adopting these river-centric criteria, India can move towards a more accurate, holistic, and sustainable assessment of its river health, ensuring "Nirmalta" for generations to come.

10. Epilogue

This report underscores a critical need for a paradigm shift in how India assesses its river health. The prevailing anthropocentric criteria, inherited from Western models, are often inadequate for the nation's unique ecological and cultural context. The report advocates for a move towards **river-centric criteria**, prioritizing the flourishing of indigenous flora and fauna as the true measure of "Nirmalta."

The proposed framework champions a scientifically sound yet practical approach. It advocates for focused, reproducible, and economically viable monitoring using key parameters like **pH, Dissolved Oxygen (DO) (especially minimums at dawn), and the Saprobic Index**. These indicators offer a more accurate reflection of ecological integrity, moving beyond the limitations of bacterial indicators which are often confounded by non-human sources and inconsistent correlations with health risks.

By embracing this streamlined, ecologically informed, and people-centric assessment, India can foster genuine river rejuvenation. This new path promises more effective management strategies, ensuring the nation's rivers not only survive but truly thrive, embodying their living spirit for generations to come.

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