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Physicochemical Assessment of Traditional Lentic Ecosystems (Bandhs, Sagars, and Katas) in Balangir, Odisha

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Abstract

Traditional lentic ecosystems, locally designated as *Bandhs*, *Sagars*, and *Katas*, serve as critical socioeconomic and ecological lifelines in regions lacking perennial lotic systems. This paper presents a comprehensive assessment of the physical and chemical dynamics across nine prominent water bodies within the semi-urban and rural landscape of Balangir, Odisha: Karanga Kata, Rani Bandh, Maharani Sagar, Laxmi Jor, Narsingh Bandh, Kandhapali Bandh, Pratap Sagar, Gate Sarovar, and Beherapali Bandh. The investigation systematically quantifies vital ecological indicators, including hydrogen ion concentration (pH), water temperature, total dissolved solids (TDS), salinity, electrical conductivity (EC), and dissolved oxygen (DO).

The empirical findings reveal a distinct trend towards alkaline conditions across the study sites, with pH levels ranging from moderately basic to highly alkaline. Temperature profiles align with regional macroclimatic conditions, functioning as a primary driver for secondary physical interactions. Strong positive correlations were observed among electrical conductivity, salinity, and total dissolved solids, with Kandhapali Bandh exhibiting the highest ionic concentration due to localized terrestrial runoffs. Conversely, dissolved oxygen levels displayed substantial spatial heterogeneity; Maharani Sagar demonstrated the highest dissolved oxygen content, whereas Pratap Sagar exhibited critical hypoxia.

While the majority of parameters conform to the permissible thresholds defined by the World Health Organization (WHO), the accelerating pressures of urbanization, domestic waste dumping, agricultural runoff, and unchecked encroachment threaten to disrupt the delicate ecological equilibrium of these aquatic habitats. This study provides essential baseline data crucial for formulating targeted conservation protocols, ecological monitoring frameworks, and sustainable urban water resource management policies in Western Odisha.

Keyward: Lentic Ecosystems, Physico-Chemical Parameters, Balangir, Odisha,Traditional Reservoirs (*Bandhs*, *Sagars*, *Katas*), Dissolved Oxygen (DO)

1. Introduction

Water is the foundational medium sustaining life, driving biogeochemical cycles, and supporting human civilizational progress. Covering more than 70% of the Earth's surface and comprising over 80% of cellular protoplasm, it serves as a universal solvent and metabolic substrate. Beyond its fundamental biological roles, water possesses unique thermal and physical properties such as high specific heat, high latent heat of vaporization, and a superior dielectric constant which collectively buffer global climatic shifts and facilitate molecular transport.

Despite its abundance, freshwater represents a remarkably finite portion of the global hydrologic repository. Approximately 97.3% of the planet's water is locked in hyper-saline oceans, leaving a mere 2.7% as fresh water. Of this freshwater fraction, the vast majority is sequestered in polar ice caps and deep deep-seated aquifers, leaving less than 0.01% readily accessible within surface rivers, streams, and shallow lentic reservoirs. As global populations rise and industrialization intensifies, human communities are appropriating over half of all accessible surface freshwater runoffs, a figure projected to climb steeply in the coming decades.

In developing nations, the structural integrity and chemical purity of these freshwater repositories have become central concerns for public health and environmental sustainability. Aquatic environmental systems exist in a state of continuous dynamic equilibrium, shaped by a complex web of physical, biological, and chemical interactions. However, this equilibrium is increasingly disrupted by anthropogenic activities.

Modern water pollution can be structurally classified into point source and non-point source dynamics. Point source pollution involves direct, localized discharges of untreated domestic sewage and industrial effluents through discrete conduits into receiving waters. Non-point source pollution, by contrast, operates via diffuse pathways. It gathers pollutants across expansive geographic areas, primarily driven by agricultural stormwater sheet-flows carrying synthetic nitrogenous fertilizers and persistent organochlorine pesticides, alongside urban stormwater wash-offs laden with heavy metals from highways and commercial centers.

The systemic degradation of natural waters is deeply tied to population growth, rapid urban expansion, and the adoption of ecologically disruptive technologies. The widespread shift toward non-biodegradable synthetics, industrial petrochemicals, and intensive agricultural strategies has introduced complex chemical stressors into vulnerable catchments. When human pressures overload an aquatic ecosystem, the natural self-purification capacity of the water body collapses. This collapse is often marked by rapid eutrophication, toxic algal blooms, severe oxygen depletion, and the formation of foul-smelling anaerobic zones. These conditions not only trigger massive fish kills and destroy aquatic biodiversity, but also lead to outbreaks of waterborne pathogens that threaten nearby communities.

In Western Odisha, particularly within the Balangir district, these environmental challenges are further amplified by unique geographic conditions. The regional urban landscape lacks major, year-round perennial rivers, making local communities historically reliant on a sophisticated network of man-made, interconnected lentic bodies. Locally known as *Bandhs* (ponds), *Sagars* (large lakes), and *Katas* (reservoirs), these structures were engineered by traditional societies to capture monsoonal rainfall, replenish local shallow aquifers, and provide stable water security for domestic, ritual, agricultural, and piscicultural activities.

In recent decades, however, rapid urban growth and systemic policy oversights have exposed these vital water bodies to severe fragmentation, unmanaged waste dumping, and extensive physical encroachment. To address these mounting challenges, this study aims to systematically quantify the physical and chemical conditions across nine key traditional water bodies in Balangir. By evaluating spatial variations in water quality and establishing a clear baseline dataset, this research seeks to inform future restoration strategies and promote sustainable, community-aligned conservation of these crucial urban ecosystems.

2. Research Objectives

To establish a clear diagnostic overview of the chosen lentic ecosystems, this research was structured around the following core objectives:

- To systematically isolate and quantify key physical and chemical parameters—including water temperature, pH, total dissolved solids (TDS), electrical conductivity (EC), salinity, and dissolved oxygen (DO)—across nine distinct traditional water bodies within Balangir, Odisha.
- To evaluate the spatial variations and statistical differences among these parameters across the different study sites, identifying localized environmental or human factors driving water quality changes.
- To compare the empirical data against international water quality frameworks, such as the World Health Organization (WHO) guidelines, to determine the safety and suitability of these waters for domestic use, aquaculture, and irrigation.
- To generate a reliable baseline dataset to guide urban planners, environmental engineers, and local conservationists in design and implementation of targeted ecological restoration strategies.

3. Review of Literature

The scientific literature contains a wealth of studies documenting the physical and chemical analysis of surface and ground waters across international, national, and regional contexts. Investigating these parameters provides crucial insights into the structural dynamics of aquatic environments, illustrating how natural landscapes adapt to growing urban and industrial pressures.

On a broader conceptual scale, Roy (2019) notes that the declining health of freshwater bodies serves as a direct indicator of wider environmental degradation, posing immediate structural threats to localized ecosystem services and regional biodiversity. Systematic water quality assessments rely on comparing observed physical and chemical values against established standard thresholds, allowing researchers to evaluate water safety and identify potential pollution sources.

Several regional studies highlight how closely water chemistry is tied to local human activities and changing seasons. Shukla and Jain (2013), in their comparative study of water sources in Ahmedabad, observed that shifts in physical and chemical parameters directly alter biotic community structures and primary productivity within urban basins.

Similarly, investigations by Thirupathaiah et al. (2010) on the Lower Manair Reservoir in Andhra Pradesh demonstrated that routine monitoring of parameters like temperature, pH, hardness, and dissolved oxygen is essential for confirming whether water bodies remain suitable for irrigation, regional fish farming, and public consumption. Mittal and Tewari (2020) evaluated the Sahastradhara stream system in Dehradun, noting that human activities and seasonal weather shifts cause noticeable fluctuations in electrical conductivity, alkalinity, and chloride levels.

The literature also underscores that while some water bodies maintain safe physical and chemical levels, they can still face significant biological stresses. For instance, Rajurkar et al. (2003) evaluated the Umshyrpi River in Shillong and found that while most chemical markers remained within acceptable limits, biological parameters far exceeded safe thresholds, rendering the water unpotable without extensive treatment. In West Bengal, Bhaskar et al. (2003) recorded highly alkaline conditions and elevated free ammonia concentrations at multiple testing sites along the Torsa River, pointing to strong anthropogenic influences.

Seasonal changes play an equally decisive role. Chauhan et al. (2013) conducted a year-long study of the Sutlej River in Punjab, uncovering significant seasonal variations that rendered the water unsafe for direct drinking, though still usable for wildlife propagation, aquaculture, and irrigation.

In coastal and unique inland landscapes, surface runoffs and human encounters continuously reshape aquatic environments. Pradhan et al. (2012) documented notable spatial variations in Chilika Lake, where multiple water quality markers regularly exceeded standard safety limits depending on localized runoff inputs. In higher-altitude environments, such as the Sidzii stream in Manipur, Jiten et al. (2012) observed that monthly variations in stream chemistry were driven primarily by natural surface runoffs and mudslides, alongside minor human impacts.

Conversely, large-scale long-term assessments, such as the work by Mohamed and Korium (2009) on Lake Nasser, show that when large water bodies are properly managed, their physical and chemical profiles can remain stable and safe across multiple seasons.

Furthermore, specific parameters often serve as reliable indicators for broader water quality trends. Khaiwal et al. (2003), in their study of the Yamuna River, demonstrated that dissolved oxygen (DO) and total dissolved solids (TDS) show strong statistical correlations with several other water quality markers, making them excellent indices for evaluating overall river health under pollution stress.

The impacts of monsoon runoffs were detailed by Gupta and Hussain (2017) along the Narmada River, where water quality dropped from "excellent" during summer and winter to "poor" during the monsoon due to land erosion, high turbulence, and poor regional sanitation. Similarly, Appavu et al. (2016) highlighted how industrial discharges and domestic dumping contaminated the Cauvery River in Erode, calling for immediate, structured management frameworks to meet WHO standards.

In Malaysia, Rahman et al. (2015) conducted multi-site testing across Perak State, showing that while basic chemical profiles indicated safe drinking conditions, long-term monitoring remained essential to guard against trace heavy metal accumulation and microbial contaminants. Meanwhile, Mohan and Babu (2018) documented distinct monthly fluctuations in temperature, pH, and nutrient concentrations within Erraranjan Lake in Karnataka, though values remained within permissible limits.

Finally, Harichandan et al. (2017) used a comprehensive Water Quality Index (WQI) to assess streams near the Gandhamardan Iron Mines in Keonjhar, Odisha. Their findings revealed very poor water quality driven by elevated TDS, iron, and manganese concentrations, illustrating how industrial mining can severely degrade surrounding aquatic ecosystems.

While these diverse studies provide an essential global and national context, there remains a critical research gap: no detailed physical and chemical water quality assessments currently exist focusing specifically on the traditional urban lentic networks and hill streams of Western Odisha. This study directly addresses that gap.

4. Materials and Methods

4.1 Study Area Profile

This research was carried out in the Balangir district, situated in the western region of Odisha, India, centered around the coordinates of the district headquarters. Covering a total geographic area of 6,575 square kilometers, Balangir is home to a population of approximately 1,648,997 people according to the 2011 census, with a landscape that remains predominantly rural and agrarian. The urban center of Balangir town is divided into 21 administrative wards and includes over 40 distinct neighborhoods, or *Padas* (such as Rugudi Pada, Sagar Pada, Tikra Pada, and Shanti Pada).

Because the town lacks a nearby perennial river, it historically relied on an advanced network of traditional water bodies, including artificial lakes and ponds known locally as *Bandhs*, *Sagars*, and *Katas*. These historic reservoirs—including Maharani Sagar, Karanga Kata, Rani Bandha, and Pratap Sagar—have functioned as the community's primary ecological and domestic lifeline for generations, sustaining local water needs through the dry summer months.

4.2 Selection of Sampling Sites

To ensure a representative evaluation of the urban and semi-urban aquatic landscape, nine distinct traditional water bodies were selected as sampling stations based on their location, size, and level of human use:

1. **Karanga Kata:** A long-standing water body located within the urban center, facing ongoing exposure to domestic activities and residential runoffs.
2. **Rani Bandh:** A historic pond historically used for domestic rituals, currently facing moderate human pressures.
3. **Maharani Sagar:** A large, prominent lentic system with extensive surface area, supporting local biodiversity and fish propagation.
4. **Laxmi Jor:** A reservoir site that receives urban surface drainage and seasonal monsoonal runoffs.
5. **Narsingh Bandh:** A traditional neighborhood pond primarily used by nearby residents for washing, bathing, and domestic chores.
6. **Kandhapali Bandh:** Located in Ward No. 2 of the Balangir Municipality, this water body is tied to local irrigation channels designed to harvest rainwater and support nearby agricultural activities.

7. **Pratap Sagar:** Located in Ward No. 16 (Pratap Sagar Pada), this historic lake was originally designed as part of an interconnected water-supply system. Today, it suffers from severe neglect, aquatic weed overgrowth, and residential encroachment.
8. **Gate Sarovar:** A semi-urban lentic ecosystem exposed to recreational activities and surface runoffs from nearby roads.
9. **Beherapali Bandh:** A pond situated on the outskirts of the town, primarily influenced by agricultural runoff and rural domestic use.

4.3 Sample Collection Protocol

Water samples were collected systematically during the early morning hours to minimize variations caused by daytime solar heating and shifts in photosynthetic activity. At each sampling station, surface water samples were taken from undisturbed zones at a depth of 10 to 20 centimeters using pre-sterilized, high-density polyethylene (HDPE) bottles. Before filling, the sample bottles were rinsed multiple times with the site's water. For parameters prone to rapid change, such as water temperature and pH, measurements were taken directly in the field using calibrated portable instruments. Samples intended for laboratory analysis were sealed, clearly labeled, stored in insulated ice chests at approximately 4°C, and moved immediately to the analytical laboratory to ensure sample integrity.

4.4 Analytical Procedures

The physical and chemical parameters were analyzed using standard scientific methods and calibrated instruments:

- **Water Temperature:** Measured on-site using a calibrated digital centigrade thermometer submerged directly in the surface water layer.
- **Hydrogen Ion Concentration (pH):** Determined using a digital portable pH meter equipped with a glass electrode, calibrated beforehand with standard buffer solutions of pH 4.0, 7.0, and 9.2.
- **Electrical Conductivity (EC):** Quantified using a sensitive laboratory conductivity meter, with results reported in microsiemens per centimeter (μS/cm).
- **Total Dissolved Solids (TDS):** Measured gravimetrically and verified using a portable TDS meter, with values expressed in parts per million (PPM).
- **Salinity:** Evaluated using a calibrated refractometer/salinity meter, recorded in parts per thousand (PPT).
- **Dissolved Oxygen (DO):** Analyzed using the standard Winkler titration method with azide modification, as well as digital polarographic DO probes, with concentrations recorded in parts per million (PPM).

5. Results and Discussion

5.1 Physicochemical Parameters Analysis

The empirical data collected from the nine traditional water bodies reveal distinct physical and chemical dynamics across the study area. The measured values for each sampling station are compiled in Table 1.

Table 1: Physicochemical Profiles of Selected Water Bodies in Balangir

Sampling Site	pH	Temperature (°C)	TDS (PPM)	Salinity (PPT)	Conductivity (µS/cm)	Dissolved Oxygen (PPM)
Karanga Kata	9.70	31.8	50.9	0.42	113	1.1
Rani Bandh	8.95	32.1	72.5	0.60	160	1.8
Maharani Sagar	10.51	31.7	80.3	0.68	173	3.1
Laxmi Jor	10.39	31.6	58.4	0.48	124	2.6
Narsingh Bandh	9.80	28.4	90.1	0.75	189	0.8
Kandhapali Bandh	10.60	32.6	145.0	1.12	323	1.1
Pratap Sagar	8.88	28.7	111.0	0.94	237	0.4
Gate Sarovar	9.58	28.4	77.9	0.65	164	0.9
Beherapali Bandh	9.12	29.2	85.6	0.71	178	1.2

(Note: The data presented above reflects representative measurements taken across the designated lentic research stations).

Discussion of Individual Parameters

Hydrogen Ion Concentration (pH)

The pH value measures the hydrogen ion concentration, indicating how acidic or alkaline the water is. It serves as a fundamental chemical marker, strongly influencing chemical reactions, nutrient availability, and the biological functions of aquatic life. The water bodies examined in Balangir consistently showed alkaline conditions, with values ranging from 8.88 at Pratap Sagar to a highly alkaline peak of 10.60 at Kandhapali Bandh.

This baseline shift toward alkaline conditions indicates significant photosynthetic activity by dense phytoplankton and submerged macrophyte populations. During active photosynthesis, these organisms rapidly consume dissolved carbon dioxide, shifting the local carbonate-bicarbonate equilibrium and increasing the concentration of hydroxyl ions in the water.

Additionally, soap and detergent runoffs from local bathing and washing activities introduce alkaline builders like sodium carbonates and phosphates, further driving up pH levels. While these basic pH levels currently fall within broadly tolerable ecological ranges, prolonged peaks above 10.0 can stress fish populations by altering ammonia toxicity and disrupting the osmoregulatory balance of vulnerable aquatic organisms.

Water Temperature

Temperature functions as a crucial independent variable that directly drives secondary physical and chemical dynamics within aquatic systems. It influences gas solubility, chemical reaction speeds, metabolic rates of aquatic organisms, and overall electrical conductivity. The observed water temperatures across the study sites varied from 28.4°C at Narsingh Bandh and Gate Sarovar to a high of 32.6°C at Kandhapali Bandh, reflecting regional seasonal warming and variations in solar exposure.

Water temperature is highly sensitive to surrounding land use and vegetation cover. Ponds that have lost their surrounding canopy due to urban development absorb more direct solar radiation, leading to elevated surface water temperatures. This physical warming has direct chemical consequences, notably reducing the water's capacity to retain dissolved gases, which can lead to localized oxygen depletion during warmer periods.

Electrical Conductivity (EC), TDS, and Salinity

Electrical conductivity measures water's ability to conduct an electric current, serving as a direct indicator of total dissolved inorganic ions and salinity levels. Total dissolved solids (TDS) quantifies the combined volume of organic and inorganic substances dissolved in the water column. The empirical data reveals a strong, direct correlation among these three markers across all study sites: electrical conductivity, salinity, and TDS rise and fall in close proportion to one another.

This structural correlation is most clearly demonstrated at Kandhapali Bandh, which recorded the highest values across all three metrics: an electrical conductivity of 323 μS/cm, a salinity of 1.12 PPT, and a TDS concentration of 145.0 PPM. This notable increase in dissolved ions stems from the pond's role in local agricultural irrigation networks. Wet weather carries fertilizers, soil minerals, and agricultural residues from nearby farming plots directly into the basin.

In contrast, urban ponds like Karanga Kata showed much lower ionic levels (EC of 113 μS/cm, TDS of 50.9 PPM), indicating lower levels of mineral leaching. While all observed TDS and conductivity levels currently sit well within safe limits for freshwater systems, the elevated concentrations at sites like Kandhapali Bandh underscore how changing land use and agricultural runoffs modify the chemical baseline of these traditional reservoirs.

Dissolved Oxygen (DO)

Dissolved oxygen is a defining indicator of health and ecological stability within lentic environments. It is essential for sustaining fish populations, driving microbial organic decomposition, and maintaining the overall balance of aquatic communities. The study uncovered severe spatial variations in dissolved oxygen levels, ranging from a relatively healthy 3.1 PPM at Maharani Sagar down to a highly critical, hypoxic low of 0.4 PPM at Pratap Sagar.

The higher oxygen levels at Maharani Sagar are supported by its larger surface area and lower average water temperature, both of which enhance natural wind-driven aeration and allow the water to hold more gas. Conversely, the extreme hypoxia documented at Pratap Sagar (0.4 PPM) highlights advanced ecological degradation. This site suffers from extensive weed accumulation, domestic waste dumping, and urban encroachment.

When large volumes of organic waste enter a confined pond, they trigger rapid growth of decomposer bacteria. These micro-organisms consume dissolved oxygen at a rate far faster than natural surface aeration or photosynthesis can replenish it. This severe lack of oxygen poses an immediate threat to aquatic life, creating anaerobic conditions that suppress fish populations, lower biodiversity, and generate foul odors and tastes through the release of toxic gases like hydrogen sulfide.

Socio-Ecological Impacts and Anthropogenic Pressures

The traditional water reservoirs of Balangir town represent a historic adaptation to the region's challenging hydrology, functioning as a vital buffer against acute water scarcity. However, the data from this study indicates that these vital socio-ecological assets are facing severe pressure from rapid, unmanaged urban growth.

The primary human stressors reshaping these aquatic systems include:

- **Unmanaged Domestic Waste and Sewage Disposal:** Because many neighborhoods lack modern, comprehensive sewage networks, nearby residents regularly discharge greywater and dispose of household refuse directly into the ponds. This ongoing input of organic waste accelerates bacterial decomposition, leading to the severe oxygen depletion observed at sites like Pratap Sagar.
- **Detergent Loading from Household Activities:** The widespread use of these water bodies for bathing and washing clothes introduces significant amounts of commercial detergents. These detergents release high concentrations of synthetic surfactants and phosphate builders, which alter surface tension, drive up pH levels, and act as primary nutrients that fuel excessive aquatic weed growth.
- **Agricultural Runoff and Chemical Influx:** Ponds located near agricultural zones, such as Kandhapali Bandh, receive consistent chemical inputs from monsoonal stormwater sheet-flows. These runoffs carry dissolved nitrates and phosphates from synthetic fertilizers, significantly elevating ionic conductivity and total dissolved solids.
- **Encroachment and Siltation:** Weak enforcement of zoning regulations has allowed residential and commercial developments to slowly encroach upon the physical margins of these historic basins. This shrinking of the shoreline reduces total water capacity, alters natural flow paths,

increases soil erosion, and accelerates siltation, leaving these vital ecosystems increasingly vulnerable to drying out during hot summer months.

Strategic Recommendations for Conservation and Management

To reverse the ecological decline of Balangir’s traditional water bodies and safeguard their role in community water security, this study proposes a series of structured, actionable restoration strategies:

Engineering and Physical Restoration Interventions

- **Desilting and Shoreline Boundary Restoration:** Routine, regulated dredging is required to remove accumulated anaerobic sludge and organic silt from pond floors. This physical intervention will restore historical depth, increase water holding capacity, and clear out embedded nutrient reserves that fuel weed overgrowth. Permanent, engineered buffer zones and clear boundary markers should be established around each site to halt further urban encroachment.
- **Diversionary Urban Sewerage Infrastructure:** Local authorities must construct dedicated perimeter drainage networks to catch residential greywater and stormwater runoffs, diverting them away from the pond basins. Untreated urban effluents must be routed through decentralized sewage treatment systems before any water is reintroduced into the natural environment.

Ecological Restoration (Bioremediation) Techniques

- **Mechanical Weed Harvesting and Biomass Management:** Thick mats of invasive aquatic weeds must be systematically harvested from heavily choked sites like Pratap Sagar to allow sunlight penetration and restore natural atmospheric aeration.
- **Constructed Wetlands and Floating Phytoremediation Ecosystems:** Installing artificial floating wetlands planted with native, hyper-accumulating macrophytes (such as *Canna indica* or *Typha domingensis*) can provide continuous, low-cost bio-filtration. These plants naturally absorb excess dissolved nitrates and phosphates from the water, lowering nutrient levels and preventing eutrophication.

Community-Led Governance and Policy Frameworks

- **Community-Based Co-Management Models:** Management policies should transition toward a co-governance model that actively partners local neighborhood associations (*Pada* committees) with municipal authorities. Entrusting local communities with day-to-day oversight fosters shared responsibility and ensures long-term maintenance.
- **Public Awareness and Behavioral Change Campaigns:** Public education initiatives should focus on the ecological and historical value of these ancient water systems, discouraging direct littering, waste dumping, and excessive detergent use within the main basins.
- **Long-Term Spatial and Chemical Monitoring:** A permanent water quality monitoring program should be established under regional environmental frameworks. Regularly tracking key physical

and chemical markers will provide the data needed to catch sudden pollution spikes early and evaluate the success of ongoing restoration efforts.

Conclusion

The physical and chemical assessment of the nine traditional water bodies in Balangir demonstrates that these historic lentic systems remain resilient but face growing environmental stress. Currently, most measured chemical markers—including total dissolved solids, salinity, and electrical conductivity—fall within the safe permissible thresholds established by the World Health Organization (WHO), confirming that these waters remain highly valuable for irrigation, fish farming, and secondary domestic use.

However, the widespread shift toward highly alkaline conditions, combined with the severe oxygen depletion documented at sites like Pratap Sagar, serves as a clear warning of accelerating ecological degradation driven by rapid urbanization, untreated waste dumping, and agricultural runoffs.

Because these ponds function as the primary hydrologic lifeline for a region lacking perennial rivers, allowing them to degrade further poses a direct threat to long-term public health, local biodiversity, and regional climate resilience. The baseline data generated through this research provides environmental planners with the diagnostic insights needed to transition from passive observation to active, structured conservation.

By implementing targeted engineering solutions, adopting biological filtration methods, and fostering active community participation, Balangir can protect its historical identity as a "town of ponds" and secure sustainable water resources for generations to come.

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