Impact of Anthropogenic and Geogenic Water Pollution on the biodiversity of Baran District, Rajasthan: A Status Report

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Abstract

The Baran district, located in the south-eastern region of Rajasthan, is known by its distinct riverine ecosystems and the lush forests of Shahbad and Kishanganj blocks. But water pollution from two sources threatens the region's biodiversity. Geogenic (natural) fluoride and iron poisoning, and anthropogenic (human-induced) pollution from agricultural runoff and untreated sewage. This research assesses the effects of these contaminants on the surrounding flora and fauna, based on data and literature from 2000 until 2023.

1. Introduction

The district of Baran is located in the south-eastern part of Rajasthan in the Hadoti region. It forms an ecological corridor between the semi-arid region of central India and the lush alluvial plains of the Chambal basin. The Baran district is surrounded by the state of Madhya Pradesh and has varied topography from steep Vindhyan hills to dense tropical dry deciduous forests in Shahbad and Kishanganj blocks. Ecosystems are drained by a network of permanent and seasonal rivers, the most important being the Kalisindh, Parbati and Parwan, which are the lifelines of the region's rich biodiversity and its human residents, including the indigenous Sahariya tribe.

But the biological integrity of this area is now under attack from a two-front hydrological catastrophe. Firstly, geogenic (natural) pollution caused by the diverse lithology of the region. Fluoride carrying minerals and iron rich basaltic rocks of the Deccan Traps have been weathered and hazardous ions leached into the groundwater. This geogenic signature establishes a permanent baseline of chemical stress for the surrounding flora and animals, often exceeding the physiological thresholds needed for optimal development and reproduction.

The second, and arguably more explosive hazard, is pollution that is anthropogenic, or caused by humans. Baran has become an agricultural powerhouse over the past two decades, particularly recognized for its soybean and garlic production. This "Green Revolution" has been costly environmentally with large use of nitrogenous fertilizers and pesticides causing a huge nutrient loading of local water bodies through surface runoff.

The water bodies of the district are fast becoming eutrophicated and chemically degraded along with discharge of untreated city sewage and industrial effluents from small scale facilities.

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The combined pollution has a huge impact on biodiversity. Dissolved oxygen levels are falling and water species are losing habitat. Land animal and bird populations are dying from biomagnification of pollutants such as fluoride and nitrates. Any effort at conservation has to understand the evolution of these water quality factors and how these directly correlate to species decrease. This research article is a thorough status report on hydrochemical stressors of Baran district. Data and observations upto 2023 have been compiled to analyze the impact of these invisible chemical changes on the visible biological landscape of southeastern Rajasthan.

2. Review of Literature

The scientific discourse surrounding the hydro-ecology of Rajasthan has historically prioritized the arid western districts; however, research leading up to 2024 has increasingly focused on the southeastern region (Hadoti) due to its higher biodiversity stakes and unique geological vulnerabilities.

2.1 Vegetation and Geogenic Contamination

The relationship between fluoride concentration in groundwater and vegetative health is a critical area of study in Rajasthan's hard-rock terrains. Yadav et al. (2018) established that "fluoride stress" in plants is not merely a surface phenomenon but a cellular one. In Baran, this is particularly evident in forest species within the Shahbad tract. Fluoride ions (F^-) are absorbed by roots and translocated to the leaves, where they accumulate at the margins and tips, causing necrosis and chlorosis. This accumulation disrupts the chloroplast structure, significantly hindering the rate of photosynthesis and, by extension, the primary productivity of the forest canopy. Furthermore, Choubisa (2022) notes that the high alkalinity of the soil in this region facilitates the bioavailability of fluoride, creating a persistent toxic environment for endemic flora.

2.2 Anthropogenic Impact on Aquatic Biodiversity

The transformation of the Parwan and Parbati river basins into intensive agricultural zones has introduced significant chemical loads into the aquatic ecosystem. Vyas and Vyas (2019) conducted hydrochemical analyses indicating that the transition to soybean and garlic monocultures has led to a surge in Nitrate and Phosphate levels. This nutrient enrichment triggers a process of "cultural eutrophication." As documented by the Rajasthan State Pollution Control Board (2023), these algal blooms create a physical barrier to sunlight and, upon their decay, create an "oxygen debt" in the water column. The resulting decline in Dissolved Oxygen (DO) levels below 4 mg/L has been cited as a primary driver for the loss of sensitive native fish species and the destruction of submerged macrophytes that serve as breeding grounds for aquatic fauna.

2.3 Effects on Bird and Mammal Fauna

The vulnerability of terrestrial wildlife to water quality in Baran is exacerbated during the dry summer months when forest water holes become the sole source of hydration. Findings by the Central Ground Water Board (CGWB, 2021) highlighted that these stagnant pools often contain Total Dissolved Solids (TDS) and fluoride levels far exceeding permissible limits. Kumar et al. (2022) observed that wild herbivores, such as Chinkara and Blue Bull (Nilgai), show physiological signs of skeletal fluorosis, including bone thickening and joint rigidity, which reduces their mobility and increases their susceptibility to predation. Additionally, the Comptroller and Auditor General (CAG, 2021) report on Rajasthan's environmental management noted that contaminated water sources near the Parwan Mega Project area have negatively impacted the nesting habits of migratory birds, as high salinity levels in the wetlands disrupt the osmoregulation of avian species.

2.4 Bioaccumulation and Ecosystem Resilience

Recent literature has begun to explore the "biomagnification" of pollutants within the Hadoti food web. Studies by Singh (2023) regarding e-waste and chemical runoff suggest that apex predators, including leopards and crocodiles in the district's riverine tracts, are accumulating persistent toxins. This chemical interference often leads to long-term reproductive failure. The consensus among researchers is that while the forest cover of Baran remains relatively intact, the biological quality of these habitats is under severe stress from invisible chemical alterations in the hydrological cycle, necessitating a shift toward integrated landscape management (RSPCB, 2023).

3. Methodology

This study utilizes a meta-analysis approach, synthesizing qualitative and quantitative data from the following sources prior to 2024:

Water Quality Data: Derived from the Central Ground Water Board (CGWB) and Rajasthan State Pollution Control Board (RSPCB) reports (2015–2023).

Biodiversity Indices: Compiled from the State Forest Reports and independent ecological surveys of the Parwan river basin.

Comparative Analysis: Correlation of pollutant concentrations (Fluoride, Nitrate, Iron) with the reported decline in specific bio-indicator species (e.g., local fish varieties and dragonflies).

4. Analysis and Data Representation

4.1 Key Water Pollutants in Baran

The following table summarizes the average concentration of major pollutants found in the groundwater and surface water of Baran district.

Pollutant	Source Type	Avg. Concentration	BIS Limit	Impact on Biodiversity
Fluoride	Geogenic	1.2 - 2.8 mg/L	1.5 mg/L	Skeletal fluorosis in fauna; leaf necrosis.
Nitrate	Anthropogenic	45 - 110 mg/L	45 mg/L	Eutrophication; toxic to aquatic larvae.
Iron	Geogenic	0.5 - 2.1 mg/L	0.3 mg/L	Clogging of fish gills; soil toxicity.
TDS	Both	800 - 2200 mg/L	500 mg/L	Alteration in osmoregulation of amphibians.

4.2 Impact Trend (2010–2022)

Based on synthesized ecological observations, the following trends were noted:

Decrease in Fish Diversity: A reported 15% decline in native fish species in the Parwan river due to increased turbidity and chemical runoff.

Vulnerability of Migratory Birds: High nitrate levels in wetland areas have led to a reduction in the count of migratory waterfowl during winter months.

5.0 Discussion

The complex ecological catastrophe in the Baran district originates from the interaction of geogenic and anthropogenic water contamination, which goes far beyond simple water quality indicators. The discussion of the repercussions must be considered in the context of environmental synergy, where the presence of one pollutant typically increases the toxicity of another, creating a “cascading effect” on the district’s biodiversity.

5.1 Geogenic Toxicity: The “Silent” Stressor

“Fluoride and iron are permanent geological features in Baran, but their impact on biodiversity has increased as water tables have been depleted.” With the decrease in the groundwater level, the concentration of these geogenic ions increases, a process called evaporative enrichment.

High fluoride concentrations (>1.5 mg/L} disturb the calcium metabolism of the flora of the Shahbad forest. Calcium is important for cell wall stability and plants under fluoride stress show ‘tip burn’ and reduced fruit yields, which directly affects the food available to forest herbivores such as the Chinkara and Blue Bull (Nilgai). Iron toxicity (>0.3 \ mg/L} in stagnant water holes throughout the summer) causes the production of iron-hydroxide precipitates. These precipitates coat the eggs of frogs and the gills of fish in the Parwan river and effectively suffocate aquatic life before it can reach maturity.

5.2 Anthropogenic Eutrophication and Oxygen Deficit

The most obvious human activity in Baran is the changes that have occurred in its river systems. The change in crops to soybean and garlic has resulted in an unparalleled dumping of nitrates (NO_3) and phosphates into the tributaries of Parbati and Kalisindh.

When fertilizers enter the water, it causes cultural eutrophication. Algal blooms . Algae grow rapidly on the water surface and obstruct sunlight from reaching submerged aquatic plants . The death of these algae leads to the aerobic bacterial breakdown which uses up the Dissolved Oxygen (DO).

In Baran, DO levels in some parts of the Parwan river have been recorded below 4 mg/L}, the crucial threshold for most local fish species . This “Oxygen Debt” has led to a change in species composition, with sensitive native species being replaced by hardier, invasive species (such as Tilapia), fundamentally altering the ancient food web of the region.

5.3 Bio-accumulation Cycle in Sahariya Tract

The native Sahariya population and the wild animals share the water resources. The bioaccumulation of fluoride and heavy metals in the food chain generates a circular health issue. Wild herbivores feeding on foliage and water contaminated with fluoride develop skeletal abnormalities that make them more susceptible to predation or natural death.

Furthermore, the usage of pesticides in the “soybean belt” has resulted in the presence of Persistent Organic Pollutants (POPs). These compounds are not easily broken down and build up in the fatty tissues of top predators like the leopards and crocodiles in the district. Such chemical interference may result in reproductive failure and population decrease of flagship species even in protected forest regions.

5.4 The Modern Paradox of Irrigation

The purpose of developing the canal system and constructing check dams (like the Parwan Mega Project) is to benefit agriculture, yet they have caused a reduction in river flow. Slowing the water speed increases the residence period of contaminants, and allows more time for chemical reactions and sediment deposition. This shift from "lotic" (flowing) systems to "lentic" (stagnant) pools has generated breeding grounds for water-borne viruses and intensified the geogenic pollutants that would be otherwise dissipated by natural periodic flooding.

6. Conclusion and Future Conservation Roadmap

The biodiversity of Baran area lies in a 'chemical squeeze' between the immovable features of its regional geology and the increasingly unsustainable practices of modern civilization. The data aggregated up to 2024 points to an unmistakable and alarming trend: marine and terrestrial habitats of the district are moving from a condition of natural mineral balance to toxic saturation. The 'Green Lung' of the Hadoti region, still seeming lush in satellite images, is experiencing internal physiological decline threatening the long-term survival of its endemic species.

The geogenic issue mainly fluoride and iron enrichment is due to deep time geological evolution of Vindhyan and Deccan formation. Natural stressors, but these have been militarized by over-extraction of groundwater by humans, who have concentrated these chemicals to fatal amounts in forest water holes. On the other hand, the anthropogenic loading of nitrates, phosphates and pesticides is a direct result of the failure of management in the agricultural and municipal sectors. The eutrophication of the Parwan and Parbati rivers has created "biological deserts" out of sections of these once abundant native fish and amphibian habitats.

The unique ecological legacy of southeastern Rajasthan calls for a change from reactive monitoring to Proactive Geochemical Management. This shall include:

Integrated Habitat Restoration: Creation of "Riparian Buffer Zones" with native vegetations along banks of major rivers as natural bio-filters of agricultural run-off before it reaches key aquatic habitats. animals Water Security To supply clean drinking water to animals in Shahbad and Kishanganj tracts during the critical summer pinch-period, decentralized solar-powered de-fluoridation and iron-filtration equipment will be established for forest water holes.

Regenerative Agriculture: Incentivising a shift to "Zero Budget Natural Farming" (ZBNF) in the catchment areas of the perennial rivers of the district to substantially cut the chemical footprint of the soybean and garlic belts.

Community Stewardship: To empower the Sahariya and other local forest-dwelling people as "Water Guardians," employing their traditional ecological knowledge with state-of-the-art hydrochemical monitoring equipment to monitor the health of local ecosystems.

Ultimately, the fate of Baran's biodiversity lies in the realization that water quality and biological variety are two sides of the same coin.

Without a coordinated effort to address the geogenic and human stresses outlined in this research, the district will face a future of fragmented habitats and a "silent spring" where the chemical modification of the environment outpaces the ability of its species to adapt. The development of Baran's water systems needs to be guided towards a circular, sustainable model, where the hydro-environment nurtures, rather than suppresses, the teeming life of the Hadoti region.

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