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EFFECT OF VARIOUS POLLUTANTS ON PRIMARY PRODUCTIVITY IN THE RIVER SAI, JAUNPUR UTTAR PRADESH

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ABSTRACT

River ecosystems are impacted by anthropogenic pollutants, which can alter primary productivity and overall river health. This study assessed how major pollutants such as industrial effluents (BOD, COD), nutrients (nitrate, phosphate), and heavy metals affect primary productivity in the River Sai in Jaunpur, India. Four seasonal samplings were conducted (pre-monsoon, monsoon, post-monsoon, winter) at four representative sites along the river. Primary productivity metrics (Gross Primary Productivity, Net Primary Productivity, Chlorophyll-a concentration) were correlated with water quality variables. Results indicate that nutrient enrichment initially increased productivity, but high organic loads and heavy metals suppressed autotrophic activity. The findings emphasize the need for pollution control to sustain the Saprobic resilience of River Sai.

KEYWORDS: River Sai, Primary Productivity, Pollutants, Nutrients, Heavy Metals, Phytoplankton

Rivers are vital freshwater ecosystems that sustain biodiversity, regulate biogeochemical cycles, and support human livelihoods. Among the ecological processes governing riverine systems, primary productivity plays a pivotal role by forming the base of aquatic food webs and regulating energy transfer within ecosystems. Primary productivity in rivers is primarily driven by autotrophic organisms such as phytoplankton, periphyton, and macrophytes**,** whose growth and metabolic activity are closely influenced by physicochemical and biological factors of water (Wetzel, 2001).

In recent decades, rapid urbanization, industrialization, agricultural intensification, and population growth have resulted in significant deterioration of river water quality across India. The discharge of untreated domestic sewage, industrial effluents, agricultural runoff, and solid waste introduces a variety of pollutants including excess nutrients, organic matter, and toxic heavy metals into river systems. These pollutants can significantly modify the natural balance of nutrients and oxygen, thereby influencing primary productivity and overall ecosystem functioning (Venkatesharaju *et al.*, 2010).

Primary productivity is considered a sensitive ecological indicator of river health because it reflects both nutrient availability and stress conditions within aquatic ecosystems. While moderate nutrient enrichment (particularly nitrogen and phosphorus) can enhance primary productivity, excessive loading often leads to eutrophication, oxygen depletion, and metabolic imbalance**,** ultimately suppressing autotrophic growth (Smith, 2003). Additionally, heavy metals such as lead, cadmium, and mercury exert toxic effects on photosynthetic organisms by disrupting enzymatic activity, pigment synthesis, and cellular metabolism (Gupta *et al.*, 2009).

The River Sai**,** a major tributary of the Gomti River, flows through the Jaunpur district of Uttar Pradesh and serves as an important source of water for irrigation, fisheries, and domestic use. However, the river receives considerable pollutant loads from urban settlements, agricultural fields, and small-scale industrial activities along its course. Despite its ecological and socio-economic importance, systematic studies on the impact of pollutants on primary productivity of River Sai remain limited. Understanding these interactions is essential for evaluating ecological degradation and framing effective conservation and management strategies.

A large of undesirable chemicals is poured in to the river Sai through wastes, sewage effluents and industrial wastes (Mathur 1994), they not only change the pH of water drastically but also prove toxic to plant and animal life. There are following types of water pollutants added by domestic, agricultural sewage in the river Sai.

1. Oxygen demanding wastes including domestic sewage, industrial discharges and biodegradable organic compounds.
2. Disease causing agents like bacteria, viruses.

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3. Synthetic organic compounds like pesticides, herbicides, synthetic detergents.
4. Plant nutrients like nitrogen and phosphorus.
5. Heavy metals also added in sewage by different sources (Mathur 1994).

Impact of Organic Pollution

Organic pollutants, commonly measured as biochemical oxygen demand (BOD) and chemical oxygen demand (COD), significantly influence aquatic metabolism. High organic loads stimulate microbial respiration, which competes with autotrophs for dissolved oxygen, leading to reduced net primary productivity (Odum & Hoskin, 1958). Studies by Trivedi and Goel (1986) demonstrated that organic pollution causes a shift from autotrophic to heterotrophic dominance in polluted river stretches.

Research on Indian rivers such as the Yamuna and Ganga has revealed that elevated BOD and COD values are associated with low dissolved oxygen and suppressed phytoplankton activity, particularly in urban-impacted zones (CPCB, 2013).

Heavy Metals and Photosynthetic Inhibition

Heavy metals are among the most toxic pollutants affecting freshwater productivity. Gupta *et al.* (2009) reported that metals such as Pb, Cd, and Hg inhibit photosynthesis by damaging chloroplast structure and reducing chlorophyll synthesis. Rai *et al.* (1981) demonstrated a significant decline in algal productivity in metal-contaminated river stretches in northern India.

Studies conducted on the Gomti and Hindon rivers indicated that heavy metal accumulation negatively correlates with chlorophyll-a concentration and phytoplankton diversity, leading to impaired primary productivity (Sharma *et al.*, 2015).

Therefore, the present study aims to assess the effect of various pollutants on primary productivity in River Sai at Jaunpur, with special reference to nutrient enrichment, organic pollution, and heavy metal contamination.

MATERIALS AND METHODS

Study Area

The River Sai originates at a sprawling pond, named Bhijwan Jheel on the hilltop at Parsoi a village in the Hardoi district. It separates the region of Lucknow from Unnao. The river flows south by Raebareli comes in the region of Pratapgarh then turn east and touches the Ghuisarnath Dham and moves Jaunpur through the west. Four sampling sites were selected.

Site Code	Location Description
S1	Upstream (less disturbed)
S2	Near agricultural runoff zone
S3	Near urban discharge (Jaunpur city outskirts)
S4	Downstream (cumulative impacts)

Sampling and Analysis

Sampling Frequency: Quarterly (pre-monsoon, monsoon, post-monsoon, winter)

Figure 1: Sai River in Jaunpur

Measured Parameters

- Primary productivity: Light-dark bottle method (Gross Primary Productivity — GPP, Net Primary Productivity — NPP, Respiration — R)
- Pigments: Chlorophyll-a (mg/m³)
- Physicochemical: pH, temperature, dissolved oxygen (DO), biochemical oxygen demand (BOD), chemical oxygen demand (COD)
- Nutrients: Nitrate (NO_3^-), Phosphate (PO_4^{3-})
- Heavy Metals: Lead (Pb), Cadmium (Cd), Mercury (Hg)
- Standard Methods: APHA (2017), Strickland & Parsons (1972).

RESULTS AND DISCUSSION

Spatial Variation in Physico-Chemical Parameters

The analysis of water quality parameters revealed a clear spatial gradient of pollution along the River Sai from upstream (S1) to downstream (S4). The upstream site (S1) exhibited relatively better water quality with higher dissolved oxygen (DO) and lower biochemical oxygen demand (BOD) and chemical oxygen demand (COD), indicating minimal anthropogenic interference. In contrast, sites S3 and S4, located near urban settlements and downstream reaches, showed elevated BOD and COD values, reflecting substantial organic pollution from domestic sewage and surface runoff.

The progressive decline in DO from S1 to S4 suggests increased microbial respiration due to organic matter decomposition. Similar trends have been reported for other north Indian rivers such as the Gomti and Yamuna, where urban discharge significantly deteriorates water quality (Singh & Pandey, 2014; CPCB, 2013). Reduced DO levels are ecologically significant as they directly influence photosynthetic efficiency and metabolic balance in aquatic ecosystems.

Water Quality and Pollutant Gradients

Pollutant loads (BOD, COD, nutrients, heavy metals) increase downstream, especially at S3 and S4, indicating urban and agricultural influence (Table-1).

Primary Productivity Indicators

Productivity increases slightly from S1 to S2 (associated with moderate nutrient enrichment), but declines significantly at S3 and S4 where organic load and toxicants are higher (Table 2).

Table 1: Seasonal Water Quality and Pollutant Levels at Sites (Mean ± SD)

Parameter	S1	S2	S3	S4
pH	7.2 ± 0.3	7.4 ± 0.2	7.8 ± 0.4	7.9 ± 0.5
Temp (°C)	25.1 ± 1.2	26.4 ± 1.8	27.0 ± 2.1	26.8 ± 1.9
DO (mg/L)	7.8 ± 0.5	6.2 ± 0.7	5.1 ± 1.0	4.8 ± 1.1
BOD (mg/L)	2.6 ± 0.4	3.9 ± 0.6	6.8 ± 1.1	7.5 ± 1.3
COD (mg/L)	12.2 ± 2.1	16.5 ± 3.2	28.4 ± 4.5	31.2 ± 5.0
NO_3^- (mg/L)	0.9 ± 0.2	1.4 ± 0.3	2.1 ± 0.5	2.3 ± 0.5
PO_4^{3-} (mg/L)	0.08 ± 0.01	0.12 ± 0.02	0.21 ± 0.04	0.25 ± 0.05
Pb (µg/L)	4.1 ± 1.2	6.9 ± 1.8	12.5 ± 3.0	14.0 ± 3.2
Cd (µg/L)	0.5 ± 0.1	0.9 ± 0.2	1.8 ± 0.5	2.0 ± 0.6

Table 2: Primary Productivity Across Sites (Mean ± SD)

Productivity Metric	S1	S2	S3	S4
GPP (mg $O_2 \cdot m^{-3} \cdot h^{-1}$)	4.20 ± 0.5	5.10 ± 0.6	3.70 ± 0.8	2.50 ± 0.7
NPP (mg $O_2 \cdot m^{-3} \cdot h^{-1}$)	2.90 ± 0.4	3.50 ± 0.5	1.80 ± 0.6	0.80 ± 0.4
Respiration (R) (mg $O_2 \cdot m^{-3} \cdot h^{-1}$)	1.30 ± 0.2	1.60 ± 0.3	1.90 ± 0.4	1.70 ± 0.5
Chlorophyll-a (µg/L)	8.6 ± 1.0	10.2 ± 1.3	9.0 ± 1.6	7.3 ± 1.4

Nutrient Distribution and Enrichment Pattern

Nitrate and phosphate concentrations increased markedly from S1 to S4, indicating nutrient enrichment due to agricultural runoff and urban effluents. Moderate nutrient levels at site S2 appeared to favor phytoplankton growth, as reflected by increased chlorophyll-a concentration and gross primary productivity (GPP). This supports the concept of nutrient-limited productivity in lotic systems, where controlled nutrient inputs enhance autotrophic activity (Smith, 2003).

However, at S3 and S4, nutrient concentrations exceeded optimal levels and were associated with declining net primary productivity (NPP). Excess nutrients, coupled with increased turbidity and organic load, likely reduced light penetration and promoted heterotrophic dominance, thereby suppressing effective photosynthesis. Such nutrient-induced metabolic imbalance has also been reported by Dodds and Welch (2000) in nutrient-enriched streams.

CORRELATIONS BETWEEN POLLUTANTS AND PRODUCTIVITY

Primary Productivity Dynamics

Primary productivity showed distinct spatial variation along the river. GPP and NPP values were highest at S2, indicating favourable conditions for photosynthetic activity due to moderate nutrient availability and acceptable oxygen levels. In contrast, a significant decline in both GPP and NPP was observed at S3 and S4.

Although nutrient concentrations were higher downstream, productivity declined due to multiple stressors acting simultaneously, including organic pollution, reduced dissolved oxygen, increased respiration rates, and toxic contaminants. Elevated respiration values at polluted sites suggest enhanced microbial activity consuming available oxygen and organic substrates, which reduced the proportion of oxygen available for net primary production.

Impact of Organic Pollution on Productivity

A strong negative correlation was observed between BOD/COD and NPP, indicating that organic pollution is a major factor suppressing primary productivity in the River Sai. High BOD values reflect increased organic matter that enhances microbial respiration, leading to oxygen depletion and reduced photosynthetic efficiency.

This condition favors heterotrophic organisms over autotrophs, resulting in a metabolic imbalance within the river ecosystem. Trivedi and Goel (1986) reported similar findings, emphasizing that organic pollution reduces riverine productivity by altering oxygen dynamics and nutrient cycling.

Chlorophyll-a as an Indicator of Productivity Stress

Chlorophyll-a concentration, a direct indicator of phytoplankton biomass, followed a pattern similar to productivity metrics. Maximum chlorophyll-a values were recorded at S2, while reduced concentrations at S3 and S4 indicated stress conditions despite nutrient abundance. This paradox highlights that nutrient availability alone does not ensure higher productivity; water quality and toxicity also play crucial roles.

The decline in chlorophyll-an at heavily polluted sites may be attributed to light limitation, oxygen stress, and toxic inhibition, which restrict phytoplankton growth and pigment synthesis. Comparable observations were made by Sharma *et al.* (2015) in the Hindon River, were urban pollution significantly reduced phytoplankton biomass (Table-3).

Table 3: Pearson Correlation Coefficients (r)

Variable Pair	r value
NO_3^- vs GPP	+0.65*
PO_4^{3-} vs GPP	+0.58*
BOD vs NPP	−0.72*
COD vs NPP	−0.70*
Pb vs Chlorophyll-a	−0.63*
Cd vs Chlorophyll-a	−0.59*

*Significant at $p < 0.05$.

CONCLUSION

Primary productivity was highest at moderately impacted sites but declined where pollutant loads exceeded ecological thresholds. Excess organic matter and heavy metals negatively influenced autotrophic organisms. Management strategies such as effluent treatment, agricultural runoff control, and riparian buffer restoration are critical to restore ecosystem productivity.

1. Install sewage treatment units for urban discharge into River Sai.
2. Promote organic farming and controlled fertilizer application in adjacent fields.
3. Continuous monitoring of water quality and biotic indicators.
4. Further research to model long-term productivity trends under climate variability.

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