Comparative Assessment of Water and Sediment Quality in Revdanada and Vaitarna Creeks, Maharashtra: Implications for Heavy Metal Contamination and Coastal Ecosystem Health

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Abstract—Tidal creeks along the western coast of India represent important coastal ecosystems that support biodiversity, fisheries resources, and nutrient cycling processes. In recent decades, however, these environments have experienced increasing pressure from urban expansion, industrial discharge, and agricultural runoff, leading to declining environmental quality. The present study comparatively evaluates the water and sediment characteristics of Revdanada Creek and Vaitarna Creek in Maharashtra, with particular attention to physicochemical conditions and heavy metal contamination. Multiple water quality parameters together with selected trace metals were examined to determine the environmental status of the two creek systems. The findings revealed contrasting pollution patterns between the study sites. Revdanada Creek showed strong influence of saline intrusion and elevated dissolved solids, accompanied by nutrient enrichment and notable accumulation of arsenic in sediments. In contrast, Vaitarna Creek was characterized by substantial organic pollution and higher concentrations of certain metals, particularly arsenic and iron, in the water column. Sediment analysis further indicated metal accumulation that may pose long-term ecological concerns for aquatic organisms. These results highlight the increasing impact of anthropogenic activities on coastal creek environments and highlight the importance of sustained environmental monitoring, improved wastewater management, and effective regulation of industrial and domestic discharges to protect aquatic ecosystem health and ensure sustainable coastal resource management.

Keywords: Aquatic ecosystem health, Coastal pollution, Heavy metals Water quality, Sediment contamination, Tidal creek ecosystems, Western coast of India.

I. INTRODUCTION

Aquatic ecosystems along the Indian coastline are increasingly subjected to environmental stress due to rapid urbanization, industrial expansion, and intensified agricultural practices (Nagendra et al., 2014; Sharma et al., 2021; Vijay et al., 2020; Prasad et al., 2009). These anthropogenic pressures contribute to the discharge of untreated sewage, industrial effluents, and nutrient-rich agricultural runoff into coastal water bodies, leading to deterioration of water quality and ecosystem health (Rajput et al., 2017; Shankar et al., 2008; Apoorva and Kundlas, 2024; Matson et al., 1997; Paria et al., 2021). As a result, many coastal aquatic systems are experiencing increasing levels of chemical contamination and ecological disturbance.

Among coastal environments, tidal creeks represent ecologically significant transitional zones linking terrestrial, freshwater, and marine ecosystems (Kästner et al.,2017). Although smaller than rivers and estuaries, creeks function as important ecological buffers that support fisheries productivity, nutrient cycling, and biodiversity conservation (Nagaraja et al., 2014; Goldin and Athalye, 2012; Singh et al., 2005; Smith and Haese, 2009; Athalye, 2013; Verma et al., 2004). These systems also serve as critical habitats for numerous aquatic organisms and provide ecosystem services essential for coastal communities (Spach et al., 2004). However, their proximity to human settlements, agricultural lands, and industrial areas makes them particularly vulnerable to pollution.

One of the major environmental concerns in coastal ecosystems is the accumulation of heavy metals and organic pollutants in water and sediments. Heavy metals such as cadmium, arsenic, lead, chromium, copper, and mercury are persistent, non-biodegradable, and capable of bioaccumulating within aquatic food webs (Mendoza-Carranza et al., 2016). Their presence in aquatic environments can adversely affect aquatic organisms, alter ecological processes, and pose potential risks to human health through biomagnification (Sahu and Bhosale, 1991). In addition to heavy metal contamination, organic pollutants and nutrient enrichment can lead to oxygen depletion, eutrophication, and overall ecological degradation of aquatic habitats.

Despite their ecological and socio-economic importance, tidal creek ecosystems in India remain relatively understudied compared to major rivers and estuaries (Sukumaran et al., 2021). In Maharashtra, several coastal creeks are increasingly influenced by anthropogenic inputs arising from industrial activities, agriculture, and expanding residential settlements. Revdanada Creek and Vaitarna Creek, located along the western coast of Maharashtra, represent two such important tidal systems that receive substantial anthropogenic inputs from nearby industrial zones, agricultural areas, and human settlements (Herlekar and Sukhtankar, 2008; Rai and Singh, 2015; Chaudhari et al., 2023; Bhadvankar et al., 2024). These pressures may significantly influence both water quality and sediment characteristics, potentially affecting aquatic ecosystem health.

Although several studies have investigated pollution in larger coastal and riverine systems, systematic comparative studies focusing on water and sediment quality in smaller tidal creeks remain limited. Comparative assessments are particularly important for identifying spatial variations in pollution patterns, understanding dominant contamination sources, and developing effective management strategies for coastal ecosystems. Therefore, the present study aims to evaluate and compare the water and sediment quality of Revdanada Creek and Vaitarna Creek in Maharashtra, with particular emphasis on physicochemical characteristics and heavy metal contamination. The findings of this study are expected to provide baseline information on the environmental status of these creek systems and contribute to improved monitoring and sustainable management of coastal aquatic ecosystems.

II. MATERIALS AND METHODS

Study Area and Sampling Design

The present study was conducted in two tidal creek systems, Revdanada Creek and Vaitarna Creek, located along the western coast of Maharashtra, India. These coastal environments are subjected to significant anthropogenic pressures arising from industrial discharges, agricultural runoff, and domestic wastewater inputs (Panchang, 2014). To assess spatial variability in environmental conditions, four sampling sites were selected in each creek, representing areas influenced by industrial activities, agricultural drainage, residential settlements, and relatively less-disturbed zones that served as reference sites. Sampling was carried out during the monsoon (September) and winter (December) seasons to evaluate seasonal variations in water and sediment quality.

Sample Collection and Preservation

Water and sediment samples were collected following the Standard Methods for the Examination of Water and Wastewater (APHA, 2017).

Water samples intended for physicochemical analysis were collected in pre-cleaned polyethylene bottles. Samples designated for heavy metal analysis were immediately preserved by adding concentrated nitric acid (HNO_3) at a ratio of 1 mL per 100 mL of sample to prevent adsorption and precipitation of dissolved metals (Patil et al., 2019).

Sediment (soil) samples were collected from the upper 5–10 cm layer using a stainless-steel grab sampler. The collected samples were air-dried at room temperature, homogenized, and passed through a 2 mm mesh sieve prior to laboratory analysis.

Field measurements of pH, temperature, electrical conductivity (EC), total dissolved solids (TDS), and dissolved oxygen (DO) were performed in situ using a calibrated portable multiparameter probe in accordance with Bureau of Indian Standards guidelines (BIS, 2012).

Physico-Chemical Analysis

Physico-chemical parameters were analyzed using standard analytical procedures. Nitrate (NO_3^-) and phosphate (PO_4^{3-}) concentrations were determined using spectrophotometric methods with a UV–Visible spectrophotometer, following APHA protocols (APHA, 2017).

Biochemical Oxygen Demand (BOD) was measured using the standard five-day incubation method, while Chemical Oxygen Demand (COD) was determined by the dichromate reflux titrimetric method (Sawant & Zingde, 2021). Salinity and alkalinity (expressed as $CaCO_3$ equivalents) were determined using standard titrimetric procedures.

Heavy Metal Determination

The concentrations of selected heavy metals, including cadmium (Cd), arsenic (As), lead (Pb), zinc

(Zn), iron (Fe), chromium (Cr), copper (Cu), mercury (Hg), and manganese (Mn), were analyzed in both water and sediment samples using Atomic Absorption Spectrophotometry (AAS) (Sharma et al., 2018). Calibration of the instrument was performed using certified standard solutions. Quality control procedures included the analysis of reagent blanks and spiked samples to verify analytical accuracy and recovery.

Quality Assurance and Quality Control

Quality assurance and quality control procedures were implemented to ensure reliability and precision of analytical results. Duplicate samples were analyzed for each parameter to assess reproducibility. Instrument calibration was conducted prior to each batch of measurements. Method validation followed the guidelines of the Ministry of Environment, Forest and Climate Change (MoEFCC, 2018), with analytical precision maintained within ±5%. Certified soil and water reference standards were also used for cross-validation of the analytical results (Singh et al., 2016).

Data Analysis

Measured physicochemical parameters and heavy metal concentrations were compared with the Bureau of Indian Standards (BIS, 2012) and World Health Organization (WHO, 2020) guidelines for water and soil quality. Seasonal and spatial variations in environmental parameters were evaluated using descriptive statistical methods. In addition, correlation analysis was performed to examine relationships between physicochemical variables and heavy metal concentrations, providing insights into potential pollution sources and environmental interactions.

III. RESULTS AND DISCUSSION

Water Quality Characteristics

The physicochemical characteristics of water from Revdanada Creek and Vaitarna Creek are presented in Table 1. The results indicate notable variations between the two creek systems, reflecting differences in environmental conditions and anthropogenic influences. The observed variations in physicochemical parameters suggest strong spatial differences between the two creek systems, indicating the influence of both natural tidal processes and anthropogenic inputs.

Total dissolved solids (TDS) were substantially higher in Revdanada Creek compared to Vaitarna Creek, indicating a strong influence of saline intrusion and tidal mixing. Elevated TDS values in coastal creeks are commonly associated with seawater ingress, evaporation processes, and the dissolution of mineral salts. Such conditions may significantly alter aquatic habitats and influence the distribution of aquatic organisms.

Salinity levels further supported this observation, with Revdanada Creek exhibiting markedly higher salinity than Vaitarna Creek. The elevated salinity suggests strong marine influence in the Revdanada system, whereas Vaitarna Creek displayed comparatively lower salinity levels typical of brackish water environments.

Nutrient concentrations also showed variations between the two creeks. Revdanada Creek exhibited higher nitrate and phosphate levels than Vaitarna Creek, indicating nutrient enrichment that may arise from agricultural runoff and domestic wastewater discharge. Excessive nutrient inputs can stimulate primary productivity and potentially contribute to eutrophication in coastal ecosystems.

Indicators of organic pollution, including biochemical oxygen demand (BOD) and chemical oxygen demand (COD), were considerably higher in Vaitarna Creek. Elevated BOD and COD values suggest substantial organic loading, likely originating from untreated domestic sewage, agricultural runoff, and industrial effluents entering the creek. High organic pollution levels can reduce dissolved oxygen availability and negatively affect aquatic organisms.
Heavy metal analysis revealed the presence of several trace metals in both creek systems. Arsenic and iron concentrations were notably higher in Vaitarna Creek, indicating potential contamination from industrial activities, agricultural inputs, or natural geochemical processes. In contrast, most other metals, including zinc, copper, chromium, and mercury, were present in relatively lower concentrations. Although some metals remained within permissible limits, their presence highlights the potential for gradual accumulation and long-term ecological impacts.

Overall, the water quality results indicate contrasting pollution profiles between the two creeks. Revdanada Creek appears to be primarily influenced by saline intrusion and elevated dissolved solids, whereas Vaitarna Creek is more affected by organic pollution and dissolved metal contamination.

Sediment (Soil) Heavy Metal Characteristics

The distribution of heavy metals in sediment samples from Revdanada Creek and Vaitarna Creek is summarized in Table 2. Sediment analysis provides valuable insight into long-term contamination patterns because sediments often act as reservoirs for heavy metals and other pollutants.

Among the analyzed metals, arsenic showed relatively higher concentrations in sediments of both creeks, particularly in Revdanada Creek. Elevated arsenic levels in sediments may result from industrial discharges, agricultural chemicals, or natural geochemical processes within the surrounding catchment areas. The accumulation of arsenic in sediments is of ecological concern because it may become bioavailable under changing environmental conditions and enter aquatic food webs.

Iron concentrations were comparatively higher in Vaitarna Creek sediments, suggesting possible contributions from natural mineral sources or anthropogenic inputs. Elevated iron levels can influence sediment geochemistry and affect the mobility and availability of other trace metals.

Manganese concentrations were also observed in both creeks, indicating potential sediment accumulation. Manganese and iron often occur together in aquatic sediments and play important roles in redox reactions that influence metal mobility and nutrient cycling.

Other metals such as cadmium, zinc, copper, chromium, and mercury were detected in relatively low concentrations. Although these metals were present at lower levels, continuous inputs from surrounding human activities may contribute to gradual accumulation over time.

Comparative Environmental Implications

The comparative analysis of water and sediment quality highlights distinct environmental conditions in the two creek systems. Revdanada Creek is primarily characterized by elevated salinity and dissolved solids, suggesting strong marine influence and potential nutrient enrichment. In contrast, Vaitarna Creek shows evidence of significant organic pollution and elevated concentrations of certain heavy metals in water.

These findings indicate that different pollution sources and environmental processes may be influencing the two creeks. Industrial activities, domestic wastewater discharge, and agricultural runoff likely contribute to the observed contamination patterns. The accumulation of metals in sediments further suggests the potential for long-term ecological impacts in these coastal ecosystems.

Continued monitoring of water and sediment quality is therefore essential to better understand pollution dynamics and to develop effective management strategies. Implementation of improved wastewater treatment systems, stricter regulation of industrial effluents, and sustainable land-use practices could help mitigate further degradation of these ecologically important creek environments.

Table 1

Physico-chemical parameters and heavy metal concentrations in water samples from Revdanada Creek and Vaitarna Creek compared with permissible limits recommended by BIS and WHO standards.

Parameter	Revdanada Creek	Vaitarna Creek	Permissible Limit
Total Dissolved Solids (TDS) (mg/L)	101124	45368	500
Alkalinity (mg/L)	80	140	200
Salinity (ppt)	162.4	17.1	–
Nitrate (mg/L)	37	18.8	45
Phosphate (mg/L)	3.94	1.04	1
Chemical Oxygen Demand (COD) (mg/L)	344	952	250
Biochemical Oxygen Demand (BOD) (mg/L)	153	380.8	30
Cadmium (mg/L)	0.1	0.05	0.1

Arsenic (mg/L)	0.03	0.5	0.05
Zinc (mg/L)	1	1	5
Lead (mg/L)	<0.1	<0.1	0.1
Iron (mg/L)	0.2	1	0.3

Physico-chemical parameters and heavy metal concentrations in water samples from Revdanada Creek and Vaitarna Creek compared with permissible limits recommended by BIS and WHO standards.

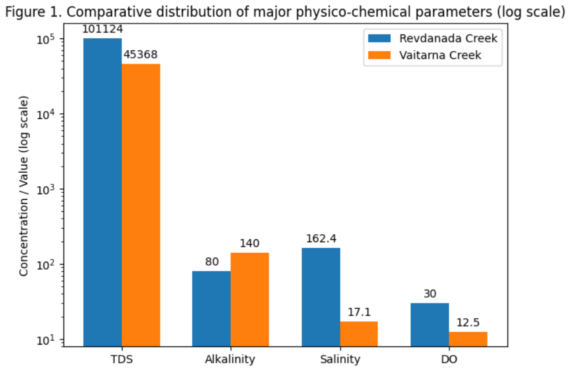

Figure 1

Comparative distribution of major physico-chemical parameters (TDS, alkalinity, salinity and DO) in water samples from Revdanada Creek and Vaitarna Creek. Values are presented on a logarithmic scale to facilitate visualization of parameters with large variations in magnitude.

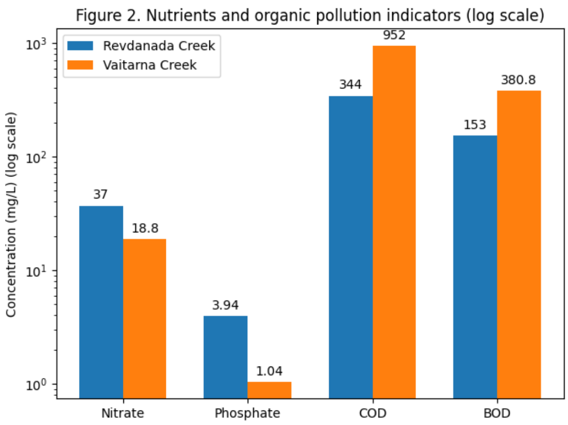

Figure 2

Comparative analysis of nutrient concentrations and organic pollution indicators in water samples from Revdanada Creek and Vaitarna Creek. The logarithmic scale was used to improve visualization of variability among parameters.

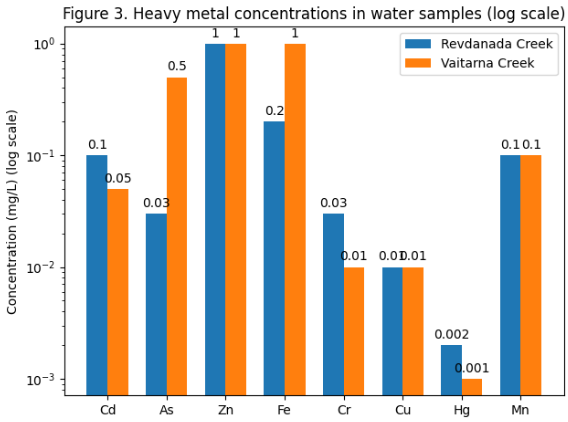

Figure 3

Distribution of selected heavy metals in water samples from Revdanada Creek and Vaitarna Creek. Concentrations are represented on a logarithmic scale to enable comparison of trace metal levels across multiple orders of magnitude.

Table 2

Heavy metal concentrations in sediment (soil) samples from Revdanada Creek and Vaitarna Creek compared with permissible limits based on international environmental quality guidelines.

Parameter	Revdanada Creek (mg/kg)	Vaitarna Creek (mg/kg)	Permissible Limit (mg/kg)
Cadmium (Cd)	0.02	<0.01	0.10
Arsenic (As)	0.50	0.10	0.05
Zinc (Zn)	1.00	1.00	5.00
Lead (Pb)	<0.10	<0.01	0.10
Iron (Fe)	0.20	1.00	0.30
Chromium (Cr)	0.02	<0.01	0.05
Copper (Cu)	0.10	<0.01	3.00
Mercury (Hg)	0.001	<0.001	0.002
Manganese (Mn)	0.20	0.20	0.10

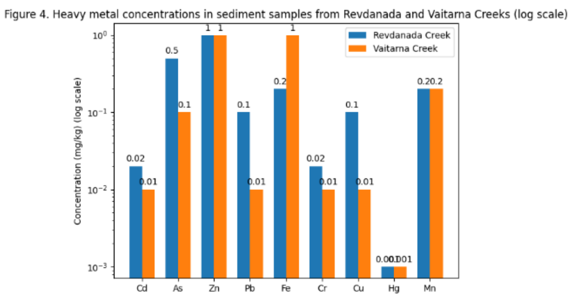

Figure 4.

Comparative concentrations of heavy metals in sediment samples collected from Revdanada Creek and Vaitarna Creek. Values are presented on a logarithmic scale to facilitate visualization of variations in trace metal concentrations across different orders of magnitude.

IV. CONCLUSION

The present study assessed the water and sediment quality of Revdanada Creek and Vaitarna Creek along the western coast of Maharashtra. The analysis revealed considerable variation in physicochemical parameters, nutrient concentrations, organic pollution indicators, and heavy metal distribution between the two creek systems. Revdanada Creek exhibited elevated levels of salinity and total dissolved solids, suggesting a strong influence of marine intrusion and tidal mixing. In contrast, Vaitarna Creek showed higher biochemical oxygen demand and chemical oxygen demand, indicating greater organic pollution associated with anthropogenic activities. Heavy metal analysis demonstrated the presence of trace metals in both water and sediment samples, with relatively higher concentrations of arsenic and iron observed in Vaitarna Creek. Sediment analysis further indicated the accumulation of certain metals, suggesting potential long-term contamination in the creek environment.

The comparative assessment highlighted distinct pollution characteristics in the two creek systems. Revdanada Creek was primarily influenced by salinity intrusion and elevated dissolved solids, whereas Vaitarna Creek displayed higher levels of organic pollution and metal contamination, likely resulting from domestic wastewater discharge, agricultural runoff, and nearby industrial activities. These findings indicate that both creek systems are experiencing environmental stress due to increasing anthropogenic pressures.

The presence of elevated nutrients, organic pollutants, and heavy metals may have significant ecological implications, including reduced dissolved oxygen availability and potential bioaccumulation of toxic metals in aquatic food webs. Such conditions may adversely affect aquatic biodiversity and overall ecosystem functioning.

To mitigate further environmental degradation, strengthening wastewater treatment infrastructure and improving regulation of industrial effluents and agricultural runoff are essential. Implementation of integrated coastal zone management strategies and community awareness initiatives could also contribute to reducing pollution pressures on these ecosystems.

Continuous monitoring of water and sediment quality is necessary to better understand long-term environmental changes in coastal creek systems. Future studies incorporating seasonal monitoring and biological assessments, including bioaccumulation studies in aquatic organisms, would provide a more comprehensive evaluation of ecological risks and support evidence-based environmental management policies.

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Conflicts of Interest
The authors declare no conflict of interest.

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