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Field-Based Daily Journal: Studying Coastal Abrasion in Environmental Engineering

Abstract

Coastal abrasion is an increasingly critical environmental issue affecting coastal ecosystems, infrastructure, and human settlements due to the combined impacts of climate change, sea-level rise, wave dynamics, and anthropogenic activities. This study presents a four-week field-based daily journal documenting coastal erosion processes in a vulnerable shoreline area through systematic observation of shoreline retreat, wave behavior, sediment characteristics, vegetation cover, and human activities. A mixed-method approach was employed, integrating quantitative measurements such as shoreline position, sediment grain size, and wave intensity with qualitative assessments including community behavior and coastal management practices. The results indicate that abrasion rates were highest in areas lacking natural vegetation buffers and in locations exposed to high-energy waves, while mangrove-covered zones exhibited significantly lower erosion. Human activities such as sand mining and coastal construction were identified as major contributing factors to shoreline instability. The study concludes that effective coastal management requires an integrated approach combining environmental engineering interventions, nature-based solutions, continuous monitoring, and community engagement to enhance coastal resilience and sustainability.

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1. Introduction

Coastal zones are among the most dynamic and vulnerable environments on Earth. They are constantly shaped by waves, tides, currents, wind, and sediment transport. However, in recent decades, coastal abrasion has intensified due to climate change, sea-level rise, and human activities such as coastal development, sand mining, and deforestation of mangroves. The Intergovernmental Panel on Climate Change (IPCC) has warned that rising sea levels will significantly increase coastal erosion risks worldwide [1].

In many developing countries, including Indonesia, coastal communities rely heavily on marine resources for livelihoods. However, coastal abrasion threatens housing, infrastructure, agricultural land, and biodiversity. Without proper environmental engineering interventions, such as breakwaters, mangrove restoration, or beach nourishment, erosion can lead to severe social and economic consequences [2].

Environmental engineering plays a crucial role in mitigating coastal abrasion through sustainable shoreline management strategies. These include structural measures (e.g., seawalls, groins, breakwaters) and nature-based solutions (e.g., mangrove planting, dune restoration, coral reef rehabilitation). However, engineering solutions must be integrated with community awareness and participation to ensure long-term effectiveness.

Daily field-based documentation provides valuable insights into how coastal abrasion evolves over time. By systematically observing shoreline changes, wave patterns, sediment movement, and human activities, researchers can better understand erosion dynamics and propose appropriate mitigation measures. This journal focuses on a coastal area experiencing significant shoreline retreat. The study aims to assess daily abrasion patterns, identify key environmental and human factors contributing to erosion, and evaluate the effectiveness of existing coastal protection measures. The findings contribute to the development of sustainable coastal management strategies [3].

2. Materials and Methods

Daily observations were conducted for four weeks along a selected coastline. The following methods were employed:

a. Shoreline Mapping:
   1) GPS measurements were taken daily to track shoreline movement.
   2) Photographic documentation was used to visually compare changes over time.

b. Wave and Tide Monitoring:
   1) Wave height and frequency were recorded using manual observation and local tidal data.
   2) Storm events were noted as key factors influencing erosion.

c. Sediment Analysis:
   1) Sand samples were collected weekly to assess grain size and composition.
   2) Areas with finer sediment showed higher erosion rates.

d. Human Activity Assessment:
   1) Observations included fishing activities, coastal construction, and sand extraction.
   2) Interviews with local residents provided insights into historical shoreline changes.

e. Vegetation Survey:
   1) Mangrove coverage and beach vegetation were assessed as natural protective barriers.

3. Results

Over the four-week observation period, measurable shoreline retreat was recorded along most sections of the study area, though the magnitude of erosion varied considerably depending on local environmental conditions and human influence. The total shoreline retreat ranged from approximately 0.5 meters in protected areas to more than 1.2 meters in highly exposed locations, particularly where vegetation cover was minimal or absent. The most severe erosion events were consistently associated with periods of high waves and spring tides, indicating a strong correlation between hydrodynamic forces and shoreline instability [4].

Spatial analysis of erosion patterns revealed that areas directly facing open ocean experienced greater abrasion compared to sheltered bays or mangrove-lined coasts. In exposed zones, wave energy directly impacted the shoreline without significant natural barriers, resulting in rapid sediment displacement and visible land loss. In contrast, locations with intact mangrove belts or dense beach vegetation showed substantially lower erosion rates, suggesting that natural ecosystems play a crucial protective role in stabilizing coastal sediments [5].

Sediment analysis demonstrated that beaches dominated by fine-grained sand were more vulnerable to erosion than those composed of coarser sand or mixed gravel. Fine sediments were easily mobilized by wave action and tidal currents, leading to faster shoreline retreat. In contrast, areas with coarser sediment exhibited greater resistance to erosion due to higher compaction and reduced mobility under wave impact. This finding highlights the importance of sediment composition as a key factor in coastal stability.

Wave monitoring indicated that average wave heights ranged between 0.8 and 1.5 meters under normal weather conditions, while during storm events, wave heights exceeded 2 meters and occasionally reached up to 2.5 meters. These high-energy waves significantly accelerated coastal abrasion by increasing sediment transport and undermining shoreline structures. Additionally, seasonal wind patterns influenced wave direction, contributing to uneven erosion along different sections of the coast.

Human activities were observed to exacerbate natural erosion processes. Unregulated sand mining, particularly near the shoreline, removed critical sediment reserves that would otherwise help replenish eroded beaches. Coastal construction, including housing and small infrastructure development, altered natural drainage patterns and weakened shoreline stability. Furthermore, the removal of mangroves for firewood or land conversion reduced the coastline's natural defense against wave energy.

Despite these challenges, some areas demonstrated resilience due to existing protective measures. Sections with artificial breakwaters experienced reduced direct wave impact, although sediment accumulation patterns were altered in adjacent areas. Meanwhile, mangrove restoration sites showed promising results, with newly planted trees beginning to trap sediments and reduce erosion over time. These mixed outcomes suggest that both engineered and nature-based solutions influence coastal dynamics in complex ways [6].

4. Discussion

The results of this study confirm that coastal abrasion is a multifaceted process influenced by the interaction between natural forces and human activities. Wave energy, tidal fluctuations, sediment characteristics, and sea-level rise collectively shape shoreline behavior, while anthropogenic disturbances further intensify erosion risks. This complexity underscores the need for integrated environmental engineering approaches rather than isolated technical interventions. One of the key findings is the critical role of sediment composition in determining erosion vulnerability. Beaches dominated by fine sand were far more susceptible to rapid shoreline retreat than those with coarser sediment. This suggests that coastal management strategies should consider sediment replenishment or beach nourishment using more stable material to enhance shoreline resilience [7].

From an engineering perspective, the study highlights significant limitations of traditional hard structures such as seawalls and breakwaters when implemented without broader environmental planning. While these structures provided localized protection, they often disrupted natural sediment transport processes, leading to increased erosion in neighboring areas. This phenomenon demonstrates that structural solutions must be carefully designed and integrated into a larger coastal management framework. Nature-based solutions, particularly mangrove restoration, emerged as one of the most effective and sustainable strategies for mitigating coastal abrasion. Mangrove roots stabilized sediments, reduced wave energy, and promoted natural sediment accumulation along the shoreline. Additionally, mangroves provided ecological benefits such as habitat for marine organisms and carbon sequestration, making them a multifunctional solution for both erosion control and environmental conservation [8].

Behavioral and social dimensions also played a significant role in coastal degradation. Many local residents were unaware of how activities such as sand mining and vegetation removal contributed to long-term erosion. This lack of awareness highlights the need for environmental education programs that inform communities about sustainable coastal practices and their direct impact on shoreline stability.

The daily journal approach proved particularly valuable in capturing short-term variability in erosion patterns that might be missed in conventional long-term studies. Continuous monitoring allowed for real-time assessment of storm impacts, tidal influences, and human activities, providing a more dynamic and comprehensive understanding of coastal processes [9].

Overall, the findings suggest that effective coastal management must integrate engineering solutions, ecological restoration, scientific monitoring, and community participation. A transdisciplinary approach is essential to balance environmental protection with social and economic needs in vulnerable coastal regions.

5. Conclusions

This field-based daily journal study demonstrates that coastal abrasion is a serious and growing environmental challenge that requires immediate and coordinated management efforts. Continuous monitoring over four weeks revealed significant shoreline retreat, particularly in areas exposed to high wave energy and lacking natural vegetation buffers. These findings highlight the vulnerability of many coastal zones to ongoing climate and human pressures.

The study emphasizes that sustainable coastal protection cannot rely solely on hard engineering structures. While seawalls and breakwaters may offer short-term benefits, they often create secondary erosion problems elsewhere along the coastline. A more holistic approach that combines structural measures with nature-based solutions, such as mangrove restoration and beach nourishment, is necessary for long-term resilience.

Mangrove ecosystems proved to be one of the most effective natural defenses against abrasion, reducing wave impact, stabilizing sediments, and enhancing biodiversity. Expanding mangrove restoration programs should therefore be a priority in coastal management strategies, particularly in regions where deforestation has weakened shoreline protection.

Equally important is the role of community engagement and behavioral change. Many erosion-related problems were linked to unsustainable human activities such as sand mining and vegetation removal. Strengthening environmental awareness through education, local participation, and regulatory enforcement is essential to reduce these pressures and promote responsible coastal stewardship.

Future coastal management should incorporate systematic long-term monitoring using modern tools such as drone mapping, satellite imagery, and automated shoreline tracking systems. These technologies can provide more precise data for decision-making and early warning of high-risk erosion zones. Ultimately, protecting coastlines requires collaboration among engineers, scientists, policymakers, and to ensure both environmental sustainability and human well-being.

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