# Chapter 6

# Summary

Coastal regions integrate numerous geological, chemical, biological, and physical interactions, making them key ecological and socioeconomic hubs. They are dynamic environments. Estuaries, coral reefs, mangrove forests, tidal flats, and seagrass beds are just a few of the many ecosystems that make these areas unique and essential to human lives and biodiversity. However, human activities including industrialization, urbanization, and pollution release are posing a growing danger to coastal areas. Coastal zones have suffered greatly from pollution, both from non-point sources like agricultural runoff and point sources like industrial effluents. This has resulted in the loss of habitats, biodiversity, and ecosystem services. Estuaries serve as important filters in the transportation of contaminants to coastal regions, which happen via a variety of routes such as riverine inputs, atmospheric deposition, and direct discharges.

Coastal regions are ecologically diverse and dynamic ecosystems that face growing threats from human activities including overfishing, transportation, tourism, leisure, and effluent discharges. The distribution, reproduction, and survival of marine creatures are all impacted by these activities and substantial changes to the physico-chemical characteristics of coastal ecosystems, which are compounded by seasonal fluctuations. Diverse marine life is supported by these ecosystems high productivity, although environmental pollution has increased significantly as a result of fast industrial and urban expansion. As they serve as natural habitats and buffers for coastal ecosystems, sediments are essential, but they also collect pollutants, especially heavy metals, which provide long-term ecological hazards. Coastal microorganisms are essential to the maintenance of biogeochemical cycles and the stability of ecosystems. These bacteria are sensitive to environmental changes even though they are resilient, which makes them useful markers for tracking the health of ecosystems and possible bioremediation agents for contaminants. The primary objective of this study is to evaluate the levels of pollution and the composition of the microbial community in the sediment and coastal water of the Bhavnagar shoreline in Gujarat, India's Gulf of Khambhat.

India has a long coastline (more than 8,000 km), yet its extensive urbanization and economic expansion have left it with serious environmental problems. The Gujarat, Gulf of Khambhat, which is home to several ports and businesses, is an important region for both environmental and economic activity. The Gulf of Khambhat undergoes complicated hydrodynamics and sediment transport due to the effect of many large rivers and strong tidal

currents. The maritime environment may be in danger from industrial operations, particularly the release of treated effluent into the ecosystem. The Gulf of Khambhat, Bhavnagar coast, which is home to a variety of industrial activity, varying tidal patterns, and a semi-arid environment, is the subject of this research. The physico-chemical properties, heavy metal concentration, and microbiological diversity in coastal water and sediment from seven coastal monitoring sites i.e., Ghogha, Kuda, Mithivirdi, Sosiya, Alang, Sartanpar and Gopnath have been determined.

During pre-monsoon (PRM), monsoon (M), and post-monsoon (POM), water and sediment samples were collected across three consecutive seasons to analyse the pollution levels in coastal water and sediment along the Bhavnagar coast, Gulf of Khambhat, Gujarat, India. Coastal water and coastal sediment samples were examined for physico-chemical characteristics and heavy metal concentrations. Standard procedures were used for the sample collection and analysis. Measurements and analyses were conducted on parameters, including temperature, pH, total suspended solids (TSS), total dissolved solids (TDS), electrical conductivity (EC), total hardness (TH), salinity, chloride levels, dissolved oxygen (DO), chemical oxygen demand (COD), and biochemical oxygen demand (BOD). Most metrics showed seasonal changes, with certain tendencies that were noteworthy and in line with earlier research along the Gujarat coast.

A typical tropical pattern was seen in the temperature, with higher values during PRM and lower values during POM. The pH levels exhibited alkaline features that are appropriate for marine life, remaining reasonably steady. Seasonal variations and tidal activity have a substantial impact on TSS and TDS levels. PRM had the highest electrical conductivity, perhaps as a result of more people being active. During PRM, total hardness and calcium content were also greater, maybe as a result of increased evaporation rates. Seasonal variations were observed in salinity, DO, and chloride concentrations, with salinity and chloride concentrations being greater during PRM and lower during the monsoon because of the entry of freshwater. The seasonal trend of BOD and COD levels was comparable, with lower concentrations during the monsoon, perhaps as a result of diluting effects.

The concentrations of dissolved heavy metals in coastal water were examined in this study at different sites. Lead (Pb), chromium (Cr), nickel (Ni), cobalt (Co), cadmium (Cd),

copper (Cu), zinc (Zn), manganese (Mn), and iron (Fe) were among the heavy metals that were analyzed. The results demonstrated that these metals average concentrations typically declined in the following order: Pb > Cr > Ni > Co > Fe > Cd > Mn > Cu > Zn. During the dry seasons (PRM and POM), there were higher concentrations of heavy metals, which were probably caused by an increase in human activities such as shipbreaking, industrial discharges, and agricultural runoff. The monsoon season, on the other hand, showed lower concentrations, which were explained by the freshwater influx's diluting impact during periods of high rainfall. Heavy metals Pb, Cr, Ni, and Cd exceeded the Bureau of Indian Standards (BIS) allowed limits, raising concerns for human health and marine life.

The study demonstrates how physico-chemical parameters are influenced by environmental factors like rainfall, river runoff, and marine activities. These alterations may have a substantial impact on the habitat and food supplies for organisms that depend on these sediments. The pH values, which varied from 8.5 to 9.5 throughout the seasons, with a noteworthy average of 9.4 during the pre-monsoon period (PRM), are among the key findings. Total available phosphorus (TAP), which fluctuated greatly and peaked during PRM, was also assessed in the research. Another important component, sulphate levels, peaked during PRM as well, indicating the influence of both natural and human activity on the sulphur cycle. Total organic carbon (TOC) and available nitrogen levels varied seasonally in a similar way, peaking in the post-monsoon and PRM dry seasons and falling during the monsoon season.

The heavy metal concentrations in coastal sediments varied greatly, with Fe being the most prevalent and Mn, Cr, Zn, Pb, Ni, Cu, Co, and Cd is the least prevalent. The concentrations of these metals often surpassed the Bureau of Indian Standards (BIS) permitted limits in all seasons. The results of the geographical analysis showed that some locations had high concentrations of various metals, which were frequently associated with specialized operations like ship repair and maintenance as well as other man-made and industrial sources. Significantly, the PRM season saw the greatest amounts of Cr, Ni, Cu, and Pb, especially in locations connected to shipbreaking and ferry services. Sites with significant geogenic inputs also had higher Mn, Zn, and Fe concentrations. According to the study, there is a considerable anthropogenic and natural effect during the PRM season, when these metal concentrations are maximum.

This study evaluated the ecological risk and concentration of heavy metals in coastal sediments, with a particular emphasis on cadmium (Cd) and other heavy metals. The findings showed that there was a significant degree of pollution as the mean concentration of Cd in the sediments was higher than the background value that occurs naturally. The level of heavy metal pollution in the area was assessed using several indices, such as the contamination factor ($C_f$), enrichment factor ($E_f$), geo-accumulation index ($I_{geo}$), ecological risk ($E_r$), and risk index (RI). According to the results of these indices, the region's overall pollution levels range from very clean to moderately dirty, with lead being the main cause of this pollution. Nevertheless, the ecological risk index showed that the total ecological danger presented by the higher Cd levels.

Considerable seasonal fluctuation was found when microbial isolates from various places and zones were analyzed. The season with the greatest number of isolates overall was the pre-monsoon (PRM) season, which was followed by the post-monsoon (POM) season (1798) and the monsoon (M) season (1225). This pattern implies that increased biological activity or environmental conditions that improve microbial measurements in intertidal zones may be linked to the PRM period. The study also demonstrated the unpredictability of the microbiological data, with minimum and maximum values exhibiting considerable variations between sites and zones and average isolate levels increasing in the PRM season and decreasing in the M season. The initial identification of the isolates depended mostly on their morphological traits, which included size, shape, colour, surface texture, and elevation. Numerous phenotypic features were noted in the study, suggesting the possibility of the existence of many strains or species. Through the biochemical analysis of 49 carefully chosen colonies, this variety was further investigated and distinctive metabolic capacities were found. These biochemical tests led to the selection of 15 colonies for genetic study using Sanger sequencing and PCR, enabling accurate identification down to the species or strain level. A thorough characterisation of the isolates was made possible by the combination of morphological, biochemical, and molecular data, guaranteeing reliable and accurate results. The final identified isolates are *Fredinandcohnia humi*, *Bacillus safensis*, *Bacillus thuringiensis*, *Bacillus horikoshii*, *Bacillus pumilus*, *Bacillus cohnii*, *Bacillus licheniformis*, *Peribacillus huizhouensis*, *Bacillus sonorensis*, *Bacillus haynesii*, *Bacillus cereus*, *Bacillus fengqiuensis*, *Priestia flexa*, *Fictibacillus phosphorivorans*, and *Staphylococcus hominis*.

There is an insufficient amount of scientific study currently available on the spatio-temporal fluctuation of physico-chemical characteristics and heavy metal content in the coastal sediment and coastal water of Bhavnagar coast, Gujarat, Gulf of Khambhat, India. Furthermore, not enough research has been done on seasonal microbiological investigations. By offering vital information that the community and local authorities may use as a reference, this research seeks to close these gaps. The knowledge acquired will be crucial for sustainably maintaining and managing the Bhavnagar coast's coastal ecosystems.