Physico-Chemical and Microbiological Assessment of Seawater Quality at Mumbai Beaches.

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Abstract:

The discharge of inadequately treated sewage and wastewater through point and nonpoint sources is putting pressure on and degrading the water quality of Mumbai's beaches and seafronts.This study presents a comparative analysis of seawater quality parameters at five prominent beaches in Mumbai: Rajodi, Aksa, Marve, Versova and Bandra. Water samples were collected from each location and subjected to comprehensive testing for total hardness, salinity, pH, electrical conductivity (EC), dissolved oxygen (DO), biochemical oxygen demand (BOD), and coliform count using the Most Probable Number (MPN) method. The results revealed variations in seawater quality across the beaches, with significant differences observed in hardness, salinity, electrical conductivity, dissolved oxygen, biological oxygen demand and coliform levels. Rajodi Beach exhibited the highest BOD levels, indicating a higher presence of organic pollutants. In contrast, pH levels across all beaches remained nearly uniform, showing slightly basic conditions. Salinity was highest at Versova Beach, followed by Marve, while total hardness was also highest at Versova. Coliform counts were elevated at Rajodi beach, while Aksa, Marve, Versova, and Bandra recorded zero coliform presence. One of the main problems that require these findings highlight the need for regular monitoring and urgent attention is sewage disposal, as large amounts of untreated sewage are dumped into neighboring coastal areas, degrading the water quality in those places. This study also focuses on the statistical estimation of coliform count and isolation of the faecal indicator coliform Escherichia coli (E. coli) in collected water samples.

Keywords: Sea Water, Hardness, Salinity, pH, Electrical Conductivity, DO (Dissolved Oxygen), BOD (Biochemical Oxygen Demand), Coliform Count , MPN (Most Probable Number) method.

Introduction:

Seawater quality assessment plays a crucial role in understanding the health of aquatic ecosystems and ensuring the well-being of human populations that rely on them. The degradation of seawater quality in coastal areas poses significant environmental and public health concerns worldwide. In rapidly urbanizing cities like Mumbai, declining seawater quality at beaches has become a pressing issue, driven by increased anthropogenic activities, inadequate wastewater management, fishing operations, maritime transport, tourism, and oil

discharges. Mumbai's coastal regions are home to several picturesque beaches that serve as recreational hubs, ecological habitats, and integral parts of the city's identity. However, rapid urbanization and industrialization have placed immense pressure on these coastal ecosystems, raising serious concerns about water quality. Understanding the dynamics of seawater quality parameters in these areas is essential for promoting environmental sustainability, protecting public health, and informing responsible coastal management practices. This field project aims to conduct a comprehensive assessment of the seawater quality at the aforementioned beaches. These beaches, known for their scenic beauty and cultural importance, attract large numbers of visitors and support fisheries, local transport, and tourism — all of which contribute to the socio-economic fabric of the city. Nevertheless, rapid population growth, urban development, and inadequate waste management have raised concerns about the cleanliness and ecological health of these coastal waters. The primary objective of this study is to evaluate and compare key seawater quality parameters across the selected beaches. Parameters analyzed include total hardness, salinity, pH, electrical conductivity (EC), dissolved oxygen (DO), biochemical oxygen demand (BOD), and coliform count using the Most Probable Number (MPN) method. By analyzing these indicators, the study aims to identify variations in seawater quality, trace potential pollution sources, and assess the overall environmental condition of each beach through systematic sampling and laboratory analysis
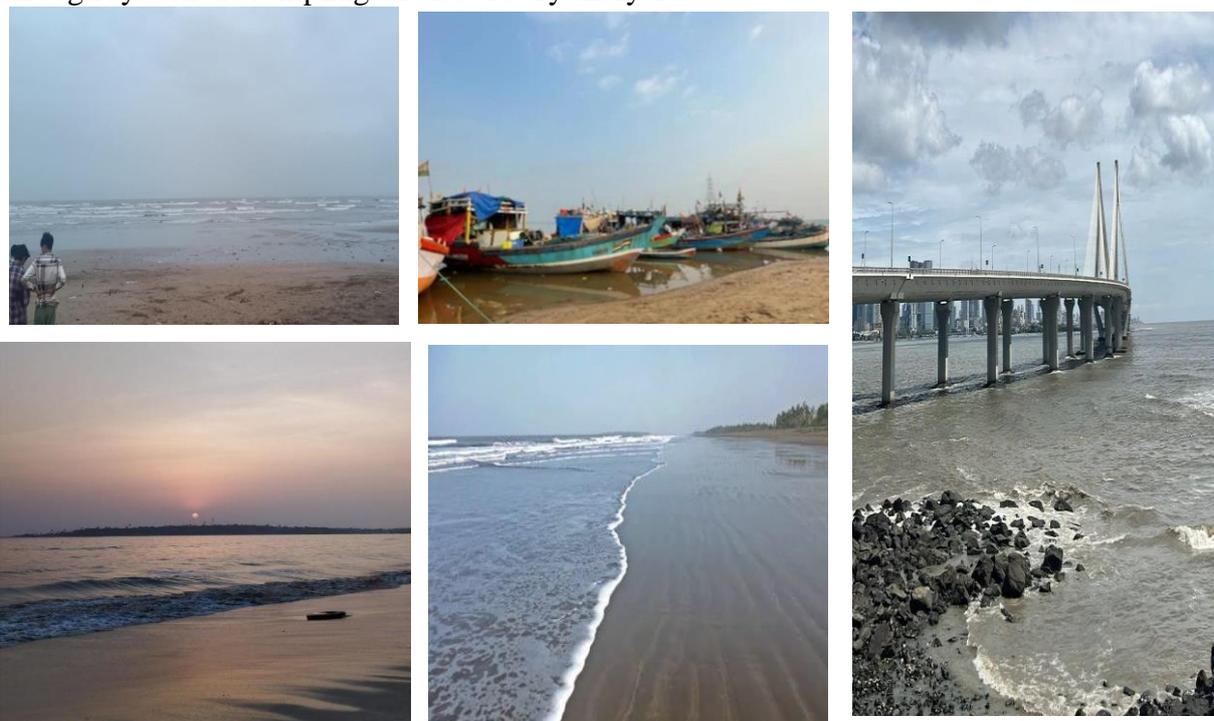
Fig. 1. Sea water sample taken from shoreline of (a) Aksa Beach (b) Marve Beach (c) Versova Beach (d) Rajodi Beach (e) Bandra Beach

Materials and Methods:

Study Area:

The coastal stretch of Mumbai plays a vital role in shaping the city's geography, economy, and culture. This study focused on five selected beaches along the Mumbai coastline, chosen based on the intensity and diversity of anthropogenic activities such as tourism, fisheries, oil discharge, and maritime transport. These human influences contribute to variations in seawater quality across different locations.

Sampling and sample collection:

Seawater samples were collected from the shoreline of each beach using the grab sampling method, which involves collecting a single sample at a specific time and location. Samples were stored in clean plastic bottles and transported to the laboratory for analysis under controlled conditions.

Sample Analysis:

Each sample was analyzed for the following parameters: total hardness, salinity, pH, electrical conductivity (EC), dissolved oxygen (DO), biochemical oxygen demand (BOD), and coliform count.

- pH and electrical conductivity were measured using digital meters (pH meter and conductometer, respectively).
- DO was determined using Winkler's method.
- Hardness and salinity were measured using titrimetric methods.
- BOD was assessed using the Five-Day BOD method.
- Coliform count was determined using the Most Probable Number (MPN) method

Observation and Result:-

The following parameters were analyzed from the collected seawater samples. Table 1 summarizes the parameters along with the methods used. Detailed descriptions of each test and its significance are provided below.

Table 1

Sr. No.	Parameter Studied	Method used
1	Salinity	Titrimetric method
2	Hardness	EDTA Titrimetric Method
3	pH	Electronic readings obtained by a pH meter
4	Electrical conductivity	Electronic readings obtained by the conductometer
5	DO (Dissolved Oxygen) BOD (Biochemical Oxygen Demand)	Winkler's method Five-Day Biochemical Oxygen
6	Determination of Coliform Count	MPN (Most Probable Number) method.

1) Estimation of hardness (EDTA Titrimetric Method)

Hardness is a measure of the concentration of divalent ions—primarily calcium (Ca^{2+}) and magnesium (Mg^{2+})—in water. Seawater is naturally hard due to its high content of dissolved minerals. These minerals are essential for the survival of marine organisms.

The hardness of the samples was estimated using complexometric titration with EDTA as the titrant.

Formula: **Hardness = volume of EDTA used (ml) x N x E x 1000**

$$\text{Volume of Sample}$$

Where:

N = Normality of EDTA (0.02N)
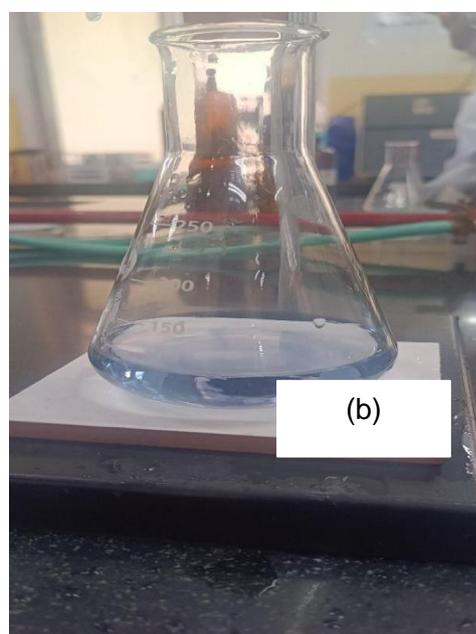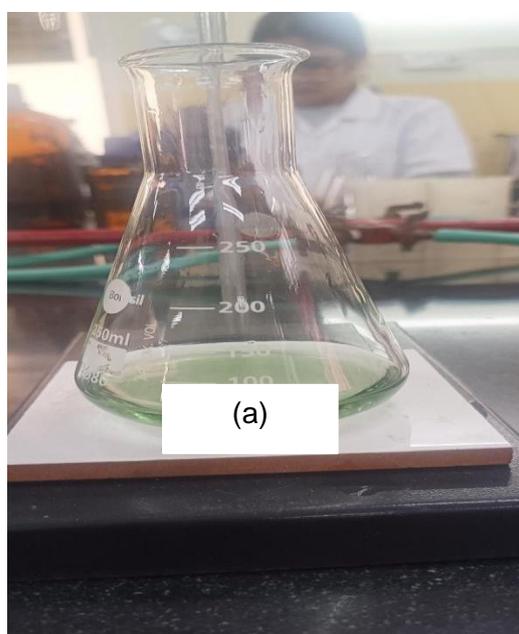
E = Equivalent weight of $CaCO_3$ (50g)

Volume of sample = 20ml

Volume of EDTA used = Burette reading (ml)

The following readings of hardness were obtained:

Beaches	Hardness calculated (ppm)
Versova	3950
Bandra	2060
Aksa	1775
Marve	2945
Rajodi	1600
Standard ($CaCO_3$ solution)	1055

Fig.2. Hardness of Sea Water Sample (a) standardization (b) Estimation

2) Determination of Coliform Count (MPN Method)

Coliforms are gram-negative, rod-shaped, non-spore-forming bacteria that ferment lactose with the production of acid and gas at 35–37°C. While commonly found in the feces of warm-blooded animals, they also occur in soil, vegetation, and aquatic environments. Due to their presence in fecal matter, coliforms are widely used as indicators of water quality and possible contamination. The Most Probable Number (MPN) method is a standard bacteriological technique used to estimate the number of coliforms in a water sample based on lactose fermentation. The presence of acid and gas in selective media indicates positive growth. Based on the number of positive tubes, McCardy's MPN table was used to determine the coliform count.

The coliform counts for each beach are summarized below:

Beaches	MPN Count
Aksa	0
Marve	0
Rajodi	8
Versova	0
Bandra	0

Fig. 3. Determination of Coliform Count (a) Turbidity and gas observed in Rajodi water sample. (b) Gram positive staining for Bandra water sample

3. Measurement of electrical conductivity (Conductometer Method)

Electrical conductivity (EC) is a measure of water's ability to conduct electric current, determined by the presence of dissolved inorganic ions such as chlorides, sulfates, nitrates, sodium, calcium, and magnesium. It is the reciprocal of resistivity and increases with ion concentration. In this study, conductivity was measured using a digital EC meter immediately after sample collection. The standard unit used is MilliSiemens per centimeter (mS/cm). While

NEQS guidelines do not specify limits for conductivity, it is often used to estimate Total Dissolved Solids (TDS). Seawater typically exhibits high conductivity due to its high salt content.

The table below shows the conductivity values recorded for each beach sample:

Sr no.	Seawater samples	Electrical conductivity (mS/cm)
1	Versova beach	1.01
2	Rajodi beach	1.02
3	Bandra beach	1.11
4	Aksa beach	1.49
5	Marve beach	1.07

Fig.4. Measurement of seawater conductivity using a conductivity meter

4. Measurement of pH (Digital pH meter):

pH measures the hydrogen ion concentration, indicating the acidity or alkalinity of a solution. Values below 7 are acidic, above 7 are basic, and 7 is neutral. Seawater generally has a slightly basic pH due to dissolved salts and carbonate ions. pH was determined using a calibrated digital pH meter equipped with a glass electrode. Automatic temperature compensation was employed to reduce temperature-related variation. Proper electrode maintenance, including rinsing with distilled water before use, was followed to ensure accuracy.

The pH values recorded for each beach sample are listed below:

| Sr. No.	Sea water samples	Temperature($°C$)	pH values
1	Versova beach	37°C	7.46
2	Rajodi beach	37°C	7.61
3	Bandra beach	37°C	7.94
4	Aksa beach	37°C	7.61
5	Marve beach	37°C	7.46

Fig.5. pH meter used to measure pH of seawater samples.

## 5. Determination of Dissolved Oxygen (Winkler's Method)

Dissolved Oxygen (DO) is the amount of oxygen dissolved in water, vital for aquatic life. Typical DO levels in healthy water are around 8 mg/L, with a minimum of 4–5 mg/L needed for survival. DO indicates water quality and pollution; low DO can harm aquatic organisms and cause chemical changes. It is also essential for monitoring wastewater treatment. DO was measured using iodometric titration, where the volume of sodium thiosulphate corresponds to the oxygen content:

$$\text{Dissolved oxygen (mg/L)} = \frac{\text{Volume of Sodium thiosulphate (ml)}}{\text{Volume of sample (ml)}}$$

The readings of dissolved oxygen:

Sr. No.	Seawater samples	DO (mg/L)
1	Aksa Beach	4.8
2	Marve Beach	5.6
3	Rajodi Beach	7.2
4	Versova Beach	2.8
5	Bandra Beach	6.4
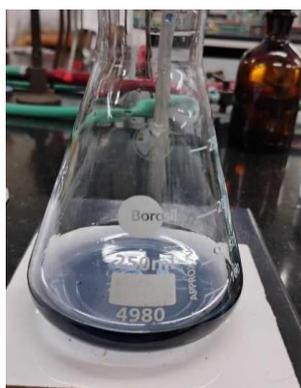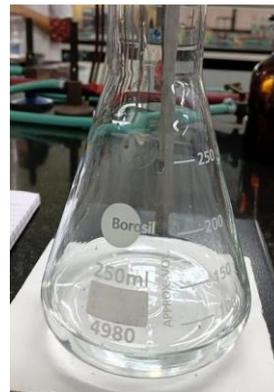
(a) Before titration   (b) After titration

6) Estimation of Biological Oxygen Demand (5-Day BOD Test)

Biological Oxygen Demand (BOD) is the amount of oxygen consumed by microorganisms to decompose organic matter in water under aerobic conditions. It reflects the level of organic pollution — higher BOD indicates greater oxygen demand and more biodegradable waste. In this study, BOD was measured using the standard 5-day incubation method at 20°C. The difference between initial and final dissolved oxygen values was used to calculate BOD.

Formula: $BOD_5 = DO_{Day\ 1} - DO_{Day\ 5}$

The BOD values recorded for the sea   are shown below:

Sr. No.	Beaches	BOD (mg/L)
1	Aksa	4.725ppm
2	Marve	5.528ppm
3	Rajodi	7.056ppm
4	Versova	2.664ppm
5	Bandra	6.264ppm

Fig.7. Determination of biological oxygen demand

7) Determination of Salinity (Argentometric Titration Method)

Salinity refers to the concentration of dissolved salts in water, typically expressed in parts per thousand (ppt). It is a key factor influencing seawater density, marine ecosystems, and ocean circulation. Coastal salinity levels can vary due to freshwater inflow, rainfall, and human activity. In this study, salinity was determined using the argentometric titration method (Mohr's method), where chloride ions in the sample react with standard silver nitrate solution in the presence of potassium chromate indicator.

Formula:

1) Chlorinity/litre = $\dfrac{\text{Estimated titre value} \times \text{Chlorinity equation} \times 1000}{\text{Volume of sample}}$
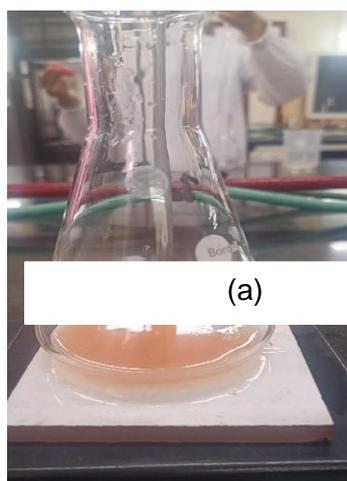
2) Salinity = $0.03 + (1.805 \times$

The constants (0.03 and 1.805) are derived from historical oceanographic data.

Results: The salinity values obtained from the seawater samples are as follows:

Samples	Salinity (in %)
Marve	18.92
Aksa	10.86
Bandra	17.47
Rajodi	10.61
Versova	25.42

(a)

(b)

Fig.8. (a) Standardisation for salinity   (b) Estimation for salinity

This research conducted a comparative assessment of the physical and chemical properties of seawater samples collected from five coastal locations. The table below summarizes the results across all measured parameters, providing insights into the water quality variations along the coastline.

Table 2: Sea Water Quality Parameters observed at different Beaches.

Parameters	Aksa Beach	Marve Beach	Rajodi Beach	Bandra Beach	Versova Beach
Salinity	10.86%	18.92%	10.61%	17.47%	25.42%
Hardness	1775ppm	2945ppm	1600ppm	2060ppm	3950ppm
pH	7.61	7.46	7.61	7.94	7.46
Electrical conductivity	1.49mS	1.07mS	1.02mS	1.11mS	1.01mS

DO	4.8ppm	5.6ppm	7.2ppm	6.4ppm	2.8ppm
BOD	4.725ppm	5.528ppm	7.056ppm	6.264ppm	2.664ppm
Coliform Count MPN	0	0	8	0	0

Interpretation and Conclusion :-

1) Hardness: Standard seawater has a hardness of 5,800–7,500 mg/L, while the sampled beaches showed lower values (1,600–3,950 ppm). This reduction may result from:

- Freshwater runoff, which dilutes seawater hardness.
- Urban and industrial effluents, altering mineral content.
- Local geography and tides, affecting ion concentrations.

These results suggest that local environmental conditions significantly influence hardness levels and merit further study

2) Coliform count: Coliform levels in seawater are typically high, but most sampled beaches showed negligible counts — except for Rajodi. This variation may result from:

- Environmental factors: Tidal dilution, high salinity, and sunlight can reduce coliform survival.
- Sampling factors: High-tide sampling or sampling away from sewage discharge can lower counts.
- Technical/lab factors: Delays in processing, poor storage, or heat exposure may reduce detectable bacteria.

These findings suggest that both environmental conditions and sampling protocols influence observed coliform levels.

3) Electrical conductivity:

Electrical conductivity in seawater is primarily influenced by salinity and temperature. Aksa beach showed the highest conductivity (1.49 mS), suggesting a higher concentration of dissolved salts, likely due to lower freshwater inflow or increased evaporation. In contrast, lower values at Versova, Rajodi, and Marve may indicate dilution from runoff or freshwater sources. Temperature also contributes, as warmer water increases ion mobility, slightly raising conductivity. Other contributing factors may include local geology and pollution, which can introduce additional ions into the water.

4) pH:

The pH of seawater samples ranged from 7.46 to 7.94, slightly less alkaline than typical seawater (~8.1). Beaches such as Bandra exhibited higher pH values, closer to normal seawater, possibly due to less pollution and better tidal flushing. pH variations are mainly influenced by dissolved carbon dioxide from organic matter decomposition, respiration, and

atmospheric absorption. Land runoff and pollution contribute additional acidic inputs, impacting pH levels through nutrient loading and subsequent algal decomposition.

5) DO:

DO values range from 2.8 to 7.2 ppm. Natural seawater typically requires DO levels above 5 ppm to support healthy marine life. Samples with DO above 5 ppm indicate well-oxygenated water, favorable for aquatic organisms. Conversely, samples with DO below 5 ppm, especially 2.8 ppm, suggest oxygen stress, which may threaten sensitive species and promote anaerobic conditions.

6) BOD:

BOD values between 2.664 and 7.056 ppm reflect the oxygen consumed by microorganisms during organic matter decomposition. Clean seawater usually has BOD below 3 ppm, indicating low organic pollution. Samples within this range suggest good water quality, while higher values point to moderate to significant organic pollution, likely from sewage or industrial effluents.

7) Salinity:

Salinity varied across the five Mumbai beaches, with several sites below the global average (~35 ppt) due mainly to freshwater from rainfall and river discharge. Although idol immersions during Ganpati Visarjan introduce pollutants and suspended solids, their direct impact on salinity is minimal. Previous studies also note salinity drops during monsoon and post-immersion periods caused primarily by freshwater influx.

Correlation Analysis of water quality parameters

Correlation is a statistical measure describing the strength and direction of a relationship between two quantitative variables, usually focusing on how closely they vary together in a linear way. A correlation coefficient (typically denoted **r**) ranges from −1 to +1, where values near +1 indicate a strong positive linear relationship and values near −1 indicate a strong negative linear relationship. A value near 0 suggests little or no linear association, though non-linear relationships may still exist; importantly, correlation measures co-variation, **not** causation.

Uses of correlation

- In **exploratory analysis**, correlation matrices reveal clusters of related variables and guide dimension-reduction techniques like principal component analysis and factor analysis.
- In **applied research** (e.g., environmental science, finance, health), correlations are used to quantify relationships, support or refute hypotheses, and screen predictors prior to building predictive or explanatory models.

	Salinity	Hardness (ppm)	pH	Electrical conductivity (mS)	DO (ppm)	BOD (ppm)	Coliform Count MPN
Salinity	1						

Hardness (ppm)	0.9517	1					
pH	-0.2859	-0.5588	1				
Electrical conductivity (mS)	-0.5317	-0.4508	0.12833	1			
DO (ppm)	-0.6934	-0.8049	0.52232	-0.0979	1		
BOD (ppm)	-0.6992	-0.8078	0.51594	-0.0849	0.99978	1	
Coliform Count MPN	-0.5469	-0.4951	-0.0171	-0.3358	0.6095	0.60073	1

Interpretation and Discussion:

Overall, this matrix shows extremely strong collinearity between some water-quality variables (especially DO and BOD), with salinity and hardness strongly associated and coliforms only moderately related to the physico-chemical measures.

1. **Reconstructing key correlations**

From the table:

- **Salinity** has very high positive correlation with hardness (0.9517) and moderately high negative correlations with pH (-0.2859), EC (-0.5317), DO (-0.6934) and BOD (-0.6992), and a moderate negative correlation with coliform count (-0.5469).
- **Hardness** correlates negatively with pH (-0.5588), EC (-0.4508), DO (-0.8049), BOD (-0.8078) and coliforms (-0.4951).
- **pH** shows a weak positive correlation with EC (0.12833), moderate positive with DO (0.52232) and BOD (0.51594), and essentially no relation with coliforms (-0.0171).
- **Electrical conductivity (EC)** is almost unrelated to DO and BOD (-0.0979, -0.0849) and has a small-to-moderate negative correlation with coliforms (-0.3358).
- **DO and BOD** have an almost perfect positive correlation (0.99978), indicating near-linear dependence.
- **Coliform count** shows moderate positive correlations with DO (0.6095) and BOD (0.60073), but only weak to moderate links with the rest.

2. **Substantive interpretation**

- **Salinity & hardness cluster:** Their near-unity correlation suggests they are essentially measuring the same underlying dimension (mineral content). Including both in a regression model will cause multicollinearity; one may be dropped or combined.

- **DO & BOD redundancy:** The 0.99978 correlation is so high that DO and BOD are practically interchangeable in this dataset; any multivariate model should not include both simultaneously, or variance inflation will be extreme.
- **pH as a bridging variable:** pH links weakly to EC but moderately to DO and BOD, suggesting that acidity/alkalinity relates more to oxygen demand than to ionic content in this sample.
- **Coliforms partly decoupled:** Microbial contamination (coliform count) is not strongly tied to salinity, hardness, or EC here, implying that pollution sources are more biological/organic than mineral. The moderate positive correlation with DO/BOD might reflect sites with high organic load and active decomposition rather than "clean" water.
- **Statistical cautions**
- Magnitudes above about $|0.8|$ signal serious multicollinearity if used together in regression or PCA; salinity–hardness and DO–BOD clearly exceed this threshold.
- Interpretation depends on sample size and context: with small n, even moderate correlations can be unstable; with large n, even small coefficients can be statistically significant yet practically trivial.
- Correlation is symmetric and does not imply causation; these associations only describe linear co-movement, not directional effects.

Conclusion:

This study presents a comparative assessment of key seawater quality parameters at five Mumbai beaches—Aksa, Marve, Rajodi, Bandra and Versova. Results showed variations in hardness, salinity, pH, electrical conductivity, dissolved oxygen (DO), biochemical oxygen demand (BOD), and coliform counts across sites. Rajodi exhibited the highest BOD and coliform levels, indicating significant organic pollution and microbial contamination. Versova recorded higher hardness and salinity, reflecting elevated ionic concentrations. pH values remained slightly alkaline and stable across all beaches. Lower DO levels at Versova suggest oxygen depletion likely due to increased organic load and human activities. Wastewater discharge and commercial activities like shipbuilding and sand dredging further contribute to pollution and land use alterations. Conservation efforts, including regular pollution monitoring and integrated management of creeks, mangroves, and wetlands, are crucial for preserving the ecological balance in the coastal ecosystem and benefits to surrounding areas. These findings highlight the impact of urbanization, sewage discharge, tourism, and fishing on Mumbai's coastal water quality. Regular monitoring, improved waste management, and public awareness are vital to prevent further degradation. The data provide a baseline for future assessments and support targeted conservation efforts to protect Mumbai's coastal ecosystems.

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