Studies on impact of sand mining on Plankton diversity along Curtorim, Zuari

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Ms. AVREL THREZA AZAVEDO

Seat No: 22P0580001

ABC ID: 444701738729

PRN: 201802223

Under the Supervision of

PROF. C. U. RIVONKER

School of Earth, Ocean and Atmospheric Sciences

M.Sc. Environmental Science

GOA UNIVERSITY

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Examined by:

Seal of the School

DECLARATION BY STUDENT

I hereby declare that the data presented in this Dissertation report entitled, **"Studies on impact of sand mining on Plankton diversity along Curtorim, Zuari"** is based on the results of investigations carried out by me in the M.Sc. Environment Science at the School of Earth, Ocean and Atmospheric Sciences, Goa University under the Supervision of **Prof. C. U. Rivonker** and the same has not been submitted elsewhere for the award of a degree or diploma by me. Further, I understand that Goa University or its authorities will not be responsible for the correctness of observations / experimental or other findings given the dissertation.

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Azavedo

Avrel Threza Azavedo

Seat No.:22P0580001

Date: 02/05/2024

Place: Goa University

COMPLETION CERTIFICATE

This is to certify that the dissertation report **"Studies on impact of sand mining on Plankton diversity along Curtorim, Zuari"**is a bonafide work carried out by **Ms. Avrel Threza Azavedo** under my supervision in partial fulfilment of the requirements for the award of the degree of **Masters of Science in the Discipline Environmental Science** at the School of Earth, Ocean and Atmospheric Sciences, Goa University.

Prof. C. U. Rivonker

Date: 02/05/2024

Sr.Prof. Sanjeev C. Ghadi

Dean of School of Earth, Ocean and Atmospheric Sciences

Date: 02/05/2024

Place: Goa University

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PREFACE

The exploration of sand plays an important role shaping our modern world. From buildings to roads, it is an essential component of our infrastructure. However, the high demand for sand has resulted in a significant environmental challenge: sand mining.

This research report is the result of a thorough investigation into how human actions, specifically sand mining, affect the variety of tiny organisms called plankton along the shores of Curtorim, Zuari. Our main goal was to understand how changes in the water's chemistry and other physical factors impact these small but vital creatures in this coastal area.

We compared the types and numbers of plankton in places where sand mining happens with those where it doesn't. By carefully studying these differences, we aimed to uncover the subtle ways in which human activities can disrupt the balance of life in marine ecosystems.

This study stands as a testament to our unwavering commitment to scientific inquiry and environmental stewardship. It is our sincere hope that the findings presented herein will not only contribute to the body of knowledge surrounding coastal ecology but also serve as a clarion call for the preservation and sustainable management of our coastal resources.

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Avrel Threza Azavedo

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ABBREVIATIONS USED

Abbreviation	Entity
mg/L	Milligram per Liter
BIS	Bureau of Indian Standard
CO_2	Carbon Dioxide
DO	Dissolved Oxygen
EC	Electrical Conductivity
NTU	Nephelometric Turbidity Units
TDS	Total Dissolved Solids
WHO	World Health Organization
HDPE	High Density Polyethylene bottles

ABSTRACT

Sand mining, driven by global construction demands, presents significant environmental challenges, particularly in aquatic environments such as rivers. This study delves into the impact of sand mining on plankton diversity in the Zuari River, Goa, focusing on Curtorim. Assessing physical, chemical, and biological parameters, researchers aimed to gauge ecosystem health and mining effects.

Sampling across sand mining and reference sites in October and January uncovered marked differences in water quality. Certain parameters such as turbidity, Total Dissolved Solids, electrical conductivity, and nitrite levels - exceed permissible limits, indicating that sand mining is likely the cause of alterations in the ecosystem function.

Phytoplankton, vital for aquatic food webs, showed diminished abundance at mining sites, possibly due to increased turbidity hindering light penetration. Similarly, lower zooplankton populations at mining sites could result from elevated suspended solids affecting water clarity. Sand mining-induced turbidity adversely impacts ecosystems by reducing light penetration, affecting primary production and phytoplankton composition. Zooplankton populations are also affected, potentially impacting survival and fecundity. The study emphasizes the urgent need for sustainable sand mining practices to mitigate adverse environmental impacts on water quality and planktonic communities in the Zuari River. Regulatory measures and conservation efforts are vital for preserving the ecological integrity of this crucial aquatic ecosystem.

Keywords: Sand mining, Zooplankton, Phytoplankton, turbidity

CHAPTER 1: INTRODUCTION

1.1 GENERAL

The sand serves as a provisioning ecosystem service and is commonly harvested from aquatic habitats, including rivers and coastlines, owing to water's significant role in sediment transport. The primary use of sand is for construction since concrete consists of 75% of sand. However, the high demand for sand has led to sand mining becoming a global environmental issue (Asabonga *et al*., 2016). Sand is crucial for groundwater recharge, nutrient replenishment in moving water, and providing habitat for various aquatic and riparian fauna. Sand is a fundamental component of modern infrastructure, used in everything from roads to buildings.

Sand mining, which involves extracting sand from beaches, seabed's, and riverbeds, often alters the physical characteristics of rivers and riverbeds. The dredging and mining often cause several alterations to the physical characteristics of these ecosystems. The erosion caused by mining in the sea or a river floor can negatively impact the biodiversity of the region. Despite policy measures, the global demand for sand has led to a vast network of sand mining operators, including in Goa.

In Goa, there are three main types of sand: ordinary sand, silica sand, and beach sand. Ordinary sand comes from rivers flowing westward from the Western Ghats to the Arabian Sea, where weathering processes aid in its deposition. The extraction of sand primarily occurs from rivers such as Mandovi, Zuari, Terekhol, Chapora, and their tributaries.

Phytoplankton

Phytoplankton, derived from the Greek words phyto (plant) and plankton (made to wander or drift), are microscopic organisms that inhabit both saline and freshwater environments. They include a variety of organisms such as bacteria, protists, and predominantly single-celled plants like cyanobacteria, silica-encased diatoms, dinoflagellates, green algae, and chalk-coated coccolithophores (Lacuna *et al.*, 2012). Some phytoplankton can fix nitrogen and thrive in regions with low nitrate concentrations. However, their growth is limited in vast oceanic areas due to low iron concentrations, as they require trace amounts of iron. Factors like water temperature, salinity, depth, wind patterns, and predator populations also influence their growth rates.

Phytoplankton, are classified into two types: dinoflagellates and diatoms. Dinoflagellates are single-celled eukaryotes with a whip-like tail and are found in marine habitats. They are smaller than diatoms and their bodies are covered with complex shells. Diatoms, on the other hand, are made of interlocking parts with a more rigid structure and move as the ocean currents do. They do not use flagella to move through the water. Diatoms are unicellular and occur in colonies or shells. They take various shapes such as stars, zigzags, fans, and ribbons. Their cell wall is made of silica, called a frustule, which has structural coloration, earning them the nickname "jewels of the sea" or "living opals."

Phytoplankton's play a crucial role in a balanced ecosystem, providing food for sea creatures like shrimp, snails, and jellyfish. They inhabit the upper sunlit layer of water bodies, allowing photosynthesis and serving as food for small creatures. They live in the photic zone of the ocean where it's possible to engage in photosynthesis. They can be degraded by bacteria or viral lysis. Phytoplankton's also play a role in biogeochemical cycles, taking up and transforming elements needed by other organisms. This ensures the uninterrupted cycle of elements between species, especially in nutrient-poor areas. They scavenge and release vitamins and micronutrients, supporting the broader marine ecosystem (Mishra *et al.*, 2015).

Phytoplankton is rich in chlorophyll. It absorbs energy and obtains nutrients from sunlight during photosynthesis. However, phytoplankton cannot survive on sunlight alone and requires inorganic nutrients like nitrates, phosphates, and sulfur. These nutrients are converted into proteins, fats, and carbohydrates. Dinoflagellates are photosynthetic and mixotrophic, taking nutrients from the sun and using a combination of photosynthesis and prey ingestion. Living in the photic zone of the ocean, phytoplankton engages in photosynthesis, absorbing carbon dioxide and releasing oxygen. However, high sun radiation can cause photodegradation, causing phytoplankton to degrade (Gireesh *et al.*, 2015).

Diatoms reproduce using asexual multiple fission, doubling in size every 24 hours with the correct amount of sunlight and nutrients. They live for six days under ideal conditions, and upon death, their shells sink, carrying atmospheric carbon into the deep sea, highlighting the importance of phytoplankton in our ecosystem (Haunost *et al*., 2020). Phytoplankton, when unchecked in an ecosystem, can lead to harmful algae blooms (HABs). These blooms can cause severe illnesses in fish, shellfish, marine mammals, birds, and even humans. HABs are a common occurrence in coastal areas and have become a global concern due to their significant impact on marine life, industry, and tourism. The issue is further exacerbated by climate change

Zooplankton

The term “zooplankton” originates from the Greek words “zoon,” meaning “animal,” and “planktos,” which translates to “wanderer” or “drifter.” Zooplanktons are ecologically significant drifting organisms that feed on bacterioplankton, phytoplankton, other zooplankton, detritus, and nektonic organisms. Zooplankton have diverse life histories and reproductive strategies, ranging from unicellular flagellates and ciliates that reproduce through cell division, to groups like copepods that produce fertilized eggs sexually, and others like tunicates, jellyfish, and chaetognaths that reproduce asexually. All marine phyla are represented within the zooplankton, either permanently as holoplankton (e.g., copepods) or temporarily as meroplankton (e.g., fish larvae) (O'brien, 2005; Bucklin *et al.*, 2010)

Zooplankton can be categorized into micro- and mesozooplankton based on their size. Microzooplankton (< 200 um) is dominated by protistan (unicellular eukaryote) consumers and smaller juvenile stages of metazooplankton species (Paffenhofer, 1998; Quevedo & Anadon, 2000). Mesozooplankton (0.2-20 mm) consists of true animals and large protists like pelagic foraminifera and radiolaria. Macrozooplankton (> 20 mm) includes larger planktonic animals like large gelatinous zooplankton. Both micro- and mesozooplankton are functionally diverse assemblages with complex feeding relationships (Stoecker *et al.,* 1996)

Zooplanktons play a crucial role in marine ecosystems as the primary grazers of phytoplankton and bacteria, and as prey for small fish. Phytoplankton, which zooplankton feed on, vary greatly in size, from picoplankton (0.2-2 um in size) to microplankton (>20 um). The size structure of phytoplankton changes across different environmental gradients. Body size is a key factor in determining the trophic position of zooplankton in the marine food web. The size-based feeding behaviour of different zooplankton groups shapes the zooplankton community across both nutrient-poor (oligotrophic) and nutrient-rich (eutrophic) systems. Changes in the size structure of phytoplankton can impact the structure of the zooplankton community, affecting how primary production is transferred to higher trophic levels.

Energy transfer in food webs is dependent on the relative size of predator and prey, known as the predator-prey mass ratio (PPMR) (Silvert and Platt, 1978; Jennings and Mckinson, 2003; Law *et al*., 2009). The larger the average PPMR in a marine food chain, the more efficiently energy is transferred from lower to higher trophic levels, as fewer trophic steps separate small and large organisms (Brown *et al*., 2004). Zooplankton exhibit a wide range in their PPMR due to their vast phylogenetic diversity and differing feeding modes. Zooplankton exhibit a range of feeding behaviours, including active ambushing, filtration, and passive suspension feeding, each with varying efficiency depending on environmental conditions. Due to this diversity in feeding behaviour, the Predator-Prey Mass Ratios (PPMRs) of zooplankton can vary significantly, spanning seven orders of magnitude.

Impact of sand mining on planktons

Phytoplankton, a microorganism, plays a crucial role in aquatic ecosystems as a primary producer and the base of the food chain, providing food for higher organisms like zooplankton and fish. Their short life cycle allows them to respond quickly to environmental changes, and their abundance and composition can indicate water quality. Factors such as current velocity, erosion, and sedimentation can affect their life. However, changes in the aquatic environment, such as those caused by aggregate mining and sand mining, can have negative impacts. These activities increase the levels of suspended solids and turbidity in the water, reducing transparency and light penetration. This can affect the primary production of the ecosystem and, consequently, zooplankton, which feed on phytoplankton. The ingestion of inorganic particles associated with phytoplankton by zooplankton can reduce the nutritional value of their food, affecting their weight, body size, and feeding behaviour.

Increased suspended contents can reduce the food particles captured by zooplankton and clog their feeding system. Sediments laden plumes created during sand mining can clog and kill micro aquatic biota, mostly plankton. These factors can decrease the survival and fecundity of cladocerans and may affect the diversity of zooplankton. Fish populations, particularly during their embryonic stages, are also directly threatened by suction dredging (Supriharyono, 2004).

1.2 AIM AND OBJECTIVES

AIM

Studies on impact of sand mining on plankton diversity along Curtorim, Zuari.

OBJECTIVES

- To assess plankton diversity in relation to physico-chemical parameters along the study area.
- To make a comparative analysis of plankton diversity and abundance across the affected and unaffected sites of sand mining

1.3 HYPOTHESIS

- Sand mining involves suspending sediments in the water column, causing turbidity and reduced light penetration, which affects phytoplankton community structure and the food web. This can impact bottom dwelling pinnate phytoplankton and zooplankton.

- Suspended solids release excessive nutrients like nitrate, potentially leading to dinoflagellate blooms.

- Blooms forming species are known to assimilate contaminants like heavy metals in the food chain

- Nutrient such as phosphate due to leaching of the sediments also support phytoplankton bloom, potentially clogging the ecosystem.

CHAPTER 2: LITERATURE REVIEW

Tan and Rohasliney (2013) conducted a comprehensive analysis of the impact of sand mining on the water quality of Kelantan River. This review synthesizes findings from various studies to understand the broader implications of such activities on river systems. It highlights significant changes in physical parameters such as total suspended solids (TSS), turbidity, and chemical parameters including nitrogen nutrients due to sand mining. High TSS and turbidity levels, as observed in Kelantan River, create stressful conditions for aquatic life, which corroborates with the observations made by Ambak and Zakaria (2010). The sedimentation and siltation resulting from sand mining and logging activities have been harmful to fish populations, which was also noted by Phua *et al*. (2004). It emphasizes the need for policies that require miners to rehabilitate old mining sites. It adds to the literature that highlights the need for sustainable sand mining practices.

Prabhakar *et al*., (2019) investigated how sand mining affects zooplankton diversity in the River Ganga. With the rapid infrastructural development in Bihar, India, the demand for coarse sand has surged, leading to intensified sand mining activities**,** they compared sites that were affected by sand mining to those that were not. The results showed that mining sites had higher levels of water turbidity, which negatively impacted the abundance and diversity of zooplankton species. These findings highlight the urgent need for sustainable sand mining practices that will help preserve the delicate ecological balance of the River Ganga.

Raghu and Vagish (2020) study sheds light on the critical environmental issue of sand mining and its harmful impact on the water quality of the Tungabhadra River in Karnataka. It highlights the local population's dependence on the river and the alarming levels of pollution caused by unregulated sand mining activities. Raghu and Vagish (2020) presents a comprehensive analysis of various physicochemical parameters, such as pH, dissolved oxygen (DO), biochemical oxygen demand (BOD), electrical conductivity (EC), total hardness, chloride, total dissolved solids (TDS) and others. The findings indicate that the river water's quality is compromised, with several parameters exceeding the World Health Organization's (WHO) recommended standards for drinking water. The high levels of turbidity, TDS, and alkalinity are particularly concerning, suggesting significant pollution and potential harm to aquatic life and human health. Based on findings of the above work, immediate action by local authorities to reduce the pollution levels in the river. It emphasizes the importance of adopting sustainable sand mining practices and proper waste management to preserve the river's ecosystem and ensure the safety of the water for the local community.

Kumar *et al.,* (2020) highlights the ecological impact of instream sand mining on the Sone River's physicochemical parameters and phytoplankton composition was investigated. The results showed that sand extraction led to significant changes in the river's physicochemical properties, resulting in increased turbidity and silica content. This, in turn, reduced sunlight penetration and affected photosynthetic activities, leading to a decline in primary productivity. Additionally, the study found a shift in phytoplankton diversity, with Bacillariophyceae becoming the dominant group due to the abundance of silica particles and alkaline water. The decrease in phytoplankton density at mining sites was a major concern this was caused by increased turbidity and the presence of suspended particulate matter, which reduces solar radiation's transmittance. While sand mining may provide economic benefits, Kumar et al., suggest that it needs to be scientifically regulated to mitigate its environmental impact. They advocate for controlled mining practices to preserve the aquatic ecosystem.

Anyanwu *et al*. (2021) studied the impact of sand mining on a river's ecosystem and plankton community. They recorded 27 zooplankton species, identifying Daphnia pulex as pollution indicators had the highest number of individuals. The sand mining activities significantly affected downstream water quality and caused eutrophication, exacerbated by nutrient enrichment from sand mining. The zooplankton was relatively low in abundance at reference site due to human activities like children swimming during the dry season. The study emphasized the need for stricter regulation of illegal sand mining to mitigate its harmful effects on the ecosystem.

A study by Alam *et al*. (2022) examines the environmental impacts of sand mining on aquatic ecosystems. Sand mining has significant ecological consequences for the Mahananda River and its tributaries in the Kishanganj district. Zooplankton are essential indicators of water quality and ecosystem health, and the study finds that sand mining leads to increased turbidity and reduced zooplankton diversity. The decline in zooplankton species richness and diversity reported in the study is a concerning indicator of ecological stress, corroborating findings from other regions experiencing intensive sand mining (Kumari & Sinha, 2019). The paper by Alam *et al*., (2022) offers valuable insights into the specific impacts of sand mining on zooplankton populations in Indian rivers.

CHAPTER 3: MATERIAL AND METHODOLOGY

3.1 STUDY AREA

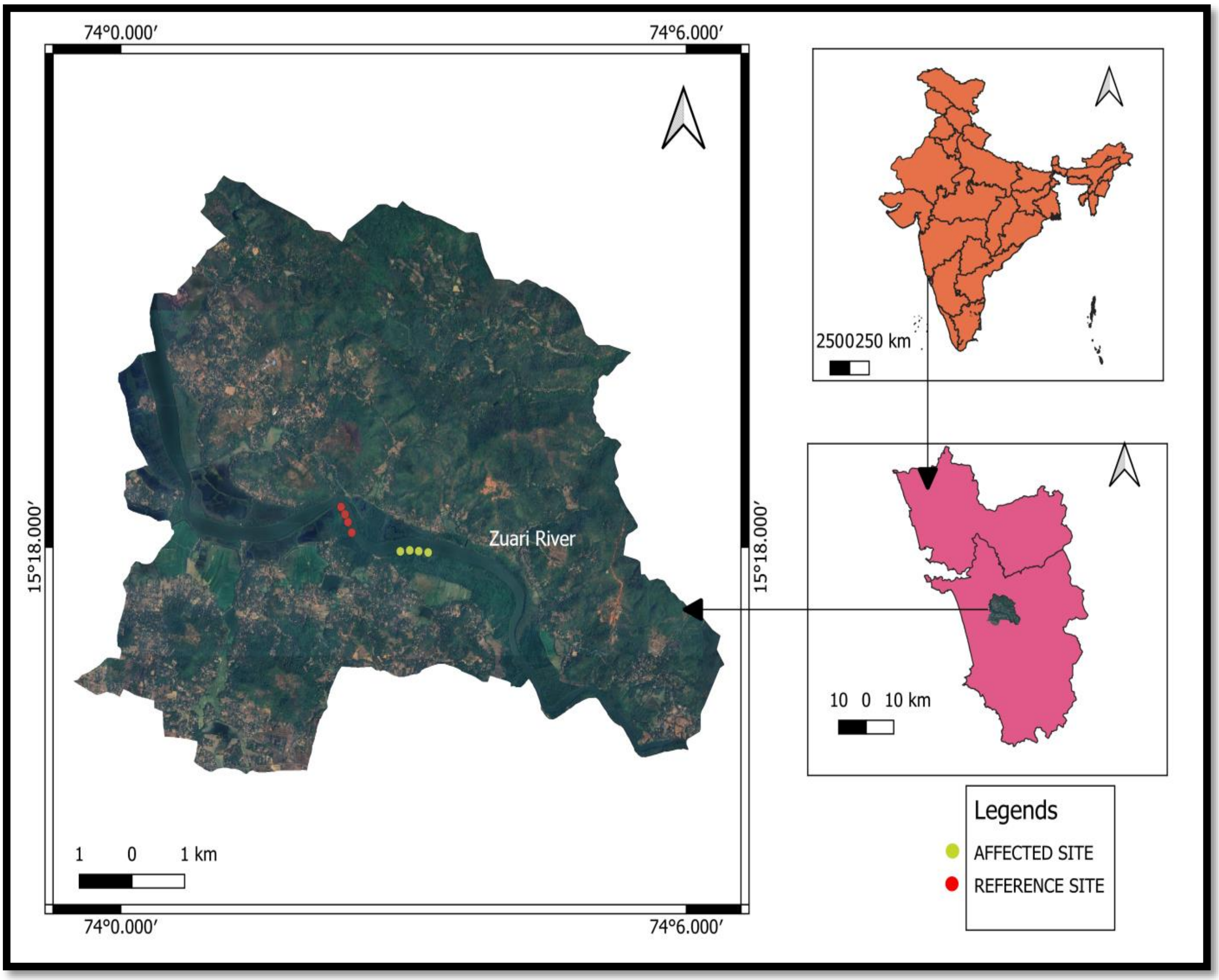

Figure 3.1 Map showing the sampling locations

Curtorim is located at 15.28°N 74.03°E. It has an average elevation of 38 metres (125 feet). Zuari river flow from this village and meets to Arabian Sea. Zuari River occupies approximately 5790 ha of water body, along about 145 km stretch of which 64 km is navigable. The estuarine mouth (Marmugao Bay) is about 6 - 7 km wide, while the upstream region narrows down to 0.5 km (Untawale *et al*., 1982).

Geophysical data acquisition with a 145 km long stretch, Zuari River is the longest river of Goa. Zuari River basin constitutes the second largest basin of Goa after Mandovi

River. With about 975 km^2 area between Netravali and Mormugao bay, it constitutes about 27% of the total area of Goa. It originates in the Sahyadri Hills as Uguem and Sanguem rivers and after flowing on zigzag stretch till Sanguem Taluka, it conjoins. The river after the confluence of Sanguem and Uguem is referred as Zuari River. Thereafter, Zuari flows in the north-western direction through the talukas of Sanguem, Quepem, Ponda, Tiswadi, Mormugao, and Salcete. It covers approximately 55 km, from Sanguem confluence point, before finally debouching in the Arabian Sea at Mormugao Bay. (Anant, 2012)

Location of Sampling Sites

Table 3.1: Locations of sampling site in the river without sand mining

Sampling Locations	Latitude	Longitude	Landmark
Location 1	15°18'9.65"N	74° 2'26.53"E	Upstream to the left side the of river Zuari in Sonvxem village ,Curtorim
Location 2	15°18'12.46"N	74° 2'24.82"E	Upstream to the left side the of river Zuari
Location 3	15°18'17.05"N	74° 2'23.06"E	Upstream to the left side the of river Zuari
Location 4	15°18'19.69"N	74° 2'21.68"E	Upstream to the left side the of river Zuari

Table 3.2: Locations of sampling sites in the river with sand mining

Sampling Locations	Latitude	Longitude	Landmark
Location 1	15°17'57.68"N	74° 2'57.87"E	Downstream to the left side the of river Zuari in Corjem village,Curtorim
Location 2	15°17'58.25"N	74° 3'3.86"E	Downstream to the left side the of river Zuari
Location 3	15°17'57.79"N	74° 3'9.60"E	Downstream to the left side the of river Zuari
Location 4	15°17'57.05"N	74° 3'15.56"E	Downstream to the left side the of river Zuari

3. 2 SAMPLES COLLECTION AND ANALYSIS

This study was conducted in the month of October and January, with collection of water and plankton once a month. For sample collection, a one-liter water sampler was used, which was then transferred into sterilized 1-liter plastic bottles and taken to the laboratory for analysis. Water temperature was determined in situ with a mercury-in-glass thermometer, while other physical and chemical parameters were analysed using titrimetric and instrumental methods. The physical and chemical parameters of the water from both the sand mining sites and reference sites were analysed.

The laboratory analyses that were performed included:

Physical Parameters: pH (measured using a pH meter), electrical conductivity (measured using a conductivity meter), turbidity (measured using a nephelometer), and total dissolved solids (measured using a conversion factor).

Chemical Parameters: Phosphate, nitrate, nitrite, fluoride (measured using a spectrophotometer), acidity and alkalinity (measured through titration), and dissolved oxygen (measured through titration).

Biological Parameters: Phytoplankton and zooplankton abundance.

To collect phytoplankton samples, a phytoplankton net was attached to one side of the boat. The boat was then towed along two locations, where sand mining is carried out and other where, sand mining is not carried out. After a certain distance, the phytoplankton net was removed from the water, and the net content was poured into HDPE bottles. To preserve the samples, they were treated with a solution containing 3% buffered formaldehyde and 1% Lugol’s iodine.

Zooplankton samples were collected using a Heron-Tranter net. The zooplankton net was attached to one side of the boat and dragged at both sites. After a certain distance, the samples were collected in HDPE bottles, and upon recovery of the samples, they were immediately preserved in 70% ethanol for further analysis.

3.3 LABORATORY ANALYSIS

3.3.1 PHYSICAL AND CHEMICAL PARAMETERS

Temperature

A laboratory thermometer was used to measure the temperature of the water at each of the six stations for both the sites. The thermometer was inserted into the obtained water sample and left there for two minutes and the readings were taken.

pH

The term “pH” stands for “potential of Hydrogen” and it is used to gauge the acidity or alkalinity of a solution. The pH level is dictated by the concentration of hydrogen ions (H^+) in the solution; a higher concentration of H^+ ions yields a lower pH value (more acidic), whereas a lower concentration results in a higher pH value (more alkaline).

Using a pH meter, the pH of river water samples collected from both the impacted and unaffected areas where sand mining occurs was evaluated in the laboratory within six hours of the water samples being collected. The pH meter was calibrated before field operations using standard solutions of pH 4, pH 7, and pH 10. The pH readings for each sample were acquired and recorded using the following procedure.

Remove the pH meter probe from the KCl solution and rinse it with distilled water. Switch on the pH meter. The monitor should activate and display a reading of 7.00. Insert the probe’s tip into the river water samples, positioning it approximately half an inch in. Wait for the beep and record the reading displayed on the monitor; this indicates the pH of the water. Rinse the probe again with distilled water. Finally, submerge the probe in a 3M KCl solution.

Note: It is important to immerse the electrode into the KCl solution when the pH meter is not in use.

Electrical Conductivity

The electrical conductivity of water refers to its ability to conduct electrical current. This is primarily determined by the concentration of ions, which come from dissolved salts, minerals, and other substances that break down into ions when they dissolve in water.

The electrical conductivity of water samples from the river of both the reference and controlled sites was measured in the laboratory with an electrical conductivity meter within six hours of the collection of the water samples. The following approach was used to acquire the EC values for each sample, and the values were reported in miliSeimens

An electrical Conductivity meter was used to determine the conductivity of the water samples. The Conductivity meter was calibrated using 0.01 M KCl solution to 1.546×10^{-3} S / Cm at 30° C. After the calibration, the probe of the Conductivity meter was rinsed with distilled water and wiped thoroughly with tissue paper. A measurable amount of water sample of approximately 40 ml each was taken for the measurements. (APHA, 2012)

Total Dissolved Solids

Total Dissolved Solids, represents the total concentration of both organic and inorganic substances that are dissolved in water. These substances can encompass a variety of elements such as minerals, salts, metals, ions, and other particles that dissolve in water. TDS is usually quantified in milligrams per liter (mg/L) or parts per million (ppm). A higher TDS level signifies a larger concentration of dissolved solids in the water, whereas a lower level indicates fewer dissolved solids (Sreenivasa 2015).

The TDS of the river water samples was calculated using the following equations

$$TDS\left(mg\ /L\ \ \right) = k \times electrical\ conductivity\ \left(\frac{\mu g}{1}\right)$$

Where value of k is 0.64

Turbidity

Turbidity refers to the measure of relative clarity of a liquid, which is an optical property of water. It quantifies the scattering of light caused by particles in the water when a light beam is passed through a water sample. The greater the light scattering, the higher the turbidity. A device known as a turbidimeter is used to measure turbidity in nephelometric turbidity units (NTU).

In the laboratory, the turbidity of water samples from all eight sites was measured using the Eutech TN-100 Turbidimeter. A specific procedure was followed to determine the turbidity values for each sample, and these values were reported in NTU. Acquire a clean, dry sample vial, handling it from the top. Rinse the vial with about 10 ml of the water sample, cap it with the black screw cap, and gently invert it several times before discarding the used sample. Repeat this rinsing process two more times. Fill the rinsed vial with the remaining grab sample (about 10 ml) up to the mark indicated on the vial. Secure the vial with the provided black screw cap. Use the supplied soft, lint-free cloth to wipe the vial, ensuring its exterior is dry, clean, and smudge-free. Apply a thin layer of silicone oil (provided) to the sample vial and wipe it with a soft cloth to achieve an even coating over the entire surface of the vial.

Position the turbidimeter on a flat, level surface and insert the sample vial into the sample well, aligning the vial’s index mark with the meter’s index mark. Push the vial until it clicks into place and cover it with the light shield cap. Activate the meter by pressing the ON/OFF button. Following the power-up sequence, the meter enters measurement mode and the display will flash “Read”. The measured reading will then be displayed.

Phosphate

Phosphates can infiltrate water bodies through a variety of natural and human-induced activities, such as agricultural runoff, discharge of wastewater, and erosion. Elevated phosphate levels in drinking water can be hazardous to health as they can degrade water quality by fostering the proliferation of bacteria and other microorganisms in water distribution systems. This can result in problems like bacterial contamination and the formation of biofilms, which could heighten the risk of waterborne diseases if not adequately controlled. The Molybdenum blue method, developed by Murphy and Riley (1962), is commonly used for phosphate analysis.

In 50 ml graduated tubes, blank (0), 2, 4, 6, 8, 10, and 12 ml of the working solution (potassium dihydrogen phosphate) are taken and diluted up to the mark with distilled water.

Add 1 ml of the mixed reagent and 1 ml of ascorbic acid, and thoroughly mix.

The absorbance is measured at a wavelength of 880 nm after 30 minutes.

A calibration curve is created by plotting the known phosphate content versus absorbance.

$$Concentration\ of\ Phosphate\ \left(\frac{\mu\ mol}{L}\right) = Average\ factor \times Optical\ density$$

Nitrate

Nitrate can infiltrate water bodies through a variety of natural and human-induced activities, such as agricultural runoff, discharge of wastewater, industrial operations, and atmospheric deposition. The main contributors to nitrate pollution in water bodies are agricultural fertilizers and animal waste.

The nitrate concentration in water samples was determined using a spectrophotometer. The standard concentrations of 0, 1, 3, 5, 7, and 9 mg/L were prepared using KNO_3 stock solution along with the unknown concentration of the water samples.

These solutions were diluted into 50 ml graduated tubes with distilled water

The absorbance was then measured at a particular wavelength. (APHA, 2012)

Nitrite

The concentration of nitrites in water bodies can be affected by several elements, such as runoff from agriculture, discharges from wastewater, and industrial processes.

The process of determining Nitrite is based on the Strickland and Parsons 1968. In an acidic solution, nitrite interacts with sulfanilamide to produce a diazonium compound. This compound then combines with N-(1-Naphthyl)-ethylenediaminedihydrochloride to create a colored azo dye.

In 50 ml graduated tubes, 0 (Blank), 1, 2, 3, 4, and 5 ml of the working solution (NaNO2) are taken and diluted to the marks with distilled water. 1 ml of sulfanilamide and 1 ml of diamine are added and the mixture is thoroughly shaken. After waiting for 20 minutes, the absorbance is measured using a spectrophotometer at a wavelength of 540 nm.

$$Concentration\ of\ Nitrite\ \left(\frac{\mu\ mol}{L}\right) = Average\ factor \times Optical\ density$$

Fluoride

Fluoride is a mineral that naturally exists in different concentrations in water sources all over the world. The levels of fluoride in potable water can fluctuate based on aspects like geological conditions.

The fluoride concentration in water is determined using a spectrophotometer at a wavelength of 622 nm.

In 50 ml graduated tubes, take 0 (Blank), 0.5, 1, 1.5, 2, 2.5, and 3 ml of the sodium fluoride working solution. Dilute these to 15 ml with distilled water, then add 8 ml of lanthanum alizarin complex and 0.4 ml of acetic acid.

Further, dilute this mixture to 25 ml with distilled water. The pH should be maintained between 4.5 and 0.02.

For the water sample, take 15 ml into a graduated tube, add 8 ml of lanthanum alizarin complex and 0.4 ml of acetic acid, and dilute this to 25 ml with distilled water.

A calibration curve is then constructed by plotting the optical density against the concentration. (APHA, 2012)

$$Concentration\ of\ flouride\ \left(\frac{mg}{L}\right) = Average\ factor \times Optical\ density \times 1.667$$

Alkalinity

Alkalinity in water is its ability to counteract acids. It represents the water's buffering capacity, which helps maintain pH stability. The primary contributors to alkalinity are carbonate (CO_3^{2-}) and bicarbonate (HCO_3^-) ions, though hydroxide (OH^-) ions can also influence the alkalinity.

The alkalinity of water can be assessed by titrating the water sample with Sulphuric acid of known values of pH, volume, and concentrations

Based on the stoichiometry of the reaction and the number of moles of Sulphuric acid needed to reach the endpoint, the concentration of alkalinity in water is calculated. Take a 100 ml water sample, add TWO drops of phenolphthalein indicator, and titrate it with 0.02 N Sulphuric acid until it turns colourless. Then, add a few drops of methyl orange indicator and continue titration with 0.02 N Sulphuric acid until the colour shifts from yellow to orange. Record the readings. (APHA, 2012)

$$Alkalinity\ \left(\frac{mg}{L}\ as\ CaCO_3\right) = \frac{Volume\ of\ H_2SO_4 \times Normality\ of\ H_2SO_4 \times 50 \times 1000}{Volume\ of\ water\ sample}$$

Acidity

Acidity in water can originate from natural processes such as the decomposition of organic matter and geological influences, as well as human activities like industrial emissions, farming, and mining. To determine the acidity of the water, both methyl orange acidity (pH 3.7) and phenolphthalein acidity (pH 8.3) are used.

Thus, in determining the acidity of the sample the volumes of standard alkali required to bring about colour change at pH 8.3 and pH 3.7 are determined. A 50 mL sample is pipetted into a flask, and 2 to 3 drops of methyl orange indicator are added. These contents are then titrated against 0.02 N NaOH.

The endpoint is marked when the colour changes from orange red to yellow, indicating the Methyl orange acidity (V1).

Next, two drops of phenolphthalein indicator are added, and the titration is continued until a pink color just appears. The volumes of the titrant used are recorded, providing the total acidity (V2). The Phenolphthalein acidity is calculated by subtracting the Methyl orange acidity from the total acidity (V3 = V2 – V1). (APHA, 2012)

$$Methyl\ Orange\ acidity\left(\frac{mg}{L}as\ CaCO_3\right) = \frac{V_1 \times Normality\ of\ NaOH \times 50 \times 1000}{Volume\ of\ water\ sample}$$

$$Total\ acidity\left(\frac{mg}{L}as\ CaCO_3\right) = \frac{V_2 \times Normality\ of\ NaOH \times 50 \times 1000}{Volume\ of\ water\ sample}$$

$$Phenolphathalein\ acidity\ (\frac{mg}{L}as\ CaCO) = Total\ acidity - Methyl\ orange\ acidity$$

Dissolved Oxygen

First, the dissolve oxygen was fixed on the site by adding Winkler's A and B solutions, a precipitate was formed. Then the samples were brought to the laboratory. 1 ml of concentrated H_2SO_4 was added in each sample and the precipitate was allowed to dissolve. After 30 minutes, 50 ml of sample was pipetted out in a conical flask and was titrated against standard 0.01 N Sodium thiosulfate solution ($Na_2S_2O_3$) using starch as an indicator. The colour change was from blue to colourless. After the burette readings were obtained, the amount of dissolve oxygen present in the sample were calculated using the following formula. (APHA, 2012)

$$Dissolved\ oxygen\ \left(\frac{mg}{L}\right) = \frac{Burette\ reading \times concentration\ of\ Na_2S_2O_3 \times 1000 \times 8}{49.2}$$

Where 8 is to converts m.eq/l to mg/l

3.3.2 BIOLOGICAL PARAMETERS

Phytoplankton sampling

The Hydro-Bios phytoplankton net was attached to the one side of the boat. The boat was then towed to two distinct locations one where sand mining occurs and another where it does not. After a certain distance, the phytoplankton net was removed from the water, and the net content was poured into HDPE bottles. To preserve the samples, they were treated with a solution containing 3% buffered formaldehyde and 1% Lugol's iodine.

Upon collection, the samples were brought to the laboratory and stored in a dark room with room temperature until enumeration. Before analysis, the undisturbed samples were concentrated to ±10 mL by siphoning the excess water with a tygon tube covered with a 10 μm Nytex filter on one end. Samples were lightly agitated before three 1 mL replicates were individually transferred into a Sedgewick-Rafter counting cell chamber (Structure Probe, Inc., West Chester, PA, USA). Species identification and enumeration of the plankton were conducted using a Nikon Eclipse Ti with a camera and Olympus IX51 at 200x magnification.

Zooplankton sampling

Zooplankton samples were collected by horizontal towing of a Heron-Tranter net. The zooplankton net was attached to the one side of the boat and was dragged at both the sites. The net content was poured into plankton bottles upon recovery of the samples; the samples were immediately preserved in 70% ethanol for further laboratory analysis. The volume of water filtered by the net was measured with a calibrated flow meter (Hydro-Bios; General Oceanics, USA) mounted at the mouth of the net. A Folsom splitter was used for subsampling. Samples were lightly agitated before three 1 mL replicates were individually transferred into a small petriplate and viewed under a zoom microscope (Olympus SZX l6. Model LG-PS2-5).

CHAPTER 4: ANALYSIS AND CONCLUSION

4.1: PHYSICAL AND CHEMICAL PARAMETER

The study aimed to investigate the changes in physical, chemical, and biological factors at sites along the Zuari River where sand mining takes place. A reference site was also selected in the same river, but away from anthropogenic activities. Four locations were chosen from each site, and in October and January, the physical, chemical, and biological factors were analysed. The data collected from both sites, for all four stations, highlights the variation of physical, chemical, and biological factors. The obtained data was also compared to the Bureau of Indian Standards (BIS), 2012 standards to evaluate the quality of the data.

Assessment of the impact of sand mining on physico-chemical parameters and the distribution of plankton is essential for ascertaining the status of the aquatic ecosystem. Sand mining causes changes in variables of physico-chemical parameters which have marked effects on primary producers in the aquatic ecosystem. It also affects the distribution of the phytoplankton community (Sharma et. al., 2007)

Temperature

Optimum temperature is essential factor which controls metabolic activities in living system Kumar *et al*., (2020). More over water temperatures is related with season, geographic location, diurnal rotation of earth and sampling time. Although temperature fluctuations in the waters are not as high as in the air, temperature affects the life of aquatic organisms. Most aquatic organisms have little tolerance for temperature changes. The water temperature was moderate. In the month of October, the temperature at all the sand mining sites was 25°C and at the reference sites was 24.5°C whereas in the month of January the temperature at the sand mining sites and reference sites was 26°C. (Table 4.1 & Fig. 4.1 (a & b)) According to Anyanwu *et al*., 2021 findings the water temperatures were moderate. The ambient surface water temperatures were influenced by seasons and sampling periods.

Table 4.1: Temperature (°C) at the sand mining site and reference site in the month of October and January

Sampling Months	Sand Mining Site				Reference Site			
October	25	25	25	25	24.5	24.5	24.5	24.5
January	26	26	26	26	26	26	26	26

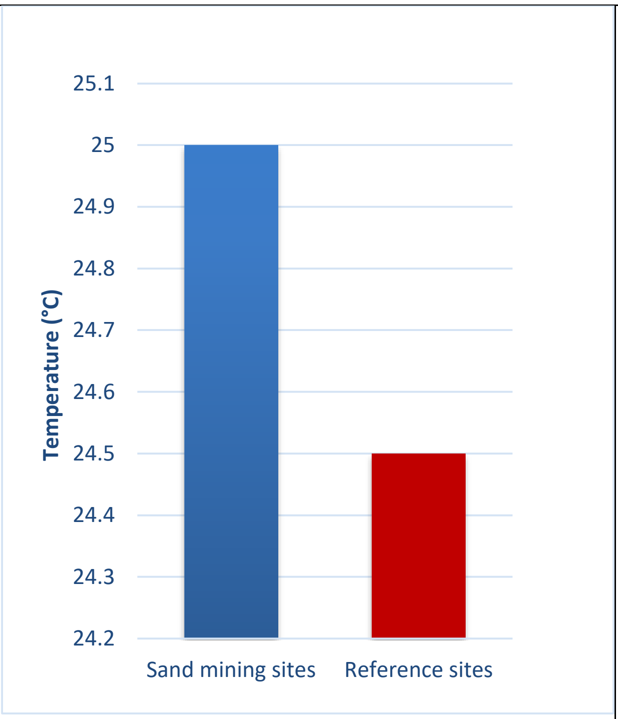

Figure 4.1 (a): Temperature (°C) at the sand mining site and reference site for the month of October

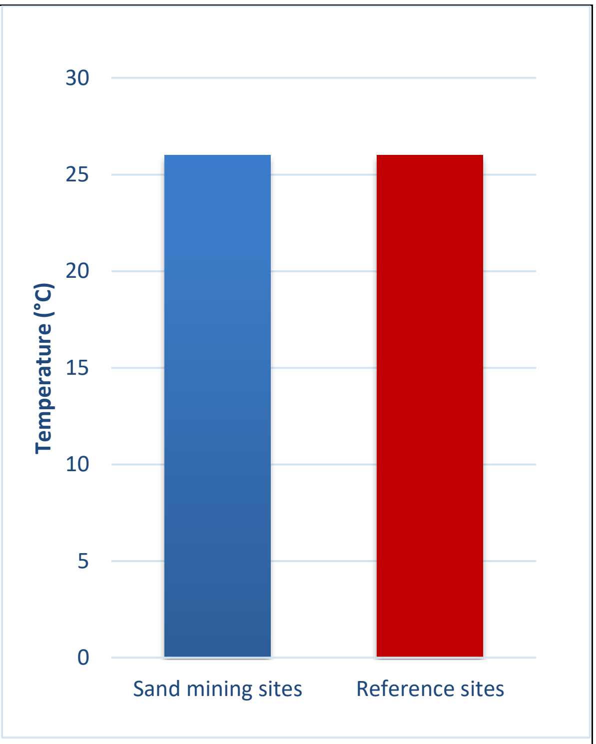

Figure 4.1 (b): Temperature (°C) at the sand mining site and reference site for the month of October

Air temperatures are the major determinant of surface water temperatures (Park *et al*., 2016), and water temperature is a critical factor in some biotic and abiotic processes in the aquatic environment (Dugdale *et al*., 2018)

pH

The pH values measured at both sites in October ranged from 6.62 to 7.06, whereas during January the values ranged from 6.83 to 7.06, (Table 4.2 & Fig. 4.2 (a & b))**.** The pH levels remained within the permissible limits at both sites. The pH of water is significant as it impacts the chemical properties of water and its interactions with other substances. High pH levels can result in the formation of mineral deposits, while low pH levels can dissolve metals and other minerals. Even slight variations in pH can affect biological activities and the health of aquatic and human life (Ahmed *et al*., 2011). The Bureau of Indian Standards (BIS) recommends a pH range of 6.5 to 8.5 for drinking water, as it is optimal for human consumption and ensures that the water is free from harmful contaminants. Drinking water with a pH outside this range can affect its taste, quality, and safety. The sand mining doesn’t have any impact on the pH but according to Seiyaboh *et al*., (2013), sand mining contributes to low pH in water bodies. However, Kumar *et al.*, (2020) suggest that water is alkaline in such cases. Similar findings were reported by Ishaq and Khan (2013).

Total Dissolved Solids

Total Dissolved Solids, it is the total amount of inorganic and organic substances dissolved in water, including minerals, salts, metals, ions, and other particles. Total Dissolved Solids is measured in milligrams per liter (mg/L) or parts per million (ppm). Higher Total Dissolved Solids levels suggest a greater concentration of dissolved solids in the water, while lower levels suggest fewer dissolved solids.

Table 4.2: pH at the sand mining site and reference site in the month of October and January

Sampling Months	Sand Mining Site				Reference Site			
October	6.62	6.65	7.06	6.91	6.67	7	6.94	7.03
January	6.91	6.85	6.87	6.83	7.02	6.85	6.95	7.06

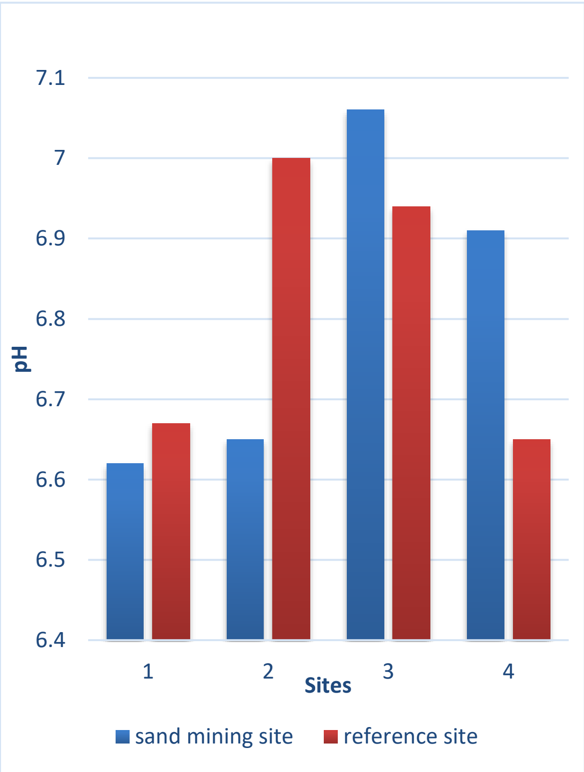

Figure 4.2 (a): pH at the sand mining site and reference site for the month of October

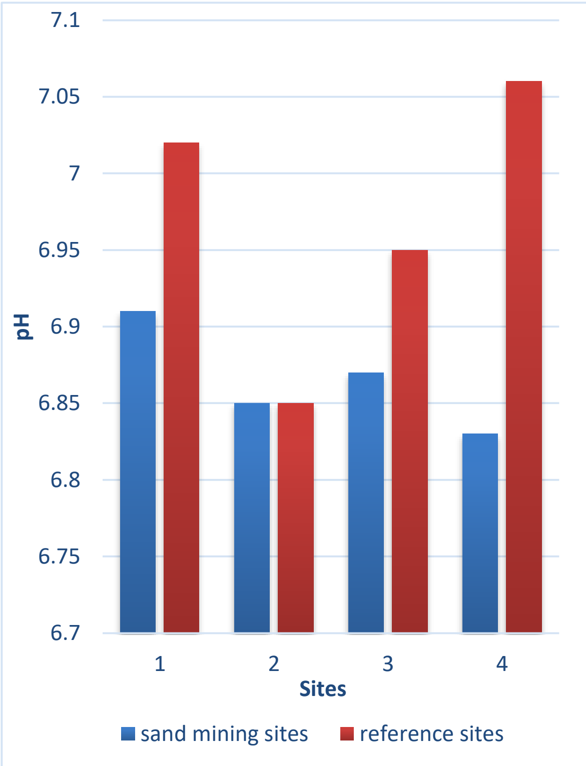

Figure 4.2 (b): pH at the sand mining site and reference site for the month of January

Total Dissolved Solids is an important factor in assessing water quality as it can affect the taste, odor, and overall suitability of water for various purposes. High Total Dissolved Solids levels may result in a salty or brackish taste, while excessively low levels can indicate a lack of essential minerals (Maliki et al., 2020) The Bureau of Indian Standards (BIS)has set the acceptable limit for Total Dissolved Solids in drinking water at 500 mg/L.

Based on the data presented in Table 4.3 and Fig 4.3 (a & b), it is evident that the Total Dissolved Solids (TDS) level in both months and at both sites has exceeded the permissible limit. The sand mining sites have higher levels of TDS as compared to the reference sites. One of the possible reasons for the increased TDS levels at sand mining sites could be the mining activities, which disturb the sediments containing minerals and salts, contributing to the increased TDS levels. The findings are similar to Tan and Rohasliney (2013) study, which also reported high TDS levels due to sand mining.

Turbidity

Table 4.4 & Fig. 4.4 (a & b) shows that the turbidity levels at sand mining sites, during the sampling months of October and January, were higher than the acceptable and permissible limits in comparison to the reference sites. In October, the turbidity ranged from 9.8-14.48 NTU, and in January it ranged from 5.92-11.03 NTU at the sand mining sites. Sand mining leads to an increase in suspended solids in the water column and decreases the quality of water, which results in higher levels of turbidity. The high turbidity levels are mainly caused by dredging activity and shaking of sediments during the sand mining process and flooding spate of water (Pankaj Kumar, 2015). Another cause of variations in turbidity levels could be the suspension of fine particles. An increase in turbidity adversely affects primary productivity by decreasing photosynthetic activities and also has a negative effect on plankton at the sand mining sites.

Table 4.3: Total Dissolved Solids (mg/l) at the sand mining site and reference site in the month of October and January

Sampling Months	Sand mining Site				Reference Site			
October	3269.5	3133.0	3373.5	3614.0	3081.0	3068.0	3289.0	2951.0
January	10439	10172.5	9607	9041.5	11147.5	12044.5	11693.5	12792

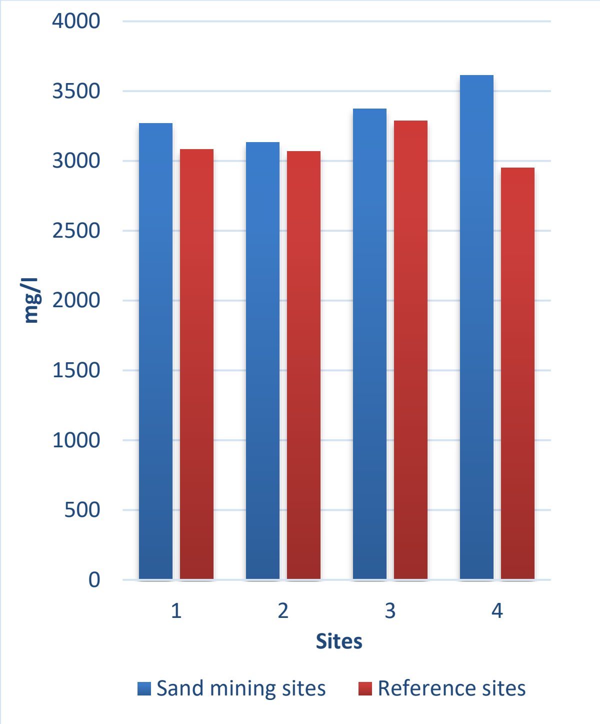

Figure 4.3 (a): Total Dissolved Solids (mg/l) at the sand mining site and reference site for the month of October

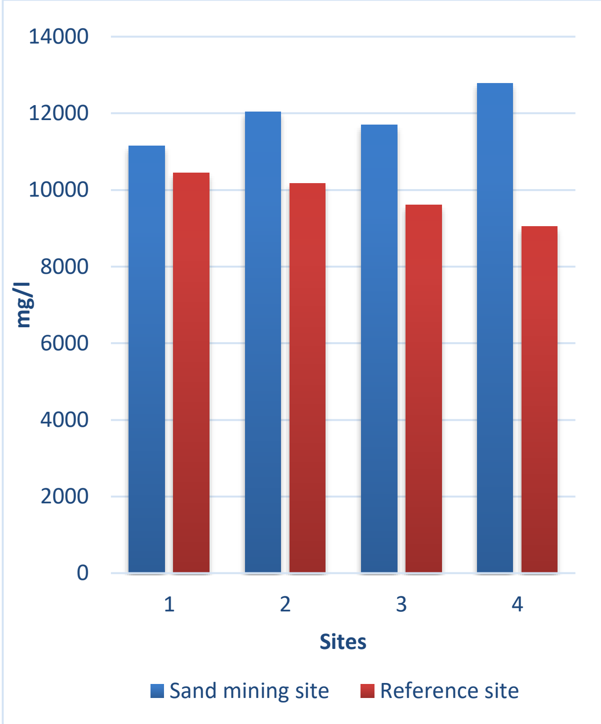

Figure 4.3 (b): Total Dissolved Solids (mg/l) at the sand mining site and reference site for the month of January

Table 4.4: Turbidity (NTU) at the sand mining site and reference site in the month of October and January

Sampling months	Sand mining Site				Reference Site			
October	9.8	14.48	10.78	12.54	4.5	4.42	5.36	3.33
January	5.92	8.12	11.03	4.35	3.5	4.75	2.64	3.32

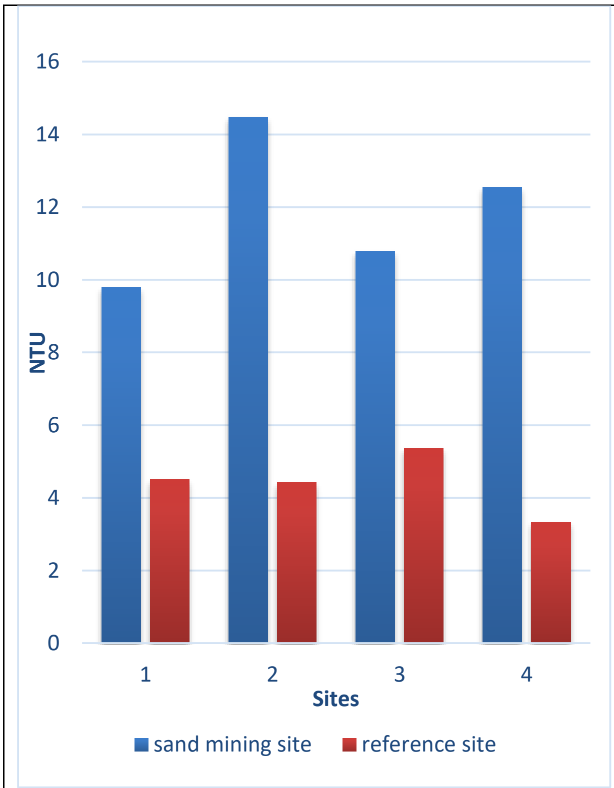

Figure 4.4 (a) : Turbidity (NTU) at the sand mining site and reference site for the month of October

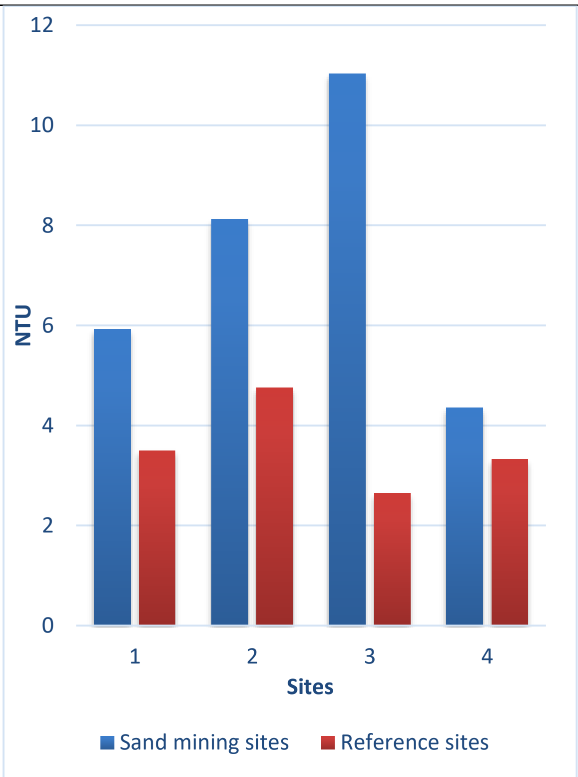

Figure 4.4 (b):Turbidity (NTU) at the sand mining site and reference site for the month of January

Researchers including Tan and Rohasliney, H. (2013), Kumar *et al*., (2020), Alam *et al*. (2022) have reported high levels of turbidity caused by sand mining sites.

Electrical Conductivity

Water that is pure and has no dissolved ions has very low electrical conductivity. However, as the concentration of dissolved ions increases, so does the water's conductivity. Higher conductivity values indicate a greater concentration of dissolved ions in the water, which means that there are more impurities present in the water such as dissolved substances, chemicals, and minerals. From Table 4.5 & Fig. 4.5 (a & b) In October, the conductivity levels at the sand mining site ranged from 4.82-5.56 mS/cm. On the other hand, at the reference site, it ranged from 4.54-5.05 mS/cm. In January, there was a sudden increase in electrical conductivity levels at the sand mining site with values ranging from 13.91-16.06 mS/cm. At the reference site, the values ranged from 12.0445mS/cm -11.1475 mS/cm. The BIS (2012) guideline value for electrical conductivity in drinking water is typically within the range of 100 to 1500 µS/cm. However, specific values may vary depending on factors such as geographical location and source water characteristics. The electrical conductivity at the sand mining activities is relatively high. The sand may contain minerals and during the mining process, these minerals may be brought to the surface and mix with the extracted sand, increasing its conductivity. Sand mining activities increase the levels of electrical conductivity in surface water (Rehman *et al*., 2016) and usually contribute to an increase in water pollution.

Phosphate

Phosphate can enter water sources through natural and human activities, such as agricultural runoff, wastewater discharge, and erosion (Farmer, A. M. 2018). The levels of phosphate in the water were found to be within the permissible limit.

Table 4.5: Electrical Conductivity (mS/cm) at the sand mining site and reference site in the month of October and January

Sampling Months	Sand Mining Site				Reference Site			
October	5.03	4.82	5.19	5.56	4.74	4.72	5.06	4.54
January	16.06	15.65	14.78	13.91	17.15	18.53	17.99	19.68

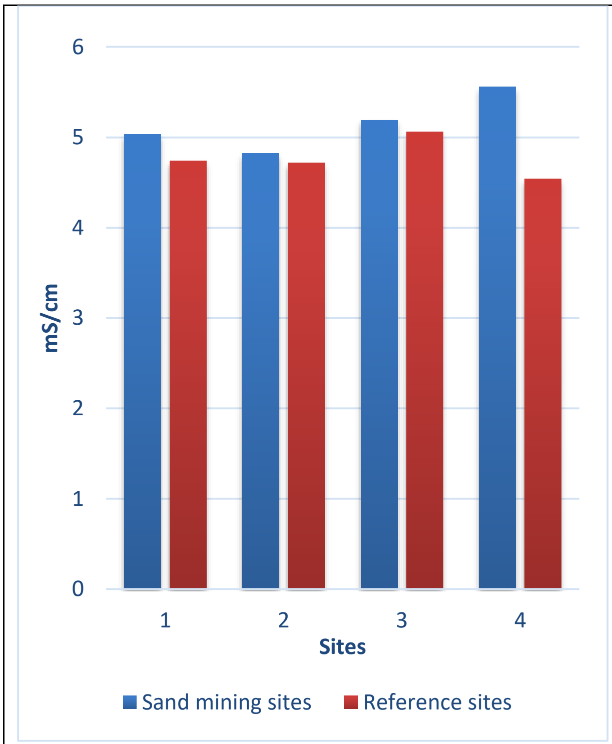

Figure 4.5 (a): Electrical Conductivity (mS/cm) at the sand mining site and reference site for the month of October

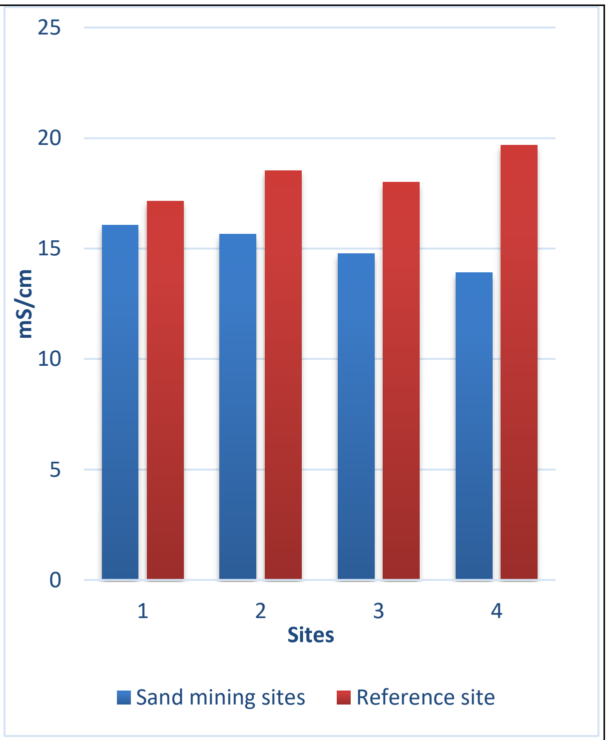

Figure 4.5 (b): Electrical Conductivity (mS/cm) at the sand mining site and reference site for the month of January

As per the Bureau of Indian Standards (BIS) guidelines of 2012, the permissible limit of phosphate in drinking water is 1 mg/L. The highest level of phosphate was reported in sand mining sites in October, which was 0.0203 mg/l, and the lowest level was found to be 0.0063 mg/l in January (Table 4.6 & Fig. 4.6 (a & b)). The levels of phosphate measured at the sand mining sites were high, but they were well below the permissible limits, as indicated in the findings of Kumar *et al*., (2020).

Nitrate

Nitrate can enter water sources through various means, including agricultural runoff, wastewater discharge, industrial processes, and atmospheric deposition, both naturally and from human activities. The primary sources of nitrate contamination in water bodies are agricultural fertilizers and animal waste. The nitrate levels observed at both the sites and for both the months were within the acceptable limit (50mg/l) and at very low levels (Table 4.7 & Fig. 4.7 (a & b)). However, these results contrast with those found in Kumar et al.'s (2020) study, which detected higher nitrate concentrations due to runoff water from nearby agricultural fields. Tan *et al*., 2013 also observed high nitrate levels at sand mining sites, which were likely due to anthropogenic sources, such as domestic sewage, agricultural runoff, and other waste effluents that contain nitrogenous compounds (Prasanna & Ranjan, 2010).

Nitrite

Nitrite levels in water sources can be influenced by various factors, such as agricultural runoff, wastewater discharges, and industrial activities. During the month of October, the levels of nitrogen nitrite in both sites were within the permissible limit of 0.1 mg/L.

Table 4.6: Phosphate levels (mg/l) at the sand mining site and reference site in the month of October and January

Sampling Months	Sand Mining Site				Reference Site			
October	0.0169	0.0203	0.0221	0.0207	0.0151	0.0179	0.0160	0.0169
January	0.0093	0.0097	0.0097	0.0097	0.0106	0.0085	0.0063	0.0093

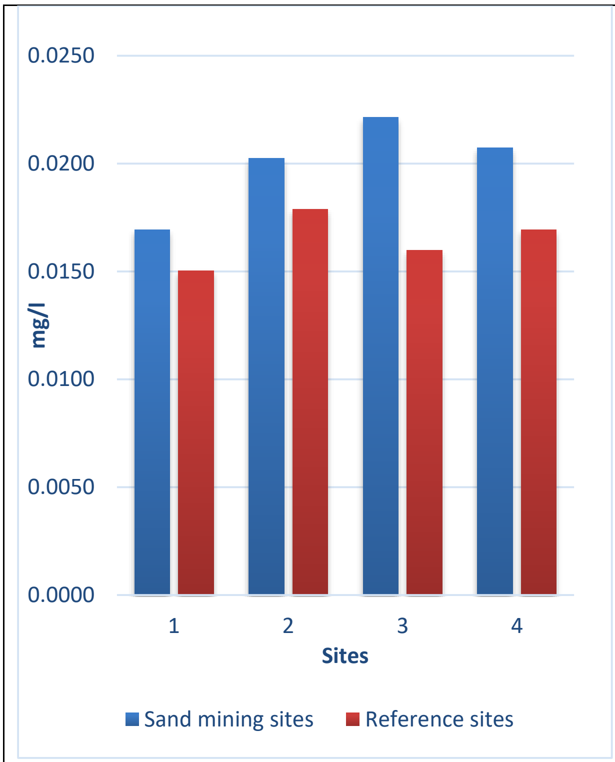

Figure 4.6 (a) :Phosphate levels (mg/l) at the sand mining site and reference site for the month of October

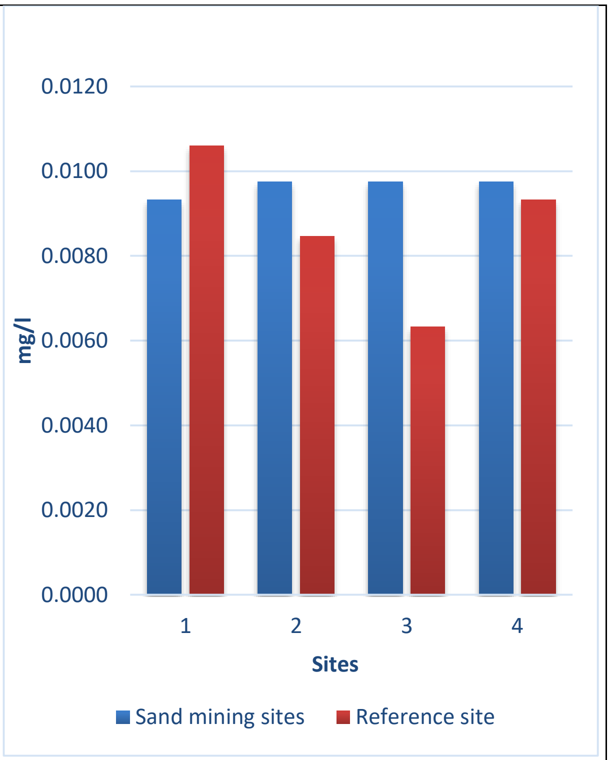

Figure 4.6 (b) :Phosphate levels (mg/l) at the sand mining site and reference site for the month of January

Table 4.7: Nitrate levels (mg/l) at the sand mining site and reference site in the month of October and January

Sampling Months	Sand Mining Site				Reference Site			
October	0.628	0.713	0.644	0.674	0.805	0.813	0.828	0.798
January	1.073	1.088	1.113	1.058	1.118	1.053	1.058	1.088

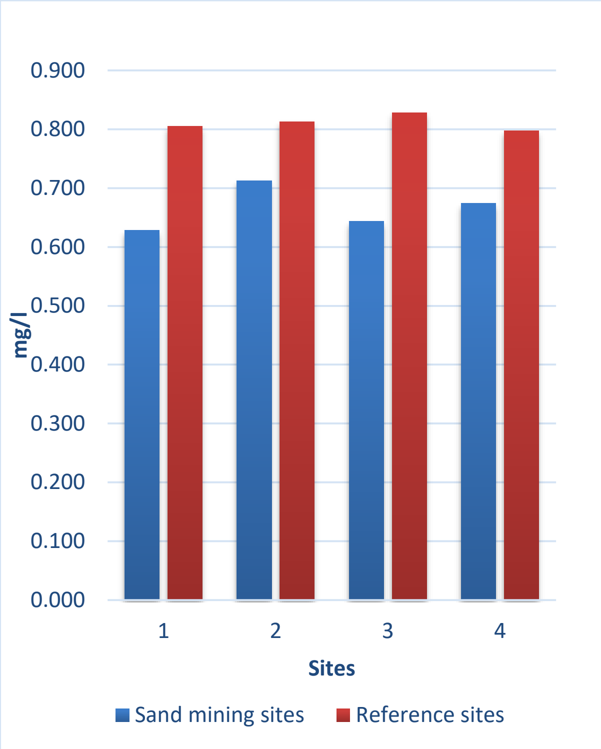

Figure 4.7 (a): Nitrate levels at the sand mining site and reference site for the month of October

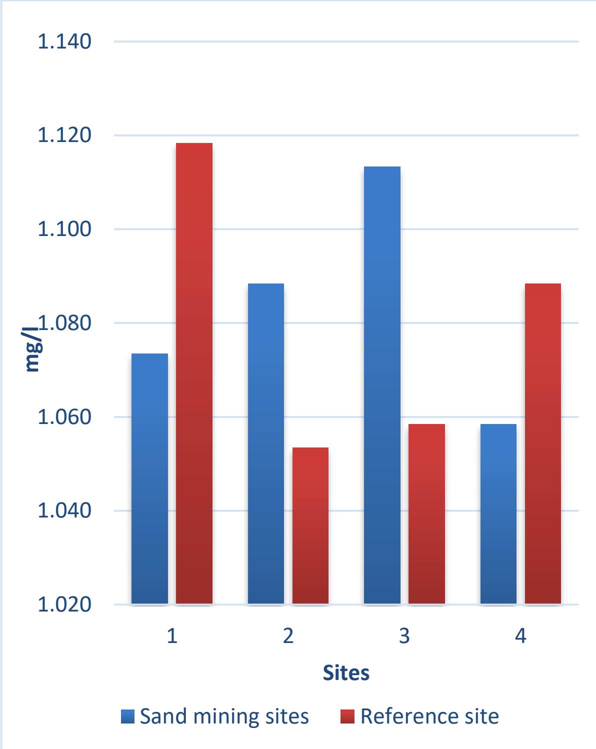

Figure 4.7 (b): Nitrates levels at the sand mining site and reference site for the month of January

However, in January, the nitrite levels at all four stations of the sand mining site exceeded the permissible limit as seen in as seen in Table 4.8 & Fig. 4.8 (a & b). High nitrite levels in a river affected by sand mining during the second sampling could be attributed to various factors, Sand mining operations can lead to increased erosion and sediment runoff into rivers. This runoff can carry excess nutrients, including nitrogen compounds such as nitrites, from surrounding land areas into the water, elevating nitrite levels. Sand mining may disturb the riverbed and surrounding habitats, leading to increased decomposition of organic matter. Microbial decomposition processes can release nitrites as intermediate products, contributing to higher nitrite concentrations in the water. Tan and Rohasliney (2013) found high levels of nitrite at sand mining sites in their research paper.

Fluoride

Fluoride is a mineral that occurs naturally in water sources at varying concentrations. The levels of fluoride in drinking water can be influenced by geological conditions and water treatment practices (Edmunds *et al*., 2013). According to Table 4.9 and Fig. 4.9 (a & b), the fluoride content at both sites was below the acceptable limit of 1mg/l as per BIS (2012) during both months. However, the fluoride content at the sand mining sites was found to be higher than the reference site.

Alkalinity

Alkalinity in water refers to its ability to neutralize acids, which indicates the water's resistance to changes in pH. The primary sources of alkalinity in water are carbonate (CO_3^{2-}) and bicarbonate (HCO_3^-) ions, although hydroxide (OH^-) ions can also contribute (Boyd *et al.,* 2015). Organic matter produced by decay and decomposition of vegetation can lead to an increase in carbonate and bicarbonate concentrations in river water, which in turn contributes to the alkalinity level.

Table 4.8: Nitrite levels (mg/l) at the sand mining site and reference site in the month of October and January

Sampling Months	Sand Mining Site				Reference Site			
October	0.0162	0.0191	0.0168	0.0179	0.0150	0.0185	0.0174	0.0168
January	0.1670	0.138	0.147	0.124	0.070	0.005	0.009	0.004

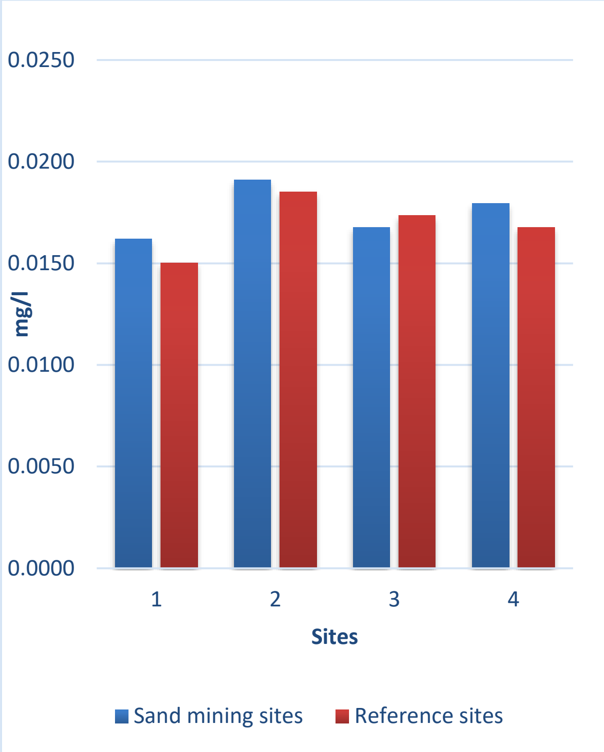

Figure 4.8 (a): Nitrite levels (mg/l) at the sand mining site and reference site for the month of October

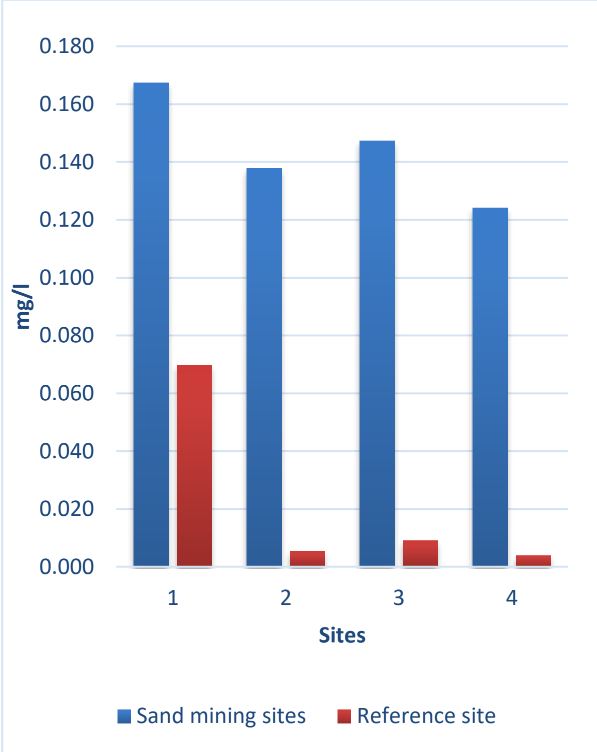

Figure 4.8 (b): Nitrite levels (mg/l) at the sand mining site and reference site for the month of January

Table 4.9: Fluoride levels (mg/l) at the sand mining site and reference site in the month of October and January

Sampling Months	Sand Mining Site				Reference Site			
October	0.08	0.09	0.07	0.06	0.04	0.02	0.03	0.04
January	0.683	0.695	0.594	0.686	0.568	0.673	0.562	0.416

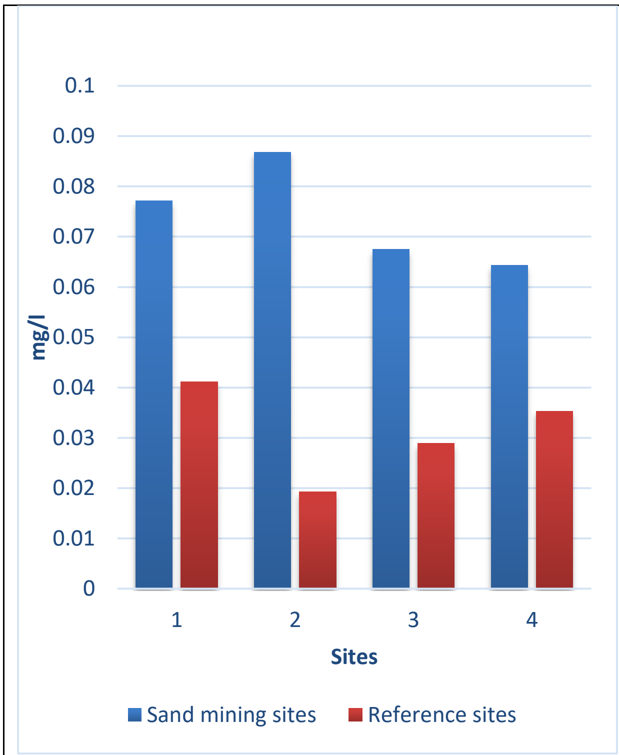

Figure 4.9 (a) :Fluoride levels (mg/l) at the sand mining site and reference site for the month of October

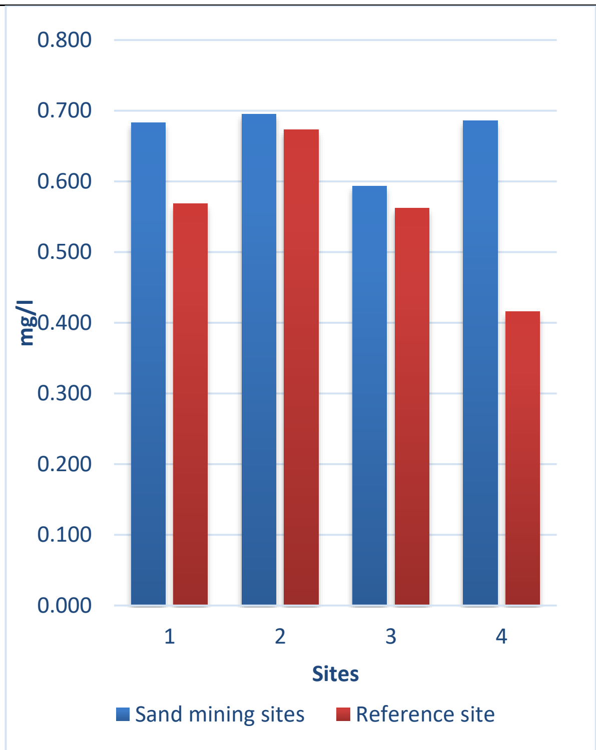

Figure 4.9 (b):Fluoride levels (mg/l) at the sand mining site and reference site for the month of January

The alkalinity level at the sand mining sites and reference site was found to be within the permissible limit (200 mg/l) as per Bureau of Indian Standards (2012) but it was higher at the sand mining site when compared to the alkalinity level at the reference sites (Table 4.10 & Fig. 4.10(a & b)).

Acidity

Acidity in water can arise from natural processes such as organic decay and geological factors, as well as human activities like, agriculture, and mining. The permissible limits for acidity in water are 200 mg/l (BIS)**.** In the sand mining areas, the total acidity levels ranged from 6mg/l to 12mg/l in October, while in the reference sites, the values ranged from 4mg/l to 10mg/l. In January, the total acidity levels were between 6mg/l to 10mg/l in the sand mining sites and 6mg/l to 8mg/l in the reference site (Table 4.11 & Fig. 4.11 (a & b)).

Dissolved oxygen

Dissolved oxygen (DO) refers to the amount of oxygen present in water. Water bodies receive oxygen from the atmosphere and aquatic plants. All aquatic animals require DO to breathe. Dissolved oxygen is an important measure of water quality as it indicates an aquatic resource's ability to support aquatic life directly (Chang, 2002)

During the sampling conducted in October, the highest dissolved oxygen values were recorded in the reference site, with the values ranging from 10.41-11.06 mg/l. However, at the sand mining sites, the values of dissolved oxygen ranged from 6.67-7.32 mg/l. Similarly, during the sampling done in January, there was an increase in values of dissolved oxygen in the reference sites and a decrease in values in the sand mining sites.

Table 4.10: Alkalinity levels (mg/l) at the sand mining site and reference site in the month of October and January

Sampling Months	Sand Mining Site				Reference Site			
October	19	18	21	23	19	18	15	19
January	32	32	31	31	31	28	22	29

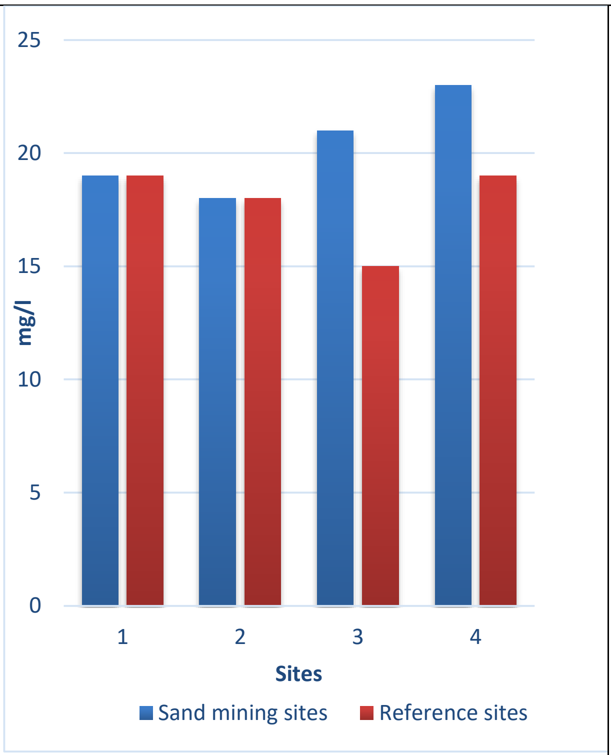

Figure 4.10 (a):Alkalinity levels (mg/l) at the sand mining site and reference site for the month of October

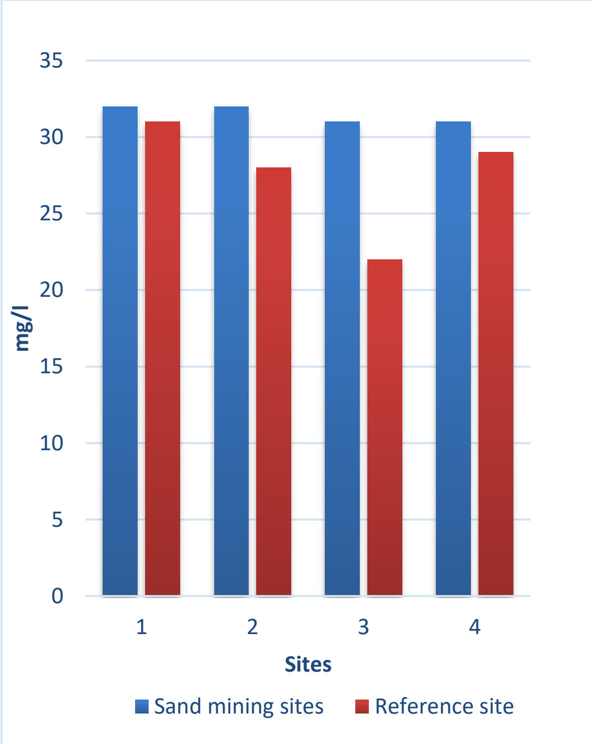

Figure 4.10 (b):Alkalinity levels (mg/l) at the sand mining site and reference site for the month of January

Table 4.11: Acidity levels (mg/l) at the sand mining site and reference site in the month of October and January

Sampling Months	Sand Mining Site				Reference Site			
October	6	8	12	12	6	8	4	10
January	6	10	10	6	8	8	8	6

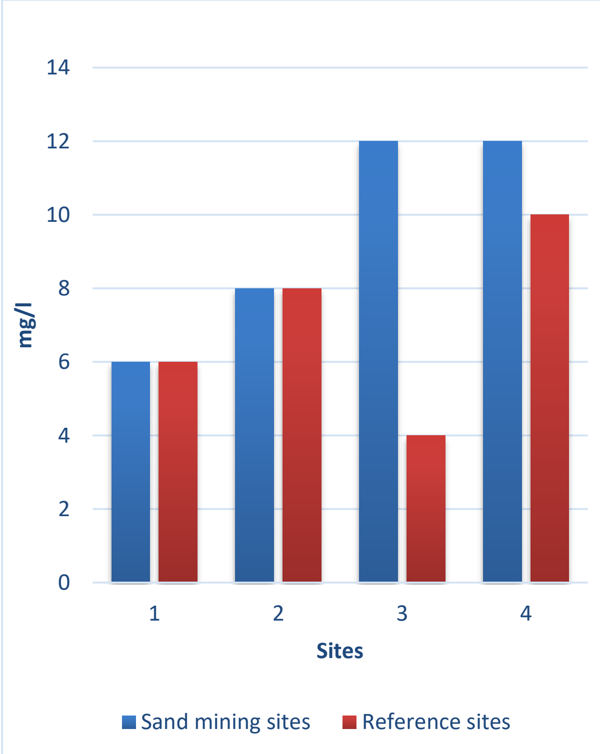

Figure 4.11 (a): Acidity levels (mg/l) levels at the sand mining site and reference site for the month of October

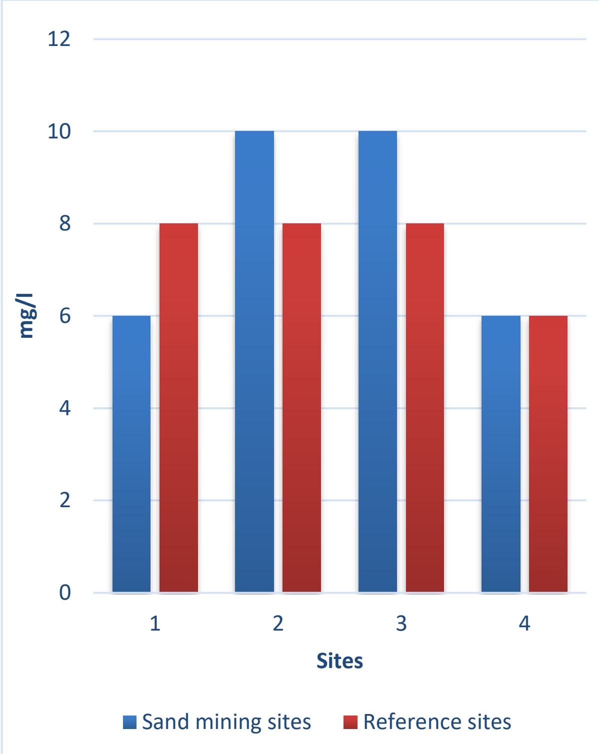

Figure 4.11 (b): Acidity levels (mg/l) at the sand mining site and reference site for the month of January

The values in the reference sites ranged from 8.46-10.41 mg/l, while at the sand mining sites, the dissolved oxygen values ranged from 5.69-6.50 mg/l. (Table 4.12 & Fig. 4.12(a & b)), the dissolved oxygen at the reference site was more compared to the sand mining sites.

The lower dissolved oxygen levels at the sand mining site could be attributed to several factors. One significant factor is the disturbance caused by sand mining activities, which can disrupt the natural balance of the ecosystem. Excavation and dredging can stir up sediments, increasing turbidity and decreasing oxygen levels. Similar findings were also found by Kumar *et al*., (2020) Higher dissolved oxygen value indicates less organic matter to be degraded by biological activities and more photosynthetic activities in aquatic environments Kumar *et al*., (2020). High dissolved oxygen value at sand mining sites was also recorded by researcher Pejman *et al*., 2009. Variations in the amount of dissolved oxygen are also related to seasonal variations in temperature (Singh *et al*., 1999).

Table 4.12: Dissolved Oxygen levels (mg/l) at the sand mining site and reference site in the month of October and January

Sampling Months	Sand Mining Site				Reference Site			
October	6.67	7.32	6.99	6.99	10.57	10.73	10.41	11.06
January	6.18	6.18	5.69	6.50	10.41	9.76	8.46	8.94

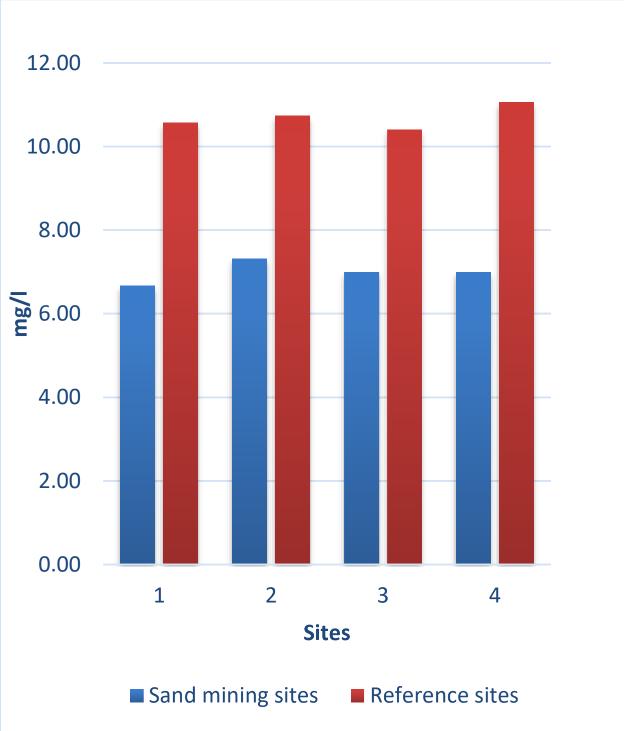

Figure 4.12 (a): Dissolved Oxygen levels (mg/l) at the sand mining site and reference site for the month of October

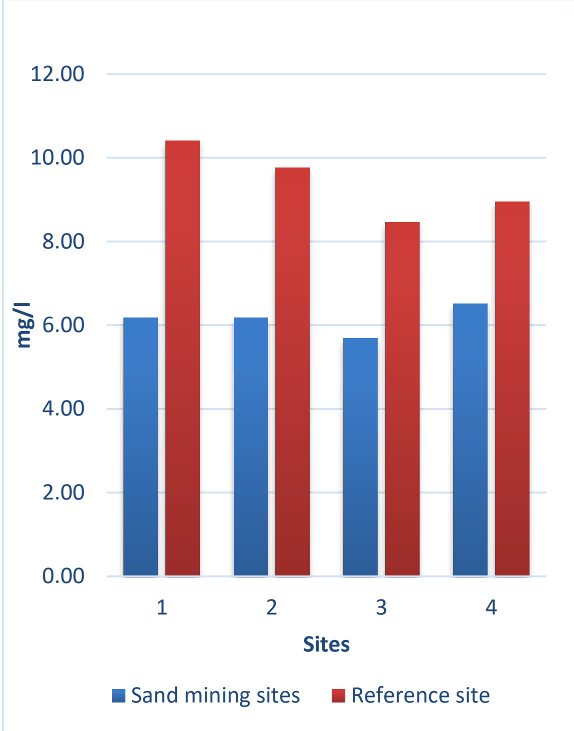

Figure 4.12 (b): Dissolved Oxygen levels (mg/l) at the sand mining site and reference site for the month of January

4.3: PLANKTON ABUNDANCE AND ANALYSIS

Planktonic organisms such as phytoplankton and zooplankton drift in the water at the mercy of water current are an essential food resource of aquatic ecosystems. They are influenced by various physico-chemical variables reflecting the environmental status. Thus, plankton serves as an integrator of hydroclimatic forcing and provides information on an aquatic ecosystems state.

Phytoplankton is a microorganism that has an important role in the aquatic ecosystem, as a primary producer in the food chain and to provide a food source for the higher organisms such as zooplankton and fish. The existence of phytoplankton in the river is influenced by physical and chemical factors (Sulawesty *et al*., 2020). Phytoplankton has a short life cycle resulting in fast response to environmental changes; therefore, species abundance and composition indirectly indicate the water quality. Sharma *et al* concluded that the distribution of phytoplankton in the freshwater ecosystem is influenced by physicochemical parameters, which are the major factors to control the dynamics and structure of phytoplankton (Hulyal & Kaliwal, Sharma *et al*). Changes in the aquatic environment may influence the abundance of phytoplankton that one species can be more dominant than the others at short time intervals throughout the year. Current velocity, erosion, and sedimentation are common phenomena in the river ecosystem affecting the life of aquatic organisms, including phytoplankton. Kumar *et al*., (2020)

From Table 4.13 & Fig. 4.13 (a & b) In October, the sand mining site had a phytoplankton count of 118 while the reference site had 145. In January, the reference site had a higher count of phytoplankton at 179, while the sand mining site had only 143.

Table 4.13: Phytoplankton abundance at the sand mining site and reference site in the month of October and January

Sampling Months	Sand Mining Site	Reference Site
October	118	145
January	143	179

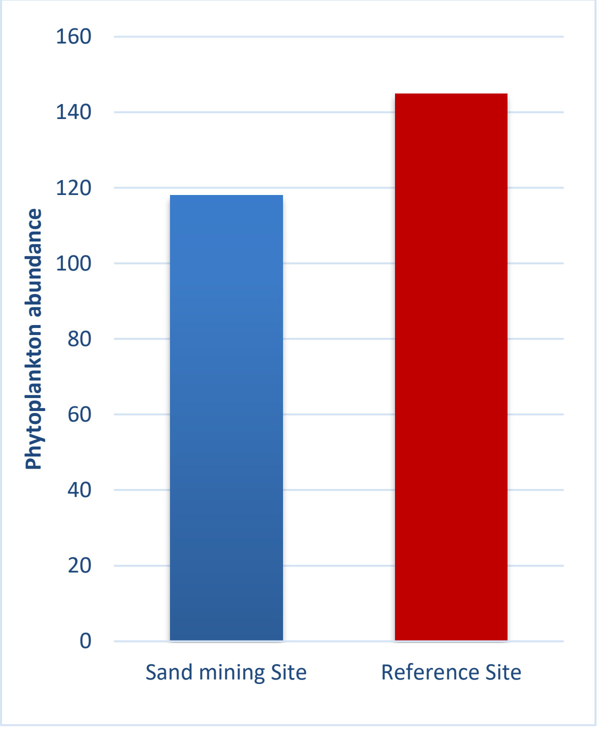

Figure 4.13 (a): Phytoplankton abundance at the sand mining site and reference site in the month of October

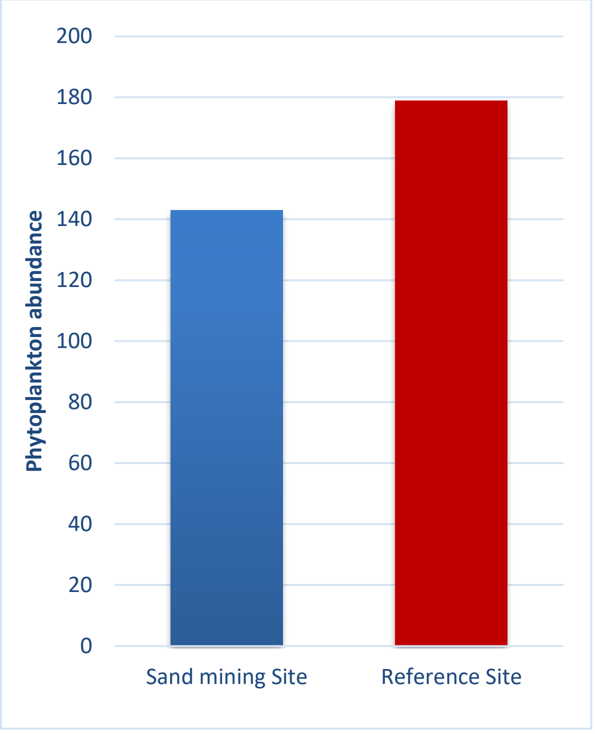

Figure 4.13 (b): Phytoplankton abundance at the sand mining site and reference site in the month of January

Phytoplankton also depleted in the course of extraction of sand from water. Comparing the abundance of phytoplankton between the sand mining site and reference site, the reference site had more phytoplankton as reference sites were undisturbed areas. The possible reason for the lower phytoplankton count in October at the reference site is due to high levels of turbidity caused by dredging activities at sand mining sites. Table 4.4 and Figures 4.4(a & b) indicates that during October, the turbidity levels were high in most of the reference site locations compared to January. Therefore, it is possible that the high turbidity levels in October resulted in a lower phytoplankton count at the reference site.

Sand mining is the main cause of high turbidity water in the river. High turbidity in the river is caused by the high content of fine sediment and organic particles. This can indirectly affect the aquatic ecosystem. When the turbidity content exceeds the natural variation of turbidity and sedimentation in the area, it begins to block the light, decreasing the water transparency. The reduction of light penetration then affects the primary production of the ecosystem. The changes in production will then affect the food chain and the composition of phytoplankton (Supriharyono 2004) as they are autotrophic. Similar result was also found by Kumar *et al.*, (2020)

The quality of the aquatic ecosystem and the ecological effects of pollution can be predicted by assessing zooplankton communities (Dorak, 2013; Rasheed *et al.*, 2017; Santos, Ferreira, 2020). Zooplanktons are microscopic organisms that are essential components of aquatic food webs as primary consumers and they respond quickly to environmental change (Sharma, Sharma, 2020). Researchers have extensively used zooplankton in the assessment of aquatic ecosystems (Xiong *et al.*, 2016; Anyanwu, Mbekee, 2020; Malik *et al.*, 2020). Due to their short life span and fast regeneration, their composition, abundance and distribution fluctuate in response to temporal and spatial variations of physicochemical environmental conditions (Rajagopal *et al*., 2010; Anyanwu *et al*., 2013). The variation of zooplankton assemblages in freshwater ecosystems is influenced by space and time (Kar *et al*., 2018). A number of studies on water quality and zooplankton assessment have been carried in bigger waterbodies (Arazu, Ogbeibu, 2017)

According to Table 4.14 and Fig. 4.14 (a & b), the reference site had more zooplankton than the sand mining site. In October, the reference site had a total of 5 zooplanktons, while the sand mining site had only 3. In January, the reference site had 6 zooplanktons, and the sand mining site had only 5. The lower zooplankton count at the sand mining sites could be attributed to sand mining, which increases the levels of suspended solids in the water column, leading to higher turbidity levels. This can directly affect the aquatic system by decreasing water transparency.

Supriharyono (2004) revealed that the reduction of light penetration affects the primary production of the ecosystem and ultimately affect zooplankton because zooplankton nibble on phytoplankton. This may be one of the factors affecting zooplankton population (Castro and Huber 2005). Yen and Rohasliney (2013) said that an increase in suspended contents may affect the zooplankton by reducing the food particles that are captured and by clogging the feeding system. McCabe and O'Brien (1983) also found that suspended sediments may affect the abundance of zooplankton by decreasing their survival and fecundity. Several studies indicate that sand mining may affect zooplankton diversity.

High turbidity decreases the ability of water to transmit light. According to Owens *et al*. (2005), sand mining impacts the physical condition of the river, including the sediment-laden plumes which reduce the depth of light penetration in water. Krishnamoorthi *et al*. (2011) reported that primary productivity in the river may be reduced due to high turbidity.

Table 4.14: Zooplankton abundance at the sand mining site and reference site in the month of October and January

Sampling Months	Sand Mining Site	Reference Site
October	3	5
January	5	6

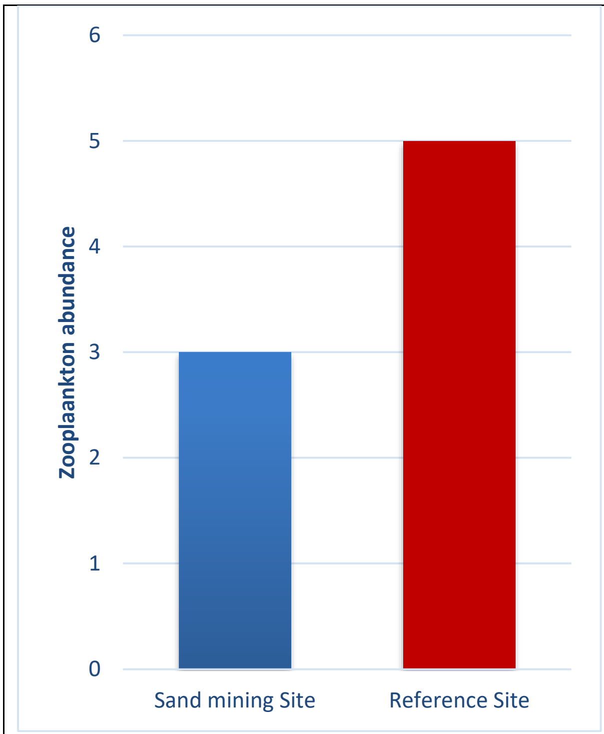	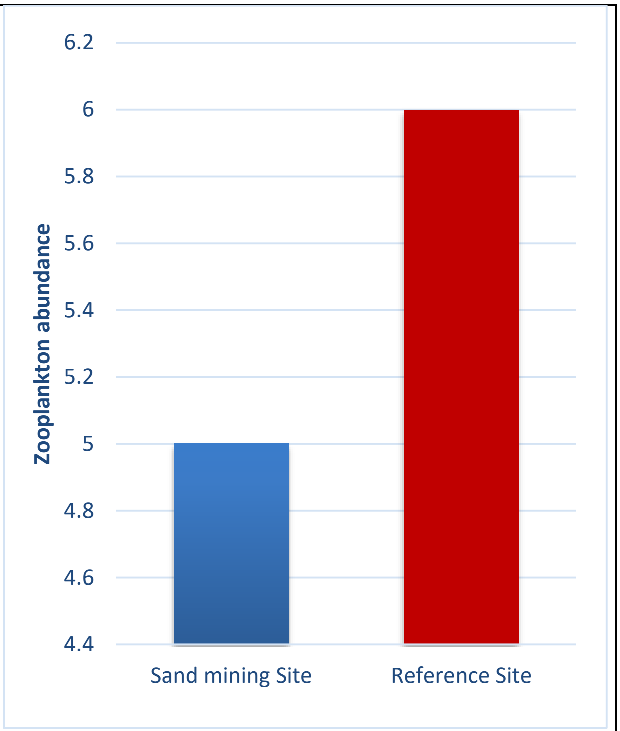
Figure 4.14 (a): Zooplankton abundance at the sand mining site and reference site at the month of October	Figure 4.14 (b): Zooplankton abundance at the sand mining site and reference site at the month of January

CHAPTER 5: SUMMARY

The study assessed the impact of sand mining activities on both physico-chemical parameters and plankton in a river ecosystem. While most physicochemical parameters remained within permissible limits according to BIS guidelines, elevated levels of phosphate, alkalinity, acidity, nitrite, and fluoride were observed at the sand mining site, possibly due to mining activities. Additionally, turbidity, Total Dissolved Solids, electrical conductivity, and nitrite levels exceeded permissible limits, and could be attributed to sand mining.

Phytoplankton and zooplankton, essential components of aquatic ecosystems, exhibited variations in abundance and distribution influenced by environmental factors such as turbidity and suspended solids. Phytoplankton, crucial as primary producers, showed lower abundance at the sand mining site compared to reference sites, potentially due to decreased light penetration caused by high turbidity. Zooplankton counts were also lower at the sand mining site, possibly due to less food availability.

The reduction of light penetration due to high turbidity negatively impacted primary production and subsequently zooplankton populations. Sand mining-induced turbidity not only affects light penetration but also affects the nutrient availability and uptake in aquatic ecosystem, with reduced primary productivity. These findings underscore the significant ecological consequences of sand mining on river ecosystems and emphasize the importance of monitoring and mitigating its impacts to maintain ecosystem health.

CHAPTER 5: REFERENCES

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