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Article

Assessing water quality in the Godavari River, Nashik: A study on specific gravity and surface tension variations

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Abstract: The Godavari River flows year-round, being a perennial watercourse, providing a steady water supply. However, rising pollution threatens its water quality. Without regular pollution control, it may face a decline similar to the River Nandini, which vanished in the 1940s along with its surrounding forest. Thus, this study investigated the specific gravity and surface tension of various water samples collected near the Victoria Bridge on the Godavari River to assess the impact of different contaminants. Samples analyzed include pure water, polluted water, saline water, water with detergent, slightly muddy water, and slightly ashy water, which might contain gold particles or gold dust in it. The findings reveal that saline water exhibited the highest specific gravity (1.025 g/cm^3), while pure water maintained a specific gravity of 1.000 g/cm^3. At point 1, the surface tension ranged from 31 to 42 mN/m. For point 2, it fell between 49 and 55 mN/m. Point 3 showed a range of 49 to 60 mN/m, while at point 4, it varied from 49 to 57 mN/m. Lastly, point 5 exhibited surface tension values between 49 and 56 mN/m at Victoria Bridge. Surface tension measurements ranged from 55 to 70 mN/m at all five points—point 1 through point 5 each displayed values within this consistent interval at Tapovan Bridge and a point near Dasak Bridge. Thus, surface tension measurements indicated that contaminants such as detergents and organic pollutants significantly reduce water's surface tension, affecting the transport and fate of pollutants. The average suspended particle mass (mg) was found to be about 13.4 (mg). These results emphasize the importance of continuous monitoring and remediation efforts to maintain water quality, especially under extreme climatic conditions.

Keywords: Godavari River; Nashik; specific gravity; surface tension; water contamination; water quality assessment

1. Introduction

The rapid growth in human population, coupled with accelerated industrialization and urbanization, has intensified various socioeconomic activities. This escalation places significant stress on natural resources, leading to both their quantitative depletion and qualitative degradation. For instance, the expansion of urban areas often results in deforestation and loss of biodiversity, as land is converted for residential and industrial use. Also, increased industrial activities contribute to air and water pollution, further deteriorating environmental quality. The strain on these resources emphasizes the need for sustainable development practices to mitigate environmental degradation and ensure the availability of essential natural assets for future generations [1].

In mid-June 2024, climate change intensified extreme heatwaves, affecting approximately 5 billion people globally. India experienced the most significant impact, with around 619 million individuals enduring severe heat conditions. Temperatures in some regions neared 50 °C, leading to over 40,000 heatstroke cases and more than 100 fatalities. Northwest areas, including Rajasthan, New Delhi, Haryana, Uttar Pradesh, and Bihar, were particularly affected [2,3].

Source water encompasses various bodies of water, such as: rivers, streams, lakes, reservoirs, springs, and groundwater, that supply public drinking water systems and private wells [4,5].

Water is essential to our existence. While it is the most prevalent and beneficial solvent in nature, it is also the most abused commodity [6].

Groundwater, a specific type of source water, is located beneath the Earth's surface in the saturated zones between soil, sand, and rock formations. It occupies the pores and fractures within these materials, similar to how water saturates a sponge [7].

Protecting these water sources from contamination is crucial, as once polluted, they can be challenging and costly to remediate [8].

The hydrosphere encompasses all water present on, beneath, and above Earth's surface. Despite covering approximately 71% of the planet, only about 2.5% of Earth's water is freshwater. Of this fraction, a mere 0.3% is readily accessible in lakes, reservoirs, and river systems [9].

Moreover, water is fundamental to life, serving as a cyclic, renewable natural resource essential for all living beings. As stated above, it constitutes approximately 71% of the Earth's surface; however, only about 1% is potable and accessible for human use. Various components of our planet—the hydrosphere, cryosphere, atmosphere, lithosphere, and biosphere—collectively contribute to the global distribution of water [10].

In India, rivers such as the River Ganga, River Yamuna, and River Sabarmati hold profound cultural and religious significance. Beyond their spiritual importance, these rivers are vital for economic activities, including agriculture, industrial operations, hydroelectric power generation, and tourism. However, the water quality of these rivers has been severely compromised due to multiple pollutants, including pesticides, heavy metals, organic waste, chemical discharges, and untreated sewage. This contamination poses significant threats to human and animal health and adversely impacts the economy [10].

Addressing this critical issue necessitates comprehensive strategies, including expanding sewage treatment infrastructure, promoting sustainable agricultural practices, enforcing stringent industrial regulations, and raising public awareness about water conservation and pollution prevention [10].

Water is indispensable for the survival of all living organisms, serving as a crucial component and an essential source in numerous biological processes and life processes of all organisms. Among various sources, river water stands out as a vital natural resource for humans, providing essential services such as drinking water, irrigation for agriculture, industry, tourism, domestic use and habitats for aquatic life, which have evolved into significant towns and cities, emphasizing the economic importance of these water bodies [9].

However, human activities associated with economic development often contribute to the deterioration of water quality. Rivers possess a natural capacity to detoxify certain pollutants, but this ability is limited. When pollutant discharges exceed this capacity, water quality declines. Indicators of such pollution include unpleasant tastes in drinking water, foul odors from aquatic environments, unchecked growth of aquatic weeds, and reductions in fish populations [9].

To assess and monitor the chemical phenomena occurring in water bodies, specific water quality parameters are evaluated, such as pH, dissolved oxygen (DO), biochemical oxygen demand (BOD), and total dissolved solids (TDS). The pH level indicates the concentration of hydrogen ions, reflecting the water's acidity or alkalinity. Dissolved oxygen is crucial for the survival of aquatic organisms, while BOD measures the amount of oxygen required by microorganisms to decompose organic matter. TDS represents the total concentration of dissolved substances in water, impacting its taste and suitability for various uses [9].

Effective management and conservation of river systems are imperative to ensure the sustainability of these invaluable resources for both ecological balance and human prosperity [9].

The degradation of aquatic ecosystems is accelerating, with the quality and availability of freshwater resources deteriorating rapidly. Contaminated water sources are currently a major environmental concern on a worldwide scale [11].

Water is fundamental to life, serving as a vital resource for all living organisms. However, when contaminated, it transforms from a source of sustenance to a vector of disease. Water pollution involves the introduction of harmful substances into water bodies, rendering them unsafe for human consumption and disrupting aquatic ecosystems. This contamination often results from human activities, leading to the degradation of rivers and other freshwater sources [12]. Contaminated water can lead to health issues such as: reproductive disorders, neurological impairments, and gastrointestinal diseases, highlighting the critical need for vigilant water quality monitoring.

Water quality encompasses the physical, chemical, and biological characteristics of water. Parameters such as: salinity, turbidity, concentrations of dissolved oxygen and carbon dioxide, as well as the presence of microorganisms, herbicides, pesticides, and heavy metals, critically influence water quality. Given water's role as a universal solvent and its impact on the vast human populace, assessing water quality is paramount.

Ensuring high water quality necessitates a comprehensive approach involving stringent goal-setting, adherence to regulations, and continuous evaluation.

Addressing these issues requires rigorous adherence to water quality monitoring protocols, regular maintenance of water supply infrastructure, and prompt corrective measures to ensure health and safety.

As ensuring the provision of potable water is a fundamental amenity for travellers [13].

Access to safe and readily available water is essential for public health, serving critical functions in drinking, domestic use, food production, and recreational activities. Enhancing water supply and sanitation, alongside improved management of water resources, can significantly bolster economic growth and substantially reduce poverty levels [14].

These developments emphasize the critical importance of ensuring universal access to clean water and adequate sanitation, not only as fundamental human rights but also as pivotal components in promoting public health and fostering socio-economic development [14].

Also, in 2010, the United Nations General Assembly formally recognized the human right to water and sanitation, affirming that everyone is entitled to sufficient, continuous, safe, acceptable, physically accessible, and affordable water for personal and domestic use [14].

Excess nitrogen and phosphorus from human activities—such as: fertilisers, wastewater, vehicle emissions, and animal waste—lead to eutrophication, causing harmful algal blooms and oxygen depletion in water bodies. The World Health Organization's permissible limits for surface water are 50 mg/L for nitrate, 3 mg/L for nitrite, and 5 mg/L for phosphate [15].

Traditional detection methods for these nutrients include the Griess reaction for nitrite and nitrate and a molybdenum blue-based method for phosphate. Innovative hydrogel test kits have been developed for on-site analysis, encapsulating reagents within a poly (vinyl alcohol) matrix. These kits are portable, user-friendly, and minimize hazardous chemical exposure. They have been successfully used for on-site determination of nutrients in water bodies, such as the Pak Bang and Bang Yai canals in Phuket, Thailand [15].

Using smartphone apps for digital image colorimetry (DIC) improves water quality monitoring by letting users take pictures of test results and use colorimetry analysis to measure nutrient concentrations. This approach makes nutrient analysis more accessible and efficient [15].

When selecting research sites, it is essential to carefully evaluate the potential for institutional conflicts, particularly where one organization may wield disproportionate influence or assert dominance. Such power imbalances can undermine collaborative efforts, disrupt operational harmony, and compromise the integrity and objectivity of the research. Ensuring equitable partnerships and mutual respect among institutions is critical to preserving the credibility and effectiveness of the research endeavor. Notable sources of conflict include team goal identification, team role multiplicity, inter-team relationships, and team competence.

To mitigate these risks, it is essential to implement conflict-sensitive research practices and select sites that minimize the likelihood of inter-team conflicts.

The imperative of safety and security in fieldwork, maintaining the safety and security of researchers and their equipment, is crucial for preserving the integrity of scientific studies. Fieldwork conducted in areas with prevalent criminal activities—such as: theft, gang conflicts, or individuals exhibiting abusive or irrational behavior—poses significant risks. Selecting secure locations minimizes these threats and fosters an environment conducive to effective research. Implementing comprehensive safety protocols is essential to protect both personnel and research assets.

This includes bodies of water such as: rivers, lakes, streams, reservoirs, and ponds. These sources are directly exposed to the atmosphere and are replenished by precipitation, making them integral to the hydrological cycle.

The study area encompasses zones around the Victoria Bridge, Folly Side, and the Tapovan Bridge, including the tranquil forested regions of Panchavati and Tapovan, known for their lush greenery and prominent banyan trees along the riverbanks. Photographic images depicting these areas have been included to provide visual context and enhance understanding of the study environment (see **Figures 1** and **2**).

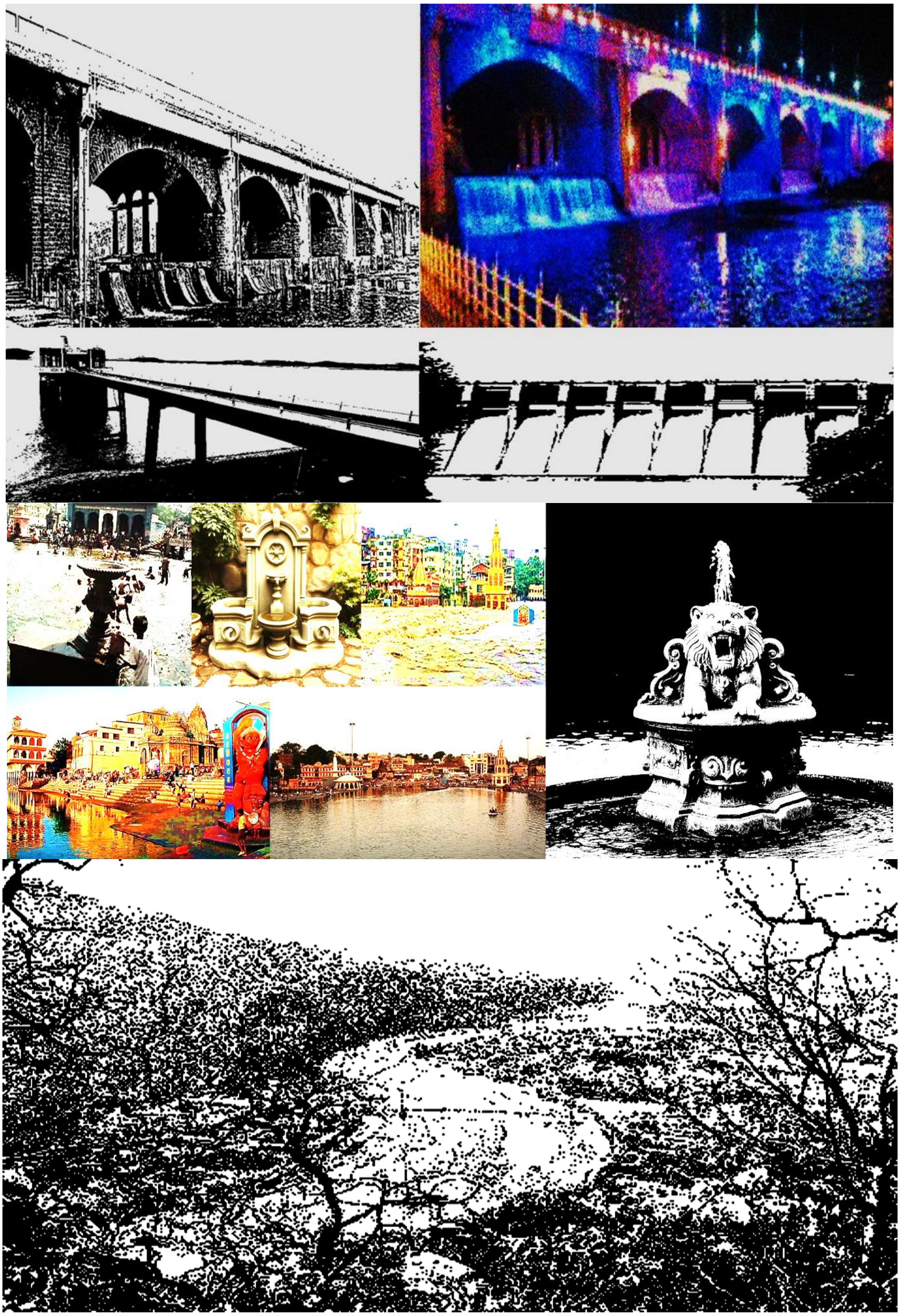


Figure 1. Photographic documentation of the sample collection sites along the River Godavari was captured, archived visually and rendered to provide compelling visual support for recreational and also illustrative representation of the locations involved in the research study [16–18].

Selecting appropriate sites for water sample collection is vital for accurate water quality assessment. Factors influencing site selection include the study's objectives, potential contamination sources, and the representativeness of the location. Studying locations when selecting a research site is important. It is imperative to consider safety, security and logistical feasibility to ensure the well-being of researchers and the integrity of the study and fundamental research materials. Research teams must assess the security of sampling sites to safeguard both personnel and essential research equipment—such as primary cameras, mobile devices, and sampling instruments—from risks including theft or damage. Environments or areas characterized by criminal activities, such as: theft, gang conflicts, gang violence, or individuals exhibiting abusive, aggressive or irrational and erratic behavior, pose significant risks and present serious threats to the safety of researchers and the integrity of data collection; therefore, such locations should be categorically avoided. Prioritizing secure locations minimizes potential threats and fosters a conducive atmosphere for conducting research (see **Figure 2**).

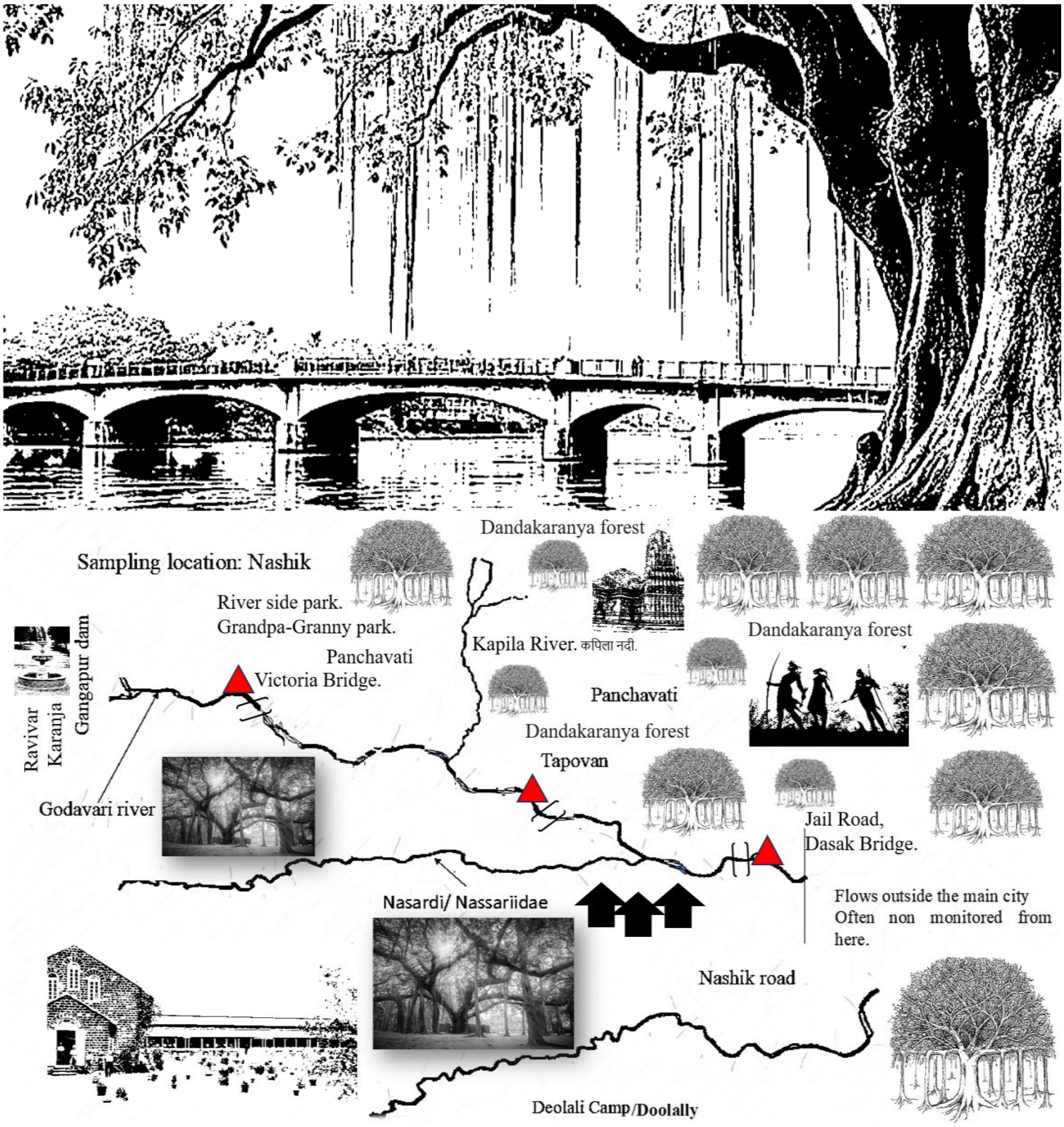


Figure 2. Sampling location on the river, a generalized view of the river flowing in the riverbed via the aqueduct, side of the folly in Panchavati.

Rivers, which play a crucial role in supporting human life, are increasingly burdened by pollutants such as: chemicals, waste, plastics, and other contaminants. The decline in water quality has become a pressing global issue recently. According to the World Health Organization (WHO), inadequate water, sanitation, and hygiene (WASH) services were linked to 1.4 million deaths and 74 million disability-adjusted life years (DALYs) in 2019, accounting for 2.5% of all deaths and 2.9% of all DALYs globally [12].

Addressing water pollution is imperative to safeguard public health and preserve aquatic ecosystems. Implementing effective waste management practices, enhancing wastewater treatment infrastructure, and promoting sustainable agricultural and industrial processes are essential steps toward ensuring the availability of clean and safe water for all [12] (see **Figure 3**).

Water quality is crucial for both agricultural irrigation and domestic uses, including drinking. Contamination can alter the physicochemical properties of water, rendering it unsuitable for these purposes [19].

In India, per capita surface water availability has been declining: from 2309 cubic meters in 1991 to 1902 cubic meters in 2001. Projections indicate further reductions to 1401 cubic meters by 2025 and 1191 cubic meters by 2050. Globally, it is estimated that by 2025, two-thirds of the population may experience water stress. Limnology, the study of inland waters, is essential for developing location-specific management strategies for freshwater bodies [19].

Despite the estimations in information cited above, projections for 2025 indicated that water resources and stress will pose significant challenges to populations worldwide; it is important to note that, in aggregate, there is enough water on Earth to meet daily human needs. However, the distribution of these resources is uneven, leading to scarcity in certain regions. The World Economic Forum has identified water scarcity as one of the largest global risks in terms of potential impact over the next decade [19].

Effective management and equitable distribution are essential to address these disparities and ensure that all communities have access to sufficient water for their daily requirements [19].

The increase of different contaminating ionic levels in the water, which poses a risk to people, plants, and animals, is largely caused by human activity [20].

For example, the Ganges River in India faces severe pollution due to the disposal of human sewage, animal waste, and industrial effluents. This contamination has led to the degradation of the river’s ecosystem, affecting both human health and biodiversity [21].

The presence of pollutants in water bodies can lead to oxygen depletion, harming fish and other aquatic organisms. Water pollution poses public health risks, contributing to the spread of waterborne diseases [21].

Addressing these issues requires stringent regulations, effective wastewater treatment, and sustainable waste management practices to protect water quality and aquatic ecosystems [21].

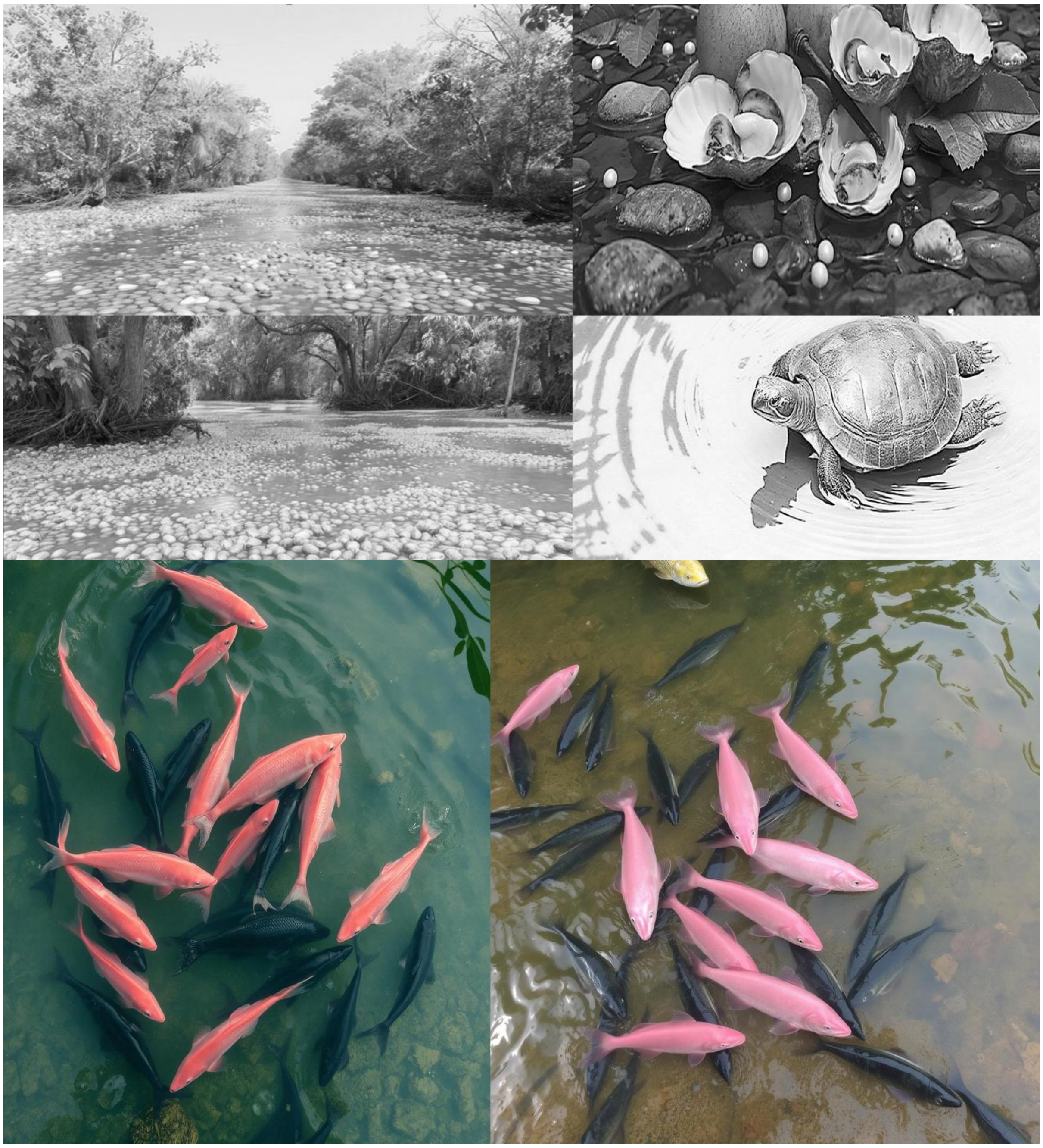


Figure 3. A broad collection of visual representations showcases environmentally favorable habitats that support rich aquatic biodiversity, including fish, turtles, oysters, molluscs, crabs, and other marine or freshwater organisms. These images illustrate thriving ecosystems where water quality, vegetation, and natural shelter conditions create ideal environments for the growth and sustainability of aquatic life.

Throughout history, people have been drawn to settling near rivers, lakes, and coastal areas due to their essential resources, including drinking water, food, irrigation, waste disposal, transportation, and recreation; as stated by Carpenter, in 1998. However, with the advent of industrial and agricultural revolutions, human activities have significantly intensified the strain on these crucial water bodies. Consequently, water quality in many of the world's rivers has declined as pollutants and their concentrations have surged. The contamination and excessive exploitation of river systems have led to severe challenges such as: water scarcity, adverse health effects, reduced recreational value, the degradation of aquatic ecosystems, and the loss of critical ecosystem services. These concerns are particularly severe in India, where a rapidly expanding population, urban sprawl, industrial growth, and intensified agricultural practices are accelerating the decline in water quality, harming ecological balance, and posing serious threats to public health [22].

Generally, the primary objectives of research on river water pollution are to assess the current water quality status by measuring key physical, chemical, and biological parameters such as: pH, turbidity, BOD, COD, heavy metals, and microbial load. Present research aimed to identify the major sources of pollution, whether from domestic sewage, industrial effluents, agricultural runoff, or other anthropogenic activities. The study will evaluate spatial and temporal variations in pollution levels by comparing data from multiple locations along the river across different seasons. It seeks to determine the impact of pollution on aquatic ecosystems by analyzing changes in biodiversity and overall ecological health.

1.1. Rivers through time: Analyzing their historical significance and human interactions

The problem is further exacerbated by insufficient pollution regulations and inadequate monitoring of industrial activities, sewage treatment facilities, and individual farming practices. Key concerns include unregulated water extraction, excessive pesticide application, and uncontrolled fertilizer usage. One of the most widespread water quality issues affecting rivers globally is eutrophication, primarily driven by increased phosphorus and nitrogen levels due to fertilizer runoff and wastewater discharge. Elevated nutrient concentrations promote excessive algal growth, leading to the decline of aquatic plants and invertebrates, depletion of oxygen levels, and fish mortality. Also, eutrophication imposes significant economic burdens, including the costs of ensuring safe drinking water, reduced opportunities for recreational activities, and declining waterfront property values [23].

Moreover, rapid industrial expansion, intensified farming practices, and the growing consumption of pharmaceuticals and personal care products have introduced an increasingly diverse array of pollutants into freshwater ecosystems. These contaminants—ranging from heavy metals and pesticides to pharmaceuticals, plasticisers, and nanoparticles—pose serious threats to aquatic biodiversity and disrupt ecosystem processes; as stated by Johnson in 2019 [23].

The Nandini River, now commonly referred to as the Nasardi, has been given this name due to uncertain social influences that have attached an unfavourable connotation to it. Historically, it was a perennial river, much like the Godavari, playing a significant role in the region’s natural and cultural landscape. The Nandini River, originating from the Anjaneri hills southwest of Nashik, converges with the Godavari River in the Tapovan area. Flowing through Nashik, the Nandini River, also known as the Nasardi River, has been identified as one of the most polluted rivers in the district, primarily due to the discharge of untreated industrial and domestic wastewater. A survey study, conducted through a review and research paper, identified River Nandini as the most polluted river in the Nashik District. The study highlights that despite the government's persistent efforts, the river remains heavily polluted, as evidenced by research findings and implemented studies [24,25].

This pollution poses significant threats to aquatic ecosystems and public health. In developing regions, it is estimated that approximately 80% of wastewater from industrial and household sources is released into water bodies without any form of treatment [16,26].

This practice leads to the degradation of water quality, adversely affecting aquatic life and rendering the water unsafe for human consumption and recreational activities [26,27].

Recognizing the severity of the situation, the Nashik Municipal Corporation (NMC) has undertaken initiatives to monitor and improve the water quality of the Nandini River. These efforts include preparing detailed reports on pollution control measures and implementing strategies to reduce the biological oxygen demand levels in existing sewage treatment plants, aligning with standards set by the Maharashtra Pollution Control Board (MPCB) [24].

Despite these efforts, continuous monitoring and effective wastewater management are essential to restore and preserve the health (quality) of the river. Public awareness and community involvement play crucial roles in supporting conservation initiatives and ensuring the sustainability of this vital water resource [20].

Maintaining water quality is crucial for the health and sustainability of both plant and animal life. Implementing effective water conservation strategies within communities is essential to ensure the longevity of these ecosystems [24,27]. Utilizing biodegradable piassava fibers in river water pollution treatment offers a sustainable alternative, as synthetic fibers contribute to environmental contamination. Synthetic textiles, such as polyester and nylon, are derived from petrochemicals and do not biodegrade, leading to persistent pollution in aquatic ecosystems.

Incorporating natural fibers like piassava can help mitigate this issue, providing an eco-friendly solution to water pollution.

In its prime, the Nandini River supported a rich biodiversity, including various species of fish, tortoises, crabs, pearl oysters, and Nassariidae. Its banks were adorned with abundant fruit-bearing trees—*Pyrus nivalis,* or Nashpati—and also flowering trees, contributing to the river's ecological richness. Which suits its favorable temperature, which is about 10 ℃ to 5 ℃ as its major climate during winters and 25 ℃ to 27 ℃ in the summer. Refer to **Figure 3**, which illustrates a healthy natural environment with a river flowing through a well-preserved landscape. However, it had vast changes from the 1990s to 2006 and then after until the present. The Nandini river, also known as the Nasardi, historically transported organic materials such as fruits and flowers along its course. Flowing through Nashik, it eventually converged with the Godavari River at the main city's periphery and flows through the rest of the city, which is unmonitored. Over time, however, the river deteriorated due to escalating pollution levels.

The influx of untreated domestic sewage and industrial effluents led to a significant decline in water quality, adversely affecting the river's flora and fauna [24,27].

Presently, the Nandini River is considered one of the most polluted rivers in the Nashik district, with its degraded state impacting the overall condition of the Godavari

River system [24,27]. Thus, the water of the Nandini River is polluted. Termed very polluted in the studies across the subject [22,23,25].

The banks of the Nandini River were historically abundant with pearl-producing oysters, leading to frequent discoveries of pearls along its shores. Presently lost with such beauty, it stands out as an ordinary river.

Precis: The Nashik district is predominantly characterized by basaltic lava flows from the Late Cretaceous to Early Eocene epochs, covering approximately 85% of the area. These flows are typically horizontal, forming a plateau-like topography. Each flow consists of a massive basal unit topped by a vesicular layer, with individual flows separated by distinct ‘bole beds’. Recent alluvial formations are found as narrow stretches along the banks of the Godavari, Mosam, and Girna Rivers within the district [28].

The Godavari River is a perennial watercourse that sustains a diverse array of aquatic species of no commerce or commercial importance. The river does not produce any aquatic fish fished for food or commerce or any pearl oysters or tortoises. Apart from the study area, the other significant information associated with this area is about its banks, which are predominantly developed into ghats, serving as hubs for recreational and religious activities, resulting in continuous human presence. Individuals who feign religious devotion are often pretenders.

Pecksniffian characters, or pseudotheists, have been prevalent throughout history along with rabble-rousers; pejoratively, those who seek to manipulate public sentiment, sometimes leading to unrest or violence. Such hypocritical behaviors are often viewed as malevolent, distorting truth and potentially influencing impressionable minds. They are often dishonest and devilish in nature, often roguish, befitting a devil. “One must learn and know all rat-runs being there on the road!”

Notably, in regions like Tapovan—a serene sanctuary in Nashik, Maharashtra, renowned for its tranquil atmosphere and spiritual significance—both genuine practitioners and such pretenders coexist. Tapovan, translating to ‘forest of penance or meditation’, is believed to have been part of the ancient Dandakaranya forest and holds significant associations with the epic Ramayana and the Shurpanaka seeking the beloved. It is also called a city of pilgrimage.

Thus, in regions like Tapovan, both genuine devotees and these imposters coexist, creating a complex social tapestry. The area, with its dense forests, has been metaphorically described as a masquerade, reflecting the intricate interplay between authenticity and deception. As a researcher, you might wonder at the ambiguous wonder: experiences or phenomena that elicit amazement precisely because they are mysterious. Yet many places are restricted to visit; can’t know them right easily.

This area, rich in spiritual heritage, has historically attracted individuals seeking enlightenment, as well as those merely adopting the guise of piety. The coexistence of authentic seekers and hypocritical pretenders in such regions emphasizes the complex interplay between genuine spirituality and superficial displays of devotion. Thus, no super understanding can be concluded from seeking information on the site prior to self-investigating it thoroughly. Consequently, there are few occasions when these areas are unoccupied, except for certain stretches historically associated with superstitions or beliefs in malevolent entities. Thus, no definitive conclusions can be drawn without conducting a thorough, firsthand investigation of the site.

The other descriptions state that the Godavari River, revered as a sacred waterway since ancient times, holds significant religious importance in India. Refer to the accompanying **Figure 1** for a visual representation of this cultural importance. According to the Ramayana, it is believed that Lord Rama bathed at Ramkund during his exile. Ramkund, located in Nashik, is considered the holiest spot in the city due to this association [29].

At Ramkund, the Godavari's flow shifts from a north-south to an east-west direction, creating turbulence that enhances dissolved oxygen levels, potentially improving water quality. This site attracts pilgrims nationwide who perform rituals and take holy baths, especially during events like the Kumbh Mela, when attendance can reach millions [29].

To understand the impact of such mass gatherings on water quality, studies have been conducted to analyze the physicochemical properties of the Godavari at Ramkund. These assessments aim to evaluate how human activities, particularly during large-scale religious events, affect the river's condition [29].

Monitoring these parameters is crucial for implementing measures to preserve the river's sanctity and ensure the health of both pilgrims and the aquatic ecosystem [29].

In many developed nations, river water quality is systematically monitored, with assessments covering a vast array of pollutants, including organic compounds, nutrients, and metals, along with numerous physical, chemical, and biological parameters. Special emphasis is placed on key indicators that have the most significant influence on river ecosystems, such as: phosphate, ammonium, nitrate, pH levels, and dissolved oxygen concentrations. These measurements help determine whether water bodies comply with established quality and ecological standards. Data from chemical and biological assessments, along with flow measurements, are often made publicly accessible through online data portals, enabling transparency and informed decision-making [23].

1.2. Further forgetting the other side and diving up and delving deeper into the research studies

Diseases transmitted through contaminated water continue to pose significant public health challenges globally, affecting both industrialized and developing nations. Diarrhoeal diseases, in particular, accounted for over 1 million of these deaths, emphasizing the critical need for improved WASH infrastructure worldwide [30].

In developed countries, while access to clean water is generally higher, challenges persist. For instance, the United States has experienced incidents like the Flint water crisis, where lead contamination posed serious health risks. Such events highlight that even in affluent nations, vulnerabilities in water infrastructure can lead to significant public health issues [30].

Addressing these challenges requires a multifaceted approach, including investments in infrastructure, community education, and robust monitoring systems to ensure the safety of drinking water and the prevention of waterborne diseases globally [30].

Contaminated water can have serious health implications. Elevated acidity levels (low pH) in water may cause gastrointestinal issues such as: hyperacidity, ulcers, stomach pain, and burning sensations. Also, when the pH falls below 6.5, metal pipes are prone to corrosion, leading to the leaching of hazardous metals like zinc, lead, and cadmium into the water supply [31].

The presence of microbial contaminants in drinking water, such as *Cryptosporidium* and *Giardia lamblia*, poses significant health risks, including gastrointestinal illnesses like diarrhoea, vomiting, and abdominal cramps. These pathogens typically originate from human and animal faecal contamination. *Legionella*, another microorganism of concern, is naturally found in water and can proliferate in warm water systems, potentially causing Legionnaires' disease, a severe form of pneumonia. In contrast, the heterotrophic plate count (HPC) is not directly linked to health effects; rather, it is a microbial assessment method used to gauge the general bacterial population in water. A lower HPC value indicates a well-maintained water distribution system, as it reflects minimal bacterial presence from natural environmental sources [32–34].

Disinfection byproducts are chemical compounds that form when disinfectants used in water treatment react with natural organic matter. Several of these byproducts have potential health implications when present in drinking water above regulated limits [32–34].

Bromate, a byproduct of ozone disinfection, has a maximum contaminant level (MCL) of 0.010 mg/L and is associated with an increased risk of cancer when consumed over long periods.

Chlorite, resulting from the use of chlorine dioxide, has a maximum contaminant level goal (MCLG) of 0.8 mg/L and an MCL of 1.0 mg/L. Long-term exposure above this level may lead to anaemia, and in infants and young children, it can affect the nervous system [32–34].

Haloacetic acids (HAA5), formed as a result of chlorination, have an MCL of 0.060 mg/L. Prolonged exposure to high levels of HAA5 may increase the risk of cancer.

Total Trihalomethanes (TTHMs), another common group of disinfection byproducts, have an MCL of 0.080 mg/L. Long-term exposure to TTHMs can lead to liver, kidney, or central nervous system issues and may also raise the risk of cancer [32–34].

These byproducts highlight the importance of carefully managing the disinfection process to minimize health risks while ensuring effective pathogen control in drinking water [32–34].

Disinfectants are commonly added to drinking water to eliminate harmful microorganisms; however, their presence at levels exceeding regulatory limits can pose health risks.

Chloramines, measured as Cl_2, have a maximum residual disinfectant level goal (MRDLG) of 4.0 mg/L and a maximum residual disinfectant level (MRDL) of 4.0 mg/L. Prolonged exposure above this threshold can cause eye and nose irritation, stomach discomfort, and potentially anaemia. Chloramines are widely used as a secondary disinfectant in water treatment systems to control microbial growth [33].

Chlorine, also measured as Cl_2, shares the same MRDLG and MRDL of 4.0 mg/L. Long-term exposure to elevated chlorine levels may result in eye and nose irritation, along with gastrointestinal discomfort. It is one of the most commonly used disinfectants in water treatment for its effectiveness against pathogens [33].

Chlorine dioxide, with an MRDLG and MRDL of 0.8 mg/L, may lead to anaemia if consumed above the regulated level over time. In infants and young children, it can also affect the nervous system. Like the others, chlorine dioxide is used to control microbial contaminants in drinking water [33].

These disinfectants, while essential for public health protection, must be carefully regulated to balance microbial control with the minimization of adverse health effects.

Although secondary drinking water standards are not legally enforceable at the federal level, the EPA mandates a specific notification requirement when the fluoride level surpasses the secondary standard of 2.0 mg/L. Community water systems that detect fluoride concentrations above this level—but still below the primary maximum contaminant level of 4.0 mg/L—are required to inform the public. This notification must be issued within 12 months from the date the system becomes aware of the exceedance, as outlined in 40 CFR 141.208 [34].

The U.S. Environmental Protection Agency (EPA) has established National Secondary Drinking Water Regulations to address aesthetic and cosmetic concerns in drinking water, such as taste, odor, and color. These guidelines, while not federally enforceable, recommend the following limits [34].

Aluminum should be maintained between 0.05 and 0.2 mg/L, and chloride levels should not exceed 250 mg/L. Watercolor should remain under 15 color units to ensure visual clarity. Copper is recommended at a maximum of 1.0 mg/L, while water corrosivity should be minimized to non-corrosive levels to protect plumbing systems [34].

Fluoride, for aesthetic purposes, should not exceed 2.0 mg/L. Foaming agents are limited to 0.5 mg/L, and iron should be kept below 0.3 mg/L due to its potential to cause staining. Manganese should be under 0.05 mg/L for similar reasons, and odor should not surpass a threshold odor number of 3 to maintain acceptable sensory quality [34].

The pH of drinking water is recommended to be within the range of 6.5 to 8.5 to balance taste and system longevity. Silver is limited to 0.10 mg/L, sulfate to 250 mg/L, total dissolved solids (TDS) to 500 mg/L, and zinc to 5 mg/L to prevent undesirable taste and mineral buildup. These standards help ensure water remains pleasant and acceptable to consumers [34].

2. Research methodology

In this study, water quality assessments of the Godavari River in Nashik city were conducted by collecting samples from ten distinct locations, as depicted in **Figure 2**, with visual support shown in **Figure 1**. Five sampling points were strategically chosen near the Victoria Bridge in the main city area, and an additional five points were selected between the Tapovan Bridge and Dasak Bridge, encompassing the vicinity of the Shurpanaka Temple. Samples were meticulously collected in clean plastic containers on different days to ensure comprehensive and statistically robust data. To collect water samples from the river without disturbing the riverbed, a pulley system was employed from the bridge. This method allowed for the safe retrieval of samples without the need to enter the water, thereby mitigating potential hazards associated with direct river access. The samples were collected independently, without any involvement from the populace, unilaterally to leverage insights, and to prevent forgery or idea theft and stop unauthorized use of concepts, prevent misappropriation, and prevent others from claiming your ideas as theirs. During the study, meticulous precautions were taken to prevent any disturbances (stringent precautions were taken to prevent disturbances) among local residents, ensuring that no individuals exhibited signs of psychological distress, cognitive impairment, or behavioral anomalies that could compromise the integrity of the research. In the event of any such occurrences, the site was promptly vacated, and water sample collection was halted to maintain ethical and scientific standards while safeguarding against unforeseen risks, stopping the counterfeiter and keeping forgers or copycats away.

Industrial effluents and urban stormwater runoff are significant contributors to water pollution in Nashik, notably impacting the Nasardi (Nandini) River. This tributary, often utilized for waste disposal, merges with the Godavari River passing by near Tapovan, Nashik, introducing pollutants that compromise water quality. The confluence occurs at the city's outskirts, an area lacking adequate monitoring, thereby exacerbating the pollution levels in the Godavari River thereafter. While the Godavari River flows perennially and does not harbor fish and other water creatures in it, like the Nandini River in its past throughout its bank. It is the most humanized riverbank and is often never vacant for cheer-up time, except for a few places that are never visited by ordinary people, believed to have been occupied by devils' spirits in the past, or have demonic forces. Thus, "the allure of temptation to the subtlety of evil influences" is a common, understandable phrase that may be adopted.

The additional environmentally beneficial expression that promotes "green earth" is keeping the good phrases in mind that support a green planet:

1) "Promote ecological resilience by safeguarding water quality, restoring native biodiversity, and maintaining the continuity of riverine ecosystems."
2) "Support a greener planet by ensuring clean water, revitalizing native ecosystems, and maintaining the uninterrupted flow of our rivers."
3) "Cultivate a sustainable planet and river water system by maintaining clean waters, replenishing natural biodiversity, and preserving the seamless flow of riverine environments is essential for life survival."

Prominently helpful recitations make up the minds of people to create healthy ecosystems.

3. Scientific evaluation

Specific gravity: Specific gravity is a dimensionless quantity that compares the density of a substance to the density of water at a specified temperature, typically 4 °C (39.2 °F), where water's density is approximately 1000 kg/m^3. Measuring the specific gravity of a liquid sample provides insights into its composition and purity. See **Table 1**, **Figure 4** [35].

4. Surface tension measurement

4.1. Surface tension reduction as an indicator of water contamination by surfactants and organic pollutants

Measuring surface tension can provide valuable insights into water pollution by detecting the presence of contaminants that alter the cohesive forces at the water's surface. When pollutants such as surfactants, oils, or organic compounds enter a water body, they can disrupt the natural intermolecular forces between water molecules, leading to a measurable decrease in surface tension [35].

By monitoring changes in surface tension, researchers can identify and quantify the extent of contamination. For instance, a study demonstrated that contaminants leached from various materials caused significant changes in air-water interfacial tensions, highlighting the sensitivity of surface tension measurements to pollution levels [35] (see **Table 2**).

Surface tension influences the behavior and transport of pollutants in aquatic environments. Understanding these dynamics is crucial for assessing the environmental impact of contaminants and developing effective remediation strategies.

In summary, surface tension measurements serve as a sensitive indicator of water pollution, enabling the detection of contaminants and enhancing our understanding of their behavior in aquatic systems. Refer to **Figure 5** for surface tension analysis conducted at the Victoria Bridge sampling locations, as indicated in **Figure 2**.

Figure 6 presents the surface tension analysis at the Tapovan Bridge sites, with corresponding sampling points also shown in **Figure 2**.

Figure 7 illustrates the surface tension analysis at the Dasak Bridge locations, based on the sampling points outlined in **Figure 2**.

4.1.1. Foaming index

The foaming index was carried out for each sample under study, and the results were documented [35].

4.1.2. Suspended particles and matter in water (Turbidity)

Turbidity is assessed using an applicative approach that uses a thick, long-fiber cotton cloth that has been previously weighed and then deposited with the filtered residue to quantify suspended matter and particles in water. The turbidity was computed using the difference and the records, taking into consideration the weight of the difference in a 100 mL water sample.

Suspended particles in water can be quantified using a practical method involving a thick, long-fibered cotton cloth. Refer to **Table 2** for the results of suspended particle analysis, and **Figure 2** for the locations of the sampling points. A graphical representation of the suspended particle data is provided in **Figure 8**.

The procedure is theorized in detail as follows:

1) Initial weighing: Accurately measure and record the dry weight of the clean cotton cloth.
2) Filtration: Pass a 100 mL water sample through the cloth, allowing suspended particles to be trapped on its fibers.

3) Drying: After filtration, dry the cloth thoroughly to remove any residual moisture.
4) Final weighing: Weigh the dried cloth with the retained particulate matter.
5) Calculation: Determine the mass of the suspended particles by subtracting the initial weight of the cloth from the final weight.

This gravimetric method provides a straightforward means to assess water turbidity by measuring the mass of particulate matter in a specific volume of water.

4.1.3. Measure of ANOVA; surface tension measurements across different sampling points

A combined overview of surface tension data from all bridge points is summarized in **Figure 9**.

Complementarily, on top of that, an ANOVA analysis was conducted on the surface tension measurements across different sampling points to evaluate variations and derive meaningful conclusions from the data. Refer to **Table 3** for the results of the ANOVA analysis (see **Figure 9**).

5. Result and discussion

Specific gravity (SG) is a dimensionless measure that compares the density of a substance to the density of water at a reference temperature (typically 4 ℃, where water's density is 1 g/cm^3). Pure water has a specific gravity of 1.000 as measured.

Table 1. The specific gravity of various water types and materials is as follows: The samples are allocated as specified in the research methodology section and illustrated in **Figure 2**.

Specific gravity (SG) of substance	Noted Specific gravity (SG) recorded at the ambient condition.
Pure water	1.000 g/cm^3
Polluted water	1.010 g/cm^3
Saline water	1.025 g/cm^3
Water with detergent	1.020 g/cm^3
Slight muddy water	1.019 g/cm^3
Slight ash filled water	1.012 g/cm^3
Slight fine powered gold water from specific sites of the river with ash.	1.013 g/cm^3

5.1. Analysis

1) Saline water (SG = 1.025 g/cm^3): The highest specific gravity among the samples is observed in saline water, attributed to dissolved salts increasing the water's density. This aligns with typical seawater SG values, which range from 1.020 to 1.030 g/cm^3, depending on salinity levels.
2) Water with detergent (SG = 1.020 g/cm^3): The presence of detergents elevates the specific gravity due to the addition of surfactants and other chemical compounds. While detergents can increase water density, their impact on specific gravity is generally moderate.
3) Slightly muddy water (SG = 1.019 g/cm^3): Suspended particles, such as silt and clay, contribute to a higher specific gravity. The extent of the increase depends

on the concentration and type of suspended sediments.

4) Slightly ash-filled water (SG = 1.012 g/cm³): The introduction of ash particles results in a minor increase in specific gravity. The effect varies based on the ash's composition and concentration.

5) Polluted water (SG = 1.010 g/cm³): General pollution, encompassing various dissolved and suspended substances, leads to a slight rise in specific gravity. The specific increase depends on the nature and concentration of the pollutants. **Figure 4**.

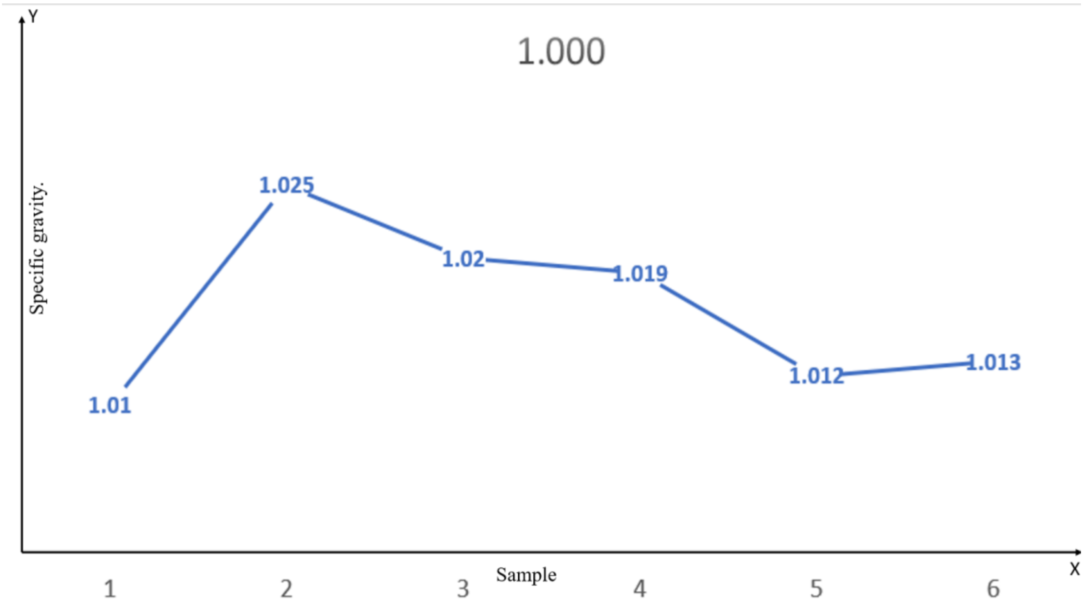


Figure 4. Graphical representation and analysis of specific gravity variations in water samples; data for water quality assessment.

The specific gravity of water increases with the addition of various substances, reflecting changes in density due to dissolved salts, chemicals, or suspended particles. Monitoring specific gravity can serve as an indirect indicator of water quality, helping to identify contamination levels and the presence of specific pollutants. However, specific gravity measurements alone may not provide comprehensive information about water quality; additional analyses are necessary to identify the exact nature and concentration of contaminants.

Assessing aquatic contamination via surface tension analysis: Insights from samples collected at the Victoria Bridge points

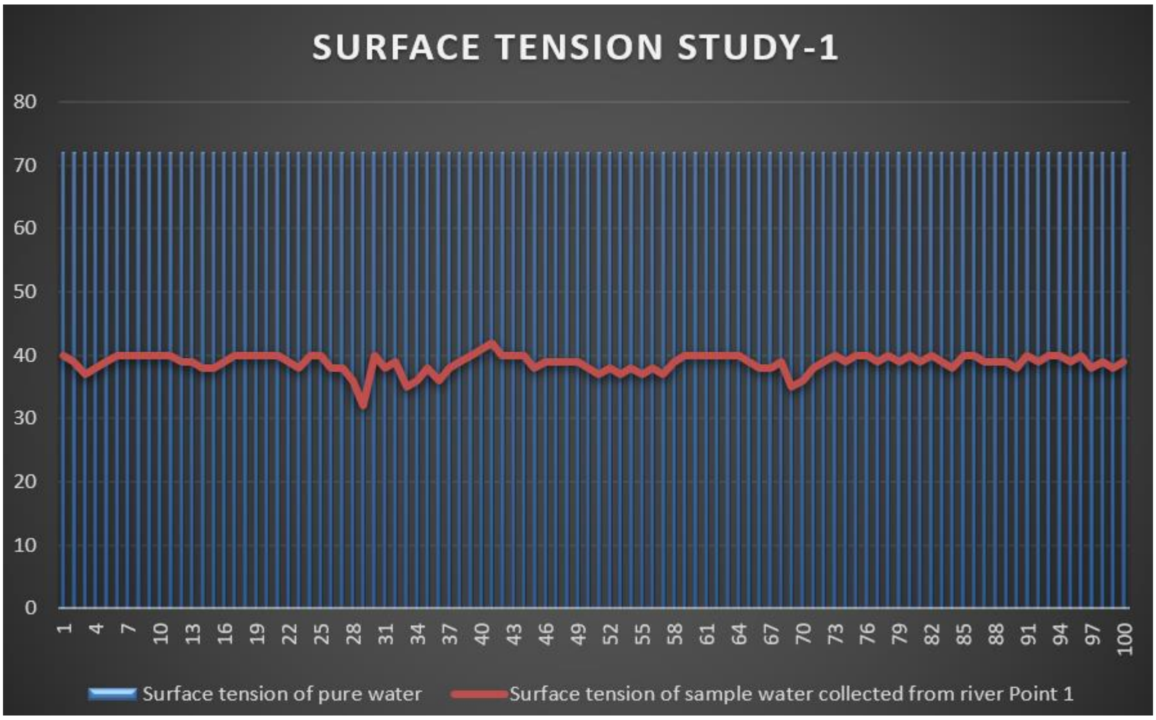
Surface tension analysis is a valuable tool in assessing water quality, as it helps detect the presence of contaminants that can alter the cohesive forces at the water's surface. When pollutants such as: oils, surfactants, or organic compounds enter a water body, they can disrupt the natural intermolecular forces between water molecules, leading to measurable changes in surface tension.

In the context of samples collected near Victoria Bridge, conducting surface tension measurements can provide insights into potential pollution levels in the area. Deviations from the standard surface tension value of pure water (approximately 72 mN/m) as measured for triple distilled water may indicate contamination. For instance, a study demonstrated that ambient impurities could cause a rapid decrease in the surface tension of ultrapure water, highlighting the sensitivity of surface tension to environmental contaminants.

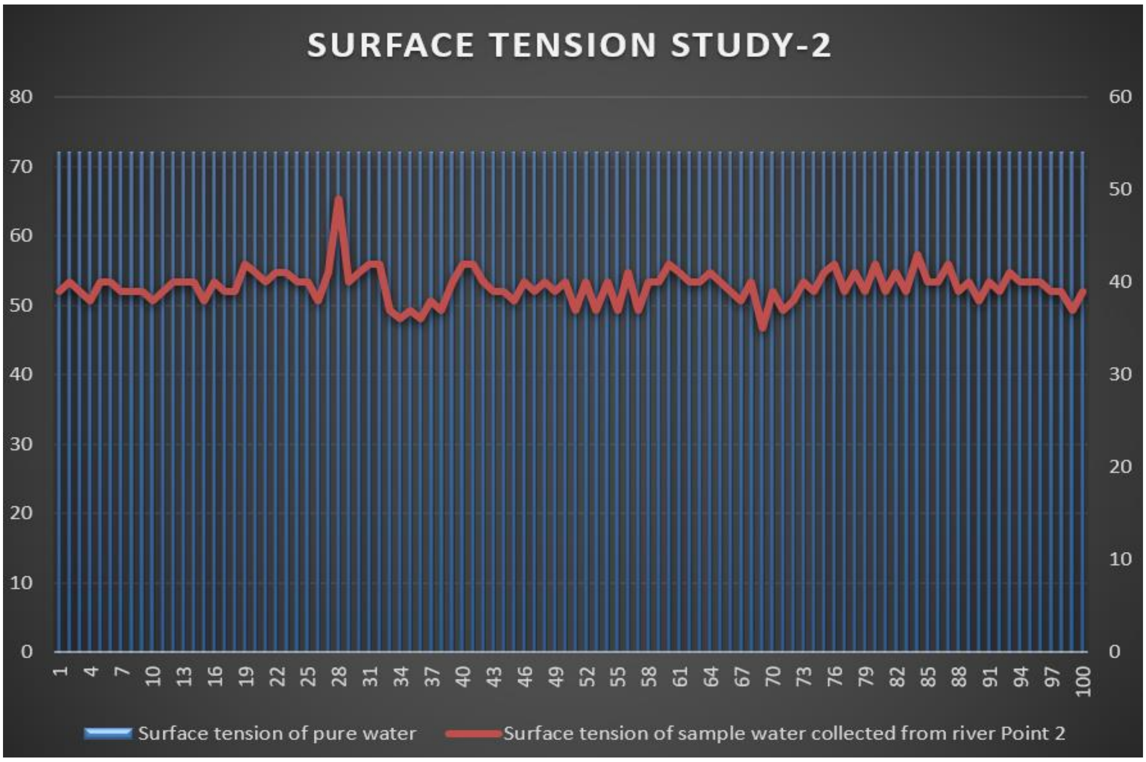
Surface tension plays a crucial role in the transport of microplastics in aquatic environments. Research has shown that surface tension forces can influence the movement of plastics, affecting their distribution and accumulation in water bodies.

Therefore, analyzing surface tension near Victoria Bridge can also focus on the behavior and presence of microplastics in the area.

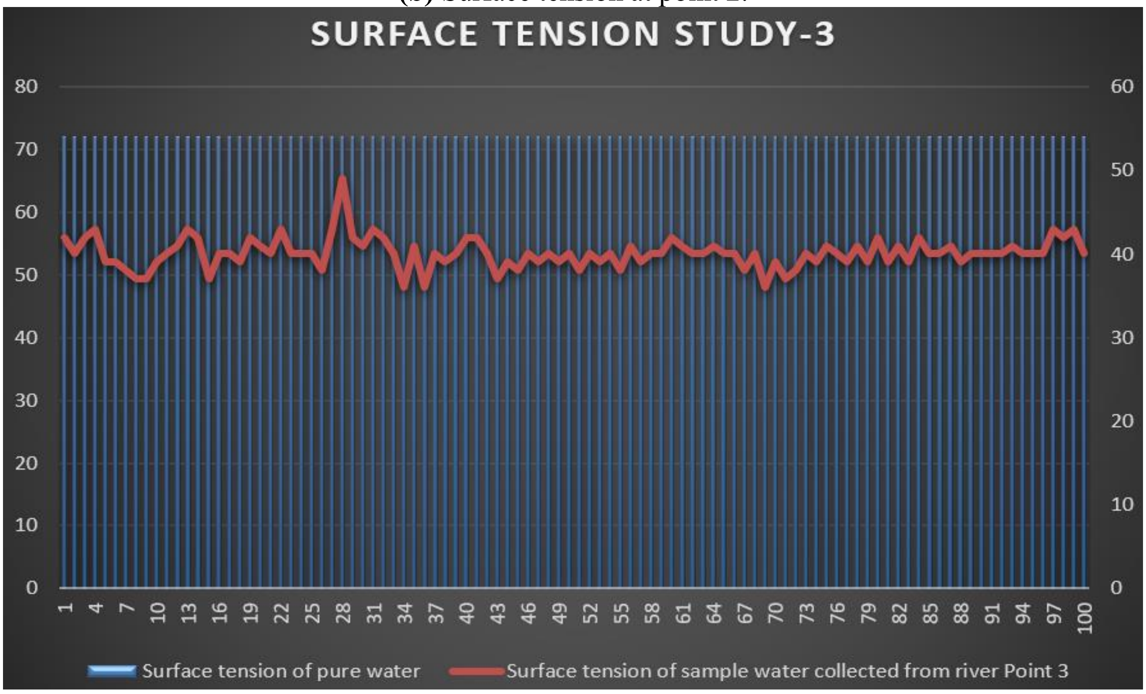
By integrating surface tension analysis with other water quality assessments, a comprehensive understanding of the environmental health near Victoria Bridge can be achieved, facilitating targeted remediation efforts and informed environmental management decisions. (see **Figures 5–7**).



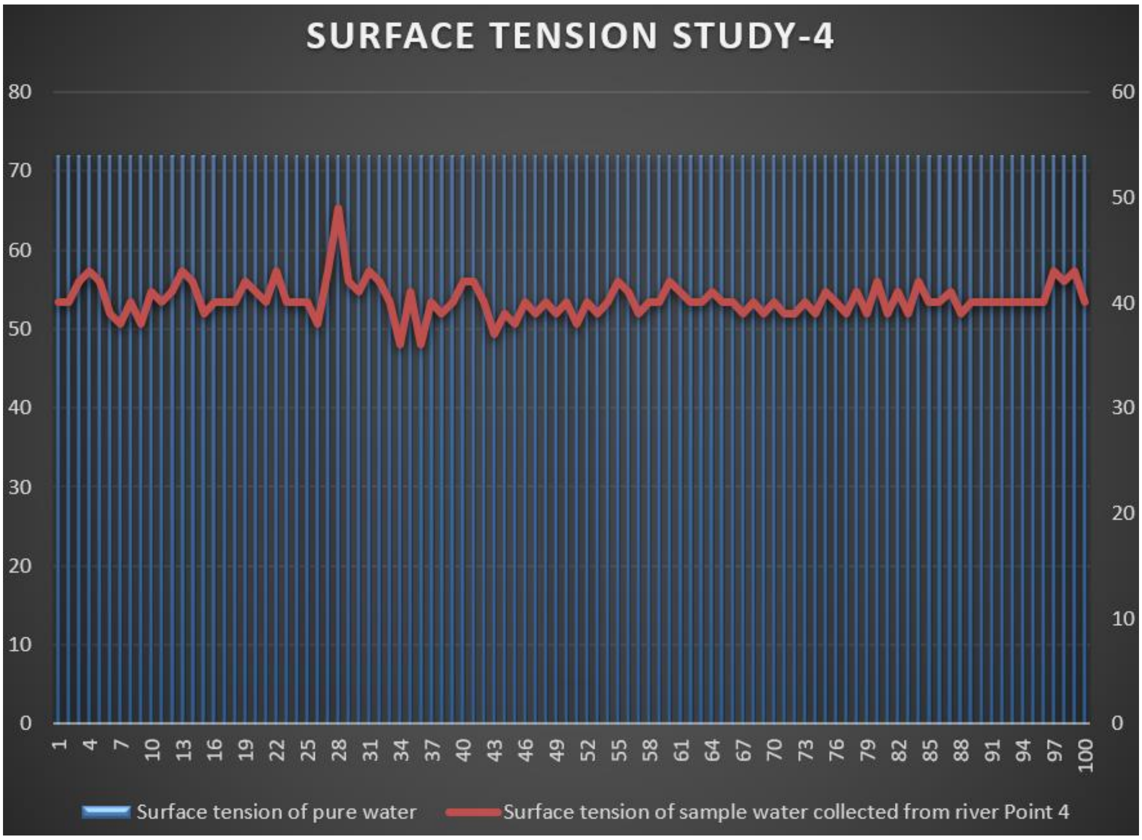
(a) Surface tension at point 1.



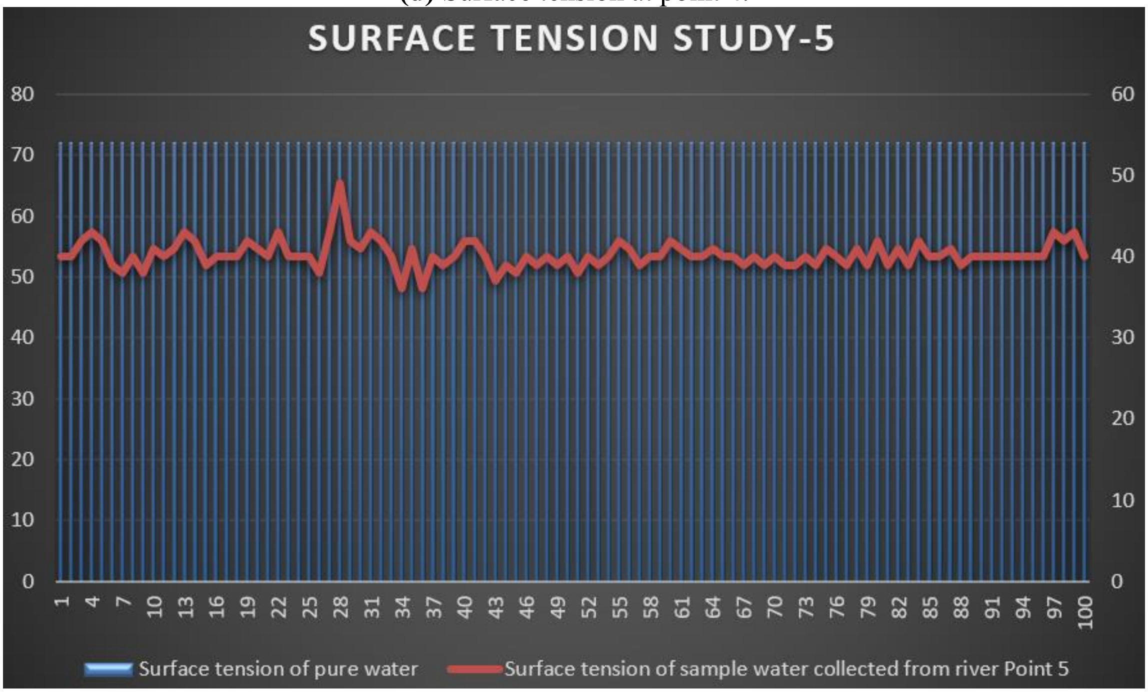
(b) Surface tension at point 2.



(c) Surface tension at point 3.

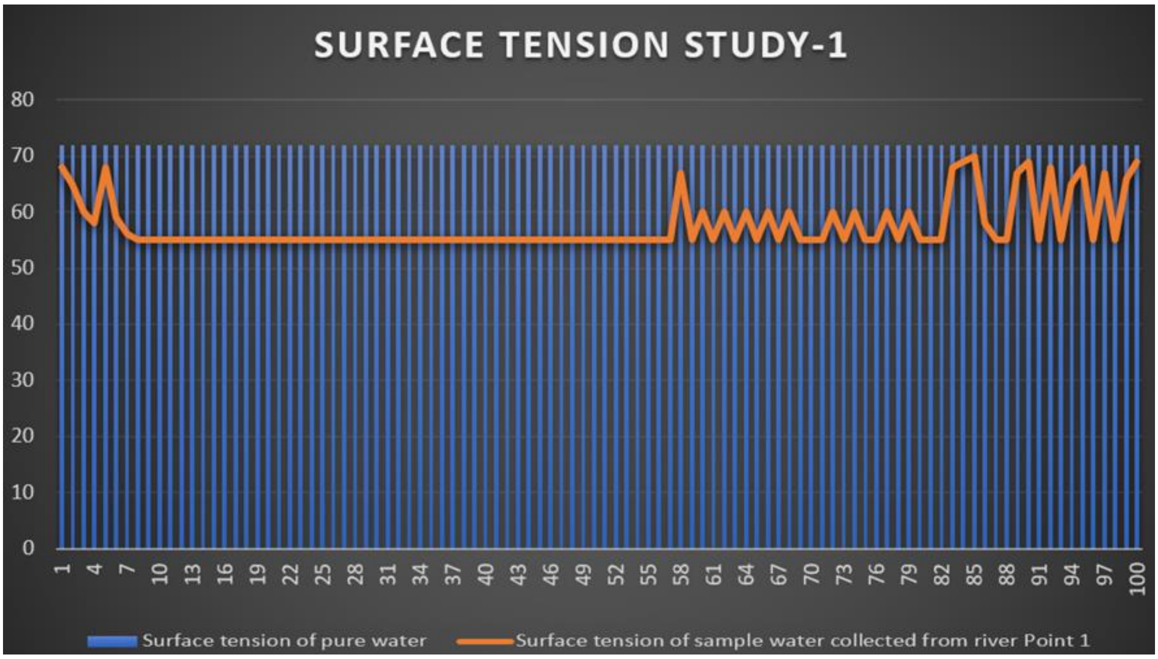


(d) Surface tension at point 4.

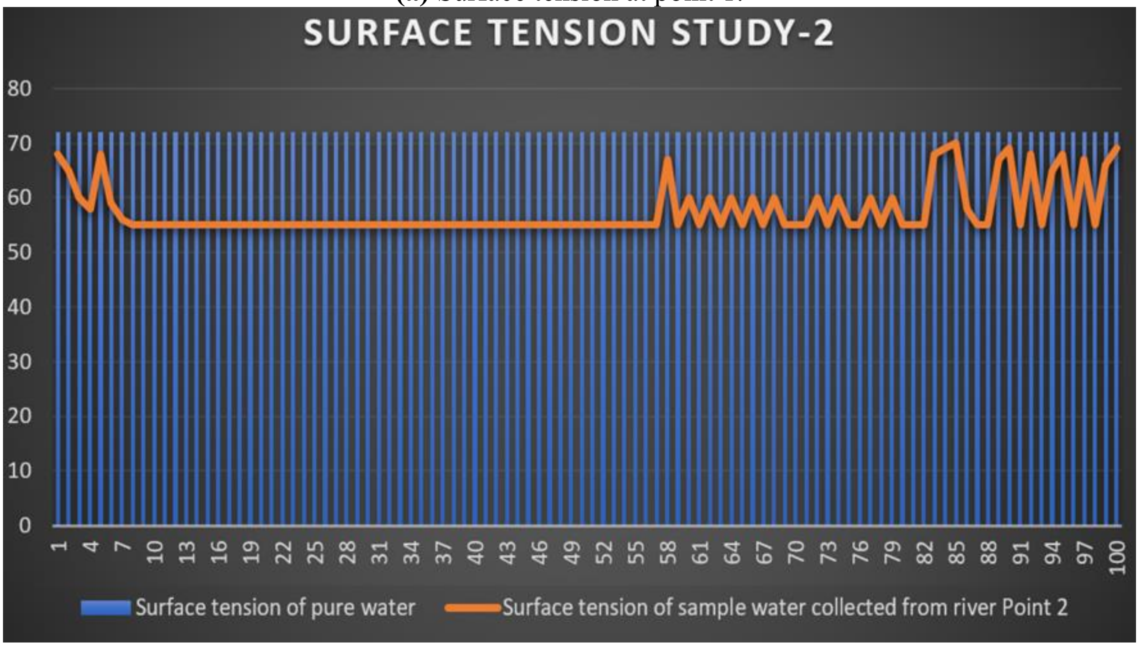


(e) Surface tension at point 5.

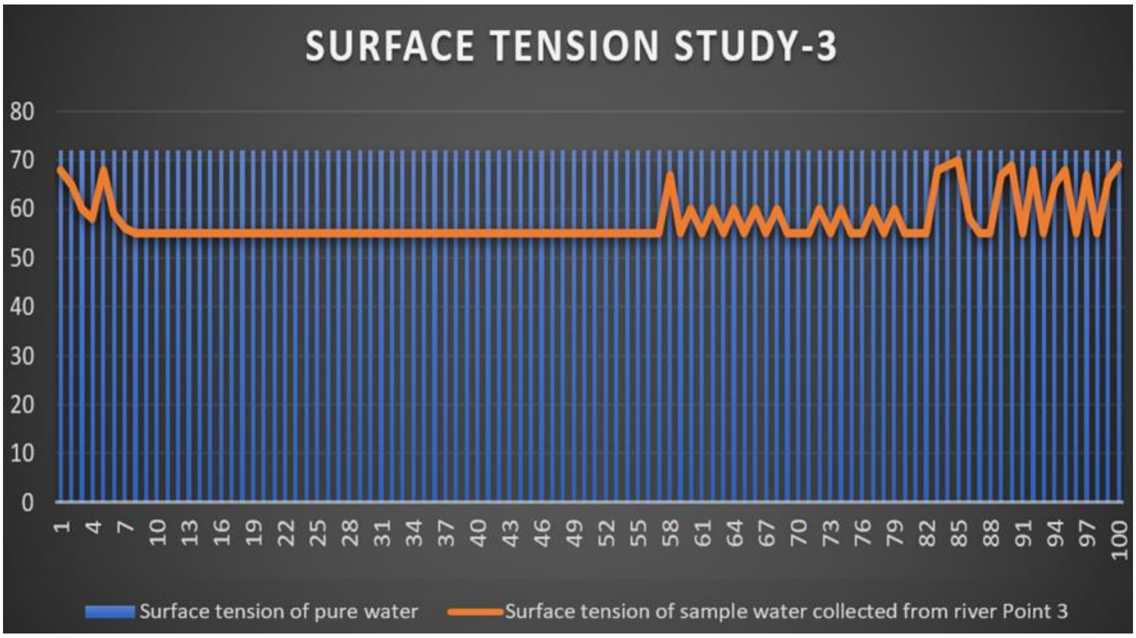
Figure 5. Assessing aquatic contamination via surface tension analysis: Discernment from samples collect at the Victoria Bridge points.



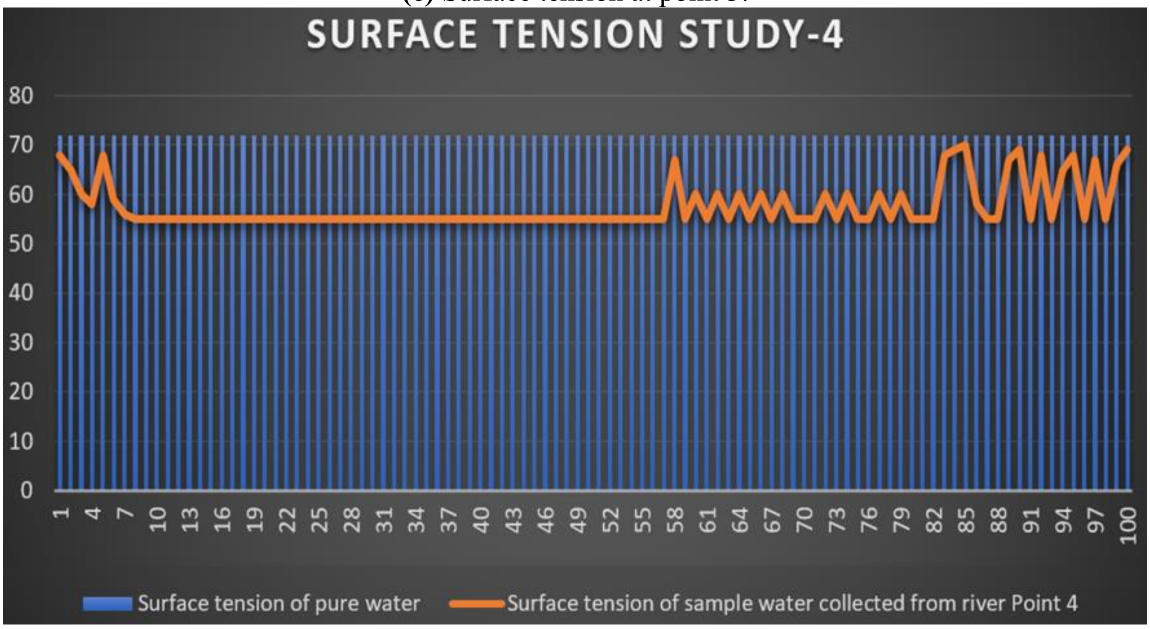
(a) Surface tension at point 1.



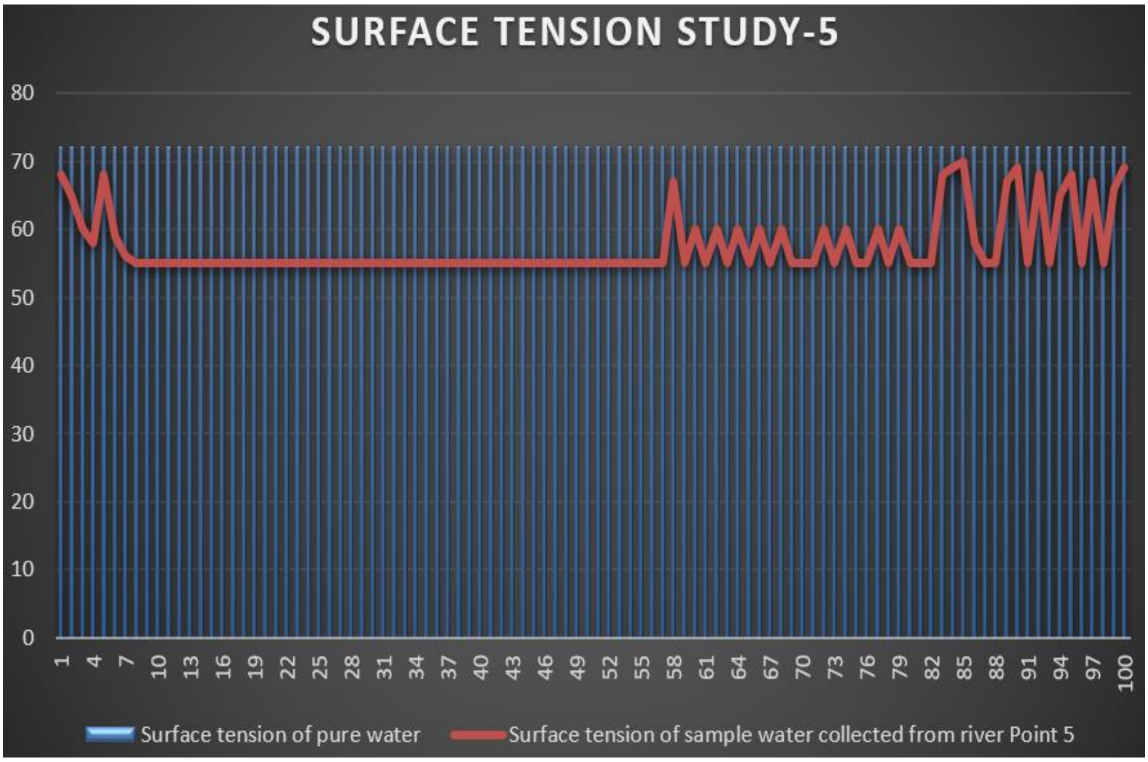
(b) Surface tension at point 2.



(c) Surface tension at point 3.

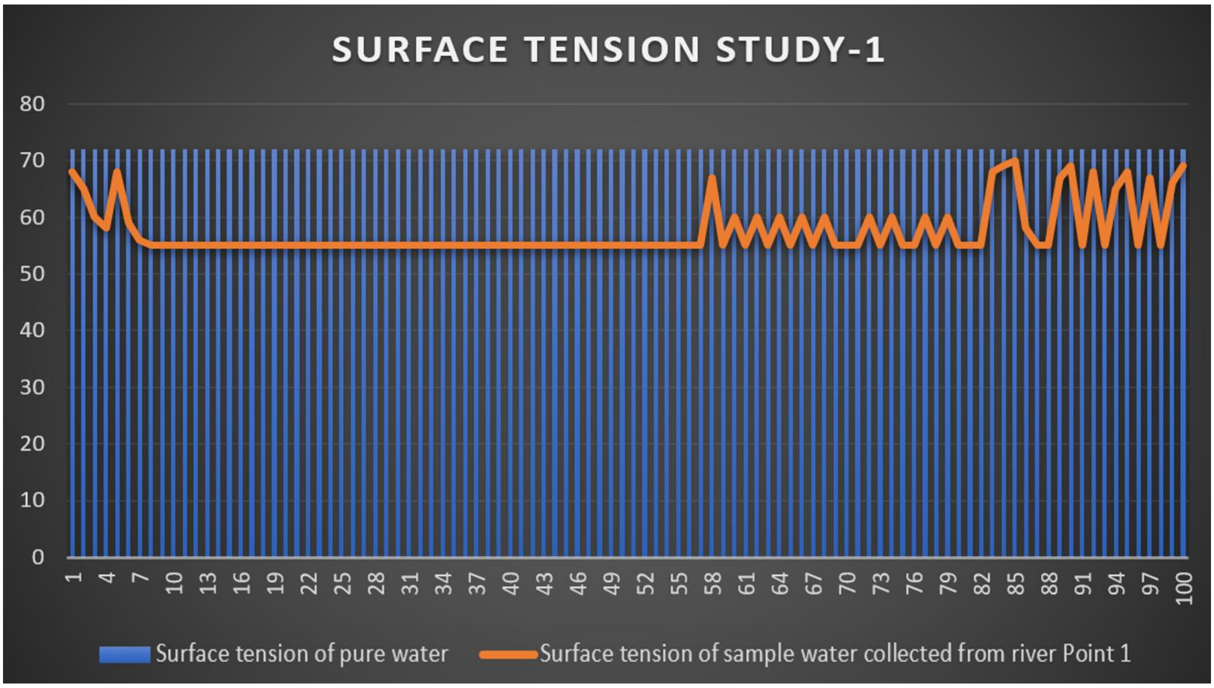


(d) Surface tension at point 4.

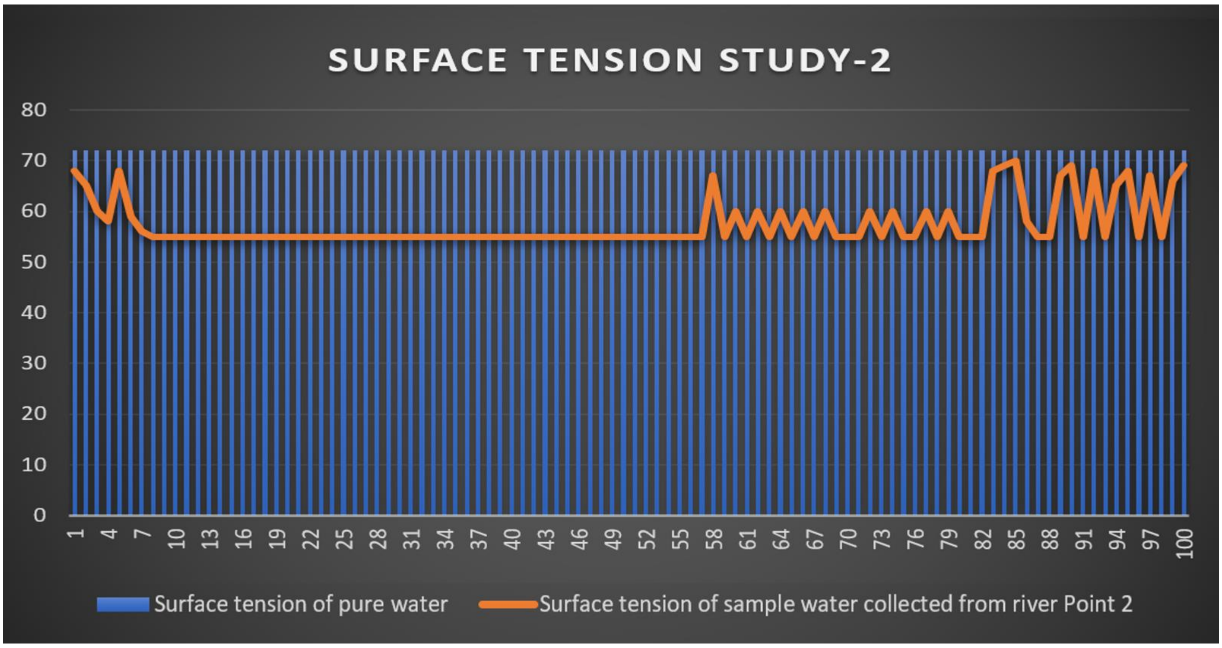


(e) Surface tension at point 5.

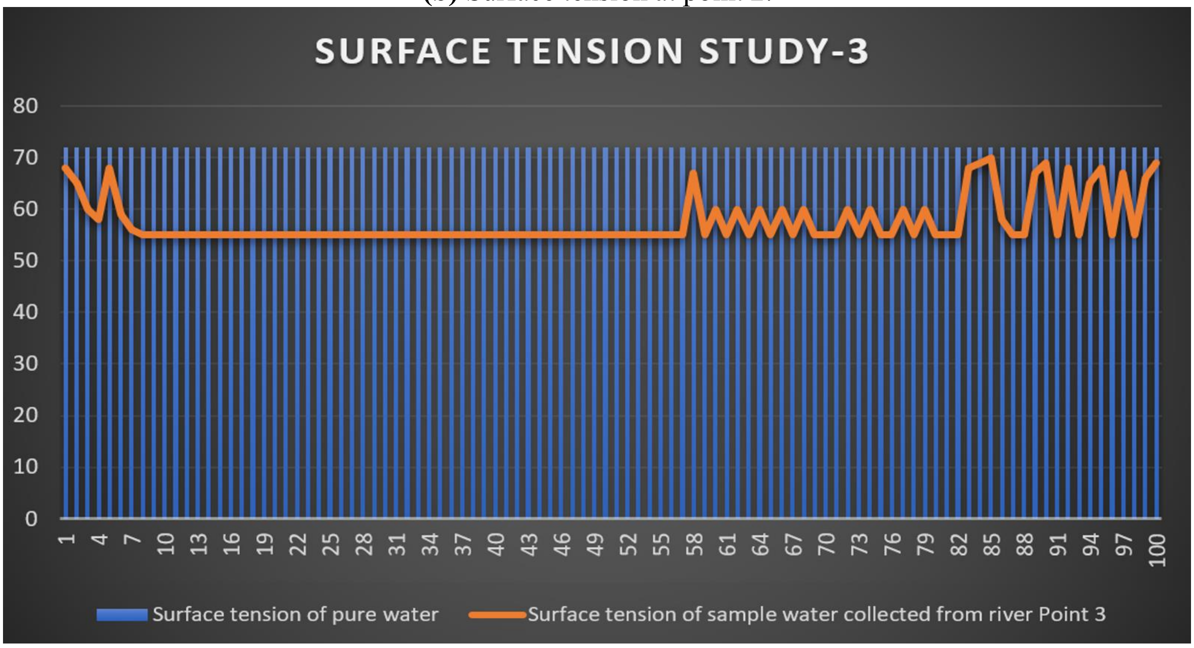
Figure 6. Assessing aquatic contamination via surface tension analysis: Insights from samples collect at the Tapovan Bridge points.



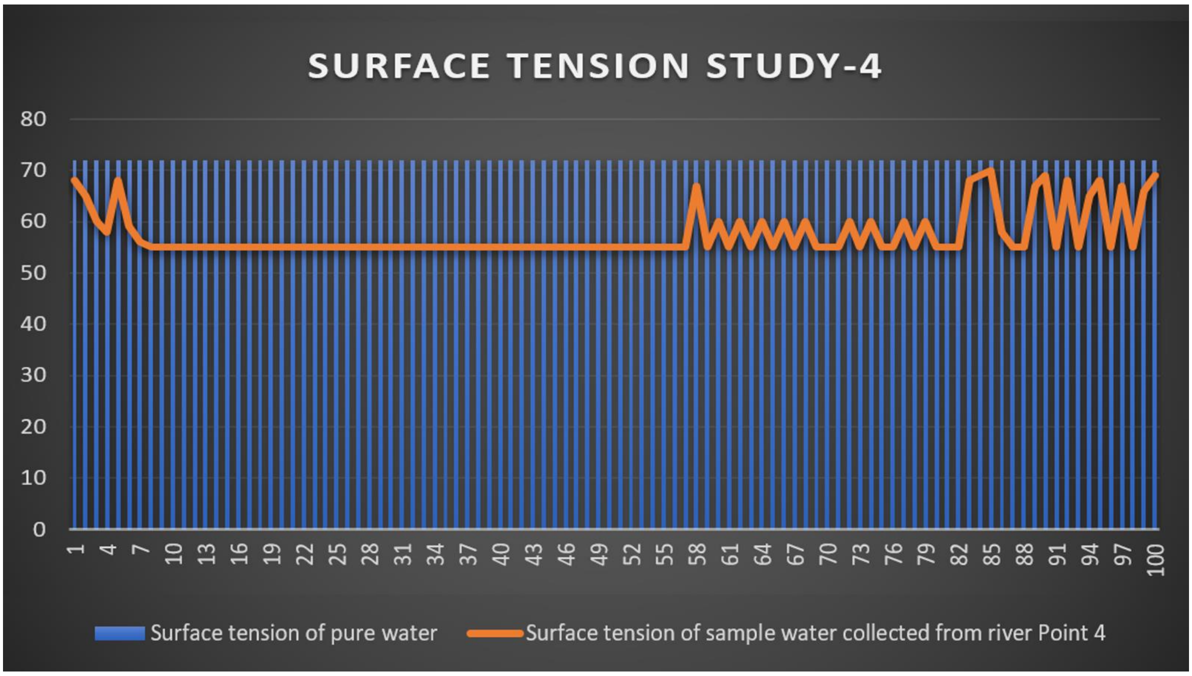
(a) Surface tension at point 1.



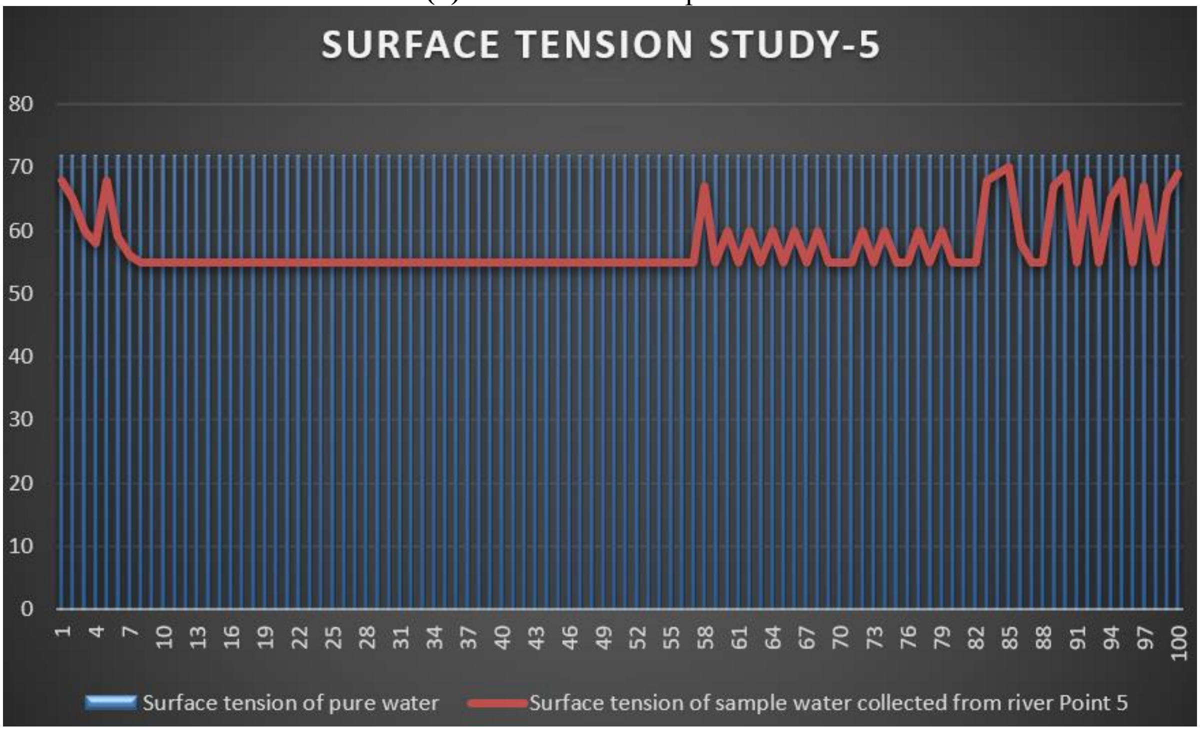
(b) Surface tension at point 2.



(c) Surface tension at point 3.



(d) Surface tension at point 4.



(e) Surface tension at point 5.

Figure 7. Assessing aquatic contamination via surface tension analysis: insights from samples collected at the Dasak Bridge points.

5.2. Foaming index

The foaming index shows no more foaming ability of the water than 1.5 cm to 2 cm on average at all sites of study, and thus no significantly high levels of detergents or shampoo or soap were determined at the time of study.

Determination of suspended particles in water: *The mass of suspended particles is calculated by multiplying the weight difference (in grams) by 1,000 to convert to* *milligrams.*

These results demonstrate the variability of suspended particle concentrations across different water samples, highlighting the importance of such measurements in assessing water quality (**Table 2**, **Figure 8**).

Below are the records of results for 10 samples represented in **Table 2**:

Table 2. Measurements of suspended particles collected from water samples. The samples are allocated as specified in the research methodology section and illustrated in **Figure 2**.

Sample number	Initial cloth weight (g)	Final cloth weight (g)	Suspended particles mass (mg)
1	5.000	5.012	12
2	5.000	5.015	15
3	5.000	5.010	10
4	5.000	5.020	20
5	5.000	5.008	8
6	5.000	5.018	18
7	5.000	5.011	11
8	5.000	5.014	14
9	5.000	5.009	9
10	5.000	5.017	17

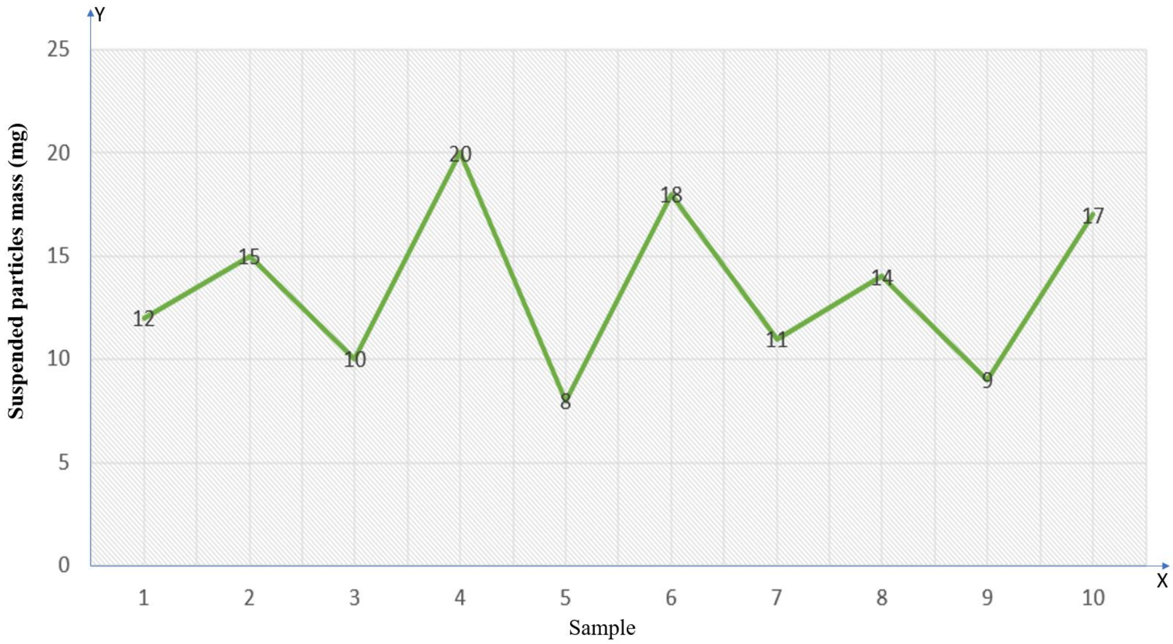


Figure 8. Graphical representation of suspended particles was recorded and analyzed and plotted for visual aid.

5.3. Results records for ANOVA

Table 3. Results record for ANOVA: The analysis of variance (ANOVA) conducted on the surface tension measurements across the five sampling points revealed statistically significant variations, indicating that the surface tension levels differed meaningfully between locations.

One-Way ANOVA					
Null Hypothesis: All Means Equal					
Alternate Hypothesis: At Least one Mean not Equal					
	df	SS	MS	*F* Score	*P* Value
Treatment	4	1766.1066	441.5267	192.6402	0
Errors	45	103.1389	2.292		
Reject Null: 0 ≤ 0.05					

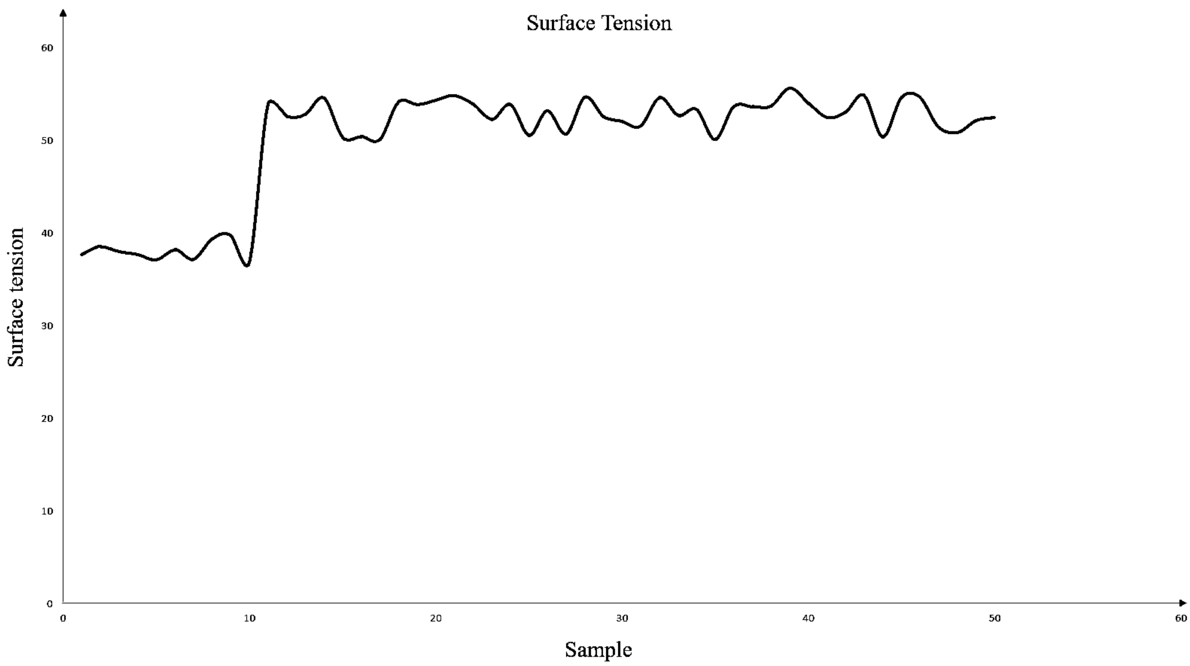


Figure 9. Interpretation of surface tension at the different points of sampling of different sites across the sampling locations, respectively.

5.3.1. Utilizing specific gravity as a preliminary indicator for contaminant detection in river water quality assessment

Specific gravity was measured to assess whether the river water has been contaminated or mixed with other substances that are similar to water, such as chemicals, salts, metals—including heavy metals—or other potential pollutants. This parameter serves as a preliminary indicator of the presence of impurities beyond common dissolved salts. While residual dry weight analysis can provide a more precise estimate of total dissolved solids, specific gravity offers a rapid, initial assessment that helps guide further laboratory testing. It is a valuable diagnostic tool for determining the potential extent of contamination and for identifying which detailed analyses may be necessary, enabling a more targeted and efficient approach to water quality assessment.

5.3.2. Surface tension as a diagnostic tool for assessing water purity and detecting dissolved impurities

Surface tension serves as a key indicator in evaluating the purity of water, offering insights into the presence and nature of dissolved substances. When water is mixed with other liquids or impurities—particularly those with properties similar to water—its surface tension typically decreases. This reduction can signal contamination and provide clues about the type and concentration of dissolved materials. Pure water exhibits a relatively high and stable surface tension, while the presence of pollutants disrupts molecular cohesion, resulting in noticeably lower values. The correlation between impurity levels and changes in surface tension is consistent and measurable, making surface tension analysis a powerful preliminary tool. It enables rapid estimation of impurity content, allowing for efficient identification and further targeted testing of contaminants in water samples.

5.3.3. Evaluation of foaming index and phenol detection for identifying surfactant and phenolic contaminants in drinking water

The foaming index serves as a useful indicator for detecting the presence of soap-like substances or detergents in drinking water. It provides valuable knowledge, a window or insight into surfactant contamination, which may affect water quality and safety. On top of that, a separate phenol detection test can be conducted to specifically identify the presence of phenolic compounds, further aiding in the comprehensive assessment of water contamination.

5.3.4. Quantitative assessment of suspended particles for estimating impurity levels in water

Determining the amount or number of suspended particles in water provides the percentage of such impurities present, offering a clear indication of the impurity level relative to the total water content.

5.3.5. Integrated preliminary assessment methods for detecting contaminants in river and drinking water quality analysis

The comprehensive evaluation of river and drinking water quality using multiple preliminary indicators—such as specific gravity, surface tension, foaming index, phenol detection, and suspended particle analysis—provides an effective and efficient approach to identifying a wide range of contaminants. Specific gravity offers a quick initial estimate of potential pollutants like salts, chemicals, and heavy metals, serving as a useful guide for more detailed laboratory testing. Surface tension further enhances this assessment by revealing subtle changes in water purity due to the presence of dissolved impurities, with measurable shifts indicating contamination levels. The foaming index, along with targeted phenol detection, is crucial for identifying surfactants and phenolic substances commonly found in household and industrial waste, which can significantly impact water safety. Meanwhile, the quantification of suspended particles delivers direct insight into the physical impurity load within the water, offering a reliable metric for assessing overall contamination. Together, these methods form a robust, multi-parameter framework for early-stage water quality analysis, enabling timely identification of pollutants and supporting the development of effective remediation strategies.

5.4. Source of potential error

A possible source of error in the experimental procedure could be unintentional, random, human error during sample collection, as well as the risk of sample contamination or mixing with foreign substances at the time of collection or at the place of collection.

6. Conclusions

A thorough investigation of surface tension and specific gravity variations is included in this environmental scientific study report on the evaluation of water quality in the Godavari River in Nashik, India. The study highlights the significant variations in specific gravity and surface tension among different water samples from the River Godavari, influenced by various contaminants. Saline water showed the highest specific gravity due to dissolved salts, while the presence of detergents and organic pollutants led to a notable decrease in surface tension, impacting pollutant dynamics in aquatic environments. These findings emphasize the critical need for comprehensive water quality monitoring and targeted remediation strategies to ensure the health and safety of communities relying on the river, particularly in the face of extreme climatic events. Specific gravity (SG) serves as an essential parameter in assessing water quality, reflecting the presence and concentration of various contaminants. This study examines the SG values of water samples under different conditions: pure water, polluted water, saline water, water with detergent, slightly muddy water, and slightly ash-filled water. The findings indicate that the introduction of contaminants or additives leads to measurable increases in SG, with saline water exhibiting the highest value (1.025 g/cm^3) due to dissolved salts. Water samples containing detergent, mud, and ash showed moderate increases in SG, corresponding to the nature and concentration of the added substances. These results emphasize the utility of SG measurements as a preliminary indicator of water contamination, facilitating the identification of pollution levels and informing subsequent, more detailed analyses. Presently, the river does not show any major signs of threat and pollution in its entire coverage where the study was carried out. Majorly, upon direct measurement, the water samples exhibited no significant levels of detergents or shampoos, as indicated by a low foaming index. When a known shampoo was introduced to the water samples, the resulting foam production was slightly lower than that observed with pure water, suggesting that the water does not exhibit characteristics of hard water. Typically, hard water contains elevated concentrations of calcium and magnesium ions, which can interfere with the foaming ability of soaps and detergents. However, in this case, the water's composition did not adversely affect foam formation, indicating a relatively low hardness level. The one-way ANOVA results indicate that surface tension values are not consistent across all samples and sampling locations, suggesting significant differences in water characteristics at the various points.

Future research may focus on employing FTIR (Fourier Transform Infrared Spectroscopy) for the identification of inorganic compounds, chemicals, and salts present in water samples. Along with that, HPLC (High-Performance Liquid Chromatography) can be utilized to analyze and quantify various impurity components. Complementary techniques such as column chromatography and paper chromatography could also be applied to detect and estimate the presence of pigments and chemical substances, offering a more comprehensive understanding of water contamination at a detailed analytical level. On top of that, reinforcing the need for continuous monitoring and pollution control in the river's management could be required each season.

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