Impact of Human Settlement on River Water Quality in Quepem Town

A Dissertation for

Course code and Course Title: ENV 651 & Discipline Specific Dissertation

Credits: 16

Submitted in partial fulfilment of Master's Degree

M.Sc. in Environmental Science

by

SHAWN FERNANDES

Seat No: 22P0580006

ABC ID:571335545999

PRN: 201811948

Under the Supervision of

DR. VARADA S. DAMARE

School of Earth, Ocean and Atmospheric Sciences

M.Sc. Environmental Science

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Seal of the School

DECLARATION BY STUDENT

I hereby declare that the data presented in this Dissertation report entitled, "Impact of Human Settlement on River Water Quality in Quepem Town" 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 Dr. Varada S. Damare 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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Shawn Fernandes
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Date: 2/05/2024
Place: Goa University

COMPLETION CERTIFICATE

This is to certify that the dissertation report "Impact of Human Settlement on River Water Quality in Quepem Town" is a bonafide work carried out by Mr. Shawn Fernandes 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.

Date: 02/05/2024

Dr. Varada S. Damare

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Senior Prof. Sanjeev C. Ghadi
Dean
School of Earth, Ocean and Atmospheric Sciences

Date:
Place: Goa University

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PREFACE

Water is a fundamental resource essential for sustaining life and ecosystem, yet it is increasingly threatened by human activities. The rapid growth of human settlements along riverbanks and their associated infrastructural developments poses significant threat to the water quality and health of the adjacent water bodies through sewage disposal and dumping of waste. The dissertation presents a comprehensive study conducted on the Kushavati river, which flows through the Quepem town, aimed to evaluate the influence of human activities on its water quality.

The human settlement in Quepem town has given rise to various challenges, chief among them being the generation and disposal of significant quantities of solid waste, much of which finds its way into the Kushavati river. Concern over the potential impact of this waste on water quality gave rise to the initiation of the present study. The study spanned from November 2023 to March 2024, encompassing the dry season, including post-monsoon, winter, and spring periods. Five sampling locations were chosen, including four within the town and one at a farther distance. Various physio-chemical and biological parameters were tested including temperature, pH, salinity, turbidity, total dissolved solids, electric conductivity, dissolved oxygen, biological oxygen demand, alkalinity, acidity, chlorides, phosphate, nitrite, total bacterial count and yeast and fungal count. The obtained results were compared against the standard set by Bureau of Indian Standards, providing a robust framework for evaluating water quality. The dissertation contributes to the existing body of knowledge on water quality assessment and provide valuable insights for policymakers and stakeholders in developing sustainable strategies for the preservation and management of water resource in similar contexts.

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Shawn Fernandes

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LIST OF ABBREVATIONS

Abbreviation	Full-form
DO	Dissolved Oxygen
BOD	Biological Oxygen Demand
TDS	Total Dissolved Solids
EC	Electric Conductivity
BIS	Bureau of Indian Standards
WHO	World Health Organisation
Mg	Magnesium
Ca	Calcium
EBT	Eriochrome Black T
EDTA	Ethylenediamine Tetraacetic Acid
%	Percentage
NaOH	Sodium hydroxide
NTU	Nephelometric Turbidity Unit
µs	Micro siemens
cfu	Colony forming unit

ABSTRACT

Water quality assessment of Kushavati river flowing adjoining Quepem town was carried out to check the impact of human settlement on its quality. This was done from November 2023 to March 2024, representing the dry season, i.e. post-monsoon, winter and spring. The surface waters were tested for pH, salinity, total dissolved solids (TDS), electric conductivity, turbidity, dissolved oxygen (DO), hardness, alkalinity, acidity, chlorides, biological oxygen demand (BOD), phosphates, nitrates and bacterial and fungal counts. Temperature ranged from 23.5-25 ^{o}C, pH from 6.77-7.36, DO from 6.34 – 7.64mg/l, BOD from 0.325 – 1.318 mg/l, phosphates from 0.115 mg/l – 0.171 mg/l, nitrites from 0.011 mg/l – 0.020 mg/l, chlorides from 11.99 mg/l – 23.99 mg/l, hardness from 19.31 mg/l – 29.17 mg/l, turbidity from 1.09 NTU – 4.96 NTU, TDS from 38.48 mg/l – 88.98 mg/l, etc. All these results were significant and within the BIS standards as seen by the t test. Bacterial counts varied from10^2-10^5 cfu/ml, yeast counts from below detection levels to 10^2 cfu/ml. These results indicate good quality of Kushavati river water. Though the dumping of solid waste seemed to have no adverse effect on water quality, it can decrease its aesthetic value and thereby its portability for various use like recreation and domestic purpose if continued for long term. The loction which was distant from human settlement had much better values of all the parameters as compared to the locations near human settlements. The dumping of waste generated through the human settlement can hamper the water quality in the long run and this issue therefore needs to be tackled by suggesting certain mitigation measures.

Key words

Kushavati River, Human settlement, Quepem town, physio-chemical and biological parameters.

CHAPTER 1: INTRODUCTION

1.1 General

Fresh water is an essential resource because it only makes up to 0.3 percent of all the water on earth. Water is essential for life and plays a significant role in how humans grow and stay alive (Balasubramanian, 2015). The river is one such kind of freshwater source. It is a naturally flowing stream which makes its way down from its source to its mouth which is usually an ocean, lake or another river. Goa, a twenty-fifth state of the Indian Union with an area of 3,702 sq. km. is blessed with 11 important rivers. This include Mandovi, Zuari, Therekhol, Baga, Colval, Saleri, Mandre, Harmal, Sal, Talpona, and Galjibag. These 11 rivers along with their 42 tributaries are significant for Goa, not only because of their water supply but also contributing to Goa's economy and biodiversity. Most of these rivers originate from the western ghats and end up in the Arabian sea. The rivers form an integral part of Goa's life by supporting agriculture, providing drinking water, and facilitate transportation. Additionally, the two major rivers, the Mandovi and Zuari river contributes to Goa's economy by supporting the tourism industry, offering activities like river cruises, cassinos and water sports. Overall, the rivers in Goa are a multifaceted resource, impacting various aspects of state's socio-economic and environmental well-being.

Rivers have a great significance in Goa in terms of its culture, economy and ecology.

- Cultural significance

Religious practices: many rivers in Goa are linked with religious practices which includes performing ceremonies like immersion of idol, bathing in water for purification, etc.

1. Festivals: rivers are important for celebration of festivals like Ganesh Chaturthi and Shigmo. Without rivers, these festivals would be incomplete.
2. Traditional practices: rivers play an important role in old age traditional practices like fishing. These practices are also a source of income for some communities.
3. Cultural Heritage sites: there are many cultural heritage sites that are situated on the banks of river like forts and temples. These sites provide historical and cultural identity to that area.

- Economic Significance
    1. Agriculture: river water provides irrigation facilities for agriculture. Goan farmers depend upon rivers like Mandovi and Zuari for cultivating their crops like rice and vegetables.
    2. Tourism: Goa is famous for its tourism activities. These activities are not only restricted to beaches but also takes place or rivers such as river cruises and boat ride like kayaking. The activities generate a lot of income for both the state as well as for the local businesses.
    3. Ecotourism: mangroves and wetlands situated along the riverbank provides opportunities for ecotourism. These diverse ecosystems attract tourist thought the world.
    4. Water supply for industry: many rivers in Goa act as a source of water for industries. Industries in Goa rely on rivers for their water supply
- Ecological significance

1. Mangrove ecosystem: riverbanks and estuaries host mangrove ecosystem. These mangroves provide area for breeding, food and shelter for fishes and other aquatic life. They also protect from coastal erosion and act as major carbon sink.

2. Biodiversity hotspots: rivers act as a rich biodiversity hotspot. It contains different species of fishes and other aquatic life including crocodiles and water snakes.
3. Nutrient cycling: rivers help in nutrient cycling by transporting nutrients and other organic matter downstream. This can help to nourish the ecosystem present downstream.

1.2 Kushavati River

Kushavati river is a tributary of Zuari river. It originates in the Sahyadri Hills of the Western Ghats and flows through Sanguem and Quepem taluka before emptying in Zuari river. it is approximately 42 km long. In Quepem taluka it covers a distance of about 20 – 22 km and provides water for various purposes including irrigation, daily use and recreational purposes. It has an aesthetic value and adds to the scenic beauty of Quepem taluka.

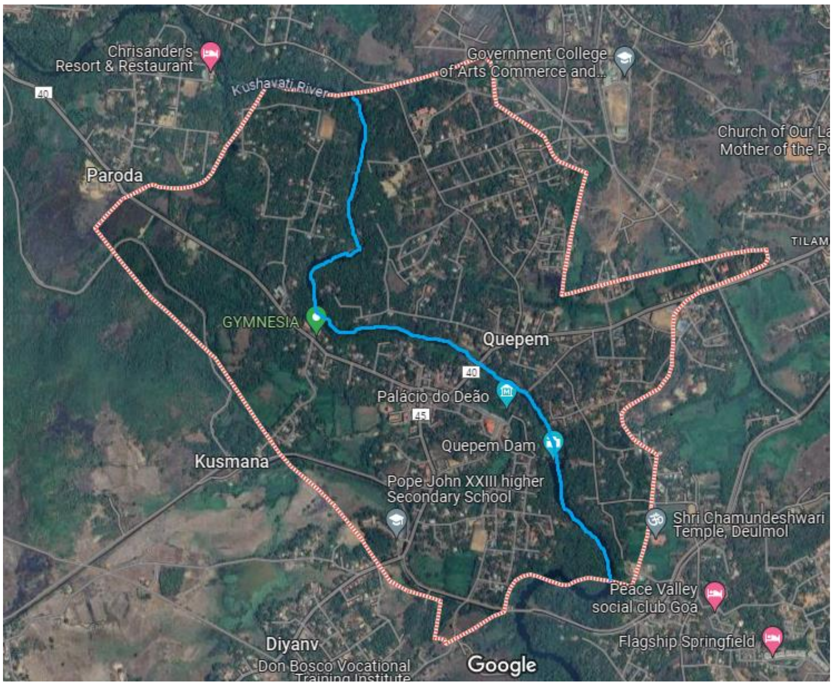


Fig 1.1: Flow of Khushavati River in Quepem Town.

1.3 Human Settlement and Its Impact on River

Rivers have been the backbone for nearly all human settlements for generations. Indeed, the development of many major cities in the world has been close to rivers which have being used by communities to meet their essential needs for drinking water, irrigation, agriculture and the assimilation of the waste (Adeloye,1990). Human settlement refers to the permanent or semi - permanent communities where people live. These can range from small villages and town to large cities. Human settlement provides communities with resources like housing, transportation and essential services like schools and health care services which help them to thrive. A human settlement is characterised by the population density that is the number of people living in the area, infrastructure like schools and hospitals, economic activities such as agriculture, industry and services, cultural and social institutions such as religious centres and community gathering and governance of panchayat or municipality.

Though human settlement provides communities with resources and vital services, it can have negative effect also. These negative effects are mostly occurring on the environment around the human settled area. For example; if a human settlement inhabits on the banks of a river, it negative effects can be seen on the river. Some ways in which human settlements can influence river water are;

- Water quality: settlements can often release pollutants in the river through sewage which will reduce the water quality and affect both the aquatic life as well as its suitability for drinking purpose.
- Habitat alteration: development along the banks of the river can cause destruction or alteration of the natural habitat which can disrupt the areas used for shelter, food and breeding.

- Flooding: improper land use planning and construction can cause flooding in the nearby areas.
- Water extraction: human settlement requires large amount of water for various purposes. Over extraction of water can lead to reduce the flow of water in the river which affects both the aquatic life as well as its availability for downstream use.
- Erosion and Sedimentation: construction, deforestation and improper land use planning can increase the amount of sediment entering the river which can lead to erosion and sedimentation downstream.
- Introduction of invasive species: human settlement can introduce invasive species to the ecosystem through recreational activities like boating. These invasive species will outcompete the native species and disrupt the ecological balance.
- Dumping of solid waste: rivers not only provide resources and services but also add to the aesthetic value of any area. The dumping of solid waste generated through human activities in and around the rivers can decrease this aesthetic value. It can also discourage recreational activities like swimming, boating and fishing in the affected areas.

1.4 Water Quality Testing and Its Importance

Rivers are a vital source of freshwater for life but are deteriorating due to the release of industrial and domestic wastewaters (Desai, 2014), agricultural runoff, etc. (Khatri & Tyagi, 2015; Onglry, 1998). Since rivers have a great significance in Goa and they can be grievously affected by human settlement, it is necessary to protect them. One way by which rivers can be protected from further degradation its by testing its water quality. Water quality testing is a scientific process which evaluates waters portability for various purposes. This is done by analysing different physical (pH, temperature, salinity), chemical (Dissolved oxygen, BOD), and biological (bacterial count) parameters. By analysing these parameters, one can get complete information on quality of water. This information is valuable for different areas including

- Public health: by conducting water quality test one can ensure that the water is safe for public use. These may also prevent the spread of water borne diseases that hampers public health.
- Environment protection: testing water quality, especially for rivers can help in protecting the aquatic life. Fishes and other aquatic life cannot survive if the water quality is not within their acceptable limit. So, by conducting water quality test one can find out which are the parameters which are not within the acceptable limit so as to produce effective mitigation measures.
- Scientific evidence: the water quality report can be used as scientific evidence for any legal framework. It can be used against any industry who are participating in polluting the water through their sewage discharge or dumping.
- Recreational activities: water quality tests ensure the safety and portability of water for recreational activities like swimming. These can protect individuals form possible health impacts due to contaminated water.

Under water quality there are various parameters. Each parameter will have separate procedure and requirements. Some parameters must be tested on the site like temperature using portable instruments which others are tested in the lab by collecting samples. After the analysis, the obtained results can be interpreted based on one's objectives. For example, the results can be compared with the BIS (Bureau of Indian Standards). It is a National Standard body in India under the Ministry of Consumer Affairs, Food and Public Distribution, Government of India which formulates certain values called as the permissible and acceptable limits for different parameters. These limits describe the water quality in India. These drinking water quality guidelines and standards are designed to provide clean and safe water for human consumption (AI-Janabi et al. 2012). Any water body with values within this limit is considered as good water and is suitable for its intended use. These BIS are followed throughout India for testing water quality, whether it may be a research institute or government organisation.

So, from the above introduction it is clear that human settlement can have impact on the water quality of river. The question here is that whether human settlement in Quepem town have any impact on the water quality of Kushavati river, especially through the dumping of waste.

1.5 AIM AND OBJECTIVES

AIM

The present study aimed to study the impact of human settlement in Quepem town on water quality of Kushavati River.

OBJECTIVES

Based on the aim, the objectives put forth to study the loopholes are as follows;

1. To determine the water quality of Kushavati River in Quepem town.
2. To compare the water quality of the same between regions of human settlement and distinct from human settlement (spatial variation).
3. To compare the temporal variation in water quality.
4. To find out the factors responsible for existing water quality by analysing the parameters.

1.6 HYPOTHESIS

Water quality is being affected negatively by human settlement. Irrespective of the season and time of sample collection, dumping of waste hampers water quality.

Fig 1.2: Source for the hypothesis: Dumping of solid waste in and around the Kushavati River.

1.7 SCOPE OF THE STUDY

1. The study can be used as a scientific evidence and secondary data. If the water quality is affected by human settlement, the report can be used as scientific evidence to prove it. It can also be used as secondary data by other students for their dissertations to compare the variation, whoever wish to work on water quality.

2. The findings of the dissertation are important for developing effective mitigation measures. From the results obtained one can identify which are the factors that affect the water quality and based on that effective mitigation measures can be developed.

CHAPTER 2: LITERATURE REVIEW

Sreenivasa and Asode (2015) from the Department of Studies in Geology, Karnataka University carried out research on assessing the water quality of Galgibagh River Sub-basin (GRSB) for its portability for drinking and irrigation purpose. Twenty-five samples were collected from different sources to analyse the physio-chemical parameters including pH, Total Dissolved Solids (TDS), Total Hardness (TH), Calcium (Ca), Magnesium (Mg), Chlorides (Cl) and Sulphate (SO_4) using standard procedures of APHA. The obtained TDS values were classified with Freez and Cherry (1979) which revealed that 64% water samples were fresh water and 36% brackish. The hardness values were classified with Sawyer and McCarthy (1967) revealing that the water was soft. The EC values were compared based on Sarma et al (1982). It was found that 68% water samples fell under class good and 32% under permissible. To check the waters portability for domestic purpose, the obtained readings were compared with BIS and WHO and it was found out that all waters were fit for domestic use. Next, to check the waters suitability for irrigation some calculations and graphs were used. First, the SAR (Sodium Absorption Ratio) was calculated. This measures the proportion of sodium ions in water. The calculations revealed that the water samples fell in class excellent. This data along with the conductivity values were plotted in the US Salinity Laboratory (USSL, 1954). The diagram revealed that 84% samples fell under field C2S1 that is medium salinity and low alkalinity, while 16% fell under field C3S1 which is high salinity and low alkalinity. The calculated Sodium Percent values revealed that 28%, 40%, and 16% of water samples fall under class excellent, good and permissible respectively for irrigation suitability and the remaining 16% were doubtful. The Wilcox (1955) diagram showed that 84% of the samples fall in excellent to good category followed by 2% % of each falling in good to permissible and permissible to doubtful.

Secondly, the RCS (Residual Sodium Carbonate) values were calculated and based on the classification 84% water samples fall under category good while 12% and 4% were doubtful and unsuitable. The research was concluded stating that all the waters of GRSB were fit for domestic purpose while 84% of the waters were fit for irrigation purpose.

Similar research was done by Sing and Kamal (2013). They assessed the quality of surface water in Goa using the water quality index. A total of 36 water samples were collected from different locations throughout Goa in two seasons (pre-monsoon and post-monsoon). The samples were collected from areas of different land use pattern like agriculture, mining, residence and barren. The collected samples were analysed for different physio-chemical parameters such as pH, TDS, Total Hardness, TSS, calcium, magnesium, calcium, chloride, nitrate, sulphate, DO and BOD. The Water Quality Index (WQI) was calculated from the results obtained after the analyses of the parameters. The WQI is a valuable and unique rating that depicts the overall water quality in a single term. This rating is valuable for selecting appropriate treatment techniques. The WQI are calculated using the drinking water standards recommended by WHO, BIS and ICMR. The WQI is categorised as follows: 0-25 is excellent, 26-50 is good, 51-75 is moderate, 76-100 is poor and > 100 is unsuitable. For monsoon the samples were found in the range of 34 to 83, 28 to 81 in winter, 34 to 86 in summer and 23 to 107 in monsoon. 94% of the samples were found within the range of good and moderate. 6% of the samples were found in poor range. The samples collected from the mining areas showed poor quality. This may be because of transportation of iron ore and the leaching from the piles dumped around the mining areas. The highest WQI values were found in monsoon season and lowest in post monsoon season. The water samples found in the range of good and moderate categories were fit for direct consumption while the samples found in range of poor categories were not fit for drinking purpose.

The Hindon river in Uttar Pradesh had become a destination for the dumping of unrelated industrial and domestic waste. To check its water quality, a study was conducted by Kumar, Kumar and Kumari from Amity University, Gurgaon (Kumar et al. 2018). The samples were collected from five locations from July 2016 to June 2017. The collected samples were analysed for physicochemical parameters including pH, EC, TDS and TSS, DO, BOD, COD, alkalinity, hardness, sodium, sulphate and nitrate. The results were compared with BIS and the WQI of the river was calculated. The pH of the water ranged between 6.44 to 7.91 which was within the standards. The EC values ranged between 1076 to 2122 us/cm. The TSS and TDS values ranged between 78 to 223 mg/l and 923 to 1342 mg/l respectively. According to the BIS standards, the permissible limit of TDS is >500 mg/l. Hence the TDS values for all the five locations were more than the permissible limit. High TDS values can cause public health issues like irritability, dizziness, provoking paralysis of tongue, lips and face. The total alkalinity values were also found more than the permissible limit. This may be due to concentration domestic waste and consumption of fertilizers in agriculture. Total hardness values ranged between 273-551 mg/l. The DO which is necessary for the survival of aquatic organism were found less than the permissible limit. It ranged between 0.8-5.1 mg/l. low DO level indicated high demand of oxygen by microorganisms to decompose the organic matter. As a result, the BOD of the water was found relatively high that is between 74-141 mg/l which is more than the standard limit of >3 mg/l. the COD values for Hindon river ranged between 232-532 mg/l. Calcium and magnesium values were also found out of the standard permissible limit. Only the nitrates and sulphate concentration values were found within the permissible limit. This is mainly because of small number of human activities near the river. Sodium concentration was found between 10-32 mg/l. The WQI was calculated for the Hindon river. The values ranged between 1369 to 2199 for all the locations. From the obtained index values, it was interpreted that the water quality of Hindon river was deteriorated at all location and was unsuitable for drinking, fish farming and irrigation purpose. The water quality was found more deteriorated in the monsoon season. The main reasons for this were industrial activities and domestic sewage disposal. To recover the water quality of Hindon river, the sewage must be treated before discharging in the river.

Rai et al. (2011) conducted similar type of research on River Ganga in Patna, Bihar, to check the water quality which was subjected to domestic and swage pollution. The water quality was estimated based on the physiochemical parameters including pH, electric conductivity (EC), Alkalinity, Total Solids (TS), Hardness, Chloride, Dissolved Oxygen (DO), Biological Oxygen Demand (BOD) and Most Probable Number (MPN). Two sampling sites were selected where people would perform holy dip, washing of clothes, bathing and discharge of local waste throughout the year. The study was done for pre-monsoon and post-monsoon in the year 2010 and the obtained results were compared with WHO standards to estimate the water quality. The pH was higher in the summer season which may be due to increase photosynthesis of algal blooms resulting in precipitation of calcium and magnesium. A narrow variation was seen in EC due to the lithology of the river. Alkalinity of the river was found higher than the limit indicating the presence of weak and strong bases of carbonates, bicarbonates and hydroxides which may be due to the increase of free carbon dioxide in the river. Soil erosion in the catchment and domestic effluents had led to higher TS in the study area. Hardness of water is due to the presence of dissolved calcium, magnesium, and mineral salts such as iron. Hard water can affect the digestive system by causing calcium oxalate in the urinary bladder. Hardness was found high in the summer season due to the increase salt concentration from evaporation. Chlorides level was found within the permissible limit. The sources of moderate chlorides level in the water can be due to the domestic sewage disposal. The dissolved oxygen of the water body was found within the limit required to support the aquatic life. BOD of water which is an important indicator of organic pollution was found higher at site 1 due to the organic waste discharge from various sources. MPN of the water body was found high due to the fecal matter, as a result the water was not fit for drinking and bathing. It was concluded by saying that the Ganga River was not fit for drinking purpose at the selected sites. Strict legal actions should be taken on those who are found contaminating the Ganga River by dumping waste.

Raghu and Vagish (2020) conducted research on the water quality of Tungabhadra River in Harihara town, Karnataka. The people of Harihara town were largely dependent on the Tungabhadra River for their daily use, but due to the sang mining in the town the river was polluted. The study focused on analysing the physio-chemical parameters to estimate the water quality. The parameters studied include pH, Turbidity, Dissolved Oxygen (DO), Biological Oxygen Demand (BOD), electric conductivity (EC), Total Hardness (TH), Chlorides and Total Dissolved Solids (TDS). Five sampling locations were selected on the river. Temperature was found high during the summer season because of increase solar radiation. The turbidity of the water was found high due to the ongoing sang mining in the study area. TDS was also found high due to the sand mining and dead organic substances. Another reason for high turbidity was the domestic waste water and garbage. The addition of carbonate and bicarbonate through the decomposition of vegetation had led to increase in alkalinity of the river. The BOD of the river was found high due to high bacterial activity and heavy organic waste in the water. As per the results obtained and analysed it seen that most of the parameters were above the permissible limit. The main reason was due to sand mining and domestic waste. It was estimated that if the present situation persist it will cause additional threat to the water in the future. To sustain the ecology of the river certain measure must be taken to mitigate the river pollution.

River Ravi, a tributary of the Indus River System was also studied for its water quality using the WQI method by Kumar and Dua (2003). The index condenses various water quality parameters into a single number, making it easier for the public to understand the overall water quality at a specific location and time. Eight key parameters, including pH, Total Dissolved Solids (TDS), Total Hardness, Calcium (Ca), Magnesium (Mg), Total Alkalinity, Dissolved Oxygen (DO), and electrical conductivity (EC), were considered for the WQI calculation. The sampling was done in Madhupur, Punjab, from January 2003 to December 2005. The calculated WQI values for the River Ravi ranged from 54.8 to 97.88, indicating generally good water quality at the sampling site, except for occasional dips below 70 during periods of increased human activity, such as dam operations, leading to pollution. Interestingly, even small amounts of certain parameters significantly influenced the index value. Thus, the WQI proves useful for comparing water quality across different sources and providing a general understanding of water-related issues in a given area. High WQI also support aquatic life since DO is the major consideration in WQI.

In Goa, Sawaikar and Rodrigues (2021) applied the CCME (Canadian Council of Ministers of the Environment) Water Quality Index (WQI) to assess the fresh water bodies. The reason was to check their suitability for drinking, recreational, irrigation, and livestock purposes. A total of four water bodies were selected; Syngenta Lake, Khandola Pond, Lotus Lake and Curtorim Lake. The samples were collected every month from January 2014 to December 2015. Total eight physicochemical parameters were analysed they were; pH, temperature, turbidity, TDS, BOD, nitrates, phosphates, and total chlorophyll. The results obtained were compared with WHO standards to estimate the WQI of the water samples. The pH of the waters ranged between 5.9 to 7.8 which were within the standards. The water bodies temperature varied between 25 to 31^{o}C, with maximum temperature recorded in May and minimum in January. The TDS values were found minimum in Khandola (32.60 to 51.45 mg/l) and maximum in Curtorim Lake (922 to !387 mg/l). Increased TDS levels can lead to eutrophication. Turbidity measures the water quality based on its clarity and TSS. The turbidity values ranged between 22 to 56.7 NTU (Nephelometric Turbidity Unit) for all the locations. Higher values were observed in monsoon season. This may be due to rainfall and surface runoff. BOD values showed significant difference throughout the study period with maximum values were found in summer and minimum in winter. High BOD in summer may be due to increase in oxygen demand for degradation of organic waste and low in winter may be due to low temperature that slows down the microbial activity. Higher nitrates level was found in monsoon and low in post-monsoon. Higher nitrates level in water can cause eutrophication. Some samples showed higher phosphate level. This may be due to the inflow of domestic waste, washing activities and cattle bathing. Also, the chlorophyll content was found higher in summer and post-monsoon in October. Comparing with the WHO standards, most of the parameters exceeded the limit. Eutrophication was found in Sygenta, Lotus and Curtorim lake while Khandola pond showed mesotrophic condition. The WQI for all the four water bodies showed poor water quality. The reasons were identified, they are; waste water, sewage, solid waste and chemicals from surrounding areas. To mitigate this issue some mitigation measures were also mentioned in the paper that is to implement utility-based restoration and development program and awareness camps to encourage the locals to maintain the ecology and hydrology of the water bodies.

Research was conducted to check the impact of development activities (construction of jetty) on the estuarine environment of Mandovi and Zuari River for Environmental Impact Assessment (EIA) in Goa by Pradan and Shirodkar (2007). The research examined the physio-chemical and biological data of water and sediment for different tidal periods. Factor analysis was carried out for the data which identified six factors explaining 91% of the total variance during high tide and 84% during low tide in Mandovi River. Similarly, in Zuari River, four factors explained 78% of the total variance during the low tide and six factors explained 83% during high tide. In the sediment analysis, two factors explained 73% of the total variance in Mandovi River and three factors explained 95% variance in Zuari River, regardless of tidal conditions. The study observed increase level of ammonia which could be due to the anthropogenic organic matter discharged in the river. Apart from this, high level of phenol, PHc, and Hg was observed which could be due to the industrial discharge, boat traffic, and barge building activities on the river banks. It was also seen that the construction activities caused disturbance to the unoxidized bed sediments which increase the turbidity and TSS that can release toxic trace elements and micronutrients in the water which can affect the aquatic life by increasing the oxygen demand in water.

CHAPTER 3: METHODOLOGY

3.1 Study Area

Quepem town is situated in South district of Goa which comes under the Quepem Muncipal Council. It is located on the banks of River Kushavati with an average elevation of 69 feet (21 meters). Curchorem and Sanvordem are the two-neighbouring town to Quepem. It has a population of about 14, 795 people out of which 7,277 are male and 7, 518 are female and is inhabited by 3613 households (as pre the 2011 census). The town is famous for its traditional festivals celebration which include the Ganeshotsav, Carnival, Shigmostav and the feast of Holy Cross.

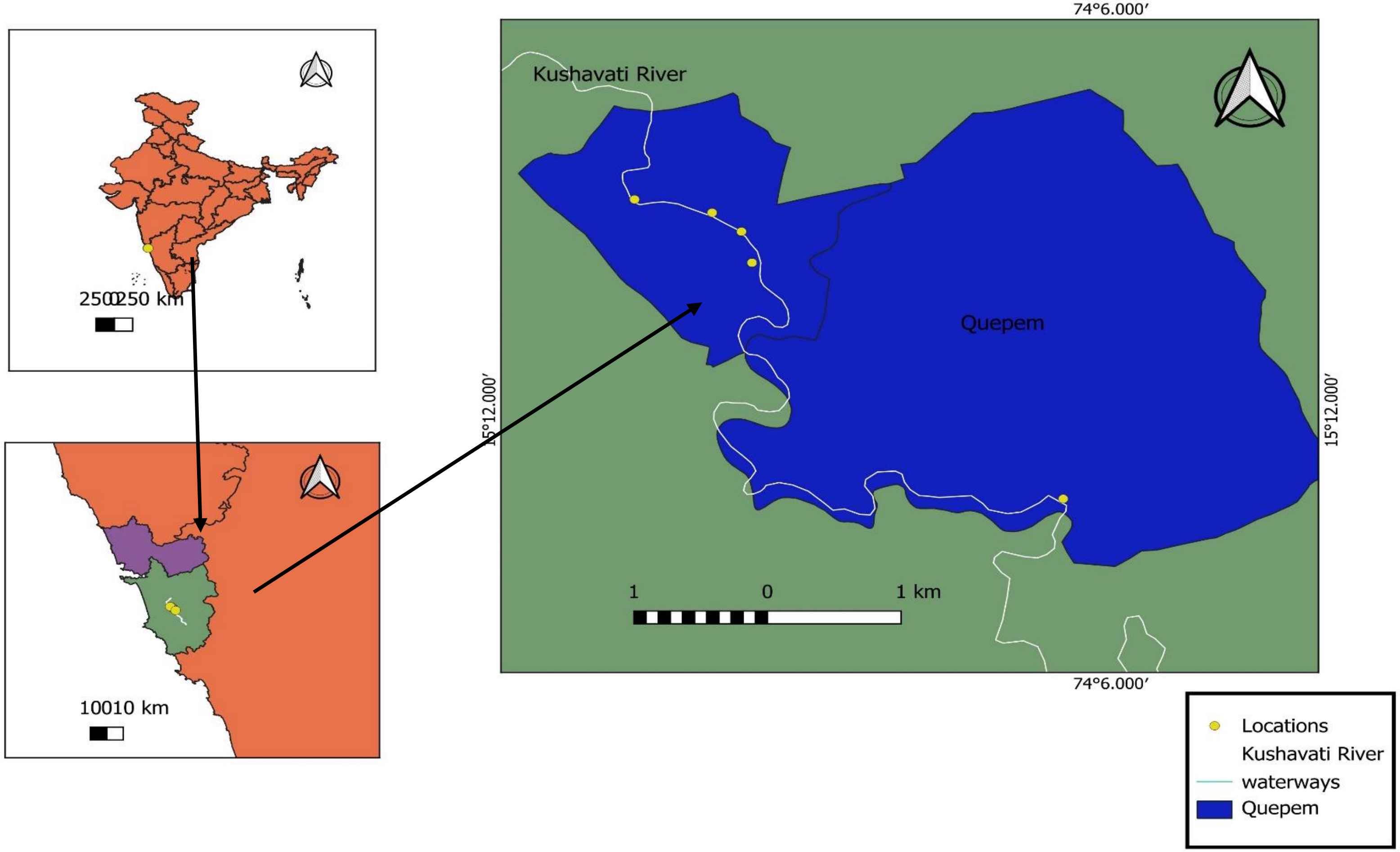


Fig. 3.1: Map of study area showing all the five sampling locations

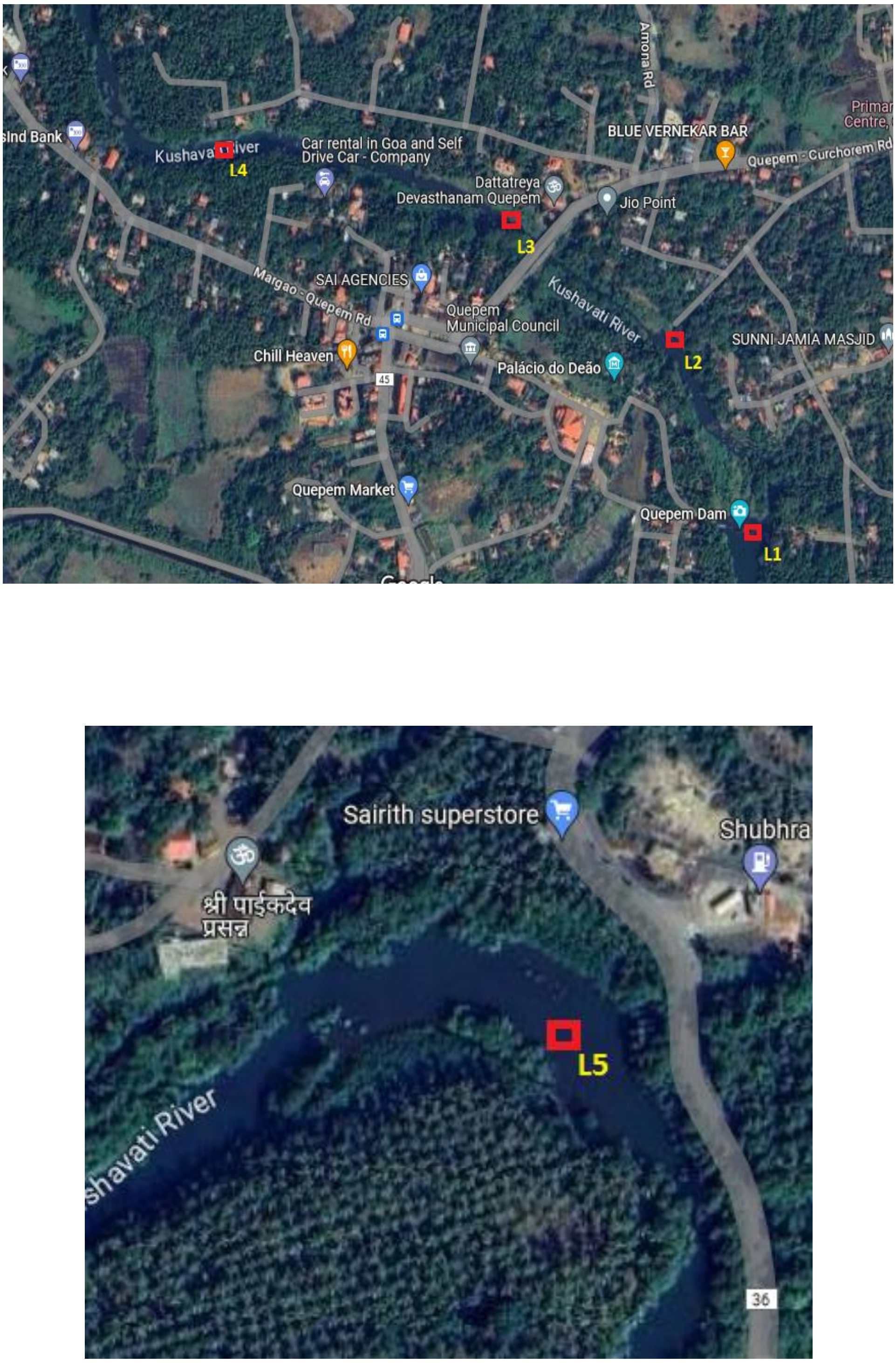


Fig. 3.2: Detail map of study area showing the locations near human settlements (L1-L4) (top) and the location distant from human settlement (L5) (bottom).

3.2 Preparation before sampling

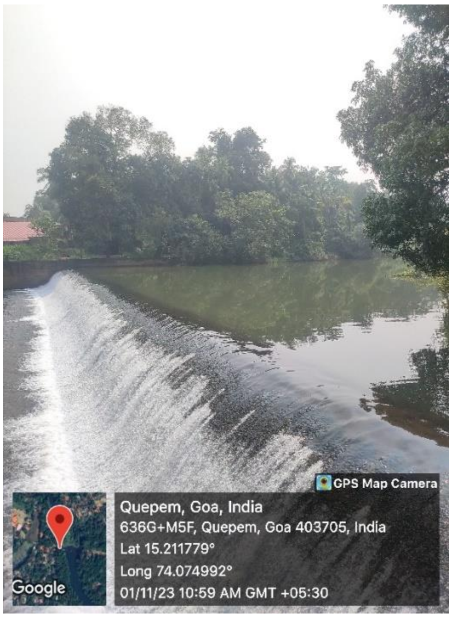
All the reagents required for the laboratory analysis were prepared and standardised before the sampling was done. The light sensitive reagents were stored in amber colour bottles and all the reagents were kept in dark place. Winkler's A and B were kept in refrigerator. Similarly, all the apparatus that were required for analysis including the bottles to store reagents were previously issued and kept. The materials that were needed to be taken on the field were also issued for example; thermometer, bottles to carry Winkler's A and B and syringes to add the reagents. All the arrangements that were required for safely transporting the samples from the field to the laboratory were made beforehand.

3.3 Sampling locations

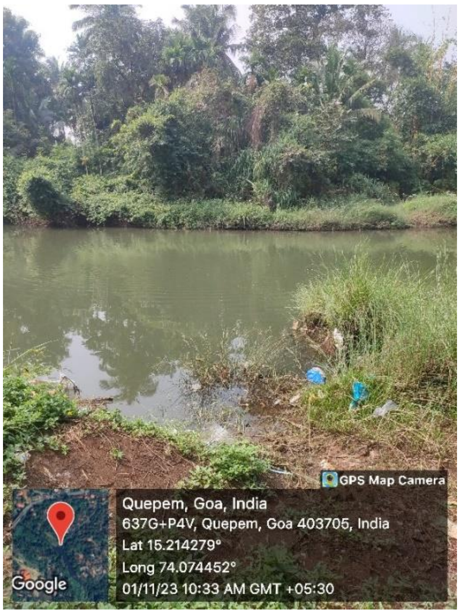
A total of five sampling locations were selected. Four (L1-l4) were near the human settlement and one (L5) was away from human settlement. All the four locations were within the town and were easily accessed by the people for various purposes including washing of clothes and utensils, bathing, collecting water for domestic use and even for dumping of solid waste. The fifth location was about 4 km distant from the human settlement and was less accessed as compared to the other four locations.

Table 3.1: Latitude and Longitude of the sampling.

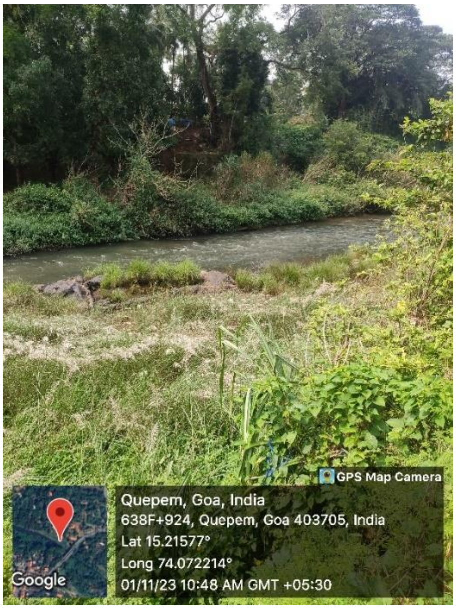
SAMPLING LOCATIONS	LATITUDE	LONGITUDE
Location 1	15.211779^{o}N	74.074992^{o}E
Location 2	15.214259^{o}N	74.074259^{o}E
Location 3	15.21577^{o}N	74.072214^{0}E
Location 4	15.216829^{o}N	74.066814^{o}E
Location 5	15.192928^{o}N	74.096666^{o}E


GPS Map Camera
Quepem, Goa, India
636G+M5F, Quepem, Goa 403705, India
Lat 15.211779°
Long 74.074992°
01/11/23 10:59 AM GMT +05:30
Google

L1


GPS Map Camera
Quepem, Goa, India
637G+P4V, Quepem, Goa 403705, India
Lat 15.214279°
Long 74.074452°
01/11/23 10:33 AM GMT +05:30
Google

L2


GPS Map Camera
Quepem, Goa, India
638F+924, Quepem, Goa 403705, India
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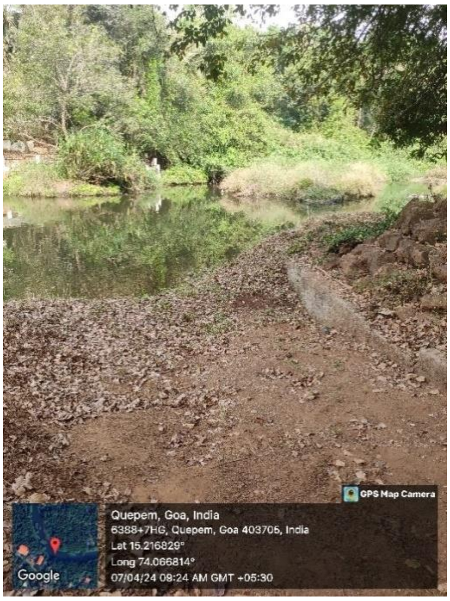
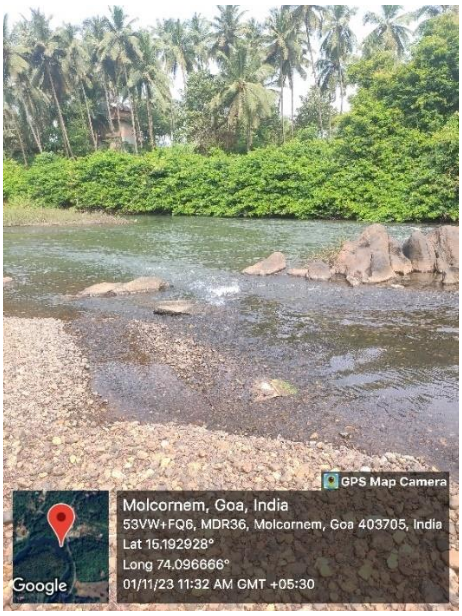
Long 74.072214°
01/11/23 10:48 AM GMT +05:30
Google

L3


GPS Map Camera
Quepem, Goa, India
6388+7HG, Quepem, Goa 403705, India
Lat 15.216829°
Long 74.066814°
07/04/24 09:24 AM GMT +05:30
Google

L4



L5

Fig. 3.3: Geo-tag photos of the sampling locations.

3.4 Sampling

Sampling was done for five times from December 2023 to March 2024. Surface water samples were collected using clean plastic bottles. The bottles were thoroughly rinsed three times with the same water before collecting the sample. Sampling was done early in the morning and then the samples were brought to the laboratory by taking proper care not to contaminate the samples. The temperature of the water body was measured at each location before taking the samples. For estimation of dissolved oxygen, the oxygen was fixed on the site by adding 1ml each of Winkler's A and B carried in ice-box.

Table 3.2: Sampling dates

SAMPLING NUMBER	DATE
1	18th December 2023
2	8th January 2024
3	29th January 20204
4	19th February 2024
5	4th March 2024

3.5 LABORATORY ANALYSIS

Various parameters tested for water quality assessment are as follows.

Table 3.3: Parameters analysed and the method used

PARAMETERS	METHOD	REFERENCE
Temperature	Thermometer	-
pH	pH meter	-
Salinity	Refractometer	-
Dissolve Oxygen	Titration	APHA (2012)
Phosphate	Spectrophotometer	Murphy and Riley's Molybdenum blue method (1962)
Nitrite	Spectrophotometer	Strickland and Paroons (1968)
Biological Oxygen Demand	Titration	APHA (2012)
Alkalinity	Titration	APHA (2012)
Acidity	Titration	APHA (2012)
Hardness of Water	Titration	APHA (2012)
Chlorides	Titration	APHA (2012)
Turbidity	Nephelometer	-
Electric Conductivity	Conductivity meter	-
Total Dissolve Solids	Conversion Factor	Todd (1980)
Bacterial Count	Bactaslyde	https://bactaslyde.com
Yeast and Fungal Count	Bactaslyde	https://bactaslyde.com

3.5.1 Temperature

Temperature of the water body was measured on the site using a thermometer.

3.5.2 pH

pH of the samples was measured using a pH meter. Before using the pH meter, it was calibrated using samples of pH 4, 7 and 9.2. After the calibration, the pH probe was dipped in the sample and the reading was noted down.

3.5.3 Salinity

Salinity was measured using a refractometer. Before using it was calibrated using distilled water. Then a drop of each sample was placed on the refractometer and the salinity of each sample was measured.

3.5.4 Dissolved Oxygen

First, the dissolved oxygen was fixed on the site by adding 1 ml each of Winkler's A and B solutions, and a precipitate was formed. Then the samples were brought to the laboratory. One ml of concentrated H_2SO_4 was added in each sample and the precipitate was allowed to dissolve. After that 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 reading were obtained, the amount of dissolve oxygen present in the sample were calculated using the following formula.

Actual amount of water involved in the reaction

$$= \frac{50\,(125 - 2)}{125}$$

$$= 49.2 \text{ ml}$$

$$\text{Dissolved oxygen} = \frac{\text{Burette reading} \times \text{concentration of } Na_2S_2O_3 \times 1000 \times 8}{49.2}$$

3.5.5 Phosphate

Estimation of phosphate was done using the Murphy and Riley's Molybdenum blue method. First, a calibration curve was constructed by taking 2, 4, 6, 8, and 10 ml of working solution in a graduated tube. Distilled water was added to the tube to make the volume to 50 ml. Then 1 ml of mixed reagent and 1 ml of ascorbic acid was added in each tube. Blank and samples were prepared using 50 ml of distilled water and 50 ml of sample respectively. Then 1 ml each of mixed reagent and ascorbic acid was added. Then the samples were kept in dark for 30 minutes. After 30 minutes, the absorbance was measured in spectrophotometer at 880 nm. The concentration of phosphate was estimated graphically.

3.5.6 Nitrites

Strickland and Paroons (1968) method were used to estimate the concentration of nitrite in water sample. To construct a calibration curve, 1, 2, 3, 4, and 5 ml of working sample was taken in a graduated tube. Then 1ml of sulphanilamide and 1 ml of dionsene was added. The same procedure was repeated for blank and samples by taking 50 ml of distilled water and 50 ml of samples respectively. The samples were incubated in dark at room temperature for 20 minutes. After 20 minutes, the absorbance was measured at 540 nm in a spectrophotometer. The concentration of nitrate was estimated graphically.

3.5.7 Biological Oxygen Demand (BOD)

BOD of the water was determined after the five days incubation method. This was done by estimating dissolved oxygen on day zero then incubating the sample in dark for five days and again estimating the dissolved oxygen. Subtracting the reading of day zero with that of day five gave the BOD of the water body.

Winkler's A and B was added in the BOD bottle containing the sample. A precipitate was formed which got dissolved after adding 1 ml of 50 % H_2SO_4. Then 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 reading were obtained, the amount of dissolve oxygen present in the sample were calculated using the following formula

Actual amount of water involved in the reaction

$$= \frac{50\ (125 - 2)}{125}$$

$$= 49.2\ ml$$

$$\text{Dissolved oxygen} = \frac{\text{Burette reading} \ \times \ \text{concentration of } Na_2S_2O_3 \ \times \ 1000 \ \times \ 8}{49.2}$$

3.5.8 Hardness of Water

For the determination of Ca, 5 ml of sample was taken and was mixed with 10 ml of distilled water. The pH of the sample was adjusted to 12 using NaOH buffer. Then the sample was titrated against 0.01 N EDTA solution by adding Patter’s and Reeder’s indicator. The transition in colour observed was from red to blue. The concentration of Ca was calculated using the formula;

1 M of EDTA is equal to 1 M of Ca

Atomic weight of Ca is 40.008g

Therefore, 1 M of EDTA is equal to 40.008g of Ca

Concentration of Ca in the water sample

$$Ca = \frac{\text{Burette reading} \ \times \ 0.01 \ \times \ 40.008}{5}$$

Calcium and Magnesium (total) was determined by taking 5 ml of sample and mixing with 10 ml of distilled water. The pH of the sample was adjusted to 10 using dilute NH_3 buffer. Then the sample was titrated against 0.01 N EDTA solution by adding EBT indicator. The transition in colour observed was from red to blue. Then the volume of EDTA consumed for Mg was calculated by subtracting the volume of EDTA consumed for Ca. The concentration of Mg was calculated using the formula;

1 M of EDTA is equal to 1 M of Mg

Atomic weight of Ma is 24.31g

Therefore, 1 M of EDTA is equal to 24.31g of Ma

Concentration of Ma in the water sample

$$Mg = \frac{\text{Burette reading} \times 0.01 \times 24.31}{5}$$

Both the values for Ca and Mg were added to calculate the total hardness.

3.5.9 Alkalinity

Hundred ml of sample was taken and 2 drops of phenolphthalein was added. The colour of the sample changed to pink. Then it was titrated with 0.02 N H_2SO_4 till the pink colour dissolves. The burette reading was noted down, which act as a phenolphthalein alkalinity. Next, two drops of methyl orange indicator were added. The sample changed to yellow. The titration was continued till the yellow colour changed to orange. This was noted as the total alkalinity. The alkalinity of the water was calculated using the formula;

$$Alkalinity = \frac{\text{Burette reading} \times 0.02 \times 50 \times 1000}{100}$$

3.5.10 Acidity

Fifty ml of the sample was taken and the pH of the sample was checked. Next, two drops of methyl orange indicator were introduced. The colour of the sample changed to orange. Next it was titrated with 0.02 N NaOH till the coloured changed to yellow. This represents methyl orange acidity. Then two drops of phenolphthalein were added. The sample colour changed to colourless. The titration was continued till a light pink colour was observed. This represents the total acidity. The acidity of water was calculated using the formula;

$$Acidity = \frac{Burette\ reading \times 0.02 \times 50 \times 1000}{100}$$

3.5.11 Chlorides

Twenty-five ml of sample was taken in a conical flask and 5 drops of potassium chromate was added to it. Then the solution was titrated against 0.014 N silver nitrate solution. The end point of the solution was obtained through colour change from yellow to brick-red. The chloride ion concentration in the sample was calculated using the formula;

$$Chlorides = \frac{Burette\ reading \times 0.014 \times 35.45 \times 1000}{25}$$

3.5.12 Turbidity

Before using, the Nephelometer was calibrated with samples of 400 NTU, 200 NTU and 20 NTU. After calibration, the readings were directly taken by putting the samples in the bottles provided with the nephelometer. The unit used for measurement is NTU (Nephelometric Turbidity Unit).

3.5.13 Electric Conductivity

The conductivity meter was calibrated by using 0.01 M KCl solution. After calibration the glass electrode was dipped in the solution and the conductivity of the solution was noted.

3.5.14 Total Dissolved Solids

Total dissolved solids were directly calculated from the electricity conductivity values by using the "conversion factor method". This method involves multiplying the measured electric conductivity by a conversion factor to get the TDS values. The most commonly used conversion factor is 0.65. Therefore, the formula used to estimate TDS values was;

$$TDS = Electric\ Conductivity \times 0.65$$

3.5.15 Bacteria, Yeast and Fungal count

Bacteria, Yeast and Fungal count was done using the Yeast and Fungi + TBC test kit of Bactaslyde (Rakiro Biotech Systems Pvt Ltd). First, the sealed Bactaslyde was labelled outside and opened. and labelled. Water sample was collected in it. After holding for one minute the water was thrown out and the slide inside the bottle was shaken to remove remnants of water. Then it was was incubated one day. After one day colonies grown on the slides were counted and compared with the bactaslyde chart to estimate the number of bacteria, yeast and fungi present in the water body.

3.6 Statistical Analysis

Student's t test was applied to test the hypotheses. It was done using the formula;

$$t = \frac{\bar{x} - \mu}{S.E.(\bar{x})}$$

Where; $\bar{x}$ = mean of the samples

μ = assumed mean

S.E. ($\bar{x}$) = Standard deviation mean

The standards followed for comparing the results obtained in the present study are given below.

Table 3.4: Bureau of Indian Standards (IS 10500: 2012 Drinking water specification).

PARAMETERS	STANDARDS (IS 10500: 2012)
pH	6.5 – 8.5
Dissolve Oxygen	5 mg/l
Phosphate	1 mg/l
Nitrite	1 mg/l
Biological Oxygen Demand	3 mg/l
Alkalinity	200 mg/l
Hardness of Water	200 mg/l
Chlorides	250 mg/l
Turbidity	5 NTU
Total Dissolve Solids	500 mg/l

CHAPTER 4: ANALYSIS AND CONCLUSION

4.1 ANALYSIS

4.1.1 Results

4.1.1.a Physical Parameters

Temperature

The temperature of the surface water noted during the period of study ranged from a lowest of 23.5^o C during January to the highest of 25^o C as shown in the Table 4.1.1

Table 4.1.1.a. Temperature (^{o}C) of the surface water samples.

	Months				
Locations	December	January 8th	January 29th	February	March
L1	25	24.5	23.5	24	25
L2	25	24.5	23.5	24	25
L3	25	24.5	23.5	24	25
L4	25	24.5	23.5	24	25
L5	24	24.5	23.5	24	25

Salinity

The Salinity of all the water samples was always zero during the entire period of study.

Electric Conductivity

The electric conductivity of the surface water samples noted during the period of study ranged from the lowest of 59.2 µs at location L4 during January to the highest of 136.9 µs at location L3 during December as shown in Table 4.1.2. The readings were plotted on a bar graph against the respective locations in Fig. 4.1.1

Table 4.1.1.b. Electric Conductivity (μs) of the water samples

	Months				
Locations	December	January 8th	January 29th	February	March
L1	88	69.4	67.7	83.38	99.56
L2	122.5	70.5	65.3	79.44	91.74
L3	136.9	70.2	61.5	85.05	90.9
L4	128.7	69	59.2	77.64	89.27
L5	136.1	77.2	79.3	90.37	105.65

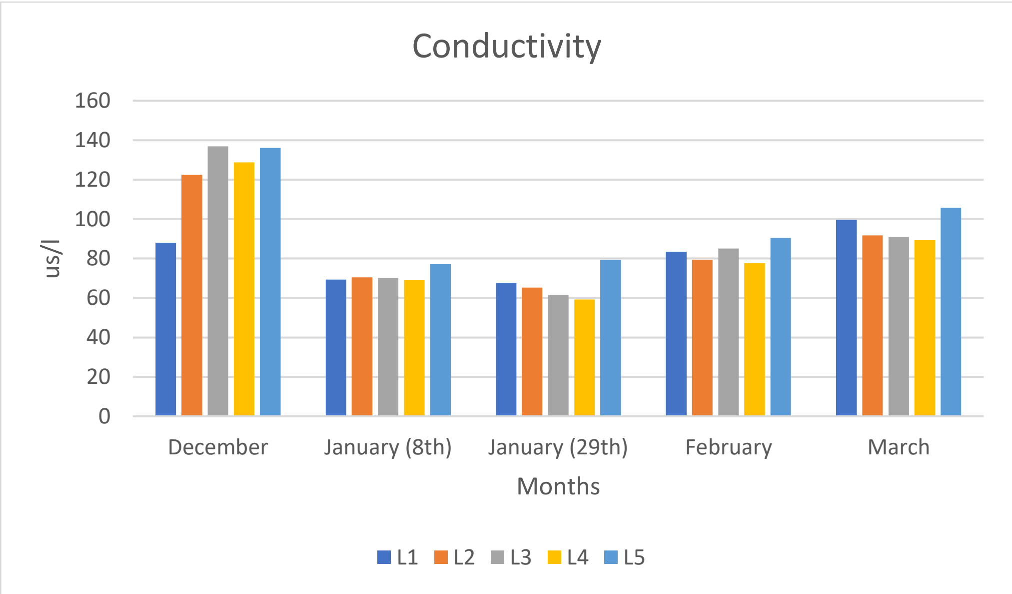


Fig. 4.1.1.a. Electric Conductivity for different locations during different sampling time.

Total Dissolved Solids (TDS)

The TDS of the water samples noted during the period of study ranged from the lowest 38.48 of mg/l at location L4 during January to the highest of 88.98 mg/l at location L3 during December as shown in Table 4.1.3. The readings were plotted on a bar graph against the respective locations in Fig. 4.1.2.

Table 4.1.1.c. TDS (mg/l) of the water samples.

	Months				
Locations	December	January 8th	January 29th	February	March
L1	57.2	45.11	44	54.19	64.71
L2	79.62	45.82	42.44	54.63	59.63
L3	88.98	45.63	39.17	55.28	59.08
L4	83.65	44.85	38.48	50.46	58.02
L5	88.46	50.18	51.54	58.74	68.67

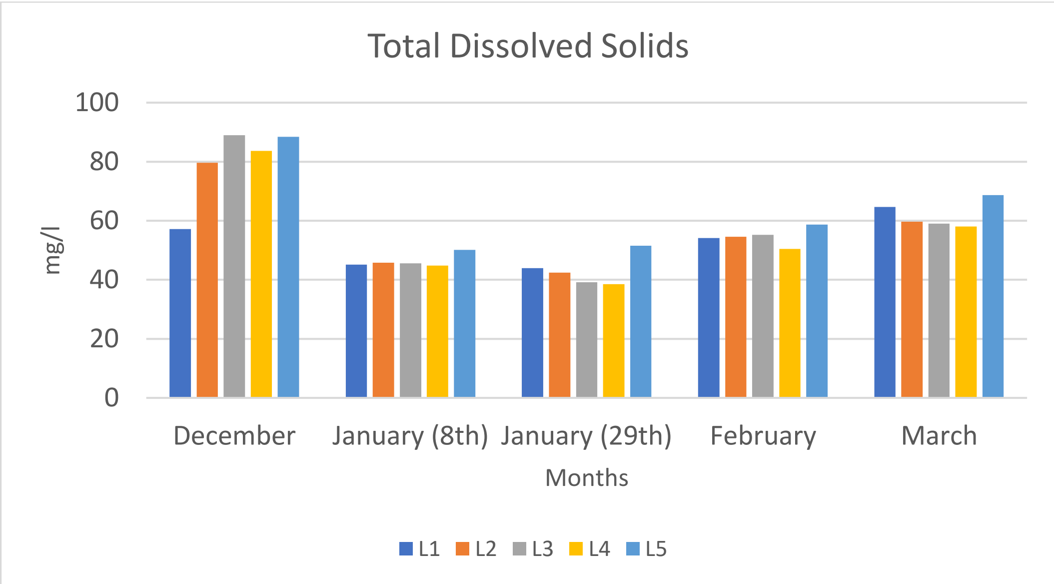


Fig. 4.1.1.b. TDS readings for different locations during different sampling times.

Turbidity

The Turbidity of the water samples noted during the period of study ranged from the lowest of1.09 NTU at location L2 during December to the highest of 4.96 NTU at location L4 during January as shown in Table 4.1.4. The readings were plotted on a bar graph against the respective locations in Fig. 4.1.3.

Table 4.1.1.d. Turbidity (NTU) of the water samples.

	Months				
Locations	December	January 8th	January 29th	February	March
L1	1.16	1.63	3.9	3.17	2.61
L2	1.09	1.42	3.57	2.95	2.77
L3	1.12	1.48	4.46	2.71	2.4
L4	1.24	1.87	4.96	3.35	2.33
L5	2.36	2.74	2.17	3.11	2.82

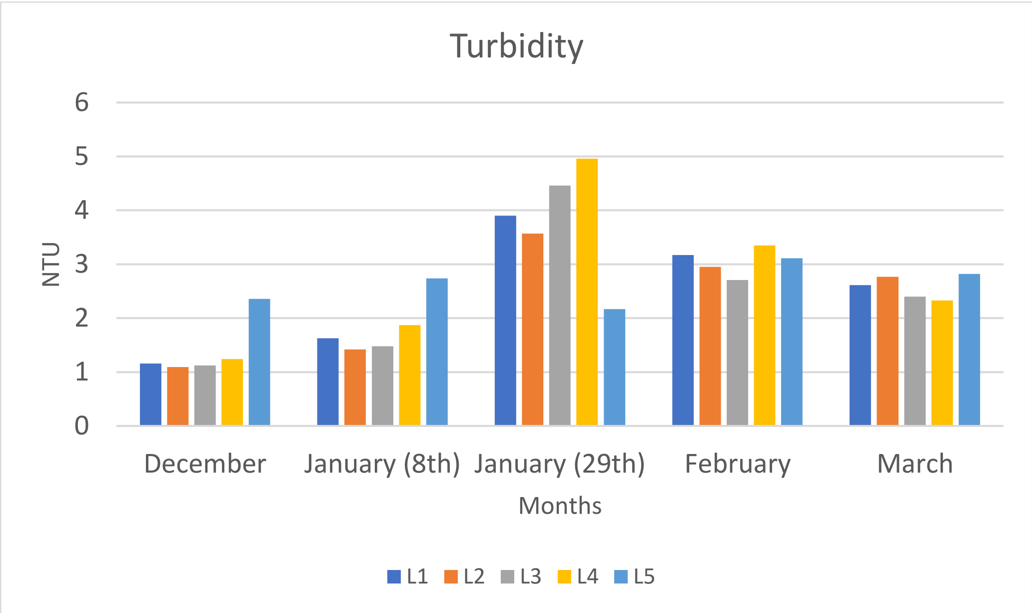


Fig. 4.1.1.c. Turbidity readings for different locations during different sampling times.

4.1.1.b Chemical Parameters

pH

The pH of the water samples noted during the period of study ranged from the lowest 6.77 at location L3 during March to the highest of 7.36 at location L2 during January as shown in Table 4.1.5. The readings were plotted on a bar graph against the respective locations in Fig. 4.1.4.

Table 4.1.1.e. pH of the water samples

	Months				
Locations	December	January 8th	January 29th	February	March
L1	6.88	7.05	7.08	6.91	6.88
L2	6.79	7.36	7.15	6.85	6.83
L3	7.02	7.26	7.12	6.87	6.77
L4	7.06	7.27	7.14	6.83	6.78
L5	7.08	7.22	7.2	6.95	6.91

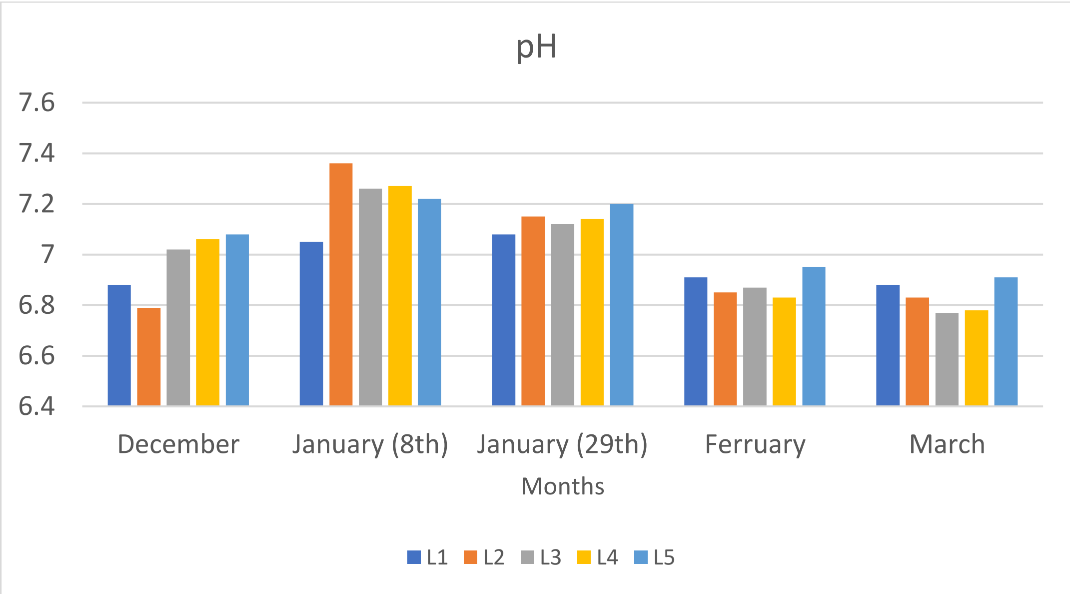


Fig. 4.1.1.d. pH readings for different locations during different sampling times.

Dissolved Oxygen

The Dissolved Oxygen of the water samples noted during the period of study ranged from the lowest of 6.34 mg/l at location L1, L2 and L3 during January to the highest of 7.64 mg/l at location L5 during February as shown in Table 4.1.6. The readings were plotted on a bar graph against the respective locations in Fig. 4.1.5.

Table 4.1.1.f. Dissolved Oxygen (mg/l) of the water samples.

	Months				
Locations	December	January 8th	January 29th	February	March
L1	6.82	6.34	7.05	7.47	6.99
L2	6.66	6.34	6.89	7.31	6.99
L3	6.66	6.34	6.89	7.47	7.15
L4	6.82	6.5	7.05	7.31	7.15
L5	6.82	6.5	6.89	7.64	7.31

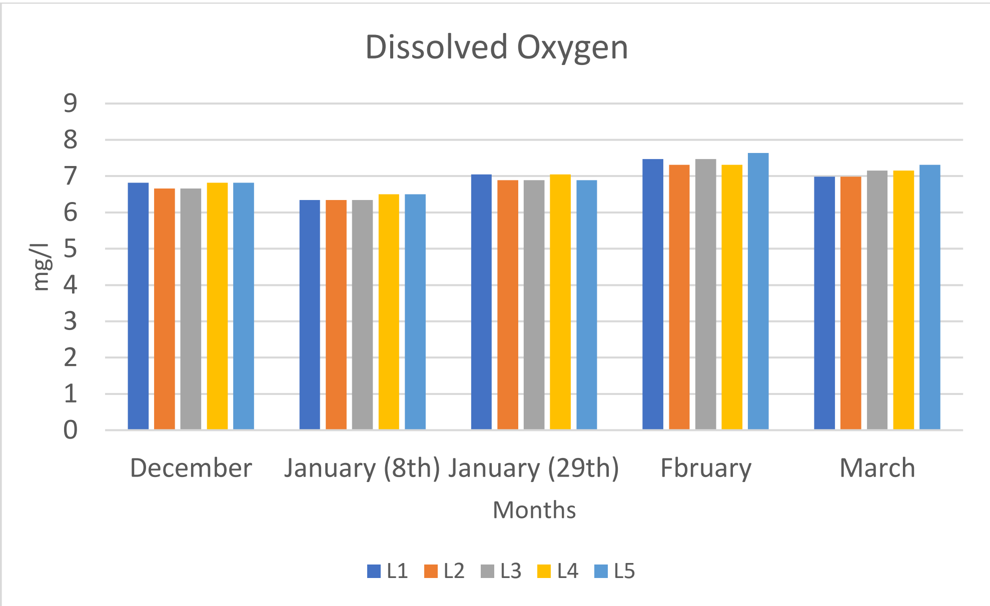


Fig. 4.1.1.e. Dissolved Oxygen readings for different locations during different sampling times.

Hardness of Water

The Hardness of the water samples noted during the period of study ranged from the lowest of 19.31 mg/l at location L2 and L3 during February to the highest of 29.17 at location L1, L2 and L5 during December and January, L5 during February and L1 and L5 during March as shown in Table 4.1.7. The readings were plotted on a bar graph against the respective locations in Fig. 4.1.6.

Table 4.1.1.g. Hardness (mg/l) of the water samples.

	Months				
Locations	December	January 8th	January 29th	February	March
L1	29.17	24.31	29.17	24.31	29.17
L2	29.17	24.31	29.17	19.31	24.31
L3	24.31	19.44	24.31	19.31	24.31
L4	19.44	19.44	24.31	24.31	24.31
L5	29.17	24.31	29.17	29.17	29.17

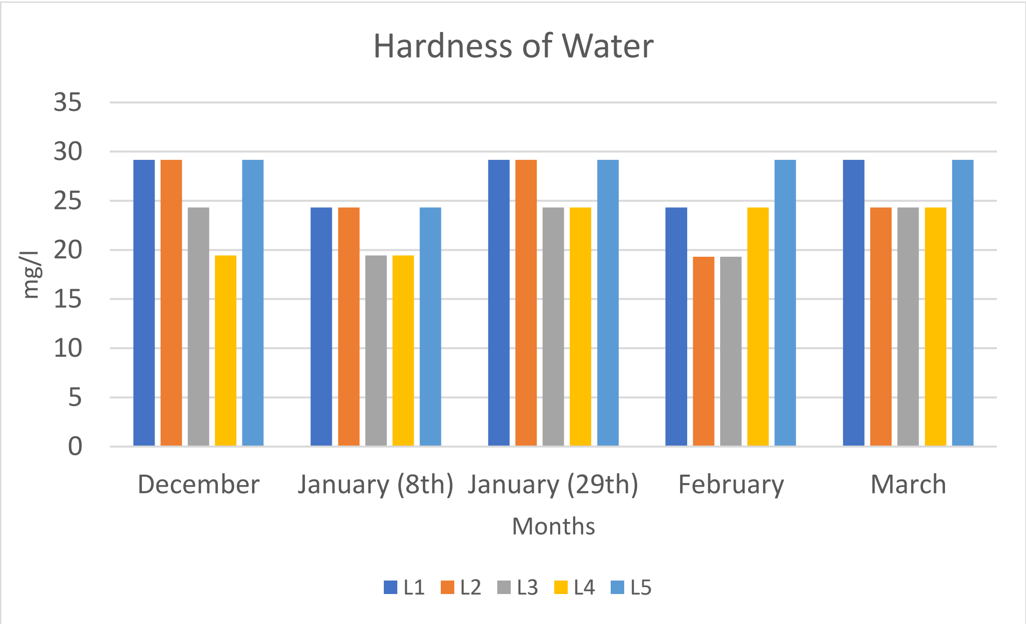


Fig. 4.1.1.f. Hardness readings for different locations during different sampling times.

Alkalinity

The Alkalinity of the water samples noted during the period of study ranged from the lowest of 24 mg/l at location L2 during February to the highest of 40 mg/l at location L2 during December as shown in Table 4.1.8. The readings were plotted on a bar graph against the respective locations in Fig. 4.1.7.

Table 4.1.1.h. Alkalinity (mg/l) of the water samples.

	Months				
Locations	December	January 8th	January 29th	February	March
L1	33	34	30	25	29
L2	40	33	26	24	28
L3	39	33	28	25	26
L4	36	32	27	23	28
L5	35	37	31	28	31

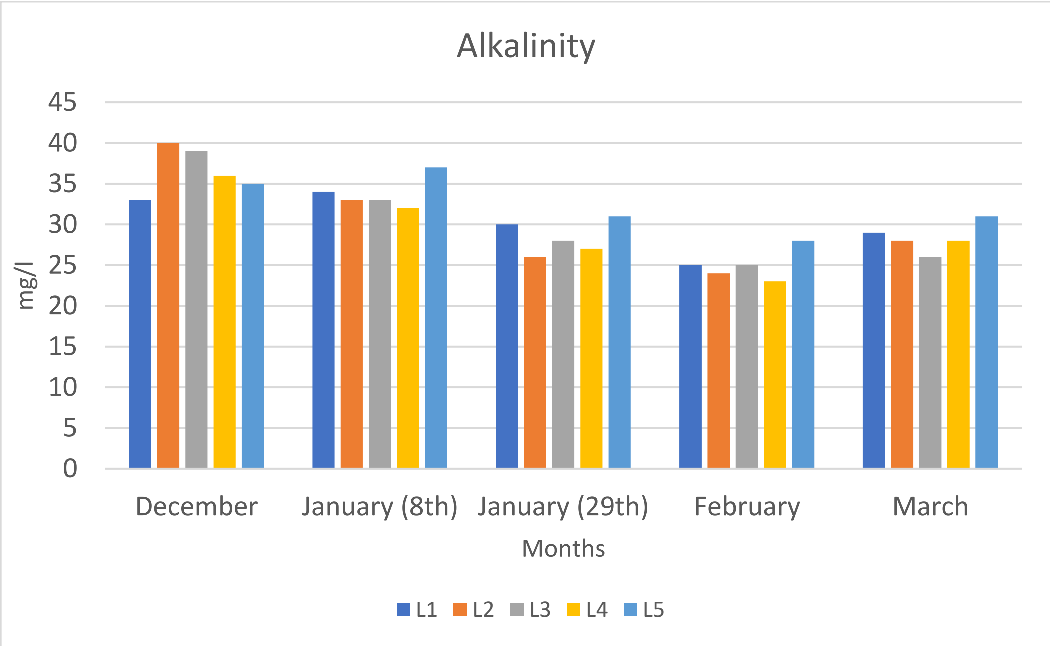


Fig. 4.1.1.g. Alkalinity readings for different locations during different sampling times.

Acidity

The Acidity of the water samples noted during the period of study ranged from the lowest of 2 mg/l at location L3 during December to the highest of 6 mg/l at location L1, L3 and L5 during January, L1, L2 and L4 during February and L1 and L2 during March as shown in Table 4.1.9. The readings were plotted on a bar graph against the respective locations in Fig. 4.1.8.

Table 4.1.1.i. Acidity (mg/l) of the water samples.

	Months				
Locations	December	January 8th	January 29th	February	March
L1	4	4	6	6	6
L2	4	4	4	6	6
L3	2	4	6	4	4
L4	4	4	4	6	4
L5	4	4	6	4	4

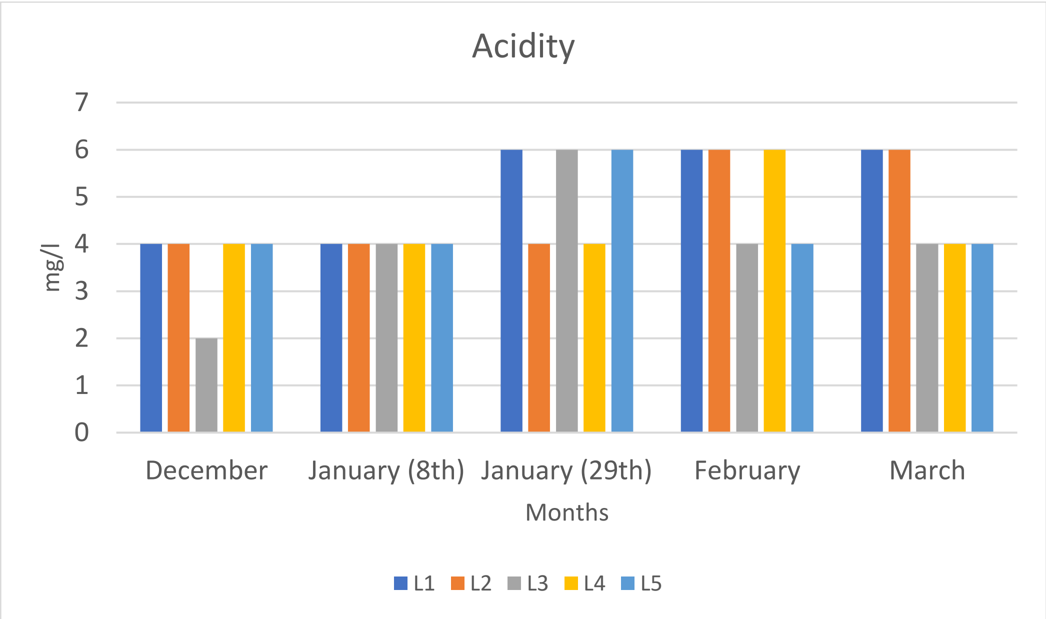


Fig. 4.1.1.h. Acidity readings for different locations during different sampling time.

Chlorides

The chloride ions concentration in the water samples noted during the period of study ranged from the lowest of 11.99 mg/l at location L1, during March to the highest of 23.99 mg/l at location L2 during December as shown in Table 4.1.10. The readings were plotted on a bar graph against the respective locations in Fig. 4.1.9.

Table 4.1.1.j. Chloride ions concentration (mg/l) in the water samples.

	Months				
Locations	December	January 8th	January 29th	February	March
L1	19.99	17.99	15.99	13.99	11.99
L2	23.99	17.99	15.99	13.99	15.99
L3	21.99	15.99	15.99	17.99	15.99
L4	21.99	13.99	13.99	19.99	13.99
L5	19.99	15.99	13.99	15.99	15.99

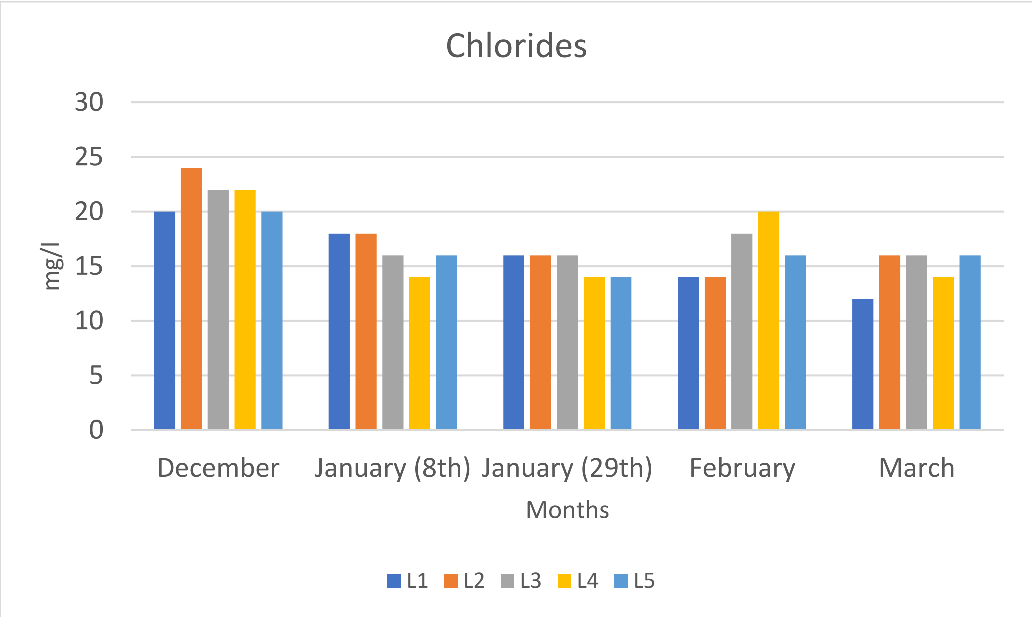


Fig. 4.1.1.i. Chloride ions concentration readings at different locations during different sampling times.

Biological Oxygen Demand (BOD)

The BOD of the water samples noted during the period of study ranged from the lowest of 0.325 mg/l at L3 during March to the highest of 1.318 mg/l at location L1 and L3 during December as shown in Table 4.1.11. The readings were plotted on a bar graph against the respective locations in Fig. 4.1.10.

Table 4.1.1.k. BOD (mg/l) of the water samples.

	Months				
Locations	December	January 8th	January 29th	February	March
L1	1.318	0.975	0.975	0.813	0.487
L2	1.3	0.65	1.138	0.65	0.975
L3	1.318	1.138	0.65	0.975	0.325
L4	1.3	0.975	0.975	0.813	0.65
L5	0.975	0.487	0.813	0.487	0.65

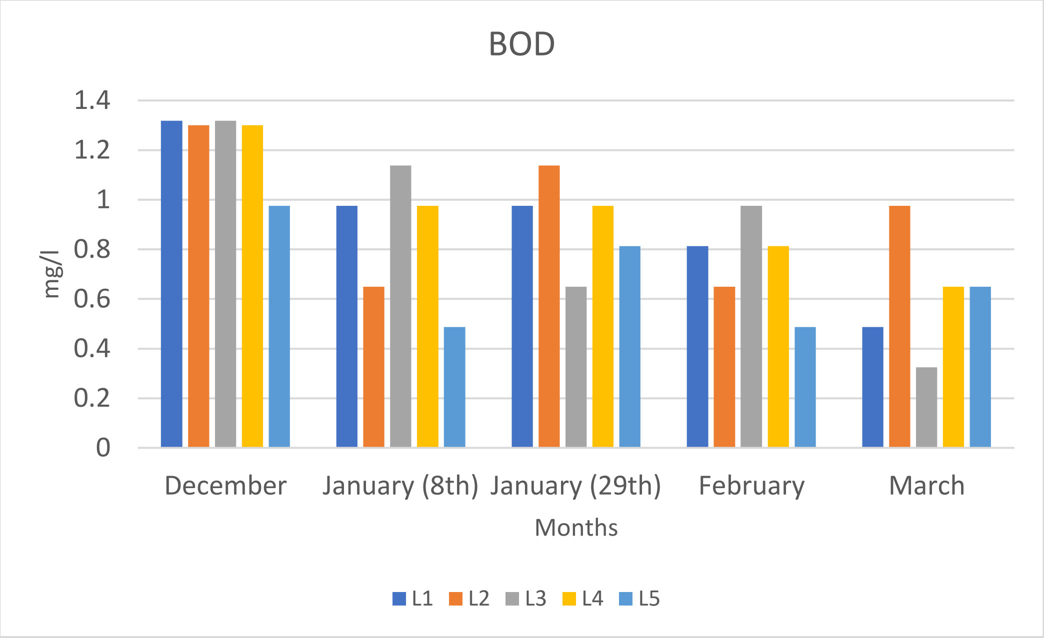


Fig. 4.1.1.j. BOD readings for different locations during different sampling times.

Phosphate

The standard graph for calculation of Phosphate concentration in the water samples is given in Fig 4.1.11. The concentration of Phosphate in the water samples noted during the period of study ranged from the lowest of 0.115 mg/l at location L5 during January to the highest of 0.171 mg/l at location L5 during February and March as shown in Table 4.1.12. The readings were plotted on a bar graph against the respective locations in Fig. 4.1.12.

Table 4.1.1.l. Concentration of Phosphate (mg/l) in the water samples.

	Months				
Locations	December	January 8th	January 29th	February	March
L1	0.159	0.118	0.131	0.156	0.146
L2	0.148	0.120	0.128	0.162	0.156
L3	0.150	0.120	0.133	0.163	0.156
L4	0.148	0.120	0.133	0.163	0.165
L5	0.154	0.115	0.131	0.171	0.171

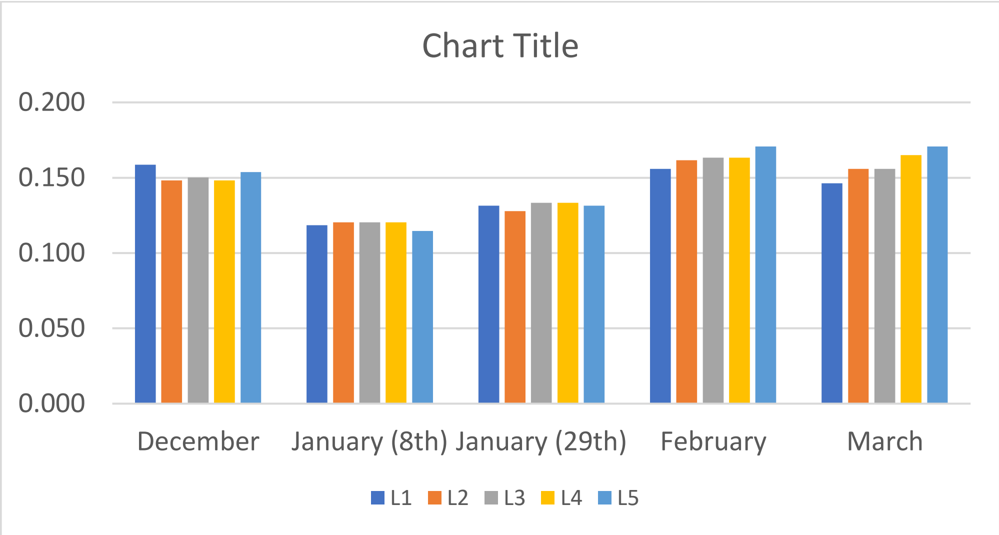


Fig. 4.1.1.k. Concentration of Phosphate at different locations during different sampling times.

Nitrite

The standard graph for calculation of Nitrite concentration in the water samples is given in Fig 4.1.13. The concentration of Nitrite in the water samples noted during the period of study ranged from the lowest of 0.011 mg/l at location L5 during March to the highest of 0.020 mg/l at location L4 during January as shown in Table 4.1.13. The readings were plotted on a bar graph against the respective locations in Fig. 4.1.14.

Table 4.1.1.m. Concentration of Nitrite (mg/l) in the water samples.

	Months				
Locations	December	January 8th	January 29th	February	March
L1	0.013	0.015	0.012	0.013	0.012
L2	0.015	0.017	0.012	0.013	0.012
L3	0.012	0.016	0.012	0.015	0.012
L4	0.012	0.015	0.020	0.017	0.013
L5	0.013	0.013	0.013	0.012	0.011

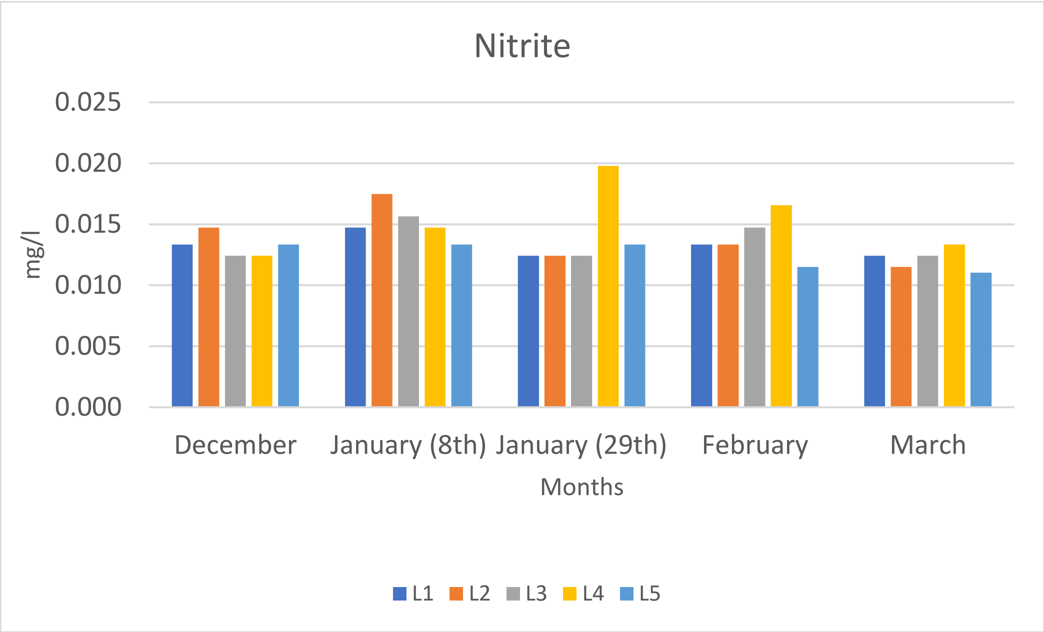


Fig.4.1.1.l. Concentration of Nitrite at different locations during different sampling times.

4.1.1.c Biological parameters

Total Bacterial Count

The Total Bacterial Count in the river water noted during the period of study ranged from $10^2 – 10^5$ as shown in Table 4.1.14.

Table 4.1.1.n. Total Bacterial Count (cfu/ml) in the river water.

	Months				
Locations	December	January 8th	January 29th	February	March
L1	10^4	10^4	10^3	10^2	10^3
L2	10^4	10^5	10^5	10^4	10^4
L3	10^4	10^5	10^5	10^3	10^4
L4	10^4	10^4	10^4	10^4	10^5
L5	10^4	10^2	10^4	10^3	10^4

Yeast and Fungal Count

Fungal Count

The Fungal Count in the river water noted during the period of study ranged from 0 to Moderate as shown in Table 4.1.15.

Table 4.1.1.o. Fungal Count (cfu/ml) in the river water.

	Months				
Locations	December	January 8th	January 29th	February	March
L1	0	Moderate	Slight	0	0
L2	0	Slight	Moderate	Slight	Slight
L3	0	Slight	Moderate	Slight	Slight
L4	0	Moderate	0	Moderate	Slight
L5	Slight	Slight	0	Slight	Slight

Yeast Count

Yeast Count in the river water noted during the period of study ranged from 0 - 10^2 as shown in Table 4.1.16.

Table 4.1.1.p. Yeast Count (/ml) in the river water.

	Months				
Locations	December	January 8^{th}	January 29^{th}	February	March
L1	10^2	0	0	0	10^2
L2	10^2	10^2	0	0	10^2
L3	10^2	10^2	0	0	0
L4	10^2	10^2	10^2	0	10^2
L5	0	10^2	0	10^2	0

4.1.1.d Statistical analysis

Student's t test showed that the average values of all the parameters were statistically different from that of the BIS standard. For n=25 and 24 degrees of freedom at α=0.05, the t_{crit} value is 1.711. The t_{stat} values of all the parameters was greater than t_{crit} with 95% significance (Table 4.1.17).

Table 4.1.1.q: Students t-test values

	Dissolved oxygen	Biological Oxygen Demand	Phosphate	Nitrite	Chloride	Total Dissolved Solids
mean	7.0104	0.87248	0.145	0.014	16.87	57.1416
S.E. (mean)	0.035397	0.058641	0.003667	0.000409	0.613279	2.994655
$\lvert t_{stat} \rvert$	56.79	36.2805	233.25	2409.78	406.645	165.964

4.1.2 DISSCUSSION

4..1.2.a Water Quality Assessment

The samples collected from Kushavati River were analysed for physio-chemical parameters and were compared with BIS (Bureau of Indian Standards) to estimate their water quality. The electric conductivity (EC) of the samples ranged between 136.9 µs/cm – 59.2 µs/cm (table 4.1.1.b). EC is the capacity of water to carry out electric current. Comparing with the previous papers done on rivers in Goa, the values were less. This may be due to low amount of dissolved salts present in water. The Total Dissolved Solids (TDS)values for the samples ranged between 38.48 mg/l – 88.98 mg/l (4.1.1.c). The BIS limit for TDS is 500 mg/l. Hence, all the samples had the TDS values within the limit. Similar results were observed in research done on Khandola Lake (Sawaiker, 2014). The turbidity of the water represents the cloudiness or haze in the water. Turbidity is used as an indicator of water pollution based on the clarity of water which may influence its portability for domestic and recreational activities. According to BIS, the turbidity of the water should be < 5 NTU to be considered as drinking water. The turbidity of present samples ranged between 1.09 NTU – 4.96 NTU (table 4.1.1.d), which are with the BIS limit. The samples had a pH range of 6.77 – 7.36 (table 4.1.1.e). Similar pH range was found for River Ganges in Patna (Rai et al 2011). According to BIS, the water should have a pH range of 6.5 – 8.5 to be considered as drinking water and also for the survival of aquatic life. If the pH moves away from this range, it can cause stress on the aquatic organism (Ramachandra and Solanki, 2007). At higher pH, nutrients like N, P and C are soluble in water and can increase the risk of being absorbed in the skin of aquatic animals. Similarly at lower pH, since the metals are soluble in acid water, they become more toxic (Ramachandra and Solanki, 2007). All the present samples had a pH range within the limit. A Dissolved Oxygen (DO) level of >5 mg/l is considered as ideal for maintaining a variety of life forms in the water (BIS). The DO of the surface waters is influenced by various factors such as salinity, temperature and atmospheric pressure (Kumar, 2018). The lowest value of DO for the water body was found to be 6.34 mg/l (table 4.1.1.f), which is above the permissible limit of BIS, indicating that the water is safe for aquatic organism. The hardness of water is due to the presence of calcium and magnesium ions in water. This ion can be added to the water either from the rocks through which the river flows or through man-made sources.

Usually, drinking hard water has no effect on human health but it cannot be used for domestic use (Rai et al 2011). The hardness values for the samples ranged between 19.31mg/l - 29.17 mg/l (table 4.1.1.g), which are well within the limit of BIS (200 mg/l). Alkalinity values for the samples ranged between 24 mg/l to 40 mg/l (table 4.1.1.h). It is the capacity of water to neutralise acid and is added due to the presence of carbonates and bicarbonates. The alkalinity values ranged within the BIS limit of < 200 mg/l. On the other hand, acidity of water is the capacity of water to neutralise base. The major contributor of acidity in water is Carbon dioxide (CO_2) which result from air pollution. The acidity values ranged between 2 mg/l – 6 mg/l (table 4.1.1.i). One reason for the low acidity value in water is the absence of any type of industries or factories in the study area that can cause air pollution thereby adding acidity in the water. Chlorides are one of the major ions in water and can occur in river through the weathering of rocks (Rai, 2010). Chloride concentration in the samples varied from 11.99 mg/l to 23.99 mg/l (table 4.1.1.j). As per the BIS limits, water should have chlorides level of less than 250 mg/l to be considered safe for use. Thus, the chloride levels in the samples were well within the limit. Biological Oxygen Demand (BOD) is the amount of oxygen required by the microorganisms to decompose organic matter in water bodies. BOD is an important indicator of organic pollution in water. Surface waters should have a BOD level of < 3 mg/l to be considered healthy water. The BOD of the Kushavati River was found to be in the range of 0.325 mg/l – 1.318 mg/l (table 4.1.1.k) which indicates that the river water is healthy and can be used for drinking and domestic use. Similar results were observed in the research done on Mandovi and Zuari River (Pradhan, 2007). Estimation of Phosphate and Nitrite concentration in the river water is important since higher concentration of which can lead to growth of algae which triggers eutrophication. This eutrophication can lead to oxygen depletion condition in river which affects the aquatic life. In a river water, the phosphate and nitrite concentration should be < 1 mg/l, respectively, to be considered as a healthy river. The highest phosphate concentration noted was 0.171 mg/l (table 4.1.1.l), and for nitrite, it was 0.02 mg/l (table 4.1.1.m). Both the values are within the acceptable limit. Hence it can be said that the Kushavati River is free from any type of algal pollution that can lead to eutrophication.

4.1.2.b Variation Analysis

Temperature of water body for all the sampling location was found similar except for L5 during December, which showed a variation of 1^0 C. Highest temperature was recorded during March, which may be due to increase in solar radiation which made the water warm. Electric conductivity was found highest during December for all the locations except L1 (Fig. 4.1.1.a). A slight increase in conductivity was seen from January (29^{th}) to March for all the locations. L5 had the highest conductivity during the study period except for December, where L3 conductivity was found slightly higher than L5. Same variations were seen for TDS (Fig. 4.1.1b). Turbidity was found higher in January (8^{th}) for all the locations except for L5 (Fig. 4.1.1.c). Between L1 – L4, L4 had the highest turbidity from December to February. An alternative trend was seen in the turbidity readings between L1- L4 and L5, where L1 – L4 showed highest turbidity from December, whereas L5 showed the lowest turbidity readings. Except for L1, the highest pH was observed in January(29^{th}) (Fig. 4.1.1.d). A trend was seen in pH where it increased from December to January(8^{th}) and then it started decreasing. The highest variation in pH was seen in L2. The DO readings were found to be somewhat similar between the locations during each sampling (Fig. 4.1.1.e). A slight variation was seen for DO readings at different sampling time. L5 had the highest Hardness reading throught the study period, whereas L3 had the lowest hardness readings except during

February, where L2 and L3 were lowest (Fig. 4.1.1.f). L1 had similar readings as L5 except for February. L2 showed highest alkalinity readings in December, whereas in rest of the months, alkalinity was found highest for L5 (Fig 4.1.1.g). From December to February, a decreasing trend was seen in alkalinity readings for most of the locations. Acidity readings were found highest for L1 throughout the study period (Fig. 4.1.1.h). All the locations showed increased acidity readings from January (29^{th}) to March. Among all the locations, major variation was seen in L3 during the study. Chloride ions concentration was seen highest in December for all the locations (Fig. 4.1.1.i). L1 showed a decreasing trend in chlorides values from December to March and for L2, it was from December to February. The Highest BOD was found in December for all the locations (4.1.1.j). A decreasing trend was seen for L3 from December to March. Whereas for L3 and L5 a wave like trend was seen with increasing during one month and decreasing during other. Highest phosphate concentration was seen during February for all the locations (Fig. 4.1.1.k.2). Similar to DO, phosphate also showed very less variation among the parameters. A dip was seen in the trend from December to January (8^{th}) and then it started raising. February and March readings were somewhat close to each other. Highest nitrate concentration was found for L3. L3 showed a mountain shape trend where the values increased from December to January(29^{th}) and decreased from January(29^{th}) to March. For L5 no variation was seen from December to January (29^{th}) indicated by straight line (Fig. 4.1.1.l.2).

4.1.2.c Dumping of Waste

While sampling, it was seen that a large amount of solid waste was dumped in and around the Kushavati River in the human-settled area (Fig. 1.4.1). This dumping of solid waste generated through human settlement can decrease the aesthetic value of Kushavati River and thereby its portability for various use like recreation and domestic purpose. Kushavati River originates in the Western Ghats and flows through the Quepem town thereby giving an aesthetic value to the town. The dumping of waste generated through the human settlement can hamper this quality and the waters portability since nobody will use water where there is waste dumped. Secondly, though at present the dumping of waste may not have any effect on the water quality but in future when the dumping of waste increases it may affect the water quality. Therefore, this issue must be tackled at present. Some of the mitigation measures to tackle these issues are given below;

1. Organising a cleanliness drive along the river to remove the water dumped in and around the river.
2. Since the river comes under the jurisdiction of Quepem Municipal Council, they should appoint a person to monitor the river.
3. Installation of cameras at certain places where there is regular dumping of waste.
4. Formulating strict rules and regulations to be followed at the river points.
5. Penalties or fines for those who are found dumping the waste
6. Checking the water quality once a year

4.2 CONCLUSION

Water quality studies of Kushavati river flowing through Quepem town was carried out from November 2023 to March 2024 to assess the impact of human settlement on river water quality. From the analysis of the physio-chemical parameters and statistical analysis, it was found that the water quality of the Kushavati river was within the BIS standards and hence good. Therefore, it can be concluded that currently the human settlement had no negative impact on the river water quality of Kushavati river during the dry spell of the year. Similar study needs to be carried out over the entire year to confirm the same. Since the dumping of waste may decrease the aesthetic value of river and may affect the water quality in the long run, such studies should be repeated in future.

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APPENDIX I

Reagents used for Analysis

- 9 N Sulphuric acid: 25 ml of concentrated sulphuric acid was added to 75 ml of distilled water.
- Ascorbic acid: 7g of ascorbic acid was dissolved in 100 ml of distilled water.
- Mixed Reagent;

a) 9.5g of ammonium molybdate was dissolved in 100 ml distilled water.

b) 3.25g of potassium antimony tartarate was dissolved in 100 ml distilled water.

c) 22.5 ml of ammonium molybdate and 100 ml of the prepared 9 N sulphuric acid was mixed together. To this 2.5 ml of potassium antimony tartarate was added and shaken.

- Phosphate stock solution: 0.1361g of potassium dihydrogen phosphate was dissolved in distilled water and volume was made up to 100 ml. Next, 10 ml of the solution was taken and diluted to 100 ml with distilled water. Similarly, 10 ml of the diluted solution was taken and diluted to 100 ml.
- Sulphanilamide solution: 1g of sulphanilamide was dissolved in 10 ml od concentrated hydrochloric acid to 60 ml of distilled water. It was moderately heated to accelerate the dissolution. After cooling, the solution was made up to 100 ml with distilled water.
- N-(1-nephthyl)-ethylenediamine dihydrogen chloride: 0.1g of N-(1-nephthyl)-ethylenediamine dihydrogen chloride was dissolved in water and made to 100 ml.
- Nitrite stock solution: 0.365g of sodium nitrite was dissolved in 500 ml distilled water. Next, 5 ml of the solution was taken and diluted to 500 ml using distilled

water. Similarly, 5 ml of dilute solution taken and diluted to 500 ml using distilled water.

- Manganous sulphate: 34.09 g of manganous sulphate was dissolved in distilled water and the volume was made up to 100 ml in a volumetric flask.
- Alkaline iodine solution: 50g of NaOH was dissolved in 50 ml distilled water. Separately,15g of potassium iodide was dissolve in 20 ml of distilled water and 1g of sodium azide was dissolved in 5 ml distilled water. All the three solutions were mixed to make volume to 100 ml using distilled water.
- 0.01 N sodium thiosulphate: 2.5g of sodium thiosulphate was dissolved in 1000 ml of distilled water.
- Starch solution: ig of soluble starch was dissolved 10 ml of distilled water. Next, 90 ml of distilled water was heated to boiling and the slurry was poured to it while stirring.
- 0.01 N EDTA solution: 0.372g of EDTA was dissolved in 1000 ml of distilled water.
- NaOH buffer: 2g of NaOH was dissolved in 50 ml distilled water.
- Ammonia buffer: 5ml of ammonia was dissolved in 45 ml of distilled water.
- EBT indicator: 0.2g of EBT was dissolved in 50 ml ethanol.
- 0.0141 N Silver nitrate: 1.1975g of silver nitrate was dissolved in 500 ml distilled water.
- Potassium chromate indicator: 10g of potassium chromate was dissolved in 100 ml of distilled water.
- 0.02 N NaOH: 4g of NaOH was dissolved in 100 ml distilled water. Next, 2 ml from that was taken and dissolved to 98 ml distilled water.

- 0.02 N Sulphuric acid: 2.8 ml of sulphuric acid was dissolved in 97.2 ml of distilled water. Next, 2 ml from that was taken and dissolved to 98 ml distilled water.
- Methyl orange indicator: 1g of methyl orange was dissolve in 20 ml ethanol and the volume was made to 100 ml using distilled water in a volumetric flask.

APENDIX II

Standard Graphs

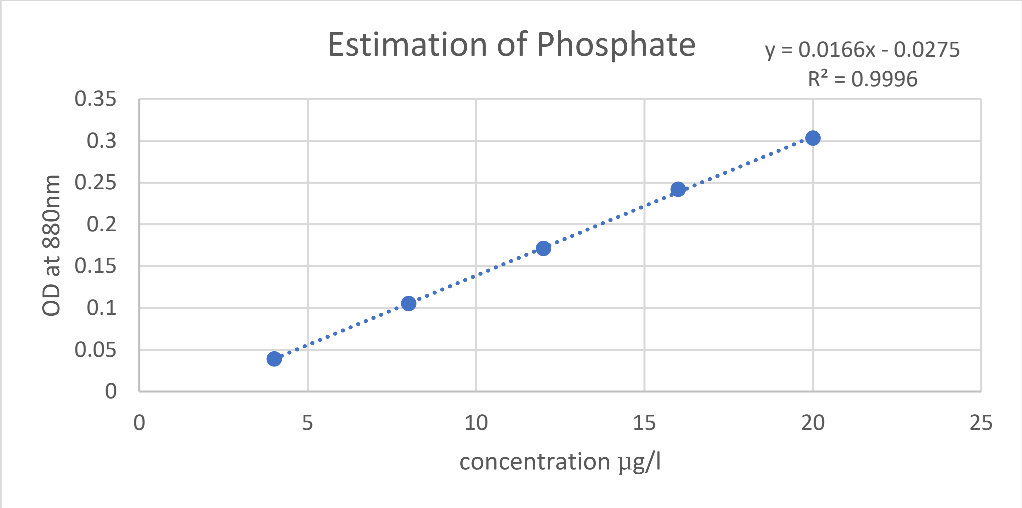

Fig. II.1. Standard graph for estimation of concentration of Phosphate in water samples.

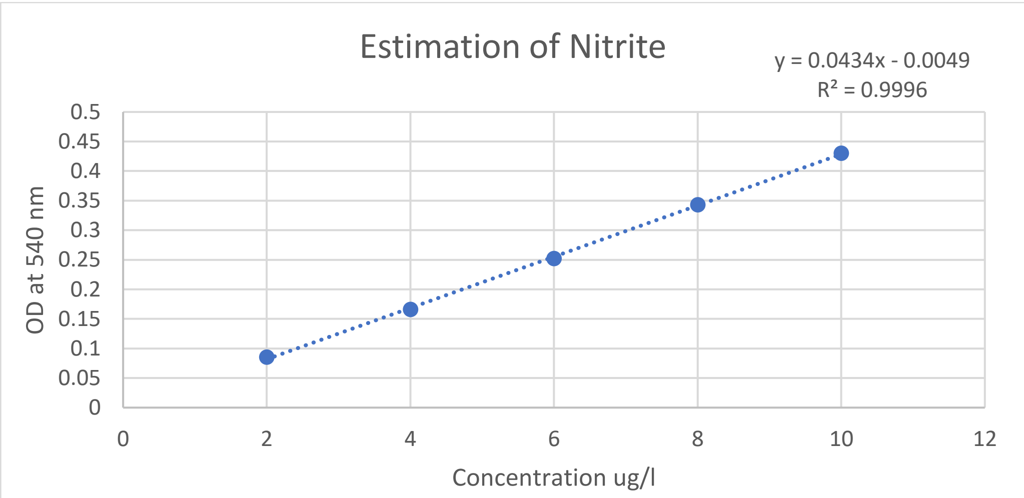

Fig. II.2. Standard graph for estimation of concentration of Nitrite in the water samples.