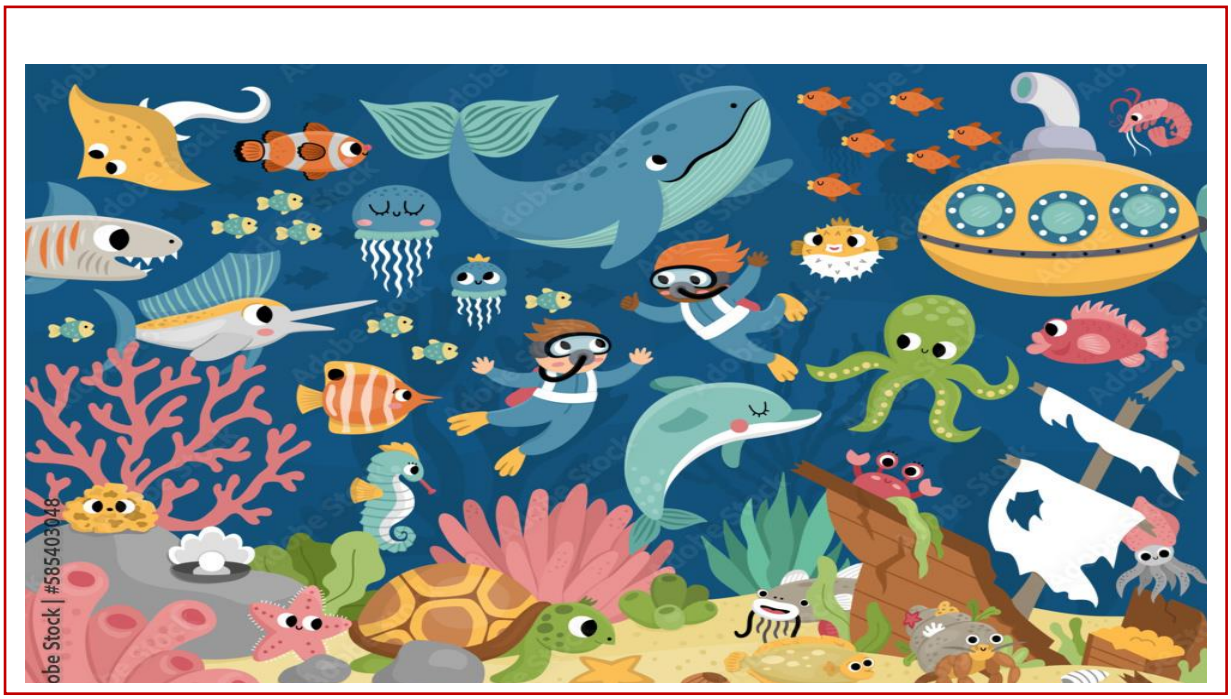
Sponsored Thesis Project Competition on

"RE-IMAGINING URBAN RIVERS"

Season- 3



Project Title: **Nadhi to Jeeva Nadhi- The rise of aquatic life**

Creator: M. Veena, Bachelor of Technology in Electronics and Communication Engineering, Vignana Bharathi Institute of Technology

CERTIFICATE OF COMPLETION

This is to certify that this thesis project titled "**Nadhi to Jeeva Nadhi – The Rise of Aquatic life**" was carried out by Shri. **M. Veena**, a student of **Bachelor of Technology**, at the **Vignana Bharathi Institute of Technology**. The research for this project was undertaken under the guidance of the afore-mentioned institute and completed during the period of **January 2023** to **June 2023**.

This project was shortlisted under the *Sponsored Thesis Project Competition on "RE-IMAGINING URBAN RIVERS" (Season- 3)* hosted by the National Institute of Urban Affairs (NIUA) and the National Mission for Clean Ganga (NMCG).

This report has been submitted by the student as a final deliverable under the competition. All parts of this research can be used by any of the undersigning parties.

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ACKNOWLEDGMENT

I extend my appreciation to the organizers of the Student Thesis Competition Season 3, the **National Institute of Urban Affairs (NIUA),** and the **National Mission for Clean Ganga (NMCG),** for providing this platform and opportunity to showcase my research. I am honored to have been a part of this competition.

I take the opportunity to acknowledgement with thanks and deep sense of gratitude towards our Principal **Dr. P.V.S. SRINIVAS**, who extended his wholehearted co-operation and encouragement in the successful completion of my project.

I am very much thankful to **Dr. SUNDEEP SIDDULA**, Director, Research & Development Cell and Associate Professor, Department of EEE who extended invaluable suggestions, encouragement, and guidance. His support played a significant role in refining my research and ensuring its quality.

I express my sincere thanks to my guide **Dr. U. POORNA LAKSHMI**, HoD, Department of Electronics and Communication Engineering who has given her invaluable suggestions, constructive criticism and expert guidance.

I would like to thank my **Parents** for their unwavering love, understanding, and encouragement. Their support has been the cornerstone of my academic journey, and I am deeply grateful for their sacrifices and belief in me.

BY

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ABSTRACT

Marine population is the combination of various Aquatic animals and plants, now it has become the marine pollution which is the combination of chemicals and trash. Plastic pollution affects aquatic animals throughout their lifecycle. From the moment they are born, they face the risk of injury or death - because they may ingest (microplastic or plastic bag can look like a lot of jellyfish, algae, or other species are eaten by aquatic animals) or get entangled in plastic. When small organisms that consume microplastics are eaten by larger animals, the toxic chemicals then become part of their tissues. In this way, the microplastic pollution migrates up the food chain, eventually becoming part of the food that humans eat. To restore the aquatic flora and fauna, we first need data to analyse what is happening inside the water. Therefore, my prototype collects three major data objects like pH, Turbidity and Count of Aquatic Species in a water body. Using this we can know concentration of pollution and share this information with concerned authorities and take actions to reduce pollution. After certain measures we can also see if the aquatic life is populating or not and what are the factors which are responsible for their growth of population.

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Chapter: 1 Introduction

Freshwater lakes are of paramount importance as they serve as vital sources of clean water, supporting diverse ecosystems and sustaining human livelihoods. Musi River, once a significant freshwater lake in India, played a crucial role in providing drinking water, supporting agriculture, and promoting biodiversity. However, the lake's health has been severely impacted due to pollution, primarily from industrial and domestic waste disposal. Harmful chemicals and pollutants have contaminated the water, leading to a decline in water quality, loss of aquatic life, and increased health risks for nearby communities. This degradation underscores the urgent need for concerted efforts to protect and restore freshwater bodies like Musi River, ensuring their sustainable use and preservation for future generations.

The proposed project aims to develop a comprehensive monitoring system for Musi River to assess the concentration of pollution and population of aquatic species. By integrating advanced water quality testing equipment and innovative data collection techniques, the project will enable real-time monitoring of various pollutants, including industrial and domestic waste, and their impacts on the river's ecosystem. Additionally, the project will employ advanced biodiversity survey methods to track and analyse the population trends of aquatic species in the river. The data collected through this project will not only provide valuable insights into the current environmental health of Musi River but also serve as a foundation for informed decision-making and the implementation of targeted conservation efforts to restore the river's ecological balance and ensure the preservation of its aquatic life for future generations.

The pollution concentration in Musi is assessed using pH and turbidity sensors. These sensors help in monitoring the water quality by measuring the acidity level (pH) and the cloudiness (turbidity) caused by suspended particles and pollutants in the river. Population of Aquatic species is measured using yolov5 model and a camera. The data collected from these sensors and model aids in understanding the pollution levels and implementing appropriate measures for environmental conservation.

The outcomes of this thesis are to:

1. Assess Water Quality: The thesis aims to provide a comprehensive assessment of the water quality in the Musi River, Hyderabad. By analysing various physicochemical parameters, such as pH, turbidity, dissolved oxygen, and nutrient levels, the study will offer insights into the current state of the river's water quality.
2. Identify Pollution Sources: The research will identify and characterize the sources and types of pollutants present in the Musi River. It will examine industrial discharges, untreated sewage, and plastic waste to understand their contribution to the contamination of the river.

3. Analyze Impact on Aquatic Flora and Fauna: The thesis will investigate the impact of pollution on the aquatic flora and fauna in the Musi River. By studying the abundance, diversity, and health of these organisms, the research will assess the ecological implications of water pollution.
4. Assess Human Health Risks: The research will explore the potential risks posed to human health due to the consumption of contaminated fish and seafood. By investigating the transfer of pollutants to higher trophic levels, the study will assess the implications for human well-being.

5. Propose Restoration Strategies: The thesis aims to propose feasible and sustainable measures for restoring and conserving the Musi River. The research will consider socio-economic and environmental factors to develop effective restoration strategies.
6. Raise Awareness and Engage Stakeholders: The study seeks to raise awareness among stakeholders, policymakers, and the public about the urgency of addressing pollution in the Musi River. By disseminating research findings, the thesis aims to foster collective action for preservation efforts.
7. Support Policy Formulation: The outcomes of the research will provide valuable scientific insights that can support the formulation and implementation of environmental regulations and policies related to water management and pollution control.
8. Promote Sustainable Practices: By identifying pollution sources and their impact, the thesis will promote sustainable waste management practices and eco-friendly initiatives to minimize pollution and conserve the river's ecosystem.
9. Contribute to Scientific Knowledge: The research will contribute to the body of knowledge on water pollution and its consequences in urban river settings. It will offer valuable insights for future studies in similar environments and contribute to the broader understanding of environmental issues.
Overall, the outcomes of this thesis are expected to contribute significantly to the conservation and restoration of the Musi River, ensuring the sustainability of this vital water body and its surrounding ecosystem for future generations.

1.1History

The Musi River, situated in the city of Hyderabad, India, has a rich history that dates back centuries. Its significance extends beyond its role as a water body to encompass cultural, economic, and ecological aspects. However, over the years, rapid urbanization and industrialization have taken a toll on the river's ecosystem, leading to the deterioration of its aquatic flora and fauna. This section delves into the history of the Musi River, highlighting its connection with aquatic life and the importance of restoration efforts to revive its ecological balance.

The history of the Musi River can be traced back to the Qutb Shahi dynasty in the 16th century when Hyderabad was founded. The river played a crucial role in the city's development, providing water for irrigation, agricultural activities, and domestic use. Its banks were adorned with lush vegetation, and the river teemed with a diverse range of aquatic flora and fauna, supporting a thriving ecosystem.

As Hyderabad evolved into a major urban center, industrialization and population growth began to exert immense pressure on the Musi River. Factories and settlements sprung up along its banks, leading to the discharge of industrial effluents and untreated sewage directly into the river. These pollutants altered the river's water quality, triggering a decline in its aquatic biodiversity.

The once-abundant aquatic flora, comprising submerged plants, floating vegetation, and riparian species, faced substantial challenges due to pollution and habitat degradation. Many native aquatic

plant species struggled to survive, while invasive species began to dominate the river's ecosystem. This disruption in the balance of flora impacted the food web and led to a decline in the abundance of aquatic fauna.

Aquatic fauna in the Musi River also faced significant challenges. Fish populations that were once abundant diminished due to the degradation of water quality and the loss of suitable habitats for breeding and spawning. As the river's water quality worsened, the ability of aquatic organisms to thrive and reproduce declined. Additionally, pollutants introduced by industries and urban runoff led to bioaccumulation of toxins in fish and other aquatic organisms, further affecting their health and reproductive capabilities.

To address the deteriorating condition of the Musi River's aquatic flora and fauna, restoration efforts have become paramount. Various stakeholders, including government agencies, non-governmental organizations (NGOs), and environmentalists, have come together to implement initiatives aimed at improving the river's health.

Aquatic flora restoration involves measures such as replanting native species, controlling invasive plants, and establishing buffer zones along the riverbanks. These efforts aim to enhance habitat quality, stabilize riverbanks, and foster a healthier ecosystem.

Similarly, aquatic fauna restoration strategies focus on water quality improvement, pollution control, and the creation of fish-friendly habitats. Initiatives such as establishing fish ladders, removing barriers to fish migration, and reducing pollution inputs have been undertaken to aid the recovery of fish populations.

Education and public awareness campaigns also play a crucial role in the restoration process. By engaging local communities, raising awareness about the importance of conserving the Musi River's aquatic biodiversity, and promoting responsible waste disposal practices, the restoration efforts can gain momentum.

In conclusion, the Musi River's history reflects its significant importance to the city of Hyderabad. However, the degradation of its aquatic flora and fauna due to pollution demands urgent restoration efforts. Through collaborative actions and a collective commitment to protecting the river's ecosystem, it is possible to revive the Musi River's aquatic biodiversity and ensure its sustained health for generations to come.

1.2Statement of the Problem

The Musi River, once a lifeline for the city of Hyderabad, India, has now become a victim of severe pollution and degradation. The escalating deterioration of the river's water quality presents a pressing and multifaceted problem that demands immediate attention. This statement of the problem

delves into the root causes and consequences of the Musi River's pollution, exploring its far-reaching implications on the environment and the well-being of the communities relying on its waters.

The Musi River, historically revered for its cultural significance and contributions to the region's development, now faces an unprecedented crisis. The rapid urbanization and industrialization that accompanied Hyderabad's growth have taken a toll on the river's health. Industrial discharges, untreated sewage, and improper waste disposal practices have become primary contributors to the contamination of the Musi River. As these pollutants find their way into the water, they disrupt its ecological balance, posing grave threats to the aquatic flora and fauna that once thrived in its pristine waters.

The consequences of this environmental degradation are far-reaching and profoundly concerning. The once-lush riverbanks that teemed with diverse aquatic plants and wildlife are now marred by the accumulation of plastic waste and other pollutants. Aquatic flora, such as submerged plants and floating vegetation, are suffocated by the presence of plastics and other debris, impacting their ability to photosynthesize and reproduce. As the flora declines, the entire food web within the river is disrupted, affecting the survival of aquatic fauna and further exacerbating the problem.

Aquatic fauna in the Musi River, including fish, amphibians, and other aquatic organisms, face dire circumstances. The ingestion of microplastics and plastic bags by these creatures poses a significant threat to their health and survival. Microplastics are mistaken for jellyfish, algae, or other prey, leading to ingestion and subsequent entanglement, resulting in injury or death. Furthermore, as small organisms consume microplastics, the toxic chemicals within these particles accumulate in their tissues. As larger aquatic animals prey on these smaller organisms, the toxins travel up the food chain, ultimately contaminating the fish and seafood that humans consume.

The consequences of pollution in the Musi River extend beyond its aquatic inhabitants. The deterioration of water quality also impacts the surrounding communities that rely on the river for various purposes, including agriculture, drinking water, and recreational activities. The presence of toxic chemicals and harmful pollutants not only affects the river's ecological integrity but also poses significant risks to public health.

Addressing the issue of Musi River's pollution requires a comprehensive and urgent approach. Raising awareness about the severity of the problem is crucial in mobilizing efforts to combat pollution and restore the river's health. The implementation of effective waste management practices, the treatment of industrial effluents, and the establishment of proper sewage treatment facilities are imperative to curbing pollution at its sources. Furthermore, the adoption of eco-friendly practices and sustainable waste disposal methods can significantly contribute to reducing the river's contamination.

In light of these challenges, the development of a prototype to collect crucial data on pH, turbidity, and the count of aquatic species represents a significant step towards addressing the problem. This data will serve as a foundation for the analysis of pollution levels and the formulation of

appropriate strategies for restoration. By sharing this information with relevant authorities and communities, the initiative aims to foster collective action towards reviving the Musi River's ecosystem and ensuring a sustainable future for this vital water body.

In conclusion, the degradation of the Musi River's water quality due to pollution is a pressing problem that demands immediate attention and action. The adverse effects on the river's aquatic flora and fauna, as well as the risks posed to public health, highlight the urgency of addressing this issue. By raising awareness, implementing effective pollution control measures, and utilizing data-driven strategies for restoration, we can work towards preserving the Musi River's ecological balance and safeguarding the well-being of both the environment and the communities dependent on its waters.

1.3 Research Aim and Objectives

Research Aim:
The aim of this research is to assess the current state of water quality in the Musi River, Hyderabad, and to investigate the extent of pollution and its impact on the aquatic flora and fauna.

Research Objectives:
1. To evaluate the physicochemical parameters of the Musi River, including pH, turbidity, dissolved oxygen, and nutrient levels, to determine the overall water quality.
2. To identify the sources and types of pollutants present in the Musi River, such as industrial effluents, untreated sewage, and plastic waste.
3. To assess the abundance and diversity of aquatic flora and fauna in the Musi River and analyze their health and reproductive status.
4. To investigate the occurrence and distribution of microplastics in the river and their potential effects on aquatic organisms.
5. To analyze the potential impact of pollution on the food chain and the transfer of pollutants to higher trophic levels, including potential risks to human health.
6. To explore existing restoration and conservation efforts in the region and evaluate their effectiveness in mitigating pollution and revitalizing the river ecosystem.
7. To propose feasible and sustainable measures for the restoration and conservation of the Musi River, considering the socio-economic and environmental aspects.
8. To raise awareness among stakeholders, policymakers, and the general public about the urgency of addressing pollution in the Musi River and promoting collective action for its preservation.
By accomplishing these research objectives, this study aims to provide valuable insights into the current state of the Musi River's water quality, the impact of pollution on its aquatic flora and fauna, and the crucial need for effective restoration and conservation efforts to ensure the sustainability of this vital water body and its surrounding ecosystem.

1.4Significance of Study:

The study on the water quality and pollution in the Musi River holds significant importance for several key stakeholders and the broader community. The research aims to provide valuable insights and contribute to various aspects, making it highly significant:

1. Environmental Conservation: The study's findings will shed light on the extent of pollution and its impact on the Musi River's ecosystem. Understanding the ecological implications is crucial for devising effective conservation strategies to protect the river's aquatic flora and fauna.
2. Public Health: The contamination of the Musi River can have severe consequences on public health, especially for communities relying on the river for drinking water and other domestic uses. The study will help assess potential health risks and prompt measures to safeguard public well-being.
3. Policy and Governance: The research outcomes can serve as a valuable scientific basis for policymakers and government agencies to formulate and implement environmental regulations and policies. It can influence decision-making processes related to water management and pollution control.
4. Sustainability: By identifying the sources of pollution and analyzing its effects on the river, the study can promote sustainable practices and waste management solutions that minimize pollution and enhance the river's long-term viability.
5. Community Awareness: Raising awareness about the Musi River's pollution and its consequences is crucial to foster community engagement and involvement in conservation efforts. The study can empower local communities to participate actively in safeguarding their natural resources.
6. Restoration Efforts: The study's data and analysis will provide valuable guidance for restoration initiatives. It can support the planning and execution of projects aimed at improving water quality, enhancing biodiversity, and revitalizing the river's ecosystem.
7. Scientific Contributions: The research can contribute to the body of knowledge on water pollution and its impact on aquatic ecosystems, particularly in urban river settings. It can also serve as a reference for future studies in similar environments.
8. Educational Tool: The study can serve as an educational tool, disseminating information about the importance of water quality, pollution control, and sustainable practices among students, educators, and the general public.
9. Long-term Planning: Understanding the challenges faced by the Musi River can aid in long-term planning for urban development, industrial growth, and conservation efforts in the region. It can foster a more holistic approach to river management.
10. Global Relevance: As water pollution is a global concern, the findings of this study can contribute to the broader understanding of environmental issues and inspire similar studies in other regions facing similar challenges.

Overall, the significance of this study lies in its potential to influence policies, raise awareness, promote conservation, and foster sustainable practices, ultimately contributing to the protection and preservation of the Musi River and its invaluable role in the socio-economic and ecological fabric of Hyderabad, Telangana, and beyond.

1.5 Organization of the Thesis

Provide an outline of the chapters and sections that constitute the thesis. The thesis is organized into several chapters, each focusing on distinct aspects of the Musi River conservation website. The chapters include:

Chapter 1: Introduction

This chapter provides an overview of the Musi River's significance, the problem of pollution, the objectives of the study, and the scope of the research.

Chapter 2: Literature Review

This chapter presents a comprehensive review of the existing literature on water pollution, conservation efforts, and the role of technology in environmental awareness and restoration.

Chapter 3: Implementation and Data Analysis

This chapter focuses on the implementation of the website and the analysis of pollution data collected from IoT devices.

Chapter 4: Results and Discussion

Here, the findings from the website implementation and data analysis are presented and discussed in detail.

Chapter 6: Conclusion and Recommendations

The final chapter concludes the thesis by summarizing the key findings, emphasizing the importance of the website's impact, and providing recommendations for future enhancements and conservation initiatives.

Chapter 2: Literature Survey

2.1 Introduction

The Musi River, located in Hyderabad, India, has a long and storied history deeply intertwined with the presence of aquatic animals in its waters. Throughout the ages, the river has been a lifeline for the region, supporting a rich diversity of aquatic flora and fauna that have played crucial roles in the ecosystem and the lives of the local communities.

Fig 2.1 Musi River

2.2 Historical Abundance of Aquatic Animals in the Musi River

Throughout history, the Musi River has been home to a diverse array of aquatic animals, contributing to its ecological richness and providing sustenance to local communities. The river's pristine waters once supported a thriving population of various fish species, crustaceans, and other aquatic organisms. Fish such as Rohu, Catla, Mrigala, and the indigenous Mahseer were abundant, supporting the livelihoods of traditional fishermen who relied on the river's bounty for their sustenance and economic well-being. Crustaceans like prawns and crabs were also prevalent, further enriching the river's biodiversity.

2.3 Cultural Significance and Traditions Surrounding Aquatic Animals

The presence of aquatic animals [1] in the Musi River held cultural and religious significance for the local communities. The river and its creatures were revered, and various religious rituals and festivals were centered around the river's life-giving properties. Devotees offered prayers and ceremonial offerings to honor the aquatic flora and fauna, considering them as integral components of the river's divine essence. Traditional fishing practices and rituals were handed down through generations, fostering a deep connection between the community and the aquatic life of the Musi River.

2.4 Impact of Urbanization and Pollution on Aquatic Animals

With the advent of urbanization and industrialization [2], the once pristine waters of the Musi River faced unprecedented challenges. Rapid urban growth led to an influx of untreated sewage and industrial effluents, directly impacting water quality and posing significant threats to aquatic animals. The rising pollution levels introduced harmful toxins and pollutants into the river, severely affecting the health and survival of fish species. Additionally, the presence of microplastics and other pollutants disrupted the aquatic food chain, leading to a decline in species diversity and habitat loss for various aquatic organisms. The degradation of the river's ecosystem had far-reaching consequences, affecting both the aquatic life and the livelihoods of local communities dependent on the river's resources.

Despite the challenges posed by pollution and environmental degradation, there is hope for the revival of the Musi River's aquatic life. Collaborative efforts by conservation organizations, governmental bodies, and local communities are underway to address pollution, restore water quality, and protect the river's ecosystem. Through ongoing monitoring and conservation measures, there is an opportunity to safeguard and rejuvenate the once vibrant aquatic animals of the Musi River, preserving its cultural heritage and ecological significance for generations to come.

2.5 Visit to Telangana State Pollution Control Department

2.5.1 Introduction to Telangana State Pollution Control Department (TSPCB):

The Telangana State Pollution Control Board (TSPCB) is a statutory authority responsible for implementing environmental laws and regulations in the state of Telangana, India. It was established under the provisions of the Water (Prevention & Control of Pollution) Act, 1974, and the Air

(Prevention & Control of Pollution) Act, 1981, following the bifurcation of the Andhra Pradesh Pollution Control Board (APPCB) in 2014.

2.5.2 Musi River Pollution: Overview and Concerns

The Musi River is one of the prominent water bodies in Telangana, flowing through the capital city of Hyderabad. However, over the years, the river has faced severe pollution issues, primarily due to industrial effluents, untreated sewage, and other pollutants being discharged into it. This section explores the key factors contributing to Musi River's pollution and the resulting environmental concerns.

2.5.3 Research on Musi River Pollution:

In-depth Study of Industrial Effluents: An investigation into the industrial activities along the Musi River's banks and their contribution to the pollution load. The research aims to identify the types of industries, their effluent treatment practices, and compliance with pollution control regulations.

Assessment of Sewage Disposal: A comprehensive study on the disposal of untreated sewage into the Musi River and its impact on water quality. The research delves into the efficiency of sewage treatment plants (STPs) and explores potential measures to minimize sewage-related pollution.

Water Quality Monitoring: A review of the water quality monitoring efforts carried out by the TSPCB and other agencies along the Musi River. The research focuses on the frequency of monitoring, parameters measured, and trends in water quality data.

Impact on Aquatic Life and Biodiversity: An assessment of the pollution's effect on aquatic life and biodiversity in the Musi River. The research aims to understand the decline of native species, changes in the river's ecosystem, and implications for the overall environment.

Regulatory Measures and Enforcement: An analysis of the regulatory measures implemented by the TSPCB to control pollution in the Musi River. The research evaluates the effectiveness of enforcement actions, penalties for violators, and challenges faced in ensuring compliance.

Community Awareness and Participation: A study on the involvement of local communities, NGOs, and other stakeholders in efforts to address Musi River pollution. The research explores awareness campaigns, citizen-led initiatives, and public participation in pollution control measures.

2.5.4 Conclusion and Recommendations:

This section summarizes the findings from the research on Musi River pollution and presents actionable recommendations for the Telangana State Pollution Control Department to tackle the challenges effectively. The recommendations may include policy changes, enhanced monitoring strategies, strengthened enforcement, and community engagement to restore and protect the Musi River's health and biodiversity.

2.6 A Report on Musi River Groundwater Quality Assessment

Water is vital for all life forms, including humans [3], and is a precious natural resource supporting diverse aquatic life in rivers, lakes, and oceans. However, rapid globalization and industrialization have led to increased pollution of both surface and groundwater, including the Musi River in Hyderabad, Telangana. The Musi River, once a source of water for the city, now suffers from severe pollution due to untreated sewage, industrial effluents, and waste disposal. This pollution poses a threat to public health and the environment. Efforts to protect and improve water quality are necessary to ensure a sustainable and healthier future for the region.

Water samples were collected from rural and urban areas of Hyderabad at five different sites during the pre-monsoon season. Various analytical methods were used to assess water quality parameters, including Electrical Conductivity meter, pH meter, Ion meter, UV Spectrophotometer, Nephelometer, and Flame photometer. Parameters measured included color, odor, pH, electrical conductivity (EC), total dissolved solids (TDS), turbidity, alkalinity, chloride, fluoride, nitrate, sulfate, sodium/potassium, total hardness (TH), biochemical oxygen demand (BOD), and chemical oxygen demand (COD). The study aimed to understand the water quality status, highlighting the impact of pollution from industrial and domestic sources on the Musi River and surrounding groundwater in Hyderabad.

The results and discussion of the water quality analysis in the pre-monsoon season for various parameters were assessed at different sites in rural and urban areas of Hyderabad. The study found that some sites had water quality parameters within permissible limits, but BOD and COD levels exceeded the acceptable standards. The pollution was attributed to industrial and domestic waste dumping in the Musi River, particularly evident at site-4. The findings indicate that water at several sites is unsuitable for drinking, agriculture, and domestic use, posing potential health risks to the population. Groundwater contamination worsens during the pre-monsoon season due to reduced groundwater levels and increased industrialization around Hyderabad.

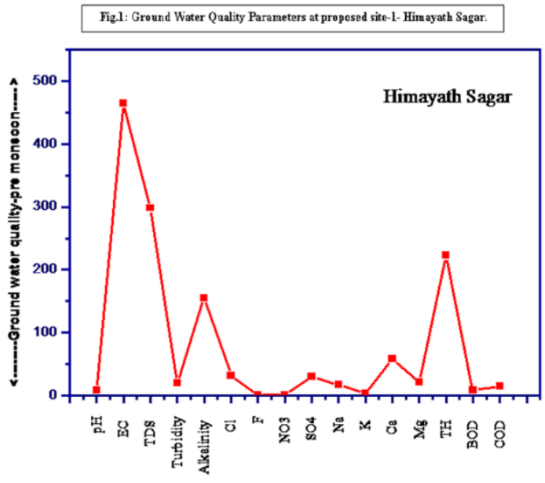


Fig 2.2 Site 1

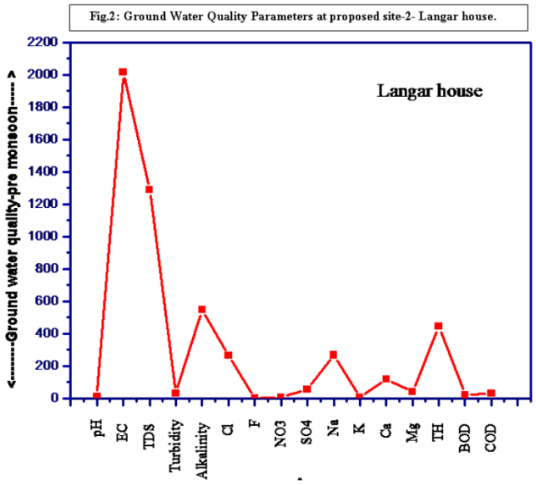


Fig 2.3 Site 2

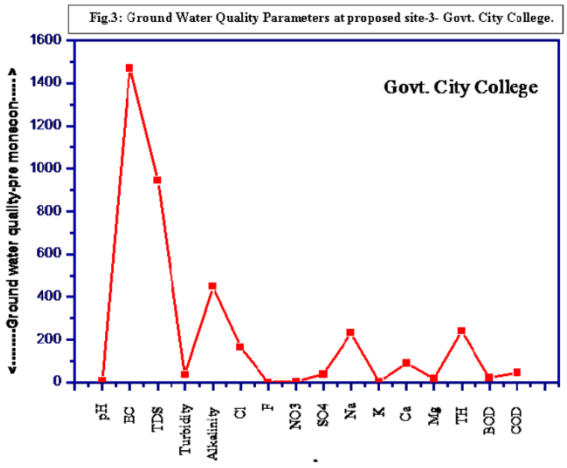


Fig 2.4 Site 3

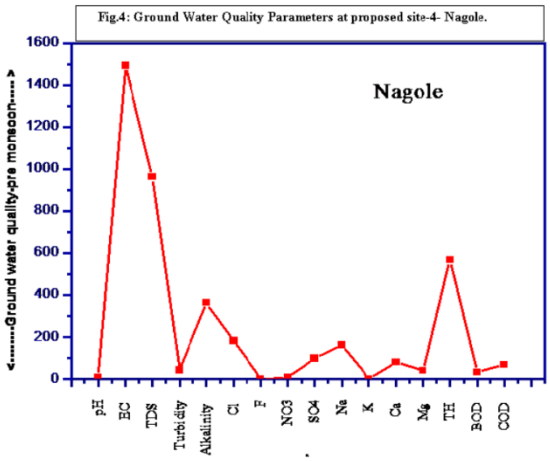


Fig 2.5 Site 4

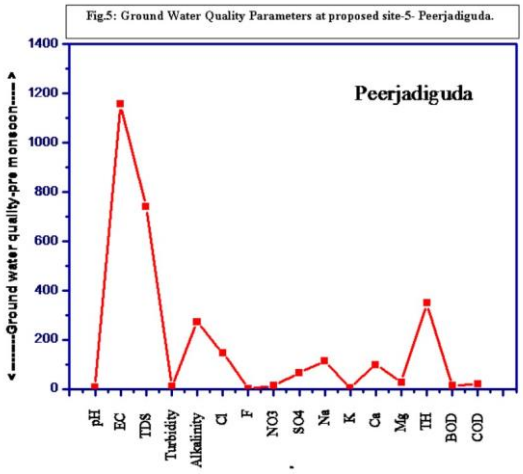


Fig 2.6 Site 5

2.7 Research on Project Design:

The below studies are comprehensive overview of the existing research on marine pollution, microplastic impacts on aquatic life, data collection for monitoring, and strategies for aquatic flora and fauna restoration. The proposed prototype that collects pH, Turbidity, and Aquatic Species count will play a crucial role in understanding pollution concentrations and assisting conservation efforts to restore marine ecosystems effectively. Sharing this information with relevant authorities will contribute to informed decision-making and actions to reduce pollution and promote sustainable management of marine environments.

Fig 2.7 Aquatic Tortoise

Fig 2.8 Aquatic Fish

1. Marine Pollution and its Impact on Aquatic Life:
- Rochman, C. M. et al. [4]
- Lusher, A. L. et al. [5]
- Wright, S. L. et al. [2]

2. Microplastic Ingestion and Entanglement in Aquatic Animals:
- Gall, S. C. et al. [6]
- Desforges, J.-P. et al [1]

3. Toxic Chemicals and Microplastics in the Marine Food Chain:
- Koelmans, A. A. et al. [7]
- Farrell, P. et al. [8]

4. Data Collection and Monitoring Techniques for Marine Pollution:
- Huang, Z. et al. [9]
- Bryan, G. W. et al. [10]

5. Water Quality Parameters for Aquatic Flora and Fauna Restoration:
- Chen, Q. et al [11]
- Sharma, S. et al. [12]

6. Use of pH and Turbidity as Pollution Indicators:
- Hale, R. C. et al. [13]
- Fong, L. N. et al. [5]

7. Counting Aquatic Species and Assessing Population Growth:
- Thomsen, P. F. et al. [14]
- Gotelli, N. J. et al. [6]

8. Aquatic Flora and Fauna Restoration Strategies:
- Barbier, E. B. et al. [15]
- Levin, N. et al. [4]

9. Effective Data Sharing with Concerned Authorities for Pollution Reduction:
- Schlüter, M. et al. [16]
- Vogel, J. (2012). [7]

10. Monitoring and Evaluation of Restoration Efforts:
- Goldman, G. T. et al. [8] - Van Allen, B. G. et al. [17]

Chapter 3: Hardware Components

3.1 Raspberry Pi 4 Board:

Raspberry Pi 4 is a popular and versatile single-board computer developed by the Raspberry Pi Foundation. It is the fourth generation in the Raspberry Pi series and offers significant improvements over its predecessors. The Raspberry Pi 4 was released in June 2019 and has been widely adopted by hobbyists, educators, and professionals for a variety of projects and applications.

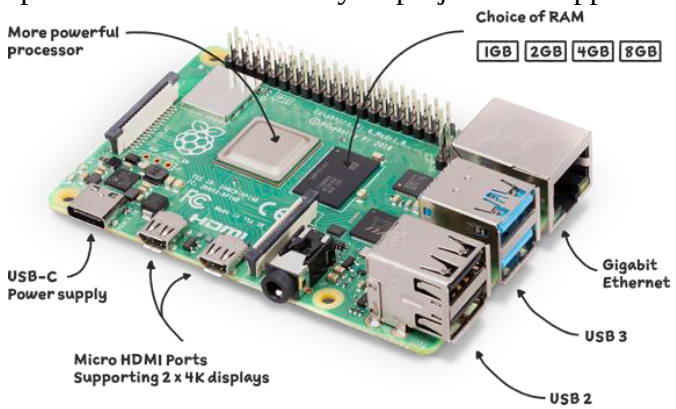


Fig 3.1 Raspberry pi 4 Board

Key features of the Raspberry Pi 4 include:
1. Improved performance: The Raspberry Pi 4 is powered by a Broadcom BCM2711 quad-core Cortex-A72 (ARMv8) 64-bit processor, running at up to 1.5 GHz. This provides a substantial performance boost compared to earlier models.
2. RAM options: It is available in different RAM configurations, ranging from 1GB to 8GB, allowing users to choose the appropriate memory capacity for their projects.

3. Connectivity: The board features built-in wireless networking with dual-band 802.11ac Wi-Fi and Bluetooth 5.0. Additionally, it has Gigabit Ethernet, four USB 2.0 ports, and two USB 3.0 ports, providing extensive connectivity options.
4. Video and display support: The Raspberry Pi 4 supports dual-monitor setups via two micro HDMI ports, capable of driving 4K displays at 60 frames per second or 1080p displays at 60/30 frames per second.
5. GPIO pins: Like its predecessors, the Raspberry Pi 4 includes a 40-pin GPIO (General Purpose Input/Output) header, allowing for interfacing with various sensors, peripherals, and other hardware.
6. Storage: It supports microSD cards for primary storage and does not have onboard storage like traditional computers.
7. Power requirements: The Raspberry Pi 4 requires a USB-C power supply with 5V and a minimum of 3A for stable operation.
The Raspberry Pi 4 is commonly used for a wide range of projects, including but not limited to:
- Retro gaming consoles
- Home media centers

- Home automation and smart home projects
- Robotics and automation
- Network-attached storage (NAS) solutions
- Educational purposes, learning programming and electronics
- Internet of Things (IoT) projects

The Raspberry Pi Foundation continues to support and update the Raspberry Pi 4 with improvements and software updates, making it a powerful and cost-effective tool for various applications.

3.2 Raspberry Pi Power Supply:

Fig 3.2 Raspberry pi Power Supply

The Raspberry Pi 4 requires a stable and adequate power supply to function correctly. The power supply needs to meet specific requirements to ensure proper operation and prevent any stability issues. Here is some important information about the power supply for the Raspberry Pi 4:

1. Voltage: The Raspberry Pi 4 requires a 5V DC (Direct Current) power supply. Using a different voltage can damage the board.

2. Current (Amperage) Rating: The Raspberry Pi 4's power requirements depend on its usage and the peripherals connected. Generally, a 3A (3000mA) power supply is recommended for the best performance, especially when using power-hungry USB devices or accessories. While the Pi might work with a 2.5A power supply, it can lead to undervoltage issues, potentially causing instability and random shutdowns.

3. Connector Type: The Raspberry Pi 4 model uses a USB Type-C connector for power. Make sure the power supply has a USB-C connector that fits securely into the Raspberry Pi 4's power input.
4. Quality: It is crucial to use a high-quality power supply from a reputable manufacturer to ensure stability and safety. Cheap or low-quality power supplies may not provide the rated output and can cause problems.
5. Multiple Peripherals: If you plan to connect power-hungry USB devices (e.g., external hard drives, high-power USB peripherals) to the Raspberry Pi 4, it's advisable to have a power supply that can handle the combined load of the Pi and those peripherals. In such cases, a 3A or higher rated power supply is strongly recommended.
6. Power over Ethernet (PoE) HAT: If you plan to use Power over Ethernet to power your Raspberry Pi 4, you will need a separate PoE HAT module. The official Raspberry Pi PoE HAT allows you to power the Pi over Ethernet, but you still need a compatible PoE network switch or injector.
If the power supply is insufficient, it can lead to unstable performance, unexpected reboots, or the Raspberry Pi 4 not working properly. It's best to use the official Raspberry Pi power supply or a reputable third-party power supply that meets the recommended specifications.

3.3 Micro SD Card (32 GB):

Fig 3.3 Micro SD Card

1. Capacity: 32GB refers to the storage capacity of the microSD card. It can store approximately 32 gigabytes of data.
2. Speed Class: MicroSD cards are often categorized by speed classes, such as Class 2, 4, 6, 10, U1, U3, etc. These classes indicate the minimum sustained write speeds in megabytes per second (MB/s). Higher classes mean faster write speeds.
3. UHS Speed Class: Some newer microSD cards also carry UHS (Ultra High Speed) speed class ratings like UHS-I and UHS-II, which offer higher data transfer speeds than traditional Speed Class cards.
4. Read and Write Speeds: The read and write speeds of a microSD card determine how quickly data can be read from and written to the card. Higher speeds are essential for tasks like recording high-quality videos or running apps directly from the card.

5. Compatibility: SanDisk microSD cards are usually compatible with various devices that support microSD HC or microSD XC formats, including smartphones, tablets, cameras, drones, and more.
6. Waterproof and Shockproof: Many microSD cards are designed to be water-resistant and shockproof, which protects your data from accidental damage.
7. Classifications: MicroSD cards are often labelled as microSD HC (High Capacity) or microSD XC (Extended Capacity) based on their capacity. microSD HC cards typically range from 2GB to 32GB, while microSD XC cards start from 64GB and can go up to several terabytes.

3.4 Card Reader:

Fig 3.4 Card Reader

A card reader is a device used to access and transfer data from memory cards to a computer or other devices. In this project, I am using a SanDisk Micro SD Card 32GB, a card reader will be a valuable tool to read and transfer data between the memory card and computer.

Features and Specifications:
Card Compatibility: Ensure that the card reader you choose is compatible with the type of memory card you are using. In your case, make sure it supports microSD cards.
Transfer Speed: Look for a card reader that offers high-speed data transfer to save time when transferring large files.
USB Interface: If you opt for a USB card reader, check the USB version (e.g., USB 2.0, USB 3.0, USB 3.1) to ensure it matches the capabilities of your computer's USB ports.
Plug-and-Play: A user-friendly card reader should be plug-and-play, meaning it can be used without the need for installing additional drivers or software.
Compact and Portable: If you plan to use the card reader on the go, consider one that is small, lightweight, and easy to carry.

LED Indicators: Some card readers have LED indicators to show the status of data transfer or card detection.

Card Write Protection: Some card readers feature a physical switch to enable or disable write protection on the memory card.

3.5 Zebronics Zeb-Crystal Pro Web Camera with USB Powered:

Fig 3.5 Zebronics Zeb-Crystal Pro Web Camera

High-resolution video: The camera may support Full HD (1080p) or even higher resolution video for clear and detailed image quality during video calls and recordings.

Auto-Focus: The camera might have an autofocus feature to keep the subject in focus without manual adjustments.

Wide-angle lens: A wide-angle lens enables capturing a larger field of view, ideal for group video calls or recording in tight spaces.

Low-light performance: Good low-light performance allows the camera to produce clear images even in dimly lit environments.

Built-in microphone: Many web cameras include a built-in microphone to pick up audio for video conferencing and online calls.

Privacy cover: Some webcams come with a physical privacy cover to ensure your camera remains disabled when not in use, enhancing privacy and security.

Plug-and-play: The camera should be easy to set up and use without requiring additional drivers or software installation.

Compatibility: It should be compatible with various operating systems and video conferencing applications.

Adjustable mount: A flexible mount allows you to position the camera on top of your monitor or laptop securely.

Frame rate: A higher frame rate, such as 30 fps (frames per second), ensures smoother video quality during real-time communication**.**

3.6 Ph Sensor:

Specifications of a pH sensor for water:

Fig 3.6 Ph Sensor

- Measurement Range: Typically 0 to 14 pH units.
- Accuracy: High-quality sensors have ±0.1 pH unit accuracy.
- Resolution: Fine resolution for precise pH measurements.
- Response Time: Rapid stabilization for quick readings.
- Temperature Compensation: Ability to adjust for temperature changes.
- Calibration: Regular calibration required for accuracy.
- Immersion Depth: Suitable for immersion in water.
- Chemical Compatibility: Materials suitable for water contact.

3.7 Turbidity Sensor:

Fig 3.7 Turbidity Sensor

Specifications of a pH turbidity sensor for water:

- Measurement Range: Typically measures turbidity in NTU (Nephelometric Turbidity Units) or FNU (Formazin Nephelometric Units).

- Accuracy: High-quality sensors have ±1 NTU accuracy.

- Resolution: Fine resolution for precise turbidity measurements.

- Response Time: Rapid response for real-time monitoring.

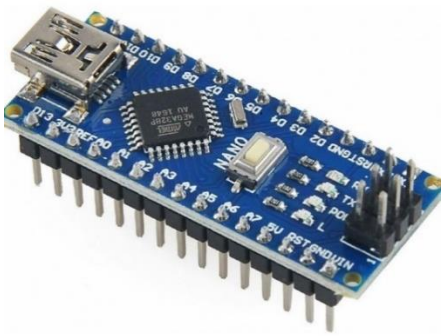
- Temperature Compensation: Ability to adjust for temperature effects on turbidity readings.

- Calibration: Regular calibration required for accuracy.

- Immersion Depth: Suitable for immersion in water.

- Chemical Compatibility: Materials suitable for water contact.

3.8 Arduino nano:



3.8 Arduino nano

Arduino Nano is a compact and versatile microcontroller board based on the ATmega328P microcontroller. It is part of the Arduino family of development boards, designed for projects requiring a smaller footprint and lower power consumption. The Arduino Nano comes in various versions, including the original 5V version and the newer 3.3V version, which is ideal for low-power applications.

Key Features of Arduino Nano:
1. Microcontroller: ATmega328P, running at 16MHz (5V version) or 8MHz (3.3V version).
2. Digital I/O Pins: 14 digital input/output pins, of which 6 can be used as PWM outputs.
3. Analog Input Pins: 8 analog input pins, allowing for analog sensor interfacing.
4. Flash Memory: 32KB of flash memory for storing the program.
5. SRAM: 2KB of SRAM for runtime data storage.
6. EEPROM: 1KB of EEPROM for non-volatile data storage.
7. USB Interface: Mini USB port for programming and communication with the computer.

8. Power Supply: Can be powered via USB or an external power supply (7-12V).
9. On-board Voltage Regulator: Allows the use of a wide range of input voltages.
10. Compatibility: Compatible with the Arduino IDE and supports various libraries and shields.
11. Compact Size: Small form factor (approx. 43mm x 18mm) for space-constrained projects.
12. Breadboard Friendly: It has 0.1-inch spaced pins, making it easy to use on a breadboard.

Table 3.1 Components Required

Components Required	Specification
Raspberry Pi 4 Board	Broadcom BCM2711
Raspberry Pi Power Supply	5V DC
Micro SD Card	32GB
Card Reader	32GB
Zebronics Zeb-Crystal Pro Web Camera	resolution 1920x 1080
Ph Sensor	0 to 14 pH units
Turbidity Sensor	±1 NTU accuracy
Arduino nano	ATmega328P

Chapter 4: Implementation

To implement this project, we will develop a prototype system capable of collecting crucial water data, including pH, Turbidity, and Count of Aquatic Species. We will deploy the prototype in various water bodies to monitor pollution levels. Collected data will be analyzed to assess pollution concentrations. Information will be shared with relevant authorities to prompt targeted actions for pollution reduction. Continuous monitoring will help evaluate the effectiveness of measures and track changes in aquatic life populations [4].

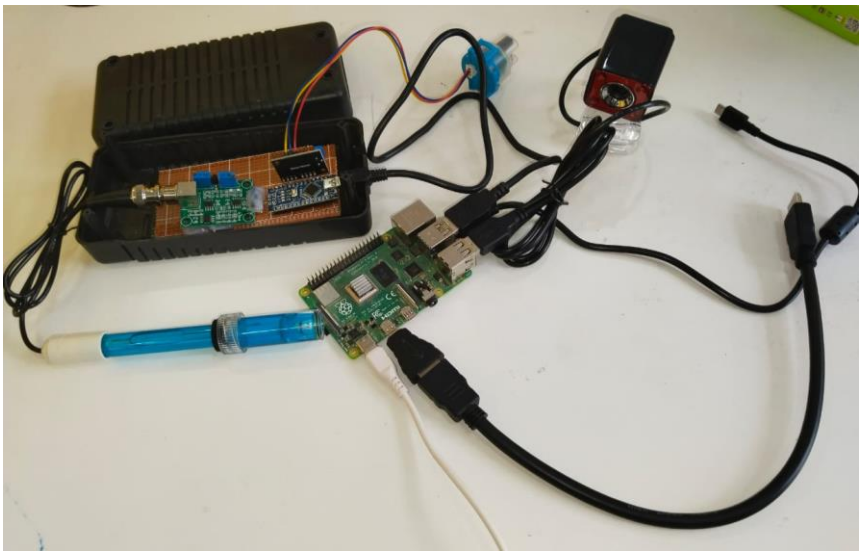


Fig 4.1 Complete picture of Project

4.1 Interfacing Ph Sensor with Arduino:

Ph Sensor has 3 pins that need to be connected to [5] Arduino. So, connect the VCC pin to 5V of Arduino and GND to GND. Connect its analog pin to A0 of Arduino. The source code for Interfacing Ph Sensor with Arduino is given below. Simply copy the code and upload it to the Arduino Board.

4.2 Interfacing Turbidity Sensor with Arduino:

You can do this by simply connecting the Turbidity Sensor [5] with Arduino Board. Connect the VCC of the Turbidity Sensor with Arduino 5V, GND to GND & Analog Output to Arduino A0 pin as shown in the image above. The source code for Interfacing Turbidity Sensor with Arduino is given below. Simply copy the code and upload it to the Arduino Board.

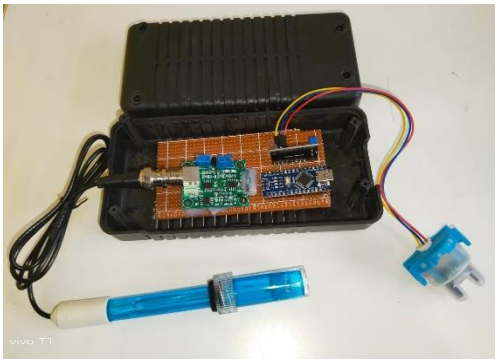


Fig 4.2 Interfacing Ph and Turbidity Sensor with Ardunio

4.3 Camera

Camera is connected to Raspberry pi to induct motion of aquatic species. The information collected through it will be communicated with concerned authorities[6].

4.4 Source Code for Ph and Turbidity Sensors:

```
#include <Wire.h>
#include <ArduinoJson.h>

const int turbsenPin = A0;
const int phsenPin = A1;
float Turbidity_Sensor_Voltage;
int samples = 600;
float ntu; // Nephelometric Turbidity Units
float ntuOffset = 1;
float calibration_value = 27 + 0.93;
int phval = 0;
unsigned long int avgval;
int buffer_arr[10], temp;
float ph_act;
void setup() {
  Wire.begin(8); // I2C address 8
  Serial.begin(9600);
}
void loop() {
  Turbidity_Sensor_Voltage = 0;
  for (int i = 0; i < samples; i++) {
    Turbidity_Sensor_Voltage += ((float)analogRead(turbsenPin) / 1023) * 5;
  }
  Turbidity_Sensor_Voltage = Turbidity_Sensor_Voltage / samples;
  float voltage = Turbidity_Sensor_Voltage;
  voltage = voltage + ntuOffset;
```

```
 voltage = constrain(voltage, 2.5, 4.2);
 // Convert the voltage to turbidity in NTU using the given formula
 ntu = -1120.4 * sq(voltage) + 5742.3 * voltage - 4352.9;

 for (int i = 0; i < 10; i++) {
  buffer_arr[i] = analogRead(phsenPin);
  delay(30);
 }
 for (int i = 0; i < 9; i++) {
  for (int j = i + 1; j < 10; j++) {
   if (buffer_arr[i] > buffer_arr[j]) {
    temp = buffer_arr[i];
    buffer_arr[i] = buffer_arr[j];
    buffer_arr[j] = temp;
   }
  }
 }
 avgval = 0;
 for (int i = 2; i < 8; i++)
  avgval += buffer_arr[i];
 float volt = (float)avgval * 5.0 / 1024 / 6;
 ph_act = -5.70 * volt + calibration_value;

 // Create a JSON object and populate it with the sensor data
 StaticJsonDocument<128> doc;
 ph_act = constrain(ph_act, 0, 14);
 ntu = constrain(ntu, 0, 3000);
 doc["ntu"] = ntu;
 doc["ph_act"] = ph_act;

 // Serialize the JSON object to a string and send it through Serial
 String jsonStr;
 serializeJson(doc, jsonStr);
 Serial.println(jsonStr);
 delay(200); // Adjust this delay according to your requirement
}
```

4.4 Yolov5 Model:

YOLOv5 is a popular and efficient object detection model that builds upon the success of previous YOLO (You Only Look Once) versions. Developed by Ultralytics, YOLOv5 is known for its lightweight architecture and impressive accuracy. The model adopts a one-stage approach, directly predicting bounding boxes and class probabilities without relying on region proposals. YOLOv5 is capable of detecting objects in real-time on both CPU and GPU, making it suitable for various

applications, including robotics, surveillance, and autonomous vehicles. The model's architecture is based on a deep neural network with a focus on streamlined components, allowing for rapid deployment and easy customization for specific use cases. Its success lies in the balance it strikes between accuracy and speed, making YOLOv5 a widely used and well-regarded solution in the field of computer vision.

This model is integrated into RaspberryPi and trained using following type of aquatic species. By this we can measure population count [6]. The type of aquatic specie we need to detect, that only will be detected by training with those images.

Fig 4.3 Orange Fish

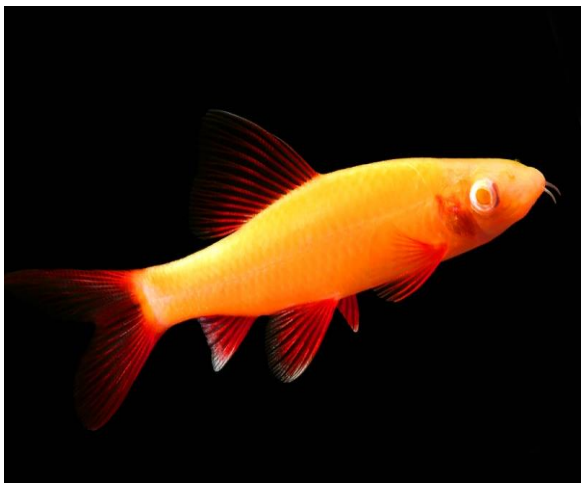


Fig 4.4 Orange Fish

Fig 4.5 Fish

Fig 4.6 Fish

4.5 Integration of Thing Speak Cloud:

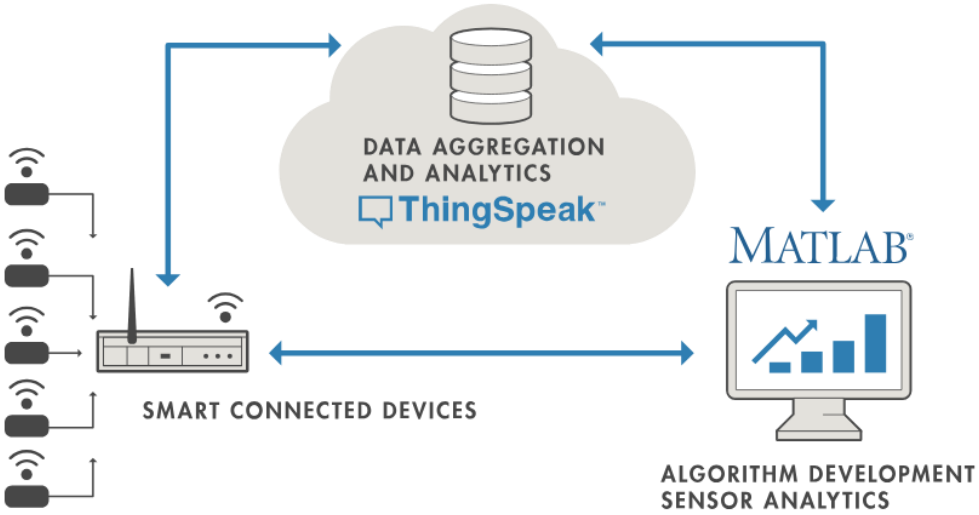


Fig 4.7 Integration of Thing Speak Cloud

Thing Speak[7] is an IoT analytics service that allows you to aggregate, visualize, and analyze live data streams in the cloud. Thing Speak provides instant visualizations of data posted by your devices to Thing Speak. With the ability to execute MATLAB code in Thing Speak, you can perform online analysis and process data as it comes in. Thing Speak is often used for prototyping and proof-of-concept IoT systems that require analytics.

You can send data from any internet-connected device directly to Thing Speak using a Rest API or MQTT. In addition, cloud-to-cloud integrations with The Things Network, Senet, the Libelium Meshlium gateway, and Particle.io enable sensor data to reach Thing Speak over LoRaWAN and 4G/3G cellular connections.

With Thing Speak, you can store and analyze data in the cloud without configuring web servers, and you can create sophisticated event-based email alerts that trigger based on data coming in from your connected devices.

Thing Speak is an open IoT platform for monitoring your data online. In Thing Speak channel you can set the data as private or public according to your choice. Thing Speak takes minimum of 15 seconds to update your readings. Its a great and very easy to use platform for building IOT projects.

Components Required:
Raspberry Pi
Power Cable
WiFi or Internet

4.5.1 Steps for building Raspberry Pi Data Logger on Cloud:

Step 1: Signup for Thing Speak

For creating your channel on ThingSpeak you first need to sign up on ThingSpeak. In case if you already have account on ThingSpeak just sign in using your id and password.
For creating your account go to www.thinspeak.com

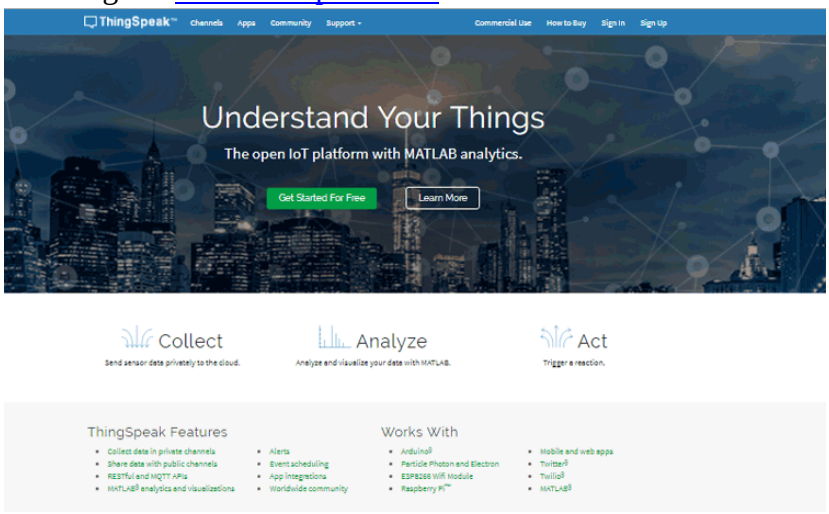


Fig 4.8 Signup Page

Click on signup if you don't have account and if you already have account click on sign in.
After clicking on signup fill your details.
Signup for ThingSpeak

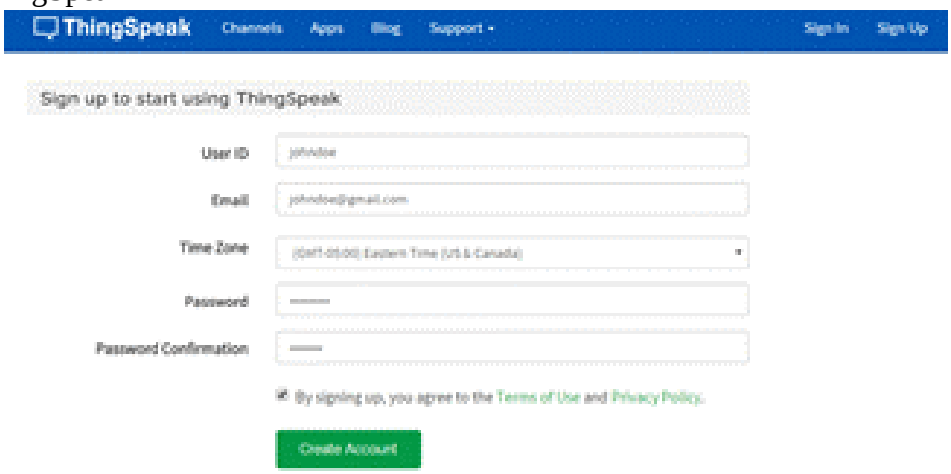


Fig 4.9 Signup for ThingSpeak

After this verify your E-mail id and click on continue.

Step 2: Create a Channel for Your Data

Once you Sign in after your account verification, Create a new channel by clicking "New Channel" button
Create Channel for Your Data on ThingSpeak

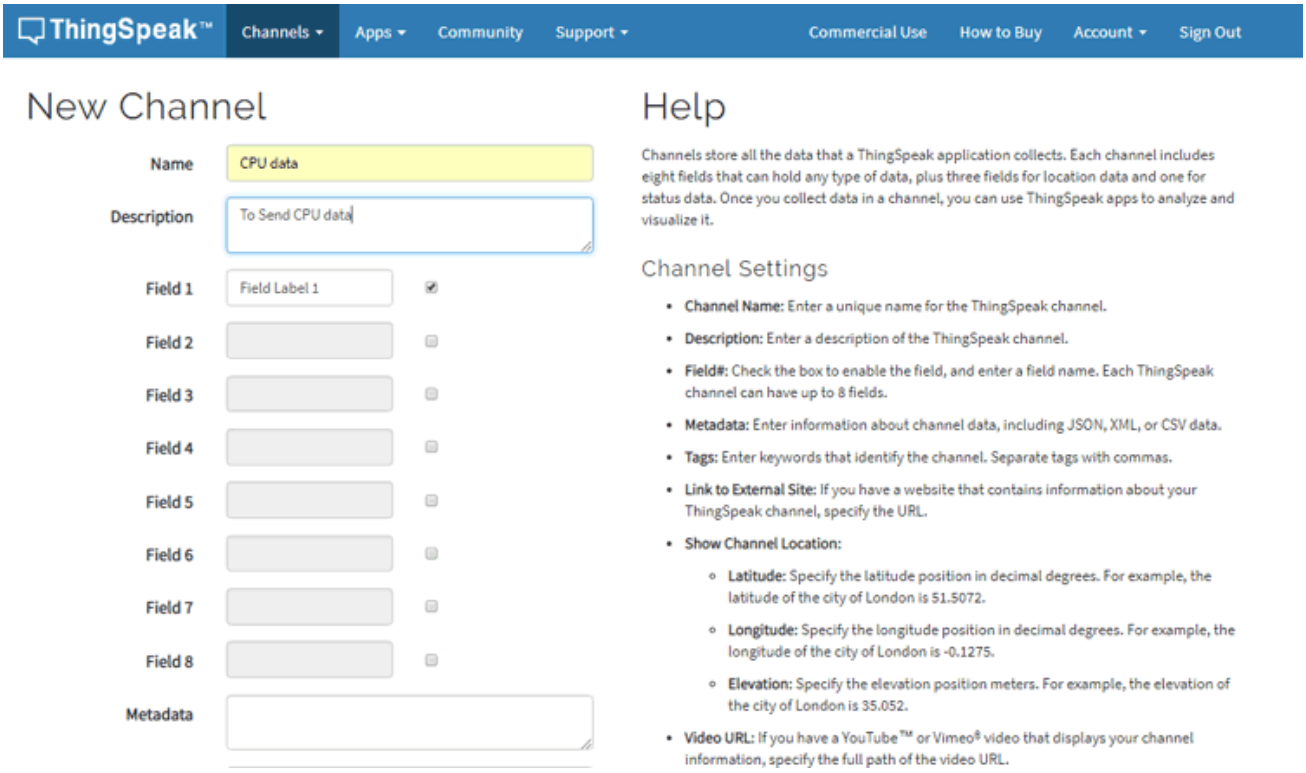


Fig 4.10 Create a Channel for Your Data

After clicking on "New Channel", enter the Name and Description of the data you want to upload on this channel. For example I am sending my CPU data (temperature), so I named it as CPU data.
Now enter the name of your data (like Temperature or pressure) in Field1. If you want to use more than one Field you can check the box next to Field option and enter the name and description of your data.
After this click on save channel button to save your details.

Step 3: Getting API Key in Thing Speak

To send data to ThingSpeak, we need an unique API key, which we will use later in our python code to upload our CPU data to ThingSpeak Website.
Click on "API Keys" button to get your unique API key for uploading your CPU data.
Getting API Key in ThingSpeak

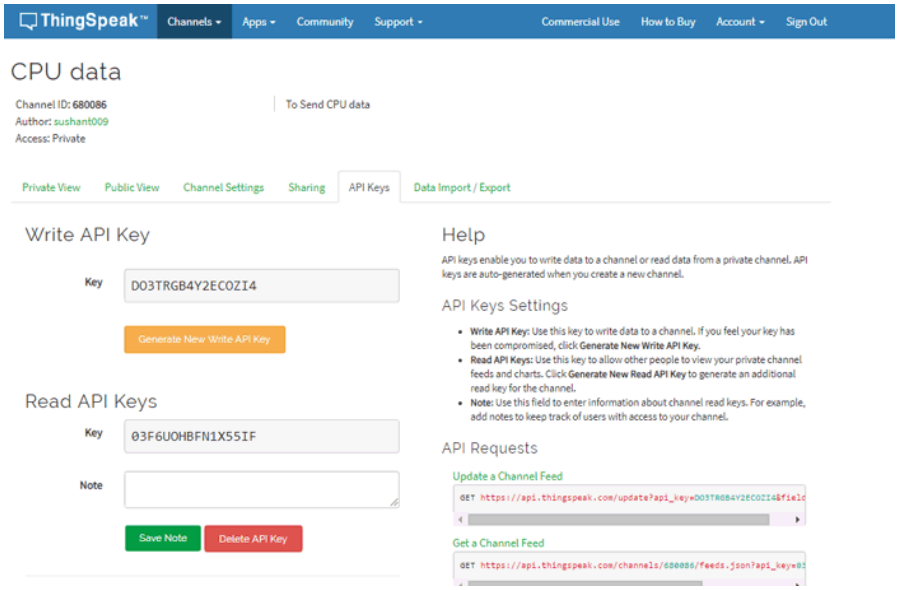


Fig 4.11 Getting API Key in Thing Speak

Now copy your "Write API Key". We will use this API key in our code.

Step 4: Python Code for Raspberry Pi

Complete code is given below, just make a file with any name and .py extension and copy-paste the code and save the file. Don't forget to replace the API key with yours. You can run the python file any time using below command:

python /path/filename.py

Assuming you already installed python in Raspberry pi using this command

sudo apt-get install python

Python Code :

```
import cv2
import torch
import requests  # Import the requests library
from yolov5.models.experimental import attempt_load
from yolov5.utils.general import non_max_suppression, check_img_size
import time
import serial
import json

ser = serial.Serial('/dev/ttyUSB0', 9600)

buffer = b""  # Change buffer initialization for bytes in Python 3

# Load YOLOv5 model
device = torch.device('cpu')  # or 'cuda' if you have a compatible GPU
print("Before loading the model")
model = torch.load('/home/pi/Desktop/best.pt', map_location=device)['model'].float().fuse().eval()
print("Model loaded successfully")
```

```
# Set image size for inference
img_size = 640

# ThingSpeak API Configuration
API_KEY = '9FJBAJAEW7DHSHYA'  # Replace with your ThingSpeak API key
THING_SPEAK_URL = 'https://api.thingspeak.com/update.json'

# Initialize the webcam
cap = cv2.VideoCapture(0)  # Change the parameter to the camera index if you have multiple cameras

# Time interval in seconds to send data
send_interval = 10  # Change this value to set the desired time interval in seconds
ntuv=0
phv=0
next_send_time = time.time() + send_interval

while True:
    ret, frame = cap.read()

    # Preprocess the frame
    img = cv2.resize(frame, (img_size, img_size))
    img = img.astype('float32') / 255.0
    img = torch.from_numpy(img.transpose(2, 0, 1)).unsqueeze(0)

    # Inference
    with torch.no_grad():
        pred = model(img, augment=False)[0]
        pred = non_max_suppression(pred, conf_thres=0.4, iou_thres=0.5)

    # Access the detected objects and draw bounding boxes on the frame
    num_detections = 0
    if pred[0] is not None:
        for det in pred[0]:
            x1, y1, x2, y2, conf, cls = det.tolist()
            if conf > 0.4:  # Adjust the confidence threshold as needed
                cv2.rectangle(frame, (int(x1), int(y1)), (int(x2), int(y2)), (0, 255, 0), 2)
                cv2.putText(frame, f'{int(cls)}: {conf:.2f}', (int(x1), int(y1) - 10),
cv2.FONT_HERSHEY_SIMPLEX, 0.5, (0, 255, 0), 2)
                num_detections += 1

    # Display the number of detections on the frame
```

```
    cv2.putText(frame, f'Number of Detections: {num_detections}', (10, 30), cv2.FONT_HERSHEY_SIMPLEX, 1, (0, 0, 255), 2)

    # Check if it's time to send data
    current_time = time.time()
    if current_time >= next_send_time:
        ntuv =0
        while 1:
            try:
                buffer = ser.readline()
                print(buffer.decode())  # Convert bytes to string in Python 3
                data = json.loads(buffer.decode())  # Convert bytes to string and then parse JSON
                print("ntu")
                ntuv = data["ntu"]
                print(ntuv)
                print("ph_act")
                phv = data["ph_act"]
                print(phv)

                buffer = b""  # Change buffer reset for bytes in Python 3
                print(" ")
                break
            except json.JSONDecodeError:
                print("Error: try to parse an incomplete message")
        # Send the count to ThingSpeak
        data = {'api_key': API_KEY,  "field1":phv ,
              "field2": ntuv,'field3': num_detections}
        response = requests.post(THING_SPEAK_URL, data=data)
        print(f'Data sent to ThingSpeak: {data}')

        # Update the next_send_time
        next_send_time = current_time + send_interval

    # Display the processed frame
    cv2.imshow('YOLOv5 Object Detection', frame)

    # Exit when 'q' key is pressed
    if cv2.waitKey(1) & 0xFF == ord('q'):
        break

# Release the webcam and close the OpenCV windows
cap.release()
```

cv2.destroyAllWindows()

Case 1: If using monitor screen then the given code is used.
Now install all libraries:
sudo apt-get install httplib
sudo apt-get install urllib
After installing libraries run your python code (python /path/filename.py)
If the code runs properly you will see some CPU temperature values as shown in below image.
Python Code for Raspberry Pi
If there are any errors uploading the data, you will receive "connection failed" message.
After installing libraries run your python code using:
python cpu.py
If the code runs properly you will see some CPU temperature values as shown in below image.

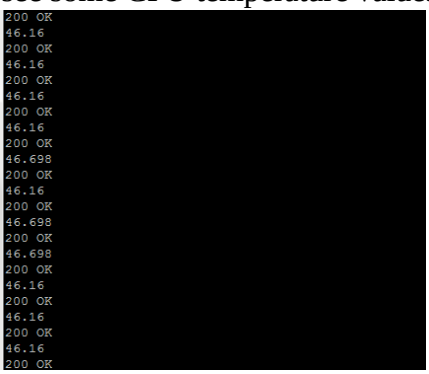


Fig 4.12 CPU tempetature

Step 6: Check Thing Speak site for Data Logging
After completing these steps open your channel and you will see the CPU temperature data is updating into Thing Speak website.
Check Thing Speak site for Data Logging

Like this you can send any sensor data connected with Raspberry pi to the Thing Speak Cloud.

The data can be stored in the form of graphs, numerical depending upon requirement. I stored in the form of graphs. The graph is given below:

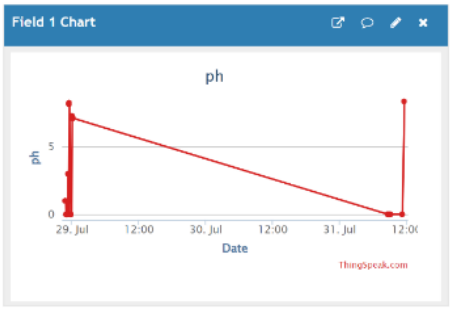


Fig 4.13 Chart

Chapter 5: Results and Conclusion

Results for Ph, Turbidity and aquatic animals count are shown in below pictures.

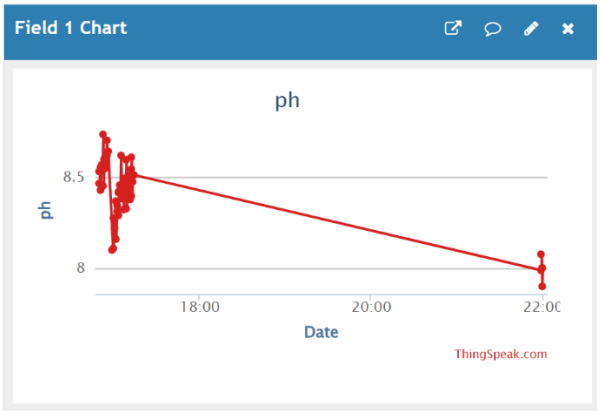


Fig 4.14 Ph Chart

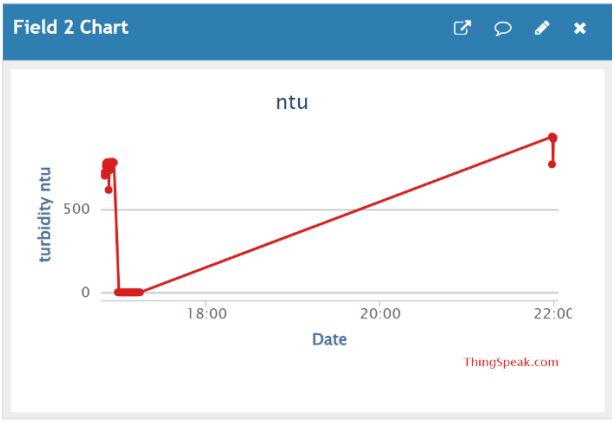


Fig 4.15 turbidity

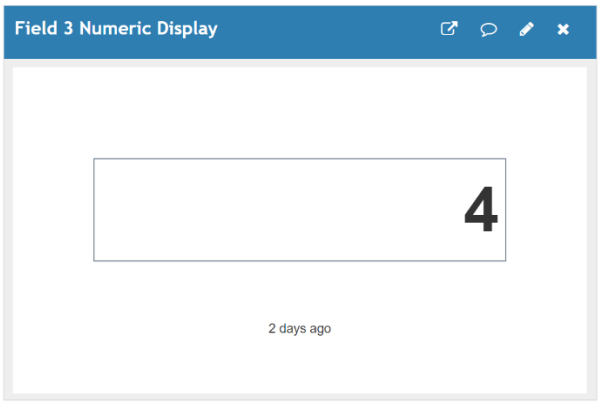


Fig 4.16 Aquatic count

Fig 4.17 Testing Project

In conclusion, this project presents a critical step towards safeguarding marine ecosystems and addressing the pressing issue of marine pollution. The combination of chemicals and trash, especially plastic pollution, poses a grave threat to aquatic animals and plants throughout their lifecycle. The detrimental effects of plastic ingestion and entanglement on marine life, along with the migration of toxic microplastics up the food chain, underscore the urgency to take action.

The prototype's collection of data on pH, Turbidity, and Count of Aquatic Species empowers us to analyze pollution concentrations and share essential information with concerned authorities. This

knowledge enables informed decision-making and targeted measures to reduce pollution levels effectively.

Additionally, monitoring the impact of implemented measures will help us understand if the aquatic life is recovering and identify key factors influencing population growth. By involving the community, policymakers, and industries, we can foster collective responsibility in preserving marine habitats. Ultimately, the success of this endeavor relies on continuous commitment to sustainable practices, fostering awareness, and proactively adapting strategies to restore and protect the diverse marine flora and fauna for current and future generations.

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