



AUTONOMOUS WATER SURFACE CLEANING ROBOT

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Abstract: Water pollution poses a significant threat to aquatic ecosystems and urban water infrastructure, with floating waste such as plastic debris, organic matter, and non-biodegradable materials accumulating rapidly in lakes, rivers, ponds, and reservoirs. Conventional cleaning techniques rely heavily on manual labor or large fuel-powered vessels, which are not only inefficient and costly but also unsustainable over the long term. This paper proposes the design and development of an Autonomous Water Surface Cleaning Robot (AWSCR) as an innovative solution to address this challenge. The robot is designed to autonomously navigate water surfaces, detect floating waste, and collect it using an onboard skimming mechanism. Core components include a microcontroller-based control system, GPS for path tracking, ultrasonic sensors for obstacle detection, and a solar-powered energy module to enhance environmental sustainability. The mechanical design adopts a catamaran-style floating chassis for stability and efficiency, while the electronics system ensures intelligent navigation and remote monitoring capabilities. The robot's performance was evaluated through simulations and small-scale prototype testing in controlled water environments. The results demonstrate the feasibility of deploying such autonomous systems for real-world water surface maintenance with minimal human intervention. This work contributes to the growing field of environmental robotics and offers a scalable, low-cost platform for improving water quality in urban and semi-urban regions.

I. INTRODUCTION

Water bodies such as lakes, ponds, rivers, and reservoirs are vital for maintaining ecological balance and providing essential services such as drinking water, irrigation, aquaculture, and recreation. However, increasing urbanization, industrialization, and human negligence have led to severe pollution in these water bodies, especially in the form of floating waste. This includes plastic bottles, polythene bags, thermocol, leaves, aquatic weed growth, and other non-biodegradable or slow-degrading materials. Such pollutants not only degrade the aesthetic value of the environment but also pose a direct threat to aquatic life, water quality, and the surrounding ecosystem.

Traditional methods of cleaning floating debris involve manual intervention using boats and nets or the deployment of large skimmer vessels. These approaches are not only labor-intensive and time-consuming but also expensive and inefficient for large-scale or continuous cleaning operations. Furthermore, manual efforts expose workers to health and safety hazards, especially in polluted or hazardous waters. Hence, there is a growing need for an autonomous, scalable, and eco-friendly solution that can operate with minimal human intervention while offering consistent and efficient cleaning performance.

1.1 Motivation

The increasing levels of water pollution, particularly the accumulation of floating waste in lakes, rivers, ponds, and reservoirs, have become a serious environmental challenge across urban and semi-urban areas. Human-induced activities such as indiscriminate dumping of plastic, leaves, wrappers, and other non-biodegradable materials are degrading the quality of surface water and disrupting aquatic ecosystems. Manual methods of waste collection—though still widely used—are inefficient, labor-intensive, and unsustainable in the long run. In many cases, cleaning operations are sporadic and dependent on the availability of labor, leading to delayed response times and poor coverage of polluted areas. Municipal bodies and environmental agencies often face financial and operational constraints in deploying continuous cleaning solutions. Relying on human-operated boats or large cleaning vessels incurs high costs and demands significant manpower. Moreover, these traditional methods expose workers to unsafe and unhygienic conditions, particularly when dealing with contaminated water. The lack of a scalable and automated cleaning mechanism further hampers the ability to maintain water quality on a consistent basis, particularly in remote or less accessible water bodies.

The urgent need for a reliable, cost-effective, and energy-efficient solution to address surface water pollution has driven the interest in robotic automation. With advancements in embedded systems, autonomous navigation, and renewable energy integration, it is now feasible to design a robot that can perform surface cleaning tasks with minimal human oversight. An Autonomous Water Surface Cleaning Robot (AWSCR) presents a practical and scalable solution to this problem by utilizing a modular, intelligent platform capable of detecting, collecting, and removing floating waste continuously.

1.2 Key Features

The Autonomous Water Surface Cleaning Robot (AWSCR) offers a modern, eco-friendly, and intelligent solution for the removal of floating waste from water bodies. Designed to address the inefficiencies of traditional manual methods, this robot incorporates autonomous technologies, energy-efficient systems, and modular design features that make it both scalable and adaptable to a variety of water environments. With the integration of smart sensors, GPS navigation, and renewable energy components, AWSCR operates continuously and reliably without the need for constant human intervention.

One of the most essential features of AWSCR is its autonomous navigation and real-time obstacle avoidance system. Using ultrasonic sensors, GPS, and onboard control algorithms, the robot is capable of navigating predefined paths while dynamically adjusting to avoid floating objects or barriers. This ensures that the robot can cover larger surface areas without becoming stuck or requiring manual redirection, significantly enhancing its cleaning efficiency.

Another standout feature is the waste collection mechanism built into the front chassis of the robot. It employs a mesh skimmer or intake scoop to gather floating debris, directing it into a removable storage bin that can be emptied periodically. This collection system is designed to handle lightweight plastics, leaves, styrofoam, and other surface contaminants typically found in urban water bodies. The modular waste bin allows for easy disposal and maintenance. Energy autonomy is another core feature. AWSCR is equipped with solar panels and rechargeable batteries, enabling it to operate for extended periods without reliance on external power sources.

1.3 Research Objectives

The primary objective of this research is to design and develop a fully autonomous, energy-efficient, and cost-effective robotic system capable of cleaning floating debris from the surface of water bodies without requiring continuous human intervention. This robotic solution is intended to improve the effectiveness, consistency, and sustainability of water surface cleaning efforts, thereby contributing to the preservation of aquatic ecosystems and urban water aesthetics.

A core focus of this project is to create an intelligent navigation system that integrates GPS tracking and ultrasonic sensors for real-time obstacle detection and autonomous path planning. The goal is to enable the robot to navigate various water surfaces, such as lakes, ponds, and canals, while efficiently identifying and avoiding obstacles, ensuring uninterrupted cleaning operations.

Another critical objective is to develop a robust and modular waste collection mechanism that can capture and store floating waste such as plastic, styrofoam, leaves, and other non-biodegradable debris. The research aims to ensure the waste collection unit is easy to deploy, maintain, and empty, while also being adaptable to different levels of pollution and water flow conditions.

Energy sustainability is also a major component of this project. The research seeks to explore the integration of solar-powered energy systems to reduce dependency on external power sources, thereby enabling longer operational durations and promoting environmental responsibility.

Additionally, this study aims to design a remote monitoring and control interface that allows users to track the robot's location, battery status, and waste bin capacity in real time. This interface should be user-friendly and accessible via both desktop and mobile platforms, ensuring ease of deployment and management.

II. LITERATURE SURVEY

The escalating concern over water pollution and the growing inefficiencies of manual cleaning methods have driven widespread research into automated and sustainable solutions for water surface maintenance. Conventional approaches, such as deploying laborers with nets or using fuel-powered skimmer boats, have been studied extensively and found lacking in terms of scalability, cost-efficiency, and safety. These traditional systems are limited by human labor, time constraints, and operational inefficiencies, especially when dealing with large or heavily polluted water bodies.

2.1 Survey of Existing Systems

Several studies and projects have emerged in recent years focusing on the development of autonomous or semi-autonomous systems for cleaning water bodies. These efforts stem from the growing global concern over aquatic pollution and the inefficiencies of conventional manual cleaning methods. Researchers and engineers have explored various mechanical designs, control algorithms, and power systems to create practical, deployable solutions for floating debris collection.

One notable study by Gupta et al. (2022) presented a solar-powered autonomous water cleaning robot equipped with a paddle-wheel propulsion system and a conveyor belt mechanism for debris collection. While effective in controlled environments, the system lacked dynamic navigation capabilities and struggled in unstructured or obstacle-rich water bodies.

A project led by Zhao and Li (2021) introduced an Autonomous Surface Vehicle (ASV) for floating trash collection using GPS-based path-following and manual remote control. Although their robot could collect significant waste over a defined path, the absence of obstacle avoidance sensors limited its autonomy and adaptability to unpredictable environments such as urban lakes with heavy human activity. **Identified research gaps**

Despite ongoing research and various prototype implementations aimed at addressing floating water pollution through robotic solutions, several critical gaps remain unaddressed in the current landscape of autonomous surface cleaning systems.

One of the most pressing limitations is the lack of true autonomy. While many existing systems claim autonomous functionality, most still rely on predefined paths or require manual intervention for navigation and obstacle avoidance. Few solutions incorporate adaptive, real-time environmental awareness, which is essential for deployment in dynamic water bodies with floating debris, varying currents, or human activity. This gap reduces their real-world applicability, especially in complex urban or natural aquatic environments.

Energy sustainability also remains an underdeveloped area in the domain. While solar-powered systems are occasionally integrated, they are often not optimized for continuous, long-duration operation. Some prototypes fail to include efficient energy management systems that balance charging, propulsion, and collection tasks. Without energy autonomy, robots must be retrieved frequently for charging, limiting operational

scalability and efficiency.

III. Proposed system

3.1 Problem Statement and Objectives

The accumulation of floating waste such as plastics, leaves, and other debris on water surfaces in lakes, rivers, ponds, and reservoirs poses a serious environmental threat. This pollution not only degrades the aesthetic and recreational value of these water bodies but also endangers aquatic life and disrupts the ecosystem. Traditional methods of cleaning, which rely heavily on manual labor and large-scale machinery, are often inefficient, costly, and limited in accessibility, especially in narrow or shallow water bodies. There is a pressing need for an autonomous, cost-effective, and energy-efficient solution that can operate continuously and adapt to varying environmental conditions to maintain water surface cleanliness without human intervention.

The primary objective of this research is to design and develop an autonomous water surface cleaning robot capable of detecting, collecting, and removing floating waste materials from water bodies without human intervention. The specific goals include:

1. To develop an autonomous navigation system using GPS and obstacle detection sensors for real-time path planning and collision avoidance.
2. To integrate a sustainable power system, such as solar panels and rechargeable batteries, ensuring extended operation with minimal environmental impact.
3. To build a scalable, cost-effective, and lightweight prototype suitable for cleaning small to medium-sized water bodies like ponds, lakes, and canals.
4. To evaluate the robot's performance in real-world conditions based on parameters such as waste collection efficiency, navigation accuracy, and energy consumption.

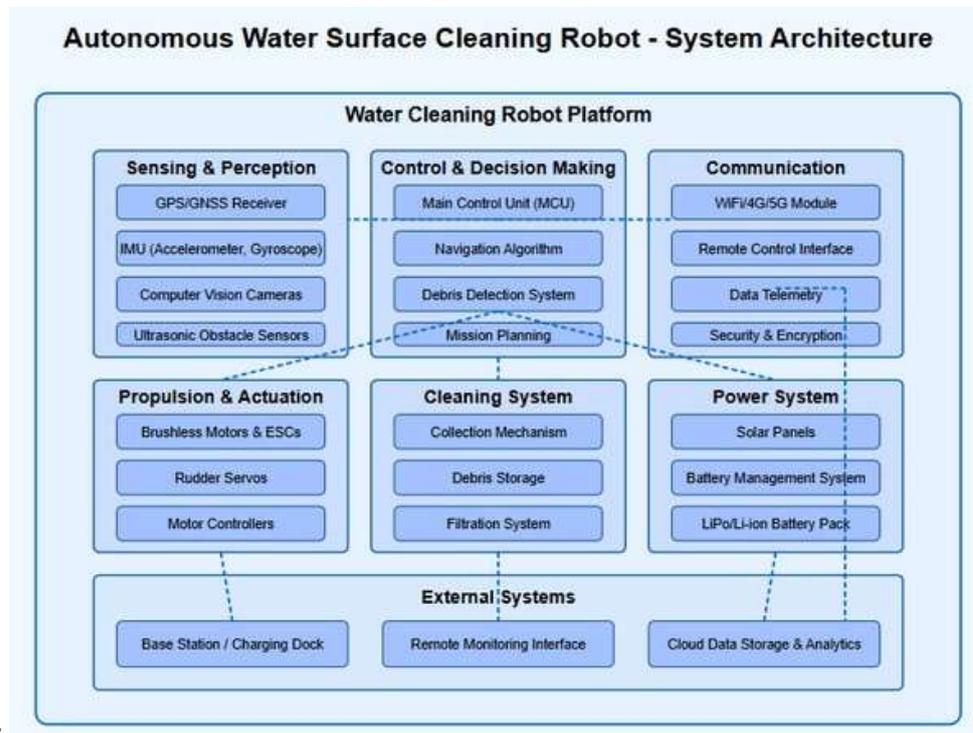
3.2 Scope of the Work

This project focuses on the design, development, and testing of a compact, autonomous robot intended to clean floating waste from the surfaces of still or slow-moving water bodies. The scope includes:

1. Target Water Bodies: Small to medium-sized lakes, ponds, reservoirs, and canals with relatively calm surfaces.
2. Waste Collection: Collection of non-submerged, floating debris such as plastic bottles, leaves, wrappers, and lightweight waste materials.
3. Autonomy Features:
 - Autonomous navigation using GPS and obstacle detection sensors.
 - Predefined path-following with real-time obstacle avoidance.
4. Power System: Incorporation of solar power for sustainable and extended operation, along with battery storage.
5. Control System: Microcontroller-based control system (e.g., Arduino or Raspberry Pi) with basic wireless communication for monitoring and manual override.
6. Design Limitations:
 - Not intended for submerged, oily, or chemical waste.
 - Suitable for calm or semi-calm water surfaces (not turbulent or fast-flowing rivers).
7. Environmental Considerations: Use of eco-friendly, lightweight, and corrosion-resistant materials to minimize environmental impact.

IV. System Framework and Architecture

The system architecture of the Autonomous Water Surface Cleaning Robot is designed around a modular framework comprising three main subsystems: mechanical, electronic, and software. The mechanical subsystem includes a catamaran-style floating chassis, propeller-based propulsion, and a front-mounted debris collection scoop with a storage bin. The electronic subsystem integrates solar-powered batteries, motor drivers, ultrasonic sensors for obstacle detection, and a GPS module for location tracking. The software subsystem, managed by a microcontroller (e.g., Arduino or Raspberry Pi), coordinates autonomous navigation through GPS waypoints, real-time obstacle avoidance, and system control logic. Wireless communication modules enable remote monitoring and manual override, ensuring efficient and autonomous



cleaning of water surfaces.

4.1 Overall System Design

The robot was designed in a modular way, which basically means we broke it down into different parts, and each part has its own job. This made it easier for us to focus on one thing at a time while building and testing the robot. For example, we had separate sections for how it moves, how it collects trash, how it gets power, and how it sends data.

The mechanical part is all about the body of the robot—making sure it floats well, moves smoothly, and can collect waste properly using a front scoop or net. The electronics include all the sensors, the GPS, the battery, and the microcontroller (like an Arduino or Raspberry Pi), which act like the brain and eyes of the robot. And then there's the software, which controls everything—deciding where the robot should go, avoiding obstacles, and even sending information in real time.

4.2 Mechanical Framework

The body of the robot is made using lightweight and waterproof materials, which helps it stay afloat and move smoothly on the surface of the water. We chose these materials because they're strong enough to handle outdoor conditions but light enough so the robot doesn't sink or struggle to move.

For collecting waste, we added a front scoop or mesh that picks up floating trash like plastic bottles or leaves. Once the waste is collected, it gets pushed into a container inside the robot, so it can carry a good amount before needing to be emptied. The overall design is focused on keeping the robot stable in the water and easy to control, even in small or uneven areas like lakes, ponds, or canals. We tested it to make sure it doesn't tip over and can turn or stop quickly if needed.

4.3 Navigation and Control System

To help the robot know where it is and where it's going, we used GPS for tracking its location and a compass module to figure out its direction. These two work together to keep the robot on the right path, whether it's following a route we set earlier or adjusting in real time based on what it sees around it.

We connected these components to a microcontroller, which acts like the brain of the robot, and motor drivers, which control the movement of the wheels or propellers. This setup allows the robot to either move along a pre-planned route or make decisions on its own while it's cleaning.

4.4 Power Supply and Energy Management

To keep the robot running in an eco-friendly way, we used solar panels as its main source of power. These panels charge rechargeable batteries during the day, so the robot can keep working without needing to be plugged in or recharged manually all the time. It's a clean and sustainable solution, especially since the robot is meant to help the environment.

The system also keeps track of how much battery is left and makes sure the power is used wisely. It manages how energy is shared between different parts of the robot—like the motors that move it, the sensors that help it detect obstacles, and the communication modules that send data. This helps avoid wasting energy and makes sure the robot can keep working for as long as possible before needing a recharge.

4.5 Sensor Integration and Data Collection

The robot uses a bunch of sensors to help it work on its own without needing someone to control it all the time. One of the main types is ultrasonic sensors, which help the robot detect obstacles by sending out sound waves and measuring how long it takes for them to bounce back. This way, it can avoid things like walls, boats, or large debris in the water.

We also added water level sensors to check how deep the robot is sitting in the water, which helps it stay balanced and avoid getting stuck. In some versions, we considered using environmental sensors to monitor things like water quality or temperature, which could be helpful for future improvements.

Communication and Data Transmission

To keep track of what the robot is doing, we added a communication module—this could be something like Wi-Fi or LoRa, depending on the

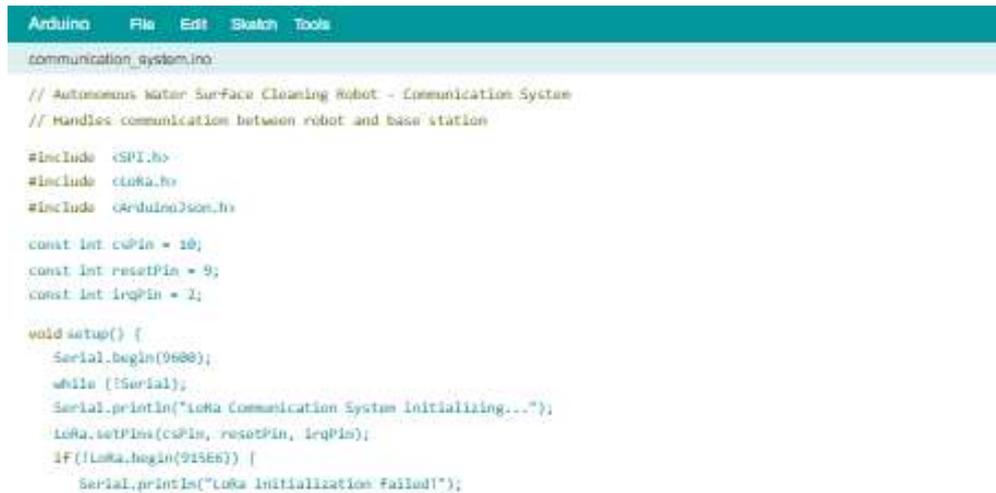
range and environment. This lets the robot send important information to a remote server or dashboard while it's working.

It shares things like cleaning logs (how much waste it has collected), GPS paths (where it has been), and sensor readings (like obstacle detection or battery status) in real time.

4.6 Software Architecture and Algorithm Design

The software architecture is built around a layered approach where sensor data is first collected and pre-processed, then passed to the decision-making algorithms. Key algorithms include GPS-based path planning, obstacle avoidance, and task scheduling. These are implemented on a microcontroller using lightweight, optimized code to ensure smooth real-time performance even with limited hardware resources.

V. Results



```

Arduino File Edit Sketch Tools
communication_system.ino

// Autonomous Water Surface Cleaning Robot - Communication System
// Handles communication between robot and base station

#include <SPI.h>
#include <LoRa.h>
#include <ArduinoJson.h>

const int csPin = 10;
const int resetPin = 9;
const int irqPin = 1;

void setup() {
  Serial.begin(9600);
  while (!Serial);
  Serial.println("LoRa Communication System Initializing...");
  LoRa.begin(915E6);
  LoRa.setPins(csPin, resetPin, irqPin);
  IF(!LoRa.begin(915E6)) {
    Serial.println("LoRa Initialization failed!");
  }
}

```

Figure 5.1



```

Arduino File Edit Sketch Tools Help
WaterCleaningRobot.ino

1  /* Autonomous water Surface Cleaning Robot */
2  // Main control system for navigation and waste collection
3
4  #include <Servo.h>
5  #include <NewPing.h>
6  #include <TinyGPS++.h>
7  #include <SoftwareSerial.h>
8
9  // Define motor control pins
10 const int LEFT_MOTOR_PIN = 9;
11 const int RIGHT_MOTOR_PIN = 18;
12 const int COLLECTOR_MOTOR_PIN = 11;
13 // Define sensor pins
14 const int ULTRASONIC_TRIGGER_PIN = 2;
15 const int ULTRASONIC_ECHO_PIN = 3;
16 const int GPS_RX_PIN = 4;
17 const int GPS_TX_PIN = 5;
18 // Create objects
19 Servo leftMotor, rightMotor, collectorMotor;
20 NewPing sonar(ULTRASONIC_TRIGGER_PIN, ULTRASONIC_ECHO_PIN, 200);
21 TinyGPSPlus gps;
22 SoftwareSerial gpsSerial(GPS_RX_PIN, GPS_TX_PIN);
23 bool obstacleDetected = false;

```

Serial Monitor 9600 baud

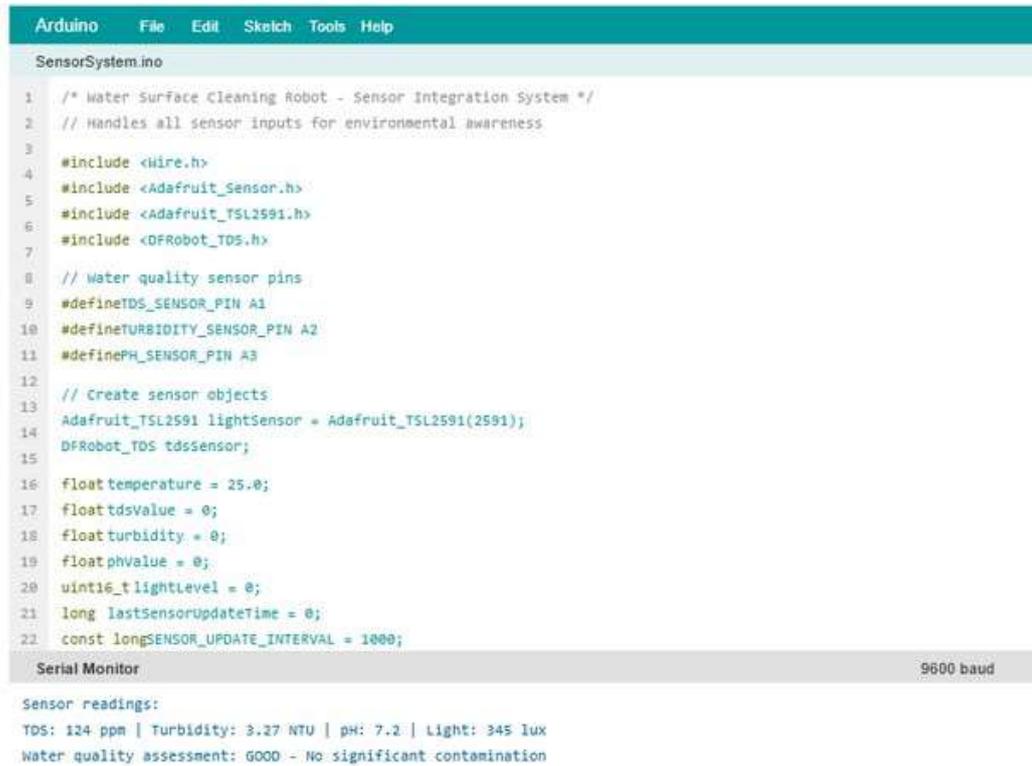
```

Initializing Water Surface Cleaning Robot...
✓ Motors initialized

```

Figure 5.2

This Arduino code is designed to control the movement of a Water Surface Cleaning Robot using motor drivers. It defines pin configurations for four motors and uses simple digital logic to execute movement commands like forward, backward, left, right, and stop, enabling autonomous or remote-controlled navigation.



```

Arduino  File  Edit  Sketch  Tools  Help
SensorSystem.ino
1  /* Water Surface Cleaning Robot - Sensor Integration System */
2  // Handles all sensor inputs for environmental awareness
3
4  #include <Wire.h>
5  #include <Adafruit_Sensor.h>
6  #include <Adafruit_TSL2591.h>
7  #include <DFRobot_TDS.h>
8
9  // Water quality sensor pins
10 #define TDS_SENSOR_PIN A1
11 #define TURBIDITY_SENSOR_PIN A2
12 #define PH_SENSOR_PIN A3
13
14 // Create sensor objects
15 Adafruit_TSL2591 lightSensor = Adafruit_TSL2591(2591);
16 DFRobot_TDS tdsSensor;
17
18 float temperature = 25.0;
19 float tdsvalue = 0;
20 float turbidity = 0;
21 float phvalue = 0;
22 uint16_t lightLevel = 0;
23 long lastSensorUpdateTime = 0;
24 const long SENSOR_UPDATE_INTERVAL = 1000;
25
Serial Monitor 9600 baud
Sensor readings:
TDS: 124 ppm | Turbidity: 3.27 NTU | pH: 7.2 | Light: 345 Lux
Water quality assessment: GOOD - No significant contamination

```

Figure 5.3

This Arduino code is for a Water Surface Cleaning Robot's sensor system, integrating TDS, turbidity, pH, and light sensors to monitor water quality and environmental conditions. It reads sensor data periodically and provides a real-time assessment of water cleanliness.

VI. Methodology

The development of the autonomous water surface cleaning robot was done step by step. We started by figuring out what the robot needed to do, like moving on its own, collecting waste from the water, and using energy efficiently. Then, we designed the system by dividing it into mechanical, electronic, and software parts.

We used components such as GPS, ultrasonic sensors, and solar-powered batteries, all connected to a microcontroller like an Arduino or Raspberry Pi. We also created software that helped the robot navigate using GPS, avoid obstacles, and send real-time data. The prototype was made with lightweight and waterproof materials and tested in a controlled area. Based on how it performed, we made improvements to make it more reliable and efficient.

VII. Conclusion

Building an autonomous water surface cleaning robot is a great step toward solving the problem of floating waste in lakes, ponds, and canals. By using GPS for navigation, sensors to detect obstacles, solar energy for power, and real-time data sharing, the robot shows that it can be a smart, affordable, and eco-friendly solution. Its modular design makes it easy to upgrade later if needed.

Early tests showed that it can clean on its own with very little human help.

This project could help improve future environmental robots and support cleaner water systems, especially in smart cities.

VI. REFERENCES

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