REMOTELY-CONTROLLED HYDRO VEHICLE FOR WATER SAMPLE COLLECTION AT VARYING WATER LEVELS

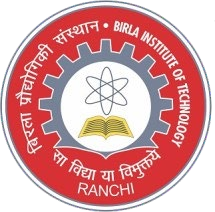
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### APPROVAL OF THE MENTOR

Recommended that the B. Tech. Minor Project entitled Hydro Vehicle for collection of water samples at pre-defined depths submitted by **Vikram Verma (BTECH/10161/21), Shambhavi Jha (BTECH/10284/21)** is approved by me for submission. This should be accepted as fulfilling the partial requirements for the award of Degree of Bachelor of Technology in **Electronics and Communication**. To the best of my knowledge, the content of this report does not form a basis for the award of any previous degree to anyone else.

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### DECLARATION CERTIFICATE

I certify that,

1. The work contained in the report is original and has been done by myself under the general supervision of my supervisor.
2. The work has not been submitted to any other Institute for any other degree or diploma.
3. I have followed the guidelines provided by the Institute in writing the report.
4. I have conformed to the norms and guidelines given in the Ethical Code of Conduct of the Institute.
5. Whenever I have used materials (data, theoretical analysis, and text) from other sources, I have given due credit to them by citing them in the text of the report and giving their details in the references.
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### CERTIFICATE OF APPROVAL

This is to certify that the work embodied in this Summer Internship Report entitled:

“**Remotely-controlled Hydro Vehicle for water sample collection at varying water levels**

”,

is carried out by Vikram Verma (BTECH/10161/21), Shambhavi Jha (BTECH/10284/21) has been approved for the degree of Bachelor of Technology in Electronics and Communication Engineering of Birla Institute of Technology, Mesra, Ranchi.

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#### ABSTRACT

This work presents a novel, cost-effective approach for river water quality monitoring using a remotely controlled, depth-specific water sampling system. The system utilizes a valve and stepper motor combination to collect water samples at varying depths. The simple circuitry facilitates easy maintenance and accessibility. Future development includes incorporating an algorithm for automated depth selection and sample collection triggered by GPS location. Additionally, the system will be equipped with a GPS module for autonomous navigation and modular collection cylinders for adaptable sampling needs. This project has the potential to significantly improve water quality monitoring efficiency and reduce operational costs.

#### ACKNOWLEDGEMENT

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***CHAPTER 1***

**INTRODUCTION**

Water sources nowadays are highly polluted. Water treatment plants are working at capacity to lower the pollutant levels and supply clean water. If we determine the properties of water at different depths before-hand, efficiency of these plants can be greatly increased. Different treatment agents will be used in proportion. Instead of going through all the procedures of water treatment, only those that are necessary in accordance with the properties obtained will be carried out. Thus arises a need for water collection at different depths. The rivers that are present in our campus cater the water needs of all the staff members and the students residing in the campus. Hence, it becomes necessary to keep in check the water present here.

### 1.1 WATER SAMPLING: Different equipments and techniques in use currently

### SAMPLERS

### Sampling iron

### It is a device made out of iron and steel and the outers are painted to prevent rusting. Here a 2 litre or smaller sample bottles are used. It’s design is very simple as it consists of a sampler bottle placed in a sampler and it is secured by a neck holder. It is to be used manually and the person using it needs to lower the device in the water body to the level where the water sample needs to be taken from.

### Diagram of a device with text Description automatically generated

### Sampling Iron

### Bailer

### Bailers are also used for water sampling. It has a versatile design as it can be constructed in a wide variety of diameters as well as materials. For it to function, there is no need of an external power source. It has a compact design makes it quiet portable, makes the cleaning process quiet easy and also it is inexpensive. The disadvantage of a bailer is that aeration might occur while transferring water to the sample bottle.

A water sample in a river

Description automatically generated with medium confidence

Bailer

### Suction Lift Pump

### It is easily available and also it is cheap. Here the sampling could be done only if the level of water is within about 20feet of the ground water level. The vacuum effect caused during the sampling process could result in losing of some dissolved gas which makes it less trustworthy for sampling.

Diagram of a pump with a few pipes

Description automatically generated with medium confidence

Suction Lift Pump

### Air-Lift Samplers

### Airlift Samplers are used for sampling bottom fauna. It is portable, inexpensive and could be used to sample most of the freshwater sources. This methods leads to a change in Carbon Dioxide levels hence unsuitable to sample pH-sensitive parameters. In-general the acquisition of water using this method is inappropriate due to its degassing effect on the samples.

### Hydraulic sampling devices used for collecting an instantaneous sample of invertebrates from the benthos. (a) SCUBA tank-powered air-lift suction sampler, (b) modified gasoline engine water pump sampler

### Air Lift Samplers

# All these methods mentioned above couldn’t be proved useful for our requirements as all of these are devices that are manually operated while we wanted to make our device to be operated remotely. Also, all these methods can sample water near the shore only while we wanted our device to go to the coordinates mentioned before-hand which makes all these less suited. To fulfill our requirements, we dug deeper into topic and stumbled upon Niskin bottles which was our inspiration for the pursual of our project. The water collecting cylinder draws inspiration from the Niskin Bottles which we have mentioned in the next topic and we took reference of “Interpretation Niskin bottle sample collection aliases microbial community composition and biogeochemical” by Elizabeth Suiter, Mary I Scranton, Stephanie Chow and Dallyce Stinson

### Niskin Bottles

### Niskin bottles are currently in use for sampling of water in oceans. It is used in acquisition of water at different levels. It is made out of PVC to prevent the water collected for sampling to react with the body of the device. Niskin bottles are based on the principle of hydrostatic pressure. It is lowered in the ocean remotely and as the depth increases, the pressure on the Niskin bottles increase, pushing the ocean water inside bottle due to hydrostatic pressure difference. It is used for sampling huge amounts of water ranging from 5 Litres to 12 Litres.

### 60.000 - Rosette for 12 Niskin bottles

### Niskin bottles

The issue we faced with Niskin bottles was mainly its size. A Niskin bottle has a capacity of minimum 5litres while our requirement was much smaller than this. We only wanted 100 to 120 ml of water at each depth. In a Niskin bottle there are separate bottles for separate depths and each bottle uses hydrostatic pressure in order to open the valves at any given depth. To make our device more portable we incorporated compartments in the cylinder which opens at which ever depth is mentioned before-hand making it a very portable and handy device. So, basically only a single cylinder collects water at several depths and compartments present in the cylinder mitigates the possibility of mixing of water.

***CHAPTER 2***

# LITERATURE REVIEW

This section offers a summary of recent literature that explores methods, technical elements and significant advancements made by researchers striving to enhance accuracy in sampling process. [Francesco](https://doi.org/10.1109/OCEANS.2012.6405015) et al (2012)[1]tackles the challenge of collecting deep water samples with small, portable autonomous surface vehicles (ASVs). They designed a lightweight, low-power system with a winch that lowers a probe 50 meters deep. This probe can take measurements and collect water samples at various depths. It avoids contamination by using special materials and is designed to be easily installed on these compact ASVs. The paper discusses initial tests of this system on a HydroNet class robotic catamaran. [Zhang](https://doi.org/10.3389/fmars.2019.00415) et al(2019)[2] proposes a new approach: using autonomous underwater vehicles (AUVs) equipped with clever algorithms. These brainy AUVs can actually find and track interesting events like algal blooms as they move with the currents. This targeted approach allows the AUVs to take measurements and collect water samples right in the heart of the action, making them much more efficient than traditional methods. The paper highlights successful examples of these AUVs being used in real-world studies and discusses exciting possibilities for the future. [Koparan](https://doi.org/10.3390/w10050655) et al(2018)[3] explores using a drone (UAV) with a custom water sampler for autonomous water quality monitoring. This tackles limitations of manual sampling, like safety risks and limited access, especially after disasters. The drone carried the sampler and had special features to survive water landings. Field tests compared drone-collected samples to traditional methods. Results showed minimal differences for most measurements. Overall, drone-based water sampling appears promising for faster, safer monitoring of large or hard-to-reach water bodies. [Zhang](https://doi.org/10.1109/ICUS52573.2021.9641354) et al(2021)[4] suggests that water quality monitoring is difficult due to the complexity, frequency, and dangers involved in collecting samples across various water environments. This paper introduces a new solution: an autonomous water sampling system built on an unmanned surface vehicle (USV). This USV carries water sampling equipment and can travel to designated spots, collecting samples safely and efficiently. The paper will explore the design of this system, its operations, and a real-world example of its use. This new approach promises to be cost-effective, safer for personnel, and allows data collection in hard-to-reach or risky areas, ultimately leading to better water quality monitoring. [Zhang](https://doi.org/10.1007/s40435-023-01163-z) et al (2023)[5] presents that freshwater monitoring with traditional USVs falls short. They can't handle the frequent, multi-depth, and multi-point sampling needed. This paper proposes a solution: a multi-dimensional water sampling USV (WS-USV). The WS-USV is built for these demanding tasks. It has both navigation and water sampling systems, allowing it to collect samples automatically from various depths and pre-set locations. Tests show the WS-USV can navigate to different sampling points and collect water samples entirely by itself, making it a promising tool for freshwater monitoring. [Madeo](https://doi.org/10.1109/TIM.2019.2963515) et al(2020)[6] This article presents a novel unmanned surface vehicle (USV) named WeMo designed for cost-effective water quality monitoring in diverse aquatic environments. The emphasis lies on affordability to facilitate widespread deployment by various stakeholders, including local communities, administrations, and even private entities. WeMo utilizes commercially available components and boasts a modular sensor array capable of measuring a range of chemical and physical water quality parameters. Additionally, bathymetric measurements are achievable. The envisioned application involves establishing a network of these USVs, essentially creating a "social sensor network" for comprehensive water quality monitoring. Furthermore, the system incorporates data analytics tools for both automated navigation and data processing. The article demonstrates successful application of this model to assess oxygen concentration. Moreover, the system has the capability to reconstruct water quality data for unmonitored locations along the USV's trajectory. In essence, this research contributes to the development of a comprehensive monitoring ecosystem encompassing data collection, storage, and analysis. This low-cost USV system holds promise for facilitating widespread and affordable water quality monitoring efforts.

Summarizing the Literature Review

These advancements promote safer data collection from hard-to-reach or hazardous areas, ultimately leading to more comprehensive and effective water quality monitoring programs. This report summarizes recent research efforts aimed at improving the accuracy and efficiency of water sample collection. Traditional methods often pose safety risks and limitations in accessing remote or hazardous locations. The following advancements in autonomous water sampling techniques are noteworthy:

1. **Deployment of Autonomous Surface Vehicles (ASVs):** [Francesco](https://doi.org/10.1109/OCEANS.2012.6405015) et al (2012)[1]developed a lightweight, low-power system utilizing compact ASVs for deep water sampling. This method offers a cost-effective and contamination-free approach.
2. **Intelligent Autonomous Underwater Vehicles (AUVs):** [Koparan](https://doi.org/10.3390/w10050655) et al(2018)[2]proposed the use of AUVs equipped with sophisticated algorithms to locate and target specific events, such as algal blooms, for sample collection. This targeted approach significantly enhances sampling efficiency.
3. **Drone-based Water Sampling:** [Zhang](https://doi.org/10.1007/s40435-023-01163-z) et al (2023)[3] explored the use of drones equipped with custom water samplers for autonomous water quality monitoring. This method proves particularly advantageous in situations where manual sampling presents safety risks or limited access, especially in the aftermath of disasters.
4. **Unmanned Surface Vehicles (USVs) for Diverse Environments:** [Zhang](https://doi.org/10.1109/ICUS52573.2021.9641354) et al(2021)[4] introduced USVs specifically designed to carry water sampling equipment, enabling safe and efficient sample collection across various aquatic environments. Madeo et al. (2020) presented a cost-effective USV named WeMo, facilitating widespread deployment by diverse stakeholders. These USVs demonstrate promise for broader water quality monitoring applications.
5. **Multi-dimensional Water Sampling USVs (WS-USVs):** [Zhang](https://doi.org/10.1007/s40435-023-01163-z) et al (2023)[5] addressed limitations of conventional USVs by developing a WS-USV specifically tailored for freshwater monitoring. This innovative USV possesses the capability to collect samples from various depths and pre-designated locations, offering a significant advancement in freshwater sample collection techniques.

# In conclusion, the field of water quality monitoring is witnessing a shift towards automation, improved efficiency, and cost-effectiveness in sample collection.

***CHAPTER 3***

# METHODOLOGY

### 3.1 APPROACH :

### 

### Approach schematic

### Using an RC stepper motor to lower the collection cylinder

### To observe the depth readings sent by the pressure sensor using the NRF module

### To stop the stepper motor when the desired depth has been reached

### To activate the solenoid water-air valve switch to let water in

### To repeat this process for all the required levels

### Again using the stepper motor to raise the collection cylinder

# 3.2 DEPTH DETERMINATION: Motivation behind choosing pressure sensor and NRF module.

After building the basis of our idea we had to implement it. One of the components with utmost importance is sensors. The first sensor which we studied through was HC-SR04 ultrasonic sensor taking the reference from the paper “Investigating the resolution ability of the HC-SRO4 ultrasonic sensor” by Nadhir Ibrahim Abdulkhaleq and Ihsan Hasan

### HC-SR04

### HC-SR04 is the most primitive kind of sensor and although inexpensive has various drawbacks making it unsuitable for our work. HC-SR04 is quite susceptible to dirt rendering it unsuitable for working in outdoor conditions. But the main reason for us not being able to use it for our project is, it is not waterproof which is why we cannot use it with our cylinder as it goes inside the water.

### Ultrasonic sensor model HC-SR04, IR sensors and Raspberry PiCamera.

### HC-SR04

### JSN-SR04T

# To overcome the issues faced by the HC-SR04, we came across another sensor namely JSN-SR04T in the research paper “Underwater detection by using ultrasonic sensor” by Hafiz Aziz

# and J Alcain. This sensor is water resistant and can be used in a rugged environment hence making it suitable for our project as we can use it for underwater purposes.

### COMPARISON BETWEEN JSN-SR04T AND HC-SR04

|  |  |  |
| --- | --- | --- |
|  | JSN-SR04T | HC-SR04 |
| RANGE | 20cm – 600cm | 2cm - 400cm |
| ACCURACY | +- 1cm | +- 0.3 cm |
| VOLTAGE | 3.0 – 5.5 VDC | 5 VDC |
| RAW DATA | YES | YES |
| SERIAL DATA | YES | NO |
| COST | $10.00 USD | $1.00 USD |

### Table1: Comparison between HC-SR04 and JSN-SR04T

# All the sensors mentioned above measure depth of water from the river-bed. What we wanted was to determine the depth from the surface of water body. In order to achieve this, the below mentioned pressure sensor was used.

### TE CONNECTIVITY PRESSURE SENSOR

### 

### 

### TE CONNECTIVITY PRESSURE SENSOR

### This sensor will be attached at the bottom of our collection cylinder and will provide real time data regarding depth of water from the surface which will be crucial while lowering the cylinder into the water.

### NRF 24L01 PA/LNA

### 

### NRF Module with Arduino

### NRF modules will be used both the transmitter end and receiver end to enable wireless communication. The data obtained by the Pressure Sensor will be sent to the operating station off-shore.

# 3.3 THE COLLECTION CYLINDER:

# Collection cylinder

# Cylindrical shape was chosen to minimize drag while in operation. Sections from the outer circumference is cut to reduce weight. Multiple platforms are made where containers are placed to facilitate water storage through valves. A wiring compartment is provided to ensure wired communication between the on-board and cylinder circuitry. At the bottom of the cylinder, an electronics bay is provided to ensure housing of the power sources and relays.

### STEPPER MOTOR, VALVES AND OTHER ELECTRONICS

### 3.4.1 STEPPER MOTOR

### 12V STEPPER MOTOR

### NEMA 17 12V Stepper motor will be used to lower the collection cylinder into the water. It provides a torque of 7.2kg-cm which will be appropriate to lift the entire structure back to surface.

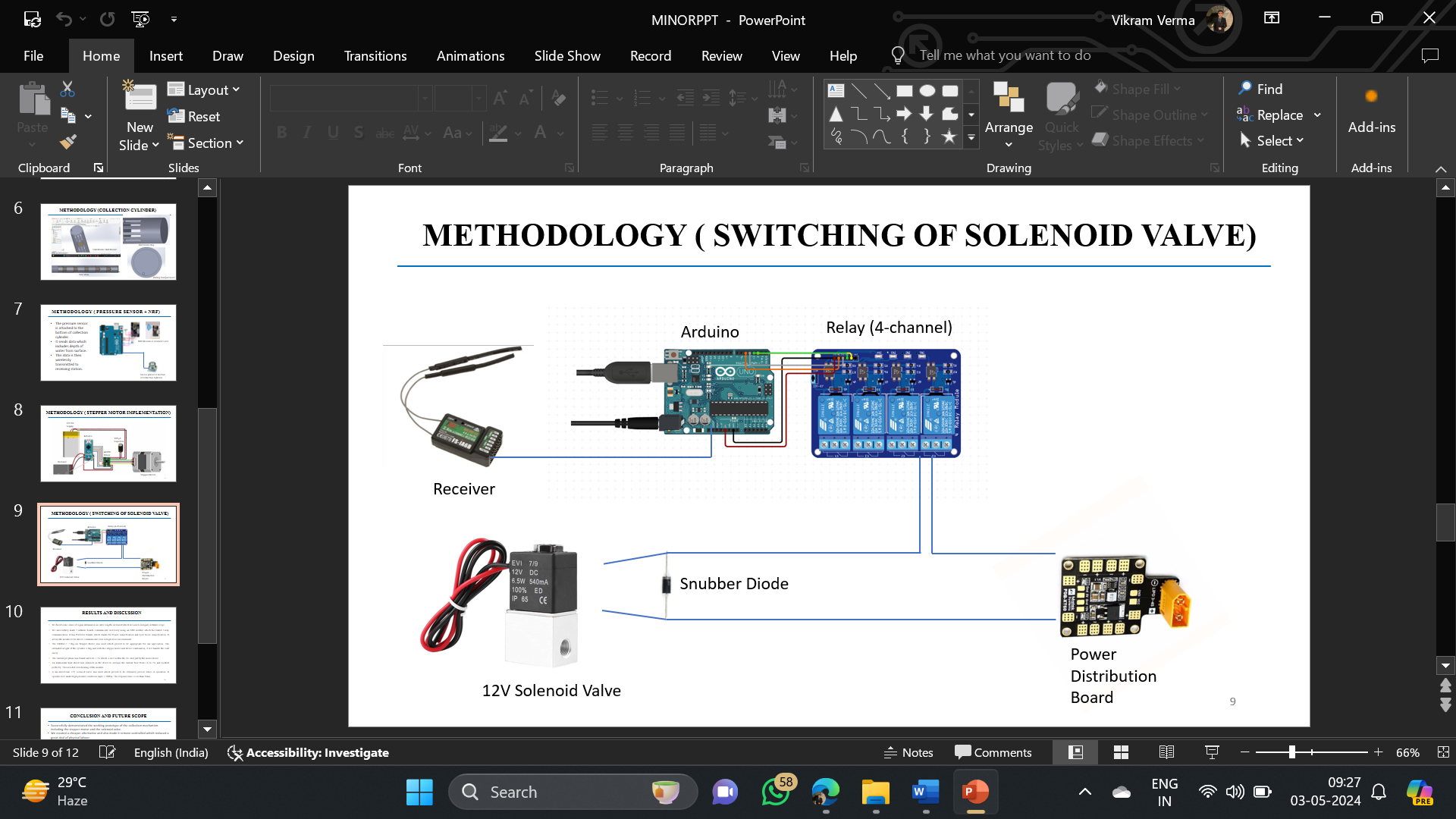
# 

Motor circuitry

### 12V DC Solenoid Valve

Solenoid Valve

This valve will be used to control water flow between the container and outside water. This will be controlled remotely via an RC controller. It can handle pressures upto 1.2MPa which is more than enough for our application. This will be toggled using a relay which in turn will get signals from the microcontroller.



Valve circuitry

### PDB-XT60

PDB-XT60

To facilitate portable power sources, the PDB( Power Distribution Board) is used to provide 5V and 12V DC supply. The Li-Po battery connects to the PDB via XT-60 adaptor and provides long term power. It contains Battery Eliminator Circuit (BEC) to increase efficiency.

***CHAPTER 4***

# EXPERIMENTAL RESULTS AND DISCUSSION

# 4.1 Results:

# The design of the collection cylinder was found feasible for practical operations.

# We faced some issues of signal attenuation as cable lengths increased which we aim to mitigate in future scope.

# Gel-filled, ultra-compact, water resistant digital pressure sensor was used which proved to be ideal for our application. The readings were accurate.

# We successfully made 2 arduino boards communicate wirelessly using an NRF module which facilitated 2-way communication. It has PA/LNA feature which stands for Power Amplification and Low Noise Amplification. It allows the module to be able to communicate even in high noise environments.

# The NEMA17 7.2kg-cm Stepper Motor was used which proved to be appropriate for our application. The estimated weight of the cylinder is 6kg and with this stepper motor and driver combination, it will handle the load easily.

# The current per phase was found out to be 1.7A which is well within the 2A limit put by the motor driver

# An aluminium heat shield was installed on the driver to increase the current flow from 1A to 2A and worked perfectly. This avoided over-heating of the module.

# A uni-directional 12V solenoid valve was used which proved to be extremely precise while in operation. It operates well under high pressure conditions (upto 1.2MPa). The response time is less than 50ms.

# There was no intermixing of water samples observed as different containers were used for every water level.

***CHAPTER 5***

**CONCLUSION AND FUTURE PROSPECTS**

We have successfully demonstrated the working of a valve and a stepper motor which is capable of sampling water at various depths which will monitor the quality of river that is responsible for catering the needs of a huge population. We have made a cheaper alternative which could also be controlled remotely and thus reduces a great deal of physical labor. The circuitry associated with the cylinder is rather simple to execute hence making it more accessible. In the future, we will create an algorithm where pre-determined depths will be fed before the process starts, and the collection will be done automatically when the vehicle reaches the point where the collection of water needs to take place. We will install a GPS module on-board the vehicle so that it could navigate to the selected collection point on its own without remotely controlling it. Also, in future we will make the collection cylinders modular which will enable us to add or remove containers as per requirement.

***APPENDIX***

**CODE IN ARDUINO IDE**

#define RCPin 2

#define RCPin2 13

#define DIR 4

#define STEP 5

#define MS3 6

#define MS2 7

#define MS1 8

#define Relay 9

 unsigned long StartTime = 0;

 unsigned long CurrentTime = 0;

 int Pulses = 0;

 int Pulses2 = 0;

void setup() {

  Serial.begin(9600);

  pinMode(RCPin, INPUT);

  pinMode(RCPin2, INPUT);

  //attachInterrupt (digitalPinToInterrupt (RCPin) , PulseTimer,CHANGE);

  for (int i = 4; i<=9; i++){

    pinMode(i, OUTPUT);

  }

  digitalWrite(MS1, LOW);

  digitalWrite(MS2, LOW);

  digitalWrite(MS3, LOW);

}

void loop()

{

    Pulses = pulseIn(RCPin, HIGH);

    Pulses2 = pulseIn(RCPin2, HIGH);

    Serial.println(Pulses2);

    Serial.println(Pulses);

    if (Pulses < 1200){

    digitalWrite(DIR, LOW);

    digitalWrite(STEP, HIGH);

    delay(1);

    digitalWrite(STEP, LOW);

    }

     if (Pulses >= 1200 && Pulses <=1800){

     digitalWrite(STEP, LOW);

    }

    if (Pulses > 1800){

    digitalWrite(DIR, HIGH);

    digitalWrite(STEP, HIGH);

    delay(1);

    digitalWrite(STEP, LOW);

    }

    if (Pulses2 > 1500){

      digitalWrite(Relay,HIGH);

    }

    if (Pulses2 < 1500){

      digitalWrite(Relay,LOW);

    }

}

    void PulseTimer(){

    CurrentTime=micros();

    if(CurrentTime>StartTime && CurrentTime-StartTime < 10000){

     Pulses=CurrentTime-StartTime;

      }

     StartTime=CurrentTime;

     Serial.println(Pulses);

   }

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