

# EFFECTIVE MICROORGANISMS (EM) DISPERSION SYSTEM FOR DILUTING POLLUTANT IN RIVER

By

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By

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# CERTIFICATION OF APPROVAL

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Approved:

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**Dr. Dennis Ling Chugn Ching**

Project Supervisor

UNIVERSITI TEKNOLOGI PETRONAS

TRONOH, PERAK

December 2013

## **CERTIFICATION OF ORIGINALITY**

This is to certify that I am responsible for the work submitted in this project, that the original work is my own except as specified in the references and acknowledgements, and that the original work contained herein have not been undertaken or done by unspecified sources or persons.

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**Sharif Ahmed Nasser Al-Sharif**

## ***ABSTRACT***

Nowadays, effective microorganism technology is widely used in treating and improving water quality for its environmentally friendly properties. The quality of river water can be considered as one of the most important concern for official authorities worldwide. In Malaysia, the local government is tending to enhance the water quality of rivers in the county by utilizing effective microorganism technology. Determining the suitable amount of the EM to improve water quality is one of the barriers that need to overcome. This report discusses one of the proposed methods for solving the issue of distributing random amount of effective microorganism (EM) in river. Utilizing an automated control system is the focal objective of this writing to dilute pollutant in river. By using such technology, effective microorganism will be poured into the river in mud-ball form based on the need of it. In this paper, developing a prototype consists of well-designed control system to test and study the impact of EM dispensation in a tank of water will be explained in details.

## **ACKNOWLEDGEMENTS**

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## LIST OF ABBREVIATIONS

- EM:** Effective Microorganism
- D.O:** Dissolved Oxygen
- IDE:** Integrated Development Environment
- AREF:** Analogue Reference
- A0:** Analogue Input (Pin 0)
- GND:** Ground
- mg/L:** milligrams per Litre
- I/O:** Inputs / Outputs
- DC:** Direct Current.
- AC:** Alternating Current, Air Conditioner.
- UTP:** Universiti Teknologi PETRONAS

# CHAPTER 1

## INTRODUCTION

### 1.0 Introduction

This chapter covers the background, problem statement, objective, and study feasibility of this project.

### 1.1 Project Background

Effective Micro-organism (EM) is a promised technology to enhance water quality of rivers which since it doesn't have negative effects on nature and require low cost [1]. In fact, Effective Micro-organism (EM) is a mixture of re-generated micro-organisms which can be found in nature. Automated EM dispenser system is assisting in distributing suitable amount of EM into a river based on Oxygen parameters measured.

### 1.2 Problem Statement

Random amount of EM in river will not improve the Oxygen level in the river, an automated system is needed to distribute minimum amount of EM in Mud ball form into a river. The design must be capable of dispersing EM mud ball based on the oxygen level in the water.

### 1.3 Objectives

The objectives are:

- ✓ To build a station that will dispense EM Mud-ball into river.
- ✓ To design a control system to monitor EM dispersion of EM in river.

### 1.4 Scope of Study

The study is limited to designing a test prototype that can dispense EM mud ball according to Oxygen level in a tank.

### 1.5 Feasibility of Study

Programming software will be used along with the controller to setup the EM dispense system. Prototype casing will be fabricated through in house Prototype Design Center.

## CHAPTER 2

### LITERATURE REVIEW

#### 2.0 Introduction

This chapter consists of a general review on effective micro-organism (EM) and the effective of EM in reducing water pollution as well as the features of the suggested control system's components. In additional, detail information of the Effective Micro-organism (EM) is generally beyond the main scope of this paper. However, the earlier studies in the literature on EM technology are highlighted. Automated control system to dispense EM into tank of water will be explained as the main objective of this research.

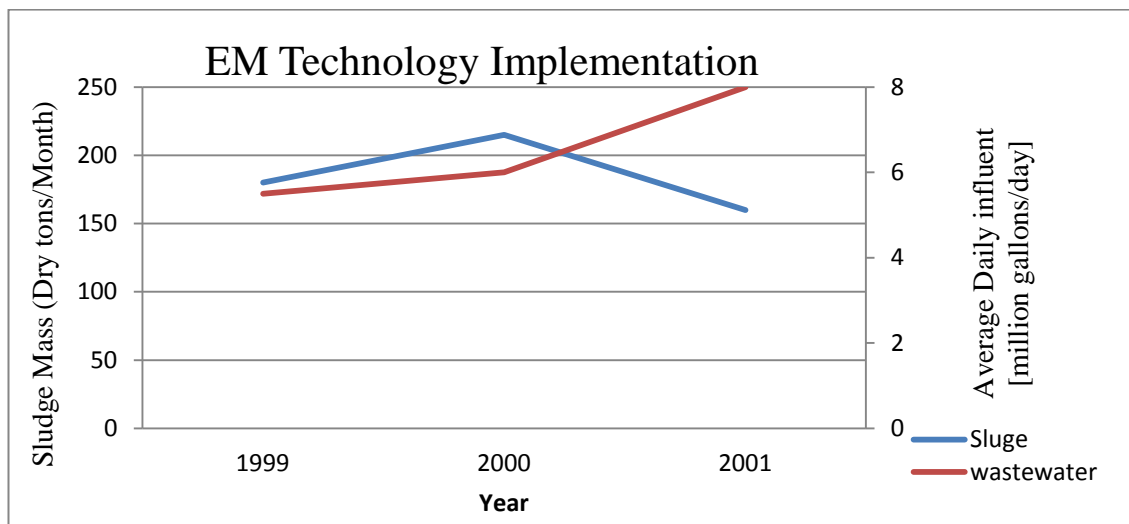
#### 2.1 Effective Micro-organism (EM) Technology for Water Quality:

According to a study of an effective Micro-organism (EM) technology for water quality project in the United States of America, the Missouri River which it is the longest river in US, which run through different states, is collecting various chemical substances and metals that influence the water quality. Due to fact that the water quality of the Missouri river is decreasing, many swimmers get skin allergies and the fish populations and the commercial fishery was destroyed as a result of Missouri river pollution. For the reasons mentioned above, serious efforts were needed to be implemented to start cleaning up the river. Effective Micro-organism (EM) method was applied for different periods to improve the water quality of Missouri river in the United States of America [2]



**Figure 1:** Polluted Water of the Missouri River in US

In additional, The Wastewater Treatment Facility in Missouri has applied an experiment to test the impact of EM technology in enhancing water quality. The figure below is a comparison between results was taken in different periods. From October 1999 to 2000, the graph show results without using effective microorganism method while in 2001; the result indicates the impact of EM technology in the water. From the period of 1999 to 2000, the amount of sludge and amount of wastewater are almost the same (as it is shown by the brown line “wastewater” and blue line “sludge” in the graph). But after applying EM technology and however the amount of the wastewater is growing up, it is clear that the amount of sludge has been decreased. In fact, the current results prove the benefit of utilizing EM technology in the city comparing to different methods in term of cost and fast response in treating water. [2]



**Figure 2:** EM Technology Implementation

Furthermore, a project was conducted by school students of Sekolah Kebangsaan Seri Kelana in Malaysia by throwing EM mud-balls into lakes to clean the water in the lake. In next two months, another amount of EM mud-balls were poured into the lake and evaluated of assessing the effectiveness and the improvement of water quality met the requirements as well as the goal of the project has achieved [1] In fact, EM solution was dispersed into the lake to improve its water quality and clarity. EM mud-balls are proved to assist reduce sludge, remove odour from the lake and control the growth of algae.



**Figure 3:** Effective Micro-organism (EM) in Mud Ball Form

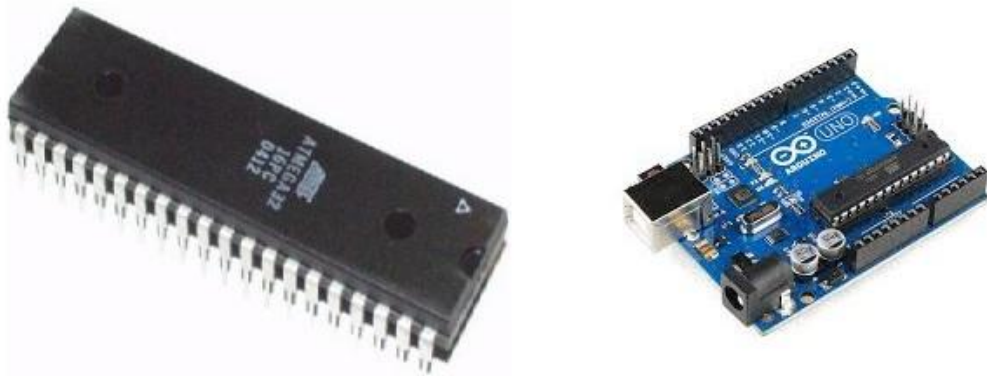
In Japan, some studies offers toxic chemicals as water treatment but this kind of treatment can be harmful for any different usage of the treated water and for environment as well. [3]. It is proven that the decreasing of pH level can be caused by increasing the amount of EM in the water. Although there are many methods used to treat water, numerous concerns raised regarding the usage of such methods. The correct and right solution should be selected to reduce the pollution in water focussing on efficient and environmentally safe disposal [4]. It can be summarized that the EM is one of the new technologies which are being developed to assist in water treatment without negative impact on the environment.

On the other hand, recently in 2012 the local government of Johor Bahru in Malaysia intended to extend the usage of the EM to protect environment. EM technology will be used in wastewater treatment, landscaping, and improve river water quality in the city. It has been stated by local government that one Million Malaysian Ringgit has been spent for applying EM technology in the state for the purpose of environmental protection and the results met the expectation [7].

## **2.2 Control System Components**

Arduino Uno is a good component compared to others microcontrollers such as PIC microcontroller which it is utilized as main brain of a control system. One of the desired advantages of the board is that Arduino is an open-source electronics prototyping platform, which designed to facilitate the process of using electronics in different desired projects. The board consists of a simple open hardware design for the Arduino board with an ATmega processor and on-board I/O support. The

software consists of a standard programming language and the boot loader that runs on the board [8].



**Figure 4:** PIC Microcontroller & Arduino Uno

On the other hand, it has been mentioned in one the early studies that the quality of the water can be determined by conducting the test to important parameters such as; Dissolved Oxygen (DO)[5]. Dissolved Oxygen sensor gives the possibility to determine the condition of the water.

Finally, Servo motors, as one type of DC motors, improve system performance and productivity and control abilities. Comparing to other DC motor types, servo motors provide all these advantages mentioned above to enhance and give the desired outputs. In fact, the designed characteristics and manufacturing techniques is making servos preferred compared to other DC motor types which lead to support designers and engineers in using servo motors as the final elements of their control system designs [9].

## CHAPTER 3

### METHODOLOGY

#### 3.0 Introduction

Quality of the water can be determined by conducting the test to important parameters such as; pH, temperature, Biochemical Oxygen Demand (BOD), Chemical Oxygen Demand (COD), Total Suspended Solid (TSS), Ammonia Nitrogen (AN), and Dissolved Oxygen (DO)[5].

In this research, the dissolved Oxygen (DO) sensor used to determine the level of the Oxygen in a tank. The prototype of this project designed to dispense EM in mud ball form into a tank. Once the programmed microcontroller receives the signal from the Dissolved Oxygen (DO) Sensor as an input of the system, an output signal sends to the final element (DC motor) to do its specific task.

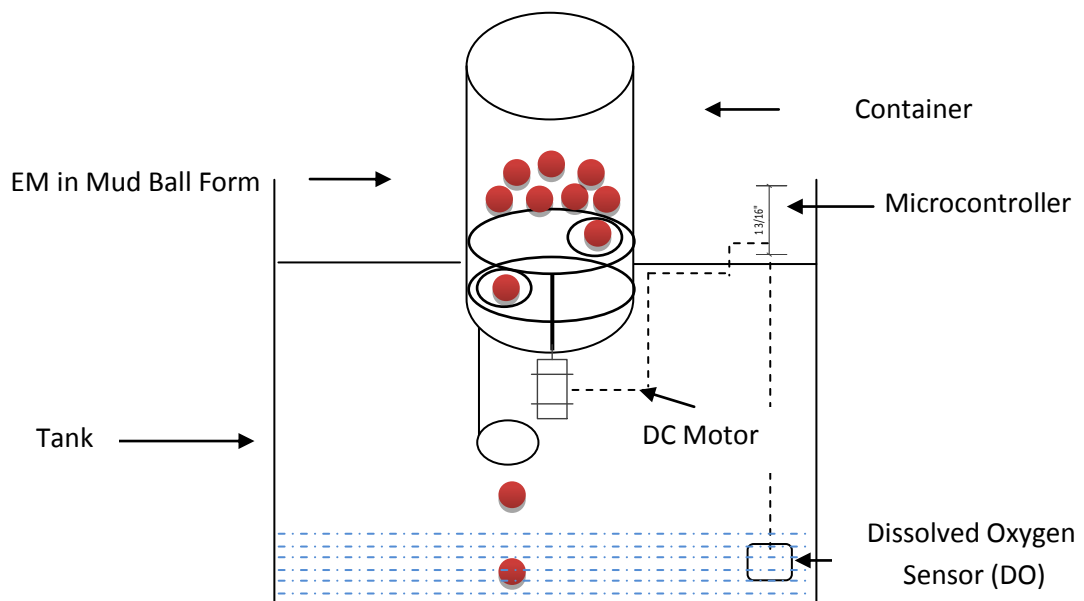


Figure 5: Prototype Design

Figure 4 shows the design of a container that is used to keep EM mud-ball, tank of water, microcontroller, DC motor, and DO meter as well. D.O meter, DC motor along with microcontroller act as a fully automated dispersion system for diluting pollutant in tank of water.

In addition, some vital factors should be taken into consideration upon the equipments selection of the demo as the following:

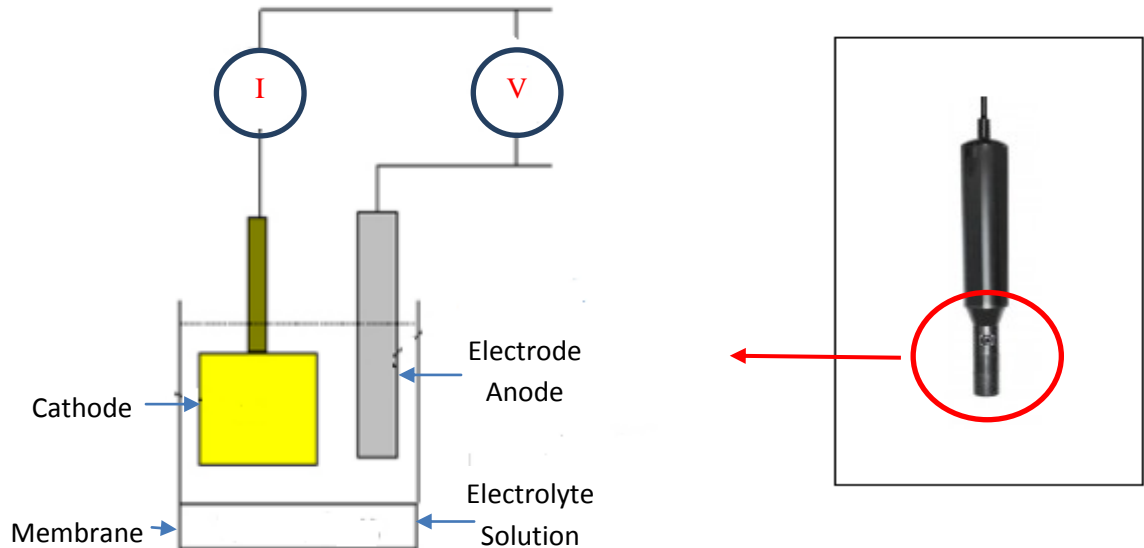
- ✓ Input and output voltage/ current of the first element (sensor) and final element (DC motor)
- ✓ Input power, I/O numbers and types of the microcontroller chip
- ✓ Output power and torque of the selected DC motor
- ✓ Electrical wire types

### 3.1 Project Equipments

Below are the detailed equipments used in this project:

#### 3.1.1 Dissolved Oxygen (DO) Meter

Dissolved Oxygen (DO) Meter (PDO-520) will be the data provider for the system. The sensor is polarographic type oxygen probe with 0.1 mg/L resolution, and (0 to 20 mg/L) in range.



**Figure 6: Polarographic Sensor**

The polarographic sensor consists of a cathode and an anode as shown in the figure above. The dissolved oxygen in a tank of water reduces at the membrane of the probe, the pair of the anode & cathode causes a current to flow in direct proportion to the amount of the dissolved oxygen in the water tank. Then, the dissolved oxygen



can be measured by calculating the amount of the current that caused due to the chemical reaction inside the electrolyte solution with present of anode/cathode pair.

Furthermore, the oxygen entering the probe through the membrane is chemically consumed result of almost zero pressure of oxygen in the probe's electrolyte. The total measured pressure is equal to the pressure gradient exists across the probe's membrane plus the oxygen rate entering the probe.

### **Partial Pressure affect on dissolved oxygen Levels**

The Oxygen of water follows Henry's law which states:" the solubility is roughly proportional to the partial pressure of oxygen in the air"

$$p_{O_2} = K_{O_2} x_{O_2}$$

Where

$p_{O_2}$ : is the partial pressure of oxygen in Torr,

$x_{O_2}$ : is the mole fraction of oxygen in oxygen-saturated water,

&

$K_{O_2}$ : is the Henry's law constant for oxygen in water (about  $3.30 \times 10^7$  K/Torr for at 298 K)

### **Empirical equations:**

$$0^\circ\text{C} < t < 30^\circ\text{C}$$

$$DO = \frac{(P-p) \times 0.678}{35 + t}$$

$$30^\circ\text{C} < t < 50^\circ\text{C}$$

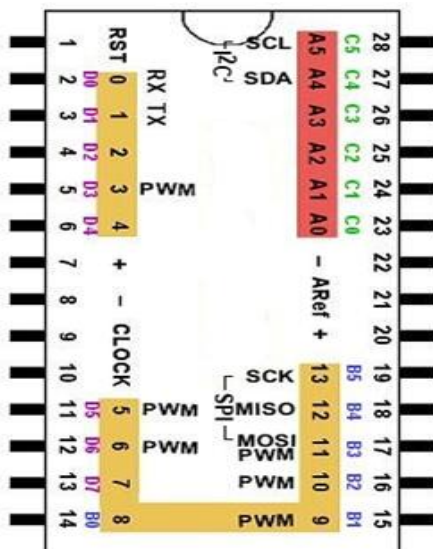
$$DO = \frac{(P-p) \times 0.827}{49 + t}$$

### 3.1.2 Microcontroller

Microcontroller (Arduino UNO) analyzes the information from the input before sending required signal to the final element.



Figure 7: Adruino UNO



ATmega328 chip is used in the Arduino Uno microcontroller board. The board consists of 14 digital input/output pins (six of the digital output can be utilized as PWM outputs), six analog inputs, a 16 MHz ceramic resonator, a USB connection, and a power jack.

Figure 8: ATmega328 (single chip micro-controller)

### 3.1.3 DC Motor

DC Servo motor (Citron C55R 6V, 11.0 kg.cm) gives the ability for the design to dispense EM mud ball into a tank by rotating a disc below the EM mud balls inside the container, upon reaching the container hole EM mud ball is dispensed. DC motor rotates according to the signal from the microcontroller. In addition, Servomotor has the ability to rotate and maintain at certain position or location according to

control pulses from a microcontroller, which result in accurate controlling in term of distribute the effective microorganism in mud ball form into a tank of water.



**Figure 9:** Servo DC Motor

### **Calculations**

In fact, the 11.0 kg.cm is enough to move more than one kg based on the following calculation:

The given Torque of the motor is 11.0 Kg.cm

For  $r = 6.5$  (radius of the container disc)

$$\gg M (\text{Mass}) = 11.0 \text{ kg.cm} / 6.5\text{cm} = 1.69 \text{ Kg}$$

Which indicates that the selected servomotor is suitable to spin the mud ball as the container is designed to carry around 1 kg.

### **3.1.4 Prototype Casing**

The prototype casing (Tank) is built using Perspex. The tank will be filled by water for test purpose.

### **3.1.5 Container**

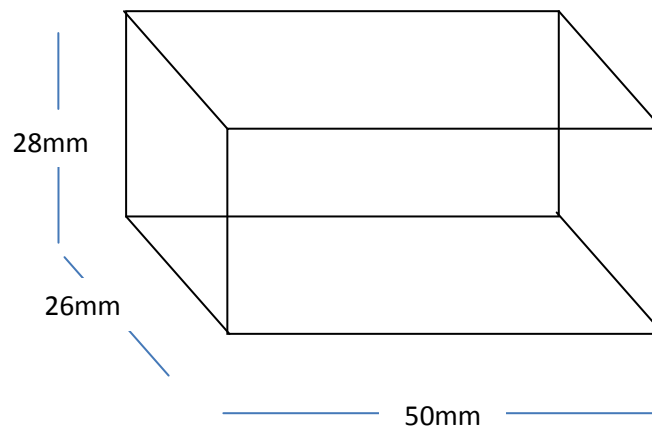
The container contains the Effective Microorganism in mud ball form to be poured into the water tank upon request.

## 3.2 Project Procedures

### 3.2.1 Fabrication of Prototype Casing

#### Water Tank

Perspex material used to build a box for the prototype. The box is used as a water tank. The design and dimensions of the box is as shown below.



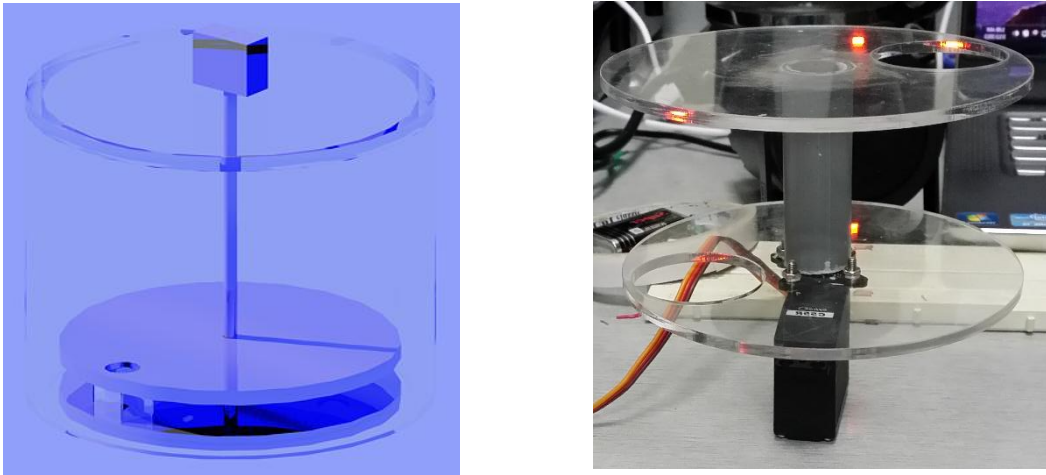
**Figure 10a:** Prototype's Tank Design



**Figure 10b:** built Prototype's Tank

## Container

EM mud balls is kept in a Plastic container that's contains two discs and a shaft connected to a servo motor.

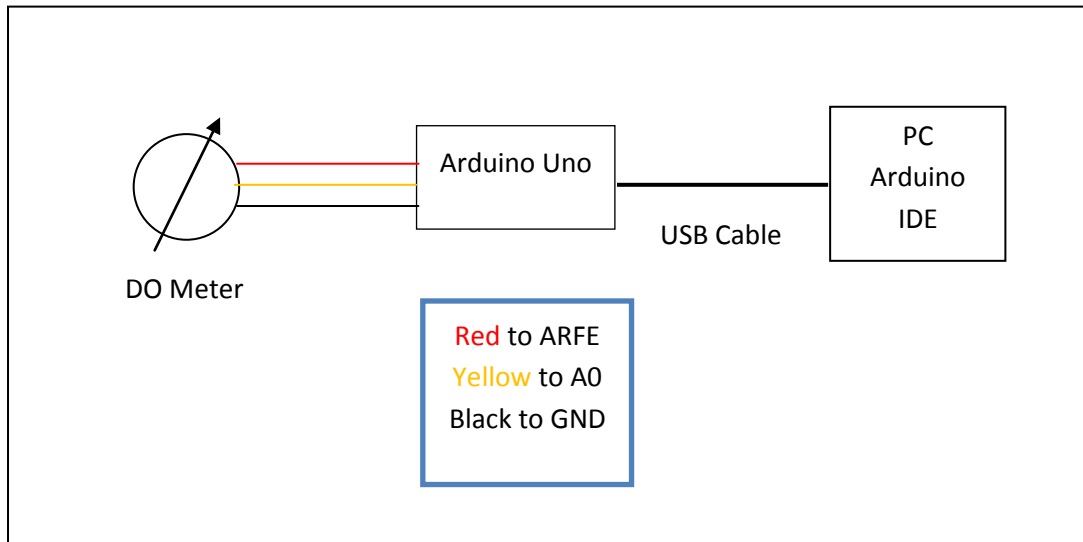


**Figure 11:** Prototype's Container

### 3.2.2 Development of Program code

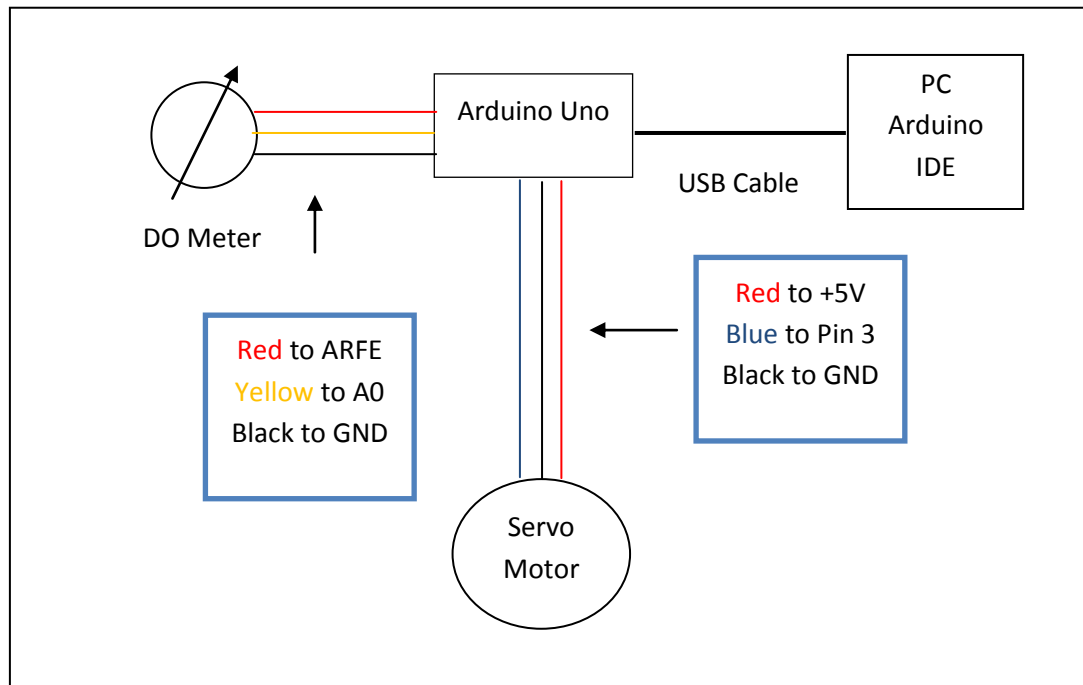
An open-source computer code developed to program the microcontroller chip, which mentioned above, as the main part of the control system to analyse and monitor the desired level of the oxygen as well as to control the final element (DC motor). The code developed by using C programming language. C language is a general-purpose programming language with features economy of expression, modern flow control and data structures, and a rich set of operators[6]. Then, the code is tested, compiled, and uploaded to the chip by using a standard program and software package (Arduino IDE). What is more, a Matlab code is developed to make the serial communication between the microcontroller board (Arduino Uno) and Matlab Program to monitor the oxygen level inside the tank.

Initially, a program code for reading dissolved oxygen in a tank of water was developed as a first step examine the sensor (DO Meter). The tested system consists of a DO meter connected to the Arduino Uno as shown in the figure below.



**Figure 12a:** DO Meter to Arduino Uno Connection

The following Step is to connect the servomotor to the above system; certain functions need to be added to the developed code to achieve the automatic control system. Servomotor consists of three wires ( Voltage [+5], Ground, and Signal) and is connected to Arduino Uno as the below:

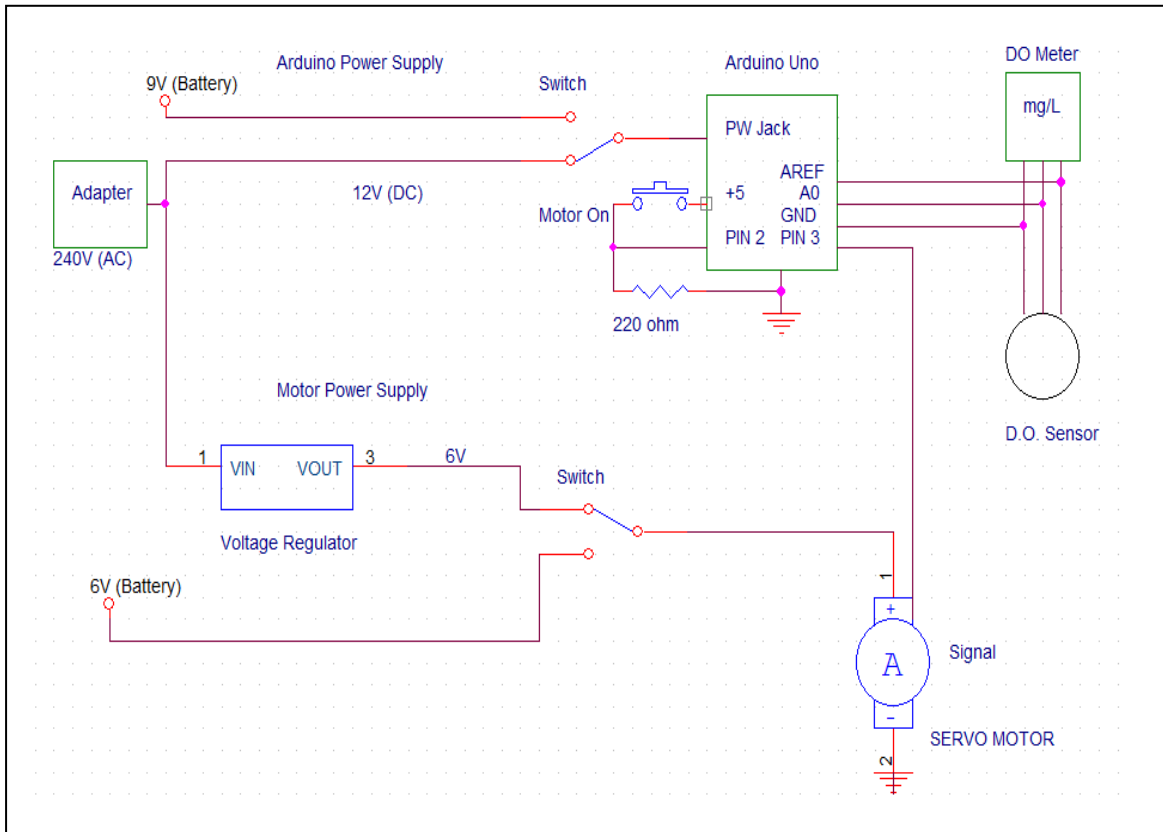


**Figure 12b:** DO Meter, Servomotor, and Arduino Uno Connection

Hence, the required code is tested and ready to be uploaded to Arduino Uno Chip.

### 3.2.3 Prototype's Electrical Circuit

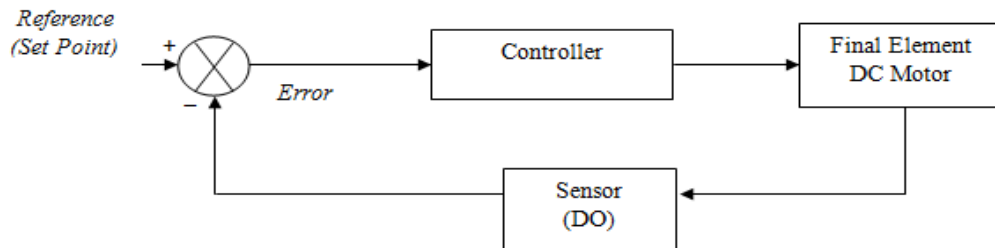
As Arduino Uno is programmed, an independent electrical circuit design is needed to connect and power the prototypes components then to be attached to the prototype casing.



**Figure 13:** Electrical Circuit for the Whole System

Figure 12 indicates that there are two possible power supplies for the electrical circuit. By using switches, either batteries or DC adapter can be utilized to power both Arduino and servomotor. (7806 IC) voltage regulator is used to ensure stable 6V is supplied to the motor. The function of the push-button is to rotate servomotor once the push-button is pressed which also can be also started automatically (based on desired value of dissolved oxygen level). In addition, three wires from DO meter is hooked up to be connected to Arduino Uno as it is shown in the figure above.

### 3.3 Control Loop Block Diagram



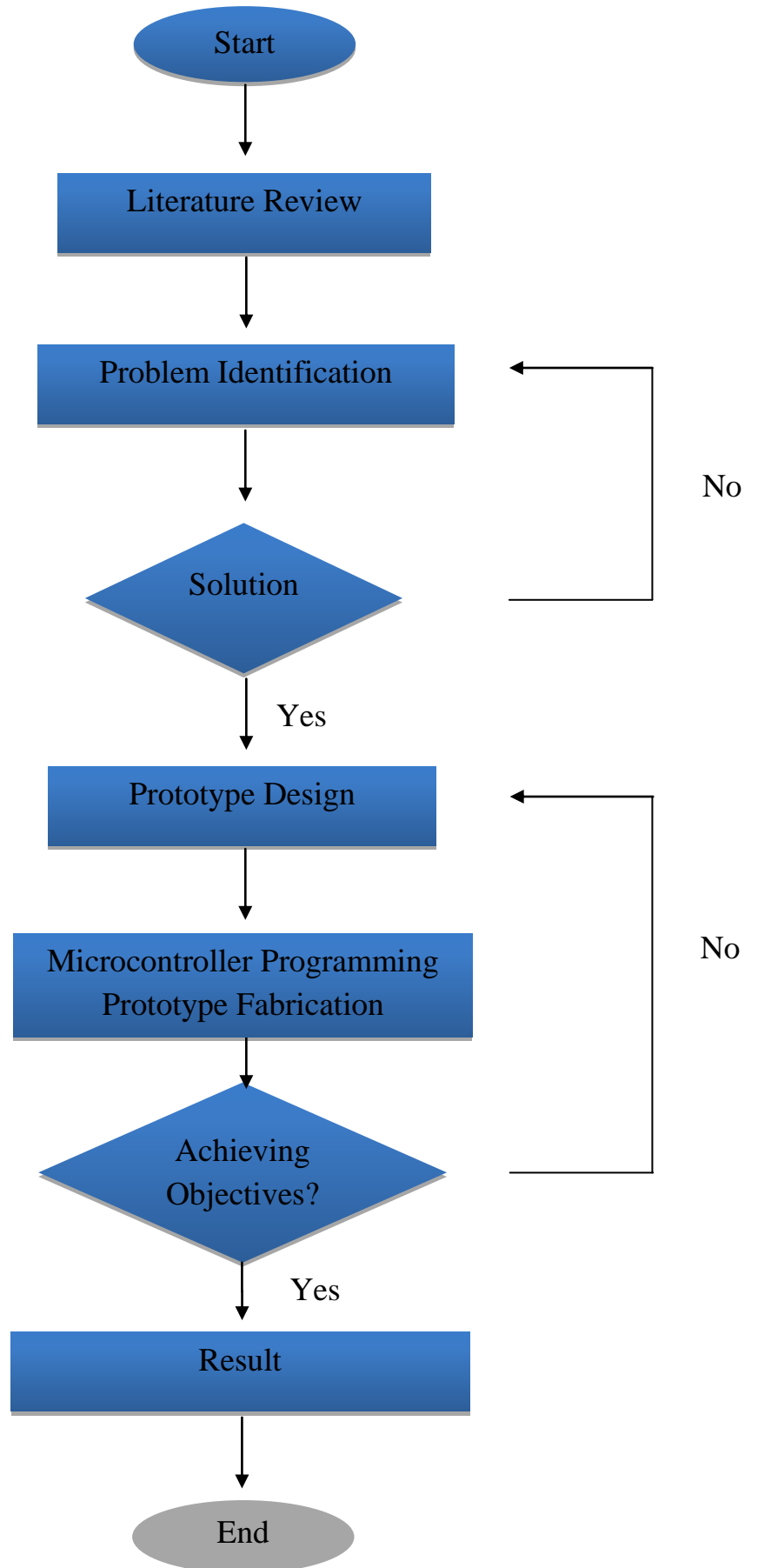
**Figure 14:** Control Loop Block Diagram

The feedback control loop shown above defines the mechanism of the automated control system that compares the measured variable to the set point to obtain the desired output

Basically, the measured variable is the Oxygen level which will be compared to the set point defined by the user. As a result of having variation due to the difference between values, the controller sends a signal to the final element (DC motor). Motor caused EM mud-ball being dispensed into the water tank, until the Oxygen level reach the steady state.



### 3.4 Flow Chart



# CHAPTER 4

## RESULTS AND DISCUSSION

### 4.0 Introduction

This chapter discusses the mathematical modelling, designed prototype, experimental analyses, and expected results for this final year project.

### 4.1 Mathematical Modelling and Coding

Based on the test results that carried out to examine D.O Meter and Arduino Uno connection, as explained early, and based on the specifications of Arduino Chip and D.O. Meter, mathematical modelling equation is developed to obtain the required output. The analog pin of Arduino Uno can read in voltages between 0 to 5 volts or in integer values between 0 (0V) and 1023 (5V).

**This:** The Resolution is  $\frac{5V}{1023 \text{ units}} = 4.9\text{mV}$  per unit

On the other hand, D.O. meter output is range from 0 to 20 (mg/L). For that reasons, the following formula is added as part of the programing code to achieve the desired output:

```
diso2 = (((analogRead(doPin)/1023)*20);
```

**Result obtained:**

<b>D.O. Meter (mg/L)</b>	<b>analogRead (Read From Pin A0)</b>	<b>diso2 Reading from PC (Arduino IDE)</b>
<b>11.8</b>	603	11.78
<b>6.9</b>	352	6.88
<b>3.5</b>	179	3.49

**Table1:** Reading Comparison

The developed C code was tested on the given system. The required code was developed by using IDE software package. The code was implemented to control the desperation system of EM mud ball in a tank of water. In addition, a Matlab code is used to make the serial communication between the microcontroller board (Arduino Uno) and Matlab Program to monitor the oxygen level inside the tank.



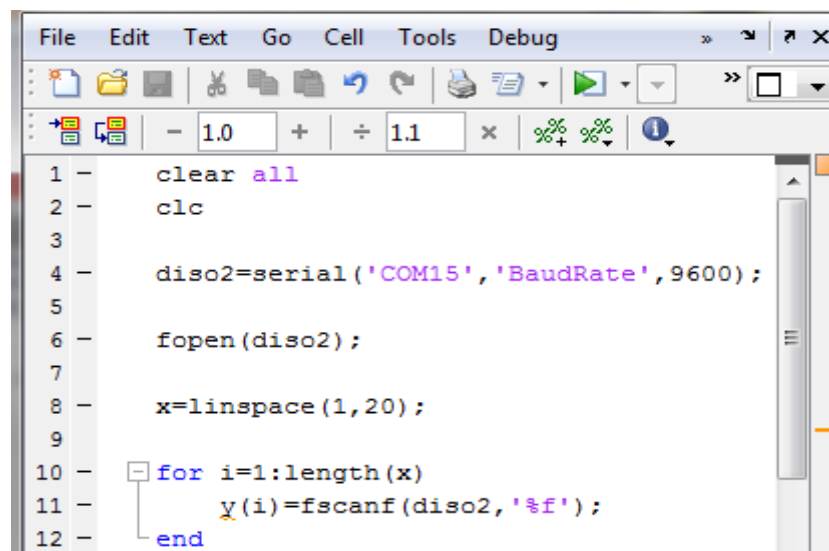
```
FYP $
pinMode(motPin, OUTPUT);
analogReference(INTERNAL);
}

void loop()
{
  diso2 = analogRead(doPin);
  diso2 = (((analogRead(doPin)/1023)*20);

  Serial.println((diso2));

  if ( diso2 < 8)
  StartMotor();
  else |
  {
  digitalWrite(motPin, LOW);
  }
  delay(1000);
}
```

Figure 15a: Arduino Sketch



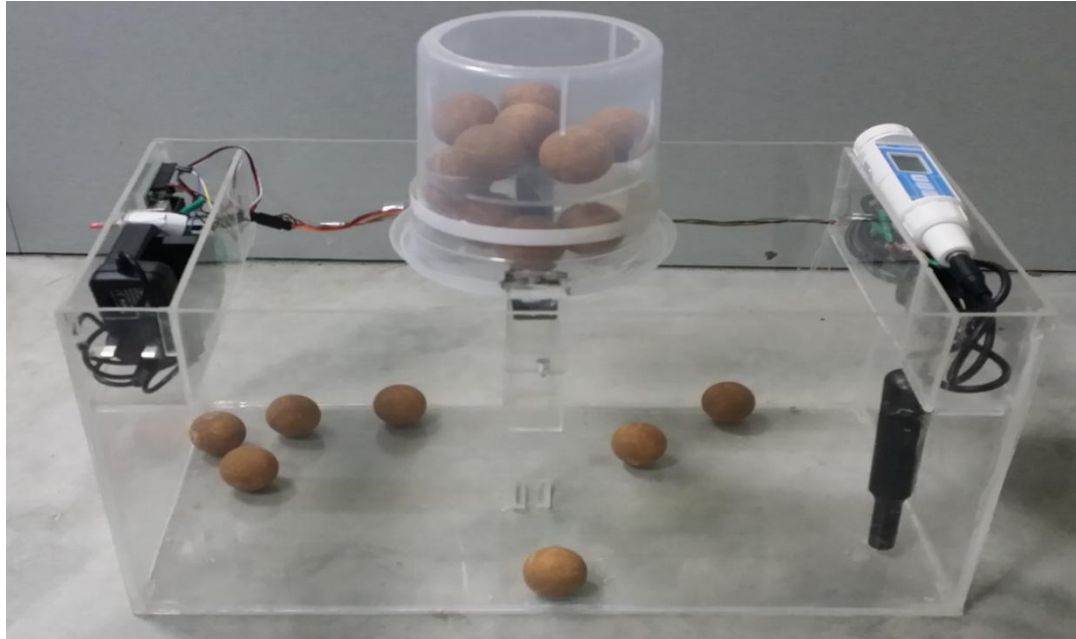
```
File Edit Text Go Cell Tools Debug
clear all
clc
diso2=serial('COM15','BaudRate',9600);
fopen(diso2);
x=linspace(1,20);
for i=1:length(x)
    y(i)=fscanf(diso2,'%f');
end
```

Figure 15b: MATLAB Code

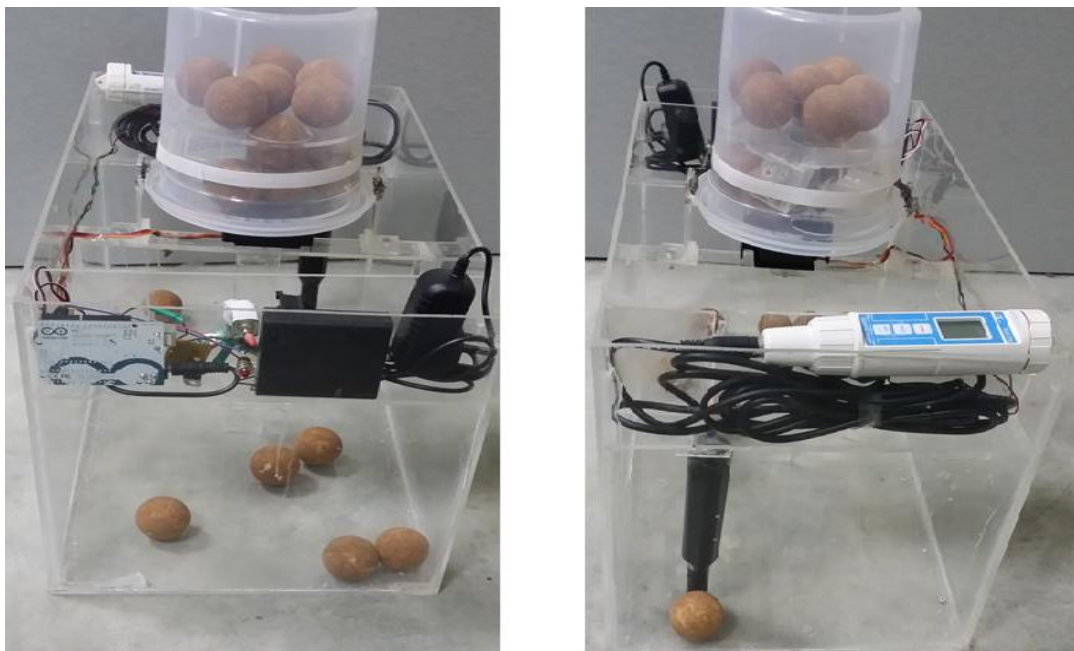
The completely developed code & MATLAB commands are attached in **Appendix I**

## 4.2 Designed Prototype

After conducting an extensive research on Effective Microorganism (EM) technology and designing a suitable system to dispense EM mud ball according to Oxygen level, a test prototype for studying the EM dispersion is developed. The prototype consists of tank of water, container, servomotor, Do sensor, and microcontroller (Arduino Uno).



**Figure 16a:** Developed Prototype



**Figure 16b:** Developed Prototype (sides view)

### 4.3 Experimental Analyzes

Upon finalizing the building of the prototype, experiments are needed to be conducted to test and study the result of EM mud ball dispersion in a tank of water based on oxygen level.

Furthermore, the desired value of the oxygen level has been set to send the signal to the final element (DC motor) if the dissolved oxygen of water inside the prototype's tanks is less than 8 mg/L (the number has been chosen for test purpose).

<b>DO Value (mg/L)</b>	<b>Motor Action</b>
Less than 8 (7 to 0)	On (rotating)
More than or equal 8 (8 to 20)	Off (stopped)

**Table2:** Desired Value Setting

To achieve the objective of this research, two types of water were utilized to test the automated dispersion system as follow:

- a) Clean Water

By filling the tank of the prototype with pure water as shown:

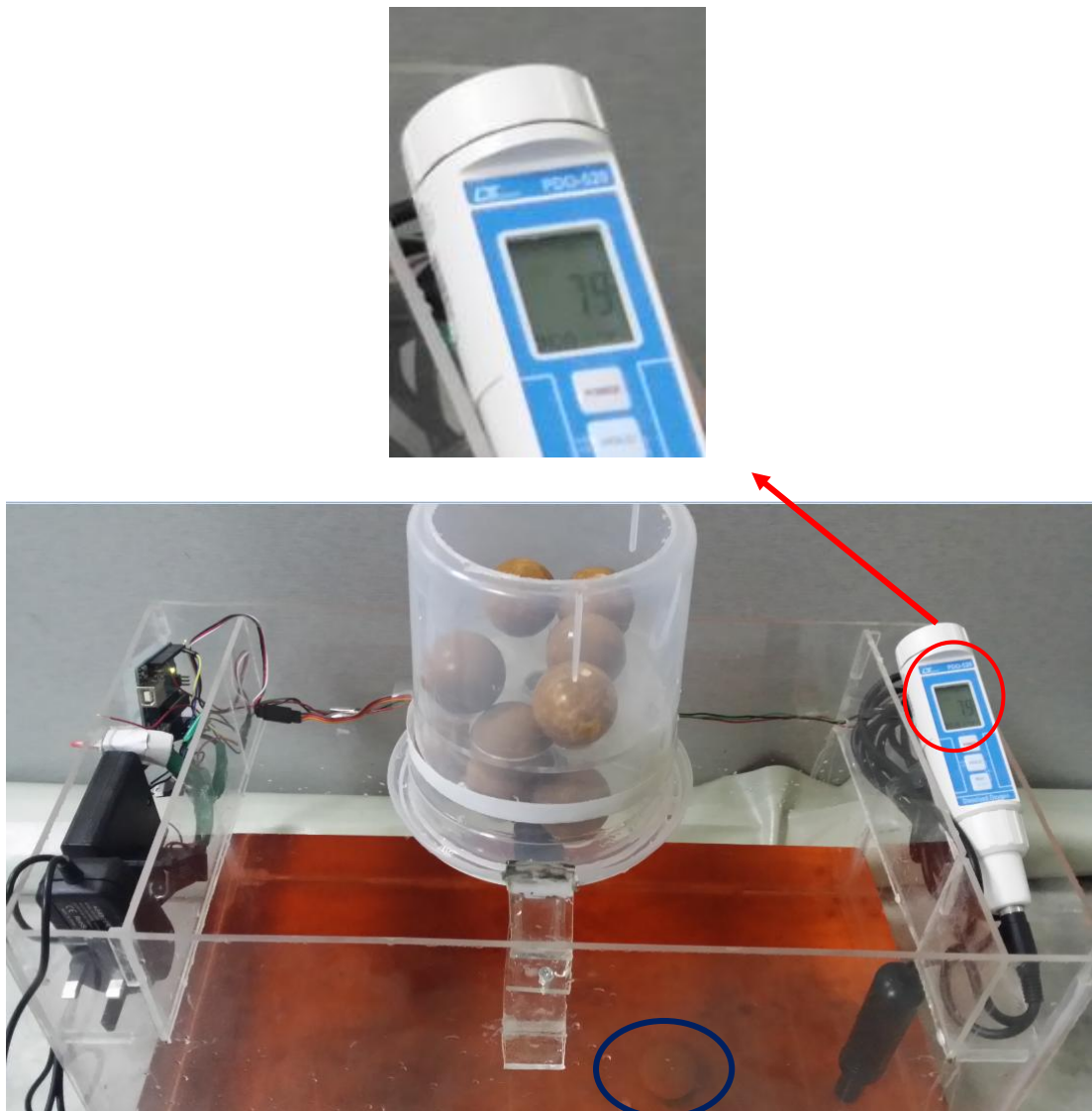


**Figure 17:** Clean Water

The DO meter indicates that the dissolved oxygen of the water inside the tank is 8.5mg/L and according to the table above the motor will not start to rotate if DO value is more than 8.0 mg/L.

b) Unclean water

The following figure showing dissolved oxygen value of unclean water.

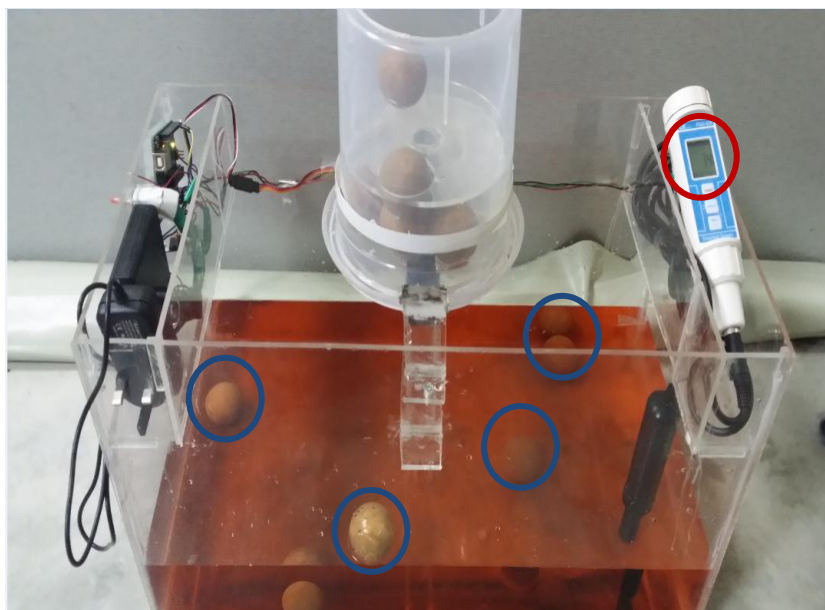
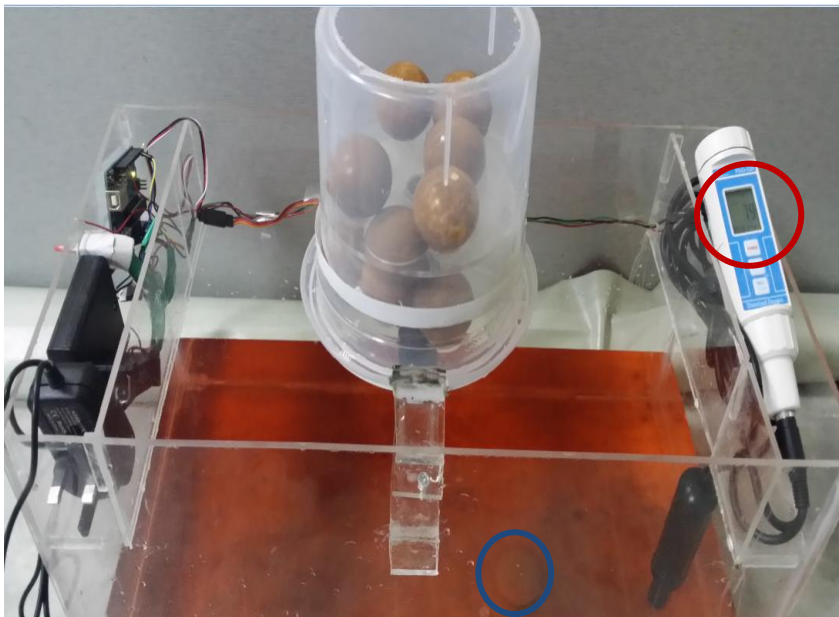


**Figure18a:** Unclean Water

As the value of the dissolved oxygen level is less 8.0 mg/L, the motor will start to rotate and dispartate EM mud balls into the tanks. (The balls utilized in the experiments are not ***REAL EM mud ball***).

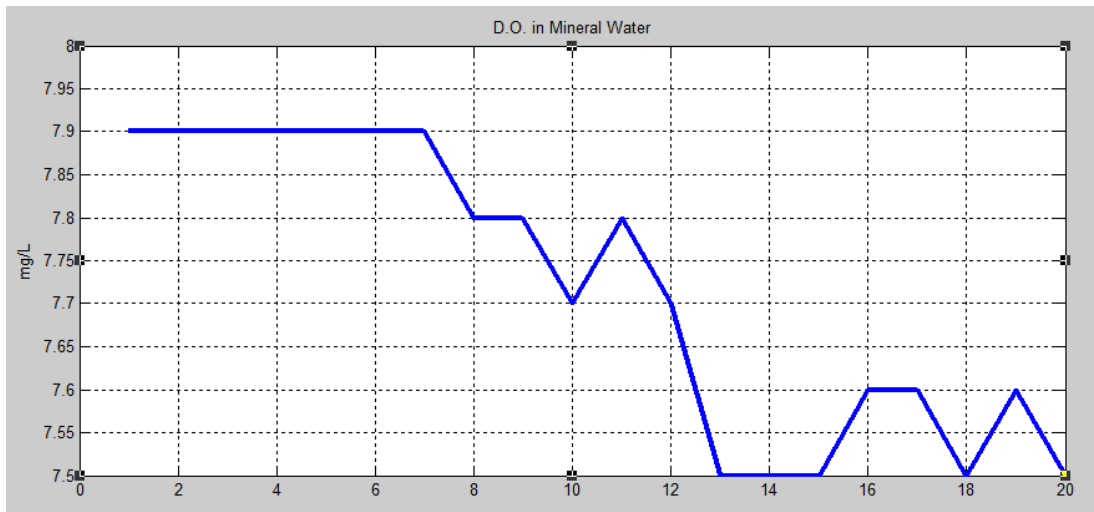


The system will keep dispense EM Mud ball into the tanks along as the value of dissolved oxygen level less than 8.0 mg/L.



**Figure18b:** Unclean Water with more EM mud ball

The level of the dissolved oxygen of the water inside the tank can be monitored by connected the system (Prototype's Circuit) to the MATLAB (serial communication) as shown the figure below:



**Figure19: D.O Reading**

The graph shows different values of the dissolved oxygen levels inside the prototype's tank for a period of time. Y-axis indicates DO level while X-axis show the time is seconds.

#### 4.4 Discussion and Expected Results

Due to the unavailability of EM mud ball, Plastic brown filled balls, almost 50g each, used as EM Mud ball to test dispersion of the designed prototype. As it has mentioned early, the paper's main scope it to build an automated control system to dispense EM into tank of water. In the second chapter, Effective Microorganisms (EM) is proven to dilute pollutant in river, Lake Etc. While controlling the required amount of EM mud ball is the problem which the author trying to solve by developing a new method as explained in this paper. In additional, by utilizing real EM mud balls in the system the blue line of the graph shown in figure (18) is expected to return back to the desired valued (ex. 8mg/L) based on the early studies discussed in this paper.



## **CHAPTER 5**

### **CONCLUSION AND RECOMMENDATIONS**

#### **5.3 Conclusion**

A control system that acts as a new and creative idea for dispensation EM in Mud Ball form is created in this final year project. The prototype is designed to pour mud balls into a tank of water based on the oxygen level inside a tank of water. Servo DC Motor is utilized to spin and distribute the mud balls into a tank of water. In addition, the serial communication between the designed prototype's system and Matlab Program will assist to monitor EM dispersion of EM in the water tank.

#### **5.4 Recommendations**

Upon achieving the main objective of this project with aforementioned specifications, one of the recommended and suggested improvements for future work is to attach keypad to the system in order to give the operator the ability to change the desired value of oxygen level without the need of reprogramming the Arduino chip. The advantage of adding keypad to the prototype will overcome the difficulties of changing the desired set point for different cases of water conditions.

Secondly, by pouring real EM balls in the designed prototype, water dissolved oxygen level will take time to be enhanced. For better results, a function is needed to be added to the developed code to control motor rotations for certain time. In other words, when D.O level inside the water reduces below the desired value, the motor will start to disperse EM mud balls into the water for specific time. Then, the system will check if D.O level returns to the defined valued else the motor will start to rotate again.

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# Appendix I

## Appendix A

### Arduino Sketch (C Program Code)

```
// Final Year Project_Step 2013 //
// EM Mud Ball Dispersion System //

#include <Servo.h>

int doPin = 0; // A0 in Arduino Board
float diso2 = 0; // Dissolved Oxygen in Water

Servo servoMotor; // Define our Servo

int button = 2; // button pin
unsigned long LastRotate; // time since button pressed

void setup()
{
  Serial.begin(9600); // serial communication

  analogReference(EXTERNAL); // voltage Reference

  servoMotor.attach(3); // servo on digital pin 3

  pinMode(button, INPUT); // button on pin 2
}

void loop()
```

```

{
  int span = 20;
  int start = 0;
  for(int i = 0; i < span; i++)
  {
    start = start+analogRead(doPin);
  }

  int state = digitalRead(button);
  /* check if button is pressed and it is
  over 5 seconds since last button press */

  diso2 = analogRead(doPin);
  diso2 = ((diso2/1023)*10);

  Serial.println((diso2));
  delay(200);

  // and it is over 5 seconds since last button press

  if (( diso2 < 8))
  {
    StartMotor(); // Call the function to start the motor
  }

  else if (state == HIGH && (millis() - LastRotate) > 5000) {
    // Call the function to change the lights

```

```
    StartMotor(); }

}

void StartMotor()
{
    servoMotor.write(180); // Turn Servo Right to 180 degrees
    delay(2000);          // Wait 2 second
    servoMotor.write(18); // Turn Servo back to center position 0 degrees
    delay(1000);          // Wait 1 second

    // record the time since last press
    LastRotate = millis();
}
```

## **Appendix B**

### **Matlab Code**

```
clear all
clc

diso2=serial('COM15','BaudRate',9600);

fopen(diso2);

x=linspace(1,20);

for i=1:length(x)
    y(i)=fscanf(diso2,'%d');
end

fclose(diso2);
disp('making plot..')
plot(x,y);
```