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The Potential of Leguminous Seeds as Natural Coagulants assisted by Arduino™ For Educational Purpose

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a b s t r a c t

The decline in water quality is caused by various environmental degradation activities, climate change population growth, and increasing living standards and urbanization. The study aims to determine the effect of variations in the concentration of tamarind and winged bean bio coagulant concentrations on turbidity sensor SKU: SENO189 and SENO244 Gravity analog TDS Sensor TDS based ArduinoTM for educational purposes. The work started with 1) the development of a measuring device with the microcontroller ArduinoTM, 2) sample preparation, and 3) sample measurement. The water quality measurement parameters are turbidity, TDS level (dependent variable), and concentration of tamarind and wingan seeds extract (independent variable). The results showed that variations in the doses of tamarind and winged bean seed extracts of 3g/0.5L, 5g/0.5L, 7g/0.5L, and 9g/0.5 reduced the turbidity and could reduce TDS values in river water. However, the most optimal dose to reduce the turbidity value and TDS value is the addition of a coagulant at a concentration of 3 g/0.5 L with a reduction in turbidity of 71.33% (tamarind seeds) and 63.17% (wingan seeds). Then the TDS reduction value was 15.58% (tamarind seeds) and 9.54% (wingan seeds). This is because tannin compounds in tamarind and winged bean seeds can precipitate protein content between molecules in peat water that do not bind to colloidal particles, forming bonds that settle quickly.The research has implications for applying programming technology on a large scale to measure water quality for society.

1. Introduction

Water quality is one of the main challenges that society will face in the 21st century and threatens human health, limits food production, reduces ecosystem function, and hinders economic growth (UNESCO, 2022). This is because water is a fundamental element for all human activities and the activities of other biological organisms. Nearly 71% of the earth's surface is covered by water, consisting of 96.8% seawater and 3.2% inland water in the form of rivers (0.41%) and groundwater (0.21%) (USGS, 2019). Currently, water quality is included in one of the SDGs goals. Quality water is explicitly recognized as part of the target on goal 6 of the

SDGs, namely "Ensure availability and sustainable management of water and sanitation for all, which aims to "improve water quality by reducing pollution, eliminating disposal and minimizing the release of chemicals and hazardous materials, halving the proportion of untreated wastewater and substantially increasing recycling and reuse globally (UNESCO, 2015). However, in reality, quality water resources continue to decline, and water pollution grows worldwide yearly. The decline in water quality is caused by various environmental degradation activities, climate change (Konapala et al., 2020), population growth, and increasing living standards and urbanization (Zubaidi et al., 2020). This irony has been going on for a long time, especially in developing countries and rural areas. Based on data from the Ministry of Environment and Forestry, in 2020, almost 57.42% of households in Indonesia disposed of their wastewater into rivers. Household wastewater is water that humans have used for various activities, such as detergent water left over from washing, soap water, and feces. This affects river pollution. In 2020, out of 113 rivers in Indonesia, 20 rivers were lightly polluted, 13 rivers were moderately polluted, and 58 rivers were heavily polluted (BPS, 2021). Based on the standard of the Ministry of Health No. 3 of 2017, good water quality is if the turbidity level is a maximum of 25 NTU, a maximum TDS of 1000, and a pH between 7-7.6 (Menteri Kesehatan Republik Indonesia, 2017).

Various processes and technologies are being researched to improve water quality in order to maintain water demand (Basuki et al., 2022). This technology is classified into three types: physical, chemical, and biological processing methods. Coagulant removal of suspended particulate matter and colloids in wastewater is one of the chemical treatment technologies (Staicu et al., 2015). Coagulation is one of the most basic methods for efficiently removing suspended solids and impurities from water. Coagulants (organic and synthetic) or natural coagulants can be used in the coagulant process (de Paula et al., 2018). In Indonesia, alum is commonly used in the coagulation process. Alum, with the chemical formula [$Al_2(SO_4)_3.14H_2O$], is a coagulant that can be used to reduce turbidity levels. When alum is added to alkalinity-containing water, it produces carbon dioxide and can reduce pH and turbidity (Kalavathy & Giridhar, 2016). However, excessive alum use causes the pH to plummet and the water to become extremely acidic, rendering it unfit for consumption (Winoto et al., 2021). The Environmental Protection Agency (EPA) has recommended a maximum aluminum contamination limit in drinking water of 0.05-0.2 mg/L. The Food and Drug Administration (FDA) of the United States has set a limit for aluminum contamination in bottled water of 0.2 mg/L. According to Minister of Health of the Republic of Indonesia 492/MENKES/PER/IV/2010, the maximum allowable aluminum content in clean water is 0.2 mg/L (Permenkes RI, 2010). This makes using alum as a coagulant to improve water quality difficult. To address these issues, seeking out renewable and natural alum coagulant substitutes, such as those derived from plants is necessary. Although chemical coagulants are more effective than natural coagulants, they are more expensive and produce difficult-to-treat deposits.

Natural coagulants are created or extracted from a variety of sources, including microorganisms, animals, and plants (both non-vegetable and vegetable) (Nimesha et al., 2022), Moringa seeds (Aras & Asriani, 2021; Ariyatun et al., 2018), aloe vera (January et al., 2021), watermelon and papaya seeds are now being identified as effective coagulants derived from plants (Anggorowati, 2021). Aside from the biocoagulants studied, natural coagulants can be derived from plant seeds because they contain polycationic proteins with cationic amino acids in their polypeptide chains (Ariyatun et al., 2018). Compared to grains from other tribes, seeds from the legume family (Fabaceae family) have a higher protein content. Tamarind seeds (Tamarindus indica L.) and winged bean seeds (Psophocarpus tetragonolobus L.), both from the Fabaceae family, are thought to have potential as biocoagulants. This is because java and winged bean seeds have a high protein content, which Moringa seeds also have (Hendrawati et al., 2013). Furthermore, tamarind and winged bean seeds are more readily available at a reasonable price. As a result, tamarind seeds and winged bean seeds can be used as natural coagulants to purify water and for school experiment.

Experimental activities for the topic of water purification in junior high school are found in KD 3.3 *"Explain mixtures and single substances (elements and compounds), physical and chemical properties, and physical and chemical changes in everyday life."* on 7th grade and water pollution pada KD 3.8 *"Examine the occurrence of pollution and its impact on the ecosystem"* on 8th grade. In general, physical methods are used in practical activities to separate mixtures and purify water, such as filtration using filters made of sand, cotton, or charcoal. However, chemical and biological methods, such as the addition of biocoagulants, are rarely used. Then, for measuring instruments used to measure water quality in schools, such as TDS meters and turbidity meters, adhere to established measuring instrument standards. As a result, innovation in measuring instruments for school practicum activities is lacking. Using the Arduino Uno microcontroller and the biocoagulant principle is one of the innovations that can be used to develop a measuring tool to determine water quality in schools.

The benefits of measuring instruments that use Arduino microcontrollers include the ability to connect to a variety of low-cost sensors to produce extremely accurate and reliable measurements (Pino et al., 2019). Several studies have used the Arduino Uno to measure school science practicums. For example, Prima et al. (2017) created a KIT practicum to measure temperature changes at specific positions on a heated rod (Prima et al., 2017). Another study employs Arduino as a practicum tool in schools, measuring pH, pressure, and temperature with the help of Excel (Walkowiak & Nehring, 2016). All of this research demonstrates the advantages of Arduino uno for practicum activities in schools and has the potential to make a difference in the world of education. Therefore, to assist teachers in developing practicum innovations, particularly on water quality issues, researchers created an arduino uno-based measuring instrument using TDS and turbidity sensors, as well as the principle of tamarind seed biocogulant and winged bean seeds. This research aims to determine the potential of tamarind and winged bean seeds as natural coagulants using a measuring instrument aided by an Arduino Uno.

2. Method

The tools needed to develop and conduct research include mikrokontroller ArduinoTM uno, sensor TDS DFRobot, sensor turbidity DFRobot, LCD 12C, jumper cables, boards, digital scales, oven, blender, 100 mesh sieve, beaker, and magnetic stirrer. Then the materials used include tamarind seeds, winged bean seeds, and distilled water. The steps taken include the following:

TDS Tools

As shown in Figure 1, the Dfrobot Analog TDS sensor is first connected to an Arduino Uno with configuration A (AC signal) to analog A1, the positive pole (+) to 5V, and the negative pole (-) to GND. The TDS probe is then immersed in the liquid tester. Following the connection of the TDS sensor to Arduino, the code must be entered into the Arduino Uno software. The code can be seen in Table 1

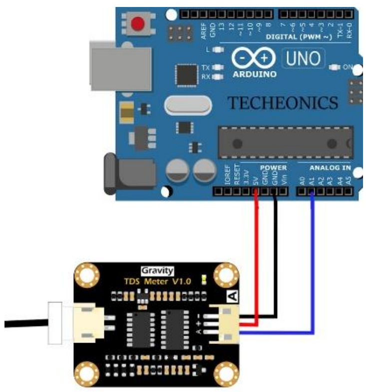


Figure 1. Installation of a TDS sensor to measure TDS levels in water.

Table 1. The ArduinoTM code of SENO244 Gravity analog TDS Sensor TDS Sensor to the ArduinoTM for water quality measurement

The Arduino™ code of TDS Sensor (part I)	**The Arduino™ code of TDS Sensor (part II)**
#include <EEPROM.h>	lcd.init();
#include "GravityTDS.h"	lcd.init(); //
#include <Wire.h>	lcd.backlight();
#include <LiquidCrystal_I2C.h>	lcd.setCursor(1,0);
#define TdsSensorPin A1	lcd.print("tdsValue,0");
GravityTDS gravityTds;	lcd.setCursor(1,1);
	lcd.print("ppm");
float temperature = 25,tdsValue = 0;	}
LiquidCrystal_I2C lcd(0x27,20,4); //	void loop()
	{
void setup()	//temperature = readTemperature();
{	gravityTds.setTemperature(temperature);
Serial.begin(9600);	gravityTds.update();
gravityTds.setPin(TdsSensorPin);	lcd.setCursor(1,0);
gravityTds.setAdcRange(1024); //	lcd.print("Nilai TDS (ppm)");
gravityTds.begin(); //	lcd.setCursor(1,1);
	lcd.print(tdsValue);
	delay(1000);
	}

TDS Tools

As shown in Figure 2, the Analog Turbidity Dfrobot is first connected to an Arduino Uno via a SIGNAL configuration (AC signal) to analog A0, VCC to 5V, and GNS|D to GND. The Turbidity probe is then immersed in the liquid tester. Following the connection of the Turbidity sensor to Arduino, the code must be entered into the Arduino Uno software. The code can be seen in Table 2.

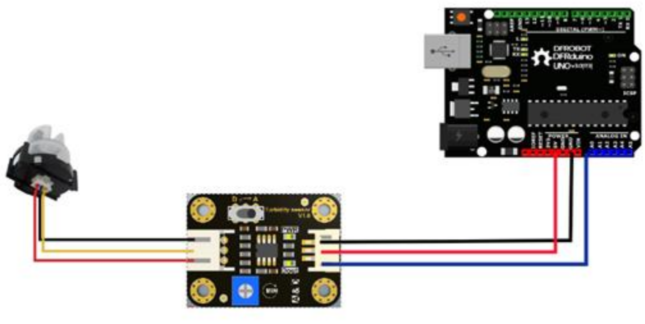


Figure 2. Installation of a Turbidity sensor to measure TDS levels in water.

Table 1. The ArduinoTM code of turbidity sensor SKU:SENO189 to the ArduinoTM for water quality measurement

The Arduino™ code of Turbidity Sensor (part I)	**The Arduino™ code of Turbidity Sensor (part II)**
#include <Wire.h>	volt = volt/800;
#include <LiquidCrystal_I2C.h>	volt = round_to_dp(volt,2);
LiquidCrystal_I2C lcd(0x27, 16, 2);	if(volt < 2.5){
	ntu = 3000;

The Arduino™ code of Turbidity Sensor (part I)

```
int sensorPin = A0;

void setup()
{
 Serial.begin(9600);
 lcd.begin();
 lcd.backlight();
}

void loop()
{

   volt = 0;
   for(int i=0; i<800; i++)
   {
      Volt+=
((float)analogRead(sensorPin)/1023)*5;
   }
```

The Arduino™ code of Turbidity Sensor (part II)

```
   }else{
     ntu = -1120.4*square(volt)+5742.3*volt-4353.8;
   }
   lcd.clear();
   lcd.setCursor(0,0);
   lcd.print(volt);
   lcd.print(" V");

   lcd.setCursor(0,1);
   lcd.print(ntu);
   lcd.print(" NTU");
   delay(10);
}

float round_to_dp( float in_value, int decimal_place )
{
  float multiplier = powf( 10.0f, decimal_place );
  in_value = roundf( in_value * multiplier ) / multiplier;
  return in_value;
}
```

Sample Preparations

Tamarind and winged seeds are extracted from the flesh of the fruit. After cleaning, the seeds are dried for 2 hours a 1050°C in the oven. After that, the seeds are blended until smooth. Then, the finely settled seeds are filtered through a 100-mesh sieve.

Experiment.

Variations of coagulant doses of tamarind seed powder and seeds dissolved in 500 mL of distilled water for use as coagulants in the future. Variations in coagulant doses: 3 g, 4 g, 5 g, 6 g, and 7 g were used to determine the effect of efficient coagulant doses of tamarind and winged bean seeds. 500 mL of household liquid waste samples are placed in the beaker. The coagulant was added to the beaker in amounts of up to 50 mL. The sample was stirred for 1 minute at 500 rpm, flocculated for 3 minutes at 200 rpm, then precipitated for 60 minutes, and the TDS concentration and water clarity were determined.

3. Result and Discussion

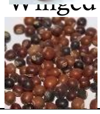
The effect of tamarind seeds and winged bean seeds on the turbidity of river water

Turbidity in water is caused by suspended matter such as clay, silt, organic matter, plankton, and other fine materials (Zhang et al., 2022). Table 1 shows the effect of winged bean and tamarind seeds as biocoagulants on decreasing turbidity using the Arduino Uno microcontroller. The ability of winged bean and tamarind seeds to act as biocoagulants is due to their high protein content, which can act as polyelectrolytes (Syamsuddin et al., 2021). *Polyelectrolytes* are polymers that have a positive or negative charge due to ionized groups. This group can dissociate in a polar solvent like water, leaving an appointment on the polymer chain and releasing opposite ions in the solution to reduce turbidity (Ajaya Bhattarai, 2004). Figure 3 depicts the condition of river water after being treated with tamarind seed extract and winged bean seeds during the coagulation process.

Figure 3. Coagulation results of various doses of tamarind (left) and winged bean seeds (right) after 1 hour

Based on the information in Table 1. The percentage decrease in turbidity in river water after being given tamarind seed extract at a concentration of 3 gr/0.5 was 71.33%, 62.55% at a concentration of 5 gr/0.5 L, 61.95% at a concentration of gr/0.5 L, and 53.66% at a concentration of 9 gr/0.5 L. Meanwhile, the percentage decrease in turbidity in river water after being treated with winged bean seed extract at concentrations of 3 gr/0.5 L was 63.17%, 5 gr/0.5 L was 51.25%, gr/0.5 L was 18.82%, and 9 gr/0.5 L was 8.

Table 3. Turbidity value of river water after addition of biocoagulants

Sample	Concentration	Initial Turbidity (NTU)	Final Turbidity (NTU)	Decreased of Turbidity (%)
Tamarind	3 g/0.5 L	134.3	38.5	71.33
	5 g/0.5 L	134.3	50.3	62.55
	7 g/0.5 L	134.3	51.1	61.95
	9 g/0.5 L	134.3	62.2	53.66
Winged	3 g/0.5 L	95.6	35.2	63.17
	5 g/0.5 L	95.6	46.6	51.25
	7 g/0.5 L	95.6	77.6	18.82
	9 g/0.5 L	95.6	87.3	8.68

1. Figure 4 depicts a graph depicting the relationship between coagulant dose variations and turbidity levels. The graph shows that a coagulant dose of 3 g/0.5 L from both tamarind seed coagulant (38.5 NTU) and winged bean seeds (35.2 NTU) resulted in the most significant decrease in turbidity values.

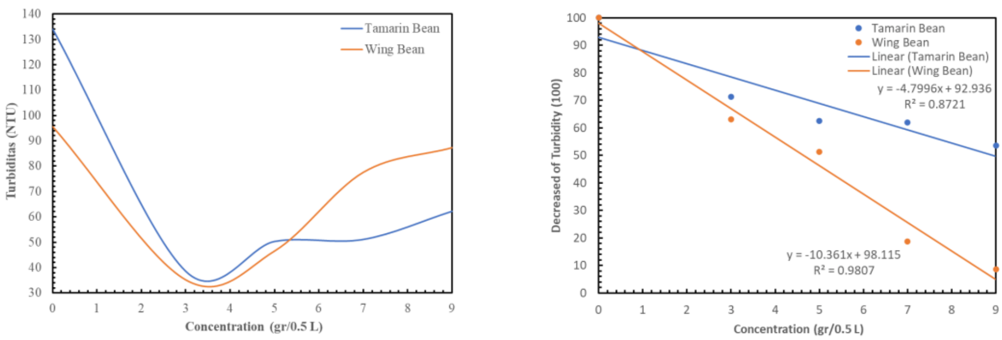


Figure 4. Relationship between coagulant dose variations and TDS levels.

These results are in accordance with research Petersen et al., (2016) examining the effect of coagulants produced by Moringa oriefera moringa seeds which can reduce water turbidity by 10.9 NTU (94%) and 13.7 NTU (91.7%). These results are also strengthened by researchSenthil Kumar et al., (2015) which found the removal of turbidity with Strychnos potatorum seed powder was 68-89%. Sasikala & Muthuraman, (2017) natural coagulants were effective in reducing 70 to 97% in water samples synthetic and surface water.According to the graph, the most significant decrease in turbidity values occurred when the river's ability to purify wastewater became saturated as more coagulants were added, and the remaining coagulants contaminated the existing solution (Poerwanto et al., 2015). The effectiveness of reducing turbidity decreases again at concentrations above 3 g/0.5 L due to the addition of excessive biocoagulants, resulting in an increased tendency for flocs to float and not settle. Excess coagulants that do not interact with colloidal particles will also cause turbidity, causing turbidity to rise above the optimum dose once more (Hendrawati et al., 2013). Furthermore, particle diameter influences turbidity looseness because the smaller the particle diameter, the greater the contact area between the coagulant particles and the colloids in the water. Contact will become closer, making the process of floc formation in water more accessible. The smaller the diameter of the coagulant particles, the more significant the reduction in river water turbidity (Elpani et al., 2020). Because the coagulant particles have a smaller diameter, the suspension is more homogeneous, and the interactions between the particles are faster, allowing flocs to form more easily. However, because the coagulant was sieved using an ordinary sieve, the particle diameter used in this study was not too small. Based on the standard of the Ministry of Health No. 3 of 2017, good water quality is if the turbidity level is a maximum of 25 NTU (Menteri Kesehatan Republik Indonesia, 2017). However, the turbidity reduction in river water after treatment with tamarind seed extract and winged bean seeds did not meet the Ministry of Health's standard. The slowest rate of decline was 38.5 NTU for Tamarind Seeds and 35.2 for winged seeds.

The effect of tamarind seeds and winged bean seeds on the TDS level of river water

The study showed that river water, after being given tamarind, and winged bean seed coagulant, affected TDS values, which can be seen in Table 2. Coagulation results of various doses of tamarind (left) and winged bean seeds (right) after 1 hour.

Table 2. TDS value of river water after addition of biocoagulants

Sample	Concentration	Initial TDS (ppm)	Final TDS (ppm)	Decreased of TDS (%)
Tamarind	3 g/0.5 L	348	293.79	15.58
	5 g/0.5 L	348	304	12.64
	7 g/0.5 L	348	311.05	10.62
	9 g/0.5 L	348	332	4.6
Winged	3 g/0.5 L	305.86	276.68	9.54
	5 g/0.5 L	305.86	283.51	7.3
	7 g/0.5 L	305.86	286.93	6.2
	9 g/0.5 L	305.86	297.23	2.82

Total dissolved solids (TDS) are inorganic salts and trace amounts of organic matter found in aqueous solutions. Calcium, magnesium, sodium, and potassium cations, as well as carbonate, hydrogen carbonate, chloride, sulfate, and nitrate anions, are the most common constituents (WHO, 1996). According to the data in Table 2, the percentage decrease in TDS in river water after being given tamarind seed extract at a concentration of 3 gr/0.5 was 15.58%, 5 gr/0.5 L was 12.64%, 7 gr/0.5 L was 10.62%, and 9 gr/0.5 L was 4.6%. Meanwhile, the percentage decrease in turbidity in river water after being treated with winged bean seed extract at a concentration of 3 gr/0.5 L was 9.54%, 7.3% at a concentration of 5 gr/0.5 L, 6.2% at a concentration of gr/0.5 L, and 2.82% at a concentration of 9 gr/0.5 L. Figure 5 depicts the graph of the relationship between variations in coagulant doses and values. According to these graphs, the most significant decrease in turbidity values occurred when river water was given a coagulant dose of 3 gr/0.5 L from both tamarind seed coagulant (293.79 ppm) and winged bean seeds (276.68 ppm).

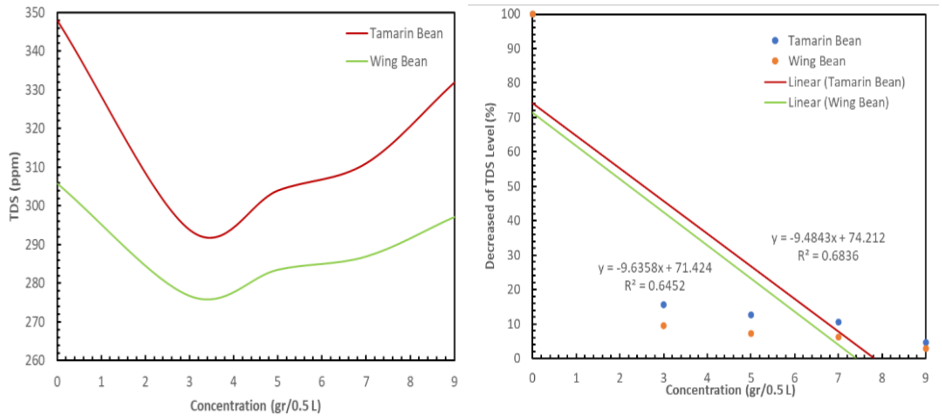


Figure 5. Graph depicting the relationship between coagulant dose variations and TDS levels.

This research is in accordance with research by Saravanan et al., (2017) who studied the use of natural coagulants such as Hibiscus rosa sinensis, Moringa oleifera, Azadiracha indica, Dohichaslablab in wastewater treatment and found that vegetable coagulants can be used in the coagulation and flocculation processes of wastewater treatment. Prasad & Rao, (2016) studied the removal of turbidity and heavy metals from waste air with vegetable coagulants such as Moringa Oleifera and Tamarindus Indica seeds and found turbidity of 1.8 NTU and 3 NTU, heavy metals of 70% and 73% and 34% and 10%. Hardness removal respectively turbidity and COD removal by using natural coagulants (potato starch and Sago) and chemical coagulants (Al2(SO4)3 and PAC) in semiconductor wastewater treatment and found 1.5g/l reduced turbidity and COD removal, removal TDS and turbidity using natural coagulants such as Acacia Catechu to treat wastewater. Removal of turbidity and TDS was found to be 91% and 57.3%, respectively. TDS levels are reduced because tamarind seed powder and winged bean seeds contain positively charged proteins that bind negatively to the wastewater (Merdana et al., 2020). The TDS value is proportional to the turbidity of the water. The higher the TDS value, the more water turbid (Kishor & Singh, 2020). (Shyshkina, 2018)It is due to the presence of numerous dissolved minerals in turbid water. Elpani et al., (2020) discovered an increase in TDS values due to the excessive use of coagulants in the sample, which lends support to this study. As a result, the higher the coagulant concentration, the higher the TDS level (Elpani et al., 2020). However, using too much coagulant will cause the solution to become saturated, making it appear stormy later. The mechanism for reducing TDS in biocoagulants is that tamarind seeds and winged bean seeds contain tannin compounds, which can precipitate protein content between molecules in peat water that do not bind to colloidal particles, forming bonds that settle quickly (Riyandini & Iqbal, 2020). Based on the standard of the Ministry of Health No. 3 of 2017, good water quality is if the turbidity level is a maximum a maximum TDS of 1000 (Menteri Kesehatan Republik Indonesia, 2017). The level of reduction in river water turbidity after being given tamarind seed extract and winged bean seeds, on the other hand, met Ministry of Health standards, with the lowest reduction being 293.79 ppm for tamarind seeds and 276.68 for winged bean seeds.

4. Conclusion

The study's findings revealed that varying the doses of tamarind seed extract and winged bean seeds by as much as 3 gr/0.5 L, 5 gr/0.5 L, 7 gr/0.5 L, and 9 gr/0.5 can reduce turbidity and TDS levels in river water. However, adding a coagulant at a concentration of 3 g/0.5 L was the most effective in reducing turbidity and TDS. The turbidity value was reduced by 71.33% (tamarind seeds) and 63.17% (winged seeds) after adding a biocoagulant concentration of 3 g/0.5

L. The TDS reduction value was 15.58% (tamarind seeds) and 9.54%. (winged seeds). According to the Ministry of Health's water quality parameters, the turbidity level of river water after being treated with tamarind seed extract and winged bean seeds did not meet good water clarity standards. However, the TDS level already meets Ministry of Health standards.

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