The waters transparency model of Lake Laut Tawar, Aceh, Indonesia

S Adhar¹, ³*, T A Barus², E S N Nababan², H Wahyuningsih²

¹Doctoral Program, Natural Resource and Environment Management, Universitas Sumatera Utara, Jalan Dr Mansur Medan, Sumatera Utara, 20155, Indonesia

²Universitas Sumatera Utara, Jalan Dr Mansur Medan, Sumatera Utara, 20155, Indonesia

³Department of Aquaculture, Faculty of Agriculture, Universitas Malikussaleh, Jalan Cot Teungku Nie, Kampus Utama Reuleut, Muara Batu, Aceh Utara, 24355, Indonesia

*Corresponding author: saifuladhar@unimal.ac.id

Abstract. Lake Laut Tawar in Aceh Province, Indonesia is an important ecosystem that has several endemic biotas such as Rasbora tawarensis and Poropuntius bargensis. Eutrophication is a potential problem in Lake Laut Tawar. To evaluate the trophic state needed the value of water transparency. This study aims to formulate a model for estimating the transparency of Lake Laut Tawar waters. The dependent variable was water transparency, and the predictors variable was the chlorophyll-a concentration, total suspended solids, and total dissolved solids. Observations and sampling were conduct starting from October 2016 to September 2017. Data analysis was using simple regression, multiple regression, and one-way ANOVA. The result showed a decrease in waters transparency (SD) was caused by increased phytoplankton density (Chl-a), suspended material (TSS), and dissolved material (TDS). But the dissolved matter did not have a partial effect if the values of other variables are constant. The model to estimate the water transparency of Lake Laut Tawar is Log SD = 1.414 – 0.322 Log Chl-a – 0.406 Log TSS.

The average values of water transparency did no differential between the seven observation stations. It is presumably because the waters of Lake Laut Tawar are easily mixed.

1. Introduction

Water clarity or transparency is to what extent the material in water decreases the passage of light through the water column [1]. Changes in water transparency related to eutrophication and phytoplankton biomass [2]. If phytoplankton biomass changes, it will affect the water transparency which also indicates has been a process of eutrophication.

The values of water transparency were represented by Secchi disk depth [2, 3, 4]. The Secchi disk depth has been used to represent water clarity [5], an index of water quality, and eutrophication for many decades globally [6]. The Secchi disk depth is controlled by algal density, suspended solids, colored dissolved organic matter (CDOM) [7, 8], and the dissolved solid correlate to Secchi disk visibility significantly [9]. Algal density or phytoplankton abundance estimated by the values of chlorophyll-a
concentration [10, 11, 7]. It is related to algal blooms in the lake waters directly [12]. The values of chlorophyll-a concentration were related inversely to the Secchi disk depth [13].

Suspended matter provided important information for understanding the variability in the underwater light field in lakes [14]. Suspended materials in the waters with a diameter >1 µm consisting of mud, fine sand, and microorganisms defined as Total Suspended Solid [1, 15]. American Public Health Association (APHA) Standard Methods define suspended solids as the organic and inorganic material in a known volume of a water sample that is retained by a filter with a pore size of 2 µm or less [16]. Suspended solid as particulate matter that increases turbidity interferes with light penetration [1, 15]. Suspended sediment, tiny floating organisms, and colored materials are the factors that determine the water transparency that measures with Secchi disk [1]. The suspended matter along with some dissolved substances impart color to the water, making water less transparent [15].

Dissolved substance are particles so small that they are considered to be in true solution, is determined by passing water through a 2 µm filter, as the portion of organic and inorganic solids, and include living organisms, detritus, and soil particles [16, 15]. Total dissolved solids can include calcium, metals, salts, minerals, and other compounds that can be both organic and inorganic [16]. Regression analysis displayed a significant correlation (R^2 > 0.7) between the total dissolved solid with Secchi disk visibility [9].

This study examines the relationship of water transparency variables with variables that intercept light in lake waters and formulate a model for estimating the transparency of Lake Laut Tawar waters. The values of water transparency that described by the Secchi disk depth (SD) as a dependent variable, and as predictors variable that intercepts the light in the water column are chlorophyll-a concentration (Chl-a), total suspended solids (TSS), and total dissolved solids (TDS). The results of this study were expected to be part of the composing of the system model of Lake Laut Tawar to anticipate and control eutrophication.

Efforts to control the eutrophication of Lake Laut Tawar are important because these lakes have the potential to increase their trophic status. This assumption is based on the population growth and increase human activities in the waters and terrestrial of Lake Laut Tawar. This can reach the level of over-exploitation of land and waters which is a major risk to water resources, [17, 18]. These activities will cause an increase in the transport of nutrients and organic matter from land to the waters which results in eutrophication in the waters [19, 20].

If eutrophication occurs in the waters of Lake Laut Tawar, it will threaten aquatic biota biodiversity [21, 22], several endemic biotas such as depik fish (Rasbora tawarensis) and kawan fish (Poropuntius bargensis) [23] will be threatened with extinction. Because eutrophication is a factor for loss of aquatic biodiversity [24], and to impact on the socio-economic and environmental problem [18]. This impact will occur because the local population who live near Lake Laut Tawar utilize the lake for fishing and aquaculture activities. The lake water is also used domestic water supply for drinking water and water discharge is used for a hydroelectric power generator. Lake Laut Tawar is also a recreation site.

Based on it can be understood the important role of Laut Tawar Lake on ecology, economics, and public health. Therefore, the preservation of Lake Laut Tawar is an important and necessary effort. One of these efforts is to determine the influence model on one of the trophic status parameters, namely water transparency. Furthermore, this model will be used as part of the model for controlling the eutrophication of Lake Laut Tawar.

2. Materials and Methods
The study was conducted in the region of Lake Laut Tawar, Aceh Tengah District, Aceh Province, Indonesia. Lake Laut Tawar is located east of Takengon Town, the capital of Aceh Tengah District. Geographically, the lake is located between 4°38'34"- 4°34'46" N and 96°51'25"- 96°59'48" E. The average depth of Lake Laut Tawar is 25.19 meters [25], the area of the lake is around 58.62 km² with a coastline of about 49.75 km. Observations and sampling were carried out for one year, starting from October 2016 to September 2017.

The observation and sampling points were selected based on land use in the catchment area and activities in the lake waters, whereas obtained 7 stations. Station 1 was a point area closes to the land
use of population settlement, plantations, and rice fields. Station 2 was a point area close to shrubs and forest land use. Station 3 was an area of lake waters close to a catchment area that land-use of shrubs, plantation, and forest. Station 4 was an area close to the paddy fields, shrubs, and plantations. Station 5 was a lake area close to rice fields, shrubs, and forests. Station 6 was lake waters close to rice fields, shrubs, plantations, and forests. Station 7 was lake waters that a floating net cage cultivation area. The map of the study area shown in Figure 1.

![Map of the study area](image)

**Figure 1.** The map of study area.

The frequency of observation and sampling is done once a month at each station. Observations or measurements had made for the parameters of Secchi disc depth and TDS concentration. A sample of water for analysis in the laboratory had carried out for the parameters of chlorophyll-a and TSS concentrations. The amount of data collected for each parameter at each station is 12 data. The total data obtained for each parameter is 84 data.

In-situ data measurements were performed for Secchi disk depth and TDS. The TDS value of Lake Laut Tawar was measured using a TDS meter. The Secchi disk depth measured using a black-and-white disk lowered into the water column until a depth where the Secchi disk was no longer visible, this point was recorded as the first value. Then the second value is done by raising the Secchi disk from an invisible position until the visible point. The average of the two values considered as a Secchi disk depth point. The measurement was carried out several times to get the appropriate average value.

Measurement of chlorophyll-a and TSS concentrations carried out in a laboratory on lake surface water samples. TSS examination in lake water samples was done gravimetrically according to SNI 06-6989.1-2004 (Indonesian National Standard). The water sample was filtered with a filter medium with a pore size of 0.45 µm that has been weighed. Residue and filter media were evaporated in the temperature range of 103 °C to 105 °C. Increased filter media is the amount of TSS in the volume of water samples. Chlorophyll-a concentration was obtained by laboratory testing refer to SNI 06-4157-1996 about testing of the concentration of chlorophyll-a in water with a spectrophotometer.

The relationship of each independent variable with the dependent variable was analyzed by simple linear regression. The strength of the relationship between the independent and dependent variables was analyzed using Pearson correlation. The variables tested for regression consist of variables that are not transformed and transformed into logarithmic form. These variables were tested by regression one by one between the independent variable and the dependent variable to obtain the best equation model. The best equation model was determined based on the highest Adjusted R Square value and the lowest Standard Error of the Estimate value and meets normality and linearity. The simple linear regression
equation is \( Y = a + bx \), where \( Y \) is the dependent variable, \( x \) is the independent variable, \( b \) is the regression coefficient, and \( a \) is a constant.

A multiple linear regression analysis was done to obtain the relationship between the influence of all independent variables (Chl-a, TSS, and TDS) on the dependent variable (SD). The test used the transformed and not transformed variables into logarithmic form, both the dependent and independent variables. After being tested one by one, the best equation model was chosen that met the requirements for normality, linearity, multicollinearity, and heteroscedasticity. The best equation selected base on the highest value of Adjusted R Square and the lowest value of Standard Error of the Estimate. The multiple regression model equation used is \( Y = a + b1x1 + b2x2 + b3x3 \), where \( Y \) is the dependent variable, \( a \) is a constant, \( b \) is a regression coefficient, and \( x \) is the independent variable.

To observe the effect of land use on changes in water transparency of Laut Tawar Lake done a comparative test to determine differences between observation stations. This comparative test was carried out with the One-Way ANOVA Test.

3. The Results and Discussion

Measurement results during the study showed that the transparency of water as SD ranged from 1.40 - 4.40 m with an average of 2.55 ± 0.74 m. The average abundance of algae as indicated by Chl-a is 9.88 ± 4.02 µg L\(^{-1}\), with a range of values ranging from 4.00 - 19.00 µg L\(^{-1}\). TSS concentrations ranged from 25 - 110 mg L\(^{-1}\), with an average of 63.70 ± 27.06 mg L\(^{-1}\). TDS concentrations had an average of 93.86 ± 20.30 mg L\(^{-1}\), where the range of values from 59 - 155 mg L\(^{-1}\). The detailed description of the study results shown in Table 1, and the correlation of independent and dependent variables shown in Table 2.

| Table 1. Descriptive Statistics of study result. |
|-----------------------------------------------|
|                  | N  | Range | Minimum | Maximum | Mean   | Std. Deviation |
| Chl-a (µg L\(^{-1}\)) | 84 |  15   |   4     |   19    |  9.88  |    4.02        |
| TSS (mg L\(^{-1}\))   | 84 |   85  |   25    |  110    |  63.70 |   27.06        |
| TDS (mg L\(^{-1}\))   | 84 |   96  |   59    |  155    |  93.86 |   20.30        |
| SD (m)               | 84 |   3.0 |   1.4   |   4.4   |  2.55  |    0.74        |

| Table 2. Pearson Correlation of variables dependent and independent. |
|---------------------------------------------------------------|
|                  | Chl-a | TSS   | TDS   | Log Chl-a | Log TSS | Log TDS |
| SD Pearson Correlation | -0.784** | -0.905** | -0.724** | -0.808** | -0.898** | -0.745** |
| Sig. (2-tailed)    | 0.000  | 0.000  | 0.000  | 0.000     | 0.000    | 0.000    |
| N                  | 84     | 84     | 84     | 84        | 84       | 84       |
| Log SD Pearson Correlation | -0.818** | -0.924** | -0.740** | -0.827** | -0.902** | -0.754** |
| Sig. (2-tailed)    | 0.000  | 0.000  | 0.000  | 0.000     | 0.000    | 0.000    |
| N                  | 84     | 84     | 84     | 84        | 84       | 84       |

Table 2 showed the correlation coefficient values between the independent and dependent variables in this study, which were transformed to logarithmic values and without transformation. Based on the Pearson Correlation value, it concluded that all independent variables (Chl-a, TSS, TDS) were very strongly and perfectly correlate with the dependent variable (SD) [26]. The variable relationship showed all independent variables (Chl-a, TSS, TDS) have a negative linear relationship to the dependent variable (SD). It indicated that the decrease in transparency in the waters of Lake Laut Tawar caused by an increase in the value of algal density, suspended material, and dissolved material in the waters.

Based on the highest correlation coefficient, the highest Adjusted R Square value, the lowest Standard Error of the Estimate value, normality, and linearity from the Simple Linear Regresion test obtained three the best relationship forms. The relationship of phytoplankton density and water transparency was obtained by the Log Chl - Log SD relationship. Relationship between suspended solid concentration and water transparency with the TSS – Log SD relationship. Correlation between
dissolved material concentration and water transparency with the relationship of TDS - Log SD. The parameter values that form the basis of the decision of the regression test are shown in Table 3.

**Table 3. Resume of regression test**

|                  | Log Chl–Log SD | TSS–Log SD | Log TDS–Log SD | References |
|------------------|----------------|------------|----------------|------------|
| R                | .827<sup>a</sup> | .924<sup>a</sup> | .754<sup>a</sup> | -          |
| R Square         | .684           | .853       | .568           | -          |
| Adjusted R Square| .680           | .852       | .563           | -          |
| Std Error of the Estimate | 0.07233 | 0.04928 | 0.08456 | - |
| F-value          | 177.622        | 477.344    | 107.955        | >3.96      |
| Sig              | .000<sup>b</sup> | .000<sup>b</sup> | .000<sup>b</sup> | <0.05 |
| t-value          | [-13.327]      | [-21.848]  | [-10.390]      | >1.993     |
| t-Sample K-S Test| .052           | .200       | .200           | >0.05      |
| Sig. Dev. from Linearity | .214 | .781 | .970 | >0.05 |

The values shown in Table 3 have concluded that the three forms of equations obtained from linear regression results are very suitable to be used. The relationship of algal abundance and water transparency in this study is shown in Figure 2 below.

**Figure 2. Graphic of Log Chl-a - Log SD relationship.**

The result of regression of the Log SD and Log Chl-a was the determinant coefficient (R²) about 0.684 and the mathematical equation:

\[
\text{Log } SD = 0.973 - 0.608 \text{ Log Chl-a}
\]

Where SD is water transparency (m) and Chl-a is the concentration of chlorophyll-a (μg L⁻¹). The Equations 1 described that the phytoplankton in the waters caused the reduction in water transparency. It is shown in Figure 2 that increasing the Log Chl-a value given a decrease in the Log SD value. The presence of phytoplankton in water inhibits light penetration in the water column [8], which caused a decrease in water transparency. It is shown that the chlorophyll-a concentration has a strong correlation with water transparency [11, 7].

Sunlight entering the waters gradually weakens following the depth of the water column. It was due to rays that penetrate the water column are inhibited by the presence of phytoplankton [8]. Increasing the abundance of phytoplankton in waters results in a decrease in the amount of light that can penetrate the water column so that the transparency of water only reaches a certain depth. It is shown that the
variables are inversely related [13]. Gradualization of attenuation of light penetration by phytoplankton in Lake Laut Tawar waters can be estimated by the Equations 1.

Phytoplankton in the waters of Lake Laut Tawar grows due to nutrients originating from the catchment area and lake bottom sediment resuspension. Run-off from terrestrial areas contains many N and P nutrients, such as from agricultural areas and domestic wastes. In addition to carrying nutrients, run-off also transports most of the suspended material from soil erosion in the catchment area [15]. The suspended material can also come from lake bottom resuspension processes [1] and vegetative debris from watersheds, and microorganisms produced in water bodies [15].

The particles in the water bodies result in a decrease in water transparency, which exhibits an inverse correlation with SD [27]. Water clarity changes were driven by an increase in the concentration of suspended sediments [28]. The relationship between TSS concentration and transparency of Lake Laut Tawar waters obtained by the linear relationship of TSS – Log SD that show in Figure 3.

![Figure 3. Graphic of TSS - Log SD Relationship](image)

Determinant coefficient (R²) of linear regression TSS - Log SD obtained by 0.853, It explains that 85.30% of the data used shows the effect on changes in water transparency. This value described the perfect relationship between TSS concentration and Secchi disk depth in Lake Laut Tawar waters. The effect of suspended material concentration on the reduction in transparency of Lake Laut Tawar waters can be estimated by the equation obtained, as:

\[
\text{Log SD} = 0.667 - 0.004 \text{TSS}^2
\]

Where SD is the transparency value of water (m) and TSS is the concentration of suspended material (mg L\(^{-1}\)). Figure 3 has shown a decrease in water transparency following an increase in suspended solids concentration. The existence of TSS in the waters of Lake Laut Tawar had cause inhibition of sunlight penetration into the waters. TSS spreads and absorbs the received light, so it was unable to penetrate a certain depth. Light entering the water was scattered by suspended sediments [29], making it difficult for light to penetrate through the waters [27]. Absorbed light in waters caused by particulate matter imparts color in the waters [29, 15, 27].

TSS concentrations in the waters of Lake Laut Tawar were assumed to be suspended values of sediment and particulate matter, which causes the spread and absorption of sunlight in the waters. The average TSS concentration in the waters of Lake Laut Tawar is 63.70 mg L\(^{-1}\), where the average ability of light to penetrate the waters is 2.55 m as the value of water transparency. The transparency value was not only influenced by TSS but also due to the density of phytoplankton and dissolved material.

The value of dissolved material in this study is assumed as TDS. TDS contains minerals and organic molecules, which are measured as inorganic salts, organic matter, and other dissolved materials in water.
The presence of dissolved material in the waters causes watercolor [15]. The color of the waters that occur is related to water transparency, where the color of the water can inhibit the penetration of light into the water column [10].

The correlation between dissolved material and the transparency of Lake Laut Tawar showed by Log SD - Log TDS relationship. The value showed the inverse relationship between dissolved material and water transparency. The higher dissolved substances will cause lower the transparency of water. The regression relationship is presented graphically in Figure 4.

![Graphic of Log TDS - Log SD Relationship](image)

**Figure 4.** Graphic of Log TDS - Log SD Relationship

Estimation of the transparency of Lake Laut Tawar waters based on the concentration of dissolved substances can be done by the equation:

$$\text{Log SD} = 2.463 - 1.057 \text{Log TDS}$$

Where SD is the Secchi disk depth is assumed to be the transparency value of water (m). TDS is the concentration of dissolved substances (mg L$^{-1}$). The coefficient of determination obtained was 0.568, which shows that from the amount of data collected, only 56.80% affected changes in transparency in Lake Tawar waters.

The determinant coefficient value of this study was smaller than the resulting research in Mosul Dam Lake, Northern Iraq that finding a correlation between the TDS with SD ($R^2 > 0.7$) [9]. This difference is caused by different research locations, this causes differences in concentration and composition of TDS. It is in natural waters determined by the geology of the drainage, atmospheric precipitation, and the water balance [15]. The sources for TDS in the lake waters are including agricultural and residential run-off, and clay-rich mountain water [30].

| Variable Dependent | Variable Independent | Adjusted R square | Std Error of the Estimate |
|--------------------|----------------------|-------------------|--------------------------|
| SD                 | Chl-a, TSS, TDS      | 0.866             | 0.2693                   |
| Log SD             | Chl-a, TSS, TDS      | 0.915             | 0.0372                   |
| SD                 | Log Chl-a, Log TSS, Log TDS | 0.910 | 0.2218 |
| Log SD             | Log Chl-a, Log TSS, Log TDS | 0.933 | 0.0336 |

Based on the description above, it is known that the density of phytoplankton (Chl-a), suspended material (TSS), and dissolved material (TDS) contributes to changes in the transparency of Lake Laut Tawar waters. To determine the effect caused simultaneously by Chl-a, TSS, and TDS on the
transparency of the Lake Laut Tawar waters conducted multiple regression analysis. Multiple linear regression analysis for each variable value transformed to logarithmic value and without transformation obtained adjusted R square value as shown in Table 4.

Table 4 showed the multiple linear regression analysis having adjusted R square values of 0.866, 0.915, 0.910, and 0.933, and the values of Standard Error of the Estimate are 0.2693, 0.0372, 0.2218, and 0.0336. Based on the values, it is known that the biggest contribution of influence occurs when all variables are transformed to logarithmic values. Therefore, the variable value that has been transformed to the logarithmic value is used for the Analysis of Variance. The F values and significance obtained in the Analysis of Variance are shown in Table 5.

| Model       | Sum of Squares | df | Mean Square | F       | Sig. |
|-------------|----------------|----|-------------|---------|------|
| Regression  | 1.270          | 3  | .423        | 385.453 | .000b|
| Residual    | .088           | 80 | .001        |         |      |
| Total       | 1.358          | 83 |             |         |      |

a. Dependent Variable: Log_SD
b. Predictors: (Constant), Log_TDS, Log_Chl, Log_TSS

Table 5 showed the significance value smaller than 0.05 and the F-value of 385,453, which is greater than the F-table value of 2.719. It is shown that the independent variables Chl-a, TSS, and TDS simultaneously affected the Secchi disk depth. These results indicate that the transparency of Lake Laut Tawar waters is closely related to the abundance of phytoplankton, the concentration of suspended and dissolved substances. The effect of each independent variable on the dependent variable was seen in the regression coefficients shown in Table 6.

| Model       | Unstandardized Coefficients | Standardized Coefficients | t      | Sig. | Collinearity Statistics |
|-------------|------------------------------|---------------------------|--------|------|-------------------------|
|             | B               | Std. Error | Beta    |       | Tolerance | VIF  |
| (Constant)  | 1.475           | .091       |         | 16.166| .000     |      |
| Log Chl-a   | -.320           | .029       | -.433   | -11.191| .000     | .541 | 1.849 |
| Log TSS     | -.392           | .028       | -.611   | -14.104| .000     | .431 | 2.318 |
| Log TDS     | -.046           | .062       | -.033   | -.738 | .463     | .412 | 2.425 |

Based on the regression coefficients in Table 6 the mathematical relationship model of water transparency with Chl-a, TSS, and TDS of Lake Laut Tawar waters obtained is:

$$\text{Log SD} = 1.475 - 0.320 \text{Log Chl-a} - 0.392 \text{Log TSS} - 0.046 \text{Log TDS}$$

The regression coefficients of Log Chl-a, Log TSS, and Log TDS variables valued negatively in the mathematical equation model showed an inverse relationship between the independent variable and the dependent variable. It is shown that increased concentrations of Chl-a, TSS, and TDS resulted in a decrease in values of Secchi disk depth (SD) in Lake Laut Tawar waters.

Significance and t-value indicated that not all independent variables have a partial effect on changes in water transparency. The negative values of the t-value shown that the variables are inversely related. The significance value of the TDS variable had a greater value than 0.05 and the t-value is smaller than the t-table (|t|-0.738 < 1.993). It showed that the dissolved matter concentration (TDS) did not have a partial effect on the transparency of Lake Laut Tawar waters. Changes in TDS concentrations only affect changes in water transparency when followed by changes in Chl-a and TSS concentrations. Although TDS did not affect SD partially, the two variables were related. TDS variables have very little or no impact on the visibility of Secchi disk [3].

[3]...
Dissolved material in the waters of Lake Laut Tawar affects water transparency because the dissolved material caused watercolor (true color) [15]. The watercolor caused the weakening of sunlight in the water column so that not all sunlight can reach a certain depth. But in this case, the color of Lake Laut Tawar waters which inhibits light penetration was not only influenced (partially) by true color caused by TDS. Weakening of sunlight in the waters of Lake Laut Tawar has been affected by apparent color caused by TSS and true color [15], and humic substances which are colored dissolved organic matter (CDOM) [7] simultaneously.

The CDOM value was not measured in this study, so the color of the waters caused by the CDOM can be assumed to be represented by the value of Chl-a because phytoplankton acts both as pigment and as particulate material [31]. The color of the waters caused by particulate organic matter in this study was assumed to be represented by TSS values, where measured TSS values include organic particulates [15]. CDOM is composed mostly of humic substances [7], where are mostly measured as suspended and dissolved substances, both of which cause water to be colored or not. Suspended substances more dominantly affect water transparency than dissolved substances [32, 33]. This caused the TDS concentration to have no partial effect on the transparency of Lake Laut Tawar waters. Two other variables, namely the Chl-a and TSS variables partially and significantly influence the Secchi Disk depth.

Because TDS did not show a significant partial effect on the multiple regression test, thus the multiple regression test was done again by including only Chl-a and TSS as independent variables. The test produces a new equation as follows:

$$\log SD = 1.414 - 0.322 \log \text{Chl-a} - 0.406 \log \text{TSS}$$

The equation has an Adjusted R square value of 0.932 and a Standard Error of the Estimate of 0.0335, which means that the Equation 5 will provide a relatively accurate estimating of the water transparent of Lake Laut Tawar.

Based on the Equation 5, the decrease in the transparency of the waters of Lake Laut Tawar was affected by the increase in the concentration of chlorophyll-a and suspended solids. Chlorophyll-a is as the abundance of phytoplankton increased due to the availability of nitrogen and phosphorus nutrients. Most of these nutrients come from catchment areas. Likewise, suspended material loaded from the catchment area brought by surface runoff into the lake. The condition of the purposively selected observation station was assumed to be influenced by the conditions of land use in the catchment area.

Water transparency observation data have shown that the data obtained as many as 12 data at each observation station were normally distributed and homogeneous. So that the One Way Anova test can be carried out to be given whether or not a difference in water transparency between observation stations. The test results show a significance value of 0.825 and an F-value of 0.475. It means that there is no significant difference between the observation stations. However, this result cannot be concluded because there is no influence of land use on the water clarity of Lake Laut Tawar. There are no differences between observation stations were caused by the Lake Laut Tawar waters that mix easily. The mixing results in a relatively homogeneous water state over the entire surface of the lake. However, to prove this assumption, further in-depth research is needed on the effect of land use on the waters of Lake Laut Tawar.

4. Conclusions

The transparency of Lake Laut Tawar waters is affected by the abundance of phytoplankton, suspended material, and dissolved material. The relationship has shown that increased abundance of phytoplankton, TSS, and TDS resulted in a decrease in the transparency of waters. Data analysis showed that the dissolved matter did not have a partial effect on the water transparency. It means changes in concentration of dissolved matter will not affect transparency values if the phytoplankton abundance and TSS concentrations values are constant. To estimate the water transparency of Lake Laut Tawar can use the equation $\log SD = 1.414 - 0.322 \log \text{Chl-a} - 0.406 \log \text{TSS}$. The average values of water
transparency did not show any difference between the seven observation stations in Laut Tawar Lake. It is presumably because the waters of Lake Laut Tawar are easily mixed.

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