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STUDIES ON TURBIDITY IN RELATION TO SUSPENDED SOLID, VELOCITY, TEMPERATURE, PH, CONDUCTIVITY, COLOUR AND TIME

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ABSTRACT

Measuring the presence of impurities in water column through gravimetric method such as total suspended solid (TSS) is rather a time consuming and labour intensive method. Surrogating TSS with turbidity (NTU) is a possible solution to this problem. Some researchers have indicated the usefulness of turbidity measurement in indicating fish larvae growth rate, gastrointestinal illness risk of human being, etc. Previous works have been carried out to model this relationship but rather limited to a single relation between turbidity and TSS, and yet, ignoring other factors such as time, temperature, etc that have influences on turbidity. The current work was carried out to better understand some underlying relations of turbidity with temperature, time, suspended solids concentration, pH, colour and velocity. In phase 1, synthetic water was used to study the relation of turbidity with suspended solid, velocity, temperature and time. Results indicated that turbidity increases with increasing temperature, suspended solids concentration, and velocity, but reduces with time. In phase 2, there were four set of parameter-modified and four set of respective control water samples. Parameter-modified water samples were subjected changes of temperature (25-70 ^{o}C), pH (5-10), color (red, yellow, blue, orange, green, brown, and black at 500 mg/L), and conductivity (100-1000 µS/cm). Results showed the relation of these parameters fell between most likely positive and negative. In addition, the current proposed model gives a high R-squared (> 0.969), low mean square error, and has a p value lesser than 0.05.

Keywords: conductivity, color, nephelometric turbidity unit, pH, total suspended solid, temperature.

1. INTRODUCTION

River is normally classified based on the Interim National Water Quality Standards (INWQS) as provided by the Department of Environment (DOE). The INWQS consists of physical, biological, and chemical parameters in which each parameter act as an immediate surrogate to the water condition that perceived as important by our scientific community. These parameters are interrelated. For instance, changing a physical property of water, e.g. temperature, will alter chemical property, e.g. rate of reaction, and eventually it alters biological process.

In the perspective of physical parameters, there are temperature, colour, taste and odour, floating debris, and turbidity [1]. Turbidity is an optical property that commonly reported in Nephelometric Turbidity Unit (NTU) and it is a measure of the amount of light scattered or absorbed by organic and inorganic matter particles suspended in the water column.

The TSS is referring to the dry mass of solids captured on top of a filter paper after filtering a measurable volume of water through a filter paper which is having a pore size of 0.45 µm [2]. TSS comprises of both organic and inorganic materials. Organic materials may include algae, zooplankton, and detritus, and for inorganic materials, there may be clay, silt, and sand [3].

Turbidity has an indirect relation with total suspended solids (TSS). Although turbidity may be influenced by other factors, the effects of TSS will be captured in the turbidity measure [4]. The factors that are not captured by TSS include particle size, particle shape, particle composition, refractive index, and particle colours [5]. Moreover, Oliver *et al.* [6] found that conductivity has negative relation with turbidity.

In addition to this, other external factors resulting from the environment have been reported to affect turbidity. For instance, Gasim *et al.* [7] found a reverse relation between stream flow and turbidity. Kenway and Hall [8] found that wind direction has effect on aquatic turbidity, and the work by Law and Jong [9] found that turbidity is high during high tide.

Apart from all these multiple variables that responsible for turbidity variation, some works have been carried out by researchers to establish the single relation between turbidity and TSS by ignoring other contributing factors, as mentioned. Their results indicated that its relation is limited to site specific. This include the work of Suk *et al.* [10] that attempts to utilize turbidimeter in estimating total suspended solids (TSS) concentration in various types of natural water bodies. Gippel [11] used turbidimeter to quantify suspended solids concentrations in forested streams. Lewis [12] used turbidimeter to estimate suspended sediment concentration in a small mountainous watershed during six storm events. Packman *et al.* [13] also made a similar attempt on streams. Their site specific results could be due to some other parameters that have not been considered in the relationship, such as temperature, etc [14].

The models that have been proposed by Randerson *et al.* [15], Holliday *et al.* [16] and Ginting and Mamo [17] on a single relation between turbidity and TSS are listed as followings, respectively:

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$$TSS = mNTU \quad (1)$$

$$NTU = aTSS^{b} \quad (2)$$

$$TSS = aNTU^{b} \quad (3)$$

where: m , a , and b are equation constants.

Many have found the direct use value of turbidity to human population sustainability and therefore, any effort towards a better understanding of turbidity in relation to other variables is worth a study. Davis [18] indicates that the growth rate of fish larvae is related to turbidity. Allen *et al.* [19] has stated that high turbidity level will lead to high risk of gastrointestinal illness. U.S. Environmental Protection Agency [20] stated that turbidity gives shelter to pathogen from disinfection. Lechevallier *et al.* [21] found that the relationship between turbidity and chlorine demand is positively related. Moreover, high turbidity will cause color, taste, and odor problems.

From the multiple relation of turbidity with other variables, this study is limited to in-situ parameters and those included in the INWQS. The objectives of this study are:

- To identify the underlying relation of turbidity, pH, conductivity, temperature, color, and TSS, broadly into positive or negative relations; and
- To construct preliminary single relation equation to relate between parameters.

2. MATERIALS AND METHODS

Phase 1: Tracer studies

In this experiment, kaolin clay was used to create suspension solids in demineralized water. The synthetic water turbidity was measured at different manipulated variables that include suspended solids concentration, temperature, and water velocity. Turbidity was measured in triplicates.

Turbidity measurements at different suspended solids concentrations

Suspended solid concentrations were prepared at 5, 50, 250, 500, and 1000 mg/L with kaolin clay into with demineralized water. The volumetric flasks were inverted several times to homogenize the suspended solids before they were subjected to turbidity measurements. This whole process was carried out at 29 °C and 0 m/s.

Turbidity measurements at different pretreated water velocities

Velocity was applied on the water filled with kaolin clay at 50 mg/L and 29 °C. The water samples were pretreated with few discrete velocities at 80, 100, 200, 500, and 1000 rpms for five minutes with the help of Teflon magnetic stir bar. During the turbidity measurement over time, the velocity of water was in stagnant condition.

Turbidity measurements at different pretreated temperatures

Different discrete temperatures were applied on the water samples that were ranged from 24 to 36 °C with an interval of 2 °C. Beakers with 50 mg/L of water sample were placed on top of few stirring hot plates where discrete temperatures were applied. The whole experiment was carried out at 0 m/s and 50 mg/L.

Phase 2: Studies sampled river water

This study involved six parameters that were pH, temperature, conductivity, turbidity, color, and total suspended solids. Water samples were taken from Terengganu River (5°18'03.02"N, 103°05'02.58"E) as shown in Figure-1. According to DOE [23], Terengganu River was under Class II based on INWQS. The selection of river was to avoid taking water samples from the cleanest river (Class I) where water parameters are too sensitive to contamination, and also to avoid water samples from the dirtiest river (Class V) where contamination would not cause any significant changes to the water parameters.

Figure-1. Sampling location at Terengganu River. Note: "." indicates the sampling location [22].

The sampled waters were later subjected to modification in pH, temperature, conductivity, and different colors. These were carried out with respective acid/base, freezer/stirring hot plates, natural salt, and different dyes.

Different colors on water sample

Seven colors (red, yellow, blue, orange, green, brown, and black) were prepared at a concentration of 500 mg/L. They were stirred with magnetic stirrer to achieve homogeneity before subjected to the measurements of pH, temperature, turbidity, conductivity, and TSS. At the same time, seven control water samples in different beakers were kept and they were also subjected to the measurements of all those parameters.

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Water sample at different pHs

Six beakers of water sample were separately added with acid or base, respectively by acid hydrochloride (HCl) or sodium hydroxide (NaOH), in order to achieve six different pHs from 5 to 10. These water samples were subjected to the measurements of color, temperature, turbidity, conductivity, and TSS. Control water samples were later subjected to all those measurement of parameters.

Water sample at different temperatures

Thirteen beakers of water sample were prepared at different temperatures from 25 to 70 ºC ± 1 ºC. This was carried out with the use of few stirring hot plates or freezer. After achieving the preset temperatures, the water samples were subjected to the measurements of color, turbidity, conductivity, pH, and TSS, within three minutes. Control water samples were later subjected to all those measurement of parameters.

Water sample at different conductivities

Six beakers of water sample were prepared at different conductivities from 100 to 1000 µS/cm. The level of conductivity was achieved with the use of sodium chloride (NaCl). After achieving the respective conductivity levels, the water samples were measured for color, pH, temperature, turbidity, and TSS. Control water samples were later subjected to all those measurement of parameters.

Correlation coefficient (r) from the relations of turbidity, pH, Temperature, Color, Conductivity, and TSS

The water samples were broadly divided into those kept as control samples and those discretely altered either pH, temperature, color, or conductivity. Correlation coefficient (r) was used to classify data into either positive or negative relation. This correlation coefficient calculation was based on linear relation as shown below:

$$y = mx + c \qquad (4)$$

where: x and y were respectively independent and dependent variables; m as the slope of the Equation 4, which indicates the sensitivity of y to the changes of x; and c as the intercept on y-axes.

Percentage of Positive Relation (PPr)

All the positive and negative relations identified from water samples after the modification of pH, temperature, color, or conductivity, are shown in Table-1. For all those positive and negative relations from control water samples without any modification of parameters are shown in Table-2.

Table-1. Positive and negative relations resulted from the modification of pH, temperature, color, or conductivity.

Relation	Col	Cond	pH	T
Tu-TSS	-	NA	+	+
Tu-T	+	+	+	+
Tu-Cond	+	+	+	+
Tu-pH	+	+	+	-
Tu-Col	NA	-	+	+
TSS-T	-	NA	-	+
TSS-Cond	-	NA	+	+
TSS-pH	+	NA	+	+
TSS-Col	NA	NA	+	+
T-Cond	+	+	-	+
T-pH	+	+	-	-
T-Col	NA	-	+	+
Cond-pH	+	+	+	-
Cond-Col	NA	-	-	+
pH-Col	NA	+	-	-

Note: "+" indicates positive relation; "-" indicates negative relation; "NA" indicates not available; "Cond" is conductivity; "Col" is color; "Tu" is turbidity; and "T" is temperature.

Percentage of positive relation (PPr) was calculated from the number of time a relation was indicated as positive relation over the total number of positive and negative relation for a particular relation multiply by 100. E.g., Tu-TSS relation, the PPr is given by 4/6*100 = 67 %.

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Table-2. Positive and negative relations from control water samples.

Relation	Col	Cond	pH	T
Tu-TSS	+	NA	+	-
Tu-T	+	-	+	NA
Tu-Cond	+	-	+	-
Tu-pH	+	-	-	-
Tu-Col	NA	-	+	+
TSS-T	+	NA	-	NA
TSS-Cond	+	NA	+	+
TSS-pH	+	NA	-	+
TSS-Col	NA	NA	-	-
T-Cond	+	+	+	NA
T-pH	+	+	-	NA
T-Col	NA	+	+	NA
Cond-pH	+	-	+	+
Cond-Col	NA	+	+	-
pH-Col	NA	-	-	-

Note: "+" indicates positive relation; "-" indicates negative relation; "NA" indicates not available; "Cond" is conductivity; "Col" is color; "Tu" is turbidity; and "T" is temperature.

Turbidity as a function of temperature, pH, conductivity, conductivity, color, and total suspended solids

From Equation 4, turbidity (Tu) can be a function of either temperature (T), pH, conductivity ($Cond$), color (Col), or total suspended solids (TSS), respectively as followings:

$$Tu_T = m_T T + c_T \quad (5)$$

$$Tu_{pH} = m_{pH} pH + c_{pH} \quad (6)$$

$$Tu_{Cond} = m_{Cond} Cond + c_{Cond} \quad (7)$$

$$Tu_{Col} = m_{Col} Col + c_{Col} \quad (8)$$

$$Tu_{TSS} = m_{TSS} TSS + c_{TSS} \quad (9)$$

where: m_T, m_{pH}, m_{Cond}, m_{Col}, m_{TSS}, c_T, c_{pH}, c_{Cond}, c_{Col}, and c_{TSS} are equation constants.

Turbidity can also be a function of combine effect from temperature, pH, conductivity, color, and total suspended solids, which can be represented by the following relation:

$$Tu_{Total} = Tu_T + Tu_{pH} + Tu_{Cond} + Tu_{Col} + Tu_{TSS} \quad (10)$$

Equations (5) to (9)df were placed into Equation 10 as following:

$$Tu_{Total} = \left(m_T T + c_T\right) + \left(m_{pH} pH + c_{pH}\right) + \left(m_{Cond} Cond + c_{Cond}\right) + \left(m_{Col} Col + c_{Col}\right) + \left(m_{TSS} TSS + c_{TSS}\right) \quad (11)$$

Since c_T, c_{pH}, c_{Cond}, c_{Col}, and c_{TSS} are equation constants, and they can be represented by a constant C_{Total} as shown below:

$$C_{Total} = c_T + c_{pH} + c_{Cond} + c_{Col} + c_{TSS} \quad (12)$$

Hence, Equation (11) can be reduced into the following:

$$Tu_{Total} = m_T T + m_{pH} pH + m_{Cond} Cond + m_{Col} Col + m_{TSS} TSS + C_{Total} \quad (13)$$

Equation 13 was curve-fitted to experimental data from temperature-, pH-, conductivity-, and color-modified water samples. This equation was also curve-fitted to experimental data of four control water samples that were

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prepared parallel to the respective parameter-modified water samples. Estimation of equation constants for control and pH-modified water samples were without C_{Total} constant due to insufficient data. This is because six equation constants from Equation 10 require at least seven experimental data for which the current availability of data was only six. Control water samples in temperature study were modeled without temperature parameter ($m_T T$). Control and conductivity-modified water samples were modeled without TSS parameter ($m_{TSS} TSS$) because of the corrosiveness of sodium chloride on filter paper that slowly dissolving its mass which was indicated on the filter mass reduction after filtering the conductivity-modified water samples with filter paper. The mass reduction observed on the used filter paper on control water samples could be due to the carry over of the corrosive effect from the used filter paper on conductivity-modified water samples as a result of vaporization during simultaneous drying in similar oven. Control and color-modified were without color parameter ($m_{Col} Col$), since the colors were only prepared in a single concentration of 500 mg/L.

3. RESULTS AND DISCUSSIONS

Phase 1: The changes of turbidity with suspended solids, velocity and temperature

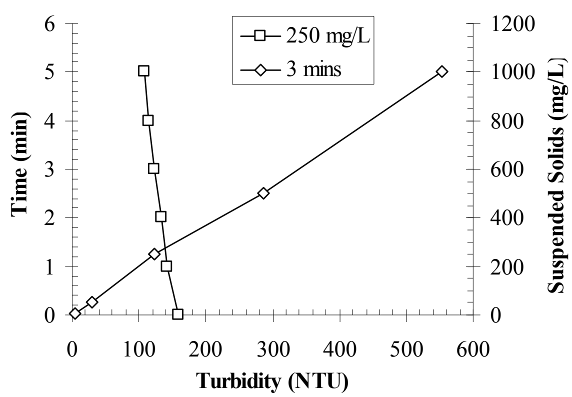

Figure-2. Turbidity changes with time and suspended solids. Default at 29 °C of pretreated temperature and 0 m/s of pretreated velocity.

Turbidity was found to change with suspended solids and time (Figure-2). Suspended solids were found to influence the rate of turbidity reduction with time. At higher suspended solids concentration, e.g. 1,000 mg/L, the rate of decreasing turbidity with time was greater than the rate at lower suspended solids concentration, e.g. 5 mg/L. The higher rate could be due to a greater amount of settleable suspended solids at higher concentration and hence, it increases the sedimentation rate of suspended solids. The lower rate at low concentration indicates that less changes of turbidity with time that was mainly due to lesser availability of settleable solids.

From other perspective, time was found to influence the rate of increasing turbidity with increasing suspended solids concentration. At shorter time, e.g. 1 minute, the rate of increasing turbidity with increasing suspended solids concentration was greater than that of at longer time period, e.g. 5 minutes. Theoretically, this is suggesting a possibility that by leaving a contaminated (suspended solids) liquid system sufficiently long enough, its natural cleansing phenomenon or better known as sedimentation will helps to reduce the turbidity of even highly turbid water to an equilibrium value that is irrespective of its initial turbidity.

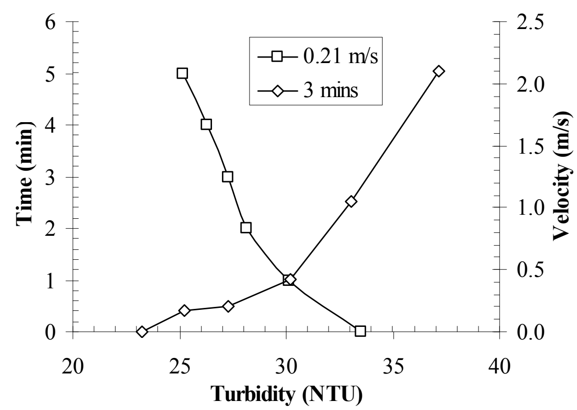

Figure-3. Turbidity changes with time and velocity. Default at 29 °C of pretreated temperature and 50 mg/L of suspended solids concentration.

Pretreated velocity on water has an effect on water turbidity. An amount of kaolin solids stirred at different speeds has resulted in different suspension levels of solids on the water body and hence, turbidity increases with increasing velocity of water [24]. Similar to the relation of turbidity-suspended solids, the water turbidity after treated by specific velocity it was also subjected to the time factor (Figure-3).

Velocity has an apparent influence on the rate of turbidity reduction with time. A higher rate of turbidity reduction with time was found at higher velocity, e.g. 2.1 m/s, compared to lower rate, e.g. 0.17 m/s. The higher rate of turbidity reduction with time could be due to a greater amount of settleable solids that was kept suspended by high velocity. An instant removal of water velocity followed by turbidity measurement at different times in turbidimeter would observed a higher rate of turbidity reduction with time for water that was pretreated at higher velocity.

In addition, time was found to have an influence on the rate of turbidity changes with changing water velocity. Similar to that of turbidity-suspended solids relation, a lower rate of increasing turbidity with increasing velocity was found at longer time period and vice versa. Hence, leaving the liquid system sufficiently

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long enough, the difference in turbidities resulted by different water velocities will gradually even out to a lower and specific turbidity value.

Both temperature and time were found to influence the turbidity of water (Figure-4). Rate of turbidity reduction with time was affected by temperature. The influence of temperature on the rate was rather inconsistently with rising and falling of rate was observed throughout the temperature from 24 to 34 ^{o}C. However, averagely the rate was found to increase at increasing temperature. This behaviour was identical to the effect of suspended solid concentration and water velocity on the variation of turbidity.

Time has an effect on the rate of increasing turbidity with increasing temperature. At longer time, e.g. 5 minutes, the rate of turbidity reduction was lesser than that of at shorter time, e.g. 1 minute. Therefore, gradually turbidity will even out to a specific value which was identically observed for the time effect on water pretreated with velocity and suspended solids concentration.

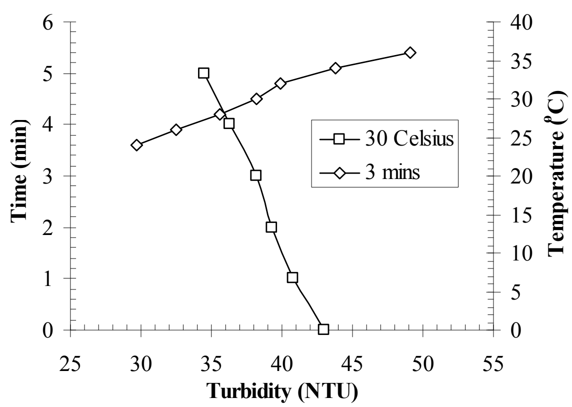

Figure-4. Turbidity changes with time and temperature. Default at 0 m/s pretreated velocity and 50 mg/L of suspended solids concentration.

Phase 2: The relations of turbidity, pH, Temperature, Total Suspended Solids (TSS), conductivity and color

The Tu-TSS relation was observed as a positive relation that its increasing TSS was accompanied by increasing turbidity. Numerous researchers have found similar observation [1]-[5]. This relation has a percentage of positive relation (PPr) of 67 % (PPr> 50 %).

Turbidity and temperature relation (Tu-T) was found as positive relation with a PPr of 86 %. This is reasonable given that increasing water temperature would increase demineralized water turbidity as reported by Amirthlingam [14]. Besides, increasing temperature would increase water kinetic thus accelerating suspension of particles.

Tu-Cond relation has a PPr of 75 % which was contradicting from the observation of Oliver [6] who stated that turbidity of water from the lake studied has negative relation with conductivity. However, in this study, conductivity has a positive relation with temperature that consists of 86 % of PPr. Since increasing temperature leads to greater turbidity, increasing conductivity would increase turbidity. Hauser [25] found a positive relation between temperature and conductivity. Increase temperature would increase the kinetic movement of ion thus increasing conductivity. Moreover, during the experiment, the increasing conductivity by sodium chloride into demineralized water was found to increase the temperature of water, which could be an indication of exothermic effect.

It was found that black and blue suppressed the turbidity unit of water. However, in the current study excluding color modification in terms of concentration, we found that natural color of water has a positive relation with turbidity with a PPr of 67 %. This could be due to the presence of humic substances which are potential to cause brown or yellow colors [26]. Besides, based on the current experiments, brown and yellow dyes increase the turbidity of water samples.

This study found that TSS-T was a negative relation and it has a PPr of 40 %. The only possible explanation for this observation could be that small increment of temperature caused by color, i.e. 28.2-28.8 ^{o}C, and pH, i.e. 28.3-29.1 ^{o}C, were only sufficient to cause dissolution of suspended particles rather than causing a greater suspension of particles.

Since T-Cond has a positive relation, and then the positive relation of Tu-T and Tu-TSS, therefore it was reasonable to observe a positive relation for TSS-Cond that has a PPr of 83 %. Besides, increasing conductivity could cause crystallization of sodium chloride that eventually could increases TSS.

The TSS-pH relation with a PPr of 83 % thus it showed a strong positive relation. This could only be explained by the effect of temperature, i.e. at increasing temperature the particles of humic substances could dissolve in water to reduce pH due to fulvic acid. This claimed is reasonable since, the PPr of T-pH was only 57 %, and also, T-pH relation was negative at the individual effect of increasing temperature on temperature-modified water samples.

T-Col was found as positive relation with a PPr of 80 %. This could be due to the increasing temperature causes dissolution of color particles in water, and also, at increasing temperature the presence of suspended particles with increasing kinetic energy that gives greater suspension ability to particles could also generate greater color in mg/L unit of Pt Co.

A positive relation of Cond-pH was found with a PPr of 75 %. This could be explained from the perspective of equilibrium state of sodium chloride in relation to pH. From this study, it can be concluded that solubility of sodium chloride increases with increasing pH.

Turbidity as a Function of Combined Effect of pH, Temperature, Color, Conductivity, and Total Suspended Solids

Individual estimation by Equation 13 on all the four parameter-modified water samples is stated below:

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- Temperature-modified water samples with an R-squared of 0.949, a mean square error (MSE) of 0.25, and a p value of 1.69 x 10^{-8} ($p < 0.05$), (Figure-5);
- Conductivity-modified water samples with an R-squared of 0.988, a MSE of 0.0012, and a p value of 5.06 x 10^{-5} ($p < 0.05$), (Figure-6);
- pH-modified water samples with an R-squared of 0.999, a MSE of 0.0004, and a p value of 6.43 x 10^{-4} ($p < 0.05$), (Figure-7); and
- Color-modified water samples with an R-squared of 0.932, a MSE of 177.7, and a p value of 4.16 x 10^{-4} ($p<0.05$), (Figure-8).

Individual estimation by Equation 13 on the four parameter-control water samples is follows:

- Control water samples in temperature study with an R-squared of 0.883, a MSE of 0.19, and a p value of 1.86 x 10^{-6} ($p < 0.05$), (Figure-9);
- Control water samples in conductivity study with an R-squared of 0.973, a MSE of 9.94 x 10^{-5}, and a p value of 2.76 x 10^{-4} ($p < 0.05$), (Figure-10);
- Control water samples in pH study with an R-squared of 0.990, a MSE of 4.04 x 10^{-4}, and a p value of 3.64 x 10^{-5} ($p < 0.05$), (Figure 11); and
- Control water samples in color study with an R-squared of 0.917, a MSE of 0.35, and a p value of 6.93 x 10^{-4} ($p < 0.05$), (Figure-12).

Overall, Equation 13 has shown good curve-fittings with all the R-squared values were calculated greater than 0.88. The estimation from the equation was closely approximated to experimental data and it has an overall calculated R-squared of 0.969 and mean square error (MSE) of 19.6. With all the p values of four parameter-modified and four control water samples were lesser than 0.05, it can be concluded that estimated turbidity value has a significant linear relationship with experimental data that was not by chance or coincident. The reliability of Equation 13 can be further validated by extending to a wider range of pH, different color concentrations, etc., and perhaps to explore any possible synergistic or antagonistic effects by changing two parameters or more at a time.

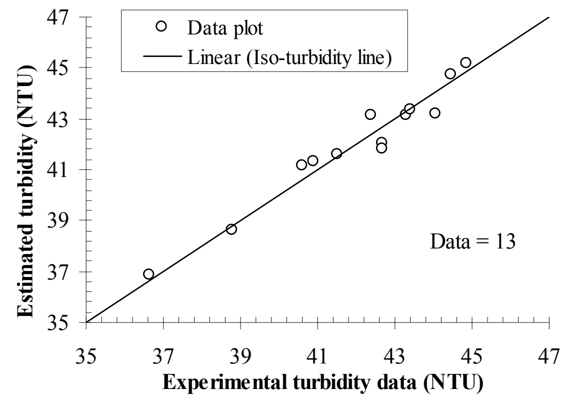

Figure-5. Comparison between experimental turbidity data and estimated values from the temperature-modified water samples.

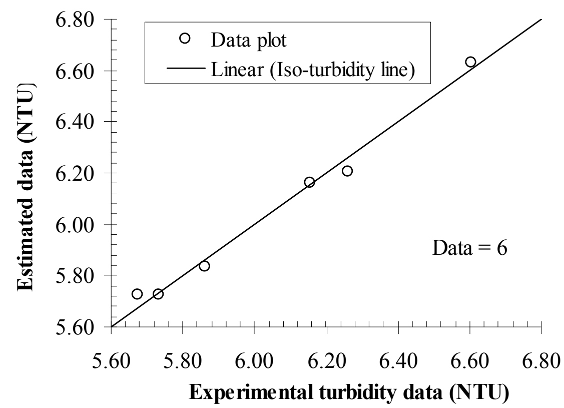

Figure-6. Comparison between experimental turbidity data and estimated values from the conductivity-modified water samples.

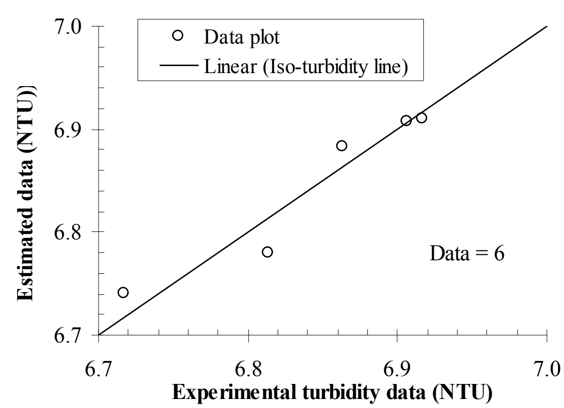

Figure-7. Comparison between experimental turbidity data and estimated values from the pH-modified water samples.

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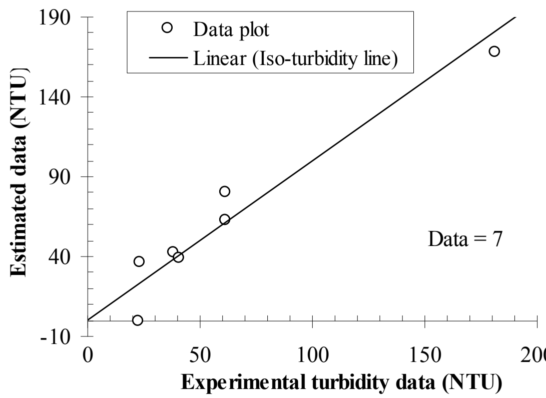

Figure-8. Comparison between experimental turbidity data and estimated values from the color-modified water samples.

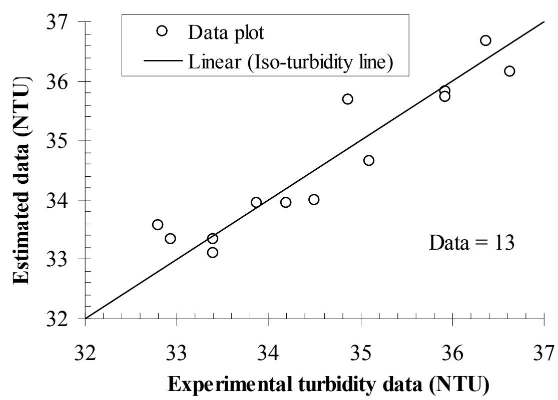

Figure-9. Comparison between experimental turbidity data and estimated values from the control water samples in the temperature study.

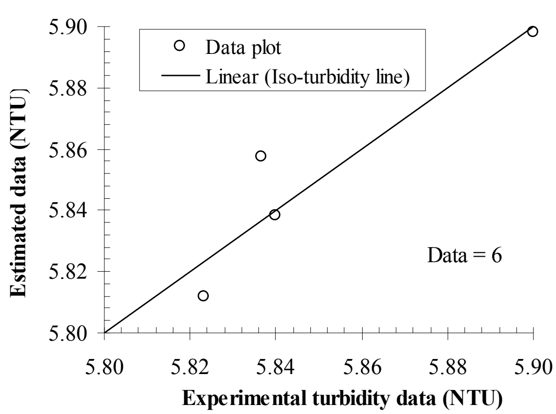

Figure-10. Comparison between experimental turbidity data and estimated values from the control water samples in the conductivity study.

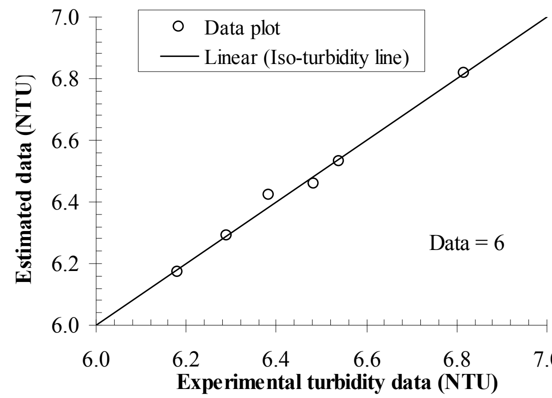

Figure-11. Comparison between experimental turbidity data and estimated values from the control water samples in the pH study.

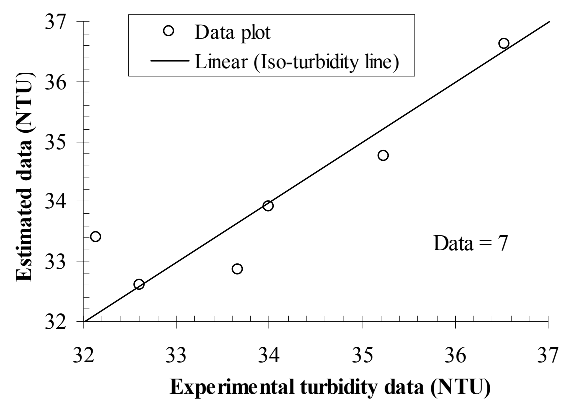

Figure-12. Comparison between experimental turbidity data and estimated values from the control water samples in the color study.

4. CONCLUSIONS

This study has shown that apart from suspended solids concentration, an additional three factors contributing to the changes of turbidity were time, temperature of water, and velocity of water. Study indicated turbidity increases with increasing water temperature and velocity of water. Time was the only factor that decreases turbidity gradually that would eventually even out turbidity value. This time factor is intimately related to flow velocity. Water in motion would keep solids suspended. The deceleration of flow reflects the shortening of settling time hence greater decrease of turbidity. Increase in temperature would further lengthen the settling time of suspended solids as result of increase in kinetic energy of particles and random motion of water molecules.

Other than generally accepted findings of a strong relationship between total suspended solids and turbidity measurement, the current studies found that the parameter of turbidity, total suspended solids, color, pH, conductivity, and temperature were either positively or

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negatively correlated to each other. Moreover, the difference in percentage on the fifteen relations as shown in Tables 1 and 2 were only indicates the likeliness of achieving positive and negative relations based on both parameter-modified and control water samples. This indicates that the consistency of having a rigid relation i.e. 100 percent on any pair of parameters either in positive or negative relation should be subjected to precaution.

From all those relations, Tu-T, TSS-Cond, TSS-pH, T-Cond, and T-Color were found as among the strongest positive relations with PPr greater than 80 %. Conversely, a PPr of 17 % was found on the relation of pH-Col.

The current proposed model has shown a good estimation on experimental data with high R-squared (> 0.969), low mean square error, and has a p value lesser than 0.05.

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