Effect of UVC Based Photocatalyst on the Degradation of Humic Acid with Variations of pH and Variations of Concentration

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Abstract. Humic acid is an organic compound that has changeable properties and is globally yellow and black in color. Humic substances act as substrates for the needs of the development of microorganisms and will give out unwanted yellow or brown colors (Adnan et al., 2022). Simply put, photocatalyst is a combination reaction between photochemistry and also a catalyst whose process with the help of a light or photo is used to speed up a chemical reaction (Chandra, 2012). The type of photocatalyst used is TiO_2 (Titanium Dioxide) which is varied with Fe_3O_4 to determine the pH of the humic acid solution. TiO_2 (Titanium Dioxide) is one type of inorganic oxide. Semiconductor materials such as TiO2 are widely used as photocatalysts of organic substances with the help of UV light. Based on research conducted by Pradipta et al. (2021), TiO_2 catalyst can be combined with Fe_3O_4, as evidenced by the high degradation by Fe_3O_4/TiO_2 nanocomposites. In the catalyst activity test using 3 variations of pH, namely 3, 7 and 10 with a concentration of 15 ppm, there are differences in each solution. Experiments were carried out at the same time but at different pH. The photocatalyst activity test was continued with variations in concentration using pH 3 (acidic), research on variations in concentrations of 15 ppm, 20 ppm and 25 ppm. The three solutions were tested using UVC light with 1 g of TiO_2 added as a catalyst so that organic compounds could be degraded. The research used, the optimum result is pH 3 (acidic) the reason is because the percentage decrease from pH 3 and other pH is different. The optimum concentration result was 15 ppm with a pH of 3 (acidic). The lower the concentration in the solution, the pollutants contained in the solution are easier to degrade. A low solution concentration of ions at an acidic pH will increase the activity of the catalyst. The percentage of degradation from pH 3 (acid) concentration of 15 ppm is 92.7954%, which means it is bigger than other pH variations.

Keywords: Photocatalyst · TiO_2/Fe_3O_4 · UVC · Humic Acid

1 Introduction

Humic acid is an organic compound that acts as a substrate for the development needs of microorganisms and will give off unwanted yellow or brown colors [1]. Humic acid itself needs to be processed especially with a photocatalyst because according to Adnan et al.

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(2022) [1], humic acid is an organic compound that can be decomposed, considering that humic acid itself can cause environmental or health problems, it needs to be processed using a photocatalyst method with UVC light so that humic acid can degraded. Water is needed by humans in everyday life, whether it is for washing or consumption. Water in nature contains a lot of humic acid which includes complex compounds, namely a mixture of macromolecular organic components that can form naturally [2].

Photocatalyst is a photochemical reaction using a catalyst with the help of a light or photo which is useful for accelerating a chemical reaction [3]. Photocatalyst comes from two words namely photo and catalyst. Photo which means light is used to activate a catalyst that will produce hydroxyl radicals and oxidize organic matter to H_2O and CO_2. A catalyst is a material used to speed up a chemical reaction. One type of light that can be used is UVC light, which can be used to increase a reaction rate. The lowest wave possessed by UVC rays is 200–280 nm, the shorter the wavelength, the greater the energy of the photon emitted [4]. The type of photocatalyst used is TiO_2 (Titanium Dioxide) which is varied with Fe_3O_4 to determine the pH of the humic acid solution. Photocatalysis technology is a combination of photochemical processes and integrated catalysts to enable chemical transformation reactions to occur. This easy and reversible water loss is the exposed structure of the sponge. This structure explains the function of the zeolite as an ion exchanger, adsorbent and catalyst [3].

Therefore, this study was conducted to determine the effect of UVC light in degrading humic acid concentration on pH, the effect of humic acid solution pH on photocatalyst, and the results of TiO_2/Fe_3O_4 concentration in degrading humic acid solution. The pH variation of humic acid was carried out so that it could be used as a comparison between different pHs and obtained the best pH results from the research conducted. Concentration variations were carried out to obtain optimum results in degrading humic acid.

2 Methods

The research was conducted using photocatalytic method, using synthetic TiO_2/Fe_3O_4 to assist the degradation process of humic acid compounds. This research uses UVC light in the process of degrading humic acid. After that, testing for variations in pH 3, 7 and 10 was carried out as well as testing for variations in the concentration of the standard solution of humic acid, namely 15 ppm, 20 ppm and 25 ppm. After testing of variations in pH and concentration variations, the best results obtained from these comparisons. The absorbance value was tested using a UV-Vis spectrophotometer with a wavelength of 254 nm.

The preparation stage carried out in this study, the initial step was the preparation of tools and materials. The number of reactors used were 4 reactors, each containing 2 UVC lamps with 8 watts of power in each reactor and a magnetic stirrer. The reactor has a length of 40 cm, a height of 45 cm, the distance from the lamp uke solution is 8 cm.

For the preparation of the humic acid mother liquor, 0.5 g of humic acid and 100 mL of distilled water were added to a 100 mL volumetric flask, after which it was homogenized. Making a standard solution of humic acid using 15 mL of humic acid mother liquor into 500 mL of chemistry with distilled water. After that, a standard solution of humic acid

was made with variations in pH 3, 7, 10 and concentrations of 15 ppm, 20 ppm and 25 ppm into a beaker.

The calibration curve was made using a standard humic acid solution with various concentrations of 10, 13, 15, 17, 20, 23, and 25. Each concentration was measured 3 times using a UV-Vis spectrophotometer with a wavelength of 254 nm. After that, the results of the absorbance measurement were obtained.

$$\%\text{Degradation} = \frac{\text{Co}-\text{Ct}}{\text{Co}} \times 100\% \quad (1)$$

The test was carried out using a UV-Vis spectrophotometer. The data obtained is then processed using the sample absorbance value equation, Co which means the initial concentration value, Ct is the concentration of organic compounds and t is time.

3 Results and Discussion

3.1 Determination of the Value of the Calibration Curve

The calibration curve was made using a standard humic acid solution with a certain concentration variation. After that it was made with 3 variations of the concentration of the standard humic acid solution, namely 15 ppm, 20 ppm and 25 ppm. Each standard concentration of humic acid solution was measured 3 times repetition using a UV-VIS¬ spectrophotometer with a maximum wavelength of 254 mm and then the value would be obtained and a calibration curve was made. The results of the analysis based on the calibration curve in Fig. 1 of humic acid standards with concentrations of 15 ppm, 20 ppm and 25 ppm are directly proportional to the linear line which means that the greater the humic acid concentration, the greater the absorbance of the humic acid [5]. The measurements made obtained the equation of the line from the calibration curve, namely y = 0.00117x - 0.0035 with a correlation coefficient value (R2) of 0.9955, the correlation coefficient value has met the requirements of r < 0.9955 [5]. The results obtained indicate that the method used has produced a good linearity, so that the results obtained can be used as a.

3.2 Determination of Type of Ray

The study was conducted using UVC light, observed for 5 h with sampling every 30 min (0, 30, 60, 90, 120, 150, 180, 210, 240, 270, and 300). Observations were made 3 times and then the absorbance value was measured using a UV-VIS spectrophotometer after which the results obtained would be averaged. The reactor design used for research is made of plywood with black walls which serve as a reflector so that light can bounce towards the solution by being given a distance from the lamp to the beaker of approximately 10 cm. TiO2 catalyst works in the photocatalyst process with the help of UVC light. UVC light is used in order to increase the rate of reduction and oxidation reactions because the degradation process of a material requires photon energy from ultraviolet light.

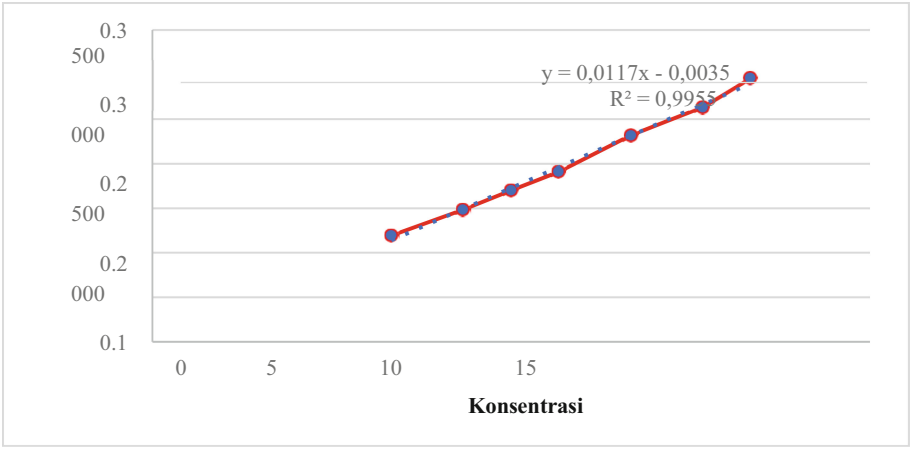

Fig. 1. Humic Acid Standard Solution Calibration Curve

3.3 pH Variation

The results obtained from variations of pH 3, 7 and 10, the best value is the variation of pH 3, so it is used for the next variation of concentration in the study, namely pH 3, which is varied with concentrations of 20 ppm and 25 ppm, after which it is compared and seen which value is the best or the most degraded humic acid. The percentage of degradation from the results of research that has been carried out can be seen in Fig. 2:

The percentage of degradation is very much needed in this study because with this percentage it can be seen that the best results from the pH variation study, if the percentage is greater then the degradation is declared good and appropriate. In Fig. 2, the increase in the percentage of humic acid degradation from variations in pH 3, 7 and 10 can be said to be unstable because at pH 7 the percentage of humic acid degradation only decreased

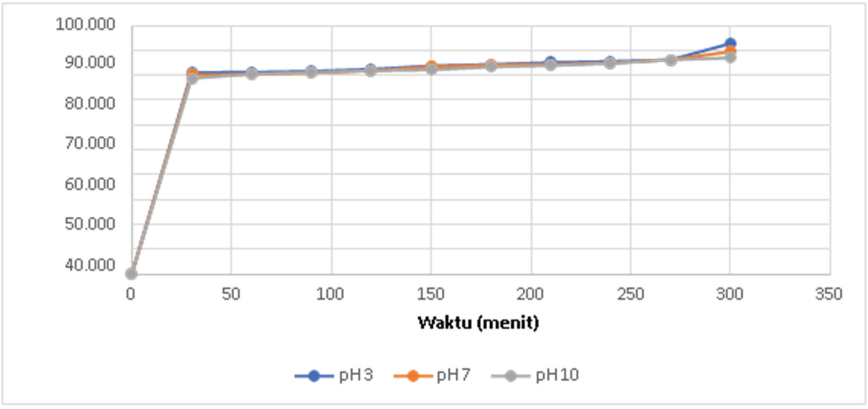

Fig. 2. Graph of Photocatalyst Degradation Percentage of Humic Acid pH Variations with Concentration of 15 ppm

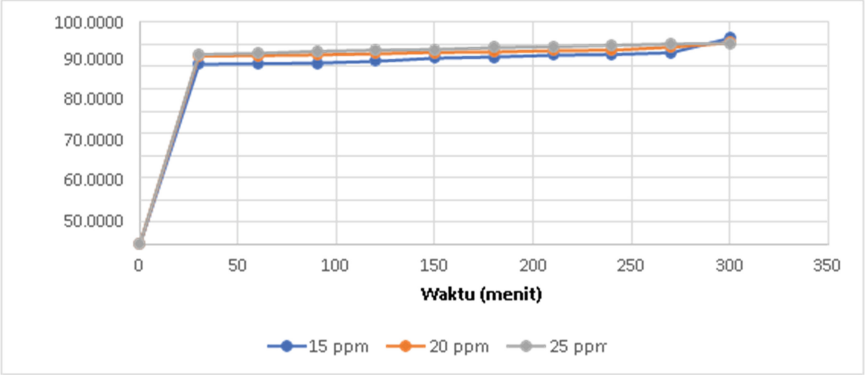

Fig. 3. Graph of Photocatalyst Degradation Percentage of Humic Acid Concentration Variations Using

slightly. Seen from Fig. 2, the best result is at pH 3 with a concentration of 15 ppm, the percentage of degradation is 92.7954%, which means it is greater than other pH variations.

3.4 Concentration Variatiom

In Fig. 3, it can be seen that the graph decreases downward according to the high concentration carried out in the experiment. The results obtained are not much different from each concentration variation, but from the results of research conducted with variations in concentrations of 15 ppm, 20 ppm and 25 ppm using pH 3, the optimum result obtained is a concentration of 15 ppm with pH 3 because the percentage of degradation is higher than the concentration 20 ppm and 25 ppm. The percentage of degradation from the results of research that has been carried out can be seen in Fig. 3.

3.5 Effect of Time on Photocatalyst Process

In the research process, time is needed, especially in the photocatalyst process, the use of the effect of irradiation time is to determine the level of effectiveness of the photocatalyst process with a TiO2 catalyst to degrade organic substances in samples of humic acid standard solutions. There are optimum irradiation times, namely 0, 30, 60, 90, 120, 150, 180, 210, 240, 270 and 300 min, every 30 min a sample is taken to measure the decrease in absorbance, and the number of samples taken is 11 samples. Each was repeated 3 times and then the average was calculated for each sample. This method is carried out for each variation of pH and also variations in concentration. After that, the percentage of degradation was calculated and taken at the optimum time of 300 min.

The percentage of degradation (%) can be increased by increasing the irradiation time which is useful for continuous adsorption and deadsorption processes. The longer the irradiation time, the higher the percentage of degradation. So the effect of time on the photocatalyst process is very useful to get optimal results [6]. This is because the irradiation time is the length of the interaction between the TiO2 photocatalyst and UV

light to produce OH radicals, besides that the longer the irradiation time, the more photon energy that can be generated [7].

3.6 Catalyst Activity Test

TiO2 photocatalyst activity can be influenced by several factors, and the most important is the crystal form. TiO2 has 3 types of crystals, namely rutile, anastase and brukit, but only 2 have catalytic activity, namely anatase and rutile [8]. Humic acid is the main ingredient to be degraded using a catalyst activity test, the degradation process uses light which is used to speed up a reaction commonly called photodegradation.

Photodegradation in general is a process to break down a compound, especially an organic compound with the help of light.

In the test of catalyst activity using 3 variations of pH, namely 3, 7 and 10 with a concentration of 15 ppm, there are differences in each solution. Experiments were carried out at the same time but at different pH. The research used, the optimum result is pH 3 (acidic) because the percentage decrease from pH 3 and other pH is different. pH greatly affects the degradation of organic compounds contained in standard solutions containing organic substances, if the pH is more acidic then humic acid degradation can run optimally, but if the pH is more alkaline then organic compounds are not degraded.

The photocatalyst activity test was continued with variations in concentration using pH 3 (acidic), research on variations in concentrations of 15 ppm, 20 ppm and 25 ppm. The three solutions were tested using UVC light with 1 g of TiO2 added as a catalyst so that organic compounds could be degraded. The optimum result is 15 ppm with a pH of 3 (acidic). The lower the concentration in the solution, the pollutants contained in the solution are easier to degrade. Humic acid organic compounds at lower solution concentrations are able to degrade organic matter contained in the solution. A low solution concentration of ions at an acidic pH will increase the activity of the catalyst.

3.7 Reaction Rate of Variations in pH

In the photocatalyst process carried out with the help of UVC light, pH variations were carried out using a concentration of 15 ppm, the pH variations used were 3, 7 and 10. To increase the rate of reaction in the photocatalyst process for each pH variation, the Langmuir-Hinselwood equation was used. The reaction rate can be seen in Fig. 4:

Seen from Fig. 4, the graph of the highest increase in the reaction rate is pH 3 (acidic), the lower or the more acidic the pH, the higher the reaction rate. It can be proven by research, pH 3 (acid) can increase the reaction rate, because the degradation of organic matter can be influenced by a speed of formation of hydroxyl radicals. pH 7 (neutral) and 10 (alkaline) the reaction rate is lower than pH 3 (acidic).

3.8 Reaction Rate Variations Concentration

At the reaction rate of 15 ppm the constant value obtained is 0.0095. At the reaction rate of 20 ppm the constant value obtained is 0.0100. At the reaction rate of 25 ppm the constant value obtained is 0.0104. From these data, the best value is from a concentration

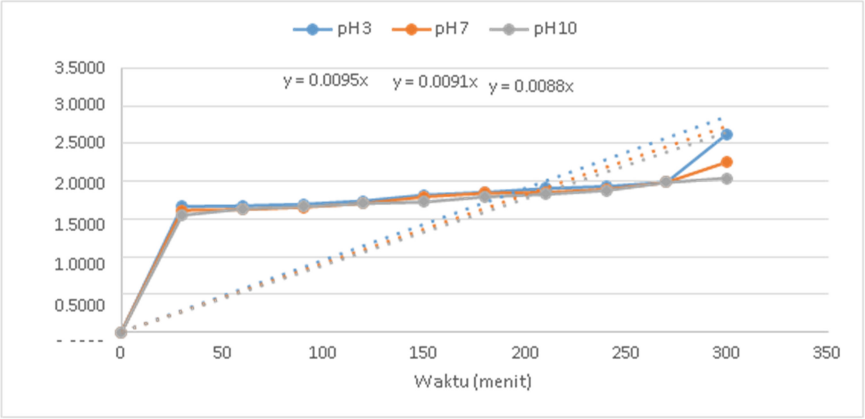

Fig. 4. Graph of Reaction Rate of pH Variations using a Concentration of 15 ppm

of 15 ppm compared to a concentration of 20 ppm and a concentration of 25 ppm. After that, the results obtained are compared with the percentage of humic acid degradation and the reaction rate of humic acid, it is known that the highest percentage of degradation is a concentration of 15 ppm, which is 92.7954% with a reaction rate constant of 0.0095/minute. The graph of the reaction rate for variations in concentration with pH 3 can be seen in Fig. 5.

Seen from Fig. 5, the graph of the highest increase in reaction rate is a concentration of 15 ppm, the lower the concentration, the higher the reaction rate. It can be proven by research, a concentration of 15 ppm can increase the rate of reaction, because the degradation of organic matter can be influenced by a speed of formation of hydroxyl radicals. Concentration of 20 ppm and concentration of 25 ppm the reaction rate is lower than the concentration of 15 ppm.

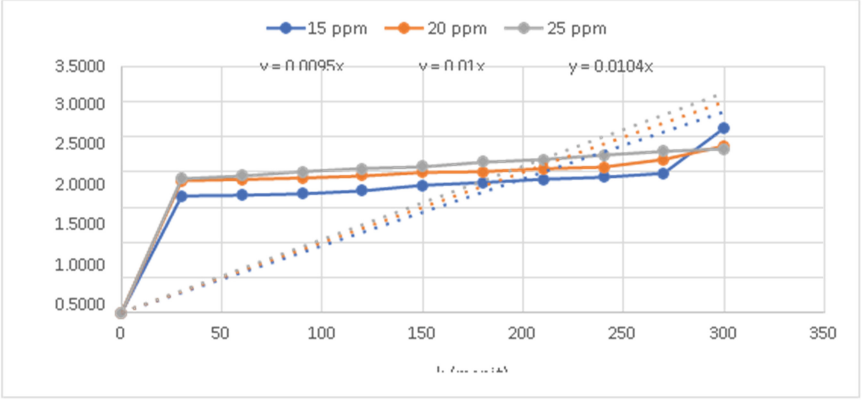

Fig. 5. Reaction Rate Graph of Concentration Variations with pH 3

4 Conclusion

In the research that has been done, the best result is pH 3. Molecules in acid can be easily degraded by hydroxyl radicals, the percentage of humic acid efficiency can also increase at acidic pH conditions. This causes the lower the pH, the more optimum it is to be able to degrade organic compounds. After obtaining the pH variation, then proceed with testing the concentration variation, from the tests carried out the concentration obtained was 15 ppm. The reason for obtaining a concentration of 15 ppm is because if the concentration in the humic acid solution is lower, the better the resulting degradation results.

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