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Research article

Electrochemical Peroxidation Method for Reduction of Chemical Oxygen Demand (COD) Carbofuran in Furadan 3GR Pesticides

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Abstract

Carbofuran is a pollutant compound derived from the pesticide Furadan 3GR which is widely used in agriculture. Various methods of carbofuran degradation have been carried out, one of which is the conventional electrochemical method. This study used an electrochemical peroxidation process to degrade Carbofuran in the pesticide Furadan 3GR. This study aims to determine the optimum conditions (time, Na_2SO_4 concentration, and volume addition of H_2O_2) for electrochemical peroxidation and to compare the effectiveness of electrochemical and electrochemical peroxidation methods by measuring the parameter of carbofuran COD reduction. The significance of the electrochemical peroxidation method and the conventional electrochemical method was compared as a preliminary test. The COD reduction of Carbofuran using traditional electrochemical methods and electrochemical peroxidation was 45.76% and 88.70%, respectively. Batch carbofuran electrochemical peroxidation process was accomplished to ascertain the optimum conditions under various operation times, the concentration of Na_2SO_4, and the additional volume of H_2O_2. The largest COD reduction of 93.78% was obtained at 10 minutes, 75 mM Na_2SO_4, and 2 mL H_2O_2. The UV-Vis spectrophotometric absorption of Carbofuran at a wavelength of 274 nm was significantly reduced from 1.377 to 0.131 at optimum conditions. The IR spectrum measurement results indicate a reduction in absorbance for the N-H group (3383 cm-1) and the C=O group (1643 cm-1) at optimum conditions. Overall, the electrochemical peroxidation process proved to be an appropriate technique for COD reduction of Carbofuran in Furadan 3GR pesticides.

Keywords: Carbofuran, COD, electrochemical peroxidation, Furadan 3GR

1. Introduction

Carbofuran with the trademark Furadan is a pesticide widely used to control weeds, insects, and plant diseases to increase agricultural productivity. The use of Carbofuran is worrying not only because of its massive use but also because of its high oral toxicity and persistence in the environment (Grawe et al., 2015). Carbofuran has been detected in soil and wastewater, and natural water due to their high solubility and mobility, with a half-life of 30-117 days (Liu et al., 2012). Several studies in Indonesia reported that carbofuran residues were found in agricultural products, rice fields, rice fields, water (Veteriner. 2008), and seawater (Prasetyo et al., 2015). Water contaminated with Carbofuran has a high Chemical Oxygen Demand (COD), so dissolved oxygen levels in the water are low. Peroxidation can be used to degrade Carbofuran in water

Electrochemical peroxidation is an electrochemical method based on the partial destruction or destruction of organic pollutants using Fenton's reagent produced from reactions at the electrodes (Brillas et al., 2009). Electrochemical peroxidation uses a single cell consisting of an inert cathode and an iron or stainless steel anode. Electrochemical treatment of organic pollutants has the advantage of being cheap and efficient; the exhaust gas does not contain toxic and hazardous materials (Matheswaran et al., 2007). However, conventional electrochemical technologies such as electrocoagulation are only able to reduce organic pollutants partially. Ilhan, 2008 reported that the COD of leachate was only reduced by 35% using the electrocoagulation method. While the development of conventional electrochemical methods, one of which is electrochemical peroxidation, can significantly reduce bisphenol-A (BPA) levels in groundwater (Ahmadzadeh and Dolatabadi. 2018), coke wastewater COD levels with a COD reduction of 65 – 92% (Liu et al., 2012., Ozyonar and Karagozoglu. 2015), COD content of paper mill effluent with a decrease in COD of 95.7% (Moussavi and Aghanejad. 2014), arsenic content in water (Arienzo et al., 2002), and kills Coliform bacteria in sludge (Olvera-Vargas et al., 2019). Interestingly, the electrochemical peroxidation method is highly recommended for the degradation of persistent organic pollutants in general, including pesticides (Brillas et al., 2009., Sirés et al., 2014), but has never been explored to degrade Carbofuran in the Furadan 3GR pesticide directly. In previous studies, it was known that the performance of the electrochemical peroxidation method in reducing COD levels of organic pollutants was influenced by time parameters, supporting electrolytes, and hydrogen peroxide. (Sirés et al., 2014., Moussavi and Aghanejad. 2014. Ibrahim and Şolpan. 2019). Therefore, in this study, a time variation test, Na2SO4 concentration, volume of addition of H2O2 in electrochemical peroxidation was carried out to obtain the best conditions for electrochemical peroxidation in reducing the COD levels of carbofuran contained in the pesticide Furadan 3GR. Furadan Solution 3GR from the electrochemical peroxidation process was also characterized to determine the presence of carbofuran in solution.

2. Materials and Methods

2.1 Materials and Tools

The tools used: a set of research glassware (Pyrex Iwaki), graphite electrodes (9 × 3.6 × 0.7 cm), iron electrodes (9 × 3.3 × 0.1 cm), DC power supply (CAL 60 IPA STD), COD reactor, analytical balance (Ohaus), hotplate (Faithful SH-2), magnetic bar, multimeter (DT-830B), UV-Vis spectrophotometer instrument (Shimadzu) and FTIR Instrument (Spectrum 100 Perkin Elmer). Ingredients used include Furadan 3GR, 30% hydrogen peroxide (Merck), sodium sulfate (Merck), 98% sulfuric acid (Merck), distilled water. Ingredients used include Furadan 3GR, 30% hydrogen peroxide (Merck), sodium sulfate (Merck), 98% sulfuric acid (Merck), distilled water.

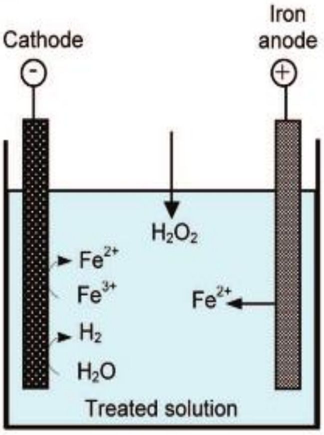

Figure 1. Electrochemical peroxidation cell

2.2 Research Procedure

This research begins with the preparation of a 300 mg/L carbofuran solution from Furadan 3GR. The prepared solution was characterized initially, including COD analysis, UV-Vis analysis, and FTIR analysis. Determination of application potential using graphite and iron electrodes was followed by a preliminary test. Preliminary tests were conducted to compare the effectiveness of the results between the electrochemical method and electrochemical peroxidation in reducing the COD levels of Carbofuran. Carbofuran electrochemical peroxidation was carried out at various times, sodium sulfate concentration, and volume of hydrogen peroxide to obtain optimum conditions. Samples resulting from electrochemical peroxidation at optimum conditions were characterized using a UV-Vis spectrophotometer (Shimadzu) at a wavelength of 200 - 700 nm to determine Carbofuran's presence and an FTIR instrument to assess the presence of functional groups in the sample.

2.2.1 Initial Preparation and Characteristics of Carbofuran

The preparation of the carbofuran solution was carried out by weighing 10 grams of the Furadan 3GR pesticide (3% carbofuran content) and then adding 1000 mL of distilled water. The mixture was then stirred for 30 minutes at 400 rpm to dissolve the Carbofuran contained in Furadan 3GR. The mixture was then filtered, and the filtrate was obtained, which was 300 mg/L carbofuran.

2.2.2 Determination of Potential

Carbofuran solution 300 mg/L volume 1000 mL added $Na2SO4$ 7.10 grams electrolyzed with a potential of 0 to 12 volts, increased by 0.50 volts every 2 minutes. Electrolysis was carried out with Fe/graphite electrodes with an electrode distance of 3 cm. The current flowing is recorded and interpreted on the E vs. I . curve.

2.2.3 Electrochemical Peroxidation

Beaker glass A 1000 ml was used as an electrochemical cell. The iron electrode was used as the anode with dimensions of 9 × 3.3 × 0.1 cm and parallel to the graphite electrode as cathode with dimensions of 9 × 3.6 × 0.7 cm. The two electrodes are fixed at a fixed distance of 3 cm. The initial pH of the sample was adjusted to pH 3 with the addition of $H2SO4$. The solution was stirred at 350 rpm during the electrochemical peroxidation process, with the potential being kept at 3 volts using a DC power supply.

2.2.3.1 Time Contact

A solution of 300 mg/L carbofuran from Furadan 3GR with a volume of 1000 mL was added with $H2SO4$ to pH 3, and then 7.1 grams of Na_2SO_4 was added. The electrochemical peroxidation process was carried out by adding 2 ml of H_2O_2 with time variations of 10 minutes, 20 minutes, 30 minutes, 40 minutes, 50 minutes, and 60 minutes.

2.2.3.2 Variation of N_2SO_4

Carbofuran solution of 300 mg/L volume of 1000 mL was added with H_2SO_4 to pH three, then Na_2SO_4 was added with various concentrations of 25 mM, 50 mM, 75 mM, 100 M, 125 mm, and 150 mM. The electrochemical peroxidation process was carried out by adding 2 ml of $H2O2$ with the optimum time.

2.2.3.3 Variation of H_2O_2

A solution of 300 mg/L carbofuran with a volume of 1000 mL was added with H_2SO_4 to pH 3, and then Na_2SO_4 was added with variations in optimum concentration. The electrochemical peroxidation process was carried out with variations in the addition of 0 mL, 1 mL, 2 mL, 3 mL, 4 mL, 5 mL, and 6 mL of H_2O_2 with optimum time.

2.2.4 Analysis of COD

Determination of the initial COD value of carbofuran samples before the electrochemical peroxidation process and after the treatment was carried out by closed reflux method spectrophotometrically according to SNI 06-6989.2-2004. The percentage decrease in the COD value of Carbofuran after the electrochemical peroxidation process was calculated using the following formula:

$$\% \text{ COD Reduction} = \frac{Initial\ Concentration - Final\ Concentration}{Initial\ Concentration} \times 100\% \quad (1)$$

2.2.5 Characterization of Electrochemical Peroxidation Result Solution

Carbofuran has been characterizing with UV-Vis and FTIR for before and after electrochemical peroxidation processes. UV-Vis spectrometry analysis was performed to obtain the maximum wavelength of the sample. Determination of the maximum wavelength of the selection was carried out by scanning a 300 mg/L carbofuran solution from Furadan 3GR using a UV-Vis spectrophotometer at a wavelength of 200 nm to 700 nm. The maximum wavelength of Carbofuran is 274 nm.

3. Result and Discussion

3.1 Determination of Potential Applications

Data were obtained from the electrolysis of 1000 mL carbofuran 300 mg/L with the addition of 7.10 grams of Na2SO4 at various potential variations, namely in the range 0 - 12 V. The inflection point of the sample electrolysis curve is the point when the redox process begins (Bachtiar and Widodo. 2015). Determination of application potential aims to obtain the potential operating range of Fe/graphite electrodes in carbofuran solution.

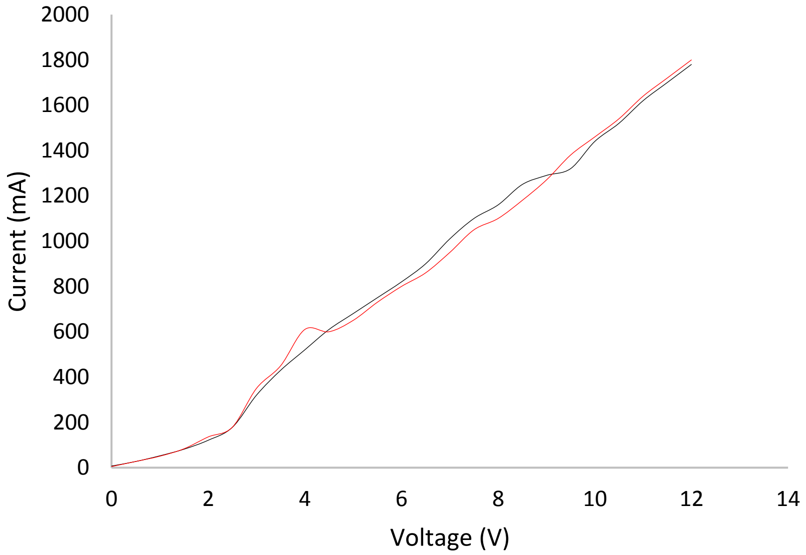

Figure 2. The curve of the relationship between potential and electrolytic current with potential

Based on Figure 2 above, information on the potential range is obtained, describing the energy level equivalent to the energy required for the electron transfer (redox) process. The magnitude and width of the possible field are specific for each solution and depend on the composition of the supporting electrolyte system and the electrodes used; in this study, the electrodes used were Fe/graphite. According to the curve, it is known that the inflection points of the solvent and Carbofuran are close to each other. The inflection point of the solvent is at 2.35 V and Carbofuran at 2.03 V. This indicates that the application potential is at a possibility greater than 2.03 V. So that the electrochemical peroxidation process in this study used a potential greater than 2, 03 V is a potential of 3 V which is kept constant.

3.2 Initial Characteristic of Carbofuran

Scanning the maximum wavelength of the Furadan 3GR solution sample using a UV-Vis spectrophotometer at a wavelength of 200 - 700 nm shows that the active ingredient Furadan 3GR (Carbofuran) has a maximum absorption at a wavelength of 274 nm. Based on research (Vimal et al., 2019), the maximum wavelength of Carbofuran is 275 nm. The difference in wavelength of 1 nm is still within the permissible tolerance limit, which is approximately 3 nm (Depkes. 2009). The absorption band in the wavelength range of 200-230 nm absorbs the inert composition of Furadan 3GR, including polyacrylic acid at 230 nm (Seeyangnok et al., 2016); *xanthan gum*; propylene glycol (Tomašević et al., 2017). The results of scanning the Furadan 3GR solution with a UV-Vis spectrophotometer are shown in Figure 3.

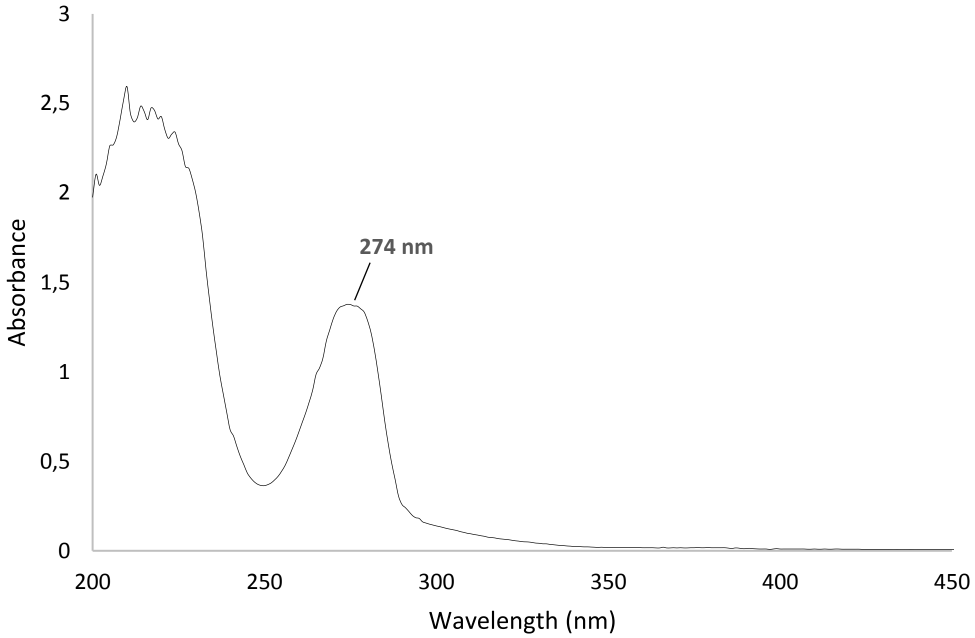

Figure 3. UV-Vis spectrum of Furadan solution 3GR

Determination of the initial COD value of Carbofuran was carried out by closed reflux spectrophotometrically according to SNI 06-6989.2-2004. COD is an important water quality parameter because COD provides an index to assess the effect of liquid waste disposal on the receiving environment. The absorbance readings on the standard calibration curve of potassium hydrogen phthalate obtained the initial COD value of Carbofuran of 590 mg/L.

3.3 Initial Test

Preliminary tests were conducted to compare the effectiveness of the results between the electrochemical method and the electrochemical peroxidation method in reducing carbofuran COD levels. Initial electrochemical and electrochemical peroxidation tests were carried out in the same cell conditions, namely using an iron electrode as an anode, a graphite electrode as a cathode, a distance between electrodes of 3 cm, a sample volume of 1000 mL, a constant potential of 3 V, an electrolyte supporting Na_2SO_4 50 mM, and operating time 10 minutes. However, in the electrochemical peroxidation process, the initial pH of the solution was set at pH 3, and during the process, 2 mL of H_2O_2 was added dropwise.

Table 1 . Comparison of the effectiveness of the results between electrochemical and electrochemical peroxidation on reducing carbofuran COD

Preliminary Test	COD Level (mg/L)	COD Reduction (%)
Electrochemical method	320,00	45,76
Electrochemical peroxidation method	66,67	88,70

Table 1 shows that the electrochemical peroxidation method is more effective than the electrochemical method in reducing carbofuran COD levels. The electrochemical peroxidation method increases the performance of electrochemical cells so that they are more capable of degrading Carbofuran. The increase in cell performance in electrochemical peroxidation was due to the addition of hydrogen peroxide. Hydrogen peroxide reacts with iron (II) ions from the anode oxidation to produce hydroxyl radicals. Hydroxyl radicals initiate radical degradation reactions in large molecules (Brillas et al., 2009).

3.4 Electrochemical Peroxidation Process

3.4.1 Contact Time

The time parameter is one of the critical parameters that must be optimized in the electrochemical peroxidation process. Research (Brillas et al., 2009., Sirés et al., 2014) reports that the operating time required for the treatment of each sample is different from one another. Proper timing and operating conditions allow the degradation of the target pollutant to produce a stable end product. The effect of a time variation of 10-50 minutes was observed on the performance of the electrochemical peroxidation process to reduce the COD level of the carbofuran solution to 300 mg/L at pH 3, electrode distance of 3 cm. A fixed potential of 3 V. Table 2 shows that the best time for electrochemical peroxidation to reduce COD levels is by 87.57% that is at 10 minutes.

Table 2. The results of the COD analysis of carbofuran electrochemical peroxidation

Time (minute)	COD Level (mg/L)	COD Reduction (%)
10	73,33	87,57
20	90,00	84,75
30	86,67	85,31
40	100,00	83,05
50	80,00	86,44

3.4.2 Effect of Na_2SO_4 Concentration

Supporting electrolytes are needed to increase the conductivity of the solution, reduce the resistance of the resolution, suppress the migration current, and increase the mobility of ions in the solution. A supporting electrolyte in the electrochemical peroxidation process is crucial in increasing or decreasing Fenton's performance. Some anions that can act as OH scavengers, such as $CO3^{2-}$, $HCO3^{-}$, $HPO4^{2-}$, $H2PO4^{-}$ will reduce the efficiency of Fenton's version because of the large number of interference reactions equations 1 – 4 (Asghar et al., 2015., Bui and Bui. 2019). Several investigations (Diagne et al., 2007., Zhou et al., 2007., Özcan et al., 2008) noted that $SO4^{2-}$ ions could increase pollutant degradation. However, an excessive amount of $SO4^{2-}$ can also reduce the oxidizing capacity of hydroxyl radicals because excess $SO4^{2-}$ will react with •OH to produce $SO4^{\bullet-}$ as shown in reaction equation 5. Although $SO4^{\bullet-}$ formed can reduce the oxidizing capacity of hydroxyl radicals, $SO4^{\bullet-}$ itself can contribute to degrading pollutants because the potential reduction value of SO4•- (E° SO4•-/SO42- = 2.60 V) is not much different from •OH (E° •OH/ H2O = 2.80 V) so it is considered better than anions other inorganic radicals (Asghar et al., 2015). The formation of radical sulfate ions in the electrochemical peroxidation cell provides a competitive effect with hydroxyl radicals as the principal oxidizing agent. The COD value at various concentrations of Na2SO4 tends to fluctuate.

$$CO_3^{2-} + HO^{\bullet} \rightarrow OH^- + CO_3^{\bullet -} \qquad (2)$$

$$HCO_3^- + HO^{\bullet} \rightarrow H_2O + CO_3^{\bullet -} \qquad (3)$$

$$HPO_4^{2-} + HO^{\bullet} \rightarrow OH^- + HPO_4^{\bullet -} \qquad (4)$$

$$H_2PO_4^- + HO^{\bullet} \rightarrow OH^- + H_2PO_4^{\bullet} \qquad (5)$$

$$SO_4^{2-} + HO^{\bullet} \rightarrow OH^- + SO_4^{\bullet -} \qquad (6)$$

The effect of variations in the concentration of Na_2SO_4 from 25 to 150 mM was observed on the performance of the electrochemical peroxidation process to reduce the COD level of the carbofuran solution to 300 mg/L at pH 3, constant potential of 3 V, and operating time of 10 minutes. Table 3 shows that the best concentration of Na_2SO_4 in the electrochemical peroxidation process is 75 mM, with a decrease in COD levels of 93.78%.

Table 3. COD analysis results of carbofuran electrochemical peroxidation result at various concentrations of Na_2SO_4

Na_2SO_4 (mM)	COD Level (mg/L)	COD Reduction (%)
25	50,00	91,53
50	73,33	87,57
75	36,67	93,78
100	66,67	88,7
125	46,67	92,09
150	50,00	91,53

3.4.3 Effect of Volume Variations in Addition of H2O2

H2O2 plays an essential role as an oxidizing agent in the Fenton reaction. In general, it has been observed that pollutant reduction efficiency increases with increasing H2O2 concentration. H2O2 as a source of hydroxyl radicals in electrochemical peroxidation. So, the determination of the optimum addition of H2O2 in the electrochemical peroxidation process is essential to obtain process efficiency. The effect of variations in the volume of acquisition of 30% H2O2 0 - 6 mL was observed on the performance of the electrochemical peroxidation process to reduce the COD level of the carbofuran solution 300 mg/L at pH 3, constant potential 3 V, operating time 10 minutes, and Na2SO4 75 mM. In each variation, 30% H2O2 was added in a controlled manner dropwise during the electrolysis process. The steady addition of H2O2 can minimize the wasted hydroxyl radicals so that the decrease in COD levels can be increased (Brillas et al., 2009).

Table 4. COD analysis results of carbofuran electrochemical peroxidation result in volume variations of 30% H2O2 addition

H_2O_2 30% (mL)	COD Level (mg/L)	COD Reduction (%)
0	310,00	47,46
1	156,67	73,45
2	36,67	93,78
3	136,67	76,84
4	130,00	77,97
5	140,00	76,27
6	123,33	79,10

Table 4 shows that the best COD reduction was obtained by adding 2 mL of 30% H2O2, 93.78%. The table shows that without the addition of H2O2, the decrease in COD levels is very small, namely 47.46%; this is due to the absence of hydroxyl radical production in the system so that Carbofuran is not degraded optimally. The reduction of COD increased with the addition of H2O2, but more than 2 mL of H2O2 reduced the percentage reduction in COD. This was due to the decrease in electrochemical peroxidation performance; in the presence of excess H2O2.

$$H_2O_2 + OH^{\bullet} \rightarrow H_2O + HO_2^{\bullet} \qquad (7)$$

$$OH^{\bullet} + R \rightarrow R^{\bullet} \rightarrow CO_2 + H_2O \qquad (8)$$

This result is following previously reported research (Sirés et al., 2014) that the decrease in the performance of the electrochemical peroxidation process in the presence of a higher amount of H2O2 exceeding the optimum ratio of H2O2 to Fe2+ causes a competitive interference reaction between H2O2 and •OH (equation 6) where The excess concentration of H2O2 acts as a radical scavenger that competes with organic molecules to react with •OH (equation 7). In addition, the excess amount of H2O2 causes H2O2, which does not react when the electrochemical peroxidation process is stopped. This condition causes an increase in COD levels during measurement, as reported by Ozyonar, 2015.

3.4.4 Optimum Conditions for Electrochemical Peroxidation

Based on the results of decreasing COD from various time parameters, Na2SO4 concentration, and volume of 30% H2O2 addition, the optimum conditions were 10 minutes, 75 mm, and 2 mL, respectively. The percentage of COD reduction of Carbofuran under optimum conditions was 93.78%, with a COD value of 36.67 mg/L. The COD value decreased significantly after treatment, indicating that hydroxyl radicals degraded compounds capable of being oxidized in the solution of Furadan 3GR pesticides, including Carbofuran, during the electrochemical peroxidation process. If the remaining oxidized compounds are reduced, the K2Cr2O7 required to oxidize the compounds in the analysis of COD levels will also decrease. The amount of necessary K2Cr2O7 in the COD analysis represents the amount of O2 needed to oxidize the mixture in the virtual environment. A low COD value indicates that the amount of O2 required to oxidize the compound is also expected in the virtual environment so that the amount of O2 that can be dissolved is more.

3.5 Characterization of Electrochemical Peroxidation Solutions at Optimum Conditions

Based on the results of decreasing COD from various time parameters, Na2SO4 concentration, and volume of 30% H2O2 addition, the optimum conditions were 10 minutes, 75 mm, and 2 mL, respectively. The percentage

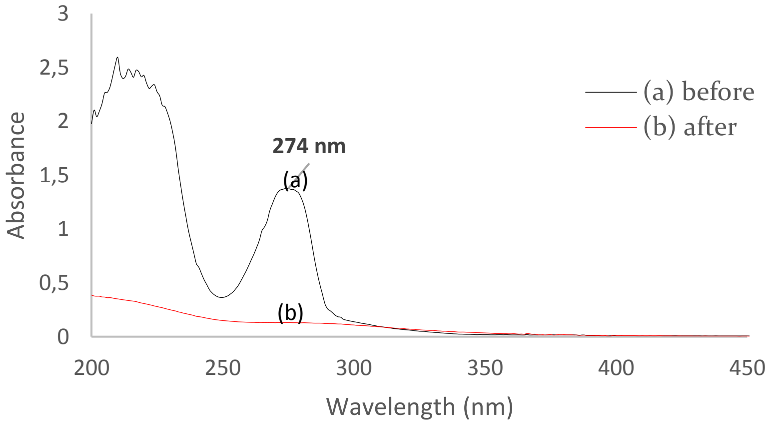

Figure 4. UV-Vis spectrum of samples before and after electrochemical peroxidation process proses

Post-treatment samples at optimum conditions were analyzed with a UV-Vis spectrophotometer to identify the occurrence of sample degradation that could be detected from the difference in absorption at the maximum wavelength of Carbofuran. The UV-Vis spectrum before and after treatment under optimum conditions is presented in Figure 4. The UV-Vis spectrum in Figure 4 shows a significant reduction in absorbance in the sample after treatment at the maximum wavelength of Carbofuran (274 nm). The decline in absorbance indicated that the concentration of Carbofuran in the Furadan 3GR solution was significantly reduced. The reduction in the absorptivity corresponds to the decrease in Carbofuran COD after the electrochemical peroxidation process. This result shows that the electrochemical peroxidation method effectively removes Carbofuran in the Furadan 3GR solution.

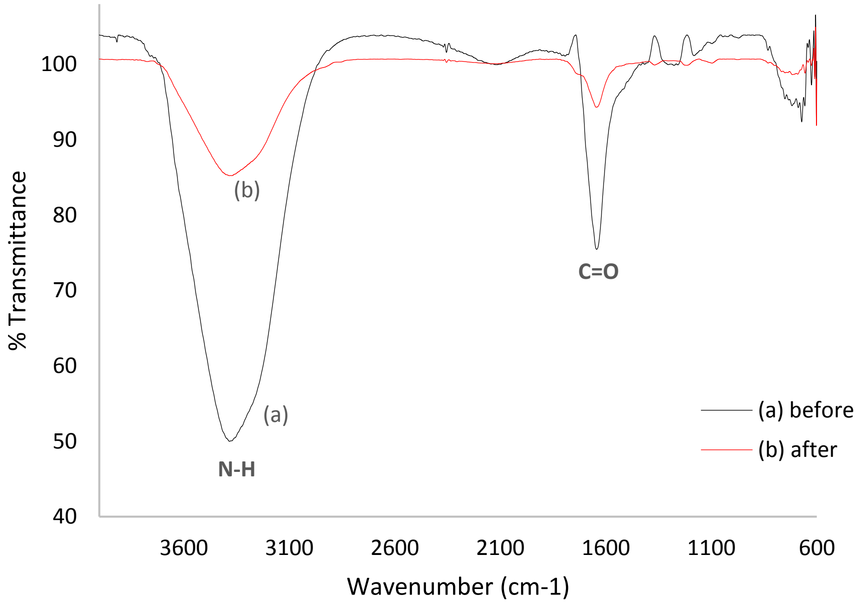

Figure 5. FTIR spectrum of samples before and after electrochemical peroxidation treatment

The FTIR absorption analysis was carried out before and after the peroxidation process at the optimum conditions presented in Figure 5. The results of the FTIR spectrum analysis of the initial sample of Carbofuran before the peroxidation process showed the presence of an NH group at a wavenumber of 3383 cm-1 and a C=O group at a wavenumber of 1643 cm-1. The fact of the N-H group indicates the interaction of hydrogen bonds between the N and H atoms with the solvent (distilled water) or the carbofuran compound itself. The C=O group refers to the carbonyl group present in the carbofuran structure (Figure 6).

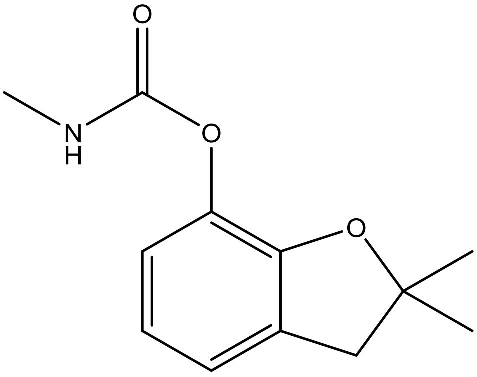

Figure 6. Carbofuran Structure

The results of the FTIR spectrum measurement in Figure 5, the spectrum after treatment at optimum conditions did not show any new absorption of functional groups. However, there was a decrease in the absorbance of functional groups in the sample after electrochemical peroxidation treatment. The reduction in absorbance occurred in the absorption area of the N-H group (3383 cm-1) and the absorption area of the C=O group (1643 cm-1). The decrease in absorbance in the functional group region indicated a reduction in the concentration of the N-H and C=O functional groups in the electrochemical peroxidation sample of Carbofuran. This shows that the compounds in the carbofuran solution from the pesticide Furadan 3GR have been degraded to simpler compounds as reported in previous studies (Ibrahim and Șolpan. 2019., Ma et al., 2009). Ma et al. (2009) succeeded in identifying the 7-hydroxy-2,2-dimethyl-benzofuran-3-one intermediate compound from the carbofuran degradation process by hydroxyl radicals using GC/MS. Ibrahim et al. (2019) reported that the intermediate 7-hydroxy-2,2-dimethyl-benzofuran-3-one was further degraded by hydroxyl radicals resulting in carbon dioxide and water as the end products. The more specific degradation end product corresponds to the loss of the carbofuran absorption band in the UV spectrum and a significant decrease in COD levels after treatment.

4. Conclusion

Carbofuran contained in the pesticide Furadan 3GR was successfully degraded using the electrochemical peroxidation method. The degradation ability of conventional electrochemical and electrochemical peroxidation methods was evaluated comparatively by measuring COD parameters. The addition of hydrogen peroxide to the electrochemical peroxidation cell can initiate radical reactions and accelerate the degradation process. COD reduction increased with H_2O_2 up to 2 mL; Further addition of H_2O_2 resulted in decreased performance of the electrochemical peroxidation process for COD reduction. The concentration of Na_2SO_4 has a significant effect on the performance of electrochemical peroxidation. The COD of Carbofuran decreased significantly from 590 mg/L to 36.67 mg/L in the electrochemical peroxidation process with a relatively short operating time of 10 minutes. The various variations carried out, the optimum conditions for electrochemical peroxidation were obtained with 2 mL H_2O_2, 75 mM Na_2SO_4 concentration, and an operating time of 10 minutes with a decrease in Carbofuran COD of 93.78%. This study proved that the electrochemical peroxidation method was more effective than conventional electrochemistry to reduce the COD levels in the Furadan 3GR pesticide.

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