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# A Low-Cost and Adjustable Frequency of Sonoreactor for Organic Wastewater Degradation

**Yosi Isfandiani[1]*, Hary Sanjaya[2], and Septian Budiman[3]**

*[1]Department of Physics, Universitas Negeri Padang, Padang, Indonesia*

*[2]Department of Chemistry, Universitas Negeri Padang, Padang, Indonesia*

*[3]Metallurgy and Materials Science Research Institute, Chulalangkorn University, Bangkok, Thailand*

**Corresponding author: isfandianiyosi@gmail.com*

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**ABSTRACT**

A low-cost and adjustable frequency of Arduino based sonoreactor for organic wastewater degradation is presented in this paper. The sonoractor is a device that uses ultrasonic concepts to degrade liquid organic waste. The key components of a sonoreactor, namely ultrasonic transducers and ultrasonic generators, use vibrations from ultrasonic waves to generate a cavitation impact. Cavitation is the formation of tiny bubbles that break down dangerous molecules in solution, resulting in the production of hydroxyl radicals H and radicals H2O2 is formed by converting OH radicals. The sonocatalyst process is carried out in a sonoreactor. Sonocatalyst is a kind of sonolysis that includes a catalyst. Ultrasonic irradiation, which occurs at frequencies between 20 until 100 kHz, is used in sonolysis. The use of a ZnO catalyst is intended to lower sonolysis efficiency and increase the development of OH radicals. Since the Sonoreactor uses a lot of electricity, it produces a lot of frequencies. Since frequency and power have a direct proportional relationship. The higher the power provided by the ultrasonic generator, the higher the output frequency generated by the transducer, resulting in increased energy production. As a result, the cavitation and hydroxyl radicals produced will become larger, resulting in much higher degradation.



## 1. INTRODUCTION

Environmental pollution is a serious issue that must be addressed in the industrial growth. Waste is a material that produces toxic and hazardous pollutant levels. Industrial waste of synthetic dyes used is the waste of liquid organic dyes of Congo Red solution (Sanjaya et al., 2018). Congo red is an indication of a synthetic dye. Waste can have a negative environmental impact, including on human health, so it is essential to improve waste. The danger of poisoning from waste varies depending on the form and characteristics of the waste. As a result, a follow-up for processing the liquid waste is needed to ensure that it is not too dangerous. Chemical deposition and coagulation were the most common methods of water treatment so far. Chemical deposition treatment of wastewater costs a lot. Another method for treating traditional industrial wastewater is to use adsorbents to remove organic dyes, which will produce in sludge. However, since the resulting sludge is a hazardous waste, it is handled further (Zuki & Sakai, 2008). Chemical deposition is an effective process of wastewater treatment. Organic dyes can be extracted to waste water using adsorbents, which result in sludge. However, the resultant sludge is treated as a hazardous waste, causing further AOPs. AOPs are advanced oxidation processes like sonolysis (Arfi et al., 2015) that are used to degrade materials. Sonolysis is an ultrasonic vibration-based process for degradation organic compounds in aqueous media (Sanjaya et al., 2018). The pressure of high frequency ultrasonic waves produces cavitation in the Sonoreactor process. Because ultrasonic waves have the ability to break chemical bonds in a solution, they were chosen. This power drives the development of the vibration and heat that happens as waves interact with solution molecules, a phenomenon is known as cavitation (Fathuroya et al., 2016). The formation of growths and the bursting of micro bubbles in a liquid is the phenomenon of cavitation (Servant et al., 2003). Extreme cavitation conditions can be used to degrade pollutant and organic compound molecules (Behnia et al., 2009; Chu et al., 2007; Tan & Yeo, 2017). Ultrasonic waves can travel through solids, waters, and molecules. The propagation is longitudinal, with parallel propagation directions (Suslick, 1989). With the addition of a ZnO catalyst, a sonoreactor was used to degrade the Congo red solution. Zinc oxide is a semiconductor that is used as a sonocatalyst for degradation of dye waste. To minimize the productivity of sonolysis, ZnO is used. As a product, there will still be significant deterioration.

Sonolysis is a technique for chemical processes and reactions that is dependent on the sonochemical effect of ultrasonic waves. The acoustic cavity effect cause fluids to get a sonochemical effect. A cavitation effect is caused by acoustic energy in the frequency range of 20 KHz untill100 KHz. As the coils are developed and pressed into the solution, cavitation normally occurs. Because of the high pressure and temperature on the surface, which can break water molecules into H radicals, this situation happens. Radicals, as well as OH radicals in aqueous solutions, sonolysis causes water to break down into OH and H, which can degrade organic compounds in the solution. The key free radicals involved in degradation reactions are OH radicals (Arfi et al., 2015). In water, the resulting OH radicals will react with one another to form H2O2. The development of this H2O2 compound reduces the value of sonolysis. A catalyst is applied to improve the efficiency of sonolysis degradation by increasing the generation of OH radicals, which accelerate the degradation of organic compounds (Selli et al., 2008).

Sonoreactors are used to break down toxic molecules in liquid waste using ultrasonic principles, and there will be used for research at FMIPA UNP's Chemical Laboratory. UNP also has an ultrasonic cleaner in the Chemistry Laboratory of the Faculty of Mathematics and Natural Sciences. This tool has two power selection buttons, namely (30 Watt and 50 Watt), which are used simultaneously to set the timer during analysis and an I/O button for setting to trigger the tool's operation. However, since the device in the chemical laboratory will not know the frequency used, we do not know how the frequency used during research affects the results. Furthermore, since the timer button is paired with the power selection button, setting the timer is always inefficient. As a result, it takes a long time to set the timer. As a result of this problem, the authors created a sonoreactor that allow them to switch the frequency and timer used during the study.

Ultrasonic generator and ultrasonic transducer are the two primary components of a sonoreactor. To solve the problem, the output frequency of the ultrasonic transducer used may be changed. The developed sonoreactor can be used in the laboratory to aid research and other activities. The aim of this tool is to use Arduino to monitor the time and frequency of ultrasonic generators and ultrasonic transducers such that the appliance can be regulated automatically. To adjust the pitch, rotate the potentio stereo, and to set the time, to use 4x4 keypad. Physical parameters are then measured to assess or describe the resulting sonoreactor. The voltage, frequency, and switching frequency of the Sonoreactor for wastewater degradation among these parameters.

The sonoreactor is made up of a piezoelectric ultrasonic transducer and an ultrasonic generator. The ultrasonic generator and pizoelectric transducer are the main components of this tool, and many other complementary components including the Arduino Uno, power supply, 4x4 keypad, dimmer, relay, fan, stereo liquid crystal display potentiometer, I2C, and switch buttons. The switch buttons are used to turn on the whole appliance, and each component has its own function. I2C, switch button, and potentiometer stereo Liquid Crystal Display The switch buttons are used to turn on the whole appliance, and each component has its own function. I2C, switch button, and potentiometer stereo Liquid Crystal Display The switch buttons are used to turn on the whole appliance, and each component has its own function.

## 2. METHOD

The sonoreactor experiment set system consists of several series, namely a keypad circuit, an Arduino uno circuit, a 20x4 LCD circuit with I2C, a dimmer circuit, a relay, a potentiometer, a series of piezoelectric ultrasonic generators and transducers. The block diagram of the Sonoreactor experimental set can be seen in Figure 1.

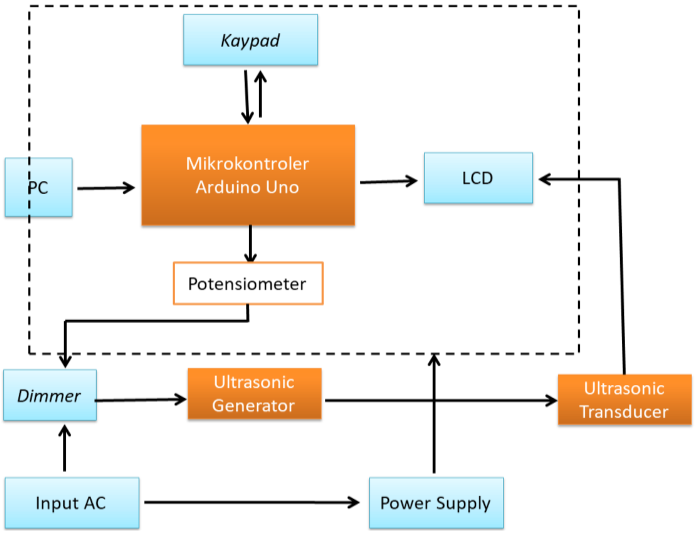


**Figure 1**. Sonoreactor System Block Diagram Design

The experimental set system, as seen in Figure 1, includes an Arduino uno, 4x4 keypad, ultrasonic generator, and piezoelectric form ultrasonic transducer. A 12 V 3 A power supply is used in this setup. The voltage source from PLN will be connected to the Dimmer and relay, which all require a 220 V AC input voltage. The dimmer will then create a 220 V output voltage, which will be used as the ultrasonic generator's input voltage source. The Arduino Uno is powered by a 12V 3A power supply. The LCD and Keypad will be activated until the Arduino is turned on, and they will run according the programs developed in the Arduino IDE. The Arduino uno will process the input signal from the 4x4 keypad before send it to the ultrasonic generator. For this type of experiment, the Arduino uno will adjust to the input signal. An alternating voltage is generated by an ultrasonic generator. Since the voltage is applied to the ultrasonic transducer, the ultrasonic transducer converts the mechanical energy to electrical energy in the form of vibrations (ultrasonic waves) in compliance with the input voltage and time.

### 2.1 Hardware design

A keypad circuit, an Arduino uno circuit, a 20x4 LCD circuit with I2C, a dimmer circuit, a relay, a potentiometer, a piezoelectric ultrasonic generator, and a transducer circuit make the Sonoreactor experimental set system. Sonoreactor is an ultrasound system for the decomposition of organic liquid waste. This research series requires use of an ultrasonic transducer. A component that converts an alternating voltage electrical signal from an ultrasonic generator into mechanical waves is known as an ultrasonic transducer. The Arduino uno is a programmable component that can handle before the tasks. A timer is controlled and used the 4x4 keypad. A dimmer is used for the voltage source of the ultrasonic generator, which can be varied, and a voltage pot is used to divert the voltage to be sent to the ultrasonic generator in the Liquid Crystal Display 20x4 series. Figure 2 shows the mechanical schematic of the sonoreactor device.

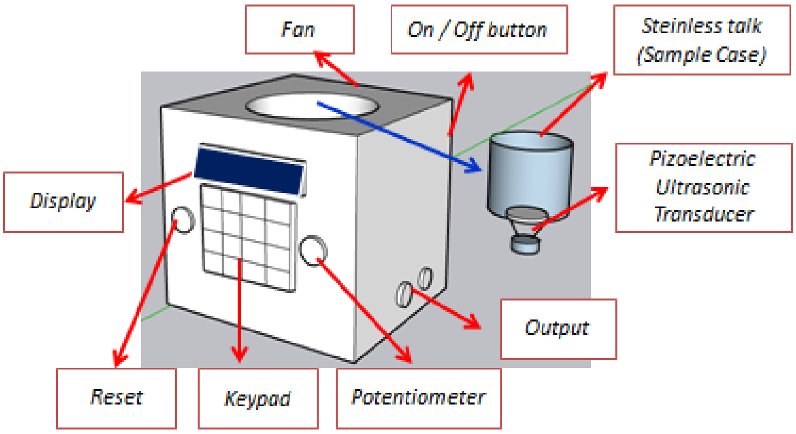


**Figure 2**. Mechanical sonoreactor design

The mechanical design of the sonoreactor can be seen in Figure 2. The generator frequency ranges when the stainless tank is filled with water and the sample is to be cleaned. To start, press the power On / Off button, and use the 4x4 keypad to input time, then turn the dimmer to select the frequency and voltage input, and then press the start button (#).The Sonoreactor will function according to the input frequency and time values that are entered and displayed on the 20x4 Liquid Crystal Display after pressing the start button. And, dependent on the timer, the tool will automatically stop. If you want to continue pushing, press the reset button to reset the report. As shown in Figure 2, the sonoreactor is made up of components arranged in an electronic circuit. Some components used serve multiple functions. In the 20V until 220V range, dimmers are used to adjust the input voltage for the ultrasonic generator source. The dimmer has an affect on the generator's input voltage. The generator will output more power if the input voltage is higher. The higher the output frequency, and the power is used. The relationship between frequency and power is directly proportional, resulting in more energy and also more vibrations (Son et al., 2012). Figure 3 shows the electronic circuit design for the sonoreactor.

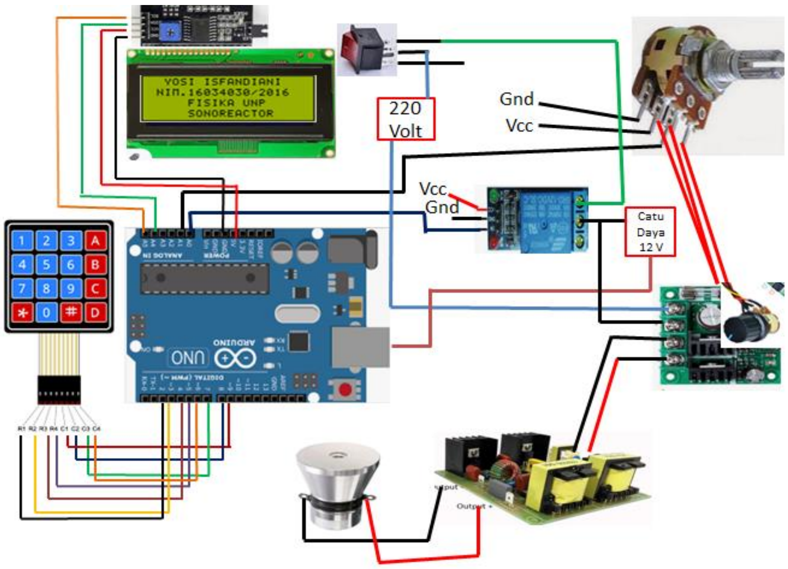


**Figure 3**. The sonoreactor electronic circuit

Ultrasonic Generators and Ultrasonic Transducers are the two main components of sonoreactors. Relay, keypad, LCD, dimmer, stereo potentiometer, and power supply are some of the supporting components. The LCD is a display component of 16 pins that are connected to I2C to store the pins that will be connected to the Arduino. I2C is connected to A4, A5, GND, and 5V pins on the Arduino. Furthermore, the keypad has 8 pins that will be connected to the Arduino pins 9.8,7,6,5,4,3,2. This circuit uses relays for switching, which are controlled by Arduino pins. While the timer is running, the relay will operate to supply electric current to the connection, and when the timer is up, the relay will turn off the electric current. On the Arduino Uno, the address pin for the relay is connected to analog pin A0, GND is connected to the GND pin, and VCC is connected to the VCC pin. A six-pin stereo potentiometer makes up the dimmer. The addressing of the stereo potentiometer is connected to the dimmer for the lower three legs of the potentiometer, while the upper leg is connected to the Arduino Uno. with the potentiometer data pins connected to A1, VCC connected to 5V, and GND connected to GND

An Arduino uno, a 4x4 keypad, an ultrasonic generator, and a piezoelectric ultrasonic transducer are used in Sonoreactor experimental set system. A 12V 3A power supply is used in this experimental system. The dimmer will then output a 220 V output voltage, which will be used as an input voltage source for ultrasonic generators. The Arduino Uno is powered by a 12V 3A power supply. The LCD and Keypad will be operational until the Arduino is turned on, and they will run according to the code developed in the Arduino IDE.

2.2 Software design

The design of the Sonoreactor software was carried out using the Arduino Uno. This programming uses Arduino IDE software. This tool functions as a controller to set the desired time via the 4x4 keypad and the frequency reading in the switch using a stereo pot that is connected to the Arduino Uno. The program is then displayed on a 20x4 LCD. After programming as needed, the program is downloaded to the Arduino Uno. The Flowchart Shape of the Sonoreactor software design can be seen in Figure 4.

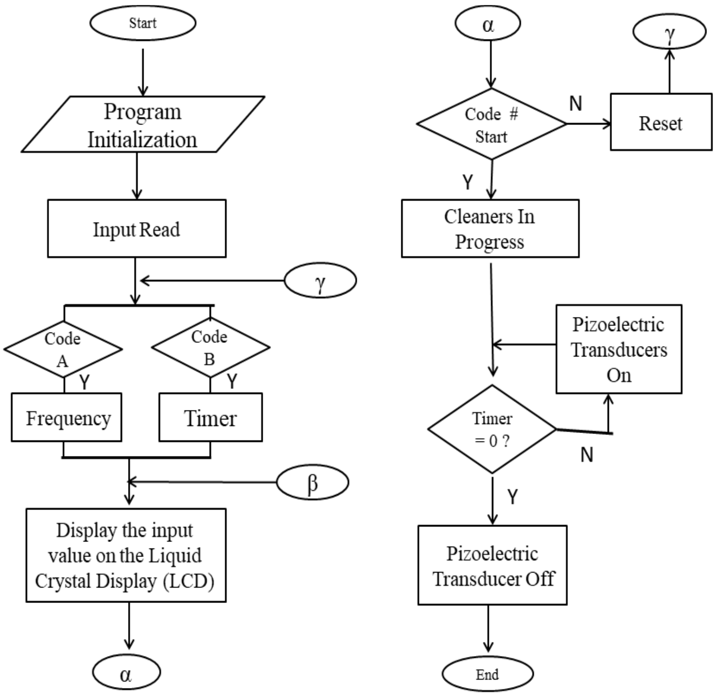


**Figure 4.** Flowchart for Sonoreactor software

## 3. RESULTS AND DISCUSSION

3.1 Sonoreactor tool timer accuracy

The stopwatch gauge is used to contrast the timer value entered through the keypad with the accuracy measurement. The research was carried out by measuring with 10 variants of the timer data to get the right accuracy. Figure 5 shows the precision data of the sonoreactor device when measured with a stopwatch.

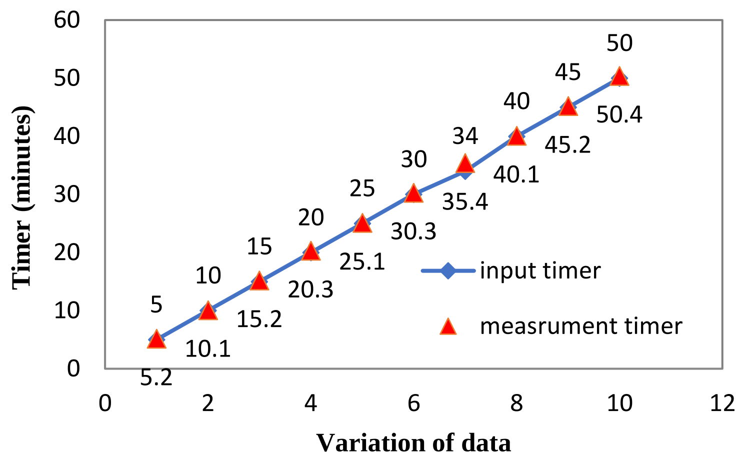


Figure 5. The results of measuring the accuracy data

The measurement tool's measure accuracy varies between 0.992 and 0.996, based on the average accuracy of 0.992.

3.2 Precision sonoreactor tool timer with stopwatch

Make the same measurement 10 times with a time value of 5 minutes makes for precision measurement. The measurement value is displayed on the LCD after timer value is entered it through keypad. Figure 6 shows the precision data of the sonoreactor device with a stopwatch measuring device.

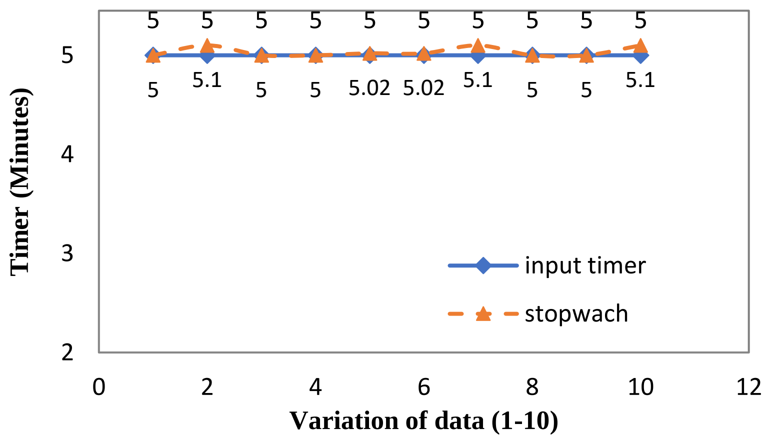


Figure 6. Data result of precision measurement

The value of measurement precision on the sonoreactor tool is very high, as seen in Figure 6. The timer precision value ranges from 0.998 to 1, with a standard deviation of 0.0216, based on average time precision of 0.998 for sonoreactor tool.

3.3. The characteristics of the dimmer circuit with the ultrasonic generator circuit

The dimmer circuit analysis is connected to an ultrasonic generator as an AC source. Where the dimmer consists of a stereo pot that is used to switch the input voltage to be used in the ultrasonic generator. This dimmer is a circuit that has a 220 V source and can produce an output voltage of 20-220 V. The best working point for the transducer is when the transducer is given an input frequency because at that time a smaller period is obtained (Al-Budairi, 2012; Sajjadi et al., 2015; Sutrisno, 2011). The output voltage will be used as the input voltage for the ultrasonic generator. The measurement of the dimmer circuit with an ultrasonic generator is shown in the graph in Figure 7 and Table 1.

**Table 1.** Dimmer Measurement with Ultrasonic Generator and Ultrasonic Transducer.

| Input Voltage (Volt) | Output Frequency (KHz) |
|---|---|
| 20 | 7.03 |
| 40 | 14.64 |
| 60 | 16.83 |
| 80 | 21.05 |
| 100 | 22.18 |
| 120 | 26.28 |
| 140 | 28.06 |
| 160 | 32.25 |
| 180 | 33.9 |
| 200 | 34.02 |
| 210 | 38.0 |

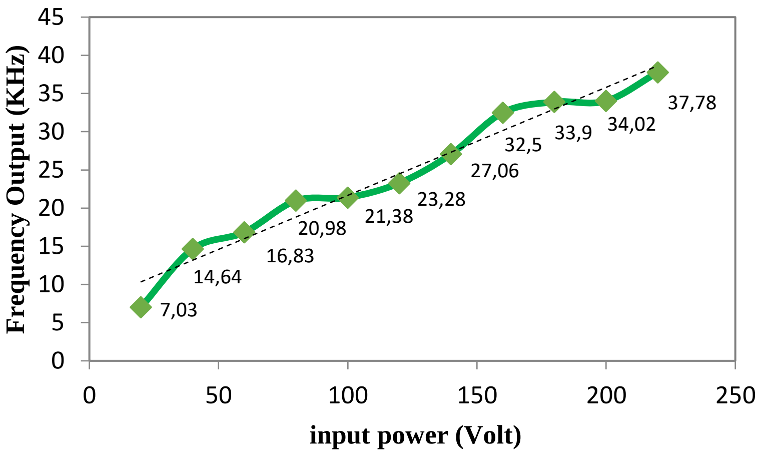


**Figure 7.** Relationship between the dimmer input voltage and the output frequency

An alternating voltage will be developed by the ultrasonic generator and then sent to the ultrasonic transducer. A piezoelectric ultrasonic transducer electrical energy signal into mechanical energy (vibration). The piezoelectric type ultrasonic transducer consumes the electrical energy generated at the ultrasonic frequency by ultrasonic generator. The piezoelectric element in the transducer can vibrate, converting this electrical energy into mechanical energy. The vibrations will then be amplified by resonance and beamed directly through the medium through a plate, results in ultrasonic waves.

3.4 Effect of Time on the percentage of degradation of the Congo Red

With an initial solution concentration of 10 ppm, the Congo Red dye was degraded by adjusting the radiation time of the Sonoreactor process at 15 minutes, 30 minutes, 45 minutes, 60 minutes, and 75 minutes. For this degradation step, 0.1 gram of ZnO is added to 80 mL of solution, then placed in the Sonoreactor apparatus. A UV-Vis spectrophotometer will be used to test the solution after it's been sonicated. The highest wavelength was obtained at 498 nm when Congo Red 10 ppm samples were measured absorbance with a wavelength range of 250-700 nm. The absorbance of 10 ppm Congo Red was measured to compare absorbance after degradation using the sonocatalyst method. The percent degradation is measured and used the absorbance result.

$$\% D = \frac{A_0 - A_t}{A_0} x\ 100\ \% \quad (1)$$

Note the A0 describes the absorbance previous to degradation and At represents the absorbance following degradation at time t (Kojima et al., 2001) . The time of the experiment was varied six times using a sample of Congo red with a concentration of 10 ppm and the addition of 0.1 gram of zinc oxide (ZnO) catalyst. Figure 8 and Table 2 shows the measurement time variation with input voltage.

**Table 2.** Sonoreactor measurement time variation with input voltage 210 volt and Output frequency 38 KHz.

| Time (minute) | absorption ($A_o$) | absorption ($A_t$) | Degradation (%) |
|---|---|---|---|
| 15 | 0.2825 | 0.1408 | 50.15 |
| 30 | 0.2825 | 0.1324 | 53.13 |
| 45 | 0.2825 | 0.1193 | 57.76 |
| 60 | 0.2825 | 0.0972 | 66.2 |
| 75 | 0.2825 | 0.0609 | 78.5 |
| 90 | 0.2825 | 0.0559 | 80.23 |

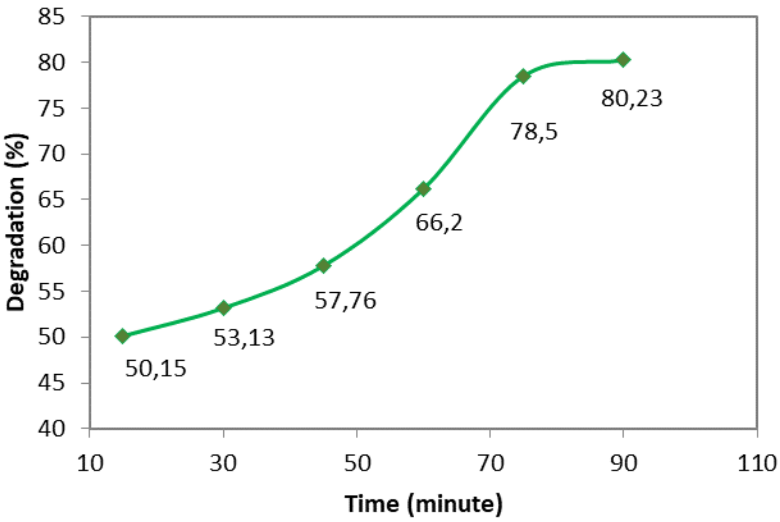


**Figure 8.** Effect of Time on Degradation of Congo Red

In Figure 8 it can be seen that the percentage value of the Congo Red degradation increases with the increasing time of degradation. This increase occurs because the cavitation will continue to increase, so that more cavitation bubbles will hit ZnO. So that the radical OH produced also increases as a result of the length of the sonolysis process (Arfi et al., 2015). This hydroxyl radical will react with the Congo Red compound and turn it into a harmless compound or actually mineralize it into CO2 and H2O (Sutanto & Wibowo, 2015). The same thing was found by (Sanjaya et al., 2017) which states that the higher the radiation time, the greater the percentage of degradation. From the visual appearance, the longer the sonocatalyst was carried out, the more faded the color of the Congo Red sample can be seen in Figure 9.


**Figure 9.** Congo Red solution before and after degradation with time variations

In Figure 9, it can be seen that the longer the sonocatalyst time, the color of the solution will be more faded or clear, so it can be concluded that time greatly affects the results of sample degradation.

3.5 Effect of Input Stress for degradation percentage of Congo Red

This is done to figure out that the input voltage controls the degradation results. The sample congo red was then measured by varying the input voltage for the same duration of time, which was 75 minutes. The frequency of the transducer is greatly affected by voltage (Kimura et al., 1996). Table 3 and Figure 10, Figure 11 show the measurement data for the relationship between the input voltage and the output frequency, and the measurement data for the relationship between the input voltage and the Congo red degradation results.

**Table 3.** Measurement of input voltage variation relationship with constant time for each experiment

| Input Voltage (Volt) | Output Frequency (KHz) | Absorption (Ao) | Absorption (At) | Degradation (%) |
|---|---|---|---|---|
| 80 | 21 | 0.2825 | 0.1935 | 31.50 |
| 120 | 26 | 0.2825 | 0.1893 | 33.1 |
| 160 | 32 | 0.2825 | 0.1738 | 38.57 |
| 210 | 38 | 0.2825 | 0.0609 | 78.5 |

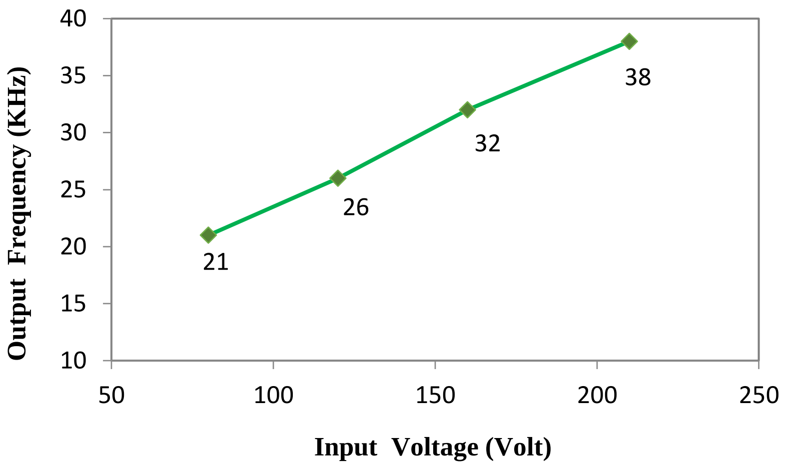


**Figure 10**. Relationship between input voltage variations with output frequency and degradation percentage

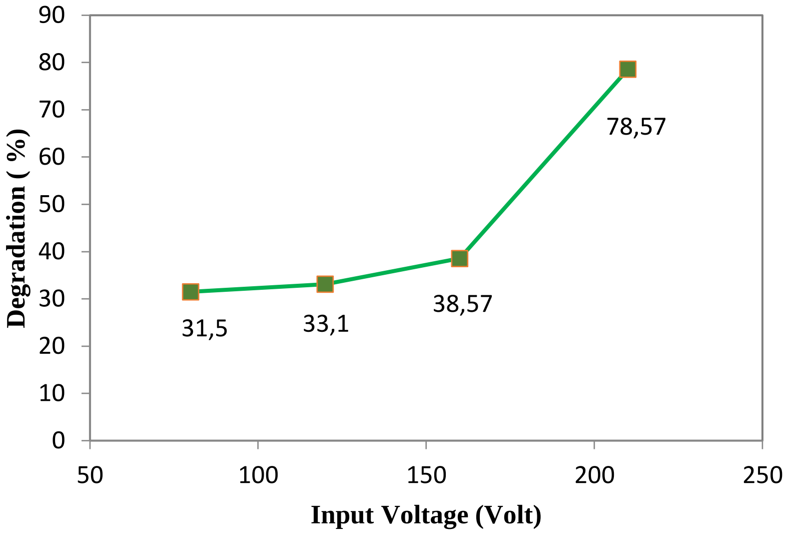


**Figure 11.** The relationship between variations in input voltage and degradation results

The percentage value of Congo Red degradation increases as the input voltage increases, as seen in Figures 10 and 11. In the sonication process, voltage has a major effect on electricity. The more power used, the more irradiation is produced (Kimura et al., 1996; Kojima et al., 2001). If the voltage is higher, the generator's power is higher, resulting in a higher output frequency on the ultrasonic transducer, which produces ultrasonic waves that produce a cavitation effect in the solution (Saif et al., 2013). Cavitation is a process the result in the bubbles deflating and securing (Parvizian et al., 2012). Hydrogen radicals and hydroxyl radicals are produced during the sonolysis process with vibrations generated in the Sonoreactor apparatus, causing chemical processes on the surface of the bubbles. Solute molecules that do not diffuse into the bubble or are on the bubble's inner surface will be more susceptible to H and OH attack (Harnum et al., 2013).

Ultrasonic waves can propagate in a liquid medium. The propagation process is longitudinal with the direction of propagation parallel. So that the characteristics of ultrasonic waves result in pariodic particle vibrations. The electrical energy at the ultrasonic frequency generated by the utrasonic generator is fed to the pizoelectric ultrasonic transducer. Electrical energy will be converted into mechanical energy by vibrating. The vibration results are then amplified by means of resonance and then emitted onto the plate into an ultasonic wave (Al-Budairi, 2012). The same thing was found by (Isariebel et al., 2009) which states that the higher the input power, the greater the resulting frequency. The input voltage greatly affects the acoustic energy produced on the sonoreactor (Navarro-Brull et al., 2019). The following is the visual form of the congo red sample by varying the input voltage with a constant time of 75 minutes can be seen in Figure 12.


**Figure 12**. The results of degradation of the Congo Red solution with variations in input stress

The results of the degradation of the input voltage variation (power) at a constant time of 75 minutes are shown in Figure 12. The high the power, the high the ultrasonic transducer's output frequency. A high frequency can also produce a lot of energy. This energy will cause cavitation, resulting in the formation of OH radicals.

## 4. CONCLUSION

For the sonocatalyst method, sonoreactors are used which operate on the principle of ultrasonic irradiation at frequencies above 20 kHz. The cavitation generated by the sonocatalyzed process will generate OH radicals. The addition of a ZnO catalyst, which can enhance the development of OH radicals, increases the degradation efficiency of sonolysis. By variation of input voltage and research time, the sonoreactor was used to degrade Congo red dye. The input voltage influences the output of the generator; the higher the power, the higher the frequency generated at the transducer, resulting in more cavitation. Cavitation leads to the formation of OH radicals which accelerate the degradation process. The percentage degradation yield was 80.23 from the input voltage variation of 210 volts at the highest time. With an input voltage of 210 volts, the percentage degradation result was 50.15 at the lowest time of 15 minutes

## ACKNOWLEDGMENTS

Many students experiencing psychological problem but felt hesitant to seek help from professional mental health care (Abdollahi, Hosseinian, Beh-Pajooh, & Carlbring, 2017). Person who experiences psychological health problems ideally received access to getting assistance from professional staff or with fully aware themselves seeking and seeing the counselors, psychologists or people who are competent on the field of psychological health.

## DECLARATIONS

### *Authorship contribution*

**Yosi Isfandiani**: Conceptualization, methodology, formal analysis, software and writing -original draft. **Hary Sanjaya**: Methodology, Validation, data curation and writing –review and editing. **Septian Budiman**: Validation, writing–review and editing.

### *Competing Interest*

The authors **declare** no conflict of interest in this study.

### *Funding statement*

This work has not been funded by any person or organization.

### *Ethical Clearance*

There are no human subjects in this manuscript, and informed consent is not applicable.

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