

## Original Research Article

### Ultrasound Assisted Sonochemical Decomposition of Methyl Orange (MO) in the Presence of H<sub>2</sub>O<sub>2</sub> and CCl<sub>4</sub>

#### ABSTRACT

Methyl orange (MO) is an orange azoic dye, which has transition range from 3.1 to 4.4. Sonochemical decomposition of methyl orange in the presence of H<sub>2</sub>O<sub>2</sub> and CCl<sub>4</sub> has given effective result to reclaim water from the effluents released by the industries. The aim of this research was to investigate the effective condition for the decomposition of MO in the presence or absence of additives. For this, 50 mg/L solution of MO was sonicated in the presence and absence of different additives. It was clearly confirmed that the rates of sonochemical decomposition of MO increased with increasing the concentration in both cases of H<sub>2</sub>O<sub>2</sub> and CCl<sub>4</sub>. The combination of advanced oxidation processes (AOPs) namely hydrogen per-oxide and carbon tetra-chloride with sonolysis harvests the decomposition of wide spectrum of organic contaminants. The combination of sonolysis with H<sub>2</sub>O<sub>2</sub> and CCl<sub>4</sub> enhances the production of non-selective radicals to improve the decomposition process. The AOPs is technically feasible and also economic. Based on the results, it was suggested that the rate of MO decomposition can be effectively enhanced by the sonolysis of CCl<sub>4</sub> and also for H<sub>2</sub>O<sub>2</sub>. It was possible to include order: - MO + 200 μL H<sub>2</sub>O<sub>2</sub> > MO + 100 μL H<sub>2</sub>O<sub>2</sub> > MO + 20 μL H<sub>2</sub>O<sub>2</sub> > MO; MO + 200 μL CCl<sub>4</sub> > MO + 100 μL CCl<sub>4</sub> > MO + 20 μL CCl<sub>4</sub> > MO.

MO+200μL H<sub>2</sub>O<sub>2</sub> > MO+100μL H<sub>2</sub>O<sub>2</sub> > MO+20μL H<sub>2</sub>O<sub>2</sub> > MO  
 MO+200μL CCl<sub>4</sub> > MO+100μL CCl<sub>4</sub> > MO+20μL CCl<sub>4</sub> > MO.

*Keywords:* Methyl orange; sonolysis; CCl<sub>4</sub>, H<sub>2</sub>O<sub>2</sub>; radical reaction.

**Comment [R1]:** Delete, are present in the title.

#### INTRODUCTION

Energy, food and water are interconnected and within the nation, water is essential for all social and economic developments. In the oncoming years, worldwide crisis may arise for energy, food, and water [1]. The percentage of increasing in concentration of organic contaminants in surface water has been observed by the past two decades [2,-3]. The removal of hazardous substances from industrial waste streams and the process of remediation of contaminants in groundwater, rock and soil is a major problem in the Asian countries [4]. As diseases spread through water which becomes unsuitable for usages in day to day life in human beings, for the usages of polluted water, water borne diseases spread throughout the world and in the awkward case, it causes the mortality of children [5,-6].

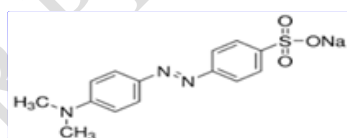
Contamination of soil and groundwater from industrial waste streams is a serious health problem. Traditional techniques to remove contaminants from soil: including landfilling, air stripping/carbon adsorption, incineration, biological activity and chemical treatment. Incineration, adsorption and landfilling merely transfer the contaminant to another phase or location (i.e., a pollution shift) and produce a potentially dangerous and toxic secondary disposal requirement. To numerous environmental factors biodegradation is very sensitive, is

**Comment [R2]:** Topics and subtopics should be numbered continuously, for example:  
 1. INTRODUCTION  
 2. MATERIALS AND METHODS

51 slow, produces unpredictable results often, and is uneconomical for highly concentrated  
 52 waste effluents. Current developments in environmental technologies involving chemical  
 53 oxidation have the potential to treat all types of organic and inorganic contaminants (volatile,  
 54 semi-volatile and non-volatile). Those processes, which all are oxygen based, are usually  
 55 termed as **A**dvanced **O**xidation **P**rocesses (AOPs).

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 57 An AOP can define as the oxidation process that generally generates hydroxyl radicals in  
 58 sufficient quantity to affect water treatment. Complete mineralization can be entailed by the  
 59 oxidative processes, implying that the final products of degradation reactions are carbon  
 60 dioxide, short-chain organic acids, and inorganic ions, typically less toxic and favorable to  
 61 biodegradation. The AOPs generally use a combination of oxidation agents (O<sub>3</sub>, H<sub>2</sub>O<sub>2</sub>),  
 62 irradiation (ultraviolet, ultrasound) and catalysts (TiO<sub>2</sub>) as a means of generating the excited  
 63 hydroxyl or hydroxyl radicals, which are more powerful oxidants than molecular O<sub>3</sub> or H<sub>2</sub>O<sub>2</sub>  
 64 [7-17].

65  
 66 Recent advances in AOPs include environmental sonochemistry, which involves the  
 67 application of ultrasound to induce in situ cavitation to destroy or accelerate the destruction  
 68 of liquid-phase contaminants [18,-19]. Some reactions involved in AOPs are found in Table 1  
 69 [20,21]. Cavitation is the nucleation, growth, and sudden collapse of gas or vapor--filled  
 70 micro-bubbles formed from acoustical wave-induced compression or refraction in a body of  
 71 liquid [19]. The number of reacted molecules per unit of ultrasonic energy is marked as the  
 72 sonochemical efficiency value. For hazardous organic dye the degradation of methyl orange  
 73 used as model in the presence of additives such as H<sub>2</sub>O<sub>2</sub>, CCl<sub>4</sub> was carried out. Because  
 74 methyl orange (MO) is a pH indicator and due to its clear color change it is very often used in  
 75 titrations. Methyl orange changes color at the pH of a mid-strength acid and is usually used  
 76 in titrations for acids. Unlike a so called universal indicator, methyl orange does not have  
 77 a full spectrum of color change, but has a sharper end point. The structure of the MO can be  
 78 observed in Figure 1.



80 **Figure 1. Structure of the methyl orange**

81  
 82 The aim of this research is to investigate the effective condition for the decomposition of MO  
 83 in the presence or absence of additives. In addition, to make comparison the percentage of  
 84 dye molecule degradation on ultrasound with &, without additives such as H<sub>2</sub>O<sub>2</sub>, CCl<sub>4</sub> at  
 85 room temperature will be made.

86  
 87  
 88 **Table 1.:- Some reactions involved in advanced oxidation processes [20-21].**

89 **Reaction steps:**

Reaction steps	
Sonolysis	$H_2O + ))) \rightarrow \cdot OH + OH^-$ $H_2O + ))) \rightarrow (1/2)H_2 + (1/2)H_2O_2$
Fenton reactions	$Fe^{2+} + H_2O_2 \rightarrow Fe^{3+} + \cdot OH + OH^-$
Sonophotocatalysis (with H <sub>2</sub> O <sub>2</sub> )	$H_2O + ))) \rightarrow \cdot OH + OH^-$

**Comment [R3]:** Figure 2 has been shifted to this part of the text, now named as Figure 1.

Adjust titles of Figures and Tables according to the corrections made in Figure 1 and Table 1.

**Comment [R4]:** The objectives were shifted towards the end of the introduction.

**Comment [R5]:** Bold and centralized.

Rows and columns of the table were adjusted.

Adjust titles of Figures and Tables according to the corrections made in Figure 1 and Table 1.

(a) Water sonolysis	$\text{H}_2\text{O} \rightarrow (1/2)\text{H}_2 + (1/2)\text{H}_2\text{O}_2$
(b) Reaction of $\text{H}_2\text{O}_2$ with H atoms (formed from water sonolysis)	$\text{H}_2\text{O}_2 + \text{H} \rightarrow \text{OH} + \text{H}_2\text{O}$
(c) Photolytic dissociation of $\text{H}_2\text{O}_2$	$\text{H}_2\text{O}_2 + h\nu \rightarrow 2\text{OH}$
(d) Reaction of $\text{H}_2\text{O}_2$ with superoxides (formed in the presence of $\text{TiO}_2$ and under UV radiation)	$\text{H}_2\text{O}_2 + \text{O}_2^- \rightarrow \text{OH} + \text{OH}^- + \text{O}_2$
(e) Reaction of $\text{H}_2\text{O}_2$ with electrons (conduction band electrons are generated from semi-conductor photocatalyst under UV irradiation). Ozone + sonolysis	$\text{H}_2\text{O}_2 + e^- \rightarrow \text{OH} + \text{OH}^-$ $\text{O}_3 + \text{OH} \rightarrow \text{OH}$ $\text{UV} + \text{H}_2\text{O}_2 + \text{O}_3$ $\text{H}_2\text{O} \rightarrow \text{OH} + \text{OH}^-$ $\text{H}_2\text{O} \rightarrow (1/2)\text{H}_2 + (1/2)\text{O}_2$ $\text{H}_2\text{O}_2 + \text{O}_3 \rightarrow \text{O}_2(\text{g}) + \text{O}({}^3\text{P})(\text{g})$ $\text{O}({}^3\text{P})(\text{g}) + \text{H}_2\text{O}(\text{g}) \rightarrow 2\text{OH}$
Semiconductor photo-catalysis ( $\text{TiO}_2$ -Semiconductor)	$\text{TiO}_2 + h\nu \rightarrow \text{TiO}_2^- + \text{OH}$ (or $\text{TiO}_2^+$ ) $\text{TiO}_2^- + \text{O}_2 + \text{H}^+ \rightarrow \text{TiO}_2 + \text{H}_2\text{O} + \text{OH}$ $\text{TiO}_2^- + 2\text{H}^+ \rightarrow \text{TiO}_2 + \text{H}_2$ $\text{H}^+ + \text{H}_2\text{O} \rightarrow \text{OH} + \text{H}^+$

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### 91 | **1.1 Fundamental Theory of Sonochemistry:**

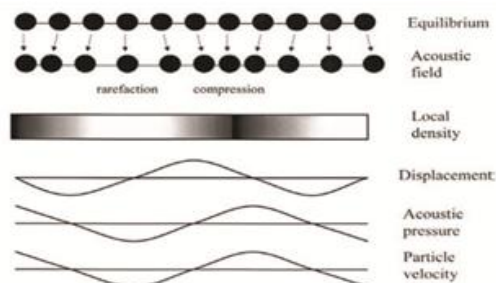
92 The study of sonochemistry is concerned with understanding the effect of sonic waves and  
 93 wave properties on chemical systems. The chemical effects of ultrasound do not come from a  
 94 direct interaction with molecular species. Studies have shown that no direct coupling of the  
 95 acoustic field with chemical species on a molecular level can account for sonochemistry or  
 96 sonoluminescence. Instead, sonochemistry arises from acoustic cavitation: the formation,  
 97 growth, and implosive collapse of bubbles in a liquid. This is demonstrated in phenomena  
 98 such as ultrasound, sonication, sonoluminescence, and sonic cavitation. The attractiveness of  
 99 sonochemistry in environmental engineering seems to stem from three major facts.

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101 -Firstly, sonochemistry can cause real chemical changes to a solution without the necessity of  
 102 adding any other compounds. Secondly, sonochemistry is often conducted at low or ambient  
 103 temperatures and pressures; thus, no heating or pressurization is required. These two features  
 104 simplify enormously the design and operation of reactors. Thirdly, in many cases, the  
 105 peculiar nature of sonochemical reactions offers alternative pathways, providing a faster or  
 106 environmentally safer degradation of contaminants. Some sonochemical syntheses have also  
 107 been successfully scaled up to plant size, providing convenient advantages such as lower  
 108 operation costs and shorter times of operation compared to traditional techniques. The present  
 109 challenge for sonochemists and acoustical physicists in the field of environmental  
 110 remediation is to provide cost-effective sonochemical solutions to large-scale problems.  
 111 Sonochemistry proceeds because the passing of acoustical waves of large amplitude, called  
 112 finite amplitude waves, through solutions causes cavitation. Cavitation can be generated

113 when large pressure differentials are applied in a flowing liquid (hydro dynamical cavitation),  
 114 or by means of an electromechanical transducer, piezo electrical or magnetostrictive, in  
 115 contact with the fluid (acoustical cavitation), according to Figure 2-4.  
 116

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 118 **Figure 1.2:** Propagation of a one-dimensional ultrasound wave (Brennen CE. 1998).  
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Comment [R7]: Quote correctly, [xx] not (Brennen). Is not in the references.

120 The aim of this research was to investigate the effective condition for the decomposition of  
 121 MO in the presence or absence of additives. In addition, was to make comparison the  
 122 percentage of dye molecule degradation on ultrasound with and without additives such as  
 123 H<sub>2</sub>O<sub>2</sub>, CCl<sub>4</sub> at room temperature will be made.  
 124

## 125 **2. EXPERIMENTAL METHODOLOGYSECTION**

126 Hydrogen peroxide, methyl orange and carbon tetrachloride were purchased from Merck  
 127 KGaA 64271 Darmstadt, Germany. All the chemicals were reagent grade and used as received.  
 128 An ultrasonicator model soniclean 250HT, 50-60 Hz was used to decompose dye molecule in  
 129 aqueous medium. The schematic diagram of the experimental setup to shown in the Figure- 3.  
 130 A conical flask with a total volume of 100 mL of 50 mg/L sample solution was used for  
 131 ultrasonic irradiation under air at room temperature around 24°C. The sonicated solution was  
 132 extracting every (0, 3, 7 and 10 min) by a glass syringe (1 ml) without exposing the sample to  
 133 air. The glass vessel was flat bottomed and was mounted at a constant position (4.0 mm from  
 134 the oscillator). The sonicated solutions were analysed by a UV-Vis spectrophotometer  
 135 (Shimadzu UV-1650).  
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 138 **Fig. 3:** Schematic diagram of the experimental set-up.  
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## 2.1 Calorimetrically measurement of Temperature Change with Sonication Time:

A technique for quantitatively evaluating an ultrasonic reaction field has been investigated. Ultrasonic power is one of the important factors for sonochemistry. Calorimetry is one of the most frequently used methods for measuring the actual ultrasonic power input for a solution.

Equation (1) gives the calculated ultrasonic output power (P).

$$P = (dT/dt) C_p M \quad (1)$$

Where,

$C_p$  is heat capacity of water (4.178 kJ/mole)

$M$  is mass of water (100 gm)

$dT$  is temperature of the sample solution

$dt$  is ultrasonic irradiation time.

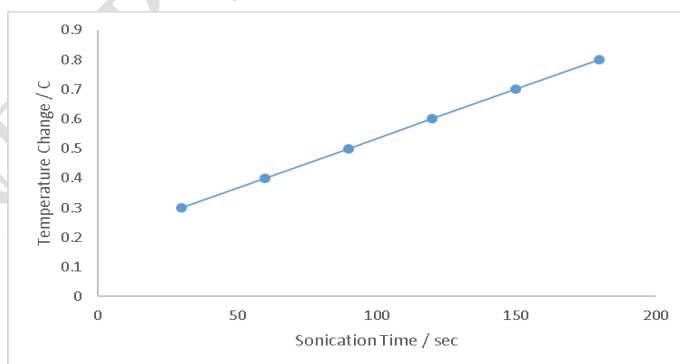
Comment [R9]: Is this unit correct?

Comment [R10]: Which units?

From the Table 2 and Figure 4, can see the temperature in the site of the reaction is increasing with sonication time. That means the rate of reaction increases or decreases with temperature. So, can say that, degradation rate of the dye stuff (methyl orange) will increase with the elongation of sonication time.

**Table 2:** Measurement of temperature change during sonication:

Observation	Sonication Time (sec)	Initial Temperature ( $^{\circ}$ C)	Final Temperature ( $^{\circ}$ C)	Temperature Change ( $^{\circ}$ C)	Actual power (Watt)
1	30	24.7	25.0	0.3	4.180
2	60	25.0	25.4	0.4	2.787
3	90	25.4	25.9	0.5	2.322
4	120	25.9	26.5	0.6	2.090
5	150	26.5	27.2	0.7	1.951
6	180	27.2	28	0.8	1.858



**Figure-4:** The change of temperature with increasing sonication time.

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Axe Y: Temperature change ( $^{\circ}$ C)  
Axe X: Sonication time (sec)

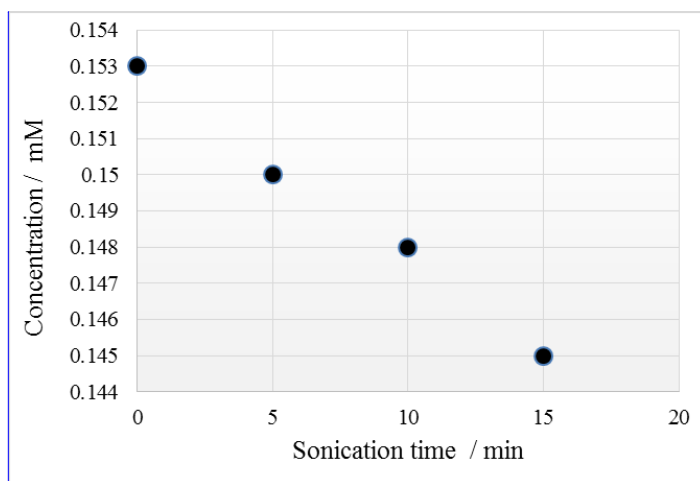
From the table 3 & figure 4, we can see the temperature in the site of the reaction is increasing with sonication time. That means the rate of reaction increases or decreases with temperature. So, we can say that, degradation rate of the dye stuff; methyl orange will increase with the elongation of sonication time.

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### 3. RESULTS AND DISCUSSION

#### 3.1 Sonochemical decomposition of Methyl Orange

Sonication experiments were conducted with Methyl Orange solutions to study the decomposition of 50 mg/L dye solution at room temperature. Figure -5 represents the effect of sonolytic decomposition of MO in aqueous solution.



Comment [R12]: No italic.

Comment [R13]: Standardize for other subtopics.

Comment [R14]: No bold.

Comment [R15]: Adjust the units on the graph axes according to suggestions in Figure 4.

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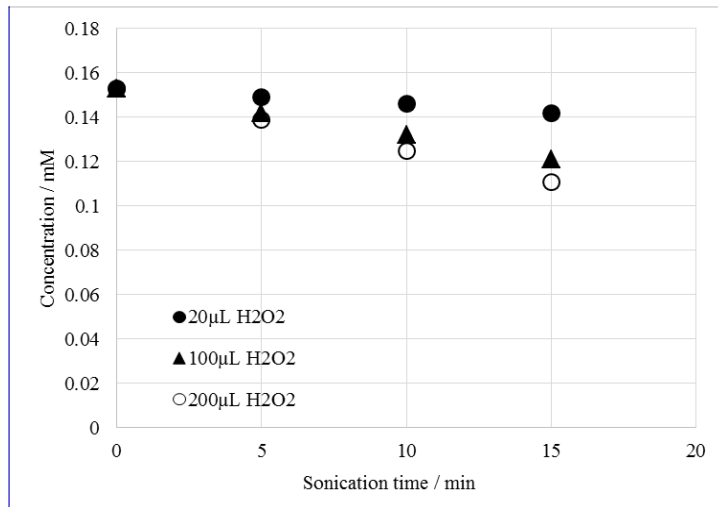
**Figure-5:** Sonochemical decomposition of methyl orange in the absence of additives.

As it can be seen from Figure 5, the concentration of MO decreased gradually as the sonication time increased. So, it can be said that, MO degrades gradually with the increase in sonication time. When no sonication occurred the concentration of MO was 0.153 mM. After sonicating for 5 mins, 10 mins and 15 mins, the concentration decreased gradually.

#### a) Sonochemical decomposition of Methyl Orange in presence of different concentration of $H_2O_2$

One of the most popular advanced oxidation processes (AOPs) methods for decomposition of organic compounds is the oxidation with  $H_2O_2$ . In the presence of  $H_2O_2$  is a key parameter for dye decomposition in AOPs technique, depending on its concentration and nature of reductants  $H_2O_2$  increase the formation rate of hydroxyl radicals in two ways. Firstly, the reduction of  $H_2O_2$  at the conduction band would produce hydroxyl radicals. Secondly, the self-decomposition as a result of ultrasound irritation would also produce hydroxyl radicals. Generally, the decolorization rate of dye increases as the  $H_2O_2$  concentration increases until an optimal concentration is achieved [22]. Recently, ultrasound irradiation was described as a possible generation of highly active OH, HOO, and H radicals [23]. However, at high concentration,  $H_2O_2$  can also become a scavenger of valence bond holes and OH radicals causing less dye to be degraded. The effect of ultrasonic irradiation combined with  $H_2O_2$  is observed only when free radical attack is the controlling mechanism. In order to investigate the effect induced from the addition of different concentration of  $H_2O_2$ , the sonolytic degradation of 100 mL of MO solution was performed. The concentrations of  $H_2O_2$  used were 20  $\mu$ L, 100  $\mu$ L, and 200  $\mu$ L of  $H_2O_2$  solution. These results are illustrated in Figure -6.

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**Comment [R17]:** Adjust the units on the graph axes according to suggestions in Figure 4.

Standardize: H<sub>2</sub>O<sub>2</sub> not H2O2. For Figures 7, 8 and 9 also.

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218 **Figure-6:** Sonochemical decomposition of methyl orange in the presence of different  
219 concentrations of H<sub>2</sub>O<sub>2</sub>.

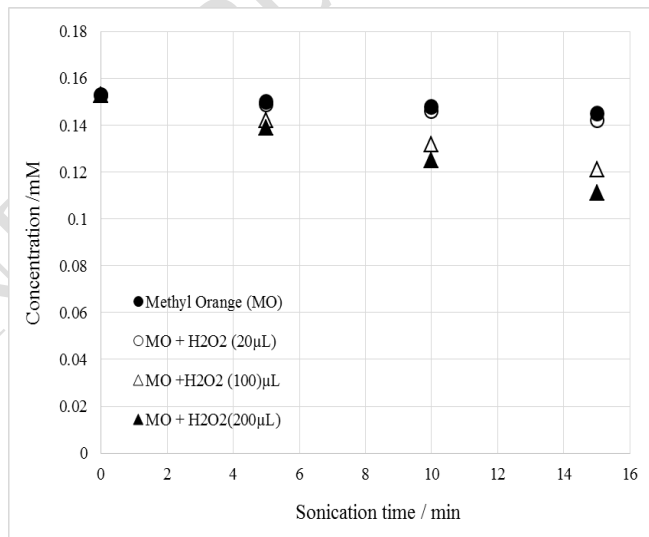
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221 The rate of dye decomposition increases with the increasing of concentration of H<sub>2</sub>O<sub>2</sub>.

222 *b) Comparison of sSonochemical dDecomposition of Methyl Orange (MO) with and&*  
223 *without dDifferent eConcentrations of H<sub>2</sub>O<sub>2</sub>.*

224 In the presence of ultrasound, the decomposition of MO without H<sub>2</sub>O<sub>2</sub> increased. But when  
225 H<sub>2</sub>O<sub>2</sub> added to the solution of MO, it enhances the rate of decomposition of MO. The higher  
226 the concentration H<sub>2</sub>O<sub>2</sub>, the rate of decomposition of MO also increases. (Figure 7).

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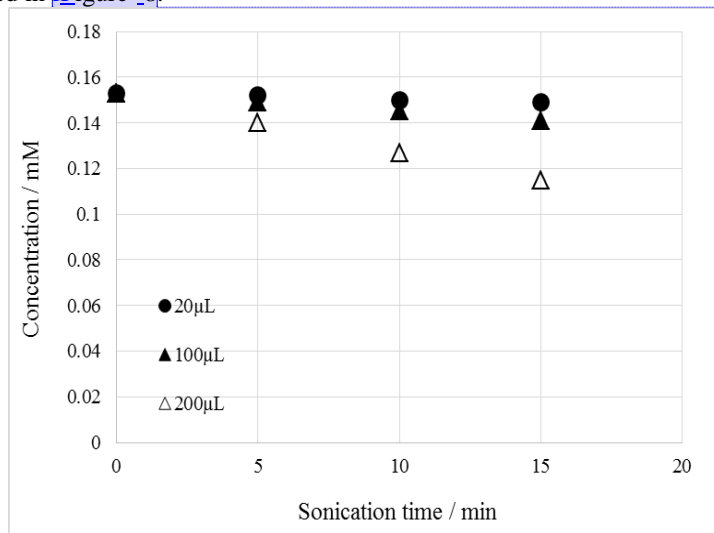
230 **Figure-7:** Comparison of sonochemical decomposition of MO with and without different  
231 concentrations of H<sub>2</sub>O<sub>2</sub>.

232 According to this [Figure 7](#) shows the increase in the concentration of H<sub>2</sub>O<sub>2</sub>, increasing the  
 233 rate of decomposition of MO and follows the trend of sequences below:  
 234 MO<sub>+</sub>200 μL H<sub>2</sub>O<sub>2</sub> > MO<sub>+</sub>100 μL H<sub>2</sub>O<sub>2</sub> > MO<sub>+</sub>20 μL H<sub>2</sub>O<sub>2</sub> > MO.

235  
 236 e) *Sonochemical Decomposition of Methyl Orange in Presence of Different*  
 237 *Concentrations of CCl<sub>4</sub>*

238 In order to investigate the effects induced from the addition of different concentration of  
 239 CCl<sub>4</sub>, the sonolytic decomposition of 100 mL of MO solution was performed. [Here](#) ~~†~~The  
 240 concentrations of CCl<sub>4</sub> used ~~were~~are 20 μL, 100 μL, and 200 μL, respectively. These results  
 241 are illustrated in [Figure- 8](#).

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 244 **Figure-8:** Sonochemical decomposition of methyl orange in the presence of different  
 245 concentrations of CCl<sub>4</sub>.

246  
 247 The rate of dye decomposition increases with the increasing of concentration of CCl<sub>4</sub>.  
 248 Recently, it has been reported that the analysis for the rate of the sonochemical  
 249 decomposition of organic compounds in water can be colorimetrically performed to  
 250 understand the sonochemical efficiency, where the rate of the sonochemical decomposition is  
 251 suggested to be reasonably correspondent to the yield of H<sub>2</sub>O<sub>2</sub>. For examples, porphyrins [24]  
 252 are so far used for the model compounds. These methods would be convenient for the  
 253 analysis of the sonochemical efficiency under an ultrasonic irradiation condition. Our results  
 254 suggested that the sonochemical decomposition of MO in the presence of CCl<sub>4</sub> would be  
 255 useful to evaluate the sonochemical efficiency, because the rate of the MO decomposition can  
 256 be effectively enhanced by the sonolysis of CCl<sub>4</sub>.

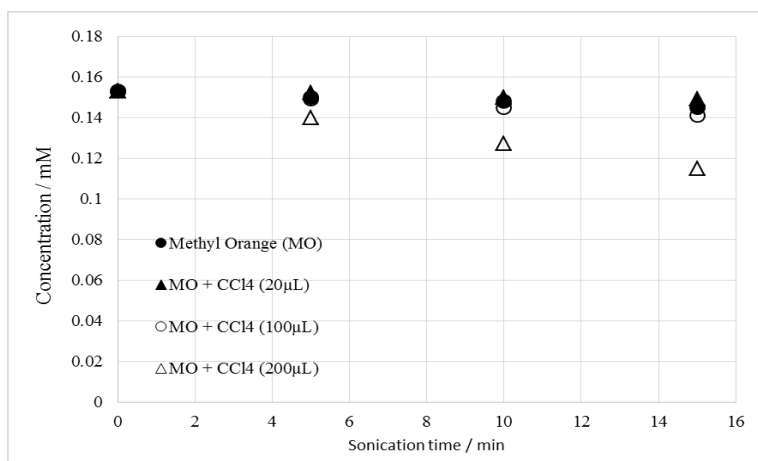
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 258 e) *Comparison of Decomposition of Methyl Orange (MO) with and without Different*  
 259 *concentrations of CCl<sub>4</sub>*

260 In this study, it was found that the rate of the MO decomposition could be enhanced by the  
 261 addition of CCl<sub>4</sub>. This reason could be qualitatively explained by the sonochemical  
 262 decomposition of CCl<sub>4</sub> to form various types of active species, which can react with MO  
 263 molecules. It has been reported that the sonolysis of CCl<sub>4</sub> in water occurs as seen in [Equations](#)  
 264 [below Eqs.](#)[25].



265  $\text{CCl}_4 \rightarrow \cdot\text{CCl}_3 + \cdot\text{Cl}$   
 266  $\cdot\text{CCl}_3 \rightarrow \cdot\text{CCl}_2 + \cdot\text{Cl}$   
 267  $2\cdot\text{CCl}_3 \rightarrow \text{C}_2\text{Cl}_6$   
 268  $2\cdot\text{CCl}_2 \rightarrow \text{C}_2\text{Cl}_4$   
 269  $2\cdot\text{Cl} \rightarrow \text{Cl}_2$   
 270  $\text{Cl}_2 + \text{H}_2\text{O} \rightarrow \text{HCl} + \text{HClO}$   
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 274 **Figure-9:** Comparison of sonochemical decomposition of MO with and without different  
 275 concentrations of  $\text{CCl}_4$ .  
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277 In the presence of ultrasound, the decomposition of MO without  $\text{CCl}_4$  increased. But when  
 278  $\text{CCl}_4$  added to the solution of MO, it enhances the rate of decomposition of MO. The higher  
 279 the concentration  $\text{CCl}_4$ , the rate of decomposition of MO also increases. Based on the  
 280 obtained results, it was suggested that the enhancement effect was dependent on the  
 281 ultrasonic irradiation condition. This would be due to that the cavitation phenomenon induced  
 282 by ultrasonic irradiation is sensitively affected by the experimental conditions such as  
 283 ultrasound frequency and power, volume of solution, etc. For example, a change in the  
 284 ultrasound frequency may affect one or many of the following factors [24,-26]: (1) the  
 285 temperature and pressure inside the collapsing cavitation bubbles,(2) the number and  
 286 distribution of bubbles, (3) the size and lifetime of bubbles, (4) the dynamics and symmetry  
 287 (shape) of the bubble collapse, (5) the effect of organic additive on bubble temperature, (6)  
 288 the effect of intermediates and products, etc. It is quite difficult to quantify the individual  
 289 effects of these factors, since they are interdependent and it is almost impossible to control  
 290 one factor without affecting the others. In addition, the rate of the decomposition would be  
 291 affected by the geometrical placement of the instrumental components such as the shape of  
 292 the reaction cell, the volume of the sample solution, the size of the used ultrasonic oscillator,  
 293 etc. According to, increase in concentration of  $\text{CCl}_4$ , the increasing rate of decomposition of  
 294 MO can be written as (Figure 9):-  $\text{MO} + 200 \mu\text{L CCl}_4 > \text{MO} + 100 \mu\text{L CCl}_4 > \text{MO} + 20 \mu\text{L}$   
 295  $\text{CCl}_4 > \text{MO}$   
 296  $\text{MO} + 200 \mu\text{L CCl}_4 > \text{MO} + 100 \mu\text{L CCl}_4 > \text{MO} + 20 \mu\text{L CCl}_4 > \text{MO}$  (Figure: 9).  
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 298

#### 299 4. CONCLUSION

300 | Sonochemical decomposition of methyl orange (MO) was studied in the absence and  
 301 | presence of different concentrations of H<sub>2</sub>O<sub>2</sub> and CCl<sub>4</sub>. MO molecule can be effectively  
 302 | removed from water by sonolysis. This study exhibits that the sonochemical decomposition  
 303 | occurs mainly through reactions with hydroxyl and chloride radicals. It was found that the  
 304 | initial decomposition of MO molecule increased. But by the addition of CCl<sub>4</sub> and also for  
 305 | H<sub>2</sub>O<sub>2</sub>, the rates of sonochemical decomposition of MO were enhanced. This process is  
 306 | technically feasible & also economic. Eventually reached to a conclusion. According to,  
 307 | increase in concentration of CCl<sub>4</sub>, the increasing rate of decomposition of MO can be written  
 308 | as:- MO + 200 μL CCl<sub>4</sub> > MO + 100 μL CCl<sub>4</sub> > MO + 20 μL CCl<sub>4</sub> > MO. Similarly, for  
 309 | H<sub>2</sub>O<sub>2</sub>, the increasing rate of decomposition of MO can be written as:- MO + 200 μL H<sub>2</sub>O<sub>2</sub> >  
 310 | MO + 100 μL H<sub>2</sub>O<sub>2</sub> > MO + 20 μL H<sub>2</sub>O<sub>2</sub> > MO.

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**Comment [R20]:** References have been adjusted. See latest manuscripts published in this Journal.

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