

Electronic Supplementary information for
improved VRC-3R⁻ model for bulk water residual chlorine decay in
the UV/Cl₂ process for a water distribution network

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TextS1.'VRC---3R-' model.

The residual chlorine decay model in the UV/Cl₂ process was derived based on the 2R model. The free radicals were added based on simple chlorine disinfection, and the non-free radical part was decomposed and extended according to the non-free radical's quick reaction part and the non-free radical's slow reaction part. In addition to the extended reaction rate constant, so it was called the 3R model. Besides, the OH• radicals were modified, and the influence of temperature was taken into account in the experiment's design and data fitting, so the model was eventually called "VRC-3R" model.

Similar to the 2R and VRC model, the 'VRC-3R-' model could accurately simulate the bulk water residual chlorine decay process with different water quality and external conditions by only three reaction coefficients. The steps were as follows:

The faster radical-chlorine decay first-order kinetics was defined as eq (1):

$$\frac{dC_{f1}}{dt} = -(K_1 \times C_{RCS} \times C_{f1}) \quad (1)$$

where C_{f1} was the concentration of RCS reacted with impurities in water, and K_1 was the rate constant of the RCS, which was expressed as eq(2):

$$K_1 = \frac{\sum_{i=1}^n [K_{RCS,i} \times C_{f1,i}]}{C_{f1}} \quad (2)$$

where $C_{f1,i}$ was the total chlorine decays' concentration of chlorine reactants i after time t , and $K_{RCS,i}$ was the rate constant of the chlorine reactants i and RCS's reaction, which was expressed as eq(3):¹

$$K_{RCS,i} = \frac{\sum_{j=1}^n [K_{i,j} C_{RCS,i}]}{C_{RCS}} \quad (3)$$

where $K_{i,j}$ was the rate constant between the i th chlorine reactant and the j th RCS; $C_{RCS,i}$ was the concentration of RCS when the i th chlorine reactant reacted with the j th RCS.

eq(2) and eq(3) were derived from the VRC model, explaining different types of complex reactions free radicals have with different types of chlorine reactants in water, as well as the influence of two factors, including the effects of different free radical and chlorine reactant concentrations in water on the equilibrium constant.

In the equation above, NRFC (None radical free chlorine) that reacted slower was also contained in this 2R model, which was expressed as follows as eq(4)(5):²

$$\frac{dC_{s1}}{dt} = -K_2 \times C_{Cl} \times C_{s1} \quad (4)$$

$$\frac{dC_{s2}}{dt} = -K_3 \times C_{Cl} \times C_{s2} \quad (5)$$

where C_{s1} , C_{s2} were faster and slower reactive substance concentrations in NRFC, respectively, and then the following equation was obtained:

$$\frac{dC_s}{dt} = \frac{dC_{s1}}{dt} + \frac{dC_{s2}}{dt} = -(K_2 \times C_{Cl} \times C_{s1} + K_3 \times C_{Cl} \times C_{s2}) \quad (6)$$

where C_s was the concentration of NRFC that reacted with impurities in the water, which reacted slower than RCS. K_2 , and K_3 , were the rate constants of faster RCS and slower NRFC, respectively.

Similarly, according to the VRC model:

$$K_2 = \frac{\sum_{i=1}^n [K_{2,i} \mathbf{g} C_{S1,i}]}{C_{S1}} \quad (7)$$

$$K_3 = \frac{\sum_{i=1}^n [K_{3,i} \mathbf{g} C_{S2,i}]}{C_{S2}} \quad (8)$$

Where $K_{2,i}$ was the rate constant of chlorine reactants i and NRFC's reaction; $C_{S1,i}$ was the residual chlorine concentration when the i th chlorine reactant reacted with NRFC; $K_{3,i}$ was the rate constant of the reaction between chlorine reactants i and NRFC in the slower part; $C_{S2,i}$ was the residual chlorine concentration that was a reaction of the i th chlorine with NRFC in slower part.

The solution of the two differential equations above, including eq (7) (8), was solved using the method proposed by Zhong Dan in 2010, which needs further investigation based on the results of this study.¹

Additionally, it was worth mentioning that the dynamics of pollutants in water reaction with ROS were expressed in eq (9):

$$dC_{f2} / dt = -(K_4 \times C_{ROS} \times C_{f2}) \quad (9)$$

where C_{f2} and K_4 were concentration and rate constants of impurities reacted with ROS, respectively.

Accordingly, it was concluded in eq(10) that the residual chlorine decay rate was expressed under the UV irradiation:

$$\frac{d[Cl_2]}{dt} = \frac{dC_{f1}}{dt} + \frac{dC_{S1}}{dt} + \frac{dC_{S2}}{dt} - \frac{dC_{f2}}{dt} = -(K_1 \times C_{CRCS} \times C_{f1} + K_2 \times C_{Cl} \times C_{S1} + K_3 \times C_{Cl} \times C_{S2} - K_4 \times C_{ROS} \times C_{f2}) \quad (10)$$

$$\text{i.e. } K_{1f} = K_1 \times C_{f1}, \quad K_{2s} = K_2 \times C_{S1} \quad K_{3s} = K_3 \times C_{S2} \quad K_{4s} = C_{ROS} \times C_{f2}$$

The reason why the contribution of ROS was reduced was that they bore the

impurities to be degraded, which were borne by effective chlorine (RCS and NRFC), so it objectively reduced the amount and concentration of the impurities reacted with effective chlorine, as well as the reaction rate of effective chlorine and impurities, thus leading to the reduction of the residual chlorine decay coefficient. Therefore, the reaction kinetics equation above minus ROS and reaction kinetics equation of impurities were used to indicate the reduction of the residual chlorine decay coefficient after sharing the degradation by ROS's pressure.

In all, it was easy to conclude that even if C_{ROS} objectively reduced part of the residual chlorine decay rate, the total reaction rate increased. These changes in the reaction rate were all caused by UV irradiation, so the residual chlorine decay curve and rate constant's difference between using UV/Cl₂ and chlorine disinfection were the total UV effects. Hence it was explained as follows as eq(11):

$$K_{1f} \times C_{RCS} + (K_{2s} + K_{3s}) \times C_{Cl} - K_{4s} \times C_{ROS} = (k_b + k_1 - k_2)[Cl_2] \quad (11)$$

$$\text{i.e. } K [Cl_2] = (K_{2s} + K_{3s})$$

where $(K_{2s}+K_{3s})$ represented the sum of the ROS's total decay rate coefficient.

The above derivation of the residual chlorine decay model in the UV/Cl₂ process was based on 2R model, extending from the decomposition of the reaction rate under simple chlorine addition to free radicals, non-radical's fast reaction and non-radical's slow reaction, so it was called 3R model. Furthermore, the discount chlorinated reactant of ROS was modified here, and the influence of temperature was taken into account in the experimental design and data fitting, and finally, the model was called 'VRC-3R' model.

Text S2. Photolysis experiments.

UV lamps of 6, 12, 16, 20 and 25 W in 254 nm wavelength were placed around the box's inner surface, respectively, to measure the UV intensity of each light opened. Because there were 5 lights, in order to measure the remaining 25 W UV light, one of the box's inside surface was removed, and the unplaced 25 W light was measured. The distance between the reactor internal lamp tube and the beaker was also fixed, so only the need was necessary to adjust the watt number of the lamp directly as a parameter. What we need to measure is the average UV intensity within the reactor.³

I. KI/KIO₃ chemical photometer determining each lamp's UV irradiation inside the reactor.

0.6mol/L KI was mixed with 0.1mol/L KIO₃, and pH was controlled to 9.2. The solution was then placed in the beaker with UV reactor. It was irradiated to generate the I₃⁻. According to the literature, the absorbance at 352nm was 26400M⁻¹cm⁻¹.⁴ The I₃⁻ concentration was measured in different UV irradiation times using the Rambo-Bill irradiation law. The formula for UV intensity to be determined was the eq(1) as follows:

$$I_0 = C \times V \times \frac{1}{\Phi} \times \frac{1}{t} \quad (1)$$

Where I₀ was UV intensity (E/s), C was I₃⁻'s concentration (mol/L), Φ was I₃⁻'s quantum yield, which was 0.74 mol/E, t was UV irradiation time (s), and V was reactor's volume. We set length, width and high as a=22cm, b=32cm and h=30cm, so the total Volume was eq(2):

$$V = abh = 22120\text{cm}^3 \quad (2)$$

Meanwhile, we took the effective volume as the beaker volume (1 L).

According to the experimental data and its calculation results, the linear relationship between the concentration and triiodine irradiation time was drawn in the UV reactor with different power of UV lamp in the following Figure 1, obtaining the slope of the fitting line and the UV intensity of each lamp calculated above, as shown in the following Table S1 below

II. The effective optical range of UV reactor

Since the container of the UV reactor was rectangular, the light was decayed internally with uneven distribution. Therefore, we measured the effective optical range for corrections.

Under 5 different powers of UV lamps, a dilute solution of H_2O_2 was used as a photosensitizer to measure the effective light range of ultraviolet light on the reactants, and the calculations were expressed in eq(3)(4)(5) as follows:

$$\frac{dC_t}{dt} = -(2.303 \times \varepsilon \times I_0 \times \Phi_{\text{H}_2\text{O}_2} \times \frac{L}{V}) \times C_0 \quad (3)$$

$$L = -V \ln\left(\frac{C_t}{C_0}\right) / (2.303 \times \varepsilon \times I_0 \times \Phi_{\text{H}_2\text{O}_2} \times C_0) \quad (4)$$

$$L = \sum_{i=6,12,16,20,25W} \frac{L_i}{5} \quad (5)$$

where C_t is H_2O_2 concentration, measured by the method of KMnO_4 , ε was the H_2O_2 light absorption coefficient per mol, L was the reactor effective light range, and $\Phi_{\text{H}_2\text{O}_2}$ was the H_2O_2 quantum yield, which had a value of 1.0 mol/E at 254nm wavelength.

The photolysis experiment of hydrogen peroxide in the UV reactor was linear fitted to the results shown in the following Table S2 and Figure 2 below:

The slope value corresponds to all UV lamps in the calculation above, and the effective light range of the reactor for all models of UV lamps was 3.12 cm.

III. Calculate the average light intensity in the UV reactor

The eq(6) for the mean light intensity inside the UV reactor was shown below:

$$I_s = \frac{I_0}{A_{irr}} \quad (6)$$

Where I_s was average UV intensity (E/s), and A_{irr} was UV irradiation area (cm²) which was represented in eq(7) , i.e.

$$A_{irr} = \frac{V_{irr}}{L} \quad (7)$$

where the V_{irr} was UV irradiation volume (cm³) equal to 22.12 L, and L was reactor 's effective optical range equal to 3.12 cm.

Previously, Bolton proposed a correction scheme for UV intensity, as follows as eq(8):

$$E_{act} = Petri\ Factor \times Reflection\ Factor \times Water\ Factor \times Divergence\ Factor \times E_{rad} \quad (8)$$

Where *reflection Factor* was expressed by eq(9):

$$\gamma = 1 - R \quad (9)$$

where γ is equal to 0.975.

Petri factor was tested as 1 by standard methods. The *Water factor* and *Divergence factor* were unknown, but the equation from Li Wentao's literature was showed in eq(10):

$$E_{act} = 1.38 \times E_{rad} \quad (10)$$

Therefore, the correction coefficient was 1.38, and the eq(10) was used to correct the

UV intensity. In addition, It was also found that:

$$\text{Water Factor} \times \text{Divergence Factor} = 1.415 \quad (11)$$

as the basic data used in subsequent studies at the same time.⁵

Finally, it was confirmed that the 1 mol light quantum energy at 254nm wavelength was 4.71×10^5 J/E, then we calculated the average UV intensity of different UV power in the reactor. The result was showed in Figure 3 and Table S3 below:

IV. Integrate with the residual chlorine decay model constructed in Section 2

As derived in section 2, K_a was related to the UV dose, where the experimental design was validated and fitted to establish the model. The eq(16)(17) were as followed as eq(12)(13):

$$I = Ft \quad (12)$$

$$K_a = f(D) = f(F \cdot t) \quad (13)$$

It was noted that all k , θ and s , including k_a , need to be fitted by experiments. Moreover, k_a was related to t in the model derivation, so the decay dynamics model was an exponential quadratic function, which was a nonlinear decay. Even if t was invariant and only the illumination change was controlled, the residual chlorine decay dynamics model still has a primary function in the exponential relationship when constructing the modified relationship between the UV irradiation illumination and the residual chlorine decay coefficient.

TextS3 The measurement method of residual chlorine:

I. Zero-range calibration

Firstly, the zero option was selected by switching the main interface menu window.

Secondly, the ultrapure water was poured into two-thirds of the petri dish which was put into the measuring pool. When putting it in, it was ensured that it could not be sprinkled outside. After that, the colour plate was installed and the slide was covered.

Finally, the confirm button was pressed to the zero.

II. Residual chlorine measurement

Firstly, the measurement options were selected by switching over the main interface menu window. Secondly, a clean beaker was prepared to mix 15 ml of residual chlorine A reagent with 5 ml residual chlorine B reagent, 100 ml water sample was added. Then, when the water sample to be measured became red, the water sample was poured into the petri dish, and was put into the measuring pool. Finally, the slide cap was installed to get the residual chlorine concentration.

III. Save the extraction usage method.

The Save Key was pressed to store up 20 datasets, and the saved data can be queried.

The extraction button was pressed, and the extraction press confirmation button was launched. After that, the measurement state was returned.

TestS4 Reagent preparation process which is necessary for residual chlorine

measurement

Residual chlorine A and B reagents were configured in a portable residual chlorine determination instrument. It was used to determine the residual chlorine's process. The determination of residual chlorine required the preparation, which was the configuration process of residual chlorine reagents A and B. Residual chlorine A and B reagents were dissolved in the ultrapure water. Ultrapure water was added to Reagent A (500 mL/ package), and to reagent B (200mL / package). A separate bottle of residual chlorine H solution (50 mL) was added to each reagent B solution until each residual chlorine B reagent solution was 250mL. The figured reagents were stored in the refrigerator at a temperature of 4-8 °C.

TestS5 Elementary reactions for the UV/Cl₂ process

The chemical equations of the main elementary reactions for the UV/Cl₂ process are listed in Table S4:⁶

Tables

Table S1 Slope of UV intensity change in different UV power

$P(W)$	k	R^2	$I_0(\mu E / s)$
6	0.063	0.9998	0.085 $\mu E / s$
12	0.106	0.9995	0.143 $\mu E / s$
16	0.121	0.9897	0.164 $\mu E / s$
20	0.145	0.9994	0.196 $\mu E / s$
25	0.202	0.9994	0.278 $\mu E / s$

Table S2 H_2O_2 lysis slope of effective light range in different UV power

$P(W)$	k	R^2	$L(\partial m)$
6	-0.105×10^{-4}	0.9997	2.73
12	-0.188×10^{-4}	0.9992	2.91
16	-0.246×10^{-4}	0.9989	3.32
20	-0.315×10^{-4}	0.9998	3.56
25	-0.387×10^{-4}	0.9987	3.08

Table S3 Average UV intensity at different UV power in the reactor

$P(W)$	Average light intensity of the UV reactor ($\mu E / s \cdot cm^2$)	average light intensity of the UV reactor (mW / cm^2)
6	0.2635	1.67
12	0.4433	3.34
16	0.5084	4.22
20	0.6076	5.63
25	0.8616	7.0

Table S4. Elementary reactions for the UV/Cl₂ process destructing organic contaminants

No.	REACTIONS	RATE CONSTANTS, M ⁻¹ S ⁻¹
UV/Cl₂		
1	HOCl + hv → HOg + Clg	$\phi_{\text{HOCl}} = 1.45$ $\varepsilon_{\text{HOCl}} = 59 \text{ M}^{-1} \text{ cm}^{-1}$
2	OCI ⁻ + hv → O ⁻ g + Clg	$\phi_{\text{HOCl}} = 0.97$ $\varepsilon_{\text{HOCl}} = 66 \text{ M}^{-1} \text{ cm}^{-1}$
3	OCI ⁻ + H ⁺ → HOCl	$k_1 = 5 \times 10^{10}$
4	HOCl → OCI ⁻ + H ⁺	$k_2 = 1.6 \times 10^3$
5	O ⁻ g + H ₂ O → HOg + Clg	$k_3 = 1.8 \times 10^6$
6	HOg + OH ⁻ → O ⁻ g + H ₂ O	$k_4 = 1.3 \times 10^{10}$
7	HOg + HOCl → ClOg + H ₂ O	$k_5 = 2 \times 10^9$
8	HOg + OCI ⁻ → ClOg + OH ⁻	$k_6 = 8.8 \times 10^{10}$
9	HOg + HOg → H ₂ O ₂	$k_7 = 5.5 \times 10^9$
10	H ₂ O ₂ → H ⁺ + HO ₂ ⁻	$k_8 = 1.3 \times 10^{-1} \text{ s}^{-1}$
11	H ⁺ + HO ₂ ⁻ → H ₂ O ₂	$k_9 = 5 \times 10^{10}$
12	H ₂ O ₂ + HOg → HO ₂ g + H ₂ O	$k_{10} = 2.7 \times 10^7$

13	$\text{HO}_2^- + \text{HOg} \rightarrow \text{HO}_2\text{g} + \text{OH}^-$	$k_{11} = 7.5 \times 10^9$
14	$\text{HO}_2\text{g} \rightarrow \text{H}^+ + \text{O}_2^-\text{g}$	$k_{12} = 7 \times 10^5 \text{ s}^{-1}$
15	$\text{H}^+ + \text{O}_2^-\text{g} \rightarrow \text{HO}_2\text{g}$	$k_{13} = 5 \times 10^{10}$
16	$\text{HOg} + \text{HO}_2\text{g} \rightarrow \text{H}_2\text{O} + \text{O}_2$	$k_{14} = 6.6 \times 10^9$
17	$\text{HOg} + \text{O}_2^-\text{g} \rightarrow \text{OH}^- + \text{O}_2$	$k_{15} = 1 \times 10^{10}$
18	$\text{H}_2\text{O}_2 + \text{O}_2^-\text{g} \rightarrow \text{OH}^- + \text{O}_2 + \text{HOg}$	$k_{16} = 1.3 \times 10^{-1}$
19	$\text{H}_2\text{O}_2 + \text{HO}_2\text{g} \rightarrow \text{H}_2\text{O} + \text{O}_2 + \text{HOg}$	$k_{17} = 3$
20	$\text{HO}_2\text{g} + \text{HO}_2\text{g} \rightarrow \text{H}_2\text{O}_2 + \text{O}_2$	$k_{18} = 8.3 \times 10^5$
21	$\text{HO}_2\text{g} + \text{O}_2^-\text{g} \rightarrow \text{HO}_2^- + \text{O}_2$	$k_{19} = 9.7 \times 10^7$
22	$\text{Clg} + \text{H}_2\text{O} \rightarrow \text{ClOH}^-\text{g} + \text{H}^+$	$k_{20}[\text{H}_2\text{O}] = 1.3 \times 10^3 \text{ s}^{-1}$
23	$\text{ClOH}^-\text{g} + \text{H}^+ \rightarrow \text{Clg} + \text{H}_2\text{O}$	$k_{21} = 2.1 \times 10^{10}$
24	$\text{ClOH}^-\text{g} \rightarrow \text{OHg} + \text{Cl}^-$	$k_{22} = 6.1 \times 10^9 \text{ s}^{-1}$
25	$\text{OHg} + \text{Cl}^- \rightarrow \text{ClOH}^-\text{g}$	$k_{23} = 4.3 \times 10^9$
26	$\text{ClOH}^-\text{g} + \text{Cl}^- \rightarrow \text{Cl}_2^-\text{g} + \text{OH}^-$	$k_{24} = 1 \times 10^4$
27	$\text{Clg} + \text{Cl}^- \rightarrow \text{Cl}_2^-\text{g}$	$k_{25} = 8 \times 10^9$
28	$\text{Cl}_2^-\text{g} \rightarrow \text{Clg} + \text{Cl}^-$	$k_{26} = 5.3 \times 10^4 \text{ s}^{-1}$
29	$\text{Clg} + \text{Clg} \rightarrow \text{Cl}_2$	$k_{27} = 8.8 \times 10^7$

30	$\text{Cl}_2 + \text{OH}^- \rightarrow \text{HOCl} + \text{Cl}^-$	$k_{28} = 1.0 \times 10^9$
31	$\text{Cl}_2\text{g} + \text{Cl}_2\text{g} \rightarrow \text{Cl}_2 + 2\text{Cl}^-$	$k_{29} = 6.41 \times 10^9$
32	$\text{Clg} + \text{Cl}_2\text{g} \rightarrow \text{Cl}_2 + \text{Cl}^-$	$k_{30} = 2.1 \times 10^9$
33	$\text{Cl}_2\text{g} + \text{H}_2\text{O}_2 \rightarrow \text{H}^+ + 2\text{Cl}^- + \text{HO}_2\text{g}$	$k_{31} = 1.4 \times 10^5$
34	$\text{Cl}_2\text{g} + \text{HO}_2\text{g} \rightarrow \text{H}^+ + 2\text{Cl}^- + \text{O}_2$	$k_{32} = 3 \times 10^9$
35	$\text{Cl}_2\text{g} + \text{O}_2\text{g} \rightarrow \text{Cl}^- + \text{O}_2$	$k_{33} = 1 \times 10^9$
36	$\text{Cl}_2\text{g} + \text{H}_2\text{O} \rightarrow \text{Cl}^- + \text{HClOH}$	$k_{34}[\text{H}_2\text{O}] = 1.3 \times 10^3 \text{ s}^{-1}$
37	$\text{Cl}_2\text{g} + \text{OH}^- \rightarrow \text{Cl}^- + \text{ClOH}^- \text{g}$	$k_{35} = 4.5 \times 10^7$
38	$\text{HClOH} \rightarrow \text{ClOHg} + \text{H}^+$	$k_{36} = 1.0 \times 10^2 \text{ s}^{-1}$
39	$\text{HClOH} \rightarrow \text{Clg} + \text{H}_2\text{O}$	$k_{37} = 5.0 \times 10^9 \text{ s}^{-1}$
40	$\text{HClOH} + \text{Cl}^- \rightarrow \text{Cl}_2\text{g} + \text{H}_2\text{O}$	$k_{38} = 1.0 \times 10^8$
41	$\text{Clg} + \text{H}_2\text{O}_2 \rightarrow \text{H}^+ + \text{Cl}^- + \text{HO}_2\text{g}$	$k_{39} = 2.0 \times 10^9$
42	$\text{Cl}_2\text{g} + \text{HOg} \rightarrow \text{HClO} + \text{Cl}^-$	$k_{40} = 1.0 \times 10^9$
43	$\text{Cl}_2 + \text{H}_2\text{O} \rightarrow \text{HClO} + \text{Cl}^- + \text{H}^+$	$k_{41}[\text{H}_2\text{O}] = 15 \text{ s}^{-1}$
44	$\text{Cl}_2 + \text{O}_2\text{g} \rightarrow \text{O}_2 + \text{Cl}_2\text{g}$	$k_{42} = 1.0 \times 10^9$
45	$\text{Cl}_2 + \text{HO}_2\text{g} \rightarrow \text{H}^+ + \text{O}_2 + \text{Cl}_2\text{g}$	$k_{43} = 1.0 \times 10^9$
46	$\text{HOCl} + \text{O}_2\text{g} \rightarrow \text{OH}^- + \text{O}_2 + \text{Cl}_2\text{g}$	$k_{44} = 7.5 \times 10^6$

47	$\text{HOCl} + \text{HO}_2\text{g} \rightarrow \text{H}_2\text{O} + \text{O}_2 + \text{Cl}_2\text{g}$	$k_{45} = 7.5 \times 10^6$
48	$\text{Clg} + \text{HOCl} \rightarrow \text{H}^+ + \text{Cl}^- + \text{ClOg}$	$k_{46} = 3.0 \times 10^9$
49	$\text{Clg} + \text{OCl}^- \rightarrow \text{Cl}^- + \text{ClOg}$	$k_{47} = 8.2 \times 10^9$
50	$\text{Clg} + \text{OH}^- \rightarrow \text{ClOHg}^-$	$k_{48} = 1.8 \times 10^{10}$
51	$\text{ClOg} + \text{ClOg} \rightarrow \text{Cl}_2\text{O}_2$	$k_{49} = 2.5 \times 10^9$
52	$\text{Cl}_2\text{O}_2 + \text{H}_2\text{O} \rightarrow \text{HClO} + \text{H}^+ + \text{ClO}_2^-$	$k_{50}[\text{H}_2\text{O}] = 2.5 \times 10^9 \text{ s}^{-1}$
53	$\text{Cl}_2\text{O}_2 + \text{OH}^- \rightarrow \text{OCl}^- + \text{H}^+ + \text{ClO}_2^-$	$k_{51} = 2.5 \times 10^9$
54	$\text{ClOg} + \text{HOg} \rightarrow \text{ClO}_2^- + \text{H}^+$	$k_{52} = 1.0 \times 10^9$
55	$\text{ClO}_2^- + \text{HOg} \rightarrow \text{ClO}_2\text{g} + \text{OH}^-$	$k_{53} = 6.3 \times 10^9$
56	$\text{ClO}_2\text{g} + \text{HOg} \rightarrow \text{ClO}_3^- + \text{H}^+$	$k_{54} = 4.0 \times 10^9$
57	$\text{ClO}_2^- + \text{Cl}_2\text{g} \rightarrow \text{ClO}_2\text{g} + 2\text{Cl}^-$	$k_{55} = 1.3 \times 10^8$
58	$\text{ClO}_2^- + \text{ClOg} \rightarrow \text{ClO}_2\text{g} + \text{OCl}^-$	$k_{56} = 9.4 \times 10^8$
59	$\bullet\text{OH} + \text{ClO}_2^- \rightarrow \text{OH}^- + \text{ClO}_2$	$k_{59} = 7.0 \times 10^9 \text{ M}^{-1}\text{s}^{-1}$
60	$\bullet\text{Cl} + \text{ClO}_2^- \rightarrow \text{Cl}^- + \text{ClO}_2$	$k_{60} = 7.0 \times 10^9 \text{ M}^{-1}\text{s}^{-1}$
61	$\bullet\text{Cl} + \text{ClO}_2 \rightarrow \text{Cl}_2\text{O}_2$	$k_{61} = 4.0 \times 10^9 \text{ M}^{-1}\text{s}^{-1}$
62	$\bullet\text{OH} + \text{ClO}_3^- \rightarrow \text{products}$	$k < 10^6 \text{ M}^{-1}\text{s}^{-1}$
63	$\bullet\text{Cl} + \text{ClO}_3^- \rightarrow \text{products}$	$k < 10^6 \text{ M}^{-1}\text{s}^{-1}$

Figures

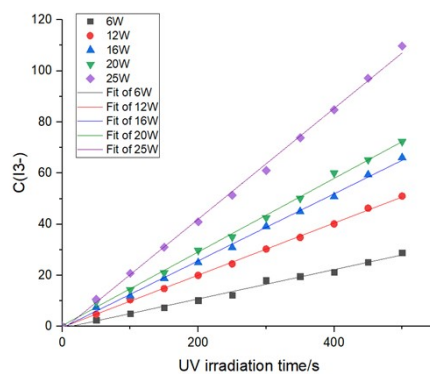


Figure 1 Formation of I_3^- under 254nm UV radiation in different power's UV lamp

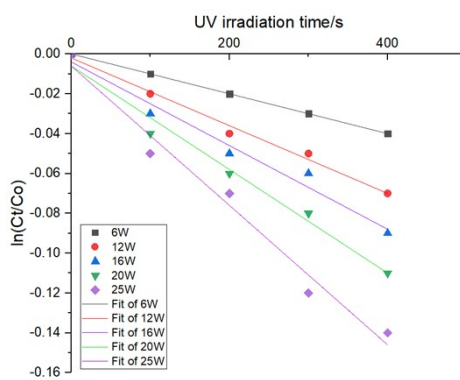


Figure 2 H_2O_2 lysis change at different UV lamp power

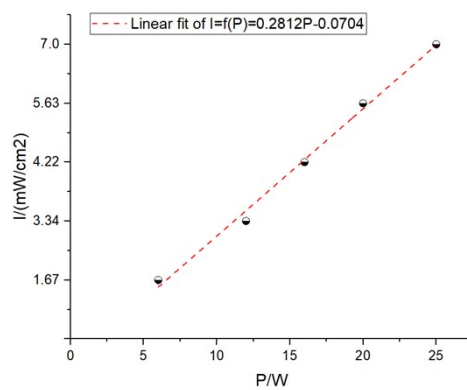


Figure 3 Linear relationship between different power and average UV intensity in the reactor

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