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### Data Article

# Data for persulfate activation by UV light to degrade theophylline in a water effluent

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#### ABSTRACT

The aim of this study was to degrade theophylline (TP) drug in a pharmaceutical effluent solution utilizing persulfate (PS). A simulated and a real effluent solution were used, with different conditions tested to optimize the degradation process. HPLC analyses and a modified-HPLC method were used to track concentrations of TP and PS respectively in the treatment process. Experiments were done in triplicates and treated data is presented as graphs. A detailed analyses of this study can be found in the article "Degradation of theophylline in a UV<sub>254</sub>/PS system: matrix effect and application to a factory effluent" [1] published in Chemical Engineering Journal.

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Specifications Table

<b>Subject</b>	Water Science and Technology
<b>Specific subject area</b>	water treatment, AOPs, UV <sub>254</sub> , persulfate
<b>Type of data</b>	Table Figure
<b>How data were acquired</b>	High performance liquid chromatography (HPLC, Agilent 1100 series)
<b>Data format</b>	Raw and Analyzed
<b>Parameters for data collection</b>	Experiments were done in triplicates in separate reactors. Room temperature was maintained throughout the reactions.
<b>Description of data collection</b>	HPLC coupled to DAD was used to track TP concentrations throughout the reaction. A modified-HPLC method utilizing KI was used to track PS concentrations. The average and error bars were obtained for each data point presented in the graph.
<b>Data source location</b>	American University of Beirut Beirut Lebanon
<b>Data accessibility</b>	Within the article
<b>Related research article</b>	<b>Author's name</b> Suha Al Hakim, Saly Jaber, Nagham Zein Eddine, Abbas Baalbaki, Antoine Ghauch* * Corresponding Author: e mail <a href="mailto:antoine.ghauch@aub.edu.lb">antoine.ghauch@aub.edu.lb</a> Phone: +961 1350 000 Fax: +961 1 365 217 <b>Title</b> Degradation of theophylline in a UV <sub>254</sub> /PS system: matrix effect and application to a factory effluent [1] <b>Journal</b> Chemical Engineering Journal <b>DOI</b> <a href="https://doi.org/10.1016/j.cej.2019.122478">https://doi.org/10.1016/j.cej.2019.122478</a>

**Value of the Data**

- Data related to treatment of a pharmaceutical effluent solution using a UV/PS system is presented.
- Researchers involved in advanced oxidation processes and treatment of pharmaceuticals in water can benefit from the following data.
- Presented data can be utilized to develop a continuous treatment system for pharmaceutical effluents by taking into consideration the effects of spiking the reactor with the oxidant or the pharmaceutical. Additionally, effect of phosphates and comparison between two different oxidants provide useful information in this process.
- The homemade reactor's setup can be utilized by other interested researchers in a study where similar commercially available UV lamps are used and system cooling is required.

**1. Data**

Calibration curve and some properties for TP and presented in Fig. 1.

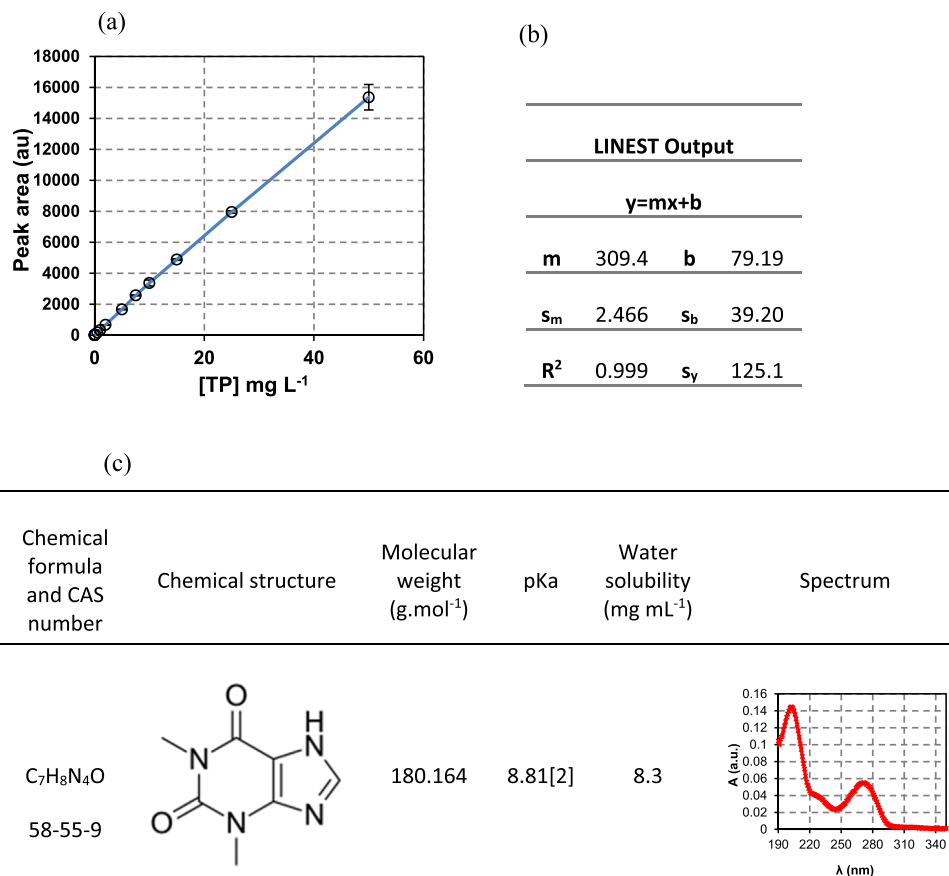
The observed rate constants, obtained for pseudo-first order fitting, for degradation of TP at different  $[PS]_0$  is presented in Table 1.

A mini review of effects of chlorides and bicarbonates on the degradation of different organic probes in PS-based AOPs are presented in Table 2 and Table 3 respectively.

TP degradation in UV/PS system in the presence of phosphates (Fig. 2) and chloroform (Fig. 4) is studied in a simulated pharmaceutical effluent with  $[TP]_0 = 10 \text{ mg L}^{-1}$  and  $[PS]_0 = 0.25 \text{ mM}$ . Comparison between UV and base activation of PS is studied with 10 mM phosphate buffer at pH = 11 used (Fig. 3). Additionally, H<sub>2</sub>O<sub>2</sub> and PS oxidants are compared (Fig. 5).

A real effluent solution containing  $[TP]_0 \approx 160 \text{ mg L}^{-1}$  is treated with simultaneous and successive additions of PS (Fig. 6a). The UV<sub>254</sub>/PS system was studied upon spiking the reactor with varying amounts of concentrated effluent solution (Fig. 6b).

The raw data corresponding to all figures and tables can be found in the file "raw data" within this article. These data include concentrations of TP and PS and the standard deviation for their measurement.



**Fig. 1.** (a) Calibration curve of TP obtained using HPLC/DAD at wavelength of 270 nm, (b) LINEST output for TP calibration curve, and (c) selected TP characteristics [2].

**Table 1**

Degradation of  $[TP]_0 = 10 \text{ mg L}^{-1}$  at  $[PS]_0 = 0.01\text{--}0.5 \text{ mM}$ .  $k_{\text{obs}}$  and linearity constant ( $R^2$ ) obtained for plots of  $\ln \frac{[TP]_t}{[TP]_0}$  versus time (min) for tested conditions upon first order fitting are presented.

[TP] ppm	[PS] <sub>0</sub> mM	$k_{\text{obs}} \times 10^{-1} \text{ (min}^{-1}\text{)}$	$R^2$
10	0.01	0.04 ( $\pm 0.01$ )	0.9675
	0.1	0.49 ( $\pm 0.02$ )	0.9553
	0.25	1.74 ( $\pm 0.06$ )	0.9933
	0.5	3.7 ( $\pm 0.2$ )	0.955

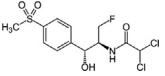
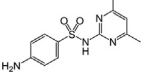
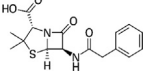
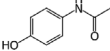
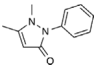
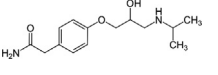
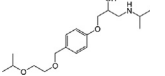
## 2. Experimental design, materials, and methods

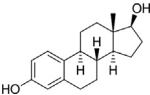
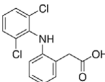
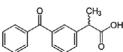


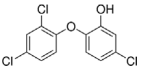
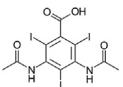
### 2.1. Experimental setup: UV reactors

A bench-scale experimental setup was used simulating the commercial UV water sterilization apparatus. Six units of a generic *1 gallon per minute* UV water disinfection element (Fig. 7a) were used in the construction of the experimental setup. The commercial units utilized originally consist of a UV 11-W low-pressure mercury lamp (LPHgL) (Philips TUV 11W G11 T5, Poland), fitted in a quartz tube

**Table 2**

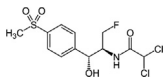
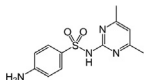
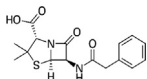
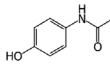
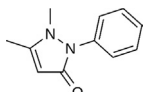
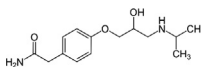
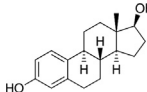
Review of the effect of chloride ( $\text{Cl}^-$ ) presence on the degradation of several organic probes in Persulfate activated systems. (+) and (-) represent an increase or a decrease in the degradation rate constant of the oxidation reaction, respectively.

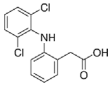
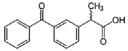

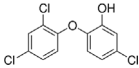
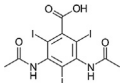
Family	Probe	Structure	PS system used	$[\text{PS}]_0$ mM	$[\text{Cl}^-]$ (mM)	$[\text{NaCl}]$ ( $\text{mg L}^{-1}$ )	Effect on $k_{\text{obs}}$	Main reactive radical species	Reference
Antibiotic	Florfenicol		UV/PS	1	1, 10, 100	58.4, 584, 5844	-	No data	[3]
	Sulfamethazine		Heat/PS	2	5, 10 100, 200	292, 584 5844, 11688	Negligible effect +	$\text{SO}_4^{\bullet-}$	[4]
	Penicillin G		Heat/PS	0.5	0.171 0.0943	10 5.51	- -	$\text{SO}_4^{\bullet-}$	[5]
Antipyretic	Acetaminophen		$\text{Fe}^{2+}/\text{PS}$	0.8	0.1	5.84	Negligible effect -	$\text{SO}_4^{\bullet-}$	[6]
			UV/PS	0.132	2, 10, 20	116.9 292, 584 117, 584, 1169	+ +	$\text{SO}_4^{\bullet-}$	[7]
	Antipyrine		Heat/PS	1.855	50, 100 18.5 1850	2922, 5844 1081 108114	- + -	$\text{SO}_4^{\bullet-}$	[8]
Beta blocker	Atenolol		Heat/PS	0.5	1, 5, 10, 50	58.4, 292, 584, 2922	Negligible effect	$\text{SO}_4^{\bullet-}$	[9]
	Bisoprolol		Heat/PS	1	0.0855	5	+	$\text{SO}_4^{\bullet-}$ , $\text{OH}^{\bullet}$	[10]

Hormone	17 $\beta$ -estradiol		UV/PS	Slow-release flow through system	0.028, 0.282, 2.82 28.2, 42.3 56.4, 564, 846, 1269	1.6, 16.5, 165 1648, 2472 3256, 32960, 49440, 74160	- + -	SO <sub>4</sub> <sup>•-</sup>	[11]
Nonsteroidal anti-inflammatory	Diclofenac		UV/PS	1	25, 50 100, 200	1461, 2922 5844, 11688	+ -	No data	[12]
	Ketoprofen		Heat/PS UV/PS Fe <sup>2+</sup> /PS	1 0.1 0.5	3.42 34.2, 342 3.42, 342 3.42, 34.2, 342	200 2000, 20000 200 2000, 20000 200, 2000, 20000	+ - + - -	No data	[13]
Persistent organic molecules Pesticides	Cyclohexanoic acid		UV/PS	2	14.1	824	-	OH <sup>•</sup>	[14]
	1,1,1-Trichloroethane		Heat/PS	15	1 10, 100	58.4 584.4, 5844	Negligible effect -	No data	[15]
	Triclosan		Heat/PS	0.155	0.15, 1, 10 20, 50	8.8, 58.4, 584.4 1169, 2922	- +	SO <sub>4</sub> <sup>•-</sup>	[16]
	Diatrizoate		UV/PS	12	1, 10, 100 500	58.4, 584.4, 5844 29220	Negligible effect -	SO <sub>4</sub> <sup>•-</sup>	[17]

**Table 3**

Review of the effect of bicarbonate ( $\text{HCO}_3^-$ ) presence on the degradation of several organic probes in Persulfate activated systems. (+) and (-) represent an increase or a decrease in the degradation rate constant of the oxidation reaction, respectively.

Family	Probe	Structure	PS system used	$[\text{PS}]_0$ mM	$[\text{HCO}_3^-]$ (mM)	Effect on $k_{\text{obs}}$	Main reactive radical species	Reference
Antibiotic	Florfenicol		UV/PS	1	1, 10, 100	-	No data	[3]
	Sulfamethazine		Heat/PS	2	5, 10, 50	+	$\text{SO}_4^{\bullet-}$	[4]
	Penicillin G		Heat/PS	0.5	0.0943	-	$\text{SO}_4^{\bullet-}$	[5]
Antipyretic	Acetaminophen		UV/PS	0.132	2 10, 20, 50, 100	- +	$\text{SO}_4^{\bullet-}$	[7]
	Antipyrine		Heat/PS	1.855	18.55, 92.75, 185.5, 927.5	-	$\text{SO}_4^{\bullet-}$	[8]
Beta blocker	Atenolol		Heat/PS	0.5	1, 5, 10, 50	-	$\text{SO}_4^{\bullet-}$	[9]
Hormone	17 $\beta$ -estradiol		UV/PS	Slow-release flow through system	4.76 11.9, 23.8	+ -	$\text{SO}_4^{\bullet-}$	[11]

Nonsteroidal anti-inflammatory	Diclofenac		UV/PS	1	25, 50, 100 and 200	+	No data	[12]
	Ketoprofen		Heat/PS	1	1, 50, 100 mM	–	No data	[13]
Persistent organic molecules Pesticide	1,1,1-Trichloroethane		Heat/PS	15	1, 10, 100	–	No data	[15]
	Triclosan		Heat/PS	0.155	1–50	–	SO <sub>4</sub> <sup>•-</sup>	[16]
	Diatrizoate		UV/PS	12	2.5, 5, 10, 20, 40	+	SO <sub>4</sub> <sup>•-</sup>	[17]

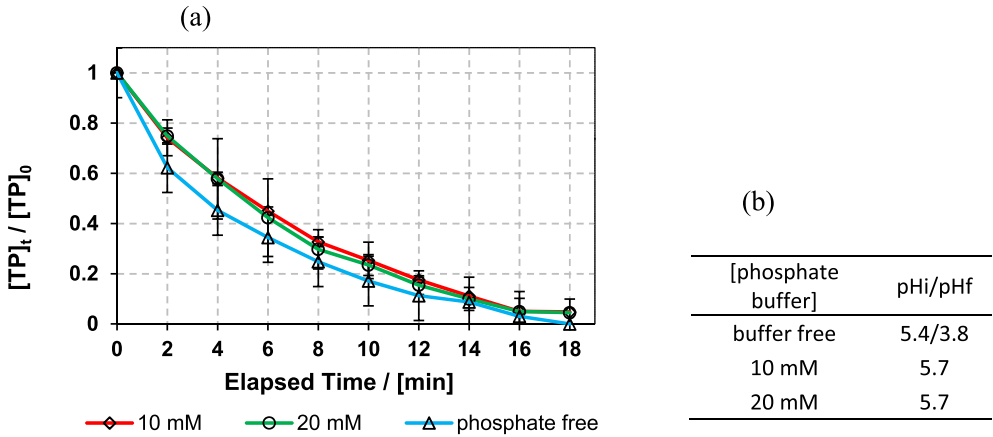


Fig. 2. (a) Effect of phosphates (0, 10 and 20 mM) on TP degradation. (b) pH in buffered and non-buffered solutions. Experimental conditions:  $[TP]_0 = 10 \text{ mg L}^{-1}$ ,  $[PS]_0 = 0.25 \text{ mM}$ . Error bars are calculated as  $\frac{fs}{\sqrt{n}}$ , where absent bars fall within the symbols.

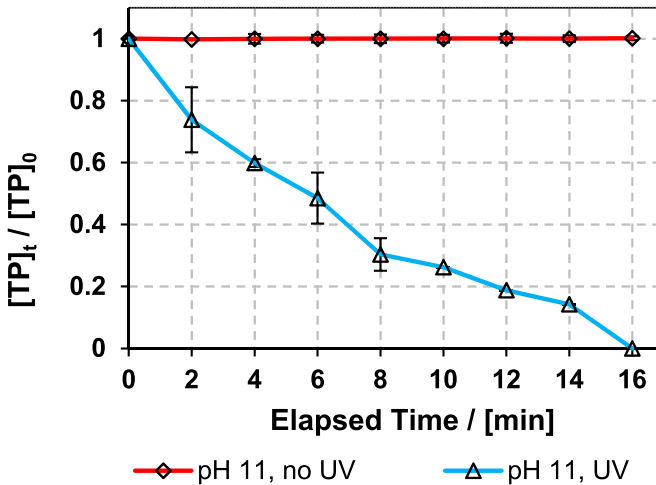


Fig. 3. Comparison between UV and base activation of PS. Experimental conditions:  $[TP]_0 = 10 \text{ mg L}^{-1}$ ,  $[PS]_0 = 0.25 \text{ mM}$ , and [phosphate buffer] = 10 mM of pH = 11 in both cases. Error bars are calculated as  $\frac{fs}{\sqrt{n}}$ , where absent bars fall within the symbols.

placed in a 280 mL 316 stainless steel casing that continuously intakes pre-filtered water. The UV lamps and their quartz fittings were utilized from the commercial product, and the stainless-steel casing was replaced by a 400 mL home-made borosilicate cylinder. The borosilicate used in the setup is as inert as the stainless-steel used in the commercial product, however the borosilicate allows easy handling and real-time monitoring of reactors to assure no precipitates were formed. Our developed system (Fig. 7b) utilizes a temperature-controlled water bath (20 °C) by the aid of a PolyScience MM7 chiller. UV-254 nm intensity was  $3.2 \text{ mWcm}^{-2} \pm 0.16$  measured using a radiometer (Model UVC-254 Lutron; Taipei, Taiwan) at a distance of 3cm, which is similar to the distance between the lamp and the termination part of the solution treated in the designed system. All experiments were done in triplicates, where two different experiments could be done at once.



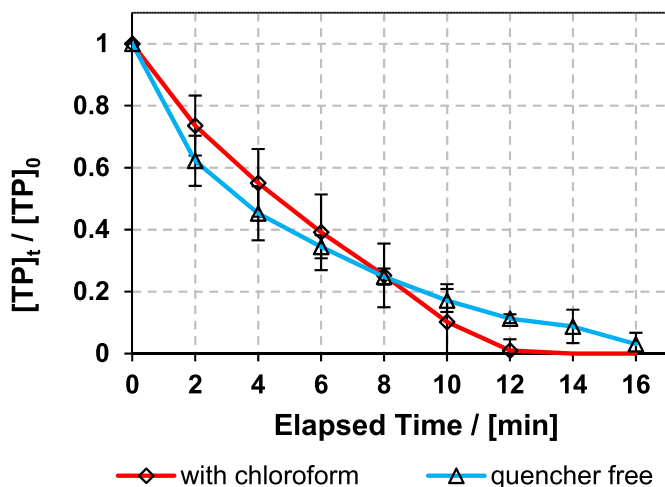
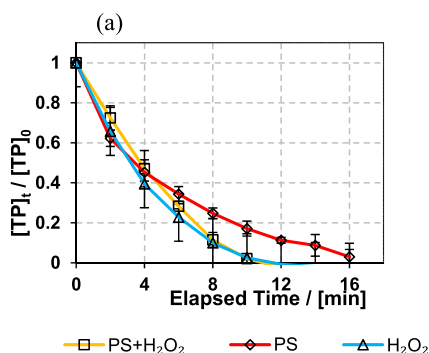


Fig. 4. TP degradation in presence and absence of chloroform used as superoxide radical quencher. Solution is saturated with chloroform at 20 °C. Experimental conditions:  $[TP]_0 = 10 \text{ mg L}^{-1}$  and  $[PS]_0 = 0.25 \text{ mM}$ .



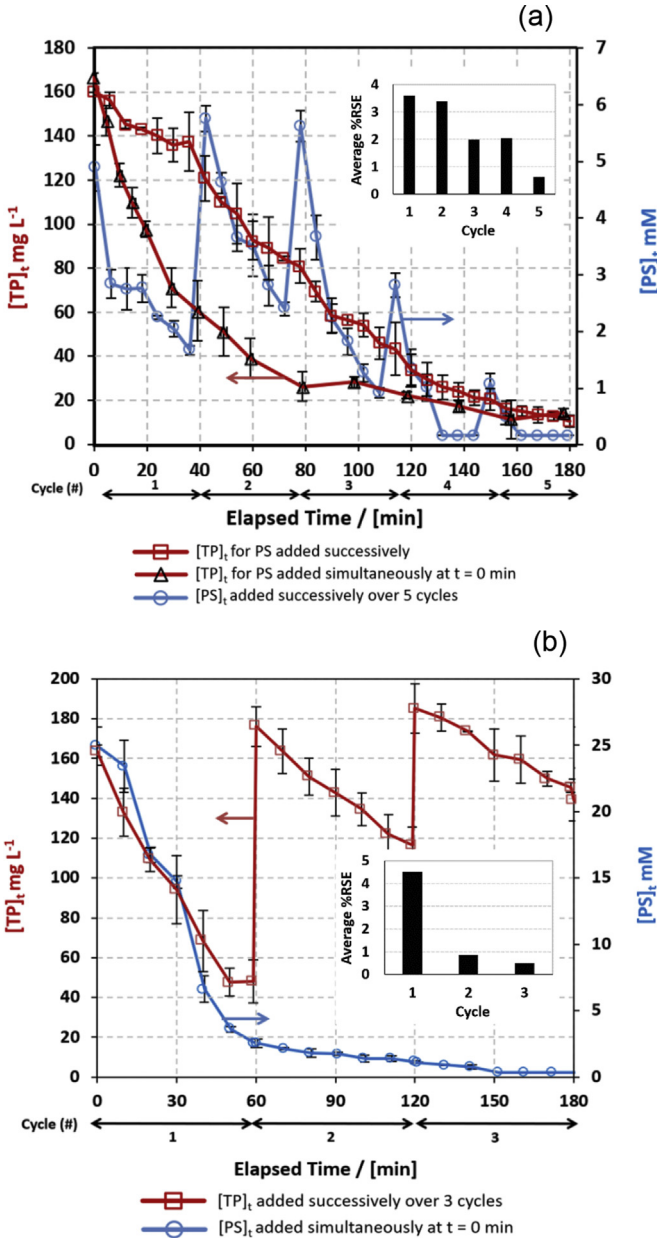
(b)

System	pH <sub>i</sub>	pH <sub>f</sub>	k <sub>obs</sub> (min <sup>-1</sup> )
PS	5.7	3.4	$1.73 (\pm 0.04) \times 10^{-1}$
PS + H <sub>2</sub> O <sub>2</sub>	5.2	5.5	$3.6 (\pm 0.4) \times 10^{-1}$
H <sub>2</sub> O <sub>2</sub>	5.4	4.4	$3.5 (\pm 0.2) \times 10^{-1}$

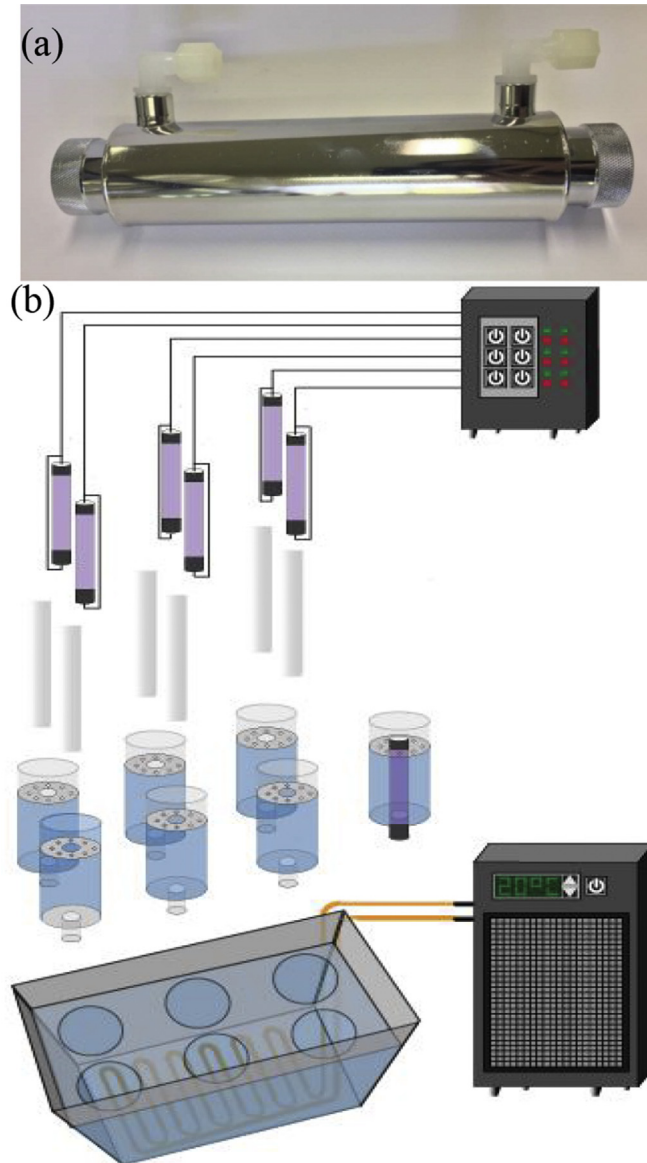
Fig. 5. Comparison of oxidation effectivity of H<sub>2</sub>O<sub>2</sub> and PS toward TP. (a)  $[TP]_t/[TP]_0$  for three different tested systems and (b) the corresponding pH at initial ( $t = 0 \text{ min}$ ) and final time ( $t = 16 \text{ min}$ ) with the calculated  $k_{\text{obs}}$ . Experimental conditions:  $[TP]_0 = 10 \text{ mg L}^{-1}$ ,  $[PS]_0 = 0.25 \text{ mM}$ ,  $[H_2O_2]_0 = 0.25 \text{ mM}$  and  $[PS]_0 = [H_2O_2]_0 = 0.125 \text{ mM}$  for the case of mixed oxidants.

## 2.2. Experimental procedure

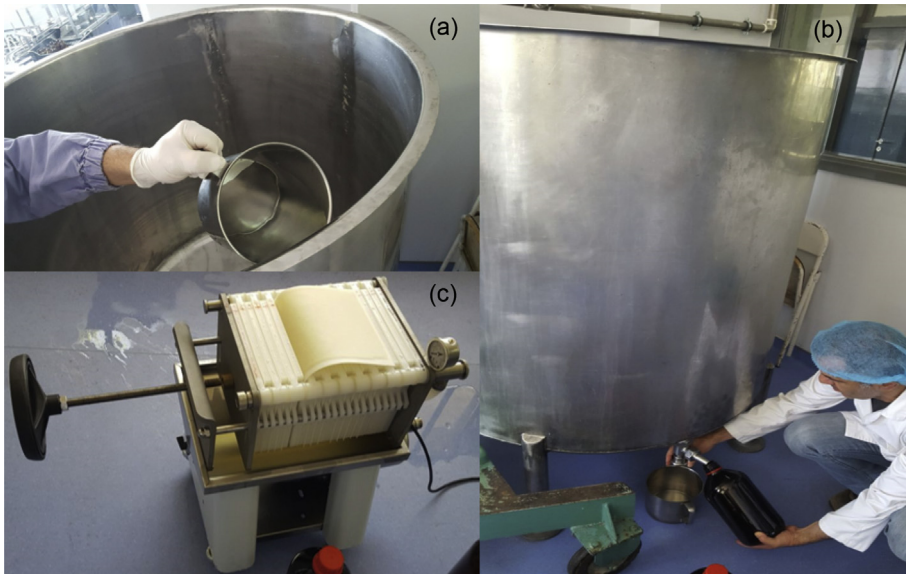
Stock solution of TP (0.555 mM) was prepared by dissolving 100 mg of dry TP powder in one liter of DI water, and that of Persulfate (PS) (100 mM) was prepared by dissolving 2.38 g of sodium persulfate in 100 mL of DI water. Both solutions were stored in dark at 4 °C for a maximum period of two weeks. For persulfate detection method potassium iodide solution (40 mM) was prepared by dissolving 6.64 g of KI and 5 g of NaHCO<sub>3</sub> in 1 L volumetric flask and left to stir overnight. Before every experiment LPHgLS (11 Watts) were stabilized for a period of 60 min. Monthly routine check of the LPHgLS's UV-254 nm intensity was performed using a UVC radiometer (UVC-254 Lutron, Taiwan) to confirm that the power of the lamps is within  $\pm 10\%$  the original value, otherwise the lamps were replaced by new ones. The water chiller was turned on and set at 20 °C 60 minutes ahead of all experiments. Temperature of water in reaction medium was measured several times during the experiment to make sure it is within a range of  $20 \pm 2$  °C. The order of addition of reagents was as follows: first Theophylline solution from stock was placed in the reactor, then DI was added, followed by additive matrix solutions (if any), finally, PS or H<sub>2</sub>O<sub>2</sub>, from stock solutions were added. Samples were withdrawn every 2 min using a



**Fig. 6.** Degradation of TP in a real pharmaceutical effluent sample in UV254/PS system. (a) PS is added either successively over 5 cycles ( $[PS] = 5 \text{ mM/cycle}$ ) or simultaneously at  $t = 0 \text{ min}$  ( $[PS] = 25 \text{ mM}$ ) to TP effluent solution ( $[TP]_0 \approx 160 \text{ mg L}^{-1}$ ). (b) Concentrated effluent solution spiked over 3 cycles of 1 h each starting at  $[TP]_0 \approx 160 \text{ mg L}^{-1}$  and  $[PS]_0 = 25 \text{ mM}$  added at  $t = 0 \text{ min}$ . The insets correspond to the average % RSE calculated for every cycle. Error bars are calculated as  $\frac{s}{\sqrt{n}}$ , where absent bars fall within the symbols.



**Fig. 7.** (a) Generic 1 gallon per minute UV continuous water disinfection element, and (b) an exploded diagram of the experimental setup.



**Fig. 8.** Wastewater samples containing TP collected from a local pharmaceutical production plant. (a) Washing of 1000 L 316 SS L mixing container, (b) collecting wastewater samples in amber bottles, and (c) filter press used in the manufacturing process.

separate syringe for each reactor and placed in 2 mL HPLC vials after filtration by a 0.45  $\mu\text{m}$  PTFE 13 mm disc filters. Wastewater used in experiments was pre-filtered using a 1  $\mu\text{m}$  ashless glass fiber filter. For the case of real pharmaceutical factory effluent, water samples were collected from washing the reactors used in the production process (Fig. 8).

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## Conflict of Interest

The authors declare that they have no known competing financial interests or personal relationships that could have appeared to influence the work reported in this paper.

## Appendix A. Supplementary data

Supplementary data to this article can be found online at <https://doi.org/10.1016/j.dib.2019.104614>.

## References

- [1] S. Al Hakim, S. Jaber, N. Zein Eddine, A. Baalbaki, A. Ghauch, Degradation of theophylline in a UV254/PS system: matrix effect and application to a factory effluent, *Chem. Eng. J.* 380 (2020) 122478, <https://doi.org/10.1016/j.cej.2019.122478>.
- [2] Dissociation constants of organic acids in aqueous solution, *Pure Appl. Chem.* 1 (1960) 187, <https://doi.org/10.1351/pac196001020187>.

- [3] Y. Gao, N. Gao, Y. Deng, D. Yin, Y. Zhang, Degradation of florfenicol in water by UV/Na<sub>2</sub>S<sub>2</sub>O<sub>8</sub> process, *Environ. Sci. Pollut. Res.* 22 (2015) 8693–8701, <https://doi.org/10.1007/s11356-014-4054-6>.
- [4] Y. Fan, Y. Ji, D. Kong, J. Lu, Q. Zhou, Kinetic and mechanistic investigations of the degradation of sulfamethazine in heat-activated persulfate oxidation process, *J. Hazard Mater.* (2015), <https://doi.org/10.1016/j.jhazmat.2015.06.058>.
- [5] S. Norzaee, M. Taghavi, B. Djahed, F.K. Mostafapour, Degradation of Penicillin G by heat activated persulfate in aqueous solution, *J. Environ. Manag.* 215 (2018) 316–323, <https://doi.org/10.1016/j.jenvman.2018.03.038>.
- [6] S. Wang, J. Wu, X. Lu, W. Xu, Q. Gong, J. Ding, B. Dan, P. Xie, Removal of acetaminophen in the Fe<sup>2+</sup>/persulfate system: kinetic model and degradation pathways, *Chem. Eng. J.* 358 (2019) 1091–1100, <https://doi.org/10.1016/j.cej.2018.09.145>.
- [7] C. Tan, N. Gao, S. Zhou, Y. Xiao, Z. Zhuang, Kinetic study of acetaminophen degradation by UV-based advanced oxidation processes, *Chem. Eng. J.* (2014), <https://doi.org/10.1016/j.cej.2014.05.013>.
- [8] C. Tan, N. Gao, Y. Deng, W. Rong, S. Zhou, N. Lu, Degradation of antipyrine by heat activated persulfate, *Separ. Purif. Technol.* 109 (2013) 122–128, <https://doi.org/10.1016/j.seppur.2013.03.003>.
- [9] D. Miao, J. Peng, X. Zhou, L. Qian, M. Wang, L. Zhai, S. Gao, Oxidative degradation of atenolol by heat-activated persulfate: kinetics, degradation pathways and distribution of transformation intermediates, *Chemosphere* 207 (2018) 174–182, <https://doi.org/10.1016/j.chemosphere.2018.05.068>.
- [10] A. Ghauch, A.M. Tuqan, Oxidation of bisoprolol in heated persulfate/H<sub>2</sub>O systems: kinetics and products, *Chem. Eng. J.* (2012), <https://doi.org/10.1016/j.cej.2011.12.048>.
- [11] A. Angkaew, C. Sakulthaew, T. Satapanajaru, C. Chokejaroenrat, UV-activated persulfate oxidation of 17 $\beta$ -estradiol: implications for discharge water remediation, *J. Environ. Chem. Eng.* 7 (2) (2018) 102858, <https://doi.org/10.1016/j.jece.2018.102858>.
- [12] X. Lu, Y. Shao, N. Gao, J. Chen, Y. Zhang, H. Xiang, Y. Guo, Degradation of diclofenac by UV-activated persulfate process: kinetic studies, degradation pathways and toxicity assessments, *Ecotoxicol. Environ. Saf.* 141 (2017) 139–147, <https://doi.org/10.1016/j.ecoenv.2017.03.022>.
- [13] M. Amasha, A. Baalbaki, A. Ghauch, A comparative study of the common persulfate activation techniques for the complete degradation of an NSAID: the case of ketoprofen, *Chem. Eng. J.* 350 (2018) 395–410, <https://doi.org/10.1016/j.cej.2018.05.118>.
- [14] Z. Fang, P. Chelme-Ayala, Q. Shi, C. Xu, M. Gamal El-Din, Degradation of naphthenic acid model compounds in aqueous solution by UV activated persulfate: influencing factors, kinetics and reaction mechanisms, *Chemosphere* (2018), <https://doi.org/10.1016/j.chemosphere.2018.07.132>.
- [15] X. Gu, S. Lu, L. Li, Z. Qiu, Q. Sui, K. Lin, Q. Luo, Oxidation of 1,1,1-trichloroethane stimulated by thermally activated persulfate, *Ind. Eng. Chem. Res.* 50 (2011) 11029–11036, <https://doi.org/10.1021/ie201059x>.
- [16] H. Gao, J. Chen, Y. Zhang, X. Zhou, Sulfate radicals induced degradation of Triclosan in thermally activated persulfate system, *Chem. Eng. J.* 306 (2016) 522–530, <https://doi.org/10.1016/j.cej.2016.07.080>.
- [17] L. Zhou, C. Ferronato, J.M. Chovelon, M. Sleiman, C. Richard, Investigations of diatrizoate degradation by photo-activated persulfate, *Chem. Eng. J.* (2017), <https://doi.org/10.1016/j.cej.2016.11.066>.