Comparative Analysis of Photodegradation of Ibuprofen and Clotrimazole Water Pollutant using UVC Rays in presence and absence of ZnO Photocatalyst

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Abstract

Recent surge in pharmaceutical micro-pollutants in water bodies calls for an efficient method to neutralize wastewater to sustain the ecosystem. One of the ways to degrade drug molecules is through photocatalytic degradation using UV rays. ZnO is known to be a common catalyst in the degradation of contaminants found in wastewater. However due to its toxicity to the environment, there is a need to objectively re-evaluate its necessity and alternatives. In addition, most studies are focused on utilization of UVA/UVB rays for the photocatalytic degradation process, as such, there are currently limited studies evaluating the efficacy of UVC for such purpose. In this work, we provide a comparative analysis of photodegradation of drug molecules using UVC ray with and without the ZnO catalyst. Ibuprofen (IBP) and clotrimazole are used for analysis. We found that the use of ZnO catalyst does not always produce better results. In some case, we found that IBP was degraded up to 94.4% more than that with the ZnO (1 g/L) up to 86.6% in 60 mins. However, without ZnO we observed secondary metabolite by-products of IBP that require longer treatment period to fully degrade. The inferior degradation strength for treatment with ZnO can be explained by increasing turbidity from adding greater concentrations of ZnO which decreases the UV transmission to the IBP solution. To support the results, an investigation on the photo-catalytic degradation of clotrimazole, an antifungal, with varying concentrations of ZnO as catalyst was also carried out. The optimum ZnO concentration was determined to be ~1000 ppm, above or under which the efficiency of the degradation suffers. Thus, the use of ZnO catalyst require strict dosage control. Such tight regulation is not required for the system using just UVC ray, but it would require a longer treatment time to completely degrade drug molecules and its by-products.

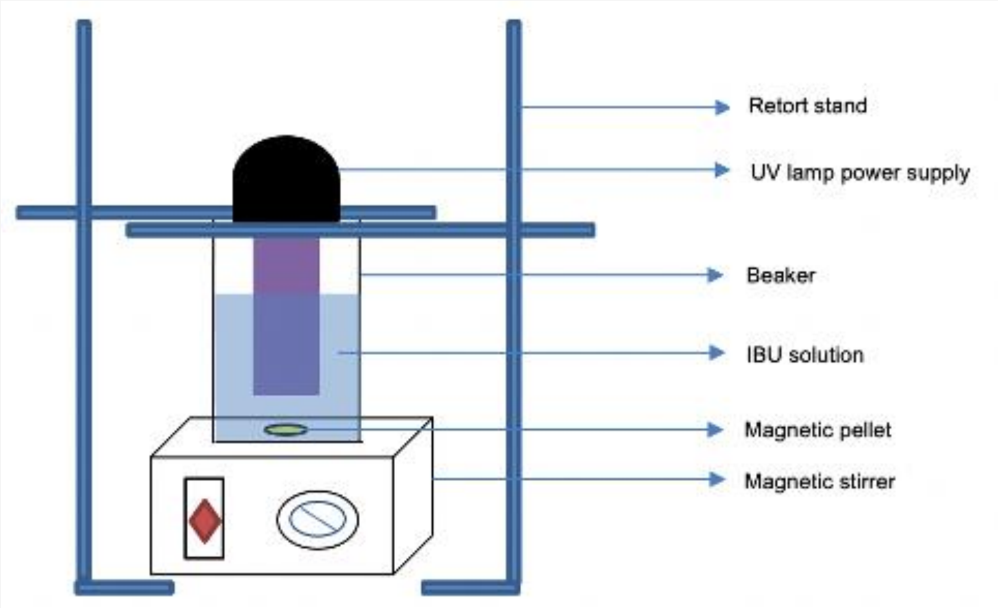
Introduction

Although the current wastewater treatment plant (WWTP) can neutralize up to approximately 95% of these pharmaceutical components, pharmaceutical micro-pollutants still end up in the environment at low concentrations, in which its toxicological effects remain.

Indonesia's Hospital Wastewater	
36% is treated	64% is discharged directly to water bodies without treatment

Ibuprofen	Clotrimazole
World's 3rd most consumed drug	Highly toxic for aquatic ecosystems; concentrations of 20 µg/l can cause lethal effects on crustaceans.
A dominating pharmaceutical micro-pollutant	
Highly toxic for the environment	

Experimental Setup



UV-Vis Spectra of IBP Contaminated Water

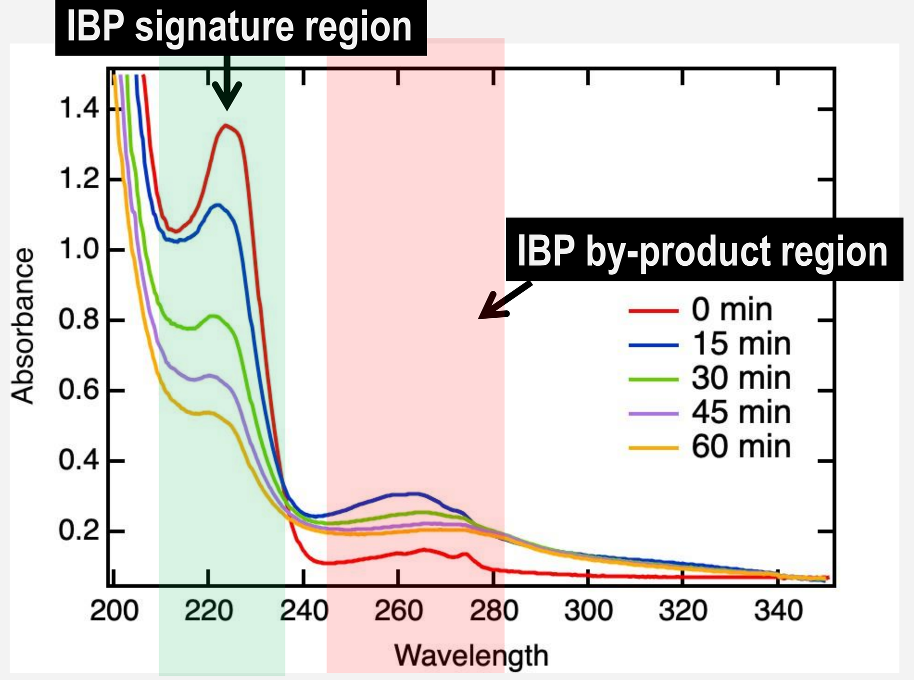
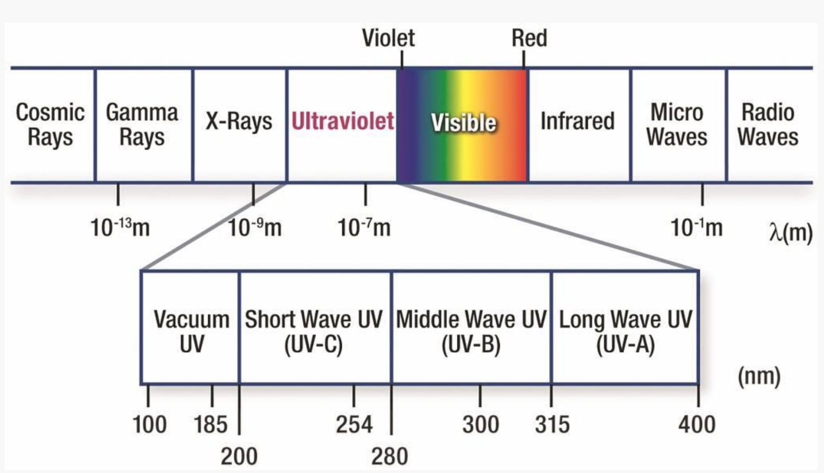


Figure 1. UV-Vis spectrum of IBP solution during the 60 minutes degradation process.

The UV Spectrum – UVA, UVB and UVC

When light has wavelengths below 400 nm, it is considered as UV light. UV light is further divided into 4 types, namely the UVA, UVB, UVC and Vacuum UV (ultra deep UV). In this work, we use lamp that emits UVC lamp.



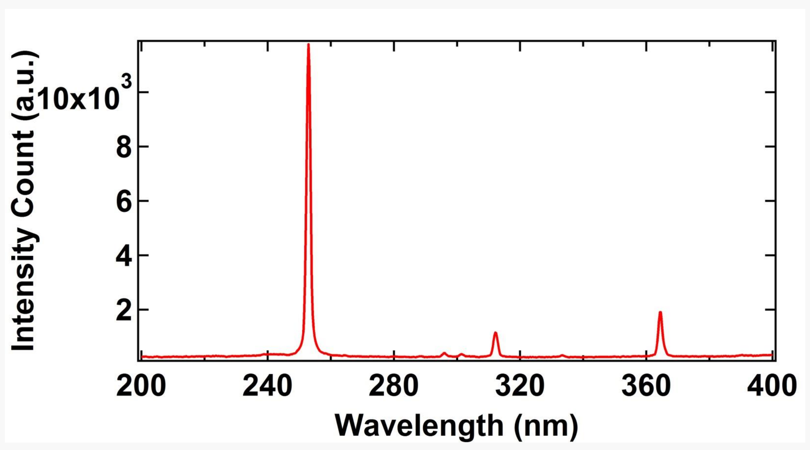


Figure 2. Spectrum of the lamp used in this experiment. The lamp exert primarily UVC light with small portion of UVB and UVA light. The lamp used has power of 7 Watt.

Degradation of IBP Over UVC Irradiation Time

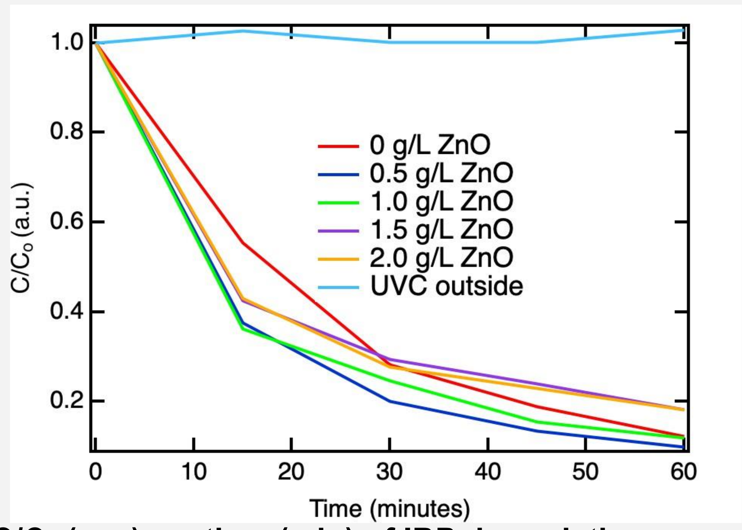


Figure 3. C/C_0 (a.u.) vs. time (min) of IBP degradation.

Degradation Rate and Maximum Degradation

$$\frac{C}{Co} = y_0 + e^{-kt}$$

C = concentration
C_0 = initial concentration
y_0 = maximum degradation potential
k = degradation rate

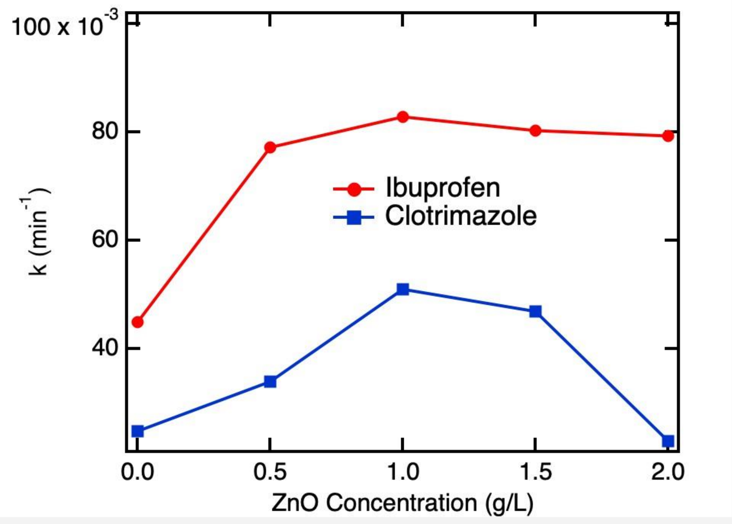


Figure 4. *k* constant (min^{-1}) vs. ZnO concentration (g/L) for IBP and CTZ degradation.

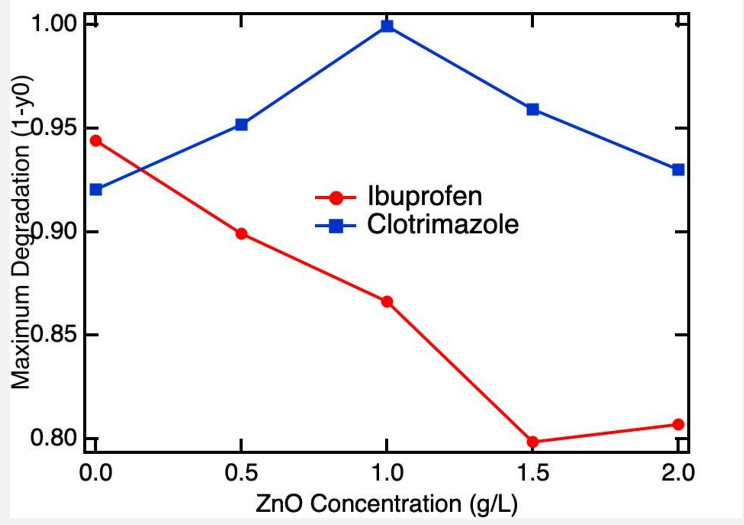


Figure 5. Maximum degradation (1-y0) vs. ZnO concentration (g/L) for IBP and CTZ degradation.

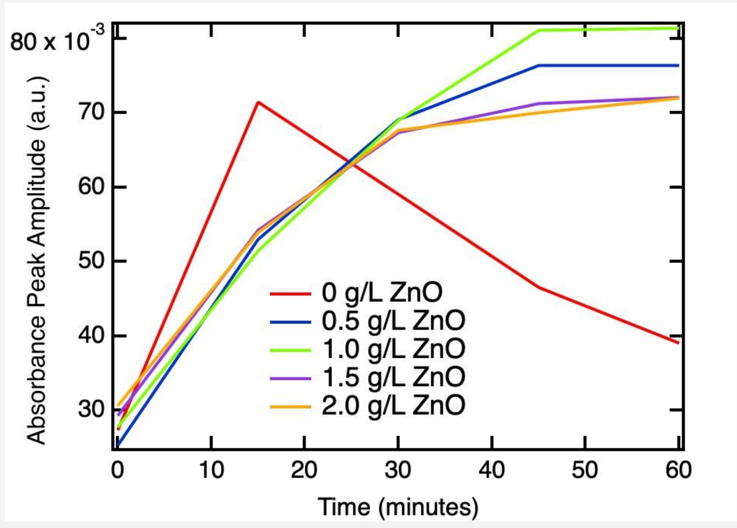
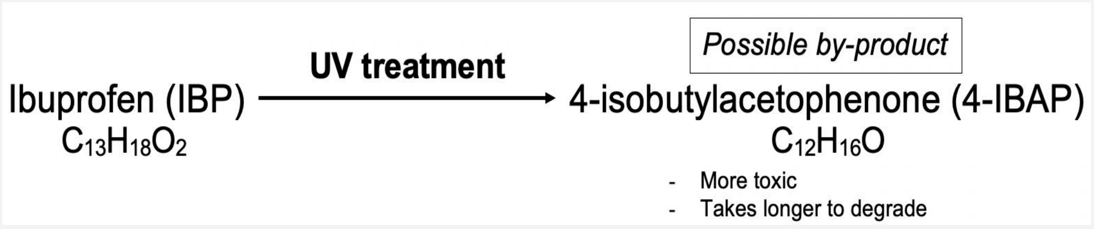


Figure 6. Absorbance peak amplitude of IBP by-product (a.u.) vs. time (min) in different concentrations of ZnO (g/L).

Analysis



	Ibuprofen	Clotrimazole
Degradation rate (Fig. 4)	Fastest degradation rate achieved at **1 g/L of ZnO** with a slight decrease in proceeding concentrations.	Fastest degradation rate achieved at **1 g/L of ZnO** with significant decrease in proceeding concentrations.
Maximum degradation potential (Fig. 5)	Greatest degradation potential achieved **without ZnO** and continually decreasing as more ZnO is added.	Greatest degradation potential achieved at **1 g/L of ZnO** with slight decrease preceding and exceeding this concentration.
By-product level (Fig. 6)	An overall decrease of by-product achieved **without ZnO**, while the addition of ZnO causes gradual formation of by-product over time.	No signs of by-product formed.

Conclusion & Recommendations

Although it was generally perceived that the addition of ZnO as photocatalyst in-creases the effectiveness of UV treatments for degrading pharmaceutical mi-cro-pollutants, our work reveals that there are various outcomes that require a careful look. We found that IBP was not as efficiently degraded when ZnO was used in the solution during the UVC treatment with maximum degradation potential of 86.6% compared to that without ZnO at 94.4%. Despite the ability of ZnO to degrade the IBP faster, this advantage is superseded by its inability to degrade the IBP by-product. In other case such as in CTZ, high degradation efficiency with and without ZnO are ob-served. The use of ZnO for degrading CTZ appears to be better than that without with maximum degradation potential of 99.9% and 92%, respectively. Optimal ZnO concen-tration was determined to be ~ 1 g/L, above which, screening effects due to an increased turbidity starts to dominate the system which lowers the photodegradation effective-ness. Overall, it is clear that UVC without ZnO is sufficiently effective in degrading IBP and CTZ with a maximum degradation potential of more than 90% in both cases. Fur-thermore, the by-product of IBP is also shown to be more effectively degraded without ZnO. Thus, we hope that our results may further encourage the adoption of a simple UVC batch-stirred treatment system to treat wastewater in households, hospitals, and pharmaceutical industries.

Acknowledgement

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