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DOCTORAL DISSERTATION REVIEW

Mgr inż. Humam Ahmed

entitled:

„Degradation of selected drug used in COVID-19 therapy in the aquatic environment by means of solar light driven processes”

1. Basis for the preparation of the review

This review was prepared on the basis of the cover letter from the Chair of the Discipline Council of Environmental Engineering, Mining and Energy at the Silesian University of Technology, Prof. DSc Krzysztof Labus, dated 15 January 2026. The cover letter concerning the resolution on the evaluation of the above-mentioned doctoral dissertation was received on 19 January 2026.

2. General information

The doctoral dissertation by MSc Eng. Humam Ahmed entitled “*Degradation of selected drugs used in COVID-19 therapy in the aquatic environment by means of solar-light-driven processes*” was prepared in the field of engineering and technical sciences, within the discipline of environmental engineering, mining and energy.

The supervisor of the dissertation is Prof. DSc Eng. Ewa Felis from the Department of Environmental Biotechnology, Faculty of Environmental Engineering and Energy, Silesian University of Technology.

3. Synthetic description of the dissertation

The doctoral dissertation consists of a total of 133 pages and contains six main chapters of a substantive nature, as well as seven additional chapters including the list of cited literature, list of figures, list of tables, and a list of publications authored or co-authored by the doctoral candidate.

The dissertation includes a total of 18 tables, 25 figures, and 128 cited literature references.

Pages 12 and 13 contain abstracts in Polish and English, which succinctly describe the aim of the study, the experiments conducted, and the most important conclusions. It should be emphasized that the content of the abstracts encourages a detailed reading of the dissertation.

The first chapter, "*Literature Review*", comprising 14 pages, provides introductory information on current issues related to drugs and pharmaceuticals used in COVID-19 therapy and their degradation in the environment. In this chapter, the Author describes in detail: antiviral drugs as emerging pollutants in the aquatic environment, advanced oxidation processes, their mechanisms, and environmental benefits. The latter part of the chapter presents a detailed characterization of the drugs used in the experiments.

In chapter 2, the research hypothesis, three scientific problems, the main research objective, and nine specific objectives were correctly formulated. Some doubt arises with regard to the content of the sixth specific objective: "*Comparing the performance of various photocatalysts.*" The question arises: comparing performance with respect to what factor? A reference indicating the basis of comparison is missing.

In chapter 2.5, "*Scope of the Thesis*", the Author succinctly describes the content of the individual chapters of the dissertation.

Chapter 3, containing numerous subsections, presents a description of the applied measurement methodology and the characteristics of the measuring equipment. Chapter 3.2, "*Water matrices*", provides information on the three types of water used in the experiment. However, this section lacks a detailed description of the methodology for sampling tap water and water from the Ostropka River. Were the samples collected once, or were composite samples prepared from several sampling points? As is well known, the physicochemical and bacteriological analysis of a single water sample may not be representative. What type of water is supplied to the water distribution system in Gliwice—surface water or groundwater? Another question concerns the rationale for selecting these three types of water for analysis. From the perspective of statistical analysis, the "*Materials and Methodology*" chapter lacks a scale and interpretation of the coefficient of determination R^2 , which is frequently used to interpret many of the relationships presented in the "*Results and Discussion*" chapter.

Chapter 4, "*Results and Discussion*", developed on pages 46–89, constitutes the main and most substantively important part of the doctoral dissertation. In this chapter, the Author consistently implements the research hypothesis, the scientific objective, and addresses the formulated research problems. The chapter presents the research results along with their mechanistic and environmental interpretation. Chapter 4 is structured as a logically closed research sequence characteristic of doctoral dissertations. The most important scientific threads in this part include: characterization of water matrices (4.1.1), evaluation of basic processes (photolysis) (4.1.2), extension to advanced processes (photocatalysis, H_2O_2) (4.1.3–4.1.5), analysis of factors modifying the mechanism (anions, adsorption) (4.1.6–4.1.7), and assessment of mineralization as a measure of environmental effectiveness (4.1.8). This structure clearly demonstrates a conscious scientific narrative rather than a mere presentation of results. Certain issues requiring clarification appear in the interpretation of results presented

in several figures, which will be discussed in detail in the section “*Substantive evaluation of the doctoral dissertation.*”

Chapter 5, “*Summary and Conclusion*”, summarizes the analytical part and interpretation of the results. This chapter contains a concise summary and four extended conclusions.

Chapter 6, “*Future Research Directions*”, is an interesting and relatively uncommon element in doctoral dissertations. It constitutes a substantive complement to the results section. The Author identifies limitations of the conducted research and indicates realistic and scientifically relevant directions for further studies, including the need to identify transformation products using advanced analytical techniques, deepen mechanistic studies involving reactive oxygen species, and assess the stability and reusability of photocatalysts. The Author’s critical reflection on the lack of FTIR and XRD analyses, which could have expanded the interpretation of adsorption mechanisms and catalyst structural changes, also deserves attention. The proposed recommendations logically follow from the obtained results, strengthen the applied character of the work, and confirm the Author’s high methodological awareness, without undermining the fundamental conclusions of the dissertation.

4. Formal evaluation of the doctoral dissertation

From a substantive point of view, the structure of the doctoral dissertation by MSc Eng. Humam Ahmed is appropriate and correct. The dissertation submitted for review constitutes a logical sequence of chapters and subchapters. The work contains all required elements of a doctoral dissertation and has a scientific-research as well as applied character. The clear and logical structure, presentation of results in the form of tables and figures, and discussion of the obtained results ensure that, despite minor linguistic and stylistic shortcomings, the reader can follow the Author’s reasoning with full understanding.

In the analytical part of the dissertation, each subsection describes the most important results and discusses them in relation to literature reports. This commendable form of analysis and discussion allows the reader to clearly identify the tangible results of each analysis without searching for them only in the summary or final conclusions. This demonstrates that the Author possesses adequate theoretical knowledge and experience in the relevant scientific discipline, as well as the skills necessary for developing and correctly analyzing the obtained results. It follows that MSc Eng. Humam Ahmed is capable of properly planning research, achieving scientific objectives, confirming or refuting research hypotheses, and correctly interpreting the results with appropriate conclusions and suggestions for future research.

Moreover, the research concept addressing a global problem—namely water pollution resulting from the widespread use of pharmaceuticals, particularly antiviral drugs used in COVID-19 treatment—is current and forward-looking. The COVID-19 virus has not

disappeared but continues to mutate, which is associated with the development of the pharmaceutical industry and the use of new medications. All pharmaceuticals used by humans are and will be present in wastewater discharged into surface and groundwater. Therefore, the research presented in the reviewed dissertation undoubtedly contributes to the development of wastewater treatment (advanced treatment) technologies aimed at neutralizing pharmaceuticals.

5. Substantive evaluation of the doctoral dissertation

The main scientific objective of the doctoral dissertation by MSc Eng. Humam Ahmed is the analysis of the photodegradation of selected pharmaceuticals used in COVID-19 therapy in the aquatic environment under the influence of solar and artificial light, both in the presence and absence of photocatalysts supporting the degradation process. As mentioned earlier, the scientific objective and research methodology were clearly and precisely defined. This section evaluates the substantive content primarily contained in Chapter 4.

Chapter 4, "*Results and Discussion*", is the central and most substantively important part of the dissertation. In this chapter, the Author presents and interprets the research results in a consistent and logically ordered manner. The results are not merely descriptive but are subjected to in-depth mechanistic and environmental analysis and discussion. The structure of this chapter is coherent and well thought out. The analysis begins with characterization of the ionic composition of the tested water matrices (Milli-Q water, tap water, and surface water), providing an important reference point for further considerations. This approach enables a reliable interpretation of differences in degradation efficiency and emphasizes the applied character of the research, extending beyond laboratory model systems.

In Figures 9a, 9b, and 9c and Table 7, the coefficient of determination R^2 is provided, indicating the percentage of observations explained by the regression model. However, interpretation of the numerical value of R^2 does not determine whether the dependence is statistically significant or random. In this part of the analysis, the application of an additional correlation coefficient (r_{xy}) with a significance test (e.g., Student's t-test) could have been useful. This suggestion also applies to further statistical analyses in subsequent subsections. The results of direct solar photolysis clearly indicate low susceptibility of the tested compounds (IPN, RTR, REM) to this process, which was correctly interpreted as justification for applying advanced oxidation processes. Importantly, this research stage fulfills a key methodological function by eliminating the risk of overinterpreting results obtained in the presence of photocatalysts.

The most important element of the "*Results and Discussion*" chapter is the detailed analysis of photocatalytic processes. The Author demonstrated that degradation efficiency depends on both the type of photocatalyst used and the physicochemical properties of the

degraded drug and water matrix composition. Particularly valuable is the distinction of dominant mechanisms for individual compounds: pseudo-first-order kinetics for isoprinosine degradation, a significant role of adsorption for ritonavir, and complex adsorption–desorption dynamics for remdesivir. This indicates a mature approach to kinetic and mechanistic analysis. An important contribution is also the analysis of the influence of selected anions (Cl^- , SO_4^{2-} , NO_3^- , CO_3^{2-}) on photocatalytic degradation efficiency. The Author correctly interprets their role as modifiers of reaction pathways through interactions with hydroxyl radicals and the catalyst surface. The results convincingly explain differences between model water and real environmental waters.

The inclusion of mineralization studies as a criterion for evaluating actual process effectiveness also deserves recognition, as it prevents limiting interpretation solely to the disappearance of the parent compound and strengthens the environmental assessment of the proposed technologies.

In summary, the “*Results and Discussion*” chapter is characterized by a high substantive level, logical coherence, and methodological correctness. The Author demonstrates the ability to critically analyze results and interpret them in the context of reaction mechanisms and environmental conditions. The presented results fully realize the main and specific objectives of the dissertation and constitute a valuable contribution to the development of knowledge on pharmaceutical degradation using solar-light-initiated processes.

After reading this part of the dissertation, several questions arise: According to the Author, can the applied degradation methods be used for effluents from municipal wastewater treatment plants? If so, at which treatment stage would these processes be applicable? Do they have economic justification in both centralized and households treatment plants?

Editorial and stylistic remarks:

- Simplification of excessively complex sentences.

In some sections, there are multiple-complex sentences that could be divided into shorter ones, which would improve the clarity of the message and facilitate the reception of the scientific content.

- Unification of grammatical tense.

In the description of the Author’s own research, the past and present tenses are used interchangeably in some places. To maintain stylistic consistency, it would be advisable to consistently use a single tense (most commonly the past tense).

- Clarification of anaphoric references.

Occasionally, pronouns such as “this,” “such,” or “the above-mentioned” appear, whose referents may not be unambiguous. It would be worth replacing them with full expressions in order to avoid interpretative ambiguity.

- Softening of categorical formulations.

In several places, strongly categorical expressions are used (e.g., “clearly proves,” “completely eliminates”). Scientific style allows for more cautious formulations, such as “indicates,” “confirms a trend,” or “suggests.”

Despite these remarks, the obtained results, their analytical processing, and conclusions confirm that MSc Eng. Humam Ahmed achieved the stated scientific objective, and the applied methodology was appropriate and consistent with the current state of scientific and technical knowledge. The dissertation has significant scientific and applied value.

The extensive scope of planned and completed laboratory research deserves praise, demonstrating the doctoral candidate’s diligence and commitment to a comprehensive analysis of the research problem. The results are presented clearly and accessibly in figures and tables.

6. Contribution of the Author to the development of the discipline

The doctoral dissertation makes a significant and original scientific contribution to the discipline of environmental engineering, mining and energy, particularly in the field of water treatment technologies and sustainable advanced oxidation processes (AOP). This contribution includes:

- a. Expansion of knowledge on the fate of pharmaceuticals in the aquatic environment.
For the first time, a comprehensive assessment of the degradation of selected antiviral drugs used in COVID-19 therapy (isoprinosine, ritonavir, remdesivir) was carried out under conditions of simulated solar radiation, taking into account real water matrices (tap water and surface water). The obtained results significantly expand the current state of knowledge regarding abiotic self-purification processes in the aquatic environment.
- b. Demonstration of the limited effectiveness of direct photolysis.
The dissertation provides new experimental evidence confirming that direct solar photolysis of the investigated drugs is an insufficient process, which is of key importance for a realistic assessment of pharmaceutical persistence in the environment and for the design of technologies for their removal.
- c. Development and comparison of effective photocatalytic systems.
The study systematically compared the effectiveness of a range of semiconductor photocatalysts, including TiO₂ P25, ZnO, and the composite SnO₂:ZnO system, demonstrating their high efficiency in solar-light-initiated processes. These results constitute a significant applied contribution to the development of energy-efficient water treatment technologies.
- d. A novel kinetic approach to the description of pharmaceutical degradation.
The dissertation makes an original methodological contribution through: confirmation of

pseudo-first-order kinetics for isoprinosine degradation, application of the Langmuir–Hinshelwood model to describe ritonavir removal, and the innovative use of a two-phase adsorption–desorption model to describe the behavior of remdesivir in photocatalytic processes. Such an approach has not previously been reported in the literature.

- e. Demonstration of the key role of water matrix composition. The study clearly demonstrated that the ionic composition of water (Cl^- , SO_4^{2-} , HCO_3^-) significantly modifies the efficiency of AOP processes, which is of direct importance for the design of environmental technologies under real, rather than exclusively laboratory, conditions.
- f. Contribution to the development of sustainable environmental technologies. The proposed solutions based on solar-light-activated photocatalysis align with current trends in energy-efficient and low-emission environmental engineering technologies, which are also important from the perspective of the energy sector and resource management.

7. Final conclusion

I hereby state that the doctoral dissertation of MSc Eng. Humam Ahmed meets the requirements set out in Article 187 of the Act of 20 July 2018 – Law on Higher Education and Science (Journal of Laws of 2024, item 1571, as amended) and may constitute grounds for awarding the academic degree of doctor in the field of engineering and technical sciences, in the discipline of environmental engineering, mining, and energy.

I recommend admitting the Author to the public defense of the doctoral dissertation and awarding her the degree of Doctor in the field of engineering and technical sciences, in the discipline of environmental engineering, mining and energy.

Furthermore, I recommend the dissertation for distinction due to the very well planned, conducted, and documented laboratory research, as well as the innovative results addressing a global problem of pharmaceutical water pollution and its mitigation.

Kraków, dnia 23 luty 2026r.

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