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Editorial

Light-Assisted Catalysis in Water and Indoor Air Cleaning: Challenges and Perspectives

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The detrimental effects of environmental pollution on human health, combined with global climate change, make it a critical contemporary problem. Despite the fact that water covers more than 71% of the Earth's surface, ensuring access to high-quality drinking water for everyone is a major concern that societies encounter in the 21st century [1]. Utilizing renewable solar light and a catalyst to mineralize various harmful chemicals present in indoor air and water sources into benign small molecules, such as H_2O and CO_2, is an attractive approach. In this context, photocatalytic processes have consistently offered smart, green, and eco-friendly scale-up methods for environmental remediation. Numerous photocatalysts have proven successful in achieving the mineralization of chlorinated pollutants, organic contaminants, dyes, or antibiotics [2–6]. An analysis of the existing literature reveals the need for research studies to focus on developing efficient photocatalysts capable of mineralizing contaminants into non-toxic CO_2. Only such photocatalytic materials should be envisaged for environmental remediation.

This Special Issue devoted to "Light-Assisted Catalysis in Water and Indoor Air Cleaning: Challenges and Perspectives" is a collection of 10 papers, including 3 reviews and 7 research articles. The aim of this Special Issue is to present recent advancements in the photocatalytic removal of pollutants, elucidating the main factors contributing to their mineralization and the implication of reactive oxygen species (ROS) through dedicated experiments. Furthermore, it encompasses the design and physicochemical characterization of various photocatalytic systems employed in environmental remediation.

In their review paper, Pavel et al. [7] presented a detailed and comparative study of the photocatalytic removal of organic (e.g., alcohols, carboxylic acids, volatile organic compounds, and phenols) and inorganic (e.g., NO_3^-) contaminants. The efficiency of multiple UV–Vis-light active photocatalysts and their corresponding degradation pathways were described, emphasizing the key factors contributing to their mineralization. The reaction mechanisms, the identification and quantification of by-products, and the implication of reactive active species (ROS) were considered for each category of the model target pollutant. Applying BiOCl and g–C_3N_4–based photocatalysts for water purification was reviewed by Ren and co-workers [8]. The authors described the preparation methods of g–C_3N_4/BiOCl composites via hydrothermal, deposition–precipitation, solvothermal, and calcination techniques. Subsequently, the authors explained the potential application of g–C_3N_4/BiOCl heterojunctions (e.g., degradation of dyes, residual pharmaceutical agents, and plasticizers) and the distinct reaction mechanisms involved in improving their performance. A comprehensive review by Galloni et al. [9] addresses the latest contributions to olive mill wastewater treatments, highlighting the potentialities and drawbacks of each removal method discussed. The authors emphasized the necessity of developing sustainable, environmentally friendly photocatalysts that could serve as valid alternatives to conventional treatment methods when optimized. In this context, the authors proposed recoverable magnetic compounds, as well as floating- and membrane-based devices, as promising alternatives to conventional TiO_2–based systems.

Citation: Balint, I.; Pavel, M. Light-Assisted Catalysis in Water and Indoor Air Cleaning: Challenges and Perspectives. *Catalysts* **2023**, *13*, 1032. https://doi.org/10.3390/catal13071032

Received: 13 June 2023
Accepted: 21 June 2023
Published: 23 June 2023

Ali et al. [10] examined how the structural, morphological, and optical properties of pure TiO_2 and TiO_2-incorporated Fe_2O_3 influenced their respective photoelectrochemical performances. The study revealed that pure titania exhibited the highest activity in the photocatalytic degradation of Rose Bengal dye under UV light, along with a superior photocurrent response, compared to the incorporated hematite counterparts. Additionally, Yang et al. [11] proposed utilizing TiO_2/hectorite composites with varying molar ratios of lithium, magnesium, and silicon as photocatalysts for the photodegradation of methylene blue (MB) under UV light irradiation. Under optimized conditions (molar ratio of Li/Mg/Si = 1.32/5.34/8), the highest removal rate of MB dye (97.8%) was revealed, while reusability tests after five runs showed only a slight decrease in the photocatalytic activity. Patel and co-workers [12] provided further evidence that photocatalytic, sonocatalytic, and sonophotocatalytic approaches play an important role in wastewater treatment, using Mn-doped ZnS quantum dots (Qds) as catalysts to remove solochrome dark blue azo dye (SDB). The authors claim that the Mn^{2+}:ZnS Qds sample showed high activity for the sonophotocatalytic degradation of SDB (89%), surpassing the rates observed for sonocatalysis (69.7%) or photocatalysis (55.2%) alone. This behavior was attributed to the enhanced electron-holes separation, increased reactive radicals, and augmented active surface area. Another application of light-assisted processes is by removing pesticides from wastewater. In this regard, Kobkeatthawin et al. [13] provide insights into the photocatalytic degradation of imidacloprid (IMI) using g–C_3N_4/TiO_2 systems. The composites were prepared by subjecting g-C_3N_4 nanosheets and Ti precursor to a hydrothermal treatment, with various weight percentages of g–C_3N_4 in relation to TiO_2 (0.5, 1, 4, 10, and 15 wt.% of g–C_3N_4). In this study, the authors obtained enhanced photocatalytic performance for the composite materials compared to bulk materials due to a synergistic effect between Ti^{3+}–TiO_2 and g–C_3N_4. The 0.5C_3N_4/TiO_2 sample displayed the highest IMI removal efficiency, reaching up to 93% within 150 min, and good stability during multiple recycling tests. In addition, Sandulescu and co-workers [14] studied the photocatalytic oxidation of phenol under sunlight irradiation using both bare and noble metal-loaded TiO_2. The experiments revealed that the supported noble metals function as visible light absorbers, assisting the separation of photo-charges and the reduction of O_2 to O_2^-. The O_2^- oxidizes mildly phenol to oxygenated products. In a parallel process, •OH radicals yielded by TiO_2 mineralized phenol to CO_2 via rapid reaction sequences. Ignat et al. [15] used active noble plasmonic metals/Ga-substituted MgAl–hydrotalcites for the photocatalytic degradation of p–dichlorobenzene and 4–nitrophenol under simulated solar irradiation. The results revealed the enhanced photocatalytic performances of the synthesized plasmonic heterostructures (Ag–MgGaAl and Au–MgGaAl) compared to both the calcined forms and hydrotalcite precursors. The paper also included a discussion on the kinetic models that governed the studied plasmonic catalysts. Zhou and co-workers [16] successfully coupled β-$NaYF_4$:Yb,Er,Gd fluorescent nanorods to a reduced TiO_2 nanocomposite and applied it to visible-light catalytic sterilization under 980 nm near-infrared (NIR) light illumination. The authors claimed that up to 98.1% of Escherichia coli were effectively eradicated within 12 min of NIR light irradiation at a minimum inhibitory concentration of 40 μg/mL. The high bacterial activity was attributed to the synergistic effect between the fluorescent nanorods and reduced TiO_2.

Collectively, these studies provide an overview of the latest advances in the development of photocatalytic materials for diverse chemical reactions utilized in the removal of pollutants from indoor air or wastewater. These research studies pave the way for improving catalytic systems and contributing to a cleaner environment.

Finally, we express our gratitude to the journal *Catalysts* for the opportunity to produce this Special Issue, and to the editorial team, especially Assistant Editors Mia Zhang and Janine Li, for their continuous support during the submission and publication process. We also extend our gratitude to the authors and referees for their diligence and contributions to the success of this Special Issue.

Author Contributions: Conceptualization, I.B. and M.P.; writing—original draft preparation, I.B. and M.P.; writing—review and editing, I.B. and M.P. All authors have read and agreed to the published version of the manuscript.

Conflicts of Interest: The authors declare no conflict of interest.

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Short Biography of Author

Ioan Balint. Dr. Ioan Balint is a Senior Researcher and currently, the Director of the "Ilie Murgulescu" Institute of Physical-Chemistry of the Romanian Academy. Dr. Balint obtained his PhD in Chemistry in 1996 at the same institute. He obtained three postdoctoral stays, one of them at the Pierre et Marie Marie Curie University in France (1998–1999), and another two at the Department of Environmental Chemistry and Catalysis in the group of Prof. Ken-ichi Aika, of the Tokyo Institute of Technology in Japan (2000–2005). He was several times, an invited professor at Tokyo Institute of Technology and Tokyo Technical University, in Japan and also gained an UNESCO Scholarship at the same institute. Dr. Balint has an extensive research background encompassing various topics such as surface science: non-isothermal gas desorption kinetic from supported-metal catalysts; solid defect chemistry; water–gas shift reaction on surface of simple and doped ionic oxides; material synthesis: mesoporous nano oxides; mono/bimetallic metal nanoparticles; catalysis: catalytic combustion of hydrocarbons; oxidative coupling of methane; hydrogenation and oxidative conversion of conversion hydrocarbons; structure-sensitive reactions; nitrate and nitrite abatement; photocatalysis/light harvesting: water and air depollution; water splitting; light-induced reactive oxygen species generation; solar cell. He was project director for 5 national grants, and has been as expert member in many national/international committees. Dr. Balint has published over 100 peer-reviewed papers in well-recognized scientific journals, and has an H-index of 21.

Monica Pavel. Dr. Monica Pavel is a senior researcher at the "Ilie Murgulescu" Institute of Physical-Chemistry of the Romanian Academy. She obtained a BSc degree in chemistry and physics in 2005 at the University of Pitesti, Romania, and a MSc degree (2006) in materials science, nanomaterials and multimaterials from the National Polytechnic Institute of Toulouse, France. From October 2007 to November 2010, she carried out her PhD studies in materials chemistry at the University of Lyon 1—Institute of Researches for Catalysis and Environment of Lyon in France under the supervision of Dr. Pavel Afanasiev. She continued as a postdoctoral researcher (2011–2013) at the University of Bucharest, Romania, with a short internship at the Institute Charles Gerhardt Montpellier, France. Her research focuses on the controllable synthesis of transition-mixed oxides and 2D materials by various methods (e.g., molten salts, organic solvents, co-precipitation, solid state reactions, ion-exchange reactions); the photocatalytic removal of pollutants (chlorinated/organic compounds, antibiotics, etc.); combustion of light alkanes, and the total oxidation of volatile organic compounds (VOCs).