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Editorial

Catalysis in Advanced Oxidation Technologies (AOTs) for Water, Air and Soil Treatment

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The environment is what supports life on Earth. However, it is dangerously affected by human activities that lead to significant pollution of the water, air, soil, etc. This alteration in our environment by inorganic, organic and microbiologic toxic substances promotes short- and long-term health problems. Catalytic advanced oxidation processes (AOPs) constitute a promising technology for the remediation of contaminated water, air and soil. The use of AOPs for environmental applications has been precisely defined by Glaze et al. [1] as water-treatment processes performed at room temperature and atmospheric pressure based on the in situ generation of powerful oxidizing agents, such as hydroxyl radicals (HO°), at sufficient concentrations to effectively decontaminate water, air and soil. Hydroxyl radical molecules non-selectively react with organic pollutants contained in the effluents through different modes of attack, simultaneously oxidizing and breaking apart these organic contaminant molecules internally.

These AOPs are particularly efficient technologies for water treatment in terms of organic micropollutant degradation. For example, the combination of UV and radicals (hydroxyl or sulphate) can effectively eliminate biorecalcitrant organic compounds at a higher removal-efficiency rate than direct UV photolysis or persulphate oxidation alone. During the last 30 years, multiple studies have compared the efficiencies of the main AOPs (for example, see references [2,3]). The following are some examples of these catalytic AOPs: photocatalysis, the (photo)Fenton process, (photo)electrocatalytic oxidation, wet air oxidation, catalytic ionization processes, catalytic ultrasonication, catalytic ozonation, persulfate treatment, etc. Despite significant advances in advanced oxidation processes in recent years, more efficient processes based on these AOPs still need to be developed to remove pollutants in water, air and soil, including the inactivation of microorganisms.

The first article of this Special Issue concerns the synthesis of novel flower-shaped C-dots/Co_3O_4{111} for improvements in catalytic activity and for selective peroxymonosulfate (PMS) conversion to sulfate radicals [4]. Due to a higher oxidative potential (E_0 = 2.5–3.1 V) and a longer half-life ($t_{1/2}$ = 30–40 µs), the sulfate radical (SO_4^{2-}) could degrade organics more efficiently than OH° (E_0 = 2.80 V, $t_{1/2} \leq 1$ µs) in neutral solutions. Catalytic degradation tests indicated that antibiotics and dyes could be efficiently degraded over flower-shaped C-dots/Co_3O_4. On the other hand, the authors showed that these catalysts could be reused efficiently because, even after six cycling runs, flower-shaped C-dots/Co_3O_4 still retained a high catalytic activity.

Usman and co-workers showed the role of ascorbic acid (AA) in improving the magnetite (Fe_3O_4)-mediated Fenton oxidation and thus in removing pentachlorophenol (PCP) for the first time in a historically contaminated soil [5]. Thus, by combining Fe_3O_4/H_2O_2 with ascorbic acid, they more than doubled the efficiency of the Fenton process for the elimination of PCP in batch slurry conditions. The authors showed that ascorbic acid allowed for increases in the formation of Fe(II), which considerably improves the capacity

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of magnetite to promote the Fenton reaction. Thus, the use of AA could enhance Fe(II) generation, thus improving its ability to remove persistent organic pollutants in historically contaminated soil.

The use of AOPs also relates to the treatment of gaseous compounds. Thus, some researchers of Strasbourg University (France) developed an efficient method for the destruction of chemical warfare agents (CWAs) by heterogeneous photocatalysis [6]. One of the main advantages of photocatalysis compared with combustion or thermal oxidation catalysis is the ability to operate at room temperature, and thus, it can be applied in remote places or in indoor environments where no heating facilities are available. They doped TiO_2 photocatalysts using Sn and Ta immobilized on SiC foams for the elimination of diethyl sulfide (DES), used as a model molecule mimicking Yperite (mustard gas) in its gaseous phase. A photoreactor has been specially designed for this application, and among the main results, the authors showed that the Sn-doped TiO_2 with a polyethylene glycol (PEG)/TiO_2 ratio of 7 exhibits the best initial activity (up to 90%), and its photocatalyst activity is strongly influenced by the adsorption properties of the support, as SiC foams adsorb DES and other sulfur compounds. Finally, after the first treatment, the catalyst can be regenerated by washing with a NaOH solution and reused with success.

AOPs, more specifically photocatalysis, can be applied to treat indoor pollution due to toxic volatile organic compounds (VOCs). In another paper, some authors developed a composite photocatalyst of carbon nitride quantum dots (CNQDs) that was used to in situ dope TiO_2 on inverse opal TiO_2-IO for the efficient degradation of toluene, a typical VOC [7]. The interest in inverse opal structures is in increasing the specific surface area and the utilization rate of visible light. With these materials, it has been shown that 93% of toluene is converted into non-toxic products (H_2O and CO_2) after 6 h of irradiation under visible light compared with only 37% when using TiO_2-P25, a reference commercial photocatalyst. In addition, the authors showed that TiO_2-IO can be used to efficiently degrade organic pollutants, such as phenol and Rhodamine B, in the liquid phase.

In another article of this Special Issue, an Estonian research team was interested in the oxidation of aqueous toluene by gas-phase pulsed corona discharge in air–water mixtures followed by photocatalytic exhaust air cleaning [8]. The low-temperature plasma of a pulsed corona discharge (PCD) as a source of active short-living oxidants represented an alternative to conventional AOPs for the degradation of organic pollutants. The authors combined PCD with the photocatalytic treatment of toluene both in air and water. Different operational parameters were evaluated, such as temperature, pH, frequency, etc., to determine the roles that each played. For example, an increase in temperature in the treated toluene solution from 20 to 30 °C resulted in a decrease in oxidation efficiency of the aqueous toluene of about 20%, showing higher oxidation rates in the gas phase. The only small problem was the production of CO in limited quantities.

The last article was devoted to the treatment of natural organic matter (NOM) based on visible-light-enhanced catalytic wet peroxide oxidation (CWPO) in the presence of Al/Fe-pillared clay [9]. NOM is a problem for drinking water production due to changes in the taste, odor and color as it is a well-known precursor of carcinogenic and mutagenic disinfection byproducts (DBPs). In this work, the authors prepared an Al/Fe-pillared clay catalyst (Al/Fe-PILC) from low-cost, technical-grade reagents for the photocatalytic wet peroxide oxidation (photo-CWPO) of NOM. The results showed a high levels of mineralization of the dissolved organic carbon and color removal of a synthetic NOM surrogate solution even under natural lighting within a laboratory and under ambient temperature and pressure. According to the authors, the integration of a step with the photo-CWPO process before typical disinfection by chlorine could assist conventional drinking-water treatment plants in the removal of NOM to produce safer drinking water.

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