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N-Doped TiO_2: An Efficient Catalyst for the Photocatalytic Treatment of Water and Wastewater under Visible Light Irradiation

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As a consequence of the rapid growth of population in urban areas, water use and reuse has become a major concern, leading to an urgent imperative to develop effective and affordable technologies for wastewater treatment. Traditional methods for wastewater treatment are usually based on physical and biological processes but unfortunately, some organic pollutants, classified as bio-recalcitrant, are not biodegradable. In this way heterogeneous photocatalysis may become an interesting water treatment technology to remove organic pollutants not treatable by conventional technique. Photocatalysis, also called the "green" technology, represents one of the main challenges in the field of treatment and decontamination of water and air because it is able to work at ambient temperature and atmospheric pressure. Heterogeneous photocatalysis is a catalytic process that uses the energy associated to a light source to activate a catalyst with semiconducting proprieties. The most common used photocatalyst is TiO_2. It is able to oxidize a wide range of toxic organic compounds into harmless compounds such as CO_2 and H_2O. Due to the value of TiO_2 band-gap energy, about 3.2 eV, it is effective only under irradiation of UV light. This is a technological limitation when aiming at implementation of large scale sustainable “green” technologies with renewable energy sources such as solar light. The main research objectives for the application of TiO_2 as a photocatalyst is the increase the photocatalytic performances of TiO_2 through the doping of its crystalline structure with non-metal ions (nitrogen) that reduce the band-gap making possible the fruitful absorption of the visible light.

The results obtained from our research activity evidenced that the doping of TiO_2 with nitrogen (N-TiO_2) has led to an enhanced photocatalytic activity in presence of visible light irradiation. The optimized formulation of N-TiO_2 has shown very effective in the removal of organic dyes, such as methylene blue and methyl orange [1], antibiotics such as spyramicin [2] and in the inactivation of *E. coli* [3]. It is also important to evidence that this optimized N-TiO_2 photocatalyst resulted also able to reduce the total chemical oxygen demand (COD) of a highly polluted wastewater such as tannery wastewater [4].

A successful implementation of photocatalytic processes at large scales, however, calls for a global interdisciplinary view over the interplay between all the important parameters that affect the capture and utilization of photons in a photoreactor [4]. Moreover, one of the most important drawbacks of photocatalytic process is that photocatalysts are often used in slurry reactors. The limitation of slurry process is that the photocatalyst in powder form must be separated from the purified water after the treatment, and the cost of this separation stage may even invalidate economically this technique. With the aim to overcome this technical limitation, two different research strategies have been developed.

The first research strategy was focused on the development of an optimized reactor configuration to enhance the photons distribution inside the core of reactor. In this case, the experimental results were carried out by using different light sources, in particular white LEDs, blue LEDs and UV lamps, with the aim to evaluate the process efficiency at different operating conditions [4]. Utilizing the collected experimental data, it was developed a simplified mathematical model able to correlate the power input of the used light sources, the geometrical properties of the reactor and of emitting sources spectra with the performances of the photocatalytic reaction. This simplified mathematical model may represent a valuable tool to design and to optimize photocatalytic processes for wastewater treatment [4].

The second research strategy was focused on the formulation of an innovative structured catalyst, in which N-TiO_2 is dispersed in transparent syndiotactic polystyrene monolithic aerogels (s-Ps) [5]. In particular, s-PS aerogels, due to their high specific surface area, present the possibility to disperse the catalysts in powder form, overcoming the aggregation phenomena that commonly happen when the catalyst is suspended in water solutions. These features allow not only to have a structured catalyst, but also to increase the photocatalytic activity of the N-TiO_2 under solar irradiation in comparison with the powder sample dispersed in solution [5].

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