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RETROSPECTIVE

Photocatalytic Degradation of Contaminants with Titanium Dioxide: A 40-Year Retrospective on the Paper by John Carey and Colleagues Published in BECT

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John Carey is probably best known for his role over many years to manage the science agenda within Environment Canada. For several years, he was the Director of the Canada Centre for Inland Waters (CCIW) in Burlington, Ontario, Canada, and he later worked with the federal Ministry of Environment in Ottawa to shape the policies and research priorities of Environment Canada. However, John Carey started his career with Environment Canada as a researcher, and during this period, he turned his attention to the issue of how to get rid of the large amounts of PCBs that had been produced for decades as an additive in transformers, hydraulic fluids and a range of other industrial and consumer products; an issue which we still have not addressed adequately to this day. In the paper published in BECT in 1976 by John Carey and his colleagues at CCIW, John Lawrence and Helle Tosine, they proposed using titanium dioxide (TiO_2) as a photocatalyst with UV irradiation to accelerate the dechlorination of PCBs. Since its publication, this article has gone on to be the most highly cited research paper published in BECT, with 721 citations as of December, 2016 (Harzing 2007).

It is astonishing that citations of this article are accruing at an exponential rate, even 40 years after the paper was originally published in BECT (Drouillard and Bennett 2015). So why has this article remained relevant in the field of photocatalysis for four decades? As the authors of the article described in their review of progress in field of photocatalysis at that time, there had been a small number of articles published previously that described the potential for using metal oxides to promote the production of hydrogen peroxide under conditions of UV irradiation. However, John Carey and his co-authors were the first to use TiO_2 as a photocatalyst for degradation of an environmental contaminant; in this case, PCBs. The enduring value of this article is that they recognized that TiO_2 was an appropriate photocatalyst and they applied this technology to degrade a chemical that was, and still is, an important environmental contaminant.

In the last 40 years, this area of research has branched in several directions. Since the publication of the Carey et al. (1976) paper, their work has been cited extensively as a seminal work guiding studies that can be classified as research on (i) the properties and mechanisms of photocatalysis, (ii) other photocatalytic materials besides TiO_2, (iii) photocatalysis in combination with other oxidative treatment technologies, (iv) photocatalytic reactor design, (v) TiO_2-based composite materials, (vi) TiO_2 photocatalysis for specific treatment applications, (vii) different forms and scales of TiO_2 for photocatalysis. In addition, the Carey et al. (1976) paper has been widely cited in reviews on photocatalysis. Figure 1 shows an analysis of the proportion of citations within each of these categories for 315 articles extracted from SCOPUS that cited the Carey et al. (1976) paper between 1980 and the present. These trend data show that citations over the first decade focused primarily on follow-up studies on specific applications of TiO_2-based photocatalysis, as well as the methods by which the catalytic process can be enhanced. For instance, the paper by Pruden and Ollis (1983) describes photocatalysis with TiO_2 to degrade trichloroethylene in water. However, more recent work has shifted to developing composite materials based on TiO_2, including nanoparticles, as well as other

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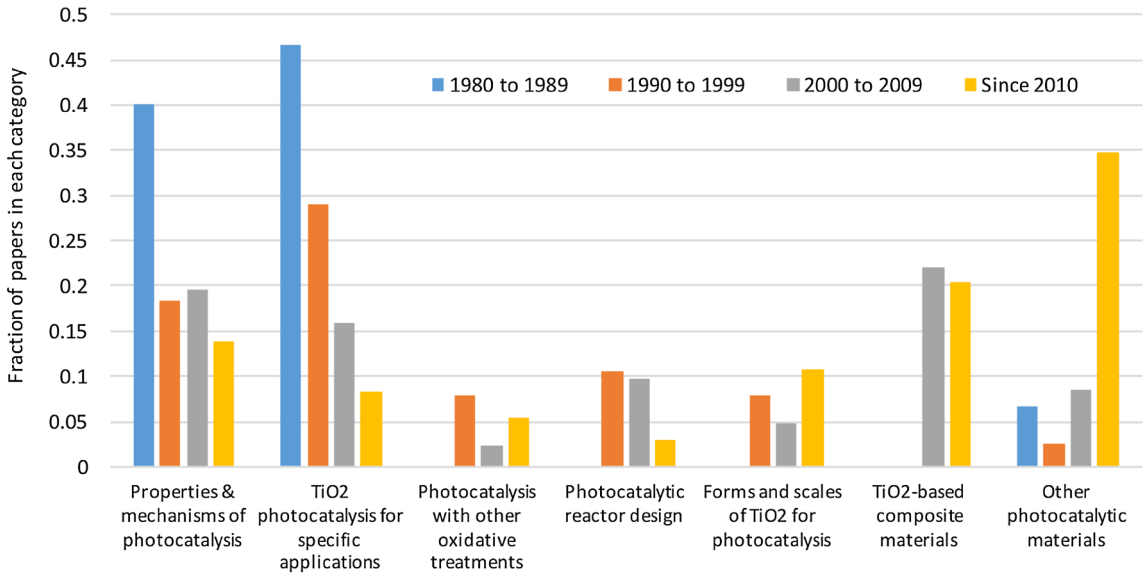

Fig. 1 Trends in the types of papers that cited the Carey et al. (1976) paper, divided according to the research category and the decade of publication

photocatalytic materials and approaches, so citations in papers that describe these types of studies have increased over the past 1–2 decades (Fig. 1). An example is the paper by Li et al. (2016) which focuses on the photocatalytic capability of nanotubes that incorporate TiO_2 in the nanomaterial structure.

It is interesting that the original article was very nonspecific about describing the form, or even the source of the TiO_2 that was used in the photocatalysis experiments. The authors just described the reaction conditions as "equal volumes of solution and titanium dioxide suspension (0.5% in water) were thoroughly mixed and irradiated in a closed glass container, usually for 30 mins". Despite the lack of detail, the article has endured as a touchstone for describing fundamental research in the field of photocatalysis. BECT strives to provide a forum where researchers can share their ground breaking research with the scientific community.

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