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Bio-organic–inorganic hybrid photocatalyst, TiO_2 and glucose oxidase composite for enhancing antibacterial performance in aqueous environments

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ABSTRACT

TiO_2-UV photocatalytic systems have been widely studied and applied for removing pathogenic bacteria in water treatment. We created a hybrid catalyst (TiO_2-GOx) by combining the inorganic photocatalyst (TiO_2) and the organic biocatalyst, glucose oxidase (GOx) that can be activated using UV radiation and glucose to generate a reactive oxygen species (ROS). More rapid disinfection of bacteria in the presence of UV and glucose was observed using the hybrid catalyst (TiO_2-GOx) than using TiO_2 particles. GOx generates H_2O_2 and superoxide under glucose-rich conditions in which heterotrophic bacteria grow quickly, this H_2O_2 and superoxide can act as disinfection agents along with the ROS (such as OH radicals) generated from the photocatalytic activation resulting from the interaction between UV radiation and TiO_2. Therefore, the rapid disinfection activity of TiO_2-GOx can be attributed to the enhancement of ROS generation due to the high catalytic activity of TiO_2-GOx in the combined glucose–UV rich environment. The hybrid catalyst (TiO_2-GOx) can be useful for disinfecting field water or wastewater with a high concentration of carbon sources such as glucose that can be assimilated by heterotrophic bacteria.

1. Introduction

UV-assisted TiO_2 inactivation of microorganisms such as pathogenic bacteria has garnered much attention in recent years due to its high efficiency in generating an antibacterial effect in aqueous environments [1–3]. During UV irradiation, highly reactive oxygen species (ROS) such as superoxide radical anions ($^{\cdot}O_2^-$), hydrogen peroxide (H_2O_2), hydroxyl radicals ($^{\cdot}OH$), hydroxyl ions (OH^-), and singlet oxygen ($^1O_2$) are generated [4]; these species are generally considered to be responsible for the inactivation of microorganisms by breaking their outer membranes or disrupting DNA inside cells [1,2]. However, an examination of the literature reveals that there is still disagreement as to which species of reactive oxygen is the major cause for the inactivation of microorganisms: H_2O_2, hydroxyl radicals, or other species [5–7]. Although the controversial issue of the major active ROS has not been resolved, it is known that the lifetime of most ROS created from UV-assisted TiO_2 photocatalytic reactions is very short both in aqueous environments and inside living cells [4,8]. Thus, to achieve the sustainable inactivation of microorganisms, it is important to ensure that ROS, regardless of species, are continuously produced in disinfection applications. H_2O_2 is an ROS that is widely used as a biocide for disinfection in a number of food-related, medical, industrial, and environmental applications, as its decomposition produces non-toxic by-products [9]. The disinfection activity of H_2O_2 is generally believed to result from the formation of highly reactive hydroxyl radicals via the interaction of the superoxide radical anion and H_2O_2 in aqueous environments [10]. Furthermore, it is believed that extremely short-lived hydroxyl radicals within living cells can be catalyzed by the presence of transition metal ions such as Fe^{2+} and H_2O_2 via the “Fenton reaction” [11]. Therefore, regardless of whether hydroxyl radicals or H_2O_2 is the main contributor to the disinfection of bacterial cells, the continuous production of H_2O_2 and other ROS is very important for maintaining the disinfection properties in aqueous environments.

Surface water, groundwater, and drinking water can be contaminated by wastewater effluents containing pharmaceuticals, hormones, chemicals in consumer products, chemicals used in farming, and

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