PHOTO-CATALYTIC DEGRADATION OF MICROPLASTICS IN WASTEWATER USING METAL MODIFIED TiO_2 CATALYSTS

ABSTRACT

Microplastics (MPs) have been acknowledged as emerging pollutants in recent times due to their widespread presence across diverse environments, raising concerns about potential human health impacts. Currently, there is a lack of regulation to mitigate their effects and limited understanding of their properties. Due to their small size and varied physical appearance, they are in advertently ingested by organisms that mistake them for food. They also adsorb other pollutants such as heavy metals and persistent organic pollutants and are passed on in the food chain. Although wastewater treatment plants (WWTPs) act as their barriers from entering into water bodies, they can also act as point sources to the receiving waters because they are not optimized for the removal of MPs. This study designed a method for microplastics degradation in water using metal-modified TiO_2 nanomaterials as photocatalysts that utilize visible light as the source of energy. The optimal photocatalytic conditions were determined using high-density polyethylene (HDPE) (2-3 mm) and polyethylene terephthalate (PET) (2 mm) as the model MPs in the laboratory and then applied for degradation of environmental MPs. The photocatalysts were prepared by sol-gel method using V, Cu, Co, and Mo as the modifying metal ions and then characterized using X- ray diffraction to determine phase and crystal structures, scanning electron microscopy for their morphology and ultraviolet-visible spectrophotometer for their light absorption properties. The metal modification with V, Co, and Mo showed a complete phase transformation of $TiO_2$to anatase phase within the crystal structure. This improved the photocatalytic properties of TiO_2within the visible region as confirmed by the narrowing of the bang energy from 3.2 eV for unmodified TiO_2 to 2.7 eV in V-TiO_2. An acidic environment was ideal for the degradation of HDPE, while a neutral to alkaline environment favoured the degradation of PET microplastic. The Fourier transformation spectroscopy (FTIR) spectra of the degraded polymers showed an absorption peak at 1710 cm^{-1} associated with the addition of a carbonyl group C=O within the polymer structure of the MPs, while the broadband around 3400 cm^{-1} was due to the formation of hydroxyl group OH as a result of oxidation during photocatalysis. The surface changes were observed using a high-resolution optical microscope and showed yellowing and deformation of the polymer surface. Dissolved organic compounds in the treated water was confirmed by increase in the chemical oxygen demand (COD). The COD levels increased to 230.0 mg/L where

photocatalysts were used, suggesting the disintegration of the MPs into smaller molecules. Degradation of both HDPE and PET polymers was a time-dependent process with noticeable mass changes observed after 200 hours for both polymers. The degradation of environmental MP samples using the different photocatalysts showed a percentage decrease in mass of between 83.0-91.7 %, indicating that the particles were being broken down. This work has provided insight into the potential of metal-modified photocatalysts for the degradation of environmental MPs in water using visible light. Based on the results, a modification could be incorporated into WWTP systems to include a step for photocatalytic degradation to enhance MPs removal from wastewater.

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